ADAPTIVE VIRTUAL ENVIRONMENTS IN MODERN MULTI-PLAYER COMPUTER GAMES

by

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February 2005

A thesis submitted to McGill University
in partial fulfillment of the requirements of the degree of
Master of Science

Abstract

Most modern computer games provide a virtual environment as a context for player interaction. Recently, many multi-player online games have adopted the persistent-state gaming model, which provides a central virtual environment with essentially infinite lifetime. However, a displeasing part of these long-lasting environments is that, like their predecessors, they are still assumed to be static, unchanging even in the long-term. In response to this fact, we introduce the *adaptive virtual environment* which automatically adapts based on activity occurring within the environment. In computer games, adaptive virtual environments are systems that correspond to real-world physical or social systems. These systems are computationally formalized by adhering to a generic adaptation model containing abstract components and procedures. Herein, as a proof of concept, we design and analyze the behavior of two adaptive versions of such systems commonly found in persistent-state games. To achieve this, we build an implementation of an abstract interactive simulator that applies the adaptation process to our example systems. Each system is internally represented as a plug-in module containing system-specific implementations of the model's abstractly-defined procedures. Performance of the adaptation process is then evaluated using simulation data. Finally, improvements such as optimizations and better movement models for agent simulation are investigated, and the general usefulness and applicability of the concepts is discussed.

Résumé

La plupart des jeux informatiques modernes offrent aux joueurs un environnement virtuel qui leur permet d'interagir entre eux. Récemment, plusieurs jeux multi-joueurs en-ligne ont adopté un modèle de jeu avec état persistant qui fournit un environnement virtuel central et dont le temps de vie est quasi-infini. Ces nouveaux environnements ont tout de même hérité du même problème que leurs prédécesseurs : on les considère comme étant statiques c'est-à-dire qu'ils ne changent pas avec le temps, même à long terme. Considérant ce fait, nous présentons *l'environnement virtuel adaptable* qui s'ajuste automatiquement en fonction des événements qui se déroulant dans l'environnement. Pour les jeux vidéo, les environnements virtuels adaptables sont des reproductions de notre monde physique ou social. Ces systèmes sont formalizés en respectant un modèle d'adaptation générique qui contient des des procédures et modules abstraits. Afin de démontrer cette formalisation, nous avons élaboré et analysé le comportement de deux versions adaptables de systèmes couramment retrouvés dans des jeux à état persistant. Pour y parvenir, nous avons construit un simulateur interactif abstrait qui qui met en application le processus d'adaptation dans chacun de nos deux systèmes témoins. Chaque système analysé par notre simulateur est réprésenté par un module d'ajout (plug-in) qui contient le comportement des méthodes abstraites spécifiques à ce système. La performance du processus d'adaptation est alors évaluée avec des données de simulation. Finalement, des améliorations, telles que des optimisations et des modèles de mouvement perfectionnés pour la simulation d'agents sont étudiées. L'utilité de ce concept et ses débouchés sont également discutées.

Acknowledgments

I would especially like to thank my thesis supervisor, Clark Verbrugge, for his patience, support, encouragement and guidance. When I had lost hope while experimenting, his belief in my research and persistence motivated me to continue. For everything he has given, he has earned my utmost respect.

As well, I'd like to thank the professors in charge of the Sable research lab (Clark Verbrugge and Laurie Hendren) for providing me with a research assistantship that not only paid for in part the costs associated with this research, but also allowed me to develop basic system administration skills. In addition, the Sable lab provided a great study environment and powerful machines for performance and concurrency analysis.

I would also like to thank the McGill School of Computer Science, in particular Alex Batko who was very responsive and helpful in the organizing of the Conquero game-playing experiment, the administration who have always been more than helpful, and all the faculty members who put their painstaking effort into teaching for the sake of the advancement of academia; they are true role models, and as such have all helped contribute in a small way. Thanks to everyone who helped out with the translation of the abstract: Alexandre Denault, Marc Boscher, Eric-Oliver Lamey, Olivier Abbe, Patrick Desnoyers, and Marc Gendron-Bellemare. Special thanks goes to Alexandre Denault for inspiring Conquero providing the Minueto game framework along with support for it. Of course, thanks goes to all the participants that made the experiment possible. This includes but is not restricted to: Francis Perron, Julia Grav, Alexandre Denault, Sokhom Pheng, Marc "mini-marc" Gendron-Bellemare, Kacper Wysocki, Olivier Hébert, Denis Lebel, Félix Martineau, Francois Poirier, Julien Vanier, Duc-Duy Nguyen, Jean-Sebastien Légaré, Raphael Bouskila, David Moise Nataf, Ali "Rushie" Rushdan Tariq, Ivaylo Tzvetkov, Mathieu Guay-Paquet, Zhentao Li, and Craig Hooker.

Finally I'd like to thank Nancy Forget, my parents and family, and the rest of my friends who have by now been hearing the sentence "I can't, I have to work on my thesis" for too long. Their tolerance has been well-appreciated.

Thank you, everyone, for your help and understanding.

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Chapter 1
Introduction and Contributions

Not very long ago, developing a computer game was largely considered a 1-person project. Many components were involved of course such as different types of programming (graphics, physics, game logic, sound, user interface) as well as designing a believable and somewhat interesting storyline, designing challenging levels, drawing impressive image scenes, creating captivating sound files, and so on. However, it was still the case that these components were small and simple enough so that it was feasible for the same person to be responsible for all of them and their integration into the final game product.

Modern computer games are large, complex software projects that require many more than one single person to produce. In fact, it is not uncommon to have 100 people working on a modern computer game during the beta-testing phase [Com03]. Computer games have become so vast that now they include a large amount of complex components. Due to the commercial aspect of the industry such as demand from consumers, game development companies do not have the time nor resources to spend analyzing the academic properties of these projects or experimenting with potential features.

Many modern computer games support online gameplay: that is, networked multi-player gameplay over the Internet. Usually a service is offered by the same companies that sell the game which allows players to meet other players to play an instance of the online game over the Internet. With a suitable design infrastructure such games can become quite large in terms of numbers of players. Large scale networked games are referred to as Massively Multi-player Online Games (MMOGs).

A specific type of MMOG, influenced in part by role-playing games, is one that doesn't recreate a new game instance every time players join the game; that is, only one instance exists and the game setting is never-ending. New players are admitted to the game at its current state and produce the history of the virtual "world" by playing. The game world state exists regardless of whether players are playing inside it. These *persistent-state* computer games have become popular, have been commercially-explored in the online gaming industry, and now form an important subfield of modern online gaming [Com04]. In this thesis, we propose and analyze a potential new feature specifically intended for persistent-state computer games.

Traditional and modern Artificial Intelligence (AI) researchers who focus on agent-based techniques separate a *virtual environment* into 2 major components: the static environment, and the dynamic agents [RN02]. Since new environment instances are continually being constructed with each new game instance, the lifetime of the environments are relatively short. Therefore, it is fair to assume that the environment is approximately unchanging, since real-world physical environments are not static but change only slowly and over the long-term. Typically the role of the environment is a constant entity that restricts the dynamics of the agents' behavior. This approximation becomes noticeable in a persistent-state online game where the life of the environment is effectively infinite. Our motivation then is to describe a generic system for environmental adaptation within these contexts.

A basic problem encountered by vendors of large scale, persistent-state gaming environments is how to continuously improve and change the virtual environment so as to maintain player interest, and also reflect the activities of players in the virtual world. In a more generic sense this falls under *content creation* [Mel03], altering or adding new virtual content to the game. Manual approaches are typically used due to the creative requirements of general content creation and the complexity of determining realistic adaptation results, but impose extra game maintenance costs and administration requirements. Automatic approaches that sensibly alter and tune the game world with minimal human intervention are thus desirable.

We present a generic model for adaptation in computer games that allows the virtual world to change automatically, with reasonable efficiency. We demonstrate the utility of our technique through two different forms of dynamic common game content: 1) an environment-based basic weather cycle that adapts wind, rain and water accumulation to variations and changes in a large-scale terrain, and 2) a simple agent-based *reputation* system that allows agents in the virtual world to respond appropriately to a player's actual behavior in a game.

Furthermore, we design and conduct a game-playing experiment to collect data from actual players for analysis. The purpose of the experiment is to improve the movement model used in the agent simulation for agent-based adaptation. We propose heuristics for agents' decisions which are functions of the game state at given times in the game experiment. The heuristic calculations are then used as input to some classification problems that learn which heuristics are good for determining the actions to take under the specific conditions.

Finally, the implementation of the simulator used to represent the adaptation of the systems designed using the framework is explained in detail. An architecture for integration of the adaptation simulator into modern game projects is proposed. Performance analyses are done on the simulations and specific optimizations are measured.

1.1 Contributions

Specific contributions of this work include:

- Design of a general adaptation framework suitable for modeling flow-based properties in game simulations. Our approach is based on cellular automata, ensuring only local information is required at each computation; this allows for reasonable scalability in distributed environments.

- Design and experimental verification of systems for two forms of popular, dynamic game content. We describe a simple, aesthetic and logically consistent adaptive weather model for game worlds, and a game reputation system that can dynamically respond to changing patterns of information dispersal and player behavior.

- Implementation of a simple multi-player computer game and organization of a game-playing experiment to obtain real data from game players. Using collected data, we analyze the value of certain proposed heuristic strategies for deciding how to move based on the state of the game. Several movement models for agents in game simulation are analyzed; among them a dynamic model based on decision-tree learning is proposed.

- Design and analysis of an implementation of the entire framework in Java. The purpose of the implementation is threefold: to see how well the concept fits into an object-oriented programming model, to analyze the behavior of the example adaptation systems described, and to assess performance feasibility and optimizations.

1.2 Road map

In the following chapter we describe other research work that is related to our endeavors. We then explain the fundamental notions and basic, underlying concepts used in our approach in Chapter 3. Following this, Chapter 4 describes in detail example applications built upon the basic model. Chapter 5 contains a study on improvement player movement in persistent-state MMOGs. Lastly, Chapter 6 fits the adaptation scheme into MMOGs and describes an implementation of a simulator used to simulate example adaptive systems.

Chapter 2
Related Work

In this chapter, we give a brief survey of the related previously-studied areas that have all in some way influenced this work. We first present the study of computational adaptation because it is by far the most relevant. Then, we will look at the work that has been done on the two core computational concepts used in the work: Cellular Automata, and Fuzzy Logic. We also discuss previous research done in and influence of systems for which we chose to apply adaptation: weather modeling (including terrain generation), and reputation schemes. We mention the difficulties involved in massive Multi-player Game Design, the constraints of the context, and how it relates to the adaptation tasks.

2.1 Adaptation

Adaptation is a traditional target of Artificial Intelligence (AI) research. It is usually viewed as a complement to the problem of Machine Learning (ML), which is is concerned with the question of how to construct computer programs that automatically improve with experience. The most common type of learning is supervised learning in which there is a collection (*sample*) of input data and output data for each input; the goal is to find a function (*classifier*) that represents the data well enough so that it can predict the output of future input sets [Mit97]. Adaptation is more closely related to the problem of unsupervised learning in which no output sets are included with the inputs, the goal being to group the data sets by some similarity metric such as n-dimensional Euclidean distance in *cluster analysis* [HTF01]. Learning tasks typically focus on finding a good static classifier assuming a very specific, fixed problem. On the other hand, in adaptive tasks the problem(*target*) is still well-defined but it also *dynamic*. Therefore, adaptation becomes an on-going, possibly never-ending process of modifying the model/system towards its ever-changing target. In addition, it is often harder to quantify what the adaptation engine is adapting to in comparison to what a learning engine is trying to learn. Unlike ML, adaptation does not have a list of classic algorithms and structures that can be easily applied to a data set because the reason for performing adaptation is comparatively much more domain-specific.

In the context of computer games, adaptation has been investigated [SSKP03], though like most other applications of AI it has been primarily directed at adapting agents (NPCs, game opponents) [CM98] rather than the environment. For example, [DdOC03] presents a scheme for online adaptation of agent behavior in action games. Similarly, [Pon04] describes genetic learning algorithms that improve game AI in real-time strategy games. Most generic AI architectures focus on agent behaviors, such as in [NC01]. Even non-constant, fluctuating environments are usually viewed as the process to react to, rather than the target of adaptation [HW95]. Our motivations more closely resemble building an *artificial model* as in done in ALife [Ste94] and co-evolving that model based on user input as in [DdOC03]; we, however, focus on constructing an adaptive environment irrespective of adaptivity of the agents.

2.2 Cellular Automata

The approach here is based on 2-dimensional Cellular Automata (CA). The theoretical basis for the cellular automaton formalism was inspired by John von Neumann's studies in self-reproducing automata [vNB66]. The aim then was not to create a new computational formalism in of itself, but instead to investigate the algorithmic analogue to the natural concept of evolution. Only a few years after von Neumann's original work had been published, Martin Gardner studied Jon Conway's Game of Life [Gar70]. He found that using the CA formalism very complex patterns could be generated from an iterative update process with relatively simple update rules. In fact, under certain conditions chaotic behavior is observed, which leads to visually-pleasing fractal patterns [WP85]. The evolution of CAs was interesting enough that it formed the core of a well-known classic computer game: SimCity [Sta96].

The Cellular Automaton has become a rather popular computational formalism in many fields of Computer Science. It seems to have become a classic formalism in the field of Modeling and Simulation, particularly in association with discrete event systems. A comprehensive general relationship between CA and DEVS is outlined in [VV00] while timed Cell-DEVS and remote execution are examined in [WG01] and [WC03], respectively. CAs have been used for weather and ecological modeling, and are amenable to simple parallelization. The details for this topic are deferred to Section 2.4.

2.3 Fuzzy Logic and Fuzzy Set Theory

Fuzzy logic was first presented in 1965 as a mathematical means for dealing with complex ill-defined systems [Zad65]. It has become popular as a control device in the domain of electronic systems, influenced in part by [Mam74]. Fuzzy Logic is also used a lot in conjunction with models and algorithms traditionally found in AI such as neural networks (neuro-fuzzy systems), adaptation (Robo-Cup Soccer [AW04]), and machine learning. A comprehensive introduction to how fuzzy control systems work is given in [HD03].

An interesting and particularly relevant formalism is the Fuzzy Cellular Automaton (FCA) [Ada94]. In this book, the problem of *identification* (or *classification*) of cellular automata is addressed. A gradient descent learning algorithm is designed for FCAs in [RGT00], where it is shown that real-valued functions can be well approximated by using a clever encoding representation for function values.

It is currently unknown whether Fuzzy Logic is used in any existing modern computer games, but a proposed usage is found in [McC00]. This article motivated the construction of the fuzzy system used in the adaptation framework presented in Chapter 3.

2.4 Ecological(Weather) Modeling and Simulation

The Weather/Ecosystem modeling and simulation field is concerned mostly with using computers as a tool to make predictions about the future behavior of a system. Geographic Information Systems (GIS) such as Global Positioning Systems (GPS) are used to retrieve precise geographic information about Earth regions in order to gain insight on the ecological behavior of the model. In many cases, the collected data is analyzed via adaptation and learning methods as in [GWJT97]. Fuzzy Systems are also used as models in this context [HAKB96].

In recent years, one research focus is to use massively parallel computers on top of an underlying DEVS formalism to model weather forecasting [WZ93]. The CA model fits well into the parallel architecture [Dag92] and into the DEVS formulation [Zei84]. Consequently, it makes a natural choice for ecological modeling within both these contexts [DZG93].

The Finite Element Method (FEM) is used in the field of Computational Fluid Dynamics (CFD) to approximate the dynamics of a continuous system by using a discrete, often triangular grid. These methods are similar to the fluid dynamics based on hexagonal CA presented in [Wol86b].

All the methods presented in this section have a common goal: they aim to realistically model real-world physical behaviors. In modern computer games however, physically realistic ecological modeling is far too costly a process; computer games already have hard, real-time requirements and efficiency is typically a great priority than realism/precision. Our approach is to focus on a model that achieves a good appearance for an immersive game experience but which is also very fast to compute.

2.5 Reputation Systems

Automated reputation systems (or trust systems) have become quite popular in recent years as an efficient method to measure trust between users.

Around the same time trust was first formalized as a computational concept [Mar94], the first widely used reputation system was introduced by the Ebay auction site(`www.ebay.com`). Ebay introduced a point-based system which allowed users to rate each other manually. The winner of an auctions(*buyers*) on Ebay are allowed to rate the starter of the auction(*sellers*) once the merchandise is received. Buyers are allowed to submit positive points, negative points, and comments about the seller. These points form the seller's reputation. The seller is not allowed to modify his/her own reputation: it is strictly formed by the buyers in the auctions held. Other buyers are allowed to view the sellers' reputation before they place a bid. Therefore, the relative amount of positive feedback (reputation level) you have directly corresponds to how satisfied others have been with your auctions. In turn, this encourages sellers to ensure prompt delivery and accurate description of the state of the merchandise.

The Ebay system was studied by the community and was soon labeled a *binary reputation system* [Del01]. It was around the same time that people started presenting mathematical frameworks for computing trust in online trading communities [Del] [YS00]. The problem with such a system is that it is not automatic: it requires each user to faithfully (and honestly) provide feedback.

Recently, a large amount of research work has been put into automated trust-measuring algorithms in distributed, especially peer-to-peer, trading environments [DGGZ03]. The Eigen-Rep system computes the a global trust value for a peer based on local trust values computed by all peers [KSGM03]. Appleseed [ZL04] uses the Semantic "Web of Trust" infrastructure for trust propagation. This kind of trust propagation has also been seen in the context of open rating systems [Guh] which were used on web sites `Slashdot.org` and `epinions.com`. These rating systems described methods for ranking users' posts based on the feedback given to the system by other users who read the posts. Although again, the systems require considerable amount of user input to work.

In modern computer games, very little research has been done on automated reputation systems. While [Jak] outlines the importance of a character's reputation in the game EverQuest, it is unfortunately completely user-based and subject to interpretation. EverQuest was the first MMORPG to introduce *factions* [mer]. Factions are basically reputation groups: collections of players that have different relationships with each other. A player or group can raise or lower his/her faction with that reputation group by performing certain actions. The faction value (positive or negative) represents how the members of that faction react to the character.

There have been some commercial attempts at incorporating locality in faction-based reputation systems, but results have been disappointing [Bro03]. Our approach was inspired by the *Dungeons & Dragons* reputation system [CDNR04], which assumes a global reputation value per character. We'll see later that this can be easily extended to groups of characters. This system states that as a player progresses his or her reputation will rise by performing "heroic deeds." Symmetrically, of course there should also be the inverse property, to degrade reputation by performing negative actions. We extend this base system by capturing locality via the flow of information dispersal throughout the virtual environment.

2.6 Multi-player Game Design

Before the growth of world-wide networking, computer games did not support multiple players unless the players were both physically using the same computer. As the Internet emerged for widely public use, games began supporting multi-player options. At first games were only playable one-on-one by modem, or multi-player over a local area network (LAN). In these times and settings the games were still relatively simple; network bandwidths and latency as well as efficient and consistent data transfers were minimal concerns.

Today, for large-scale Massively Multi-player (MMP) games the teams grow to 100 people or more and could cost anywhere from under 5 million to 30 million dollars to develop [Com03]. For groups of such large sizes, clever software engineering techniques such as good project coordination are required to ensure efficient work flow [Ruc02].

Multi-player games are faced with the problem of sending data over networks. This simple fact adds a burden to the game designers in several different ways [SKH02]. First and foremost, the game designers are faced with constructing a consistent *protocol* which must be implemented as a communication mechanism between the hosts. This is usually a simple task in itself. However, since sending data by network is comparatively slow and much more prone to error it is fairly important that the protocol and network architecture remain simple and efficient [RRER03]. Another notable problem with multi-player game design that has been arising lately particularly in online games is cheating and security [YC02]. This is particularly bothersome in larger scale games where the problem is a lot harder to control [BL01].

Massively multi-player games add more issues to these problems. The main issue in massively multi-player games is *scalability*. In fact, this is such a problem in large-scale games that game designers have had to look into entirely new network topologies [Fun96] and architectures [CFKJ02] to deal with such large numbers of players. Of particular interest is the divergence from the typical client/server model to new distributed models [Qua03]. In fact, the use of Multicast UDP in [DG99] influenced the network design of the multi-player game-playing experiment described in Chapter 5. We will talk more about choices for network design in computer games in Chapter 6.

2.7 Terrain Generation

Terrain generation is an interesting problem faced by virtual world creators. The problem is how to automatically generate terrain for a virtual world that satisfies a set of criteria. Typical criteria for computer games are *realistic*, *smooth*, and *randomized*.

A fundamental structure in terrain modeling is the *height field* [EMP+98], here after denoted the *altitude map*. A common way to produce random altitude maps is via *general stochastic subdivision* [Lew87]. A more intriguing way of generating realistic terrain which is related to the adaptation concept is to take existing real elevation data and apply water flow erosion to sculpt the surface details [KMN88].

According to [O'N01], the Perlin Noise algorithm is a procedural method which acts as a base algorithm for techniques used in computer games. Fractal landscapes [HM95] have also become popular due to their straight-forward recursive implementation. We will soon see that the method for scaling bitmaps in [Mar99] is quite similar to the techniques used in our adaptation model.

Chapter 3
A General Model for Adaptive Environments

The Adaptive Virtual Environment (AVE) concept splits itself naturally into two major components: *generic* adaptation concepts and *system-specific* adaptation concepts. A specific system is a particular AVE that is well-defined and exhibits behavior particular to a given physical or social system; it can be thought of as an instance of more generically-defined *adaptation model*. The particular AVEs both adhere to the generic model and define the semantics of the data representation present within the model.

In this chapter, we describe in detail the generic model that example systems implement. For clarity, we well refer to example AVE systems as *applications of the model*. Some specific applications of the model will be examined in greater detail in Chapter 4.

The chapter is divided into two sections: the first section presents the fundamental computational notions that are required to present the core formalisms used in the model. The second section presents the core procedural and data abstractions which are used to manipulate the AVE undergoing the adaptation process.

3.1 Fundamental Notions

In this section an overview of the fundamental background knowledge is presented. These concepts form the foundation upon which the adaptation framework is constructed. The ideas described herein are by no means complete nor extensive; they are merely presented as reminders of the basic notions and to present conventions for notation. Where applicable, references will be given to more comprehensive sources.

3.1.1 Cellular Automata

One of the attractive features of CAs is their unique and inherent ability to capture the influence of local properties. This main fact is what inspired the use of CAs as a central notion in the adaptation framework.

Classical One-Dimensional CA

A classical one-dimensional cellular automaton is a 4-tuple (C, Q, τ, f), where $C = (\cdots, c_{-3}, c_{-2}, c_{-1}, c_0, c_1, c_2, \cdots)$ is a *bi-infinite lattice* of discrete *cells*, Q is a set of *cell states*, $\tau : C \rightarrow C^n$ is a neighborhood function, and $f : C^n \rightarrow Q$ is a transition function [Wol83]. The *index* or *position* of a cell is an integer representing the cell's position in the integer range. $c_0 \in C$ has position 0 and is labeled the *midpoint cell*. Paired with the formalism itself is usually a discretized notion of time via *time steps* $(t_0, t_1, \cdots)$ where t_0 is the initial time step.

The *configuration* of a cellular automaton C_k, is the lattice of cells in their corresponding cell states at time t_k where C_0 is the initial configuration. In general, the configuration of the cellular automaton C at time t is denoted C_t. C_t is obtained by the simultaneous application of the transition function on the cells' neighborhood in C_{t-1}. That is, if $q_t(c)$ is the value of cell c at time t, then $\forall c_k \in C_t, c'_k \in C_{t-1}, q_t(c_k) = f(\tau(c'_k))$. The *evolution* of the CA is a term meaning how the states change over time. Unless otherwise noted, it is commonly assumed that the default state set is $Q = \{0, 1\}$ and the initial configuration is $C_0 = \mathbf{0} = \{\cdots, 0, 0, 0, \cdots\}$.

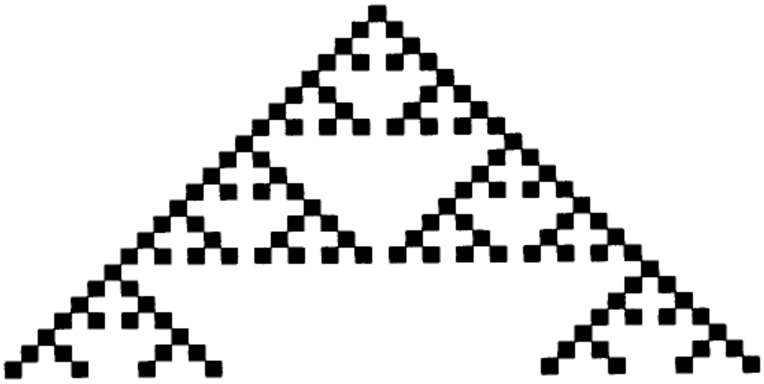
Here is a simple example of taken from [Wol83]. The initial configuration is a *simple seed*: $C_0 = \{c_0 = 1, c_n = 0 \text{ for } (n \neq 0)\}$. The neighborhood is only the direct neighbors of each cell: $\tau(c_n) = \{c_{n-1}, c_{n+1}\}$. The transition function is $f(\tau(c_n)) = q(c_{n-1}) + q(c_{n+1}) \pmod 2$.

Such a simple function leads to an interesting evolution. If we look at the C_t vs. t graph, assuming that time increases down the axis and we represent graphically a black dot for 1s and a white dot for 0s, we get the picture seen in Figure 3.1.

An extensive examination of general cellular automata can be found in [Wol86a].

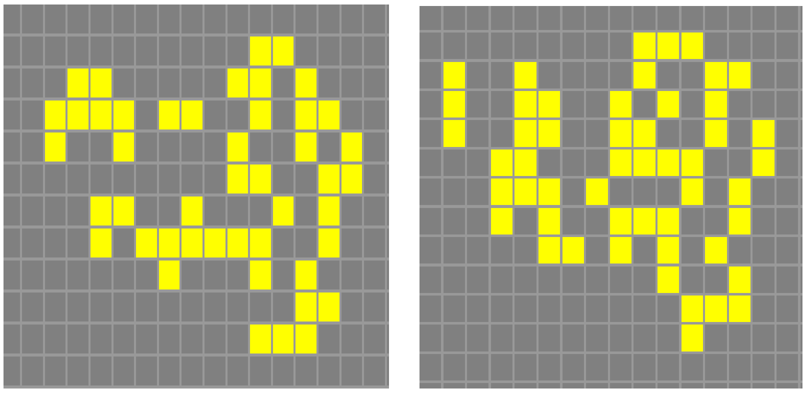
Two-Dimensional CA

Two-dimensional cellular automata are more complex structures than their one-dimensional predecessors. First, the bi-infinite lattice is extended to a two-dimensional rectangular grid of cells. As in the first case, we assumed some form of connectedness between cells and that each cell is discrete. For the sake of simplicity, let's assume that this grid is bounded (equivalently: there exists no straight paths of infinite length) with finite dimension. We'll see in Section 4.1.1 that there exists more than just a single way of defining connected, unbounded grids.



Source: [Wol83]

Figure 3.1: Evolution (C_t vs. t) for a simple CA example.



Source: `http://www.bitstorm.org/gameoflife/`

Figure 3.2: The effects of one iteration in Game of Life.

Secondly, the neighborhood function becomes two-dimensional in the sense that a cell can have neighbors in more than just 2 directions (left, right AND up, down). We'll also see later that even the notion of a neighborhood can be awkward to define using the rectangular grid.

Finally, the states are often more generally simple scalar values instead of bits (0 or 1).

The first popular use of two-dimensional CAs were described in the Jon Conway's Game of Life [Gar70]. An example transition in the game is found in Figure 3.2.

A list of analyses, results, and facts about two-dimensional CAs can be found in [WP85].

3.1.2 Fuzzy Control

Fuzzy control is a method which uses fuzzy set theory and fuzzy logic to regulate the behavior of systems. The fuzzy control mechanism consists of three general concepts: fuzzification, fuzzy rule evaluation, and defuzzification. We will describe how these concepts work together after we describe some of the basics.

Fuzzy Sets

A fuzzy set is a generalized extension of a classic *crisp* set. A fuzzy set intentionally quantifies vague linguistic terms such as "HOT" and "TALL". A fuzzy set is defined entirely by its *characteristic function*, $\mu(x) : D \rightarrow [0, 1]$, where D is some arbitrary domain outlined by the task at hand. We follow with an example.

In the classic set theory, the membership operator($\in$) is a boolean function that takes as arguments an element and a set and whose value represents whether the element is contained in the set. That is, crisp sets are sets where the membership is a discrete binary property. For example, $3 \in S = \{1, 2, 3, 4\}$ is clearly true whereas $5 \in S$ is clearly false. However, the truth value of the linguistic interpretation of "x is TALL" depends on how "TALL" is defined which in turn depends on who is interpreting the claim. That is, the expression "x is TALL" is vague unless we quantify "TALL". One way to do that is describe "TALL" as the fuzzy set:

$$\mu_{TALL}(x) = \begin{cases} 0 & \text{if } x < 65; \\ \frac{x-65}{19} & \text{if } 65 \leq x < 84; \\ 1 & \text{if } x \geq 84. \end{cases}$$

This is a set with full and partial(fractional) membership, the meaning of which depends on the concept of fuzzy logic. The membership function is graphically illustrated in Figure 3.3.

Fuzzy Logic

Fuzzy Logic is based upon fuzzy set theory. In Fuzzy logic, a logical term has a *fuzzy truth value* which is a value in the interval $[0, 1]$. A value of 1 represents "absolutely true" while a value of 0 represents "absolutely false". Values in between are interpreted with confidence proportional to how far the value is from the absolute values: 0.2 could mean "hardly true" ("very false"), where 0.85 could mean "very true" ("hardly false").

The value of a membership function $\mu_S(x)$ represents the truth value of "x is in S". In other words, it represents x's *degree of membership* in S. From the previous example, a person whose

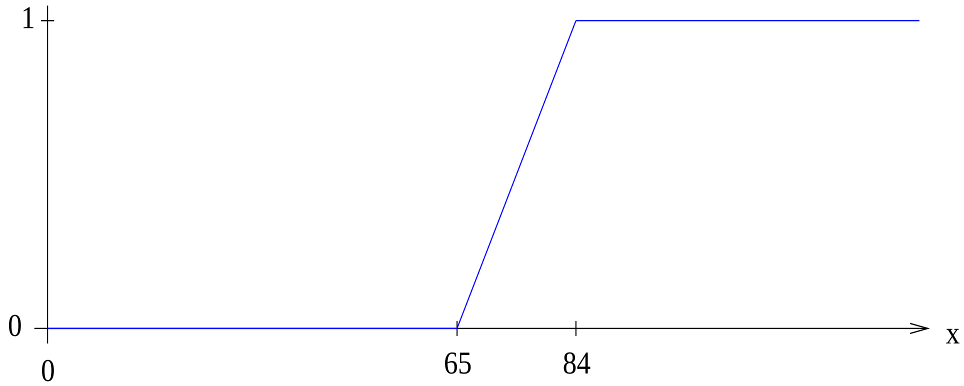


Figure 3.3: The graph of the membership function, $\mu_{TALL}(x)$, vs x for the fuzzy set "x is TALL".

height is 71 inches would have a $\frac{6}{19} = 0.316$ degree of tallness, whereas a person whose height is 78 inches would have a degree of 0.684 degree of tallness.

Conjunction and disjunction of fuzzy logical terms have been defined in several ways. The most common definition is that the truth value of "x is X and y is Y" is $min(\mu_X(x), \mu_Y(y)$, with a similar function for disjunction using max. The value of an inverse of a logical term, ie. "x is not in X", is given by $1 - \mu_X(x)$.

We now have the components we need to construct a *fuzzy rule base*. A rule base is an intuitive way to describe the behavior of a system. A rule base consists of a collection of *rules*. Rules are linguistic terms of the form "if A then B". The antecedent, A, is a general logical term while the consequent, B, is a simple logical term which is usually in the form of a command.

A 3-step Guide for Fuzzy Control

We assume that we have a control system where we are given several options that change the state of the system in different way, we would like to control the system by making decisions such that the state of the system approaches some appropriate target state or long-term behavior.

Before we present a common usage via the 3 main steps, we must first define the problem at hand. Take for a simple example a task faced by many students every morning on their way to school. Their options are to go directly to school, stop for coffee first, and/or grab breakfast first. We assume for simplicity of our example that the coffee shops used in thesis example analogies do not sell breakfasts and the coffee sold by the breakfast restaurant contains a substance which the student is violently allergic to. The option taken depends on the time the student arrives at school, how hungry and tired he/she is.

Step 1: Fuzzification. We define the following fuzzy membership functions. In all cases, if the value is lower than 0 it is rounded to 0 or if the value is higher than 1 it is rounded to 1.

1. $\mu_{TIRED}(x) = \frac{12-x_{slept}}{12}$, where x_{slept} is the number of hours of sleep the student got the night before.

2. $\mu_{HUNGRY}(x) = \frac{x_{ate}}{24}$, where x_{ate} is the number of hours it has been since the student's last meal.

3. $\mu_{LATE}(x) = \frac{x_{arrival}}{30}$, where $x_{arrival}$ is the number of minutes the student arrives after the class has started.

4. $A = \{EAT, COFFEE, CLASS\}$ is the set of linguistic command variables, each describing an actions to be taken by the student.

We also define command sets such as EAT, COFFEE, CLASS. Elements of these sets are actions; memberships are the degree to which these actions are desired.

Step 2: Query the Rule-base. We define the rule base. Here, $y \in A$ is a rule's suggested consequential action:

1. IF ((x is HUNGRY) AND (x is not LATE)) then (y is EAT)

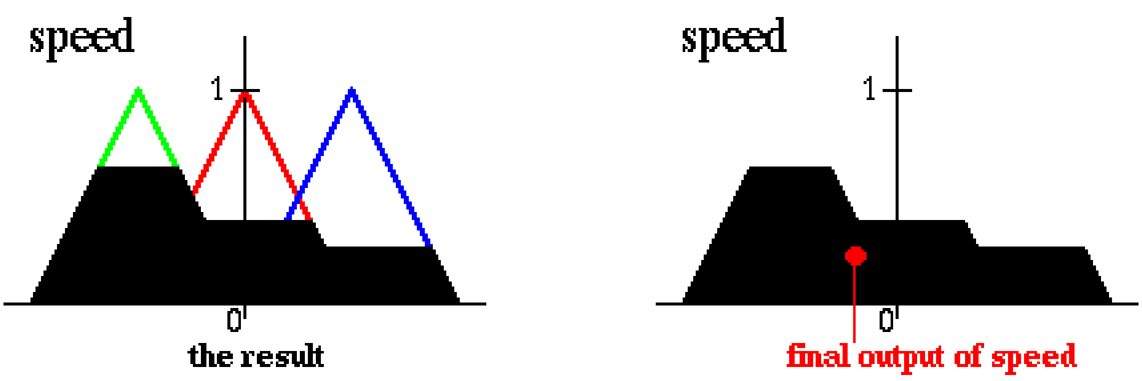
2. IF ((x is TIRED) AND (x is not LATE)) then (y is COFFEE)

3. IF (x is LATE) then (y is CLASS)

So if the student only had 5 hours of sleep and ate supper at 19:00 the night before, class is at 8:00 and we arrive at school at 8:12, then $\mu_{TIRED} = 0.58$, $\mu_{HUNGRY} = 0.54$, and $\mu_{LATE} = 0.4$. The values of the consequences are the sum of all antecedents that yield the given consequence. In this case, eating would score $min(0.54, 0.6) = 0.54$ (ie. the student is more hungry than early), getting coffee would score $min(0.58, 0.6) = 0.58$, and going directly to class would score 0.4.

Step 3: Defuzzification. In the example above, it is clear which option is more desirable: you simply choose the maximum membership over each action set to determine which action to take. In particular, the student would choose to get a coffee before going to class because his attentiveness is more important. However, while this method of defuzzification is the simplest and most obvious in this case choosing is not always so straight-forward.

Here, we assumed that the actions are completely independent: the student either eats, gets coffee, or goes to class but can't pick more than one action. By construction, there is no overlap in the fuzzy sets defined by the actions. In general, however, the consequence of these rules define new fuzzy sets whose membership functions may overlap in their graph



(a) (b)

Source: `http://www.doc.ic.ac.uk/ nd/surprise_96/journal/vol2/sbaa/article2.html`

Figure 3.4: (a) The region produced by center-of-gravity defuzzification in a fuzzy controller with an action set containing 3 overlapping fuzzy actions, and (b) The center of gravity, and the chosen (red) action.

representations. In these cases it is less clear as to which action to choose, so we must resort to a more distinguishable method for defuzzifying the collection of fuzzy values into one crisp decision.

One common method used is the center-of-gravity calculation. A bounded region is constructed by taking the union of all regions under the membership functions for which the top is of the region is bound by the membership value of the linguistic variables, the bottom is bounded by the x-axis, the sides by the boundaries of the membership values of the fuzzy sets. The center of gravity of this region is found. The chosen action is the highest membership value of all fuzzy membership functions at the center of gravity. An example of such a region is displayed in Figure 3.4.

As a consequence, fuzzy controllers permit the flexibility of making decisions even in cases when the action to choose is ambiguous due to nature of the system. It is often harder to choose between an ambiguous action set than it is to describe a linguistic variable by an defining an arbitrary membership function. Thus, essentially, fuzzy controllers use math to calculate the best action to choose given the descriptions of the linguistic variables. The model can then later be re-used; it just needs the linguistic variables' membership functions and rules describing how to act.

A thorough source for learning about fuzzy sets, fuzzy logic, and fuzzy control is [Wan96].

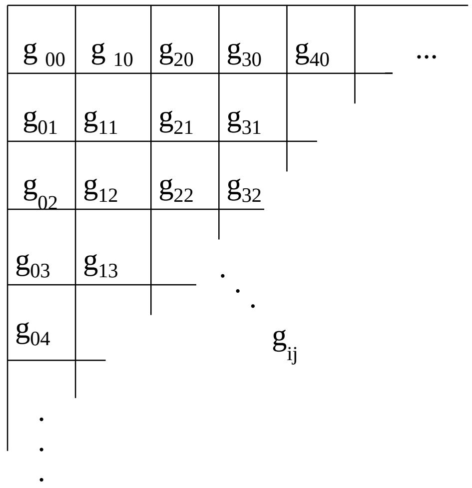


Figure 3.5: The virtual terrain.

3.2 Basics of the Adaptation Model

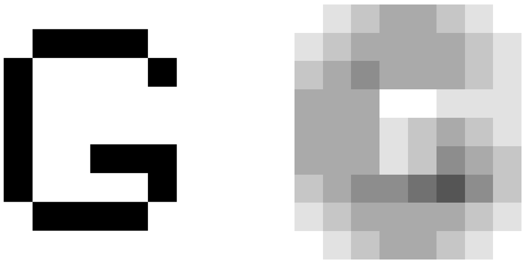
Our model is based on a finite continuous 2-dimensional space, the virtual terrain, R. The virtual terrain is partitioned into a discrete mapping or *grid*, G. In the examples below we use the familiar situation of a subset of $R \subset \Re^2$ and a square grid G, though we believe that the techniques we use apply equally well to any *metric space* [BBI01]. This is partially shown by applying the same adaptation techniques used in a rectangular grid to a hexagonal grid in Section 4.1.1.

We define the metric space (G, g_d), and a surjective mapping $f : G \rightarrow R$. For convenience and clarity, we will call the points in our metric space *grid sections* or *cells*, and the metric space itself the *grid*, without loss of generality. G is a discrete grid approximation of its continuous counterpart R with the association that any grid section in R is representative of a continuous, bounded region in R (via f). For simplicity we as well assume that f describes a *complete partition* of R; that is, $\bigcup_{g \in G} f(g) = R$ and $\bigcap_{g \in G} f(g) = \emptyset$. The easiest way to think of this grid is as an overlay covering the continuous Cartesian plane with grid lines defined by the set of lines that cross the axes at integer coordinates. The idea is illustrated in Figure 3.5.

An important requirement for *locality* that is supplied by the metric space is the notion of a neighborhood. In "nice" metric spaces such as hexagonal grids, the neighborhood of a point is defined as all points which are of distance 1 away. However, sometimes, the neighborhood is not so intuitively defined [Tou]. Such is the case in our rectangular grid approximation, where there are 2 commonly used definitions of neighborhood: the 4-neighborhood and the 8-neighborhood [DHS00]. The 4-neighborhood of a grid section consists of the sections found directly north, south, east, and west of the section whereas the 8-neighborhood also includes the diagonal points on the surrounding box: sections immediately to the northeast, northwest, southeast, southwest. In general however, any neighborhood function can be used. The notion of a cell neighborhood allows us to describe the locality of a grid section on the grid. Local sections are sections which are *close by*; where *closeness* is objectified further by the the value of the distance function between the two cells.

The grid contains abstractly-defined *properties*. Properties are similar to local variables: they are given the ability to hold values and change with respect to computation time. Each grid section has a different instance of the property variable so that the value of a property on a grid section is completely independent of the value of the same property on a different grid section. To contrast, the procedure which changes the values is defined on neighborhood cells, making them locally-dependent. The idea is to use this generic model and then describe your properties depending on the context of the system in which the model is used. For instance, imagine that we have a mountainous virtual environment. We define the *altitude* property to be the value of the height of the surface with respect to the lowest point in the environment. Then, the altitude property would have a high value in high-mountain region but low value in the flat regions. Altitude is only one example property; in general, a virtual environment is made up of several different properties. We will denote the value of a given property $g_{ij}[\textit{property name}]$, where i and j are coordinates in some two-dimensional discrete partition described by f. The collection of grid sections and values of all properties on all grid sections is defined as the *current state*. The list of these properties and the semantics tied to them form a major component of a *virtual system*. These systems can be seen as instances, applications, or implementations of the generic model. We will discuss the construction of such systems in much greater detail in Chapter 4.

Coupled with the notion of state is a procedural process which describes how the state changes with respect to time. Since the systems we are typically interested in modeling are *self-reproducing* [vNB66], we do not describe these state changes as independent of each other and solely dependent on time itself. Instead as is done in the CA formalism, we discretize time into a series of *timesteps* $T = (t_0, t_1, t_2, ...)$ called the *timeline* and describe the state of the system as a function of the previous state. In other words, the state of the system at t_i is entirely and only dependent on the state of the system at t_{i-1}. Here,we assume that the virtual environment begins its life at t_0 and that the timeline is evenly divided among timesteps so that the actual time spent between t_i and t_{i+1} is constant for all i. In doing so, the timeline T simply becomes an approximation of the continuous concept of time. The accuracy of the approximation depends on the actual time taken to get from t_i to t_{i+1}. We will denote the



(a) (b)

Figure 3.6: The effects of one iteration of blurring on a letter image, A letter is displayed closeup (a) before and (b) after the blurring of the image.

value of a property p on grid section g_{ij} at time t as $g_{ij}^t[p]$.

The process is formulated as an an iterative update algorithm. This algorithm is just a list of functions that modify the state of the grid. The system begins in some initial state and this algorithm just applies these functions independently and simultaneously based on the current state of the system to give the next state of the system. Note that given this description of the model at any given time, t_i, the state of any future configuration, t_j, is obtained by applying the iterative algorithm $(j - i)$ times. As a result, the evolution of the system without any external influence is completely deterministic. The following pseudo-code summarizes the core of the process:

$$\forall i \in \mathbf{N} = \{0, 1, ...\}, \forall g \in G, g^{t_{i+1}}[p] \leftarrow f_p(\tau(g^{t_i}[p])) \tag{3.1}$$

where g_p is the value of property p on grid section g, f_p is the transition function for property p, and $\tau(g)$ describes the neighborhood of g.

A simple example of an application of local property updates is *blurring* or *spatial low-pass/box filtering* in the field of image processing [Bax94]. Each pixel $p_{x,y}$ (corresponds to a grid section) in an image has a scalar *intensity* property, $I(p_{x,y})$, and a neighborhood of nearby pixels $\tau(p_{x,y})$. To create a blurred image, a new intensity for each point is defined:

$$p'_{x,y} = \frac{I(p_{x,y}) + \sum_{p \in \tau(p_{x,y})} I(p)}{|\tau(p_{x,y})| + 1}$$

and a simultaneous update rule is applied: $\forall x, y : p_{x,y} \leftarrow p'_{x,y}$. A good demonstration of the locality of the effects of the blurring algorithm can be found in Figure 3.6. The larger-scale effects of blurring an image are shown in Figure 3.7.

We extend this model to include a means for tweaking the state of the system externally. That is to say that the system can evolve in and of itself by the continual application of

(a) (b)

Source: `http://www.geocities.com/danjnm_2000/dragons.htm`

Figure 3.7: The effects of one iteration of blurring on a dragon image. A dragon is displayed (a) before and (b) after the blurring of the image.

iterative updates as in the classical CA case, but we introduce an *event-based interface* for external entities to interact with the system at any given time. We do this to mainly for the purpose of allowing player agents to provide input into the evolutionary growth of the virtual environment, but these external entities need not only be player agents. The external agents can also be autonomous artificially intelligent, simulated expert systems, or simply completely random. The major point here is that we have a system that evolves on its own but can be perturbed by outside influences or *events*.

As before, events are abstractly defined. Semantics for events only exist when the events are formally described in a meaningful context. Events have an *event type*. An event is exactly what its name implies: it is something than can occur in the system. Instances of events are called *occurrences*. An occurrence is a 2-tuple (e, t) where e is the event type and t is the timestep. The occurrence set, $O = \{o_1, o_2, ...\}$ precisely describes the external causality of the virtual environment; the method for which O is formed is an abstract layer only functionally defined by the model. This layer acts as the interaction interface between the system and the model: the system is described by the implementor so that the rules that govern external interaction can be domain-specific. External entities interacting within the virtual environment have control over the production of occurrences in the system. Transitively, they have limited control over the evolution of the state of the virtual environment.

The adaptation process aims to modify the values of the properties over time based on the impact of events that occur in the system. This is done by defining a functional specification for the changes that get applied in the iterative algorithm. By using this specification, the iterative state-update process is uniform over all functions. Since the process is defined until the end of time, the adaptation process will continually adapt to any and all external influence it is subject to, leaving a completely automatic self-adapting system.

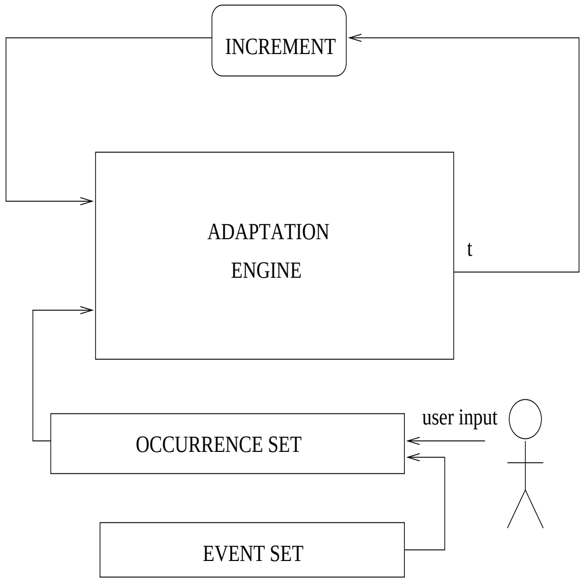


Figure 3.8: The causal block diagram representing the general adaptation process.

As a result of the abstractions, the model splits itself into an adaptation engine module which is completely generic and the adaptation system sub-modules which are not at all generic. These sub-modules plug into the adaptation engine and use it to modify the state of the adaptation system. The implementor of the system modules is completely free to build a customized virtual environment which adheres to the adaptation model, and use the adaptation engine to perform the adaptive tasks required by the system.

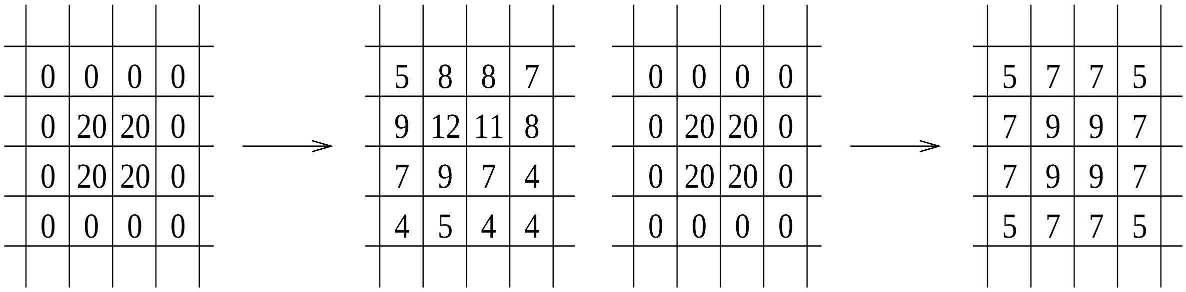
The general idea is summarized by a *causal block diagram* [PdLV02] in Figure 3.8.

3.2.1 Generic Adaptation Procedures

Experimental evidence has shown that there are some generic adaptation concepts which are common to most systems and thus can be more generically formulated. Such algorithms further generalize the model and hence increase the overall usefulness of the framework. Most concepts listed below are simply intuitive constructions obtained by reflecting upon the adaptation process.

Simultaneous Cell-Update Masks

As stated in the previous section, the value of the properties on each cell change in time as a function of the values on neighboring cells at the previous time step. It is natural for programmers to implement the effects of the updates to cell values (at a given time in the



(a) (b)

Figure 3.9: A region affected by modifications after 1 timestep of blurring using (a) sequential iterative updates and (b) simultaneous update rules

timeline) as a sequential iteration over all grid cells. This causes a bias problem, because for a given cell-update, the value of its neighbors could already have been modified due to the order of the iteration. The effect of the bias in an example of blurring is demonstrated in Figure 3.9a.

The modifications made to the cells assume no intermediate representations between time steps: their values change simultaneously. The new value is strictly a function of current values. There can also be any number of properties on a grid cell. To implement this, we propose using *cell-update masks*, or simply *masks*.

Masks are temporary grids that hold only the modifications to be applied to the grid for each grid cell. The adaptation algorithms calculate the modifications, store the modifications temporarily in the corresponding section in the grid. When all the calculations are done for the iteration, the mask is then applied to the grid: all modifications in each grid section in the mask are applied to the corresponding grid section in the real grid. Then, the mask is cleared for the next time step, and the process repeats at each time step.

Vector Averaging and Angular Propagation

As in blurring, grid properties in cellular automata are commonly scalar properties. SimCity is an example of classic game that relies on cellular automata techniques [Sta96], associating scalar quantities with grid cells. In SimCity each grid cell may have scalar properties such as pollution levels, crime rates, land value, and so on. There is, however, no reason to restrict grid properties to scalar values.

We define a *discrete vector field* as $V_G : G \rightarrow \Re^2$, so that for each grid section $g \in G$, there exists an associated vector. The vector at cell $(3, 2)$ will be denoted $\vec{g}_{3,2}$. Note that a 2-dimensional vector can be thought of as a magnitude and angle; when we are interested in just one component of the vector we can reduce it to the scalar case; e.g., a simple angle value

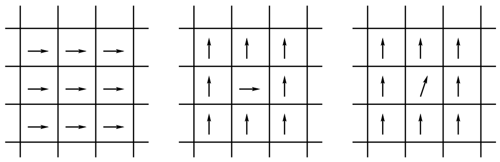


Figure 3.10: Affect of an update on one grid section (assuming $\gamma = 1$), showing a) before the change b) before the update on the middle grid section c) after the change and update

$\theta_{3,2}$.

Vector averaging is a technique analogous to image blurring, except on vector components rather than scalar components. We initially ignore the vector's magnitude and assume it does not change. Each $\vec{g}_{i,j}$ is then modified to have a new angle computed as a weighted average of its own state and neighboring angles. Suppose we have an average angle $\overline{\theta_g}$ for a grid section g and its neighborhood. We define a *shift from* $(\vec{g'}, \vec{g})$ for each neighbor g' as the difference $\overline{\theta_g} - \theta_{g'}$. In the special case where $g' = \bar{g}'$, the shift represents the discrepancy between an angle and its relative neighborhood average. For simplicity, we assume that all angles have the smallest possible magnitude and sign respect the unit circle convention. That is, $-\pi \leq \theta \leq +\pi$, $\theta_g = 0$ points "east", $\theta_g = -\pi$ point is "west", $\theta_g = +\frac{\pi}{2}$ points "north", and $\theta_g = -\frac{\pi}{2}$ points "south". Note that we assume this for <u>all</u> angles, so that *shift from* $(\hat{\imath}, -\hat{\jmath}) = -\frac{\pi}{2}$, not $\frac{3\pi}{2}$. If the result of any mathematical calculations gives an angle outside these bounds, the angles are immediately *cyclized* (repetitive addition or subtraction of 2π) until they are within these bounds. An immediate consequence of this construction is that given any two vectors, *shift from*$(\vec{v}_1, \vec{v}_2) =$ *cyclize*$(\theta_2 - \theta_1)$.

As in blurring, the values approach their current relative neighborhood average. The total angular change for g is then some proportion of shift from g, for some constant γ, $\delta_g = \gamma \cdot$ *shift from*$(\vec{g})$. The update rule then becomes: $\forall g \in G : \theta_g \leftarrow \theta_g + \delta_g$, applied simultaneously (using masks) over all grid sections.

To demonstrate the effects of vector averaging, consider a single grid section surrounded by its *8-neighborhood* [Tou], all of its vectors pointing eastward ($\theta = 0$) with arbitrary magnitude, as seen in Figure 3.10. Now, if we shift each surrounding vector by 90°, the average will shift by $\Delta\theta = (8/9) * 90° = 80°$, so the update will shift the middle vector's angle by $\delta = \gamma\Delta\theta$. Since the middle vector has shifted, upon the next application of the update (the next iteration) it will in turn cause a difference in average of all points for which it is a neighbor. This will cause those grid sections' vectors to update, and so on. As a result, a change in angle propagates through the grid via its neighboring cells, but loses influence each iteration.

The long-term effects of a sudden change in angles over time is called *angular propagation*. The effects of the changes are transferred to the surrounding areas over time until the influence of the change is negligible. By adjusting weight parameters such as γ local turbulence can be damped according to the needs of the system being modeled. A high value for γ may signify a region particularly sensitive to change, whereas a lower value indicates a resistance to change.

Angular propagation can be caused by occurrences of events. The propagation shown in this section was an example of a specific type of propagation applied to changes in angles of vectors. However, the propagation concept itself is more general. If after 3000 iterations of blurring a sudden block of black pixels were added, the event would cause an impact that would propagate the dark colors to spread around evenly over the image. The system is thus adapting to the occurrence by propagating effects of event occurrences to its surroundings.

Flow-based Fuzzy Property Update Rules

Non-constant scalar properties on grid sections can be modified differently than simple averaging. When blurring, values are modified and set directly to the value of a given calculation involving local and neighboring values (the average). A *flow* instead describes the transfer of information between neighboring grid sections. When using flows, properties values are treated as quantities that are displaced from one grid cell to a neighboring grid cell. The *flow function* for a given property or set of properties describes precisely how information is transferred from one grid cell to the next.

Vectors on each grid section describe a strength and direction of flow. The flow function computes how much of a property is transferred from a grid cell to the cells in its neighborhood as a result of the value of the vector property. Therefore, a flow function takes a vector as a parameter and returns a set of *displacement maps* of the form $(g, g' : g[p] \leftarrow g[p] - k \cdot g[p], g'[p] \leftarrow g'[p] + k \cdot g[p])$ where g' is a neighbor of g, $k \cdot g[p]$ is the amount of the property p to be displaced from g to g', and $0 \leq k \leq 1$. The adaptation process applies the flow changes described by the displacement maps for each grid section at each iteration of the computation.

We use a fuzzy approach similar to fuzzy control to compute flow displacements for a more natural flow dispersal. The flow function can be formulated as a fuzzy controller. Formally, the flow function consists of n fuzzy components: $z_1, z_2, \cdots, z_n$. Here, z_j is an arbitrary fuzzy membership function $z_x(\vec{g}) \in [0, 1]$ which represents the raw influence of that component over a given property. The influences of the components are analogous to the values of the actions obtained by querying a fuzzy rule-base. The displacements returned by the flow functions are analogous to the actions chosen by a fuzzy controller. Fuzzy control is still used to query a rule-base and the outcomes measure the influence of the displacement actions. The rule-base is created by the designer of the example application system.

In this case we allow simultaneous actions to be chosen and performed. The result of this difference is that several displacement maps are created, each with different values of the proportion parameter, k. To obtain k, the membership values are normalized so that they represent the local influence in comparison to other influences:

$$f_x(\vec{g}_{i,j}, p_{i,j}) = \frac{z_x(\vec{g}_{i,j}, p_{i,j})}{\sum_{y=1}^{n} z_y(\vec{g}_{i,j}, p_{i,j})}$$

To make this more clear, consider a scenario where the components are associated with the four major cardinal directions: z_N, z_E, z_S, z_W. The amount transfered in each direction is proportional to the corresponding flow influence value f_{dir}. At each iteration, $\Delta p_W = k_p * f_W(\vec{g}_{i,j}, p_{i,j}) * p_{i,j}$ is the amount of $p_{i,j}$ that is displaced westwards, where the proportion parameter $0 < k_p <= 1$ is the *rate of transfer*. The simultaneous update rules for this component would then be: $R_1 : p_{i-1,j} \leftarrow p_{i-1,j} + \Delta p_W$ and $R_2 : p_{i,} \leftarrow p_{i,j} - \Delta p_W$. Components for other directions are treated similarly. Note that it is also possible to define hybrid components, formed by the conjunction or disjunction of the fuzzy properties; e.g., $z_{NW} = z_N$ AND z_W. Then the displacement of moisture would be listed as a rule set in a fuzzy controller system as is done in [McC00].

The actual behavior of the flow depends on the membership functions used; if a system demands a smooth flow, then naturally the membership functions should reflect that. The role of the fuzzy membership functions are to shape the flow. If, for instance we use a "crisp" function, one with a sharply-defined peak such as:

$$z_N = \begin{cases} 1 & \text{if } \pi/2 - \epsilon <= \theta <= \pi/2 + \epsilon; \\ 0 & \text{otherwise.} \end{cases} \tag{3.2}$$

for small ϵ, then the westward flow will move somewhat discretely. A smoother function like:

$$z_N = \frac{4}{\pi}\sqrt{(\frac{\pi}{4})^2 - (x - \frac{\pi}{2})^2} \tag{3.3}$$

will lead to a smoother spreading.

Several advantages are gained by formulating the flow function as a fuzzy controller. First, it allows the designers of an application system to describe linguistic variables for flow components. Linguistic variables quantify vagueness by construction and as such can be easier to model when the exact information is not available. Secondly, the examples above use vectors for flow components, but this is not generally necessary. Flow components can also be scalar or other values, as long as a membership function can be defined from the arbitrary domain to a value in $[0, 1]$. This fact allows designers to define complex arbitrary components that can still be made meaningful by way of a particular membership function. Thirdly, the rule base is a widely familiar construct and often easy to use as well as easy to modify. Rule bases give the application designer a natural modeling environment along with the flexibility of describing flows based on logical statements that can involve many factors. Lastly, fuzzy controllers can themselves be internally adaptive [Wan96], allowing the flow functions to change based on given criteria.

In this chapter, the core concepts of the generic adaptation model were introduced. The abstract model is simply a grid that is separated into grid cells paired with an adaptation process that modifies the values of grid cell properties automatically over time. The properties are global but can have different local values on individual grid sections. Adaptation is a process that changes the local properties values automatically over time. Local adaptation is adaptation which uses the values of neighboring cells to influence the modification of grid cell property values. External entities are allowed to interact with the adaptive system by causing occurrences of specified events. The adaptation process reacts to these occurrences by applying abstract adaptation procedures at each iteration. Examples of external entities could be players, or artificially intelligent bots.

The adaptation procedures are defined by the specific application of the model. The procedures defined by the applications are algorithmic modifications of the generic properties. Semantics for abstractly defined properties and adaptation procedures are given by the description of the application system. The application systems are therefore thin instances of the generic model. Examples of such application systems will described and analyzed in the following chapter.

Chapter 4
Applications of the Model

In this chapter, we show specific applications of the generic abstract model. The aim of these applications is to emulate real-world systems. For this reason, we also call these applications example systems. Since these systems are built in the adaptation model presented in Chapter 3, they are inherently locally-adaptive. The applications in fact define semantics of a context by giving meanings to property values and providing specific procedures that describe the evolution of the data values over time. Additionally, each application specifically describes the events that can occur in the system and the entities that can cause them. In the end, an example system describes an *adaptive virtual environment* (AVE) which game players can explore.

In designing example virtual environments for systems to apply the adaptation model to, we noticed that systems we had created can be classified into 2 top-level categories: *environment-based* applications, and *agent-based* applications. Both types of applications adapt based on a set of criteria; the difference is how the criteria is obtained. Environment-based applications are adaptation systems that adapt depending entirely on values in the environment itself. Agent-based applications adapt depending on the observations of agent behavior data as well as environmental factors. Agents here take on their usual definition: they are simply entities that interact with the system (or with each other) in some way.

Each section describes one or more applications of the model. Initially, the system is described in general; and the criteria for adaptation in these systems are discussed. Then, the system is formalized conceptually by breaking it down into its major algorithmic components. Adaptation algorithms operate on meaningful data which are mapped to property values in the model. The components are then fit into adaptation procedures, each of which calculates the changes to values due to local adaptation. The adaptation process applies these changes at each iteration of the overall process. We also suggest events that may occur in each system along with their effects on the system and analyze the behaviors of the systems using the implementation described in Chapter 6.

4.1 Environment-based Applications

Environment-based applications are adaptive systems that change over time based on the values of the surrounding environmental properties. Examples of environmental properties will be given in the specific system being described.

Typically in modern games, the only role played by the environment is to provide a virtual setting for the players to play in. The setting has a certain effect on the immersion and the experience felt by the players, but is usually purely aesthetic rather than responsive. The only interaction players have with the environment is with other players or other agents (monsters, etc.). The players can discover the world in time, but they can never really change it, not even indirectly. The environment can change due to game progression, but just in a predefined way.

Environment-based adaptation is an automatic means for the environment to adapt to itself; for example, a tree growing around a physical barrier (power lines) instead of through it, the water level of the sea rising as a consequence of lunar positioning, natural selection. These are all examples of environment-based adaptation.

These examples all contain objects, entities, or things the players should be able to interact with. By expanding the interactive capabilities of the entities and the environment, players could affect the state of the system more meaningfully than by simply gaining more levels and more equipment. In certain cases, allowing the players to interact with the environment, even in very simple ways, should in turn lead to some adaptive behavior, ie. a long-term reaction from the environment. For example, in a medieval fantasy setting, a powerful player sorcerer could cast a spell to remove the natural production of water in a given region. An environment-based application would react to this: after some time the ecosystem would die or deteriorate unless it found another source of water.

4.1.1 An Adaptive Weather System

In computer games, weather simulation is commonly implemented to contribute to a pseudo-realistic world. It is common because it is easy to implement as a randomized system and adds realism. A physical world without any weather would soon become unbelievable. The overall end result is that the players' game experience is improved, most players are satisfied with a random weather simulation system because to them it *appears* like a possible real system. When one cannot make the computerized system behave exactly like a real-world system, making parts of the world at least appear real is a general goal in computer games.

The goals of this research are similar. In particular, we focus more on improving the appearance of the system rather than making it more realistic. That is, we search for an adaptation process that emulates real-world adaptation.

Weather simulation is typically considered a computationally intensive application, largely reserved for supercomputers. In the virtual worlds of computer games, however, physical accuracy is less critical, and much simpler approaches suffice to produce aesthetic, in-game climate effects. Note that by proposing to add adaptation to a non-adaptive simulation system we are proposing to make it more like the real system it is modeling. As such, we are also indirectly and inevitably making the system more realistic. However, this is not our intention; it is a coincidental consequence.

Weather System Description

In its simplest form, a weather cycle displaces moisture: water from lakes and seas is carried by wind to cooler locations, where the reduced water capacity of cooler air causes condensation; rain water eventually runs downhill to refill lakes and oceans [Ent04]. There are several factors that can affect this process, including altitude and terrain structure, wind, temperature, and so on. Each of these can be quantified as a value-based property in our system. The value of the property indicates the significance of the factor in the AVE.

We have modeled our weather system upon the following basic precepts:

1. Wind gathers moisture from bodies of water, and loses water at higher altitudes.

2. Water flows downstream.

3. Altitude affects wind patterns.

These basic precepts will be transformed into adaptation procedures (update rules) following the process outlined in Section 3.2. We must however first properly define the data in the adaptive weather system.

There are 2 basic scalar data values suggested by the basic precepts listed above: moisture and altitude. Moisture represents the density of water in the air. Swamps, bodies of water, humid regions have high moisture, whereas dry places like deserts have low moisture. Altitude is the height of the ground relative to sea level. High regions like hills or mountains have high altitude whereas lower regions like valleys and oceans have low values. The geographic location usually influences a region's climate because each physical location has a different configuration of their surrounding environmental properties.

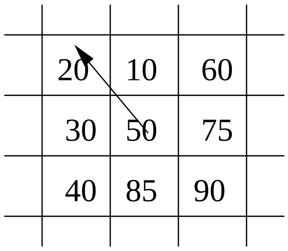


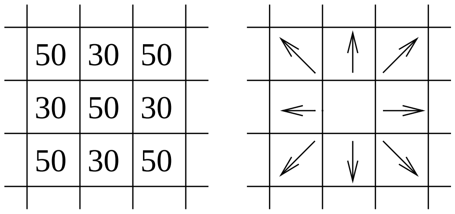
Figure 4.1: Example gradient vector representation. Grid cells show local terrain altitudes.

The scalar values were limited to being between two chosen extremes: $g_{low} = -5000$ and $g_{high} = 5000$. It can never be the case that a value is higher than the high extreme or lower than the low extreme. In this system, the physical correspondence is that there are saturation thresholds for moisture and dryness. A good example is that an ocean or sea cannot get any more moist: they are at g_{high}.

There is 1 basic vector value: the wind. The magnitude of the vector describes the strength of the wind and its direction describes the direction of the wind. There is one more vector property which is an induced property called the *gradient vector*. The gradient vector on a grid section points to the direction of descent, and its magnitude represents the steepness of the grade. Due to gravity, moisture flows downstream in the direction of the gradient and is described as a a fuzzy flow controller (see Section 3.2.1).

The gradient is a vector sum composed of vector components whose magnitudes are differences in altitude values of surrounding cells. The magnitudes of the vectors are determined by subtracting the terrain altitude from the altitude of a neighboring cell, with corners of the 8-neighborhood having a weight factor or $\frac{\sqrt{2}}{2}$. The direction of each vector in the sum is given by the position of the neighbor relative to the center. Figure 4.1 shows an example gradient induced from the altitude values of its surroundings. If we assume unit vectors for each of the cardinal directions and therefore the identities $\hat{N} = -\hat{S}$ and $\hat{W} = -\hat{E}$, then the calculation looks like:

$$
\begin{aligned}
\vec{v}_{grad} &= (50-10)\hat{N} + ((50-60)sin(\frac{\pi}{2})\hat{N} + (50-60)cos(\frac{\pi}{2})\hat{E}) \\
&\quad +(50-75)\hat{E} + ((50-90)sin(\frac{\pi}{2})\hat{S} + (50-90)cos(\frac{\pi}{2})\hat{E}) \\
&\quad +(50-85)\hat{S} + ((50-40)sin(\frac{\pi}{2})\hat{S} + (50-40)cos(\frac{\pi}{2})\hat{W}) \\
&\quad +(50-30)\hat{W} + ((50-20)sin(\frac{\pi}{2})\hat{N} + (50-20)cos(\frac{\pi}{2})\hat{W}) \\
&= 54.142\hat{N} - 60.35534\hat{E} - 56.2132\hat{S} + 48.28427\hat{W}
\end{aligned}
$$



(a) (b)

Figure 4.2: Example of degenerate cases where (a) $\vec{v}_{grad} = 0$ and (b) $\vec{v}_{wind\_avg} = 0$.

$$= \quad 108.64\hat{W} + 110.35\hat{N}$$

giving a vector with angle $tan^{-1}(110.35/108.64) = 45.45°$ north of west.

The inverse gradient points in the direction of ascent, and is used to determine how wind direction is altered by the current terrain. If a gust of wind is pointing into a wall, it will instead blow around it. For wind to move around higher-altitude obstacles it must therefore be pushed away from the direction of the inverse gradient or, equivalently in 2D, towards the direction of the gradient.

Another induced property is the current local average wind value. The average wind value is a vector whose magnitude is equal to the sum of all wind magnitudes in the 9-region divided by 9; the average direction is precisely the direction obtained by the sum of all the vectors. Comparing the current wind value with the current average gives a summary of how the current wind value on a cell differs from its immediate surroundings.

Note that degenerate data representations are possible, as shown in Figure 4.2. For instance, it is possible that the gradient has a 0 magnitude even though not all of the neighbor values are equal to the current cell value. As well, the current average could have no direction at all when all the vectors sum to a vector whose component magnitudes are all 0, or worse: numerical error could lead to an arbitrary angle. These are of course due to the fact that what is described here are approximations. In practice, we should be aware of these limitations and deal with them accordingly.

Weather Adaptation Procedures

There are 3 major adaptation procedures in the weather system: `moisturewind`, `gradDev`, and `rain`. The procedures are functional algorithms that perform the actions needed for adaptation such as checking the values of some criteria and modifying values as a consequence. In this subsection, we will thoroughly explain the steps in each procedure.

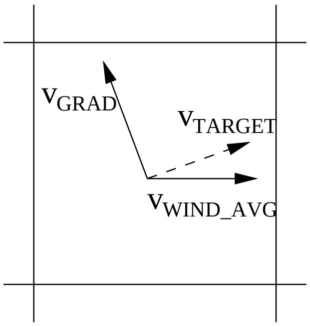


Figure 4.3: An example of obtaining $\vec{v}_{target}$ given $\vec{v}_{grad}$, $\vec{v}_{wind\_avg}$, and $\alpha = 0.8$

The `gradDev` procedure represents the bending of the wind vectors over time due to the values of altitude. The procedure uses the vector averaging and angular propagation concept explained in Section 3.2.1. The current wind vector is shifted towards some target vector, denoted $\vec{v}_{target}$. The shift is scaled by some damping parameter, $0 < \gamma < 1$, which roughly corresponds to the speed of the shift since one shift is applied per iteration of the adaptation process. For example, when $\gamma = 0.1$ it would theoretically take 10 shifts before $\vec{v}_{wind} = \vec{v}_{target}$, as opposed to 100 shifts if $\gamma = 0.01$, assuming of course no perturbation from other factors such as angular propagation. Note that the damping parameter γ is similar to the weight parameter used in Reinforcement Learning [SB98] update rules. The damping parameter is chosen by the modeler depending on the specific needs of the system.

As previously mentioned, the most influential contributing factor to the wind shifting is the gradient vector. We also incorporate an inertial factor, to give a smoother flow pattern; we designate $\vec{v}_{target}$ as some composition of the gradient vector and current average wind vector. The composition is such that $\theta_{target} = \theta_{wind\_avg} + \alpha \cdot \mathit{shift\ from}(\vec{v}_{wind\_avg}, \vec{v}_{grad})$. An illustration of obtaining $\vec{v}_{target}$ is found in Figure 4.3. Again, α is a damping parameter which affects the smoothness of the transitions versus the angular propagation due to influence from the surroundings. This parameter further increases the flexibility available to the users of the application.

Moisture is displaced in two ways: by the `rain` procedure and by the `moisturewind` procedure. Both procedures use fuzzy flow-update rules to transfer scalar values between neighbors. Similarly to the `gradDev` procedure, each flow-update rule has a damping parameter ($k_{moisturewind}$ and k_{rain}) associated with them which scales the actual modification allowing the modeler to easily modify the influence of the moisture-altering procedures.

In the `moisturewind` procedure, four independent components that comprise the wind are represented by the cardinal directions: $\vec{v}_N, \vec{v}_E, \vec{v}_S, \vec{v}_W$. The value of each component is calculated

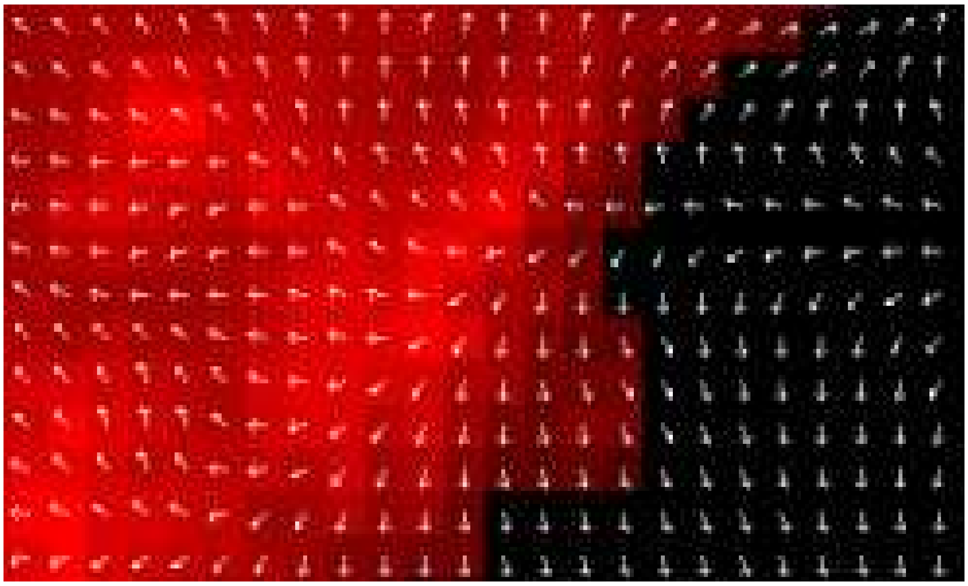
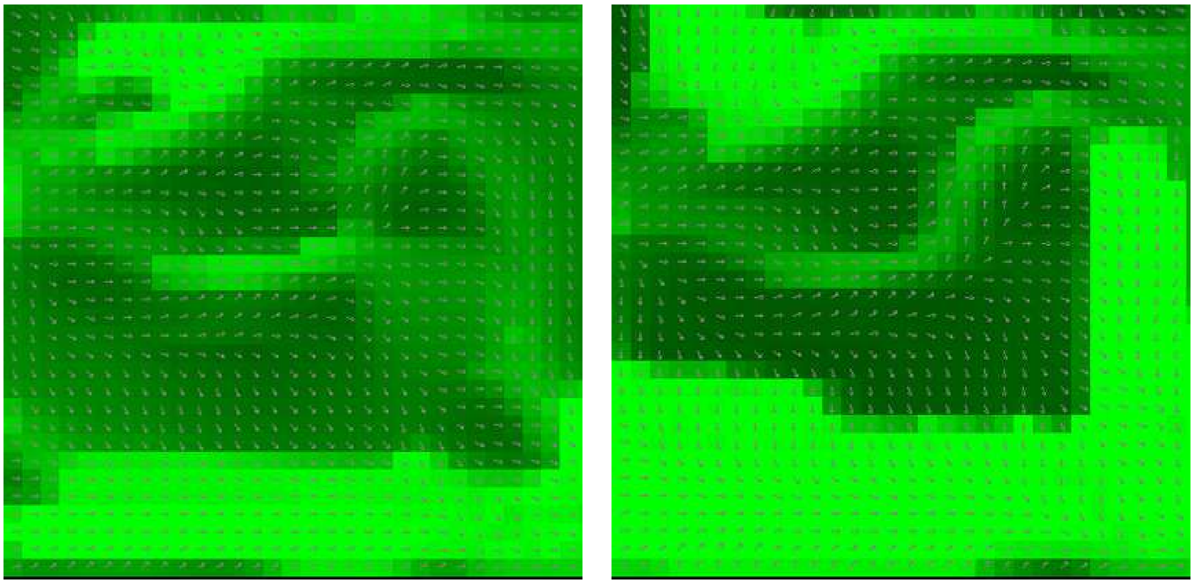


Figure 4.4: An example weather system configuration after several hundred iterations showing wind and altitude values. Bright red areas are high (land/mountains), black areas are low (seas), and the arrows show the direction of wind movement.

by a fuzzy membership function. Any fuzzy membership function can be used, providing yet more flexibility to the user of the application. In most of our simulations, a *semi-circular* fuzzy membership was used (see Equation 3.3). The values are then normalized, and represent a proportion of the amount of moisture displaced to surrounding grid sections, again as per the method in Section 3.2.1.

The `rain` procedure represents the downpour of water from higher regions. It uses the same vector component breakdown and same idea as the `moisturewind` procedure except that the gradient is used instead of the current wind value. The rationale here is that the gradient points towards downwards slope, the corresponding physical meaning being that some of the moisture is carried down the slopes by gravity instead of purely carried by the wind.

A screenshot of the wind and altitude in weather system simulation is given in Figure 4.4. The image shows an eastern ridge (brighter red) of Pakistan next to a flatland (black) region. The system was given an initial configuration of $\forall g, g[\vec{v}_{wind}] = 50\hat{i}$ (all wind vectors point eastwards). Figure 4.5 shows another 2 screenshots of the south-western part of the Pakistan map shows the moisture levels at 2 different times in the evolution of the moisture spread.



(a) (b)

Figure 4.5: An example weather system configuration after (a) 100 iterations and (b) 300 iterations showing moisture values and wind vectors. Bright green areas signify high moisture regions whereas darker region correspond to dry regions.

Terrain Generation

Automatic terrain generation is often desired for computer games. Since terrain influences weather and represents a crucial part of any real-world natural environment, it seems to fit intuitively into a weather system.

Two methods were investigated for terrain (altitude) generation. The first method includes 3 steps: a coarse random distribution, a smoothing pass, and rescaling. The first step was a simple iteration over every grid section that assigned some uniformly random value between g_{low} and g_{high} to the altitude property on that grid section. The resulting altitude maps are too coarse to be realistic, so they are blurred a number of times to smooth the surface. The smoothing also removes many of the sharper parts of the altitude map. To accommodate, the minimum and maximum values over the entire grid are found, and then then for each grid section the value of altitude is scaled proportionally to $[g_{low}, g_{high}]$. As a result, there contains at least one value (the maximum value) that is equal to g_{high} and at least one value (the minimum value) that is equal to g_{low}. The advantage of this first method is that it is easy to implement, simple to understand, and rather efficient. However, the disadvantage is that it provides a less realistic result which may be extremal in local variation.

The second method used real-world physical location data obtained by the DIVA-GIS project

[RHG03]. The DIVA-GIS information archive contained sufficiently accurate altitude maps of many locations across the world. The problem for this particular application was that the maps were actually too detailed to be easily represented during prototyping. Therefore, a re-sampling process was run to downscale the data: the points were organized into 2x2 square regions containing 4 points each, the values of the 4 altitude points are averaged and then considered 1 point in the new map. In the case of odd-number points on one of the axes, the last row or column of sections becomes 3x2, 2x3 or 3x3. This special case creates a loss-of-information bias towards the outer points, but since the loss is minimal the bias is not a critical issue. Since the boundary of these maps is arbitrary, we could have also simply omit the outermost points altogether. We chose to include them as to encourage the least amount of information loss. The re-sampling is repeated until the map is sufficiently small enough to represent on a screen. Some larger samples were also kept for performance measurements to be taken (see Section 6.3).

Boundary Conditions

Carefully-designed boundary conditions are important for many systems to behave properly. One common mistake in system design is to simply omit dealing with boundary cases. Such errors often eventually lead to erratic observed behavior.

Two different boundary schemes for grids were examined. The first scheme was strictly-bounded: the grid simply "ends" at the boundary points. In this scheme, the assumption is made that there is nothing beyond the last grid section on a grid. The east-most grid sections have no eastern neighbors. Similarly for all extreme sections and directions possible in grid layout. Consequently, the extreme points had fewer neighbors which causes some bias in the calculations containing local property values. The effects of this bias on the random method of terrain generation can be seen in in Figure 4.7: as a result of generating a random terrain, the outer ridges have lower altitude than the rest of the grid.

The other boundary scheme is to have no boundaries at all. The east neighbor of the eastern-most point on the grid is the western-most point in the same row. Similarly for western neighbors of western extremities, and for the north/south axis as well. This boundary scheme corresponds to the torus mathematical topology. This scheme also removes the bias on the edges. By default unless otherwise mentioned, this boundary condition was used in all simulations.

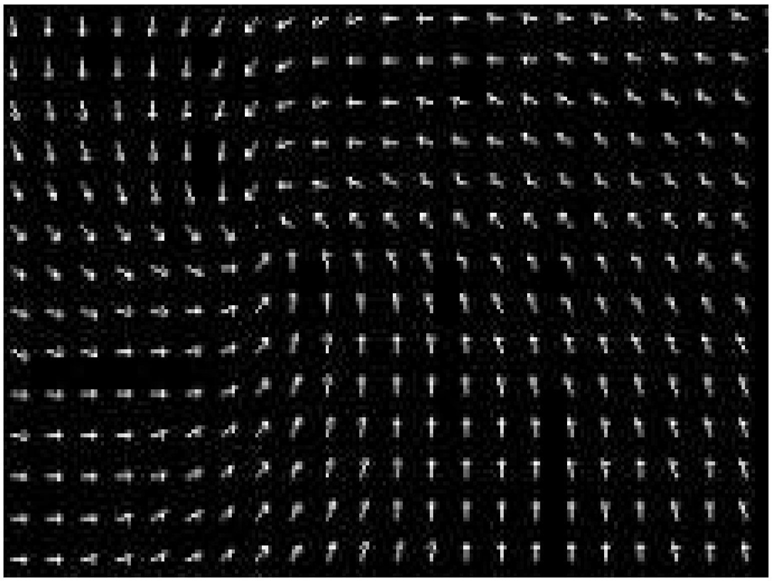


Figure 4.6: An example tornado.

Weather Events

Incorporating interesting weather *events* is also possible and likely desirable. Events can be anything that affects the properties in the system such as earthquakes, tornadoes, tsunamis, storms, etc..

We have modeled "tornadoes" as local, non-linear dynamical systems with the stable fixed points at their centers. A 2-dimensional dynamical system [Str01] represents the wind flow within a specified sub-grid such that the center point is fixed point in a stable spiral. Within this sub-grid, the wind vectors are no longer influenced at all by outward sources; they are only part of the tornado. The outer vectors are treated normally. As a result, the effect of the tornado's turbulence is spread with decreasing influence out to the surrounding grid sections via angular propagation.

The tornado moves by slightly displacing the sub-grid (along with it, the fixed point) at each iteration and reassigning the values in the sub-grid dynamical system around it. The movement of the tornado is defined by some arbitrary function of timesteps and could be randomly generated in the same way that path models are generated for mobile agents (see Section 6.2). Figure 4.6 shows a screenshot of a tornado on a flat terrain. We will measure the efficiency of the implementation of tornadoes in Section 6.3.

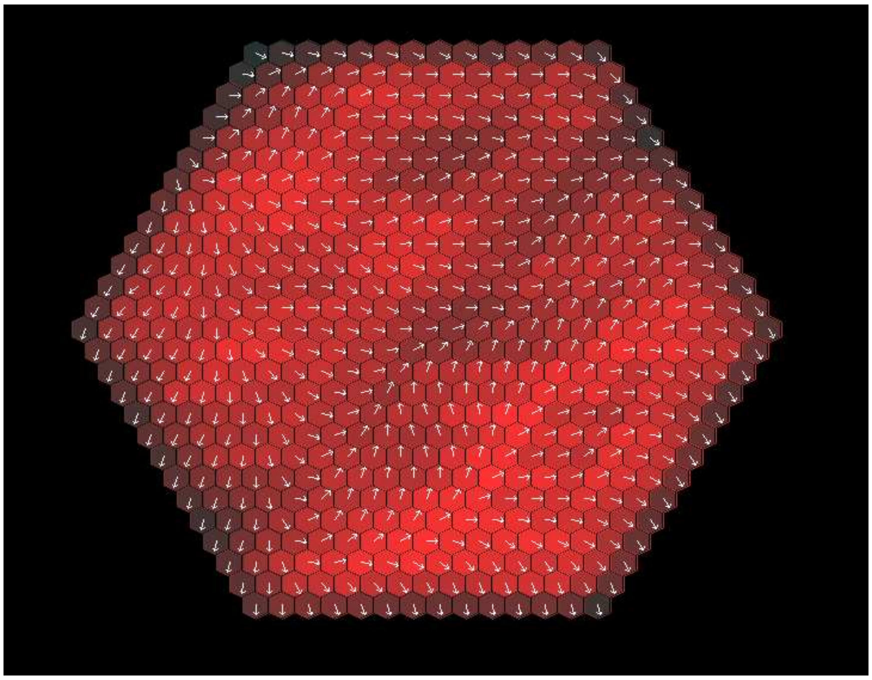


Figure 4.7: An example hexagonal grid in the weather system.

Hexagonal Grid Representation

As stated in Section 3.2, since the adaptation process is based entirely on neighbors in some metric space the theory extends to metric spaces other than a rectangular grid. A hexagonal grid is a "nice" metric space because notion of neighborhood is particularly intuitive. Two cells are neighbors in a hexagonal grid if they share an edge, or equivalently, if the distance between them is 1. A neighborhood of a cell in the hexagonal grid is its 6 immediate neighbors.

The adaptation process here remains unchanged. The neighboring cells are equally distant from a given cell, so the gradient calculation becomes even simpler because there are no special case "corner-neighbors". Six fuzzy actions instead of 4 need to be defined for the flow controllers in the moisture spread procedures, but otherwise flow updates remain the same.

A capture of the hexagonal grid weather system is displayed in Figure 4.7.

Analysis of Weather System Behavior

All the major components of the weather system have now been described. The question still remains: how does this system behave? The answer to this question is presented in detail here.

An important concern is the performance of the adaptive system; it must of course be at least efficient enough to be usable. We will defer performance analysis until we describe the implementation in more detail, in Chapter 6. Another important concern is how well it achieves its purpose: does it act in a stable, aesthetically appealing manner or does it produce completely random and/or meaningless weather effects.

Moisture dispersal seems to happen as smoothly as expected. Areas of pure saturation develop in the flatter regions, bits of moisture are carried around the edges of these areas and in particularly windy areas. Playing with the values of the damping constants for the effect of wind vs. rain produces the expected resulting behavior, which is reassuring.

As mentioned in the description of the `gradDev` procedure, there are several factors that affect the wind's change. A concern, then, is whether the combination of these influences leads to the wind changing forever or does it instead approach convergence to a fixed state. If the wind vector moves towards the gradient every iteration, it is certainly going to converge eventually. However, the average wind vector might not necessarily remain the same and, in particular, might move away from the gradient. In cases where the average wind moves away from the gradient, $\vec{v}_{target}$ also moves away from the gradient. As a result, the direction of wind change will depend on which side of $\vec{v}_{target}$ the wind vector is on, which depends on α.

If $\alpha = 1$, then $\vec{v}_{target} = \vec{v}_{grad}$ so no matter how deviant the wind average is, the wind vector will always approach $\vec{v}_{grad}$ and so is certain to converge. In contrast, if $\alpha = 0$, the wind will always approach the average. In our chosen starting state, this immediately converges as well since the average wind vector for every grid cell is $\frac{50}{9}\hat{\imath}$. What about convergence conditions when $0 < \alpha < 1$? A closed-form expression for convergence conditions would be useful to have.

Assuming we ignore magnitude, in general the wind vector, $\vec{v}_{ij,wind}$, on a given grid section g_{ij} will undergo the following update at each iteration:

$$\begin{aligned}
\theta_{ij,wind} &\leftarrow \theta_{ij,wind} + \gamma \cdot \mathit{shift\ from}(\vec{v}_{ij,wind}, \vec{v}_{ij,target}) \\
&= \theta_{ij,wind} + \gamma \cdot \mathit{cyclize}(\theta_{ij,target} - \theta_{ij,wind}) \\
&= \theta_{ij,wind} + \gamma \cdot \mathit{cyclize}(\theta_{ij,wind_avg} + \alpha \cdot \mathit{cyclize}(\theta_{ij,grad} - \theta_{ij,wind_avg}) - \theta_{ij,wind})
\end{aligned}$$

At first, the update rule looks like it takes the form of a *one-dimensional iterated map* [Str01] Iterated maps are discrete-time dynamical systems in which a value $x_{i+1} = f(x_i)$ where i is an iteration number. Research has been done on these systems; well-known techniques exist for analyzing them. Unfortunately for us, not only do we actually have a set of these equations, the function f is dependent on many of the set's previous iteration values not just its own previous value. If it were only for the former, then we could simply treat the wind-bending as a collection of independent iterated maps and solve a general equation which would apply to all of maps. The set of iterated values is $\{\forall i, j | \theta_{ij,wind}\}$ and $\theta_{ij,wind\_avg}$ is actually a function of the

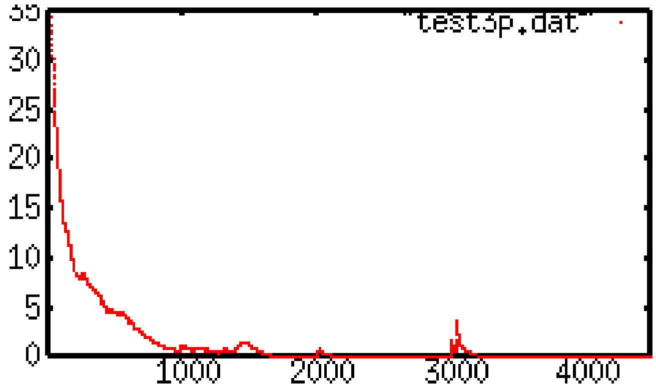


Figure 4.8: Δ_{mask} as a function of the timestep in a simulation run on the Pakistan terrain map.

neighborhood property values $\tau(g_{ij}[wind])$. Therefore we have a $(height \cdot width)$-dimensional iterated map with equations of the form $\theta_{ij,wind} = f(\theta_{i-1,j-1,wind}, ..., \theta_{i+1,j+1,wind})$. This is a complex system and hence it is difficult to solve analytically. It is also the case that components of an adaptation system may be arbitrarily complex, and so proving convergence in general will be difficult. Direct, practical techniques are more convincing.

We choose a quantitative approach to measure the convergence and effects of the damping parameters on the system's behavior. In doing so, we define the overall change in wind-deviations from one timestep to the next as the sum of a change in angles over all grid section. Formally, this sum is:

$$\Delta_{mask} = \sum_{i,j} |\theta^{t}_{ij,wind} - \theta^{t-1}_{ij,wind}|$$

At a fixed point, the wind vectors don't change at all so this sum will continually be equal to 0. Note that Δ_{mask} is expressed in radians.

An experiment was conducted to measure the values of Δ_{mask} over time, assuming default values of $\alpha = 0.2$ and $\gamma = 0.1$. The maps of Pakistan, North Korea, and a randomly generated terrain were used, each of which had both heights and widths of at least 50 grid cells. Every experiment converged to $\Delta_{mask} < 1$ in less than 3000 iterations and convergence graphs look similar. Figure 4.8 shows the precise values as a function of timestep using the Pakistan map. The experiment included dynamically adding altitude values at certain times, which will be explained below.

In general, the function is not non-decreasing: there are iterations where the Δ_{mask} actually increases. Increases are usually small (< 1) but not always negligible which implies that it is not necessarily only caused by numerical error. However, on all 3 tests, the Δ_{mask} did indeed converge to essentially 0 ($\approx 10^{-13}$) after 7000-8000 iterations and remained at this value endlessly. In fact, the converged value never reached exactly 0 due to some minimum amount of numerical error.

As mentioned above, patches of altitude were added to the map dynamically during its evolution. The reason for this functionality is to see how the system reacts to sudden changes once it has stabilized. A small patch of approximately 10-15 altitudes of g_{high} were added at $t \approx 1500$ and a larger patch (20-30 altitudes of g_{high}) at $t \approx 3000$. Both patches of altitude were added to completely flat areas. The system reacted to these "sudden growths" by slowly bending the wind vectors around them, and returned to a stable/fixed state within at most 100-150 timesteps, as show in Figure 4.8.

The tests above assume specific values of α and γ. We have shown convergence and stable behavior in a particular case. Above, it was implied that convergence is somewhat dependent on the values of these damping parameters. Looking back at the equation for the update of $\theta_{ij,wind}$ we see that γ is just a proportion of the shift towards $\vec{v}_{target}$. So as long as $\gamma > 0$ then convergence only depends on α. Therefore, simulations were run on the Pakistan map with $\gamma = 1$ and $\alpha = \{0.0, 0.05, 0.1, 0.15, ..., 0.95, 1.0\}$. The results of the simulations are displayed in Figure 4.9. Note that not all values are present. Each simulation was stopped at 10000 iterations if it had not yet converged. Many had not converged.

The simulation runs for varying alpha values lead to a discovery of cyclic behavior in certain cases. The corresponding representation in the convergence graph is a long stretch of non-continuous periodic values. In every case, the cycles started at some point before the 10000th timestep and continued well beyond that point. As well, the cycles only formed when $\Delta_{mask} < 5$, meaning the system had almost converged but entered a cycle instead of continuing. Re-running the tests using a graphical interface showed that in all cases, a cycle corresponded to 2-6 neighboring wind vectors alternately "flipping" from one orientation to the another and then back, while the rest of the map remained fixed. Detecting these cycles is non-trivial but not difficult, however it does add an extra consideration to remember when using the application. Values between 0.1 and 0.6 do not converge, while $\alpha > 0.7$ seem to take longer to converge. This isn't necessarily a critical issue since the cycles only occur at low levels of Δ_{mask}. One could simply stop adapting once a threshold point of $\Delta_{mask} \leq 1$ is reached. The specific cause of this strange behavior remains unknown.

The last interesting addition to the system was *control points*. It is possible that one may want some of the wind vectors to be entirely immune to change; for instance, as a way of ensuring boundary conditions. This was enabled both statically and dynamically, and was tested on several maps. The results were as expected: the control points allow the modeler to force certain shapes of flow by using control points.

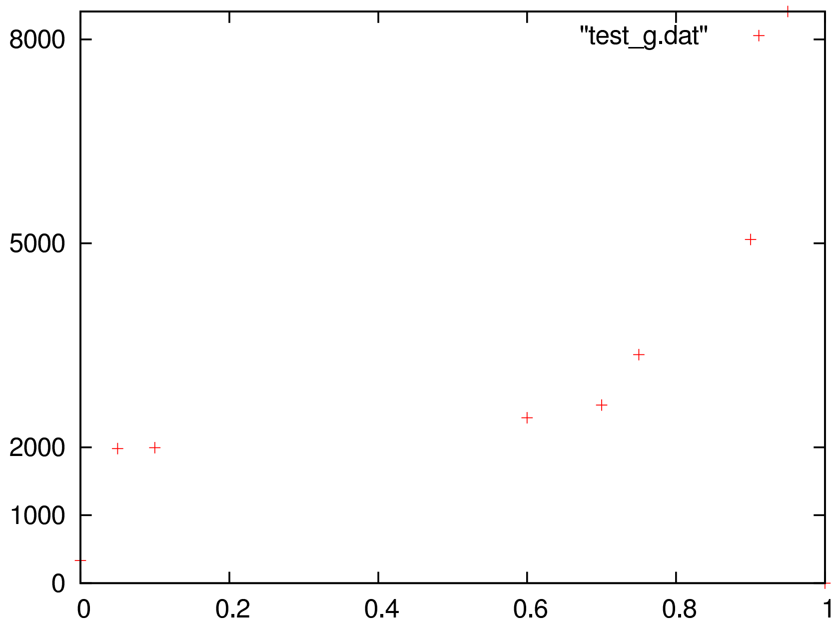


Figure 4.9: Maximum timestep until convergence as a function of α after many simulation runs on the Pakistan terrain map.

4.2 Agent-based Applications

Agent-based applications differ fundamentally from environment-based applications in that *agents* contribute directly to the adaptation process. In environment-based adaptation, an application designer could define agents in the AVE to interact with its surroundings and somehow allow them to modify an environmental value. However, the adaptation process still only adapts to the actual changes in the environment. In agent-based adaptation, properties of the actual agents themselves are used to influence the adaptation process. That is, the adaptation process observes the agents and their actions in addition to the rest of the environment. The focus of the process is on the behavior of the agents, but uses environmental properties as well. Note that this model presumes only localized information propagation but global effects could be easily incorporated.

As briefly mentioned earlier, agents are simply entities that can interact with the environment or other agents. This definition is generic enough to allow agents of all kinds, and indeed the flexibility is desired. Player agents are agents that are controlled by players of the game. Player agents are usually called *characters*. Non-player agents come in many forms: monsters ("mobs"), player companions ("pets"), non-player characters ("NPCs") which can be guards, merchants, mercenaries, enemies, peasants, etc.. Agents need not be restricted to living creatures but commonly are in MMOGs. In typical (static) virtual environments, the agents are the only dynamic aspects of the environment. Here, both the environment and the agents are dynamic and capable of influencing each other.

4.2.1 An Adaptive Reputation System

A player character's in-game reputation is often an important component of the game environment, particularly for persistent-state games in which the same character is re-used for long periods of time. Player actions that harm or help non-player agents agents should result in a logically consistent reaction to the player, giving a greater sense of reality to the game environment. This is necessarily a dynamic property: player reputations need to be constantly updated, and should also ameliorate over time and distance.

In order to allow reputation to more realistically disperse, a word-of-mouth model is employed to flow the impact of events caused by the agents. A game character's reputation is built by the spread of hearsay amongst the populace; *reputation flow vectors* modeling the communication patterns of the general populace in each grid section are used to describe the direction in which word of a positive or negative action will spread.

For our example system we developed a virtual communication terrain which, as in the weather example, is represented as a discrete vector field. The difference is that the vectors on this vector field do not change with respect to a static value such as the gradient. These vectors are influenced solely by the agents' velocity vectors currently occupying the corresponding grid cell and some of its surroundings as well. The same wind model used in the weather system then traces out the flow of reputation information.

In our case we simulated route popularity by tracking movements of semi-randomized agents moving between cities following smooth curved paths, choosing destinations probabilistically based on distance and city size to discover trade routes. The basic movement model for simulations is described below. In Chapter 5, movement models for agents are examined in much greater detail.

Reputation events are abstractly defined even in this application: they are events that all agents can cause that can potentially modify their reputation. They are only slightly analogous to the weather system events because in these cases, the players are free to generate occurrences as well as computer-controlled entities. Rescuing the princess, killing a commoner, stealing from tavern, etc.. These are all examples of reputation events.

Positive and negative *reputation points* (RPs) are created on a grid section when a reputation event occurs at that location. The amount of RPs is proportional to the severity of the event. These points are displaced via the flow, and also dissipate at a slow rate. For each point that dissipates on a grid section, the reputation of the player is altered at that location. This process repeats until all the reputation points have dissipated, causing a local alteration in the player character's reputation. RP is one of the scalar grid properties.

The player character's *reputation value* is another example of a scalar grid property. Whereas the reputation points dissipate over time, they slowly modify the reputation value. Positive reputation points will modify the reputation value to a higher value, representing an increase in good reputation. Negative reputation points lower the reputation values.

Reputation Adaptation Procedures

The adaptation process in the weather system includes one cycle that iterates over all the grid sections performing update calculations. In contrast, the adaptation process for the reputation system is split into 2 parts: the agent update cycle, and the grid update cycle. The grid update cycle is analogous to the weather system's update cycle in that it performs calculations as an iteration over all the grid sections. The agent cycle performs the agent-based update calculations and their movement/interactivity simulation. Therefore, the reputation adaptation procedures are split into two categories based on which update cycle they are contained in.

There are 3 main adaptation procedures: `repEvent` and `agentBend`, which are part of the agents cycle and `repwind`, which is part of the grid cycle. The `repEvent` procedure generates reputation events probabilistically depending on a few parameters. In the simulations, it is assumed that agents provoke reputation events and so the reputation events only occur at the current location of an agent. For each agent, that agent generates an event with a probability of P_{event}. If an event is generated by an agent, it is a good event with probability P_{good} or negative otherwise. A generated event has a severity proportional to its reputation points, which is uniformly randomly generated between $g_{low} = -5000$ and $g_{high} = +5000$. When an event is generated by an agent, the reputation points are deposited on the grid section the agent is currently occupying.

The `agentBend` procedure modifies the values of the reputation flow vectors given the orientation of the agents. In essence, an "aura" of vector influence is created by each of the agents. The aura for a single agent is a small sub-grid surrounding the agent (centered on the agent) of vectors. Each of the vectors have the same direction of the agent's velocity and have magnitude linearly inversely proportional to the Manhattan distance (in grid sections) away from the center grid section, to a maximum of 3 grid sections away from the center. The idea is illustrated in Figure 4.10. The resulting reputation flow vector for a grid section is the vector sum of all

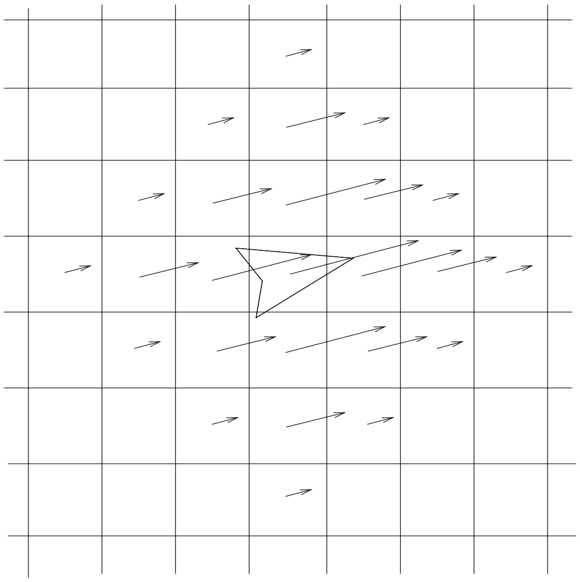


Figure 4.10: The aura of reputation flow vector influence created by one agent

the vectors induced by all the agents' auras on that grid section. The reputation flow vectors for all grid sections describe the flow of communication via agents throughout the grid.

The `repEvent` procedure spreads the reputation points using fuzzy flow-updates exactly like moisture was spread by the wind in the weather system. The vectors in this case are the reputation flow vectors. Here, however, reputation points are temporary. This procedure also converts a number of reputation points to reputation value. Since this procedure is executed repetitively, the reputation points will either be carried by the reputation flow vectors to neighboring cells or converted to reputation values. When converted to reputation values, the converted values are added to the reputation value on the current grid section.

The reputation value on a grid section corresponds to the value of a given player character's reputation at that location. Initially, the reputation is equal to $g_{mid} = \frac{g_{low}+g_{high}}{2} = 0$, neutral. The reputation value added (or subtracted, in the case of negative reputation points) to the grid section converted from reputation points pertains to the player who caused the event. In our simulations, there is only one player and the events are generated at random locations decided by the paths of agents. The system is extended to groups of players in a following subsection.

A Movement Model for Mobile Agents

Despite the vastness of virtual environments in recent MMOGs, within them there seems to exist a finite set of *interest points* placed by the game designers for the players to discover and interact with. Examples of such interest points in existing games are: cities, settlements, borders, spawn points, cavern entrances, trade/merchant stations, meeting points, etc.. Non-player agents often have reasons to visit these interest points as well as player agents. Over time, these interest points become basins of player activity in the VE. It is clear that throughout the course of game-playing, players do two things:

1. travel to and from interest points

2. remain at interest points for some period of time (presumably doing something interesting)

Our simple movement model is composed of 4 major components: the graph which dictates which interest points are connected to (reachable by) which interest points, which interest point is chosen to be the next agent's destination, the shape of the path taken by the agent to reach its destination, and how long the agent remains at the interest points. The simple version that we present in this Chapter is completely random based on a few common sense assumptions. More complex models for agent movement are investigated in Chapter 5.

Each interest point has a coordinate position in the continuous space which the grid is approximating. The graph connecting some of the vertices is then a *proximity graph* [Tou91]: the length of the edges correspond directly to distances between vertices (interest points). Agents can only travel to an interest point s_{dest} from s_{source} if the edge (s_{source}, s_{dest}) is in the edge set of the graph.

Interest points have a scalar *significance*, or size. The higher the value of the significance, the more interesting this point is to visit. It is assumed as well that agents generally prefer shorter distances than long ones, more so than how interesting a place is to visit. Therefore, when an agent chooses a new destination, each neighbor of the current interest point is assigned a weight value $w_{neighbor} = size/distance^2$. The neighbor is then chosen at random with a probability proportional to its weight.

Agent paths are assumed to be slightly non-linear. A path model is derived from a continuous function $f(t)$ defined over $t \in [0, 1]$ with the constraint that $f(0) = f(1) = 0$. The values of this function at $0 \leq t \leq 1$ are considered points on a 2D plane with Cartesian coordinates $(t, f(t))$ and are then transformed to the path's coordinates by using basic affine transformation methods [FvDFH95]. The transformation defines a parametric curve on the continuous space with $\mathbf{f}(0)$ representing the starting interest point and $\mathbf{f}(1)$ representing the end-point. The transformation is represented by Figure 6.3. Basic non-linear functions were used such as sinusoids, quadratics, cubics, quadrics, conics, and compositions of these as well. To generate a path, a random model was chosen along with random parameters (eg. amplitude) and the agent followed the path outlined by the curve $\mathbf{f}([0, 1])$.

Finally, the time between interest points was not explicitly modeled. At each iteration of the adaptation process, with a probability $P_{agent\_newdest}$ a random agent was chosen among the agents to choose a new destination. Once the agent reaches the destination, it "hovers" around the destination choosing random straight paths and turning to remain within a given radius of the interest point. When not following a path, the agents use a typical velocity-based Newtonian physical model for movement. Shifts in direction and velocity are probabilistically determined.

Faction versus Reputation

Faction is a system similar to reputation that is currently used in a number of modern persistent-state games, notably EverQuest. Faction is a system that measures relationships between individuals and/or groups and is at times misunderstood to be the equivalent of reputation [Bro03]. The terminology used is as follows: "an individual's *faction* with another group is high" means that the other group has a good relationship with the individual. Factions are often symmetrical, but the system allows uni-directional like/dislike relationships in general. The key point here is that faction systems measure the status of relationships between individuals and groups. Faction is used in games to decide on actions or general moods of NPC groups per individual.

A player character's reputation is really how well-respected he is in general amongst others; it is about how others perceive him, not about how well they get along. Reputation is a more general concept. Ideally every player has a place in the world. The player character's reputation is a way to quantify that notion: a high value means a good reputation, a low value means a bad reputation. In this application, the value of reputation is not only quantified, it is localized and presented as part of an automatic adaptation process in a dynamic environment. In general, a player character's reputation is a function of that player's actions while playing the character.

Adding locality to an existing faction system has been investigated in a commercial setting, as mentioned by the author of [Bro03]. The implementation details were difficult to deal with. On the other hand, the system presented here has locality pre-built into the adaptation model. The reputation system is just simply an instance; locality is provided implicitly as a natural consequence of using the generic adaptation model described in Chapter 3.

Reputation Groups

The reputation simulator as described above manipulates the value of a single player character's reputation. The reputation value kept on the grid is the value of the single player character's reputation at that location. In general, if there are N player characters in the game and each had a reputation, this would require that each grid section have $2N$ integer variables (1 for reputation points of reputation events caused by a player character, 1 for reputation value of a player character). Typically, these games host hundreds of thousands of players [Com04]. Modeling reputation in EverQuest would require $430000 \cdot 2 \cdot 4$ bytes= 3.36 MB per grid section! This is clearly impractical.

The proposed technique to fix the practicality issues of the implementation would be to conglomerate individual character's reputations into groups. Player characters by default would not be part of any group. Therefore, individual characters would only gain reputations when associated with a group. The reputation of the group on the whole is what is represented in the grid. Whenever a player character in the group causes a reputation event, the reputation value for the whole group would be altered. Therefore, the reputation would be shared with the group that player characters are associated with.

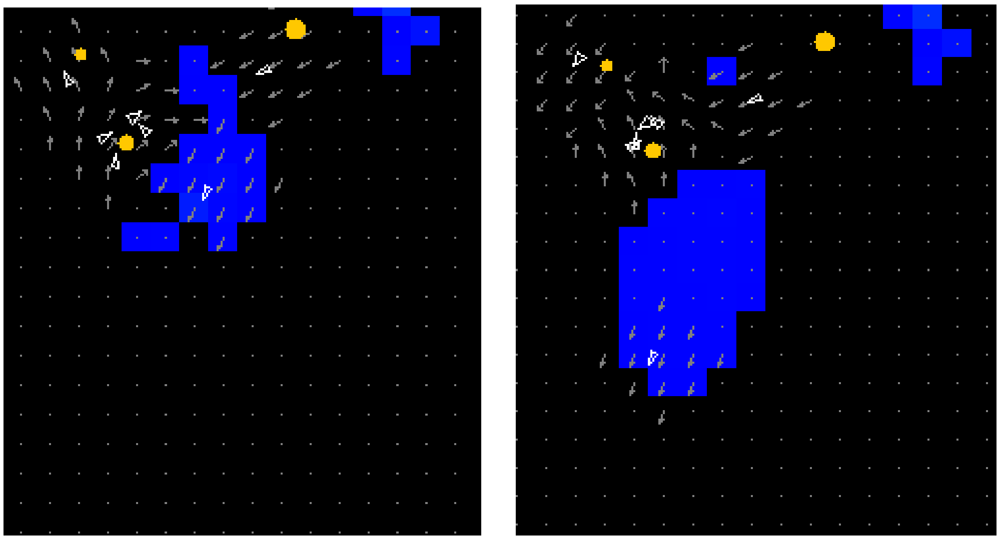
There are 2 ways to conquer the problem of a malicious player joining the group and immediately ruining the group's reputation. A *membership value* could be associated with each member. The impact of the reputation events would be weighed by these membership values. The reputation reflected upon the individual player character from the group could also be a function of the membership value. In addition, membership values allow any player's character to be part of multiple reputation groups. In this case, the player character's reputation could be the average of both groups, or some other function of both groups' reputation values, such as a weighted (by membership) average of the reputation values.

The second method involves a screening process for joining groups. Essentially, this would force some kind of initial requirements on the part of the player character before he/she could join the reputation group. This method could be used in conjunction with membership values. Players could decide which group to join and there could be a review process involved with joining the group. The process could be automatic or based on the decisions of the more important members of the group.

Analysis of the Reputation System's Behavior

As expected, in general the reputation system was more dynamic in comparison to the weather system. The agents movement was a very interesting part of the observations. In particular, the spreading of reputation points across the grid was quite enjoyable to observe during the simulations. A screenshot of the agents movement and the reputation point spread is seen in Figure 4.11.

In the reputation simulations, the values of the parameters for probabilities were $P_{agent\_newdest} =$



(a) (b)

Figure 4.11: The grid of agents (white triangles), positive (blue) reputation points, grey communication terrain, and orange interest points. The snapshot in (b) is was taken only a few iterations after (a) to show the spread of the reputation points caused by a moving agent.

0.01, $P_{event} = 0.001$ and $P_{good} = 0.7$. Agents, on average, choose a new destination every 100 iterations. Events were generated on average every few seconds. The terrain was either "cloudy" with spreading of reputation points via agents, or "spotty" for some time if the agents did not frequent the area containing reputation points.

In practice, the dissipation rate of reputation points converting to reputation value seems to work quite well at the value of 1 per grid section per iteration. The impact of an event has the potential to spread out quite evenly if agents pass by to carry the reputation points but otherwise the resulting reputation value is too local to be noticed.

The reputation value fields end up being smooth, with brighter peaks near the more significant interest points. The reputation field is show in shown in Figure 4.12. Since the probability of a good event is greater than a bad event, we expect the picture to be lighter than darker. By construction of the movement model for these agents, most of the activity will be centered around the larger interest points. The smoothness around the "blotches" of of reputation value are due to agents moving out of or into the corresponding interesting regions.

The highly dynamic and non-deterministic nature of the reputation application makes it somewhat difficult to analyze the behavior of the system. The application would need to be tested in a real gaming environment. In the next chapter, We will partially apply the reputation in a real game environment and see how the reputation fields look when applied to different

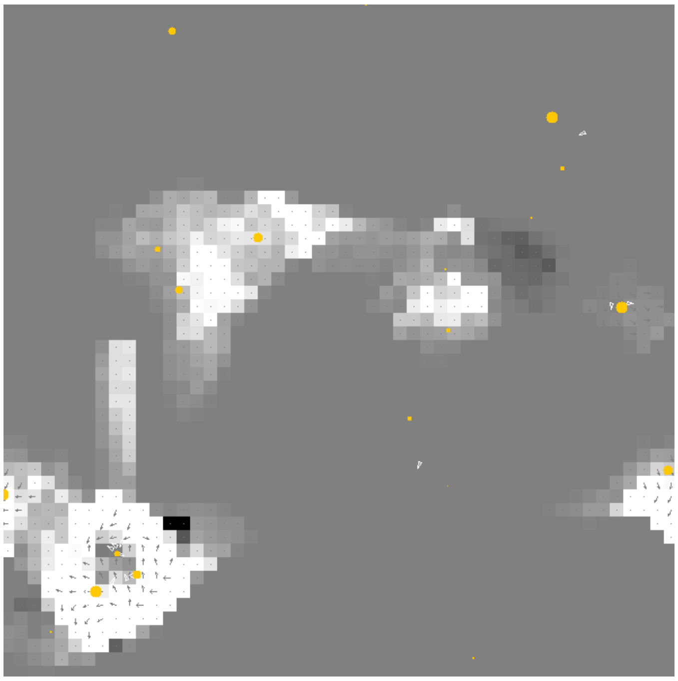


Figure 4.12: The grid of reputation values. Bright values mean good reputation, darker values mean bad reputation.

movement models for agent.

The weather system and reputation system applications are example systems that use the model and fit into the adaptation process. The adaptation procedures used by each application, as well as other related concepts are introduced. The behavior of the systems was described by using data observations from the the simulation runs. As well, the major difference between agent-based and purely environment-based applications is shown.

The systems presented here are 2 adaptive virtual environments that game designers could have built to use in their games; both adhere to the generic adaptation model presented in the previous chapter. This chapter demonstrated the design of these two systems by first describing the application, relating the system to its real-world counterpart, and then breaking down the system's components into data a procedures that act on that data. By using the generic adaptation model, locality is implicitly provided by construction.

Finally, the existence of a simulator that implements the 2 systems shows that such systems are actually realizable. This proves that such systems could be functionally included in a persistent-state game setting. We will investigate the implementation of the simulator and discuss performance details in Chapter 6.

Chapter 5
Movement Models for Mobile Agents

In a previous chapter (specifically, Section 4.2.1), we proposed an artificial model for agent simulation between interest points for the purpose of generating input data. The model was based on several assumptions and designed to be simple, but not necessarily realistic. As a result, the generated data may not be actually suitable to use because it may not be representative of true player movement in MMOGs.

The purpose of this chapter is to describe a methods for building good, intuitive movement models for agent simulation. We do so by analyzing real player movement data collected by means of a game-playing experiment. We discuss the important elements of the construction of an agent simulation model, describe the analyses performed on the collected data, discuss the results of the analyzes, and conclude with some general remarks.

Note that this particular chapter should be considered a case study on movement models in general. We will examine the effects of applying the results of this study back to the reputation system simulations in Section 5.5. But, the overall goals in this chapter are focused more on analyzing movement in a particular class of games (namely, persistent-state MMOGs) which possibly exclude adaptation concepts altogether. That is, we are searching here for a good movement model for agent movement in persistent-state MMOGs within all kinds of virtual environments, not only adaptive virtual environments.

As in Section 4.2.1, we assume that player agents in virtual worlds travel to and from interest points. There are three obvious questions one could ask about this travel:

1. How do players choose which interest points to travel to?

2. When do players decide to choose a new destination?

3. How do the players get to the target interest point?

We are interested in finding answers to all such questions, but here we focus primarily on the first and second. Answering the third question involves finding a function that generally describes the path taken by agents in 2D space and justifying its correctness.

This chapter will first describe the game used in the game-playing experiment. Second, the data gathering techniques that are applied are described. Then 4 movement models are constructed based on reasoning about the data. The models are compared and validated, partly by showing the effects when the models are used in agent-based adaptation simulations.

5.1 Conquero

Due to a lack of information data available from commercial persistent-state MMOGs, the immaturity of free/open MMOG implementations, and the logistic complexity of implementing data-collecting functionality in existing MMOG projects, we were unable to perform a large-scale experiment. Here, we describe an experiment using a specially-made game to provide an approximation to the real data.

The goals of the game-playing experiment are as follows:

1. Design a simple game that is complex enough to encourage interesting movement. A simple game is easy for players to learn and is easier to implement. We take a high-level approach to analyzing movement in MMOGs, therefore including many game details adds unnecessary overhead to both the implementation and the experiment.

2. Player movement must be clearly related to points of interest. This is our basic assumption about how players move in MMOGs, therefore it must be present in the game as well if the collected data is to reflect real MMOG data.

3. Players must pause at interest points for some time. Again, this is to enforce our assumptions about player behavior in MMOGs. Often, the interest point will be a city, in which case the player will spend some time navigating through it to find a particular person or shop. In other cases, there will be other things to investigate, monsters to fight, people to meet, or things to do. All these things require staying in close proximity of the interest point for some time.

4. Incorporate collaboration *and* conflict. If people were completely alone in a persistent-state environment they would likely move differently than in an environment full of other players. For instance, players usually form groups and go visit interest points together. Conflict is required for 2 reasons. If there is no conflict, players will soon get bored since

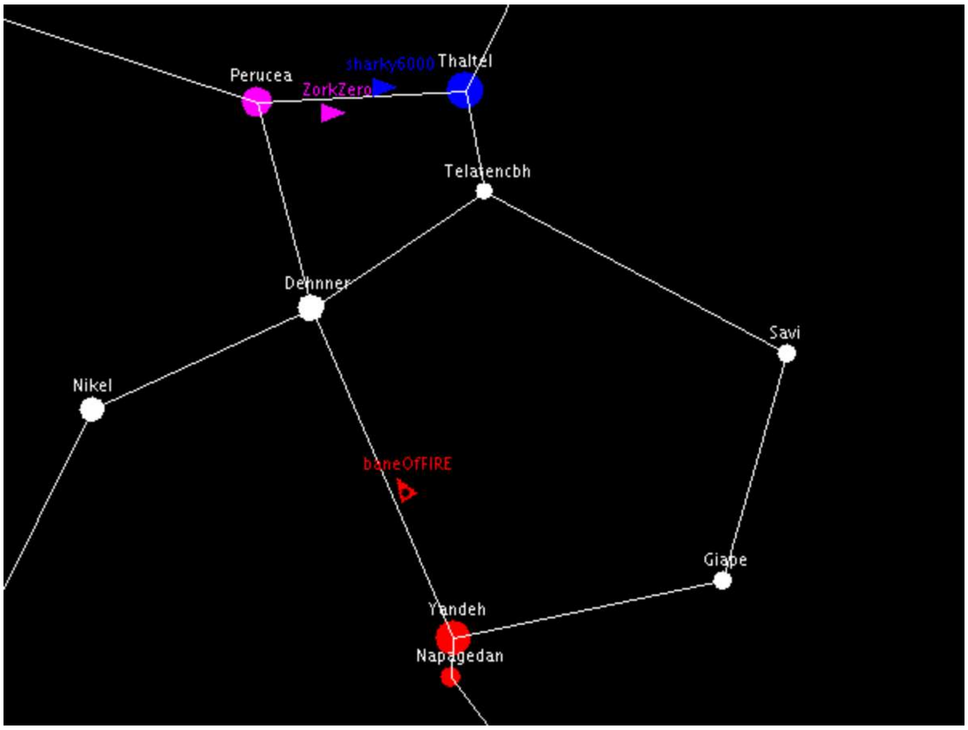


Figure 5.1: Screenshot of Conquero

they would have no challenging objectives. Conflict in MMOGs also influence players' movements. If a character dies from a fight or there is a rush to get a certain item, players will move from place to place differently than if this conflict was resolved.

5. Ensure enjoyable gameplay. The game must be somewhat fun to play so that players play the game seriously and somewhat competitively. If the players do not enjoy playing, they will not play the game "correctly" (as would a real MMOG player), and hence would add a bias to the collected data from the experiment.

To reach these goals, we implemented *Conquero*: a game of team capture.

Conquero is a multi-player network game consisting of players who each get to control one agent in a continuous, rectangular 2D virtual terrain with no obstacles. The agents are free to move in this terrain and movement is simulated using a basic Newtonian physical model similar to the one described in [Rey94]. The virtual terrain contains a number of randomly distributed command centers (interest points) which form the nodes of a graph. The edges of the graph are obtained by applying a *relative neighborhood graph* [Tou80] algorithm on the set of points in the planar terrain. The players are grouped by a pre-assigned team and allowed to communicate throughout the game.

The goal of the game is to conquer all the command centers. To capture a command center, an agent must move near and remain near a command center for a fixed interval of time (a few seconds) as long as no other agent is also near the same command center. When a command center is captured, it becomes owned by the team of the agent which captured it. A team can conquer a command center on 2 conditions: (a) if the team currently does not control any command centers, a member can attempt to capture any one in the graph, otherwise (b) a team member can attempt to capture any command center which is directly connected to a command center already owned by that team.

Each agent also has a level value which determines how strong it is. An agent gains levels when any member of its team gains control of a command center. The agents lose levels whenever their team loses control of command centers. Each command center has a size; the levels gained and lost are proportional to the size of the command centers.

Agents are also allowed to engage in close-range combat. The agent's current level determines how much damage it can endure before dying, how much damage potential it can incur to opponents, its resistance to damage, its weapon range, and its stamina. A swing is an action performed by the user which draws a line of a given length from the center of the agent's avatar straight forward: if the line intersects an opponent, then a damage potential dice-roll is compared against the target opponent's "armor resistance" dice-roll to determine the damage from a hit. When an agent receives damage, its current live total ("hit points") decreases. Once the life total reaches 0 or below, the agent dies. Death causes a loss of 1 level and the agent to respawn in a totally random location on the terrain.

One might ask why we let the players continue playing after death. The point here is to make the game experience a continual never-ending struggle since the intent is to approximate real behavior of persistent-state MMOGs. As such, we set the consequences of character death in Conquero be similar to the case in real, persistent-state MMOGs.

5.2 Game-playing Experiment

The experiment consisted of 20 player subjects which were organized into the 5 teams of 4 players each. Teams were assembled by groups of friends so as to encourage collaboration and communication between team members, mirroring the way people play real MMOGs.

Two games were played: a trial game, and a real game. The trial game was meant to introduce the game to the players so they can get familiar with the movement, controls, captures, combat, sounds, and general gameplay. The trial game lasted 22 minutes and the real game lasted 68 minutes. Player movement updates were sent several times per second by the game

Event Type	Instances
Update	658303
Capture	820
Hurt	553
Kill	258

(a)

Event Type	Instances
Update	2004607
Capture	1347
Hurt	2196
Kill	1143

(b)

Table 5.1: Collected information for (a) trial game and (b) real game

clients and constituted by far the majority of the logged information. The event type statistics for each game are summarized by the tables 5.1a and 5.1b.

A simple calculation shows that the average number of movement updates logged by the server per second was approximately 500 in both cases: in the trial game $658303/(22 \cdot 60) = 498.71$ and the real game $2004607/(68 \cdot 60) = 491.33$. Clients were set to send updates 100 times per second. The experiments consisted of 20 clients, which means many ($(2000 - 500)/2000 = 75\%$) packets were being dropped by the network, most likely due to overload. Luckily, after using the simulator to replay the game based on the data collected, even at full speed the game seemed to run in slow motion. This implies that the positions of the players were being updated much more required. Evidently, 100 updates per second per client led to an overflow of information sent out over the network. This makes sense because even with such a high packet loss, the game applied movement updates quite smoothly during the experiment. This was confirmed by everyone who took part in the experiment.

The virtual terrain had a width of 1200 pixels and height of 1000 pixels. Information about each command center and the graph is contained in Table 5.2. A screenshot of the graph is found in Figure 5.2.

5.3 Building a Movement Model

The main goal is to search for a probabilistic model whose parameter values are inspired by collected statistics on observed data. Let us consider the answer to our first question: how do players choose which interest points to travel to? We first have to find a way to formalize the problem at hand. In this section, we formally define the model we seek to build. Note that from this point on, we ignore the trial game because the data is biased by player. We deal only with the real data set.

We define the movement model as a 5-tuple $(A, S, T, \mathbf{P}_T, \mathbf{P}_P)$ where A is the set of agents, S

Command Center	x	y	Size	Degree	Neighbor Set
1	1023	393	10	3	{ 2, 3, 23 }
2	1024	286	17	1	{ 1 }
3	1112	380	13	3	{ 1, 4, 5 }
4	1140	357	19	1	{ 3 }
5	1148	777	11	2	{ 3, 24 }
6	19	75	10	1	{ 15 }
7	222	517	12	2	{ 11, 15 }
8	232	130	22	3	{ 10, 12, 15 }
9	254	890	11	1	{ 17 }
10	332	56	25	2	{ 8, 12}
11	341	512	10	3	{ 7, 13, 17 }
12	346	81	13	3	{ 8, 10, 16 }
13	358	399	11	3	{ 11, 14, 18 }
14	426	333	25	3	{ 6, 7, 8 }
15	43	234	11	3	{ 11, 14, 18 }
16	450	278	19	2	{ 12, 14 }
17	466	741	18	3	{ 9, 11, 19 }
18	489	465	10	4	{ 13, 14, 19, 20 }
19	618	557	11	3	{ 17, 18, 22 }
20	629	354	10	3	{ 18, 21, 23 }
21	658	127	11	1	{ 20 }
22	839	859	12	2	{ 19, 24 }
23	886	362	10	2	{ 1, 20 }
24	886	870	14	2	{ 5, 22 }

Table 5.2: Info about the Graph and Command Centers in the Conquero experiment

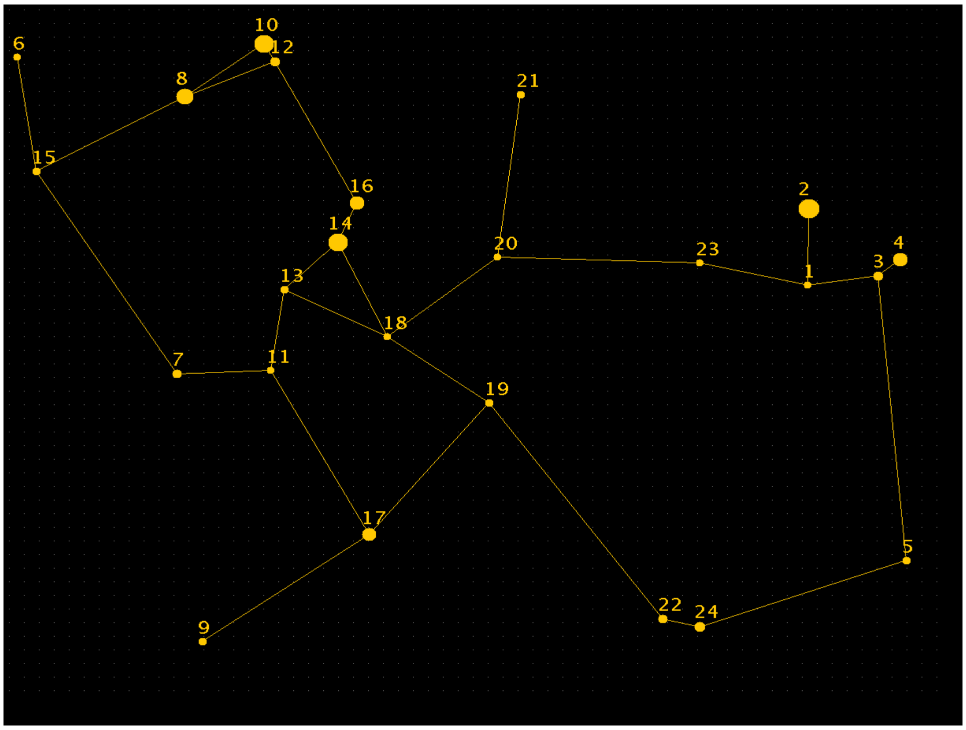


Figure 5.2: Screenshot of the Graph used in the Conquero Experiment

is the set of interest points, T is a discrete timeline, $\mathbf{P}_T$ and $\mathbf{P}_P$ are families of independent and identically-distributed probability distributions. $P_{T,a}(t, s_i|s_j) \in \mathbf{P}_T$ is the probability that agent a at time t will begin traveling to interest point s_i given that it is now *near* s_j. $P_{P,a}(t, s_i|s_j) \in \mathbf{P}_P$ generates a path taken by agent a from s_i to s_j. Here, *near* means within a small fixed distance away from the point. We are interested in finding general closed form expressions for P_P and P_T.

Before any research effort was spent on analyzing the movements of player agents, simulations for the reputation system were based on a much simpler movement model, described in Section 4.2.1. First of all, the graph was always a clique so that every point was a neighbor, and agents chose a neighbor probabilistically where each neighbor had a probability proportional to the value of *size*/*distance*^{2}. We label this movement model MM_{random}. For the remainder of this chapter, we propose improvements on this basic model.

Initially, we make the assumption that every agent's movement is independent of the other agents' movements. The reason to assume this is for simplicity: we would like to see how agents move in general, not necessarily requiring other agents to be present. We also assume that the next interest point traveled to is dependent only on the location of the current interest point, and not on the locations of previously visited interest points. Again, this assumption might not necessarily be appropriate in this context: we are essentially assuming that players are ahistorical. Our hope is that these assumptions are not too strong that they compromise the value of the movement models built from this analysis. We expect the significance of any correlation to be small enough to ignore. Ideally, however, correlation caused by movements of other agents and previously visited destinations would be integrated into the model.

We consider a player's entire movement as sequences of visits to and from interest points: $Movement(a_{name}) = (s_1, s_2, ..., s_{n_{name}})$, where n_{name} is the number of interest points visited by agent a_{name}. Specifically, given the above assumptions, we define a *discrete data instance* as simply a link in the chain: $d_{name,i} = (s_i, s_{i+1})$. The list of all data instances forms the *data set* which use as input to a *classification system*.

5.3.1 Classification and Statistical Learning

Classification problems have the following form: there exists a collection of data instances, which is a known/sampled subset of a much larger set of real data D_{real}, of the form $\mathbf{x_i} = [x_{i,1}, x_{i,2}, ..., x_{i,n}]$ and a set of *classes* $Y = \{y | y \text{ is a simple (non-set) element}\}$. Each instance is accompanied by a class so that the *data set* can be seen as an augmented matrix:

$$D_{sampled} = \left(\begin{array}{cccc|c} x_{1,1} & x_{1,2} & ... & x_{1,n} & y_1 \\ x_{2,1} & x_{2,2} & ... & x_{2,n} & y_2 \\ ... & ... & ... & ... & ... \\ x_{m,1} & x_{m,2} & ... & x_{m,n} & y_m \end{array} \right)$$

Assuming that there is a classifier f that will satisfy $f(\mathbf{x}) = y$ for every possible instance $\mathbf{x} \in D_{real}$, the goal is to use $D_{sampled}$ to search for a good generic approximator (*hypothesis*), h, to f.

The elements of the input vectors $\mathbf{x}$ are typically called *features* and the value of a given feature j of instance i is $x_{i,j}$. These features describe independent qualities of a system. For example, weather features such as temperature, humidity, outlook (sunny, rainy, or overcast), whether or not it is windy, could describe conditions that affect the outcome of a certain decision. And, under a given set of weather conditions, it may or may not be desirable to play golf. This is a concern for golfers and the decision problem is a typical example used when introducing supervised learning techniques [Mit97]. The decision to be made is whether or not to play golf on a given day. In this case, $Y = \{play, don't play\}$. Since $|Y| = 2$, the golf example is a special case called a *binary classification problem*. Data was collected by observing the weather conditions and the outcome of the golf-player's decision every day for two weeks.

Then, machine learning techniques were applied to build a hypothesis for determining whether to play golf on a given day based on the weather conditions.

We build a program that analyses the data and uses classification to find a good approximator for the true function P_P based on collected data. In particular, we would like to find a good feature or set of features that classifies the target interest point in a link, s_{i+1}, given the source s_i. We propose intuitive heuristic functions for selecting the destination given the feature values of the state at the source. We are also interested in general statistics such as the proportion of destinations that are neighbors of the source and the proportions of classifications correctly identified by our heuristics.

We define our 3 heuristics as follows:

- $h_1(s_{from}, s_{to}) = \frac{size(s_{to})}{dist(s_{from}, s_{to})}$
- $h_2(s_{from}, s_{to}) = \frac{size(s_{to})^2}{dist(s_{from}, s_{to})}$
- $h_4(s_{from}, s_{to}) = \frac{size(s_{to})}{dist(s_{from}, s_{to})^2}$

where $dist(s_1, s_2)$ is the Euclidean distance between interest points s_1 and s_2. The decision algorithm for a given heuristic simply calculates the heuristic value over all possible destination points given the source point and chooses the one with the maximum.

We define the neighborhood feature as $N(s_{from}, s_{to}) = 1$ iff s_{from} and s_{to} are directly connected, 0 otherwise. Finally, we describe the classes $Y = \{0, 1, ..., 7\}$. $y = 0$ corresponds to the observed situation in which none of the hypotheses correctly chose the destination. $y = 1$ corresponds to the observation that heuristic 1 correctly classified the instance (ie. correctly chose the destination). Similarly for classes $y = 2$ and $y = 4$ for heuristics 2 and 4. Cases $y \in \{3, 5, 6, 7\}$ represent bitwise OR combinations of the base cases. For instance, $y = 6$ means heuristic h_4 and h_2 chose the correct destination, but h_1 did not. Thus, the rows in our matrix D have the form $[N, h_1, h_2, h_4, y]$.

Upon examining our empirical data, we noticed that self-loop links ($s_{to} = s_{from}$) occur more often than initially expected. Upon reflection, this is due to the method used to detect links: if an agent suddenly goes out of the reach of an interest point– even by just a single pixel– and then comes back in reach of the same interest point, a self-loop link is inserted in the movement chain. These are degenerate cases, so we exclude them altogether.

In our experiment, the number of rows $m = 4457$. Table 5.3 summarizes the collected statistics on the whole data set. Immediately we notice that we never find the case where both h_2 and h_4 predict correctly, which could be because each emphasize an opposing factor in the ratio. Note that from these calculations it appears that the agent explores (visits a target node

Statistic	$N=1$	$y=1$	$y=2$	$y=3$	$y=4$	$y=5$	$y=6$	$y=7$	$y>0$
Number of Total	2527	41	24	48	268	34	0	940	1355
Proportion of Total	0.567	0.009	0.005	0.011	0.060	0.008	0	0.211	0.304
Proportion of $y>0$	0.91	0.030	0.018	0.035	0.198	0.025	0	0.694	1
Proportion of $y=7$	0.947	0	0	0	0	0	0	1	–

Table 5.3: Statistics of collected data

that is not a direct neighbor) a little less than half of the time. On average, the heuristics choose the correct destination 23.5% of the time. The first two h_1 and h_2 predict the correct destination with approximately 22% while h_4 chooses correctly 27% of the time, implying that h_4 is somewhat better for determining the destination. An interesting observation is that both at least one and all heuristics choose the correct destination more than 90% of the time when the destination and source are neighbors. The simplest intuitive construction then is a model that chooses simply between exploring and not exploring. Basing the probabilities on these calculated statistics leads to the following proposed agent behavior: explore 45% of the time and choose a neighbour (via the heuristics) 55% of the time. These rules yield a decent, simple movement model we shall call MM_{simple}. However, the accuracy of the heuristics for deciding the next destination gives us incentive to search for other, possibly better, models.

We are also interested in the agents' *rest times*: the time spent near a given command center while the agent is not traveling between command centers. To measure this value, we subtracted the last time the agent left a command center to the first time it reached the same command center (effectively treating chains of self-loop links as just one link). The mean rest time was computed to be 17.079 seconds, with a standard deviation of 25.958 seconds. To model the rest times in our movement models, we simply observe the value of random variable $Y = \frac{Z-\mu}{\sigma}$ where Z is normally-distributed random variable with mean 0 and standard deviation 1, $\mu = 19.079$, and $\sigma = 25.958$. Y then becomes a normally-distributed random variable with the desired mean and standard deviation [WIS96]. We consider negative values of Y to give a rest time of 0.

We now apply some learning techniques to see if a function can be learned to choose the correct outcome based on the values of the heuristic. It may seem futile to do this with the problem as we have stated it above. After all, the learned classifier will simply reiterate to us what we already know since the classes are defined entirely on the heuristics we chose ourselves. Therefore, the value of our function will simply determine which heuristics choose correctly given a source and destination. So why not formulate the problem so that the source interest point is one of the input values and the destination is the output value? The answer is twofold: i) we are interested in the threshold values that decide which heuristic to use and ii) we are interested in the generic problem of movement between interest points on an arbitrary graph. Solving the learning problem for this data set might give a good movement model for agents in this particular graph layout, but will not be at all generic. However, we still investigate this alternative formulation in Section 5.3.2 to see what kind of agents it generates.

We choose the C4.5 decision-tree learning software [Qui92] for several main reasons: it finds threshold points for continuous features, it applies the information theory of entropy and information gain to measure the most representative features, and it is efficient. As well, decision trees make a natural choice for dictating NPC behavior. A typical implementation of modern AI for NPCs is *scripting* [Toz02]; scripts are simply a list of rules that are executed sequentially to evaluate the situation and decide how to react. Decision trees perform the same function with the added value that there exist efficient, well-known algorithms for optimizing behavior.

After running the C4.5 algorithm on the data set, we obtain the decision tree seen in Figure 5.3. It is worth mentioning that the time taken to read all the data from file, compute the decision tree, and output the tree to standard output took a total time of 0.151 seconds on a PentiumIV 1.7Ghz machine with 512megs of RAM. These results imply that assembling small-scale, simple classification problems and generating a decision tree from learning is feasible in during actual game time.

Once the decision tree is obtained, the procedure for deciding which interest point to target next is straight-forward and efficient. For each potential destination point: a) calculate the value of the 3 heuristics once and b) navigate the decision tree to get a solution and record it. Then, the probability of an action is the proportion of the number of repetitions of a solution versus total solutions. For example, let us say a given interest point s_1 has 3 neighbors: s_2, s_3, and s_4. Passing s_2 through the tree requires calculating the values $h_k(s_1, s_2)$. Let us say the decision tree outputs 7. Similarly, for the other neighbors it outputs 4 and 6. Then, h_1 was valid once, h_2 twice, and h_4 thrice. Therefore for this given situation, the heuristic chosen is h_1 with probability $\frac{1}{1+2+3}$, h_2 with probability $\frac{2}{1+2+3}$, or h_3 with probability $\frac{3}{1+2+3}$. Since both the heuristics and a single decision tree navigation is computable in constant time (time taken $\approx log_2 N$, where N is the number of tree nodes which is constant for a given tree), the time taken for the decision still remains linear in the number of potential destinations. We shall label this movement model $MM_{chooser}$ because it chooses a neighbor heuristically.

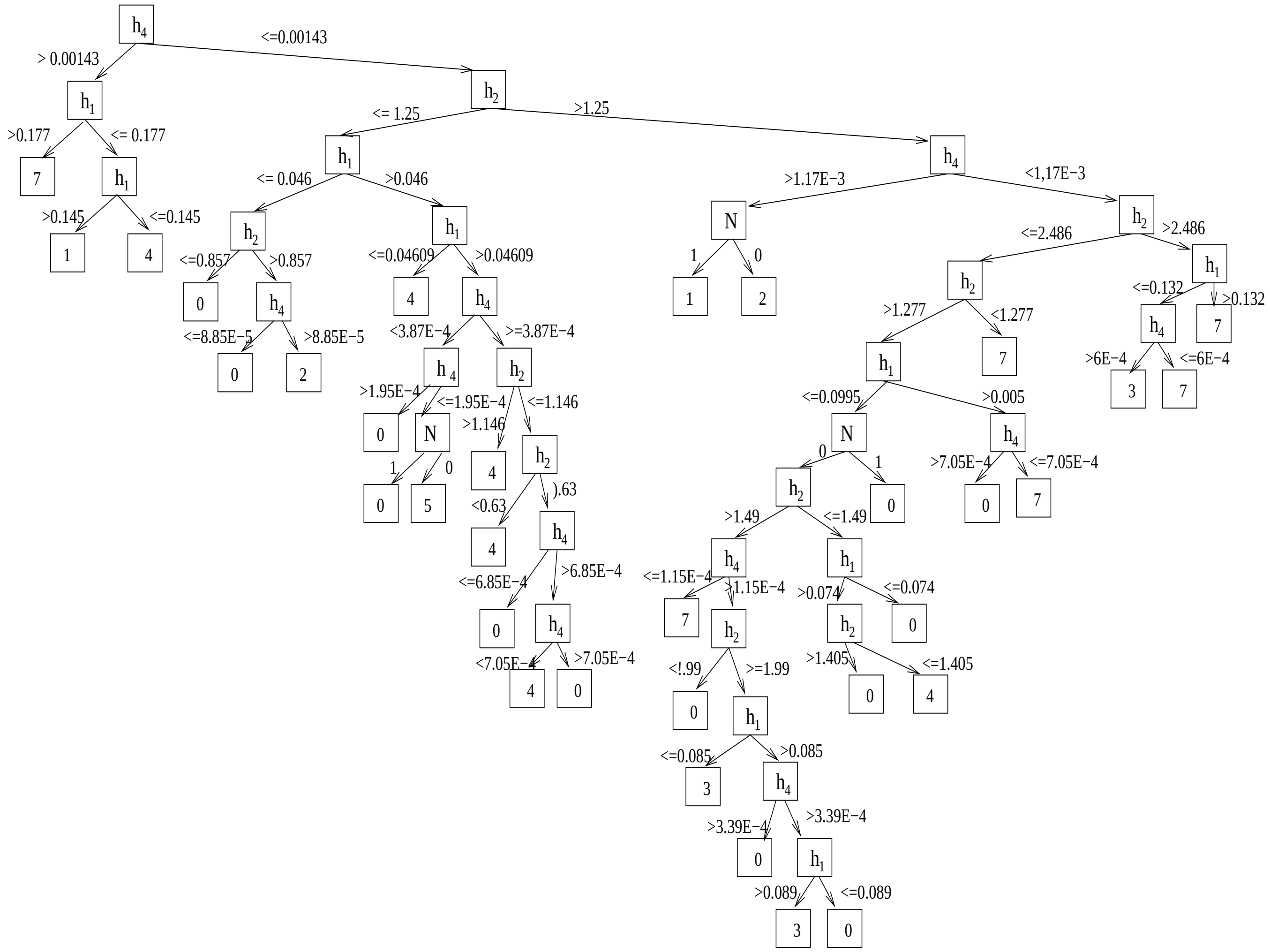


Figure 5.3: Decision tree for heuristic selection in $MM_{chooser}$ learned by C4.5

5.3.2 Learning How to Move in a Dynamic Environment

The previous section explained the basics of classification and proposed a particular formulation for a classification problem. The resulting hypothesis function learned from the data chooses between which of the proposed heuristics to use when deciding between neighbors. The results of the analysis rely on one major assumption: that the heuristics $\{h_1, h_2, h_4\}$ are the only ones that impact the decision of the agent.

In a dynamic environment such as Conquero, there are many factors other than the distance and size of the next command center. For example, the position and strength of the enemies are likely to affect how the agents move in such an environment. As such, while Conquero was built solely to provide an experimental context for gathering data, it introduces other dynamic factors to consider when analyzing player movement. These factors are particularly relevant in the context of computer games which require some level of dynamic stimulation.

Our new classification problem consists of a data set M, where our class set $Y = \{1, 2, 3, ..., 24\}$ represents the next command centers an agent could visit. The feature set is the vector x which somehow summarizes the current global state of the game at the time before the agent leaves the current navigating command center. These features are each then a function of the state of the graph and state of all the agents at that given time. Note that we still assume that only the state at the given time affects the decision of the agent.

Now we are faced with a problem faced by many AI researchers: how to define the set of features. The problem is somewhat easier in a discrete game such as Chess or Checkers where it is certain that the state does not change before the final decision on a move made. That is not the case in our formulation: for instance, an agent may start heading for Command Center 4 (CC_4) from CC_1 but then another agent will beat arrive at CC_1 first, giving him reason to change his mind and head towards CC_{22}. In addition, we are dealing with a conceptually continuous environment, so the features described will be continuous geometric measures.

Our motivation is to describe as many relevant features as possible and let the learning algorithm decide on the best ones to use. To do so we define 16 global features and 9 features for each command center. There are 24 command centers, which means $|\mathbf{x}| = n = 16 + 24 \cdot 9 = 232$. The description of each feature follows. Note that the features described below are somewhat rudimentary; it is out of the scope of this research to search for higher quality continuous features, but one that would be interesting to measure in Conquero would be the *dominant regions* [TiH00] of the agents.

All global features are described from the point-of-view of the currently traveling agent. Unless otherwise noted, the features are continuous and in $\Re^+$. The global features are:

- $oldCC \in \{1, 2, ...24\}$: the source/current command center the agent is at
- $mopx$: the mean x position of the agent's opponents
- $mopy$: the mean y position of the agent's opponents
- $mtpx$: the mean x position of the agent's teammates
- $mtpy$: the mean y position of the agent's teammates
- coo : command centers owned by agent's opponents
- cto : command centers owned by agent's team
- dco : distance to closest opponent
- dct : distance to closest teammate
- dcc : distance to closest command center
- $dcuc$: distance to closest unowned command center
- $dcoc$: distance to closes owned command center

All command center specific features are described with respect to that command center from the point-of-view of the currently traveling agent. The features associated to a particular command center, CC_i are:

- $CC_i[neighbor] \in \{0, 1\}$: the neighbor feature (1 if CC_i is a neighbor of $oldCC$, 0 otherwise)
- $CC_i[own] \in \{0, 1, 2\}$: the ownership feature (0 if unowned, 1 if owned by agent's team, 2 if owned by opponents)
- $CC_i[size]$: the size of the command center
- $CC_i[dist]$: the distance from the agent's location to the command center
- $CC_i[h_1]$: the value of $h_1(oldCC, CC_i)$
- $CC_i[h_2]$: the value of $h_2(oldCC, CC_i)$
- $CC_i[h_4]$: the value of $h_4(oldCC, CC_i)$
- $CC_i[nop]$: number of opponents close to the command center

- $CC_i[nte]$: number of teammates close to the command center

The data points were collected for each transition from command center to command center over the course of the game-playing experiment for each agent in the game, as in the previous classification task. The resulting decision tree has depth 52, and has 1809 nodes (904 decision nodes, 905 leaf nodes). The algorithm took 10.953 seconds to compute the decision tree on the same hardware used for the previous classification task. The tree is included in text form in Appendix A.

To our surprise, the root decision node splits on feature $CC_4[h_4]$. We expected that $oldCC$ would be the most determining feature for choosing a new destination. Upon closer inspection, it seems that after splitting on $CC_4[h_4]$, the left subtree degenerates into cases specifically concerned with neighborhood values $CC_4[neighborhood]$ and $CC_5[neighborhood]$. The result we expected starts on the second level, the top of the first right subtree, where $oldCC$ is split by values. $CC_i[nop]$ and $CC_i[nte]$ are often found near the top of the trees as well; they seem to make good determining features.

The priority given to $CC_4[h_4]$ remains somewhat unsettling. Referring back to Table 5.2 we recall that the degree of CC_4 is 1, which is particularly bad in Conquero: if a team only owns a command center of degree 1 then you are forced to conquer its only neighbor which opponents can easily block by remaining near it. Still, why CC_4 and not the others degree 1 command centers? Looking back at Figure 5.2 we notice that CC_4 is the degree 1 command center farthest from the higher-degree clusters.

In fact, the split on the first node is due to the number of cases collected which had CC_4 as a target. It turns out that CC_4 was the next target 13.8% of the time, 3 times larger than the expected fair average of 4.16% ($= \frac{1}{24}$). This surplus in the data collected with CC_4 as a target justifies using it as a first criterion for decision-making because it provides the most information.

The precise reason that CC_4 was chosen particularly more than the others is not entirely known. CC_4 is a bit larger than other leaf nodes, and it is very close to CC_3, which makes it easy to gain control over 2 command centers very quickly. As well, the 2 close command centers are in a relatively deserted area compared to the opposing side of the map and as such was rarely guarded if they were already conquered along with the surroundings. This last fact made these 2 close points a vulnerable break-in region during raid attacks from teams who had suddenly lost all their command centers.

5.4 Other Movement Models

In the previous section, we proposed two similar movement models, MM_{simple} and $MM_{chooser}$. The simple movement model just chooses randomly between exploring and visiting neighbors, but then chooses a neighbor at random. When visiting a neighbor, the chooser calculates the heuristic values for each neighbor, runs the decision tree to find the class associated with that neighbor, and then uses the class info to choose a heuristic to use to determine the next neighbor. We also presented $MM_{learned}$ which uses a global decision tree learned from the experiment to decide where to move.

The first two movement models were designed by reasoning about the statistics of the observed data from the experiment. Up to now, the models that have been described are entirely independent of the game-playing experiment explained in Section 5.2. That is, once the data is processed and the model is built, the model no longer depends on the experiment data. We describe one last movement model that is dependent on the data, $MM_{experiment}$: a movement model that simply replays the recorded game movements. In this model, agents do not choose between cities. Agents move exactly as they did in the game experiment. This movement model is of no direct value to us, but it will be interesting to compare against the other movement models.

5.5 Applying the Models to Agent-based Adaptation

We now recall our initial motivation for studying movement models: to provide slightly better than random models for mobile agents. In this chapter we have described, in total, 5 movement models: MM_{random}, MM_{simple}, $MM_{chooser}$, $MM_{experiment}$, and $MM_{learned}$, and how they were obtained, but we have not shown how these movement models fit into our adaptation scheme.

Here, we show how well these movement models work in agent-based adaptation, specifically as applied to the reputation simulation. We construct a reputation test that includes the graph used in the game experiment (Figure 5.2) and the agents to be exactly those used in the game. We run 5 different simulations: one for each movement model. In each simulation, every agent uses the movement model specified by the simulation specifications. We run each simulation with the same random seed so that every simulation produces the same sequence of probabilistic choices; the differences in each simulation are therefore solely the cause of the agents' movements. Otherwise, we use the same constants that were described in the reputation simulations in Section 4.2.1; that is $P_{agent\_newdest} = 0.01$, $P_{event} = 0.001$ and $P_{good} = 0.7$. Therefore, the agents will produce the exact same sequence of reputation occurrences in all cases, and in particular an equal number of bad events and good events.

We run the simulations for 5000 iterations each and we save the state (and take a screenshot) of the reputation field at iteration 500, 1000, 2000, and 5000. The saved state includes all the reputation values for each grid section in the grid. We then measure the dissimilarity between saved states at each iteration for each simulation. The distance metric used is intuitive: the sum over all grid sections of the absolute value of the differences in reputation value. These values are listed in tables 5.4a-d. Screenshots of the reputation field at iteration 1000 are displayed in Figure 5.4.

From the screenshots, it is apparent that none of the reputation fields are unambiguously similar. It was expected that the reputation fields for simulations involving the simple and chooser models would be noticeably similar because they are the most similar movement models. It was also expected that the experiment model and learned model would look somewhat similar. However, these are only qualitative hypotheses.

Examination of the quantified dissimilarities also supports the general claim that the models produce radically different results. The quantitative results also reinforce the qualitative hypotheses mentioned above. We notice expected results as well, such as the consistent large dissimilarity between the random model and the learned and experiment models, especially in the longer term (after 5000 iterations).

In the end, if we assume that the experiment model is the "correct values" then surprisingly MM_{simple} seems to be the best approximation for it in every case. This is encouraging because this model is efficient and easy to implement.

It remains, however, somewhat difficult to make claims about the quality of the proposed movement models in a context outside of settings similar to Conquero. We believe that the movement information obtained from a real persistent-state game would differ significantly from the movement information we have collected for this experiment. As well, the online modification of agents' reputations would likely affect their movement, adding a feedback loop into the system. To this end, we are currently investigating similar research potentialities in larger open source games such as [Pan]. Of course, the validation used here is better than no validation whatsoever. More importantly, this study exposes the complexity of trying to find accurate, general and predictive models for agent movement in games.

	MM_{random}	MM_{simple}	$MM_{chooser}$	$MM_{experiment}$	$MM_{learned}$
MM_{random}	0	8882	9777	8464	11518
MM_{simple}	8882	0	7401	6078	8318
$MM_{chooser}$	9777	7401	0	7055	10065
$MM_{experiment}$	8464	6078	7055	0	7882
$MM_{learned}$	11518	8318	10065	7882	0

(a)

	MM_{random}	MM_{simple}	$MM_{chooser}$	$MM_{experiment}$	$MM_{learned}$
MM_{random}	0	18752	19729	17411	24366
MM_{simple}	18752	0	17635	13843	19994
$MM_{chooser}$	19729	17635	0	16070	21687
$MM_{experiment}$	17411	13843	16070	0	17055
$MM_{learned}$	24366	19994	21687	17055	0

(b)

	MM_{random}	MM_{simple}	$MM_{chooser}$	$MM_{experiment}$	$MM_{learned}$
MM_{random}	0	30075	32230	32408	39132
MM_{simple}	30075	0	31823	31807	37293
$MM_{chooser}$	32230	31823	0	32608	35550
$MM_{experiment}$	32408	31807	32608	0	35246
$MM_{learned}$	39132	37293	35550	35246	0

(c)

	MM_{random}	MM_{simple}	$MM_{chooser}$	$MM_{experiment}$	$MM_{learned}$
MM_{random}	0	57515	56635	86410	82102
MM_{simple}	57515	0	54052	82475	79589
$MM_{chooser}$	56635	54052	0	84353	82713
$MM_{experiment}$	86410	82475	84353	0	98774
$MM_{learned}$	82102	79589	82713	98774	0

(d)

Table 5.4: Dissimilarity of reputation fields in simulations at iteration (a) 1000 (b) 2000 (c) 3000 and (d) 5000. Smaller values mean more similar while larger values mean more dissimilar.

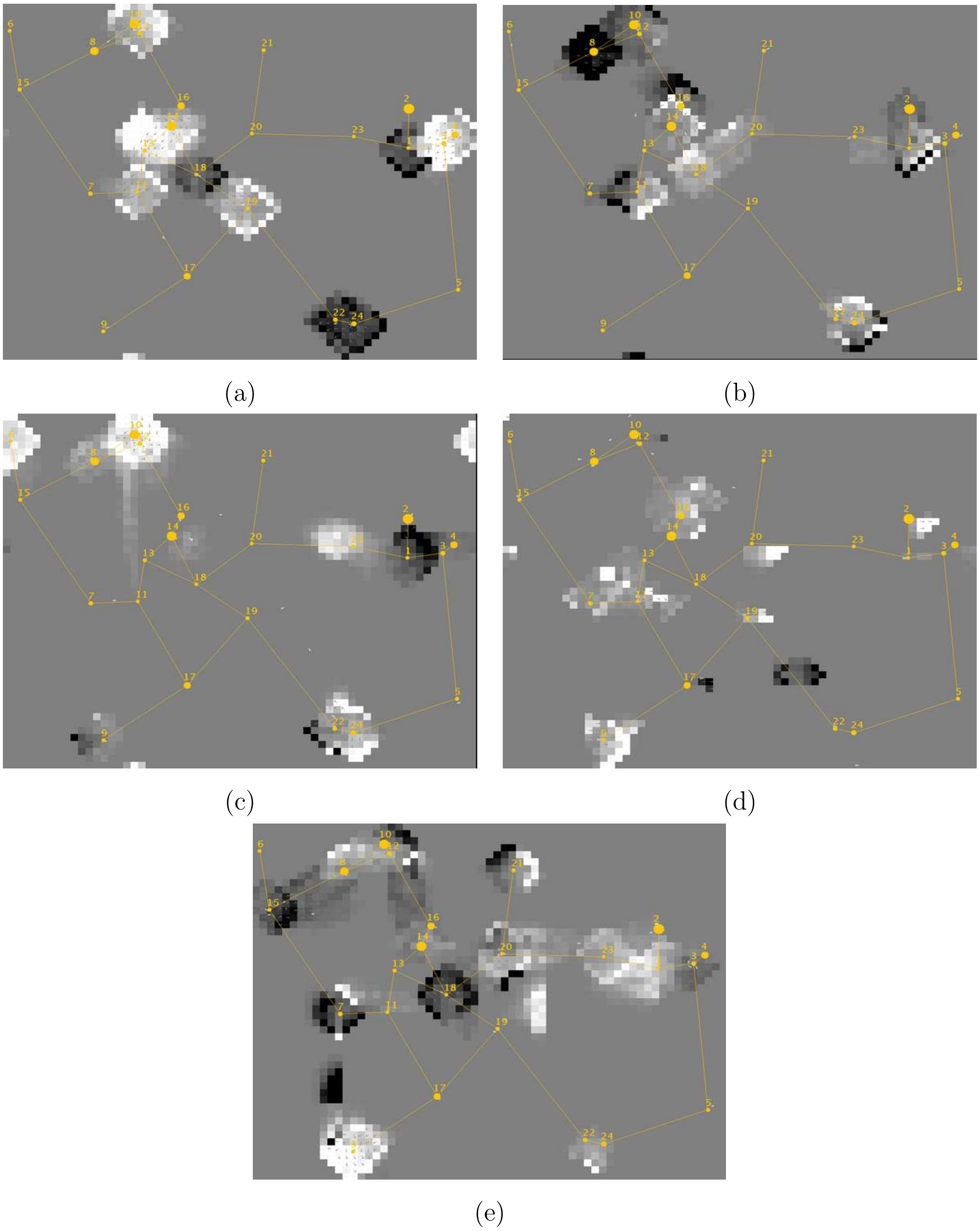


Figure 5.4: Screenshots of the reputation field at iteration 1000 using (a) MM_{random} (b) MM_{simple} (c) $MM_{chooser}$ (d) $MM_{experiment}$ and (e) $MM_{learned}$

Chapter 6
An Implementation of the Adaptation Framework

This chapter describes in technical detail the design and implementation of the adaptation simulator used in the experiments described in the previous chapters. We begin with a broad overview of how adaptation fits into modern games, followed by an analytical breakdown of the actual adaptation engine. We then describe some tests to evaluate the performance of the implementation, describe a few optimizations, rerun the tests, and conclude on the quality of the optimizations.

6.1 Adaptation in Modern Persistent-state Games

The design and implementation of modern multi-player online persistent-state games are heavily influenced by both the efficiency of the network and efficiency of rendering graphics. Rendering graphics is for the most part a client-side issue; that is, it depends mostly on the performance of the computer running the game client. The efficiency of the network, however, is largely dependent on the infrastructure and the architecture of the game's network protocol. In these types of games in particular there is an abundance of information being passed over the network, and so optimal network performance is a high priority.

By far the most popular architecture in general is the client/server architecture because it captures the nature of most network tasks and is widely-used. As well, the reliable connection-oriented Transfer Control Protocol (TCP) fits quite well in the client/server architecture. Studies show however that the client/server architecture is inadequate for multi-player games because the large load endured by the server makes the network *unscalable*. As such, there are current research projects devoted to optimizing network performance in modern games. For the most part, these projects stem from the existing algorithms studied in distributed simulation now

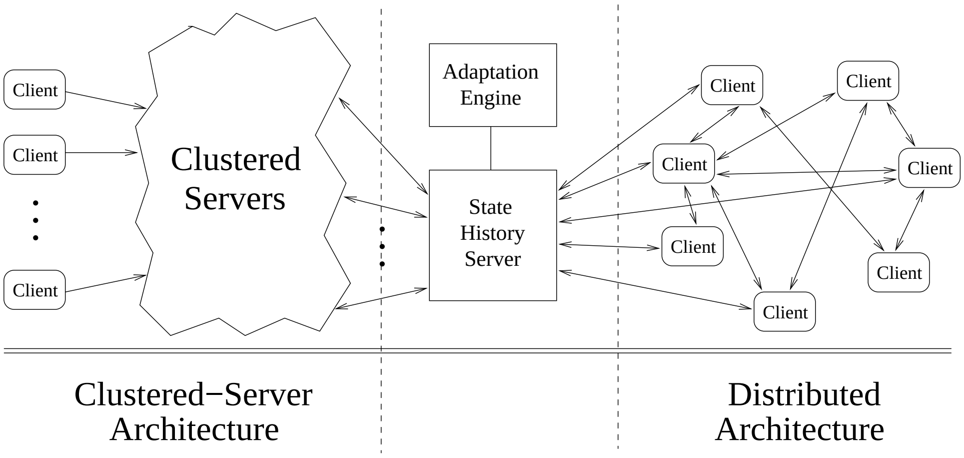


Figure 6.1: The general layout of the adaptation architecture

evaluated in a game context. Of them, 2 generic alternative architectures have been proposed: the clustered-server architecture, and the distributed architecture.

Clustered-server architectures try to keep the general layout of the client/server architecture while trying to reduce the load on a single server. The idea is that there still exists a central authority, but that central authority may be composed of many computers in a cluster which are themselves distributed. Example implementations include the mirrored-server architecture built on Quake in [CFK01], the proxied-server system in [MFW02] and the hierarchical server architecture found in [Fun96].

Distributed implementations attempt to spread some of the previously server-side processing computation across client machines. Note that this is fundamentally different than clustered-server architectures because in this case we are allowing clients access to state information, which is potentially sensitive. This solves the scalability problem but introduces other problems such as state inconsistencies, cheating, and load-balancing. Examples include MIMAZE [DG99] and EternaZ [Qua03].

We would like to extend these architectures now to include the process of adaptation in the virtual environment. We first introduce a critical concept: the *state history server* (SHS). The SHS acts as a global camera: it keeps track of the global state of the game by taking "snapshots". It is responsible for collecting state information from clients and/or servers periodically, possibly re-assembling separated parts of the state to form the global state, storing the history of the game state, and providing the history of the game state to the adaptation engine. The SHS is also responsible for sending state updates back to the clients and/or servers as a result of the adaptation. The general idea is illustrated in Figure 6.1. Note, in particular, that the proposed logical concept fits into every one of the major network architectures currently used in MMOGs.

In the next section, in fact in this entire chapter, we analyze in detail only the adaptation engine component of the general architecture. We do not assume that it is trivial to implement the SHS or the communication between the SHS and the clients and server, but it is outside of the scope of this research. We focus mainly on proving that the implementation of a modular and efficient adaptation engine is feasible.

6.2 Design and Implementation of the Adaptation Engine

The adaptation engine is written in Java. Some of the data-gathering and processing tasks where handled by Perl and shell scripts, but they are not required components. In both languages, prototyping is easy. Java inherently offers object-oriented principles and supports most popular design patterns while Perl is superior for lower-level tasks such as parsing data in a particular format and reporting analyses done on output data from program executions.

Most design concepts mentioned in this section, unless otherwise noted, were taken from [LG01]. First, I will list the major modules and show the *module dependency diagram*. Then, for each module a list of the major components is presented, as well as any non-trivial programmatical challenges faced in the implementation, algorithms used, and design patterns used.

The engine relies on 2 packages provided externally: hexIT [Lan03] and Minueto [Den04]. hexIT is a Java package that provides an API for using and drawing 2D hexagonal grids. Minueto is a reasonably efficient gaming and graphics framework for Java which is intuitive to use.

The major modules are:

- Abstract Simulator
- Plug-in Adaptation Systems
- Abstract Fuzzy Controller
- Abstract Grid API
- Movement Modeling
- Core Utilities and Data Structures
- Conquero
- Game Data Analyzer

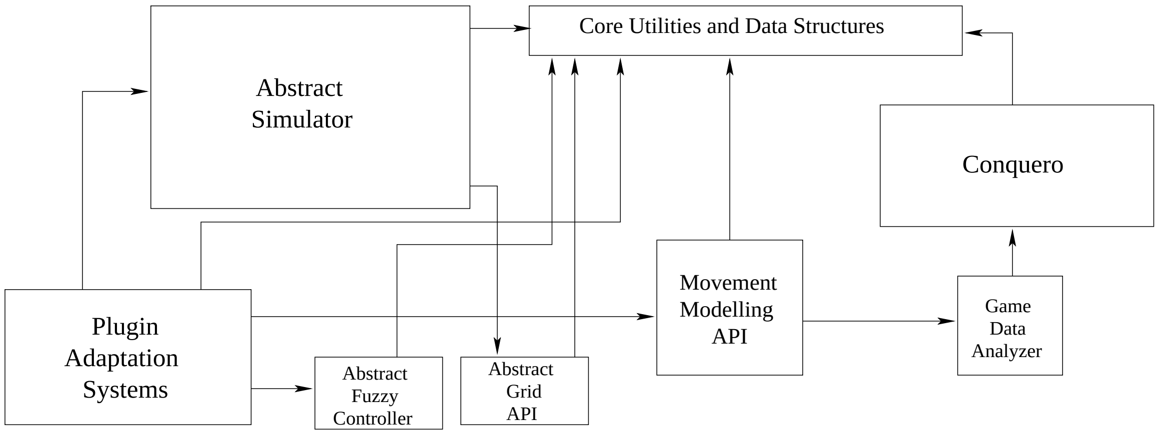


Figure 6.2: The module dependency diagram of the implementation

The dependencies between each module and approximate relative size/significance of each module are given in Figure 6.2.

Abstract Simulator

The abstract simulator module has two major components: the simulation engine, and the Graphical User Interface (GUI). This module is the largest, most significant part of the entire implementation. It is essentially the construction of the pseudo-code in Equation 3.1 with many abstract helper functions.

The GUI component is solely responsible for graphical representation of and user interaction with the behavior of the simulations. It is composed of 3 sub-components: the Control Panel, Grid Panel, and Button Panel. The Control Panel allows the user to control the state of the simulator. The button panel provides buttons that allow the user to dynamically enable or disable features in the simulation. The grid panel shows the state of the grid during the simulation and allows the user to inspect and modify the values on the grid dynamically.

The engine component has no subcomponents. It provides the tools which are independent of the specific adaptation scheme used, such as vector propagation and fuzzy flow-updates. The component specifies an abstract `simloop()` method which must be overridden by subclass *plug-ins*. The plugins are adaptation systems which have access to the grid and implement a particular adaptation scheme, as defined in Chapter 4. By keeping this base component separate from the plugin systems, we allow it to be independently optimized.

One non-trivial challenge was finding the correct set of thread synchronization constraints between the engine and the GUI: writing code free of non-deterministic behavior while keeping a certain level of performance. It was also hard to decide what should be part of the abstraction and what part of the plugins.

Plugin Adaptation Systems

This module consists of 2 major components: the adaptive weather system and the adaptive reputation system. There is also a minor component called the aggregate system. Each component has a separate simulation loop that modifies the grid as detailed in Chapter 4.

The plugin systems have a relatively straight-forward implementation. They each override the `simloop()` method specified by the abstract simulator, contain specific code logic particular to the adaptation system while using as many generic concepts (shared methods from the base class) as possible to encourage code reuse.

The weather plugin defines 3 main grid-altering methods: `moisturewind`, `gradDev`, and `rain`. The first displaces moisture between cells based on the current wind vectors. The second bends the wind vectors towards the gradient vectors. The third displaces moisture directly based on the gradients. There are 2 extra functions that clear and apply the calculated mask (separate grid containing grid cell differences, see Section 3.2.1) to the current virtual terrain: `cMask` and `aMask`. Recall from Section 3.2.1 that masks are used to emulate fair simultaneous updates.

The reputation plugin also has 3 main grid-altering methods: `repEvent`, `agentBend`, and `repwind`. The first method generates reputation events. The second method shapes the reputation vector field based on the orientations of the agents. The third method spreads the reputation points based on the values of the reputation vector field. This plugin has similar mask functions.

The generic adaptation concepts were conceived during the implementation of these plugin systems. The most challenging part of implementation of these components was code maintenance. Throughout the course of the implementation, these components were the most actively-modified. The volatility of the code made it somewhat difficult to keep track of the current functionality.

Abstract Fuzzy Controller

The abstract fuzzy controller module is composed of a set of minor components for representing arbitrary fuzzy sets and generic tools for operating on these abstractly-defined sets.

To define a particular fuzzy set, the implementor must extend the `FuzzySet` class and override the `membership(Object)` method. The operations provided include those required to resolve a decision in a fuzzy control problem: conjunction, disjunction, negation, and centroid-of-gravity calculation. Once these fuzzy sets are defined, the implementor creates an instance of a `FuzzyController`, adds the conditions and consequences, and polls it for a decision.

Abstract Grid API

The abstract grid API module provides an interface to a grid whose layout and connectivity is abstractly defined. That is, it is an API for accessing grid sections and neighborhoods, computing distances between sections while hiding the actual grid being used. There are 3 main methods in an abstract grid:

```
/** Returns a set of all sections on the grid. */
public Set getGridSections()

/** Returns the set of all neighbors (of distance d away from gs) */
public Set getGridNeighbors(GridSection gs, double d)
```

There are 2 major components that extend the abstract API: the `RectangularGrid`, and the `HexGrid`. The former is used to represent the virtual terrain as it is represented in Figure 3.5. The latter is used as the hexagonal representation demonstrated in Figure 4.7.

Movement Modeling

The movement modeling module is composed of 2 major components that work together side-by-side: the movement model API, and the path modeler. The movement model API consists of an abstract base class, `MovementModel`, and 5 subclasses: one for each movement model described in Chapter 5. The three important methods in the base class are as follows:

```
/** Returns the next point to be visit. */
public abstract Point getNextP(RepAgent a);

/** Generate a number of agents that will move in this model. */
public void generateAgents(int num)

/** Move the agents, given the currently specified time. */
public void move_agents(long time)
```

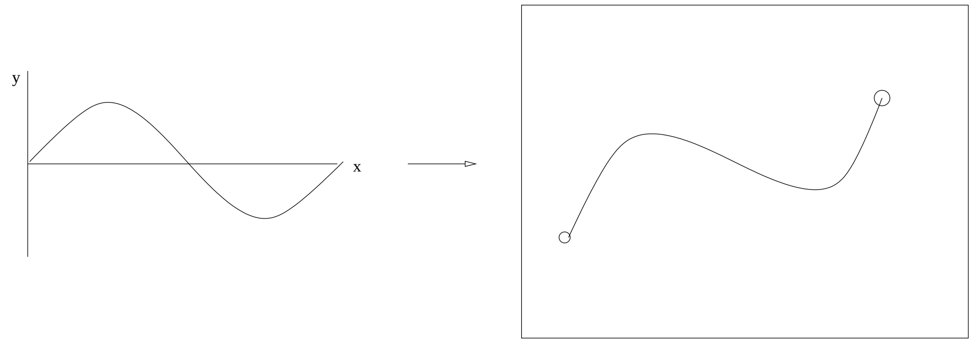


Figure 6.3: An example conversion of a path model

The last 2 methods have a generic implementation that is only overridden by the implementation of $MM_{experiment}$ because it must move the agents directly. Otherwise, the movement models use the generic implementation which chooses a path to take via the path modeler.

The path modeler component is used to design a precise path for the agents to follow when they are traveling between specific locations in the virtual terrain. The path modeler is another abstract API which encourages extensibility: the abstract base class `PathModel` allows for the implementation of arbitrary two-dimensional parametric curves. It contains 3 important methods:

```
/** Construct a path model with given source and destination coordinates. */
public PathModel(int startx, int starty, int endx, int endy)

/** Get the next point on the path at time t, 0 <= t <= 1 */
public Point val(double t)

/** An arbitrarily varying continuous function on the normal Cartesian
    plane where val_y(0) = 0 and val_y(1) = 0.  */
public abstract double val_y(double t);
```

The value returned by `val(double t)` is a point on the virtual terrain at time `t` assuming the agent takes a path from its start position to its end position governed by the function `val_y()`. To get this value, a simple change of coordinate systems calculation using affine transformations is done (see Section 4.2.1). An example of a transformation is given in Figure 6.3.

To emphasize the applicability of the API, several types of path models are implemented: parabolic, cubic, sinusoidal, quadric, generic polynomial, and composite paths. A `PathChooser` object is constructed which generates specific paths needed by the agents. The `PathChooser` object follows the *factory* design pattern.

Core Utilities and Data Structures

This module exists mainly to act as a central resource for providing generally useful objects, methods, and algorithms. It provides 6 major components: the `Utils` class, the `Debug` class, the discrete probability distribution class, the agent classes, the proximity graph data structure, and the decision tree data structure.

The `Utils` class is a collection of static helper methods and also provides the central random number generator used by all other classes. This allows us to reproduce the exact outcome of an experiment by simply reusing random seeds.

The debug class allows control of debug information to be printed and/or logged. The scheme prints no debug information by default (debug level 0) and prints messages whose detail depend on the debug level set by the programmer. This was particularly helpful when searching for the cause of erroneous behavior in the implementation.

The discrete probability distribution class provided a means for non-uniform sampling from a set of predefined objects. The class allows the programmer to add items, each with given weights attached to them. Then, when drawing from the set, the probability of drawing an item is equal to its weight divided by the total of all the weights.

The agent classes follow the linguistic relationship: `GameAgent` is a `RepAgent` is a `SimpleAgent` is an `Agent`. The first and basic description of an agent is an entity that has a current position and current velocity, implemented by `Agent`. When agents were used in more than one system, `SimpleAgent` was constructed which contained an extra parameter to specify to which system the agent belonged. A `RepAgent` is an agent that contains specific information relevant to the reputation experiment (ie. its reputation value) and `GameAgent`s contain Conquero-specific information such as hit points, stamina, and current level.

The proximity graph data structure is an implementation of a regular graph with each vertex having (x, y) coordinates in a two-dimensional space (in our case, the virtual terrain). A point in the terrain is represented by the `Point` object. In the Conquero experiment, this object is extended to `City` to represent a command center which has an extra size parameter value, the `Graph` class is extended to `DirectedGraph`. Finally, the `Graph` object supports special graph constructions. From just a set of points `Graph.RNGize()` will construct the graph as its relative neighbourhood graph. Similarly for `Graph.MSTize()` and its minimum spanning tree.

The decision tree data structure is an implementation of a binary decision tree. The factory pattern is used again here because decision trees are only imported via files: they are never actually constructed by the programmer. This decision tree data structure is created by parsing the output generated by the C4.5 software [Qui92]. This became a tricky task when large trees were split into collections of subtrees, because the software used does not represent the textual output of the full tree. The output of large trees are decomposed into many smaller subtrees while using annotations to indicate small subtrees. Each subtree is then listed separately.

The algorithm used to overcome this problem is as follows:

1. Collect all the lines of textual data and name for each subtree.
2. Parse each tree individually possibly marking some nodes as degenerate *subtree reference* nodes, marking the name of the subtrees to which they should attach in the node. Add the map (name, tree) to a global hash.
3. Recursively, traverse the base tree depth-first. When a subtree reference node is encountered, read the name marked on the node and retrieve the corresponding subtree. "Tie" the subtree to the main tree by replacing the degenerate node by the root of the subtree.

Conquero

Conquero has 3 major components: Minueto, the game client, and the authority server. Minueto is an external package that was used for its efficient graphics rendering. The game itself is entirely network-based. It uses a mix of 2 commonly used network protocols: UDP for situations where efficiency is critical, and TCP for situations where reliability is most critical.

The client first connects (over TCP) to an authority server to validate its requested player name and IP address. If the IP address is new and the name is already taken by another player then the connection is rejected. If the name is a duplicate but the IP addresses is the same one that asked for that name, then the server assumed this is a reconnect and the connection is accepted. After the server receives the number of players required, the games starts and the main window spawns.

Critical information such as hits, kills, captures, etc. is passed through the server and validated by TCP. The server is responsible for ensuring fairness and consistency by implementing locking mechanisms to avoid concurrency problems. Non-critical position updates are sent via multicast UDP. All clients subscribe to the same multicast IP address and all move update packets are sent to that address. The result is intended to be a good use of the network protocols given their advantages and disadvantages.

The authority server does 2 more things other than respond to TCP events. Before starting, it opens a Java runtime environment and runs a shell script which checks the amount of space left on the disk partition which used for logging. This ensures that a game experiment will not fail due lack of disk space for recording game data. Secondly, it also acts as a non-graphical client. That is, it subscribes to the same multicast address that the clients are connected to and just logs the packets it receives as well as the TCP packets.

A non-trivial part of the implementation was including *dead-reckoning* [SZ99]. To implement dead-reckoning, two important things needed to be considered: a dynamic counter and accurate synchronized time-stamping. Luckily, the environment used by the game-playing experiment had synchronized clocks using NTP [Mil85] and hence we assumed an accurate global clock. The dynamic counter consistently remeasured the rate of updates by averaging the number of updates it processed in the last fixed interval of time. This provides a window of historical data suitable for a simple dead-reckoning algorithm: to apply dead-reckoning, the client simply applies, in one step, a number of updates to the agent which was equal to the update rate multiplied by the difference between the current time and the timestamp. The resulting position is the extrapolated position given the agent's velocity and timestamp. If further updates are received which contradict any predicted positions, the positions are immediately changed to reflect the values by the new update, to ensure maximum consistency. Note that applying immediate correction is the simplest way of dealing with the inconsistencies introduced by dead-reckoning; researchers have proposed other means, such as Time Warp [Mau00] and linear convergence [SKH02].

Game Data Analyzer

The game data analyzer module is itself a single component. It is independent of most of the other logic used in the implementation. It has one general function: to process the data collected during the game-playing experiment described in Section 5.2.

The data analyzer has 3 important analyses of the data: *tofro-stats*, *tofro-shapes*, and *tofro-data*. The tofro-stats analysis processes an entire game log and computes overall statistics above the game log such as the ones found in Table 5.1. This analysis also outputs the data for the first classification problem explained in Section 5.3.1. The tofro-shapes analysis shows, graphically, the paths taken by the agents between command centers. The tofro-data analysis simulates the entire game from the game log for each agent. At every transition of command centers it also measures the values of the features described in Section 5.3.2 and outputs the data set for the second classification problem.

Name	HOME	HUMAN	TOFU	MAGIC
CPUs	1	1	2	4
CPU model	Pentium IV	AMD Athlon	AMD Athlon	AMD Opteron
CPU bus width (bits)	32	32	32	64
CPU speed (MHz)	1716	1250	1667	1794
CPU cache size (kB)	256	256	256	1024
Total Memory (kB)	515484	516216	2069368	3613560
Operating System	Debian[2] Linux	Debian[2] Linux	Debian[2] Linux	Gentoo Linux
Kernel Version	2.6.5	2.4.26	2.4.20	2.6.7

Table 6.1: Descriptions of the machines used to measure performance.

6.3 Performance Measurements

In this section, we will describe the test environments used for experiments that were run to measure the performance of various parts of the implementation. The testing environment includes specifications of hardware used to perform the tests, specification and layout of any input data/files that were commonly-used, and any relevant miscellaneous information. Then, each performance test is described individually.

We begin with a descriptions of the environments used to run each test, summarized in Table 6.1. We will refer to these machines throughout the rest of the chapter.

Existing altitude maps of geographical regions were used as input data for the weather simulations. The data was obtained using the DIVA-GIS software and information archive [RHG03]. The number of points in the data set was enormous. This was a problem because the simulations would span several hundred screens and so was not graphically representable. The data was reduced by summarizing large portions of the actual data by the average of the altitude values in the area, as as described in Section 4.1.1.

The first such altitude map to be used was `prk_alt.dat`, a 48x40 altitude map of North Korea. The other altitude map is `pak_alt.dat`, a 63x51 altitude map of Pakistan. Larger versions are `pak_alt2.dat` (127x102), `pak_alt3.dat` (255x204), and `pak_alt4.dat` (1022x817).

The reputation simulations load settings from a configuration file called the *repfile*. Each repfile contains the number of agents, the graph, the probability of causing events, vertex sizes, etc. The probability that an event occurs on a given timestep is `prEv`. The probability that occurred events are good is `prEvGood`, otherwise they are bad. All reputation simulations use `prEv` = 0.001 and `prEvGood` = 0.7. These numbers were chosen arbitrarily. The `test_rep3` repfile

[2]Debian Sarge on *HOME* and *HUMAN*, Debian Woody on *TOFU*.

	Wtr+GUI	Wtr+NOGUI	Wtr GUI Overhead	Rep+GUI	Rep+NOGUI	Rep GUI Overhead
HOME	120.072	76.92	35.94%	40.17	9.92	75.3%
HUMAN	71.88	45.23	37.1%	18.46	7.43	59.75%
Averages			**36.52** %			**67.53** %

Table 6.2: Data obtained by running performance tests on the graphical interface

uses 20 agents, a random clique graph with 20 vertices of maximum size 12, and a virtual terrain of 700x700 pixels (50x50 grid cells). `test_rep3-2` doubles those values: ie. 40 agents, a random clique graph with 40 vertices of maximum size 24 and a virtual terrain of 1400x1400 (100x100). Similarly, `test_rep3-3` doubles the values of `test_rep3-2` and `test_rep3-4` quadruples the values of `test_rep3`.

All performance tests were done on code compiled by Sun's Java 1.5 compiler and run using Sun's Java 1.5 interpreter. All performance tests used the same random seed (= 290423987).

GUI Overhead

The purpose of this test is to measure the average overhead added by the GUI. TOFU and MAGIC are server machines only accessible via network, and were therefore not used for this test. This fact is important to know, especially since the machines presented below are more similar than the server machines. The GUI overhead presented here might be much larger than what would be observed on more powerful machines. The test runs for 10000 iterations in the weather simulator with altitude map `pak_alt.dat` and reputation simulator with repfile `test_rep3`.

The results of the tests are listed in Table 6.2. Based on the observed overheads, it is clearly inappropriate to do server-side experimenting with the interface enabled. Thus, subsequent tests do not include the interface components. The interface remains a tool mainly intended for visually observing the effects of the adaptation process.

Weather Simulations

The purpose of this test is to measure the general performance of the weather simulations. The weather simulation is run for 10000 iterations on all 4 machines, first on `pak_alt`. Tests on the larger maps `pak_alt2`, `pak_alt3` are then run to get a sense of how well the algorithm scales. The results of the tests are listed in Table 6.3.

Note that average times are calculated over only four and entirely different machines: this is intentional. We would like to summarize the results as to express them in the most general context possible. That is, while the results per machine are still shown for the most part, we rely on the average to give a good generic estimate for the results independent of the hardware used.

If we assume that the time taken per iteration per grid section is constant, then we expect that the total time taken in one iteration to be a linear function of the number of grid sections. That is $f(G) = k_1 + k_2 \cdot |G|$. Using 3 maps, we get 3 equations:

$$43.244 = k_1 + (63 \cdot 51)k_2 \tag{6.1}$$

$$177.564 = k_1 + (127 \cdot 102)k_2 \tag{6.2}$$

$$692.77 = k_1 + (255 \cdot 204)k_2 \tag{6.3}$$

Solving the system of linear equations 6.1 & 6.2 gives $(k_1, k_2) = (-1.06, 0.013789)$. Similarly, solving the system 6.2 & 6.3 gives $(k_1, k_2) = (6.73, 0.0131881)$. So, it seems that constant overhead is lost going from maps `pak_alt.dat` to `pak_alt` whereas overhead is added in the case of going from maps `pak_alt2` to `pak_alt3`. This could be due to thresholds of memory and cache being crossed in the second transition, but unfortunately we do not have any memory usage data to justify this. It is still reassuring that the constants k_2 are approximately equal (error of approximately 6.01×10^{-4}) reinforcing the belief that the performance of the computation grows linearly.

Tornadoes

The tornado effect is an optional effect included in the weather system. On HOME using `pak_alt.dat` after 10000 iterations the tornado calculations took on average 1.0389 ms. The tests were repeated on HUMAN, TOFU, and MAGIC and the results were, respectively: 1.268, 1.188, and 1.185. This gives an average time of 1.17 ms/iteration. If this cost was added to the current simulations, then it would take $\frac{1.17}{43.244+1.17} = 2.6\%$ of the current total time per iteration. It is interesting that complex weather effects such as simple tornado simulations do not add significantly to the overall cost.

Reputation Simulations

The purpose of this test is to measure the general performance of the reputation simulations. The weather simulation is run for 10000 simulations on all 4 machines, first on repfile `test_rep3`.

Map	Machine	$t/iter$	t[cMask]	t[aMask]	t[moisturewind]	t[gradDev]	t[rain]
1	HOME	65.734	0.044	6.32	14.89	38.60	5.88
1	HUMAN	45.226	0.046	4.89	9.72	27.75	2.82
1	TOFU	30.137	0.017	3.35	5.48	19.63	1.66
1	MAGIC	31.879	0.009	2.26	7.68	16.88	5.05
1	(averages)	**43.244**	0.029	4.21	9.44	25.72	3.85
1	(proportions)	—	0.07%	9.7%	21.8%	59.5%	8.9%
2	HOME	261.312	0.177	27.54	59.73	151.26	22.61
2	HUMAN	182.775	0.275	20.45	38.82	112.07	11.16
2	TOFU	138.446	0.116	14.35	28.88	84.28	10.82
2	MAGIC	127.724	0.040	9.21	30.14	68.30	20.034
2	(averages)	**177.564**	0.152	17.89	39.39	103.98	16.16
2	(proportions)	—	0.09%	10.1%	22.2%	58.6%	9.1%
3	HOME	1021.33	0.81	93.81	237.30	599.04	90.37
3	HUMAN	721.029	1.149	79.77	153.4	441.99	44.72
3	TOFU	527.22	0.71	54.24	119.60	338.48	44.19
3	MAGIC	501.498	0.238	36.82	119.30	267.28	77.86
3	(averages)	**692.77**	0.727	66.16	157.4	411.7	64.3
3	(proportions)	—	0.1%	9.55%	22.72%	59.43%	9.28%

Table 6.3: Results of the performance measurements on the weather simulations. All listed times are in milliseconds (10^{-3} seconds), and maps used are `pak_alt#` .

Map	Machine	$t/iter$	t[`cMask`]	t[`aMask`]	t[`MM`]	t[`repwind`]	t[`aBend`]	t[`repEv`]
1	HOME	9.747	0.304	0.686	0.162	8.351	0.196	0.464
1	HUMAN	7.433	0.405	0.883	0.116	5.872	0.139	0.18
1	TOFU	4.677	0.181	0.916	0.1	3.386	0.82	0.012
1	MAGIC	5.477	0.088	0.254	0.061	4.966	0.074	0.034
1	(averages)	**6.834**	0.245	0.457	0.11	5.644	0.31	0.173
1	(proportions)	—	3.6%	6.68%	1.6%	82.6%	4.5%	2.5%
2	HOME	43.864	2.241	2.592	0.315	37.985	0.636	0.093
2	HUMAN	38.3	3.2	3.684	0.235	30.523	0.616	0.045
2	TOFU	18.31	0.728	3.88	0.205	13.292	0.17	0.038
2	MAGIC	23.23	0.335	2.05	0.138	20.492	0.149	0.061
2	(averages)	**30.93**	1.626	3.05	0.223	25.6	0.393	0.06
2	(proportions)	—	5.26%	9.87%	0.7%	82.7%	1.27%	0.2%
3	HOME	158.588	7.366	10.115	0.94	138.75	1.235	0.176
3	HUMAN	134.06	10.184	14.695	0.737	107.271	1.077	0.96
3	TOFU	75.857	3.088	15.59	0.567	56.12	0.416	0.076
3	MAGIC	89.95	1.447	7.69	0.417	79.93	0.325	0.14
3	(averages)	**114.6**	5.52	12.02	0.665	95.52	0.63	0.34
3	(proportions)	—	4.82%	10.5%	0.6%	83.35%	0.55%	0.3%
4	TOFU	1705.474	164.59	246.366	32.767	1257.501	3.954	0.295
4	MAGIC	1498.64	25.895	153.584	27.26	1289.595	1.751	0.554

Table 6.4: Results of the performance measurements on the reputation simulations. All listed times are in milliseconds (10^{-3} seconds), and repfiles used are `test_rep3-#` .

Then the test is rerun on the larger field in `test_rep3-2`, `test_rep3-3` and `test_rep3-4`. The movement model used in these simulations was MM_{random}. The results of the tests are listed in Table 6.4.

Performing calculations analogous to the ones performed in the weather simulations, we observe values $(k_1, k_2) = (27.7172, 0.00032128)$ from repfile `test_rep3.txt` to `test_rep3-2.txt` and $(k_1, k_2) = (3.04, 0.002789)$ from repfile `test_rep3-2` to `test_rep3-3`. This is rather unexpected for two reasons. Firstly, the overhead is less in the second case. Secondly, the constant k_2 differs by an order of magnitude, implying either irregularities in the observations or a non-linear relationship. However, since the values are so small, it is likely that the inaccuracy of the observed readings are playing a role in the discrepancy.

Machine	$t[MM_{random}]$	$t[MM_{simple}]$	$t[MM_{chooser}]$	$t[MM_{experiment}]$	$t[MM_{learned}]$
HOME	0.174	0.156	0.201	0.458	1.817
HUMAN	0.122	0.102	0.154	0.444	1.765
TOFU	0.122	0.094	0.13	0.228	1.111
MAGIC	0.067	0.058	0.094	0.167	0.515
(averages)	0.121	0.103	0.145	0.324	1.302
(proportions[3])	0.3%	1.12%	1.56%	3.41%	12.44%

Table 6.5: Results of the performance measurements on the different movement models in the reputation simulations. All listed times are in milliseconds (10^{-3} seconds), and the repfile used was `test_rep3` .

Movement Models

The movement model is an optional effect included in the reputation system. The processing time taken up by the movement models was measured on each system listed and gave the following averages: 0.121ms for MM_{random}, 0.103ms for MM_{simple}, 0.145ms for $MM_{chooser}$, 0.324ms for $MM_{experiment}$, and 1.302ms for $MM_{learned}$. Note that in $MM_{experiment}$, the moves are drawn directly from large input files and not simply generated as the rest.

The tests on repfile `test_rep6.txt` were run for 10000 iterations using MM_{random}. `test_rep6.txt` is a repfile recreation of the terrain and graph used in the Conquero game-playing experiment. This test was repeated on each machine but using different movement models. The results for the movement models are summarized by Table 6.5.

As expected, the learned model takes the longest because it calculates the value of 232 features based on the current state, pass these through a decision tree, and then make a decision. The random and simple models are low because they do not do any processing of the current state. The chooser model only slightly less efficient than the simple model, which is encouraging considering it is calculating the value of 3 heuristics and passing through a decision tree. The inefficiency of the experiment model is due to the fact that it is reading its moves from a large (83M) log file.

[3]of total average time taken per iteration taken from Table 6.4

6.4 Optimizations

In this section, we will describe optimizations designed to improve the performance of the implementation. Each optimization will then be evaluated by re-running tests with the optimization enabled and compared to the values obtained in the previous section. First, minor optimizations are suggested. Then the larger, more significant optimizations are described in their own subsections.

One simple optimization is to use *tabular look-up approximations* for trigonometric functions sine and cosine. The optimization upon startup inserts the values of sine and cosine in a table for $1000 \cdot 2\pi$ values ($0.000 \cdot 2\pi$ to $1.000 \cdot 2\pi$). In fact, only one table need be stored since $cos(x) = sin(x + \frac{\pi}{2})$. Larger angles are mapped by repeatedly adding or subtracting 2π until the angle is in the desired interval. Then, the true values are linearly extrapolated between the two approximate values contained in the lookup tables.

The first weather simulations we rerun using this optimization. An improvement was expected, especially since the weather simulations use trigonometric functions more than the other two systems. The observed average times per iteration are: 63.667 ms, 43.93 ms, 37.116 ms, and 31.142. This gives an average of value of 43.964 ms, slightly (1.7%) *higher* than the unoptimized result. Therefore, it is clear that Java must be doing something efficient in their Math class to save on execution time.

6.4.1 Caching

Caching is a common optimization technique used throughout Computer Science. The general idea is to remember a value once it is calculated so that future calculations need only read the *cached* value rather than recompute the value repeatedly. Note that caching really just trades space (memory) for time (performance). It is usually the case that the trade-off is worth doing when the programmer expects a given calculation to be repeatedly calculated.

There is one obvious application of caching in the weather system: gradient-caching. The gradient need not be re-calculated unless it changes. In fact, this is a general optimization technique that can be applied to all environment-based adaptation schemes since the influence of the adaptation is based on the environment which we expect to change little. However, this optimization does add a bit of programmatical complexity. This is because the programmer is forced to take care of the special case of when the gradient vectors change.

To measure the value of this optimization, the first set of weather simulations were once again rerun. The average times per iteration observed is: 55.87, 36.53 ms, 25.86 ms, and 28.81 ms. This gives an average of 36.77 ms per iteration, corresponding to a 15% improvement. This is an encouraging, significant result.

6.4.2 Concurrency

A natural optimization for computations on discrete grid cells is parallelization. In our case, we do not have access to powerful parallel machines, but we can emulate the idea of parallelization through software and hardware using concurrency and multiple processors.

A multi-threaded version of the weather simulation loop is implemented. The multi-threaded version simply partitions the grid into independent portions, and assigns the responsibility of carrying out the calculations for that portion to each thread independently of the other threads. At every iteration, the threads perform the grid-base calculations concurrently and then wait while a central thread applies global duties such as clearing and applying the mask.

The threads were synchronized by using a typical n-process barrier mechanism, where $n \in \{1, 2, 3, 4\}$. The synchronization code is outlined in Figure 6.4. Two counting semaphores and 2 boolean condition variables were used in the n worker threads and single main thread. The workers performed the adaptation procedures on the a section of the grid while the main thread performed the global procedure and thread management. One important note is that Java's built-in concurrency features such as monitors and object locks were used.

The purpose here is to find a partition of the terrain that is intuitive, easy to compute, and splits the region into subregions of equal area. If 2 (or 3) threads were invoked, then the terrain was split into 2 (or 3) rectangular regions by taking the longest side and finding the midpoint (or the one third and two third points) and then using the perpendicular bisector of the edge at that point as a new boundary between split regions. The 4-thread version split the region into 4 quadrants similarly, but uses the midpoints of each side inside of just the longest side.

The weather tests were rerun on the multi-processor machines TOFU and MAGIC. In this case, all the tests were rerun so that the effect of larger maps on the concurrent implementation could be found. The results of the simulations are listed in Table 6.6.

There are some comments to make on these observations. Firstly, it seems odd that dual-processor (TOFU) performs better than quad-processor (MAGIC) when using 4 threads on 2 out of the 3 maps. From Table 6.1, we notice that the speeds of the processors are approximately equal, and that MAGIC has twice the amount of memory that TOFU has. Therefore, it seems likely that the different major versions of the Linux kernel (2.6.x vs 2.4.x) could be the culprit. It would be interesting to investigate this further.

[4]compared to the single-thread version.

[5]the value of $\frac{t_{singlethread}}{t_{multithread}}$ or simply $proportion^{-1}$

```java
// perform work ...

synchronized(WT.obj1) {
   WT.count1++;
   if (WT.count1==WT.threads)
      WT.obj1.notifyAll();
   while (!WT.flag1)
      try { WT.obj1.wait(); }
      catch(Exception ie) {}
}
synchronized(WT.obj2) {
   WT.count2++;
   if (WT.count2==WT.threads)
      WT.obj2.notifyAll();
   while (!WT.flag2)
      try { WT.obj2.wait(); }
      catch(Exception ie) {}
}

// loop back
```

Worker Threads

```java
// start iteration

synchronized(WT.obj1) {
// workers work.
   while(WT.count1!=threads)
      try { WT.obj1.wait(); }
      catch(Exception ie) {}
}

// do post-work seq. comp

synchronized(WT.obj2) {
   synchronized(WT.obj1) {
      WT.count1 = 0;
      WT.flag1 = true;
      WT.flag2 = false;
      WT.obj1.notifyAll();
   }
   while (WT.count2!=threads)
      try { WT.obj2.wait(); }
      catch(Exception ie) {}

   WT.count2 = 0;
   WT.flag1 = false;
   WT.flag2 = true;
   WT.obj2.notifyAll();
}

// loop back
```

Main Thread

Figure 6.4: Java code for thread synchronization in the concurrent weather simulation

Map	Machine	# of threads	$t/iter$	Improvement[4]	Proportion[4]	Speed-up[5]
1	TOFU	2	18.94	11.197	63%	1.59
1	TOFU	3	14.76	15.377	49%	2.042
1	TOFU	4	12.37	17.767	41%	2.4363
1	MAGIC	2	19.964	11.92	63%	1.597
1	MAGIC	3	17.462	14.417	55%	1.826
1	MAGIC	4	16.9	14.979	53%	1.89
2	TOFU	2	79.623	58.823	58%	1.74
2	TOFU	3	62.706	75.74	45%	2.21
2	TOFU	4	55.175	83.271	40%	2.51
2	MAGIC	2	83.027	43.973	65%	1.54
2	MAGIC	3	72.803	54.921	57%	1.7544
2	MAGIC	4	66.53	61.194	52%	1.92
3	TOFU	2	315.843	211.377	60%	1.67
3	TOFU	3	316.693	210.527	60%	1.665
3	TOFU	4	332.908	194.312	63%	1.584
4	MAGIC	2	325.13	176.368	65%	1.54
4	MAGIC	3	273.93	227.568	55%	1.83
4	MAGIC	4	271.09	230.408	54%	1.85

Table 6.6: Results of the concurrent weather simulation tests. All listed times are in milliseconds (10^{-3} seconds), and the altitude maps used were `pak_alt#`.

Secondly, when running the weather simulation test on `pak_alt3.dat` adding threads on TOFU seems to slow down the process instead of speed it up, but this does not happen on MAGIC. This implies that TOFU has reached some kind of threshold: either concurrent memory access is slowed down due to the fact that there is a lot of information being stored in memory and the cache memory becomes filled too quickly, or the amount of memory is too much to hold in RAM so virtual memory is used in which case a lot of overhead is added for swapping information in and out from secondary memory.

We now use these observed values to approximate how much of the weather simulation computation is due to sequential (single-threaded) computation versus parallel (multi-threaded) computation. As a tool to help us measure the influence of these two separate values, we use Amdahl's Law [Amd67]:

$$speedup = \frac{1}{(1-p)+\frac{p}{n}} \tag{6.4}$$

where *speedup* is the best possible attained speedup, p is the proportion of time spent in the parallel part of the program, n is the number of processors, s is the proportion of time spent in the sequential part of the program, and $s + p = 1$.

Using 2.51 as the best speedup attained on 2 processors, we get $p = 1.2032$. There are other instances for which TOFU beats its theoretical maximum: both when using more than 2 threads on the first 2 maps. This means that on TOFU we are experiencing *superlinear speedup* [HM89]; it is sometimes when multiple CPUs are used and is typically due to the effects of processor caches. In these cases, so we cannot use these exceptional cases to find the values we are interested in.

In the case of the third map, the max speedup obtained by TOFU is 1.67. In this case, we obtain $(p, s) = (0.8, 0.2)$. The same calculations are repeated for MAGIC in all 3 cases and the values obtained are: $p = 0.63$, $p = 0.64$, and $p = 0.613$. This gives an average of $\bar{p} = 0.67$ and $\bar{s} = 0.33$. Therefore, roughly one third of the time in the concurrent implementation is spent doing sequential computation.

6.4.3 Buffering

The buffering technique proposed here is similar to the *double-buffering* [FvDFH95] technique that has been widely-applied in the domain of Computer Graphics. The core concept involves holding two objects (*buffers*) in memory: a *scrap buffer* and a *display buffer*. The application works on the scrap buffer while displaying the display buffer to the user. When the application has done the work it needs, the roles of the 2 buffers are interchanged. Typically, switching the roles of these 2 buffers is a very efficient process, more efficient than working on the same buffer that is being displayed. As a result, a performance improvement is generally observed.

Here, a similar strategy is used. There are 2 buffers: one called the *write buffer* and the other called the *read buffer*. The write buffer is never displayed, only modified. The read buffer displayed and inspected by the main algorithms. Both buffers hold a single independent grid. Initially, the two buffers are created and are identical. Each iteration, the algorithms inspect the read buffer and calculate all changed needed to be done, but instead apply the changes to the write buffer directly instead of temporarily storing the values in a mask and applying the mask later. Before the next iteration begins, the roles of the two buffers are switched so that the read buffer then contains the grid with recently-modified values.

When the simulations enable buffering, the methods that modify the values of the state do so directly to the write buffer. Therefore, Buffering effectively allows the removal of the `applyMask` and `clearMask` functions and so should have an effect on the performance.

The obtained results for average time per iteration on the weather simulations were 69.96ms, 47.72ms, 33.32ms, 32.01ms, giving an average of 45.75 ms/iteration. The time taken per iteration including buffering takes 2.5ms longer. These results clearly conclude that the memory requirements added to help gain performance have slowed down the implementation enough to make the optimization not worth including.

6.4.4 Aggregation

Two major application systems have been implemented (weather and reputation) that are somewhat similar in that they are based on the the same iterative adaptation scheme and data representation (grid layout). The performance of each individual system has been measured independently and in several different environments. As well, all optimizations have focused on improving performance of an individual system or part of a system. All performance comparisons have been done on the previous recorded results of the simulations runs using those systems.

A simple optimization is proposed to combine the simulations to create an aggregate simulation which uses the same grid and a merged simulation loop which uses algorithms from both systems separately but on a shared grid. Since the plugin-systems have a simple interface, integrating many of them in a single simulation engine is quite easy. The interface for each algorithm in a plugin-system is just a method that takes the coordinate positions to be updated and performs the computation. All that is required by the aggregate simulator is to create an object of the plugin-system's type, and to include invocations of the required algorithms provided by the plugin-system on the plugin object.

Once again simulations were run and performance data collected from them. Map 1 was used for weather and `test_rep3.txt` for reputation. The average time per iteration on the 4 different machines was: 72.94ms, 53.18ms, 35.08ms, and 31.17ms. The average value is 48.08 ms/iteration. The sum of the averages that were done independently is $43.244 + 6.834 = 50.078$. This corresponds roughly to a 4% improvement.

The improvement offered by aggregating the two systems is rather small, but not negligible. This might be due to the fact that we are only combining the iterative process and the grid not the actual data nor the procedures themselves. Combining the data and procedures would be removing in part from the usefulness of the plug-in abstraction. In a commercial game, sharing a grid between multiple systems is a must. This aggregate model proves that multiple adaptation schemes can easily be contained in the same virtual environment.

We introduced this chapter with an explanation and demonstration of the integration of the general adaptation scheme into the context of modern persistent-state computer games. Adaptation of weather and reputation are examples of adaptation schemes that we might find in such games. The integration of adaptation in the software design sense gives a practical justification for the usefulness of these schemes.

The basic structure of the plug-in systems and logical control flow were described in Chapter 4. Here, we extended these ideas by a thoroughly detailed breakdown of the actual implementation of the simulator. Since the implementation is modular, creating new modules is straight-forward.

Performance was measured by running the simulator and tracking the times spent in certain methods. The two major systems' performances were analyzed in detail on several different testing environments. The average was used to reduce and local error or bias cause by a particular testing environment.

Several optimizations were proposed. The simulations were rerun with these optimization enabled so as to allow us to quantify the value of an optimization. Some of the optimizations failed (enabling the optimization lead to slower simulations) and some succeeded. In particular, concurrency and caching seemed to help out a lot (45% and 15% improvement repsectively) and system aggregation helps out a small amount (4%). Buffering and simple tabular trigonometric functions proved to be not worthwhile.

The implementation here is generic enough that any plug-in system could literally be dropped in to the framework and used. To summarize, the adaptation framework used here is versatile, robust, and extendible.

Chapter 7
Future Work and Conclusions

In this thesis, we have described a generic adaptation scheme for modeling and designing adaptive virtual environments in persistent-state computer games. Our adaptation model is composed of several familiar computational formalisms such as data flow and cellular automata. The model implicitly provides the notion of locality for large-scale environments.

The model enforces a discrete timeline upon which the iterative update cycle is built. This update cycle defines generic adaption process because it contains a list of abstractly-defined adaptation procedures. This procedural abstraction allows for specific functional adaptation algorithms to be separately implemented and maintained. Specific adaptive virtual environments are simply defined by the cellular properties and adaptation algorithms. The simulator can be used to test each adaptive virtual environment completely independently. Merging adaptive virtual environments in one aggregate adaptive virtual environment is as simple as including all the specific procedures in the list to be run by the update cycle.

The model described is generic and intuitive. It is meant to be used by game designers who are interested in building an adaptive virtual environment in their game. Two adaptation systems are explained in detail, which serve as a good stepping stones for a designer who would like to model his/her own different adaptive virtual environment.

The two example systems use some generic adaptation concepts that would likely be reused in future systems as well. Local averaging helps distribute the impact of sharp changes to surrounding neighbors. Using flow as a means for quantified information dispersal is also a good way to spread the influence of events to surrounding neighbors. Both were used and demonstrated to work in the example systems.

The entities inside of a virtual environment are really what make the environment react since entities are allowed to interact in the system. The evolution of the adaptive virtual environment is then non-deterministic because the entities here will be mostly player characters.

The interaction with an adaptive environment adds a significant importance to the player characters' actions because they can cause an event that can change the environment forever. As such, this encourages a real history of the world to develop over time, and players to be part of a dynamic, realistic world.

As an extension to agent-based adaptation, movement models for mobile agents in game environment simulations were investigated. The aim was to build a probabilistic model for agent movement behavior. Specifically, a multi-player network computer game was designed for a game-playing experiment which collected data to analyze.

The game, called Conquero, involved short range combat and team capture of command centers. Simple heuristics for movement information were proposed solely based on size of the next command center and distance from the next command center. The values of the heuristics were placed into a classification system to see if they were sufficient for deciding which command center to visit next. The heuristics were extended to include many other kinds of data prominent in Conquero, such as data that is dynamic like properties of other agents. Dynamic agents were built by providing the agents with decision trees that were learned from the dynamic features. Since the computation of these dynamic features was very efficient, incorporating learning features based on decision-tree classification is likely feasible. In the context of Conquero, five movement models were described after analyses were performed.

The movement models proposed were re-applied to the reputation system to see what kind of reputation fields they would give. Interesting results appeared. Using the same seed for the central random number generator, the 5 models produced quite different results, as confirmed by Figure 5.4 and Table 5.4.

The performance of the movement models was generally quite good. In particular, the decision-tree learning method seems to be computationally efficient and serves as a structure for agent decision-making quite well. However, domain-specific heuristics are required to transform observed sensory data into something meaningful, implying that some form of knowledge will have to be pre-programmed even into learning agents.

Finally, we have shown that the use of the adaptation scheme is feasible and suggested an architecture for applying the the process in modern computer game projects. We have showed that all the concepts given fit easily into the object-oriented paradigm, allowing for modular design, code reuse, and easy future modification.

Both the efficiency and performance of the simulations are encouraging. Even at the worse case scenario, the iterations never took longer than 1 second in total. Considering that adaptation is a long-term effect, this level of performance is quite acceptable. We have further give experimental evidence of the effect of some simple optimizations. In fact, some of the performance improvements are impressive and encouraging. Other than the caching of the gradient, the optimizations were independent of the application system.

After all is considered, it seems that adaptive virtual environments are interesting to study and would add an entertaining new element to a game-player's gaming experience. It remains to be seen if players themselves would enjoy playing their character in such environments. We suspect this new feature would be enjoyable for the most part, since it has been proven in the game development industry that players enjoy new content. We are hoping, if not expecting, to soon see adaptive virtual environments in commercial persistent-state games.

7.1 Future Work

There is a good amount of potential for future work on adaptive virtual environments. We will list the most interesting here and describe each briefly.

Improved Adaptation Systems

The 2 systems proposed in Chapter 4 are quite basic systems. For instance, the weather system is missing some key elements for it to be realistic, such as temperature, evaporation, growth of vegetation, atmospheric pressure and so on. Implementing some of the weather events suggested in the chapter on these applications, such as tsunamis, earthquakes, floods, etc. would also be another way of improving the existing implementation. Although, adding such feature would also add complexity and cost.

In the reputation system, it would be nice to implement support for the reputation groups and membership values. A better movement model is needed than the random one supplied. Ultimately, it needs to have a movement model that corresponds to real movements of players in persistent-state games.

Other Adaptation Applications

We have proposed and analyzed two adaptation applications that could be applied in modern games. There are, of course, many other possibilities for applying adaptation in computer games.

One rather obvious application is an adaptive economy. An adaptive economy based on supply and demand could be implemented by flowing information and resource availability through the grid. Values of items would adapt over time and location, which would change the prices of items sold by vendors. Events in this system could be inflation, theft, or sudden loss/gain of resources. For example, a forest fire causes a drop in wood supply.

It would also be beneficial if social aspects of environments such as law, politics, etc. could be quantified. For example, one could envision an adaptive law enforcement system. Crime would be a measurable scalar property. The amount of law enforcement per region would also be a scalar property that would adapt to the crime rate of the region. As a result, in the long run more law enforcers would surround the areas with higher crime, causing the crime rate to go back down.

Grid Partitioning

In large-scale environments, the virtual environment terrains might not necessarily be rectangular. Most of these games in fact are using the notion of "zones," arbitrary but strict partitions of some larger world. These often correspond to management by separate servers, and so there can be significant inter-zone communication costs. Arbitrary decomposition into zones can also of course produce an overall world shape that may not easily map to a regular grid.

Zones, however, are still typically quite large and can contain up to 1000 characters. This may make it reasonable to adapt zones separately, perhaps with a relaxed consistency model between zone borders.

Integration of Adaptation Architecture in a Large Persistent-state Computer Game

In Chapter 6, the implementation of the adaptation engine part of the entire adaptation architecture was shown in detail. The simulators show the adaptation engine running the adaptation process on the example systems. However, the state history server was not implemented and remains a future project.

Ideally, an existing game project that is somewhat well-known could be modified so that it would simply dump information to the state history server and accept modifications from the state history server. This server would be responsible for collecting data and storing it in an efficient way, communicating with the adaptation server, and assigning changes back to the game servers and/or clients. The important part of this future consideration is to have a sufficiently large player base for the game.

The Conquero Experiment, Revisited

Due to resource constraints, Conquero was intended to be an approximate microscopic version of the events that happened over longer periods of time in a larger persistent-state multi-player game. However, the game is small, simple and dynamic. As well, its overhead view allows players to see the entire state of the game at all times. It forces players to remain near command centers instead of accurately modeling behavior based on player interest. Movement models could also be improved.

An interesting venture would be to recreate the Conquero experiment using an existing multi-player game, or even better an existing persistent state game. The benefits of this would be that the data would reflect the actual constraints of a more representative game interface.

A Generic Model for Adaptive Agents

The movement model learning done in Chapter 5 could also be applied to agents *online*, during the game. The decision tree construction was computationally efficient, and so this makes it possible to implement a movement model where the decision tree is built and used incrementally and dynamically. In fact, we need not restrict the learning agents to decisions based on movement. Agents could collect a set of data via predefined sensors, calculate the value of predefined heuristic functions, build a classification problem, solve it, and then use the solution to make a decision from a set of predefined actions. The adaptation process here would be to simply recreate the decision tree every so often as to keep it up-to-date from new observations.

Appendix A
Learned Decision Tree

The following is a text representation of the decision tree learned from the second classification problem described in Chapter 5:

```
C4h3 <= 4.36315E-5 :
| oldCity = 1.0 : 14 (0.0)
| oldCity != 1.0 :
| | oldCity = 2.0 : 14 (0.0)
| | oldCity != 2.0 :
| | | oldCity = 3.0 : 14 (0.0)
| | | oldCity != 3.0 :
| | | | oldCity = 4.0 : 14 (0.0)
| | | | oldCity != 4.0 :
| | | | | oldCity = 5.0 : 14 (0.0)
| | | | | oldCity != 5.0 :
| | | | | | oldCity = 19.0 : 14 (0.0)
| | | | | | oldCity != 19.0 :
| | | | | | | oldCity = 20.0 : 14 (0.0)
| | | | | | | oldCity != 20.0 :
| | | | | | | | oldCity = 21.0 : 14 (0.0)
| | | | | | | | oldCity != 21.0 :
| | | | | | | | | oldCity = 22.0 : 14 (0.0)
| | | | | | | | | oldCity != 22.0 :
| | | | | | | | | | oldCity = 23.0 : 14 (0.0)
| | | | | | | | | | oldCity != 23.0 :
| | | | | | | | | | | oldCity = 24.0 : 14 (0.0)
| | | | | | | | | | | oldCity != 24.0 :
| | | | | | | | | | | | oldCity = 6.0 :
| | | | | | | | | | | | | C18nop > 23.0 : 7 (3.0)
| | | | | | | | | | | | | C18nop !> 23.0 :
| | | | | | | | | | | | | | C11nte > 3.0 : 8 (3.0)
| | | | | | | | | | | | | | C11nte !> 3.0 :
| | | | | | | | | | | | | | | C10nop > 23.0 : 8 (3.0)
| | | | | | | | | | | | | | | C10nop !> 23.0 :
| | | | | | | | | | | | | | | | C14nop <= 24.0 :
| | | | | | | | | | | | | | | | | C16nop > 0.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | C16nop !> 0.0 :
| | | | | | | | | | | | | | | | | | mopx <= 699.231 :
| | | | | | | | | | | | | | | | | | | C13nop > 24.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | C13nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | vy <= -0.011 :
| | | | | | | | | | | | | | | | | | | | | mopx <= 658.923 : 8 (4.0)
| | | | | | | | | | | | | | | | | | | | | mopx !<= 658.923 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | vy !<= -0.011 :
| | | | | | | | | | | | | | | | | | | | | cto <= 7.0 : 15 (14.0)
| | | | | | | | | | | | | | | | | | | | | cto !<= 7.0 :
| | | | | | | | | | | | | | | | | | | | | | C17dist <= 365.121 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C17dist !<= 365.121 : 15 (3.0)
| | | | | | | | | | | | | | | | | | mopx !<= 699.231 :
| | | | | | | | | | | | | | | | | | | mopx <= 736.87 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | mopx !<= 736.87 : 8 (2.0)
| | | | | | | | | | | | | | | | C14nop !<= 24.0 :
| | | | | | | | | | | | | | | | | mopx <= 658.923 : 10 (2.0)
| | | | | | | | | | | | | | | | | mopx !<= 658.923 : 8 (2.0)
| | | | | | | | | | | | oldCity != 6.0 :
| | | | | | | | | | | | | oldCity = 7.0 :
| | | | | | | | | | | | | | C17nop <= 0.0 :
| | | | | | | | | | | | | | | C24nop > 21.0 : 5 (3.0)
| | | | | | | | | | | | | | | C24nop !> 21.0 :
| | | | | | | | | | | | | | | | C10nop <= 24.0 :
| | | | | | | | | | | | | | | | | C11dist <= 430.094 :
| | | | | | | | | | | | | | | | | | C8nte > 3.0 : 15 (3.0)
| | | | | | | | | | | | | | | | | | C8nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | C15nte > 3.0 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | C15nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | C16nte > 6.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | C16nte !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | mtpx <= 672.667 :
| | | | | | | | | | | | | | | | | | | | | | C12nop > 0.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C12nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | C9nop > 24.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | C9nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | dco <= 5.0 : 8 (3.0)
```

```
| | | | | | | | | | | | | | | | | | | | | | | | dco !<= 5.0 : 11 (65.0)
| | | | | | | | | | | | | | | | | | | | | mtpx !<= 672.667 :
| | | | | | | | | | | | | | | | | | | | | | C12dist <= 439.15 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | C12dist !<= 439.15 : 15 (2.0)
| | | | | | | | | | | | | | | | | C11dist !<= 430.094 :
| | | | | | | | | | | | | | | | | | mtpy <= 487.375 : 15 (11.0)
| | | | | | | | | | | | | | | | | | mtpy !<= 487.375 :
| | | | | | | | | | | | | | | | | | | mopy <= 452.429 : 17 (4.0)
| | | | | | | | | | | | | | | | | | | mopy !<= 452.429 : 18 (2.0)
| | | | | | | | | | | | | | | | C10nop !<= 24.0 :
| | | | | | | | | | | | | | | | | mopx <= 635.083 : 9 (2.0)
| | | | | | | | | | | | | | | | | mopx !<= 635.083 : 11 (2.0)
| | | | | | | | | | | | | | C17nop !<= 0.0 :
| | | | | | | | | | | | | | | C17nte <= 3.0 : 18 (2.0)
| | | | | | | | | | | | | | | C17nte !<= 3.0 :
| | | | | | | | | | | | | | | | dcc <= 13.4536 : 15 (2.0)
| | | | | | | | | | | | | | | | dcc !<= 13.4536 : 17 (3.0)
| | | | | | | | | | | | | oldCity != 7.0 :
| | | | | | | | | | | | | | oldCity = 8.0 :
| | | | | | | | | | | | | | | C1nte > 0.0 : 1 (3.0)
| | | | | | | | | | | | | | | C1nte !> 0.0 :
| | | | | | | | | | | | | | | | C18nop <= 0.0 :
| | | | | | | | | | | | | | | | | C24nop > 0.0 : 20 (2.0)
| | | | | | | | | | | | | | | | | C24nop !> 0.0 :
| | | | | | | | | | | | | | | | | | C12nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | C20nte > 0.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | C20nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | C4nte > 0.0 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | C4nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | C12nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | C15nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | C7nop > 23.0 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | C7nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C6own = 0.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C6own != 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C6own = 2.0 : 15 (0.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C6own != 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C19nop > 0.0 : 6 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 3.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 147.078 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 19.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 19.0 : 15 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 147.078 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 0.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 697.874 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 697.874 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 528.348 : 16 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 528.348 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 234.344 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop > 5.0 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop > 0.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy > 519.667 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !> 519.667 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 853.366 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx > 17.8885 : 10 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !> 17.8885 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist <= 432.0 : 10 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !<= 432.0 : 15 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 853.366 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto > 1083.21 : 10 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !> 1083.21 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy > 361.0 : 15 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !> 361.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 14.5602 : 6 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 14.5602 : 12 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 234.344 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop <= 349.092 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop !<= 349.092 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 14.1421 : 10 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 14.1421 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 20.2237 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 20.2237 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 17.0 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 17.0 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 657.423 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 657.423 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 511.958 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 511.958 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | C15nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | dct <= 137.033 :
| | | | | | | | | | | | | | | | | | | | | | | | mopx <= 608.038 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 608.038 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | dct !<= 137.033 :
| | | | | | | | | | | | | | | | | | | | | | | | ply <= 222.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | ply !<= 222.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | ply <= 234.0 : 15 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 234.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | C12nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | plx <= 338.0 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | plx !<= 338.0 : 12 (3.0)
| | | | | | | | | | | | | | | | | | C12nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | C7dist <= 443.128 :
| | | | | | | | | | | | | | | | | | | | plx <= 338.0 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | plx !<= 338.0 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | C7dist !<= 443.128 :
| | | | | | | | | | | | | | | | | | | | vy <= 0.023 : 10 (6.0)
| | | | | | | | | | | | | | | | | | | | vy !<= 0.023 : 18 (2.0)
| | | | | | | | | | | | | | | | C18nop !<= 0.0 :
| | | | | | | | | | | | | | | | | cto <= 3.0 :
| | | | | | | | | | | | | | | | | | mopx <= 566.261 : 14 (2.0)
| | | | | | | | | | | | | | | | | | mopx !<= 566.261 : 12 (2.0)
| | | | | | | | | | | | | | | | | cto !<= 3.0 :
| | | | | | | | | | | | | | | | | | C24dist <= 559.99 : 10 (2.0)
```

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| | | | | | | | | | | | | | | | | | C24dist !<= 559.99 : 15 (3.0)
| | | | | | | | | | | | | | oldCity != 8.0 :
| | | | | | | | | | | | | | | oldCity = 9.0 :
| | | | | | | | | | | | | | | | C9nop > 21.0 : 15 (2.0)
| | | | | | | | | | | | | | | | C9nop !> 21.0 :
| | | | | | | | | | | | | | | | | C14nte > 3.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | C14nte !> 3.0 :
| | | | | | | | | | | | | | | | | | C13own = 0.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | C13own != 0.0 :
| | | | | | | | | | | | | | | | | | | C13own = 2.0 : 17 (0.0)
| | | | | | | | | | | | | | | | | | | C13own != 2.0 :
| | | | | | | | | | | | | | | | | | | | C21nte > 3.0 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | C21nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | C8nop > 23.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C8nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | C11dist <= 13.4536 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 13.4536 :
| | | | | | | | | | | | | | | | | | | | | | | | C4nte > 0.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C4nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C7nop > 23.0 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C7nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop > 24.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy > 525.385 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !> 525.385 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 671.667 : 17 (38.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 671.667 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 445.01 : 17 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 445.01 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 712.8 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 712.8 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | dco <= 158.862 : 17 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | dco !<= 158.862 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 464.783 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 464.783 : 7 (2.0)
| | | | | | | | | | | | | | | oldCity != 9.0 :
| | | | | | | | | | | | | | | | oldCity = 10.0 :
| | | | | | | | | | | | | | | | | C17nte <= 0.0 :
| | | | | | | | | | | | | | | | | | C14dist <= 606.981 :
| | | | | | | | | | | | | | | | | | | C18nte > 3.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | C18nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | C13nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | C11nte > 6.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | C11nte !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | C12nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | C15nte > 5.0 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | C15nte !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C8nte > 0.0 : 8 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | C8nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C7nte > 0.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C7nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C10dist <= 13.1529 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 22.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 22.0 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C10dist !<= 13.1529 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C6nop > 24.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C6nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 189.667 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 189.667 : 12 (14.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 3.0 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 14.4222 : 12 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 14.4222 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 269.082 : 12 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 269.082 : 8 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist <= 398.898 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !<= 398.898 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 712.037 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 712.037 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C12nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | cto <= 1.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | cto !<= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 251.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 251.0 : 12 (5.0)
| | | | | | | | | | | | | | | | | | | | C13nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | plx <= 358.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | plx !<= 358.0 :
| | | | | | | | | | | | | | | | | | | | | | mtpy <= 282.667 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | mtpy !<= 282.667 : 8 (2.0)
| | | | | | | | | | | | | | | | | | C14dist !<= 606.981 :
| | | | | | | | | | | | | | | | | | | C22nop <= 0.0 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | C22nop !<= 0.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | C17nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | mopy <= 495.385 : 3 (2.0)
| | | | | | | | | | | | | | | | | | mopy !<= 495.385 : 17 (2.0)
| | | | | | | | | | | | | | | | oldCity != 10.0 :
| | | | | | | | | | | | | | | | | oldCity = 11.0 :
| | | | | | | | | | | | | | | | | | C16dist <= 689.536 :
| | | | | | | | | | | | | | | | | | | C23nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | C18nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | C14nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | C1nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | cto <= 7.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C9nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C16nop > 0.0 : 13 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C8nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 234.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dco <= 12.3693 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dco !<= 12.3693 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.023 : 7 (14.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.023 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 234.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nte > 0.0 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nop > 24.0 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 0.0 :
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 617.667 : 18 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 617.667 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 427.308 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 20.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 20.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 427.308 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 247.649 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 247.649 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 499.038 : 17 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 499.038 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 648.584 : 13 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 648.584 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 656.269 : 14 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 656.269 : 17 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 180.413 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 180.413 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 206.828 : 7 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 206.828 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 681.333 : 7 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 681.333 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 386.374 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 386.374 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 19.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= -0.048 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= -0.048 : 7 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 475.808 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 541.286 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 541.286 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 475.808 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 624.619 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 624.619 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C9nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C9nop > 24.0 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C9nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 596.667 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 596.667 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | cto !<= 7.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C11dist <= 12.2066 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 12.2066 :
| | | | | | | | | | | | | | | | | | | | | | | | | C16nte > 3.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C16nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C15nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C7nop > 21.0 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C7nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C18dist <= 141.039 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 21.0 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 21.0 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C18dist !<= 141.039 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop > 24.0 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte > 0.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy > 0.113 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !> 0.113 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 423.001 : 13 (9.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 423.001 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 122.674 : 17 (8.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 122.674 : 13 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C15nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 418.5 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 418.5 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C1nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | mopy <= 505.952 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | mopy !<= 505.952 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | C14nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | dcoc <= 13.6015 :
| | | | | | | | | | | | | | | | | | | | | | | mopx <= 651.75 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | mopx !<= 651.75 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | dcoc !<= 13.6015 :
| | | | | | | | | | | | | | | | | | | | | | | dcuc <= 14.5602 :
| | | | | | | | | | | | | | | | | | | | | | | | C16dist <= 52.6973 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C16dist !<= 52.6973 :
| | | | | | | | | | | | | | | | | | | | | | | | | dct <= 133.462 : 13 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | dct !<= 133.462 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | dcuc !<= 14.5602 :
| | | | | | | | | | | | | | | | | | | | | | | | cto <= 4.0 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | cto !<= 4.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | C18nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | cto <= 3.0 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | cto !<= 3.0 : 18 (6.0)
| | | | | | | | | | | | | | | | | | | C23nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | dcoc <= 14.2127 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | dcoc !<= 14.2127 : 19 (3.0)
| | | | | | | | | | | | | | | | | | C16dist !<= 689.536 :
| | | | | | | | | | | | | | | | | | | C5nop > 0.0 : 22 (3.0)
| | | | | | | | | | | | | | | | | | | C5nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | dct <= 358.286 :
| | | | | | | | | | | | | | | | | | | | | mtpy > 741.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | mtpy !> 741.0 :
| | | | | | | | | | | | | | | | | | | | | | dcc <= 13.3417 : 19 (4.0)
| | | | | | | | | | | | | | | | | | | | | | dcc !<= 13.3417 : 24 (3.0)
| | | | | | | | | | | | | | | | | | | | dct !<= 358.286 :
| | | | | | | | | | | | | | | | | | | | | mtpx <= 460.375 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | mtpx !<= 460.375 : 1 (2.0)
| | | | | | | | | | | | | | | | | oldCity != 11.0 :
| | | | | | | | | | | | | | | | | | oldCity = 12.0 :
| | | | | | | | | | | | | | | | | | | C11nop > 21.0 : 4 (3.0)
| | | | | | | | | | | | | | | | | | | C11nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | dcuc <= 993.413 :
| | | | | | | | | | | | | | | | | | | | | C22nop > 0.0 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | C22nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | C12nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | C6nte > 0.0 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | C6nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C16nop > 24.0 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C11nop > 0.0 : 8 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C11nop !> 0.0 :
```

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| | | | | | | | | | | | | | | | | | | | | | | | | | | C15nop > 23.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C15nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C14dist > 295.007 : 8 (8.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C14dist !> 295.007 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct > 300.832 : 16 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct !> 300.832 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte > 5.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 292.333 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 292.333 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 17.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 17.0 : 10 (15.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 954.713 : 8 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 954.713 : 10 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist <= 450.948 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist !<= 450.948 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.021 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.021 : 16 (9.0)
| | | | | | | | | | | | | | | | | | | | | | C12nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | mopy <= 475.808 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | mopy !<= 475.808 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | dcuc !<= 993.413 :
| | | | | | | | | | | | | | | | | | | | | mopx <= 631.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | mopx !<= 631.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | oldCity != 12.0 :
| | | | | | | | | | | | | | | | | | | oldCity = 13.0 :
| | | | | | | | | | | | | | | | | | | | C9nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | C1nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | C10nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | C15nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C22nop > 0.0 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C22nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C23nop > 21.0 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C23nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop > 24.0 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 3.0 : 11 (11.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.125 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nte > 6.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nte !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 672.0 : 11 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 672.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 591.769 : 14 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 591.769 : 16 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 21.0 : 11 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 0.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 5.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 3.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 24.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 12.53 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 12.53 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= -0.056 : 14 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= -0.056 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop > 21.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy > 6.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto > 14.5602 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !> 14.5602 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist <= 17.4929 : 11 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !<= 17.4929 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 13.6015 : 14 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 13.6015 : 11 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 362.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 362.0 : 14 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 0.0040 : 11 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 0.0040 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 702.769 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 702.769 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.125 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 20.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 20.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 574.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 574.0 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 435.154 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 435.154 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15dist <= 342.584 : 14 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15dist !<= 342.584 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo > 19.0 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !> 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 13.4536 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 13.4536 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 12.2066 : 10 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 12.2066 : 14 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | C15nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C22dist <= 1003.89 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | C22dist !<= 1003.89 :
| | | | | | | | | | | | | | | | | | | | | | | | | vx <= -0.017 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | vx !<= -0.017 : 15 (3.0)
| | | | | | | | | | | | | | | | | | | | | | C10nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | coo <= 20.0 : 10 (2.0)
```

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| | | | | | | | | | | | | | | | | | | | | | | coo !<= 20.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | C1nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | C1nop <= 23.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | C1nop !<= 23.0 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | C9nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | ply <= 891.0 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | ply !<= 891.0 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | oldCity != 13.0 :
| | | | | | | | | | | | | | | | | | | | oldCity = 14.0 :
| | | | | | | | | | | | | | | | | | | | | plx <= 1021.0 :
| | | | | | | | | | | | | | | | | | | | | | C10nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | C17nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C23nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C7nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop > 23.0 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte > 6.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 23.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 21.0 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 522.462 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 0.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop > 0.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 13.6015 : 13 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 13.6015 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist > 347.96 : 13 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !> 347.96 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 0.0010 : 16 (29.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 0.0010 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop <= 14.1421 : 13 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop !<= 14.1421 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist <= 9.0 : 16 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 9.0 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop > -0.017 : 13 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !> -0.017 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 429.577 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 429.577 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist <= 6.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist <= 33.2866 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !<= 33.2866 : 16 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte <= 473.25 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte !<= 473.25 : 16 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 571.008 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 571.008 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 522.462 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist <= 117.209 : 18 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !<= 117.209 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte <= 15.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte !<= 15.0 : 13 (9.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 555.739 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 555.739 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx > 667.381 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !> 667.381 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop > 21.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 562.261 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 562.261 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 677.731 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 677.731 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc <= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 6.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 6.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc !<= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 2.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop > 24.0 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.4222 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.4222 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 6.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 708.038 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 708.038 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.0357 : 8 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.0357 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C7nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 639.5 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 639.5 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 12.2066 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 341.6 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 341.6 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 12.2066 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 643.269 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 643.269 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C23nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C20dist <= 255.947 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C20dist !<= 255.947 : 12 (3.0)
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| | | | | | | | | | | | | | | | | | | | | | | C17nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 438.926 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 438.926 : 5 (3.0)
| | | | | | | | | | | | | | | | | | | | | | C10nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | mopx <= 572.87 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | mopx !<= 572.87 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | plx !<= 1021.0 :
| | | | | | | | | | | | | | | | | | | | | | C5nop > 0.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C5nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | C3nte > 3.0 : 10 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | C3nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | coo <= 17.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | coo !<= 17.0 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | oldCity != 14.0 :
| | | | | | | | | | | | | | | | | | | | | oldCity = 15.0 :
| | | | | | | | | | | | | | | | | | | | | | C18nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | C16nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C6nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C11nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | dct <= 9.05539 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop <= 0.0 : 11 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !<= 0.0 : 12 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | dct !<= 9.05539 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 540.043 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 3.0 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13dist <= 13.4536 : 7 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13dist !<= 13.4536 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 659.333 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop > 21.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 33.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 33.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 15.0 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 15.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 302.552 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 302.552 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 356.679 : 8 (19.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 356.679 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 570.909 : 8 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 570.909 : 7 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 659.333 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco <= 89.2749 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 512.191 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 512.191 : 8 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco !<= 89.2749 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx > 0.011 : 6 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !> 0.011 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 484.423 : 12 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 484.423 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 307.875 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 307.875 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 540.043 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12dist <= 393.406 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.0357 : 14 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.0357 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 453.667 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 453.667 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12dist !<= 393.406 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.038 : 6 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.038 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 24.0 : 6 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.1421 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.1421 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 417.0 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 417.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C11nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C11dist <= 12.7279 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 12.7279 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= 0.021 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= 0.021 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C6nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 1173.69 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 1173.69 : 6 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | C16nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 419.0 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 419.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 501.577 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 501.577 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | C18nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | dco <= 52.3927 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | dco !<= 52.3927 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | oldCity != 15.0 :
| | | | | | | | | | | | | | | | | | | | | | oldCity = 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | C1nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C17nop > 23.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C17nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | vx <= 0.154 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C6nop > 0.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C6nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C7nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nte > 3.0 : 14 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16dist <= 12.3693 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16dist !<= 12.3693 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nte > 5.0 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nte !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nte > 3.0 : 14 (9.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 0.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 19.4165 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 19.4165 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop > 0.0 : 14 (6.0)
```

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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 13.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 197.709 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 197.709 : 14 (10.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 13.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop > 18.0 : 14 (25.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 18.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 14.2127 : 12 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 628.304 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 628.304 : 14 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop > 369.333 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !> 369.333 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 101.203 : 14 (9.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 101.203 : 12 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 526.231 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 526.231 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C7nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.1421 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.1421 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct > 208.082 : 12 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct !> 208.082 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 986.071 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 986.071 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop <= 24.0 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C12nop !<= 24.0 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | vx !<= 0.154 :
| | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 664.333 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 664.333 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | C1nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | mopy <= 445.609 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 445.609 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | oldCity != 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | oldCity = 17.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C12nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C8nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc <= 666.325 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 2 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C9nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= -0.148 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8dist <= 409.941 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= -0.153 : 19 (8.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= -0.153 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8dist !<= 409.941 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 574.417 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 574.417 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= -0.148 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 24.0 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 335.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist <= 858.242 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 438.792 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 438.792 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist !<= 858.242 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco <= 130.138 : 9 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco !<= 130.138 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 335.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 884.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C7nop > 24.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C7nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 3.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 11.7047 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 586.609 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 586.609 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 11.7047 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 0.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 6.0 : 9 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop > 6.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx > 411.539 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !> 411.539 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop > 0.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy > 0.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 14.0 : 11 (8.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 14.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist > 3.0 : 9 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop > 6.0 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop > 5.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop <= 12.6491 : 9 (10.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop !<= 12.6491 : 19 (27.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist <= 49.1935 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 49.1935 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 581.385 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 581.385 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist > 5.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !> 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte > -0.05 : 11 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte !> -0.05 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 470.696 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 470.696 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 624.333 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 624.333 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 884.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 18.0 : 1 (2.0)
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 18.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.0010 : 22 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.0010 : 19 (9.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C9nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 884.0 : 9 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 884.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 655.125 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 655.125 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop <= 24.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct <= 71.0634 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct !<= 71.0634 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc !<= 666.325 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C3dist <= 238.355 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23nop > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= -0.103 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= -0.103 : 23 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C3dist !<= 238.355 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nop > 0.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 12.7279 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 12.7279 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 233.0 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 233.0 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C8nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 1.0 : 12 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 133.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 133.0 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C12nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 344.0 : 8 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 344.0 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 618.609 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 618.609 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | oldCity != 17.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C3nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C1nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C9nte > 3.0 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C9nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 0.0 : 9 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop > 0.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 461.707 : 20 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 461.707 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nte > 6.0 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nte !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop > 0.0 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 21.0 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 0.131 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 3.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 23.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop > 3.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop > 0.0 : 14 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= -0.0040 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 269.833 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 269.833 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto > 28.8444 : 14 (24.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !> 28.8444 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist <= 692.385 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17dist !<= 692.385 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= -0.0040 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop > 3.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nop !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop <= 374.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist <= 16.0 : 14 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11dist !<= 16.0 : 20 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop !<= 374.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte <= 654.378 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nte !<= 654.378 : 14 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 518.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 518.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 0.131 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx > 0.0 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 474.231 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 474.231 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte <= 13.6015 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte !<= 13.6015 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 886.5 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 886.5 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 451.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 451.0 : 7 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 646.792 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 646.792 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C21dist <= 424.924 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 535.0 : 15 (2.0)
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 535.0 : 22 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C21dist !<= 424.924 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 19.0 : 19 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 2.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 2.0 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nte <= 3.0 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.011 : 16 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.011 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nte <= 3.0 : 13 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nte !<= 3.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= -0.025 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 870.0 : 24 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 870.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= -0.025 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 590.5 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 590.5 : 19 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 3.0 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 13.0 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 13.0 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C1nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C1nte <= 3.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C1nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C21dist <= 455.439 : 20 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C21dist !<= 455.439 : 4 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | C3nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | C3nop <= 23.0 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C3nop !<= 23.0 : 5 (2.0)
C4h3 !<= 4.36315E-5 :
| C4N = 0.0 :
| | C5N = 0.0 :
| | | C4h3 <= 0.00102719 :
| | | | C19N = 0.0 :
| | | | | oldCity = 1.0 : 1 (0.0)
| | | | | oldCity != 1.0 :
| | | | | | oldCity = 3.0 : 1 (0.0)
| | | | | | oldCity != 3.0 :
| | | | | | | oldCity = 4.0 : 1 (0.0)
| | | | | | | oldCity != 4.0 :
| | | | | | | | oldCity = 6.0 : 1 (0.0)
| | | | | | | | oldCity != 6.0 :
| | | | | | | | | oldCity = 7.0 : 1 (0.0)
| | | | | | | | | oldCity != 7.0 :
| | | | | | | | | | oldCity = 8.0 : 1 (0.0)
| | | | | | | | | | oldCity != 8.0 :
| | | | | | | | | | | oldCity = 9.0 : 1 (0.0)
| | | | | | | | | | | oldCity != 9.0 :
| | | | | | | | | | | | oldCity = 10.0 : 1 (0.0)
| | | | | | | | | | | | oldCity != 10.0 :
| | | | | | | | | | | | | oldCity = 11.0 : 1 (0.0)
| | | | | | | | | | | | | oldCity != 11.0 :
| | | | | | | | | | | | | | oldCity = 12.0 : 1 (0.0)
| | | | | | | | | | | | | | oldCity != 12.0 :
| | | | | | | | | | | | | | | oldCity = 13.0 : 1 (0.0)
| | | | | | | | | | | | | | | oldCity != 13.0 :
| | | | | | | | | | | | | | | | oldCity = 14.0 : 1 (0.0)
| | | | | | | | | | | | | | | | oldCity != 14.0 :
| | | | | | | | | | | | | | | | | oldCity = 15.0 : 1 (0.0)
| | | | | | | | | | | | | | | | | oldCity != 15.0 :
| | | | | | | | | | | | | | | | | | oldCity = 16.0 : 1 (0.0)
| | | | | | | | | | | | | | | | | | oldCity != 16.0 :
| | | | | | | | | | | | | | | | | | | oldCity = 17.0 : 1 (0.0)
| | | | | | | | | | | | | | | | | | | oldCity != 17.0 :
| | | | | | | | | | | | | | | | | | | | oldCity = 18.0 : 1 (0.0)
| | | | | | | | | | | | | | | | | | | | oldCity != 18.0 :
| | | | | | | | | | | | | | | | | | | | | oldCity = 22.0 : 1 (0.0)
| | | | | | | | | | | | | | | | | | | | | oldCity != 22.0 :
| | | | | | | | | | | | | | | | | | | | | | oldCity = 24.0 : 1 (0.0)
| | | | | | | | | | | | | | | | | | | | | | oldCity != 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | oldCity = 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | C9dist <= 476.319 :
| | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.0 : 20 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 481.231 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 481.231 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | C9dist !<= 476.319 :
| | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C22nte > 3.0 : 5 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C22nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C21nte > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C21nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop > 24.0 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 0.0 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 595.8 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto > 7.0 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !> 7.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 206.247 : 23 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 206.247 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 0.0 : 23 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop > 513.701 : 3 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !> 513.701 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= -0.039 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= -0.039 : 1 (20.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 1102.0 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 1102.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 69.6419 : 4 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 69.6419 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 595.8 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist <= 346.217 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist !<= 346.217 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C21dist <= 376.809 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C21dist !<= 376.809 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | oldCity != 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | oldCity = 5.0 :
```

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| | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C5nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop > 23.0 : 3 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 545.167 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco > 247.194 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco !> 247.194 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nte > 0.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 3.0 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 3.0 : 24 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 545.167 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 0.0 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C21nop > 0.0 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C21nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nte > 0.0 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 567.8 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 24.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 702.375 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 1.0 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 410.67 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 410.67 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 702.375 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 192.271 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 192.271 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 13.8924 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= -0.037 : 1 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= -0.037 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 419.609 : 24 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 419.609 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 13.8924 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop > 3.0 : 24 (21.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 192.762 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 192.762 : 24 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 567.8 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 1020.29 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 1020.29 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 433.714 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 433.714 : 24 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 487.111 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 487.111 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C5nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.012 : 22 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.012 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 861.667 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 861.667 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 22.0 : 6 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 22.0 : 4 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | oldCity != 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | oldCity = 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | C16nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C13nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte <= 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco <= 12.083 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 540.72 : 9 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 540.72 : 3 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco !<= 12.083 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nop > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13dist <= 110.164 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13dist !<= 110.164 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 21.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= -0.011 : 17 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= -0.011 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop > 21.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 453.282 : 18 (11.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 453.282 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 483.5 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 483.5 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop > 0.0 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist <= 672.507 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 0.0 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 528.692 : 23 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 528.692 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 594.5 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 2.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 2.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 326.956 : 24 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 326.956 : 5 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 594.5 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 0.0 : 1 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 543.659 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 13.9284 : 17 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 13.9284 : 22 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 543.659 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 485.167 : 17 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 485.167 : 1 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nop !<= 0.0 :
```

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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 437.423 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 437.423 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 537.375 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 537.375 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 490.522 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 490.522 : 22 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 21.0 : 24 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 474.308 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 474.308 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 232.573 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 232.573 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist !<= 672.507 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19dist <= 224.849 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 20.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 223.652 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 223.652 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 622.81 : 22 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 622.81 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 20.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 21.0 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 21.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19dist !<= 224.849 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 0.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 21.0 : 5 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 10.2956 : 5 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 10.2956 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 499.385 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 191.638 : 17 (11.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 191.638 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 13.6015 : 17 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 13.6015 : 11 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 499.385 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 451.367 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 451.367 : 9 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop <= 23.0 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nop !<= 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13dist > 114.726 : 24 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13dist !> 114.726 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.075 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.075 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcoc > 340.852 : 20 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcoc !> 340.852 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 1149.0 : 22 (9.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 1149.0 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte !<= 5.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 395.524 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 395.524 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C13nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc > 430.298 : 7 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc !> 430.298 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist > 876.097 : 11 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist !> 876.097 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 558.13 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 558.13 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | C16nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 732.446 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 732.446 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | oldCity != 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | oldCity = 20.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C9dist <= 858.597 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 354.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20dist <= 435.58 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.048 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop > 0.0 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= 0.036 : 16 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.036 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= 0.048 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 584.5 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 584.5 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20dist !<= 435.58 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist <= 810.987 : 21 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist !<= 810.987 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 354.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 528.087 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nte > 3.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist <= 853.663 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 422.143 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 422.143 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy > 521.115 : 9 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !> 521.115 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 23.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 6.0 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 249.0 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 249.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 23.0 : 21 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 151.212 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 151.212 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop <= 458.0 : 21 (11.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !<= 458.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 0.069 : 23 (13.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 0.069 : 21 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 14.0357 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 14.0357 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist !<= 853.663 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcoc <= 14.4222 : 14 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcoc !<= 14.4222 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 528.087 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc <= 14.7648 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc !<= 14.7648 :
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 575.538 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco <= 13.6015 : 13 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dco !<= 13.6015 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 575.538 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist <= 677.956 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5dist !<= 677.956 : 23 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C15nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 698.038 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 698.038 : 12 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 50.5371 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist <= 502.594 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist !<= 502.594 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 50.5371 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 510.25 : 24 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 510.25 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C9dist !<= 858.597 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc <= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop > 21.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct <= 232.034 : 19 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct !<= 232.034 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcuc !<= 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.4222 : 3 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.4222 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 475.154 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 475.154 : 23 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 19.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte > 3.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C21dist <= 463.039 : 2 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C21dist !<= 463.039 : 13 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 606.667 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 606.667 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist <= 321.204 : 24 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C23dist !<= 321.204 : 19 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | oldCity != 20.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity = 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C23nop > 24.0 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | C23nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8dist <= 386.374 : 12 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8dist !<= 386.374 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nte > 0.0 : 17 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C17nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4nop > 0.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20dist > 565.836 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20dist !> 565.836 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= -0.011 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx > 0.044 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !> 0.044 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 445.042 : 20 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 445.042 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= -0.011 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist <= 606.36 : 20 (17.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C24dist !<= 606.36 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity != 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= 0.192 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 520.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop > 0.0 : 16 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nte > 0.0 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19dist <= 239.708 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= 0.021 : 21 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= 0.021 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19dist !<= 239.708 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy > 0.048 : 18 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !> 0.048 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= -0.035 : 17 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= -0.035 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 14.1421 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 14.1421 : 20 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 520.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop > 0.0 : 15 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C8nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C9nop > 24.0 : 20 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C9nop !> 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte > 3.0 : 2 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2dist <= 14.1421 : 3 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C2dist !<= 14.1421 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte > 6.0 : 1 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte !> 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy <= -0.146 : 5 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vy !<= -0.146 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nte <= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 365.059 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 365.059 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 22.6274 : 5 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 22.6274 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 507.0 : 19 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 507.0 : 20 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 3.0 : 20 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity > 21.0 : 20 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !> 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 8.06226 : 20 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 8.06226 : 1 (34.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 509.538 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 509.538 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nte !<= 6.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 572.375 : 18 (2.0)
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 572.375 : 20 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C3nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx <= 1106.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | plx !<= 1106.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= 0.192 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 18.0 : 21 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 18.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 614.783 : 13 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 614.783 : 16 (2.0)
| | | | C19N != 0.0 :
| | | | | C23nte > 3.0 : 23 (3.0)
| | | | | C23nte !> 3.0 :
| | | | | | C13nte > 0.0 : 3 (2.0)
| | | | | | C13nte !> 0.0 :
| | | | | | | C20nte <= 0.0 :
| | | | | | | | C10nop > 0.0 : 12 (2.0)
| | | | | | | | C10nop !> 0.0 :
| | | | | | | | | C14nop <= 0.0 :
| | | | | | | | | | C11nop > 24.0 : 5 (2.0)
| | | | | | | | | | C11nop !> 24.0 :
| | | | | | | | | | | C5nop <= 23.0 :
| | | | | | | | | | | | C22nop > 24.0 : 11 (2.0)
| | | | | | | | | | | | C22nop !> 24.0 :
| | | | | | | | | | | | | C15nte <= 0.0 :
| | | | | | | | | | | | | | C5nop > 21.0 : 3 (2.0)
| | | | | | | | | | | | | | C5nop !> 21.0 :
| | | | | | | | | | | | | | | C4h3 > 0.0 : 5 (2.0)
| | | | | | | | | | | | | | | C4h3 !> 0.0 :
| | | | | | | | | | | | | | | | oldCity > 24.0 : 17 (3.0)
| | | | | | | | | | | | | | | | oldCity !> 24.0 :
| | | | | | | | | | | | | | | | | C18nop > 909.555 : 17 (6.0)
| | | | | | | | | | | | | | | | | C18nop !> 909.555 :
| | | | | | | | | | | | | | | | | | C11nte <= 0.0 :
| | | | | | | | | | | | | | | | | | | C10nop <= 14.0357 : 24 (8.0)
| | | | | | | | | | | | | | | | | | | C10nop !<= 14.0357 :
| | | | | | | | | | | | | | | | | | | | C14nop <= 6.0 :
| | | | | | | | | | | | | | | | | | | | | C16nop <= -0.05 : 19 (13.0)
| | | | | | | | | | | | | | | | | | | | | C16nop !<= -0.05 :
| | | | | | | | | | | | | | | | | | | | | | C10nop <= 14.3178 : 19 (5.0)
| | | | | | | | | | | | | | | | | | | | | | C10nop !<= 14.3178 : 24 (37.0)
| | | | | | | | | | | | | | | | | | | | C14nop !<= 6.0 :
| | | | | | | | | | | | | | | | | | | | | C10nop <= 418.862 : 24 (2.0)
| | | | | | | | | | | | | | | | | | | | | C10nop !<= 418.862 : 19 (3.0)
| | | | | | | | | | | | | | | | | | C11nte !<= 0.0 :
| | | | | | | | | | | | | | | | | | | mopx > 5.0 : 11 (2.0)
| | | | | | | | | | | | | | | | | | | mopx !> 5.0 :
| | | | | | | | | | | | | | | | | | | | C13nop <= 595.957 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | C13nop !<= 595.957 : 24 (4.0)
| | | | | | | | | | | | | C15nte !<= 0.0 :
| | | | | | | | | | | | | | mtpy <= 559.333 : 15 (2.0)
| | | | | | | | | | | | | | mtpy !<= 559.333 : 19 (2.0)
| | | | | | | | | | | C5nop !<= 23.0 :
| | | | | | | | | | | | C5nop <= 24.0 : 5 (2.0)
| | | | | | | | | | | | C5nop !<= 24.0 :
| | | | | | | | | | | | | dco <= 272.391 : 1 (2.0)
| | | | | | | | | | | | | dco !<= 272.391 : 24 (2.0)
| | | | | | | | | C14nop !<= 0.0 :
| | | | | | | | | | mopx <= 545.308 : 18 (2.0)
| | | | | | | | | | mopx !<= 545.308 : 11 (2.0)
| | | | | | | C20nte !<= 0.0 :
| | | | | | | | ply <= 355.0 :
| | | | | | | | | mtpy <= 581.6 : 24 (2.0)
| | | | | | | | | mtpy !<= 581.6 : 7 (2.0)
| | | | | | | | ply !<= 355.0 :
| | | | | | | | | C24dist <= 575.243 : 20 (3.0)
| | | | | | | | | C24dist !<= 575.243 : 18 (2.0)
| | | C4h3 !<= 0.00102719 :
| | | | oldCity = 2.0 : 3 (0.0)
| | | | oldCity != 2.0 :
| | | | | oldCity = 3.0 : 3 (0.0)
| | | | | oldCity != 3.0 :
| | | | | | oldCity = 5.0 : 3 (0.0)
| | | | | | oldCity != 5.0 :
| | | | | | | oldCity = 6.0 : 3 (0.0)
| | | | | | | oldCity != 6.0 :
| | | | | | | | oldCity = 7.0 : 3 (0.0)
| | | | | | | | oldCity != 7.0 :
| | | | | | | | | oldCity = 8.0 : 3 (0.0)
| | | | | | | | | oldCity != 8.0 :
| | | | | | | | | | oldCity = 9.0 : 3 (0.0)
| | | | | | | | | | oldCity != 9.0 :
| | | | | | | | | | | oldCity = 10.0 : 3 (0.0)
| | | | | | | | | | | oldCity != 10.0 :
| | | | | | | | | | | | oldCity = 11.0 : 3 (0.0)
| | | | | | | | | | | | oldCity != 11.0 :
| | | | | | | | | | | | | oldCity = 12.0 : 3 (0.0)
| | | | | | | | | | | | | oldCity != 12.0 :
| | | | | | | | | | | | | | oldCity = 13.0 : 3 (0.0)
| | | | | | | | | | | | | | oldCity != 13.0 :
| | | | | | | | | | | | | | | oldCity = 14.0 : 3 (0.0)
| | | | | | | | | | | | | | | oldCity != 14.0 :
| | | | | | | | | | | | | | | | oldCity = 15.0 : 3 (0.0)
| | | | | | | | | | | | | | | | oldCity != 15.0 :
| | | | | | | | | | | | | | | | | oldCity = 16.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | oldCity != 16.0 :
| | | | | | | | | | | | | | | | | | oldCity = 17.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | oldCity != 17.0 :
| | | | | | | | | | | | | | | | | | | oldCity = 18.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | oldCity != 18.0 :
| | | | | | | | | | | | | | | | | | | | oldCity = 19.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | | oldCity != 19.0 :
| | | | | | | | | | | | | | | | | | | | | oldCity = 20.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | | | oldCity != 20.0 :
| | | | | | | | | | | | | | | | | | | | | | oldCity = 21.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | | | | oldCity != 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | oldCity = 22.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | | | | | oldCity != 22.0 :
| | | | | | | | | | | | | | | | | | | | | | | | oldCity = 23.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | | | | | | oldCity != 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | oldCity = 24.0 : 3 (0.0)
| | | | | | | | | | | | | | | | | | | | | | | | | oldCity != 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | oldCity = 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop > 0.0 : 17 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 279.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 20.0 : 5 (4.0)
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| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 20.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 427.167 : 18 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 427.167 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 279.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto <= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc > 14.2127 : 2 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !> 14.2127 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 11.4018 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 11.4018 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx <= 690.0 : 19 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpx !<= 690.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | cto !<= 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte > 3.0 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C19nte !> 3.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcoc <= 397.554 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop <= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct <= 10.2956 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 683.762 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 683.762 : 5 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dct !<= 10.2956 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx > 609.231 : 3 (22.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !> 609.231 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 77.9295 : 2 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 77.9295 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity <= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop <= 382.167 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte > 23.0 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C11nte !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop <= 558.323 : 2 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C10nop !<= 558.323 : 3 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C18nop !<= 382.167 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop > 513.696 : 2 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C14nop !> 513.696 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 49.6488 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 > 134.213 : 23 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !> 134.213 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 6.0 : 2 (7.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 6.0 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 49.6488 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop <= 114.543 : 3 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C16nop !<= 114.543 : 23 (8.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | oldCity !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop <= 520.827 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 520.827 : 3 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= -0.048 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= -0.048 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop <= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 14.3178 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 14.3178 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C1nop !<= 24.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 <= 143.837 : 5 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C4h3 !<= 143.837 : 3 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C22nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx <= -0.048 : 5 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | vx !<= -0.048 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | dcoc !<= 397.554 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy <= 495.75 : 18 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mtpy !<= 495.75 : 23 (5.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 401.0 : 23 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 401.0 : 2 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | C20nop !<= 21.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx <= 533.5 : 23 (6.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !<= 533.5 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx > 576.962 : 2 (4.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopx !> 576.962 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy <= 433.808 : 9 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | mopy !<= 433.808 : 8 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | oldCity != 1.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte > 0.0 : 10 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | C16nte !> 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc <= 4.47214 : 14 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | dcc !<= 4.47214 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo <= 13.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | coo !<= 13.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nop <= 0.0 : 3 (84.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | C5nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply <= 765.0 : 2 (3.0)
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ply !<= 765.0 : 3 (3.0)
| | C5N != 0.0 :
| | | C19nop <= 23.0 :
| | | | C20nop <= 0.0 :
| | | | | coo <= 22.0 :
| | | | | | C19dist <= 569.088 :
| | | | | | | C4nte > 5.0 : 19 (2.0)
| | | | | | | C4nte !> 5.0 :
| | | | | | | | C4nte > 0.0 : 5 (2.0)
| | | | | | | | C4nte !> 0.0 :
| | | | | | | | | C17nte <= 0.0 :
| | | | | | | | | | C24nte <= 0.0 :
| | | | | | | | | | | vy <= 0.029 :
| | | | | | | | | | | | coo > 20.0 : 22 (13.0)
| | | | | | | | | | | | coo !> 20.0 :
| | | | | | | | | | | | | mtpy > 701.8 : 5 (4.0)
| | | | | | | | | | | | | mtpy !> 701.8 :
| | | | | | | | | | | | | | mopx > 655.0 : 5 (4.0)
| | | | | | | | | | | | | | mopx !> 655.0 :
| | | | | | | | | | | | | | | C4h3 <= 0.0 : 22 (23.0)
| | | | | | | | | | | | | | | C4h3 !<= 0.0 :
| | | | | | | | | | | | | | | | oldCity <= -0.0070 : 5 (4.0)
| | | | | | | | | | | | | | | | oldCity !<= -0.0070 : 22 (4.0)
| | | | | | | | | | | vy !<= 0.029 :
| | | | | | | | | | | | vy > 0.099 : 22 (4.0)
| | | | | | | | | | | | vy !> 0.099 :
| | | | | | | | | | | | | ply <= 456.0 : 21 (4.0)
| | | | | | | | | | | | | ply !<= 456.0 : 5 (6.0)
| | | | | | | | | | C24nte !<= 0.0 :
| | | | | | | | | | | ply <= 859.0 : 5 (2.0)
| | | | | | | | | | | ply !<= 859.0 : 22 (5.0)
| | | | | | | | | C17nte !<= 0.0 :
| | | | | | | | | | dct <= 221.576 : 17 (3.0)
| | | | | | | | | | dct !<= 221.576 : 22 (7.0)
```

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| | | | | | C19dist !<= 569.088 :
| | | | | | | mtpy <= 567.2 : 4 (3.0)
| | | | | | | mtpy !<= 567.2 : 22 (3.0)
| | | | | coo !<= 22.0 :
| | | | | | C17nte > 3.0 : 16 (2.0)
| | | | | | C17nte !> 3.0 :
| | | | | | | mopx <= 641.308 : 22 (7.0)
| | | | | | | mopx !<= 641.308 : 7 (3.0)
| | | | C20nop !<= 0.0 :
| | | | | coo <= 18.0 : 19 (3.0)
| | | | | coo !<= 18.0 : 14 (3.0)
| | | C19nop !<= 23.0 :
| | | | coo <= 20.0 : 1 (3.0)
| | | | coo !<= 20.0 : 7 (2.0)
| C4N != 0.0 :
| | C11nop <= 0.0 :
| | | C16nop <= 0.0 :
| | | | C24nop <= 24.0 :
| | | | | cto <= 1.0 :
| | | | | | C5dist <= 673.933 :
| | | | | | | C20nop > 0.0 : 4 (3.0)
| | | | | | | C20nop !> 0.0 :
| | | | | | | | C2dist <= 128.6 : 2 (3.0)
| | | | | | | | C2dist !<= 128.6 : 5 (4.0)
| | | | | | C5dist !<= 673.933 :
| | | | | | | mopy <= 515.538 : 17 (2.0)
| | | | | | | mopy !<= 515.538 : 1 (2.0)
| | | | | cto !<= 1.0 :
| | | | | | C13nte > 0.0 : 4 (2.0)
| | | | | | C13nte !> 0.0 :
| | | | | | | C14nte <= 3.0 :
| | | | | | | | C19nte <= 0.0 :
| | | | | | | | | C8dist <= 391.261 :
| | | | | | | | | | mtpy <= 495.75 : 5 (2.0)
| | | | | | | | | | mtpy !<= 495.75 : 15 (2.0)
| | | | | | | | | C8dist !<= 391.261 :
| | | | | | | | | | C3nop <= 23.0 :
| | | | | | | | | | | C1nop <= 24.0 :
| | | | | | | | | | | | C24nte <= 0.0 :
| | | | | | | | | | | | | dcoc <= 167.61 :
| | | | | | | | | | | | | | C20nte <= 3.0 :
| | | | | | | | | | | | | | | C4h3 > 0.0 : 1 (2.0)
| | | | | | | | | | | | | | | C4h3 !> 0.0 :
| | | | | | | | | | | | | | | | oldCity > 23.0 : 1 (4.0)
| | | | | | | | | | | | | | | | oldCity !> 23.0 :
| | | | | | | | | | | | | | | | | C18nop > 3.0 : 4 (2.0)
| | | | | | | | | | | | | | | | | C18nop !> 3.0 :
| | | | | | | | | | | | | | | | | | C11nte <= 3.0 :
| | | | | | | | | | | | | | | | | | | C10nop <= 0.0 :
| | | | | | | | | | | | | | | | | | | | C14nop <= 113.071 :
| | | | | | | | | | | | | | | | | | | | | C16nop > 23.0 : 4 (6.0)
| | | | | | | | | | | | | | | | | | | | | C16nop !> 23.0 :
| | | | | | | | | | | | | | | | | | | | | | mopx <= 16.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | | | mopx !<= 16.0 :
| | | | | | | | | | | | | | | | | | | | | | | C13nop <= 14.7648 : 4 (27.0)
| | | | | | | | | | | | | | | | | | | | | | | C13nop !<= 14.7648 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | C14nop !<= 113.071 :
| | | | | | | | | | | | | | | | | | | | | vy <= -0.197 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | | | vy !<= -0.197 : 1 (9.0)
| | | | | | | | | | | | | | | | | | | C10nop !<= 0.0 :
| | | | | | | | | | | | | | | | | | | | cto <= 501.0 : 1 (2.0)
| | | | | | | | | | | | | | | | | | | | cto !<= 501.0 : 4 (2.0)
| | | | | | | | | | | | | | | | | | C11nte !<= 3.0 :
| | | | | | | | | | | | | | | | | | | C17dist <= 446.75 : 4 (2.0)
| | | | | | | | | | | | | | | | | | | C17dist !<= 446.75 : 5 (2.0)
| | | | | | | | | | | | | | C20nte !<= 3.0 :
| | | | | | | | | | | | | | | C4h3 <= 540.333 : 23 (2.0)
| | | | | | | | | | | | | | | C4h3 !<= 540.333 :
| | | | | | | | | | | | | | | | oldCity <= 938.667 : 4 (4.0)
| | | | | | | | | | | | | | | | oldCity !<= 938.667 : 2 (2.0)
| | | | | | | | | | | | | dcoc !<= 167.61 :
| | | | | | | | | | | | | | C5nop > 24.0 : 4 (2.0)
| | | | | | | | | | | | | | C5nop !> 24.0 :
| | | | | | | | | | | | | | | dco <= 6.08276 :
| | | | | | | | | | | | | | | | C4h3 <= 490.609 : 2 (2.0)
| | | | | | | | | | | | | | | | C4h3 !<= 490.609 : 1 (2.0)
| | | | | | | | | | | | | | | dco !<= 6.08276 :
| | | | | | | | | | | | | | | | C4h3 <= 485.923 : 1 (14.0)
| | | | | | | | | | | | | | | | C4h3 !<= 485.923 : 5 (9.0)
| | | | | | | | | | | | C24nte !<= 0.0 :
| | | | | | | | | | | | | mopx <= 579.885 : 2 (2.0)
| | | | | | | | | | | | | mopx !<= 579.885 : 4 (2.0)
| | | | | | | | | | | C1nop !<= 24.0 :
| | | | | | | | | | | | dcuc > 14.2127 : 1 (6.0)
| | | | | | | | | | | | dcuc !> 14.2127 :
| | | | | | | | | | | | | coo <= 19.0 : 4 (3.0)
| | | | | | | | | | | | | coo !<= 19.0 : 1 (2.0)
| | | | | | | | | | C3nop !<= 23.0 :
| | | | | | | | | | | C3nop <= 24.0 : 23 (2.0)
| | | | | | | | | | | C3nop !<= 24.0 :
| | | | | | | | | | | | dco <= 11.0 : 5 (2.0)
| | | | | | | | | | | | dco !<= 11.0 :
| | | | | | | | | | | | | vx <= 0.087 : 1 (4.0)
| | | | | | | | | | | | | vx !<= 0.087 : 2 (2.0)
| | | | | | | | C19nte !<= 0.0 :
| | | | | | | | | vx <= -0.051 : 24 (3.0)
| | | | | | | | | vx !<= -0.051 :
| | | | | | | | | | ply > 568.0 : 1 (3.0)
| | | | | | | | | | ply !> 568.0 :
| | | | | | | | | | | mopy <= 465.208 : 2 (2.0)
| | | | | | | | | | | mopy !<= 465.208 : 5 (2.0)
| | | | | | | C14nte !<= 3.0 :
| | | | | | | | mtpy <= 409.667 : 1 (2.0)
| | | | | | | | mtpy !<= 409.667 : 17 (2.0)
| | | | C24nop !<= 24.0 :
| | | | | coo <= 19.0 : 5 (3.0)
| | | | | coo !<= 19.0 : 22 (2.0)
| | | C16nop !<= 0.0 :
| | | | coo > 22.0 : 4 (2.0)
| | | | coo !> 22.0 :
| | | | | mopx <= 609.833 : 14 (2.0)
| | | | | mopx !<= 609.833 : 15 (2.0)
| | C11nop !<= 0.0 :
| | | mopx <= 611.571 : 9 (2.0)
| | | mopx !<= 611.571 : 17 (2.0)
```

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