SDL, a graphical language useful to describe social simulation models

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Abstract. Simulation, and specifically social simulation, is a discipline that usually involves professionals with different formation. This implies that the modeling languages, tools and infrastructures used to model can be diverse. This paper has the main objective of show a graphical language, widely used in the engineering field, which allows a complete graphical and no ambiguous description of a simulation model. The language, named SDL (Specification and Description Language) is defined by the ITU-T (on the Z.100 recommendation). Since SDL is a standard different tools understand the language, allowing a simulation or an automatic code generation from the SDL description of the model. This paper has two main sections, first we describe the rudiments of the language, and second we shown an example of a multi-agent system description using SDL language.

Keywords: Social simulation, MAS, SDL language, formalization.

1. Introduction

The construction of a simulation model sometimes lacks in the formalization process, needed to understand the structure and the behavior of the model before any specific implementation. Different advantages exist related with the conceptual model use. Among them we remark five. (i) Textual specification is less precise than formalization. (ii) Formalization represents in a detailed way, the existing dynamic relations between the different key elements of the process. (iii) This knowledge of the model behavior helps in the implementation process, keeping the independency between the model and the tool selected to carry out the implementation. (iv) Formalism improves the communication channels between the personnel related with the construction of the simulation model. (v) Some authors, like Brade [1] suggest that the a formalization of a simulation model can be considered a product by itself, empathizing the idea that the formalization process helps in the complete understanding of the relations derived from the system observation.
This problem, which has been discussed largely in the simulation area, now is discussed in the more specific area of the social simulation [2], with some semi formal approximations like the *Agent Modelling Language* of Trencansky and Cervenka [3] among others.

Because the purpose of a model is not only to predict the behavior of the system, but also explain and understand its behavior or perceive new questions [4], the formalization process can be an inestimable tool in order to obtain these benefits.

This paper proposes the use of a well known language, SDL, to represent a simulation model, and specifically a social simulation model.

In the simulation area other formalisms exists, like Petri Nets [5], [6], [7] or DEVS [8], [9] among others. More specifically in the area of multi-agent simulation some efforts have been done to develop a formalism [10],[11], [3], [12].

The proposed language, SDL [13],[14],[15],[16], (acronym of Specification and Description Language), is a well known standard widely use in the engineering and telecommunications area. Since SDL allows the definition of distributed systems, the model defined with SDL is ready to be executed over different computers without the need of modify its structure. Of course the platform selected to perform the simulation must allow this feature.

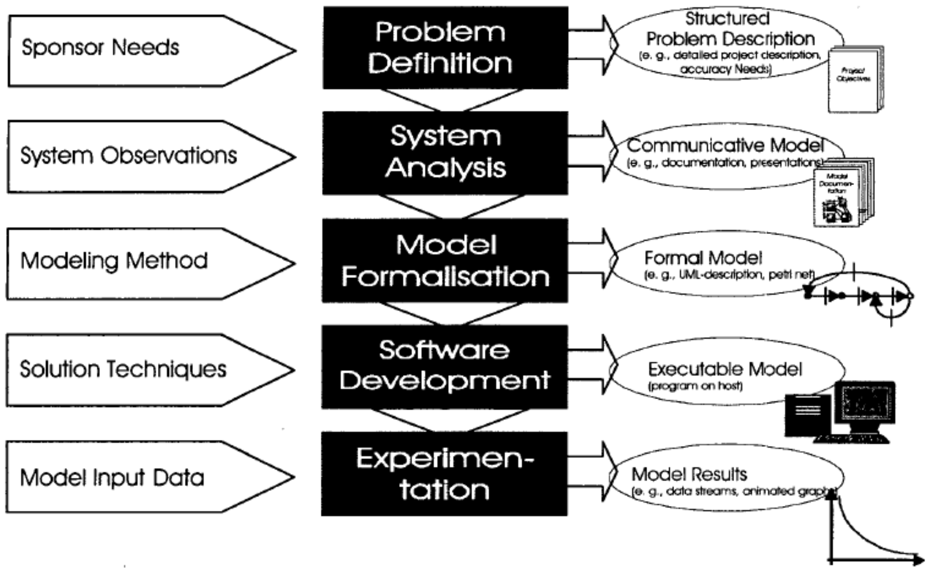


Fig. 1. The formalization of a simulation model can be considered a product by itself, since allows a better understanding of the system behavior [1].

Why SDL? SDL is a powerful and modern language used in different areas, not only in the simulation area. It was been standardized by the International Telecommunications Union (ITU) on the Z.100 recommendation, and can be used easily in combination with other standard languages, like UML.

Anyway is not our intention to say what is the best language or formalism to be used to represent social models, we think that a language is good if it is useful to simplify, document and understand better the modeling process. As Vangheluwe [17] say, the specification language must be comprehensible and unambiguous, helping personnel without technical formation it's quickly understanding. Nevertheless, the language must be powerful to allow the model complexity representation.

With this objective we present a methodology easy to use but completely formal, which allows acquiring a deeper understanding of the model behavior and helps in its implementation process, keeping the independency between the model and the tool selected to implement the model.

In the next section we describe the more important elements of the SDL language.

2. SDL language

SDL is an object oriented formal language defined by the International Telecommunications Union–Telecommunications Standardization Sector (ITU–T) (the Comité Consultatif International Telegraphique et Telephonique [CCITT]) on the Z. 100 recommendation. The language was designed for the specification of event oriented, real time and interactive complex systems. These systems can involucres different concurrent activities that use signals to perform the communication [14], [16], [15]. SDL is based in the definition of four levels (one kind of diagram for each level) to describe the structure and the behavior of the models: system, blocks, processes and procedures. In SDL *blocks* and *processes* are named *agents*, and the outermost block, the *system* block is an agent itself. In the next figure this hierarchy is shown.

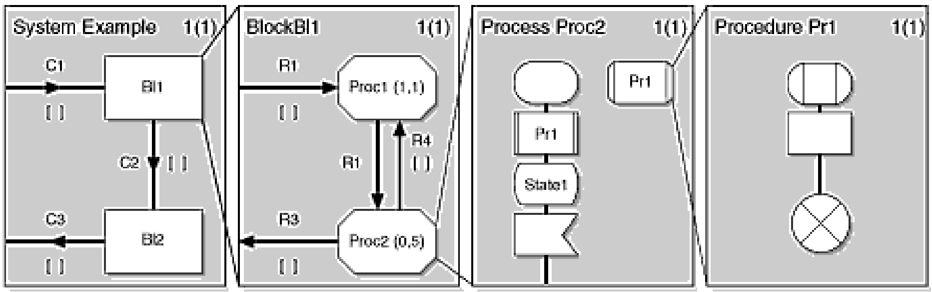
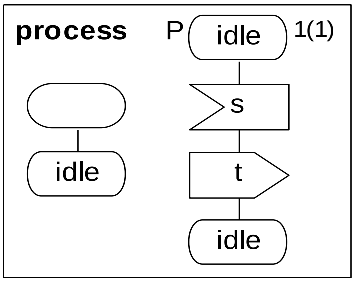


Fig. 2. An structural vision of an SDL model. 4 main different levels exist (source: http://www.iec.org/online/tutorials/sdl/topic04.html)

The different concepts that the SDL language covers are:

1. The structure: through the system, the blocks and the processes and its related hierarchy.
2. The communication: through the signals, the communication paths (the channels), and the parameters that can be carried by the signals.
3. The behavior: defined with the different process.
4. The data: based in ADT (Abstract Data Types).
5. The inheritance: useful to describe relations between objects and its specializations.

A textual SDL exists, this paper is focused in the graphical representation of the language (named SDL/GR), however all the discussion is valid for its textual representation too (named SDL/PR), since both are equivalents [15].




```
process P;
  start;
  nextstate idle;
  state idle;
    input s;
      output t;
      nextstate idle;
  endstate idle;
endprocess P;
```

Fig. 3. The same model represented by GS-SDL and PR-SDL.

To know more about the SDL language the recommendation Z.100 [15] can be consulted, or the web site www.sdl-forum.org. The next sub sections have a brief description of each one of the different levels of SDL.

2.1. System diagram

This is the outermost agent. As we said is unique and represented in the first level of model decomposition. Here you can find the basic elements that constitute the model and the communication channels between them and the exterior. The next figure shows an example of a system diagram containing three blocks [18].

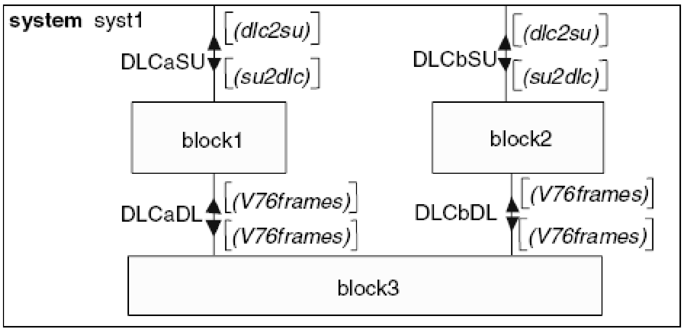


Fig. 4. System diagram. In this example the system is formed by three blocks, named *block1*, *block2* and *block3*. The behavior of these blocks is not represented here; we must wait to see this behavior in the next diagrams. As you can see *DLCaSU* channel (and *DLCbSU* channel for the *block2*) are receiving and sending signals from and to the exterior of the model (the signals are *dlc2su* and *su2dlc* for both blocks).

Each rectangle represents an *agent* (in this case a block). Usually these blocks represent elements of the system that can be decomposed in other SDL elements (blocks or process). The lines between the blocs are communication channels; in this case (as we can see in the next sub section) the channels are bidirectional and delaying channels. Each one of the channels joins the objects through the ports, and may have a name (in this case all the channels have a name). The name of the channels and the ports are important to define the final destination of the different signals, for instance if the path that can follow a specific signal is not unique.

For each one of the different blocks (or process) represented in this first diagram a new diagram (block or process diagram) is build, defining the division of the model in smaller components (the model structure).

2.1. SDL communication channels

The SDL communication channels that can be found in the SDL diagram are delaying and non delaying channels.

The non delaying channels allow the automatic transmission of the information (signals). There is no delay in the signal transmission. The representation of these channels is shown in Fig. 5 and Fig. 6.

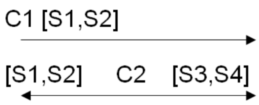


Fig. 5. SDL representation for non delaying channels. The name of the channel is C1 and C2, the signals that can carry the channels are S1, S2, S3 and S4.

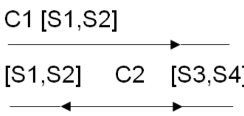


Fig. 6. SDL representation of delaying channels.

In a simulation model the time related to each signal belongs to the model behavior, hence this time must be represented in the specification of the model. A problem exists regarding this with SDL, since there is no way to define the duration of a delay in a delaying channel [15]. In the next section, reviewing the adaptation of SDL for a social simulation model we analyze this problem and show the proposed solution.

2.2. SDL block diagrams

For each one of the different blocks defined in the system diagram is needed to define a block diagram. In the next figure is shown the definition of two of the blocks of the Fig. 6.

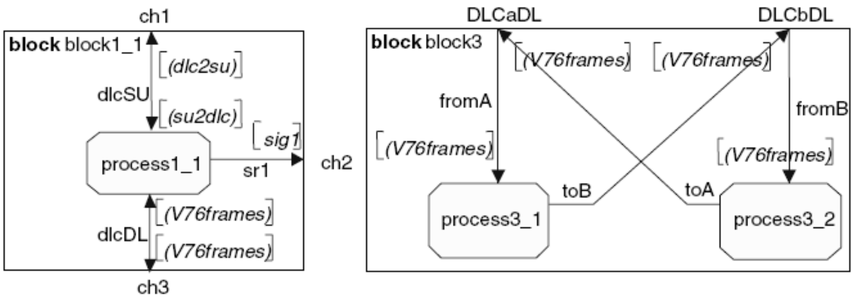


Fig. 7. SDL blocks diagram [18].

In this case the blocks have one and two process, and no more blocks (*process1_1* in the case of *block1_1* and *process3_1* and *process3_2* in the case of *block3*). The hierarchical decomposition can be all the extensive as needed to represent correctly the structure of the system. In this case the communication mechanism is based on non delaying channels.

2.3. SDL process diagram

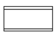
Similar as we detail the structure and the decomposition of the blocks agents, we must detail the structure and the decomposition of the process agents (in new process or in a process diagram detailing its behavior).

Process diagram defines the behavior of the agents when a specific signal is received. Process diagram uses different graphical elements to represent its behavior. In the next lines we describe some of the more important.

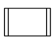
Start.  This element allows defining the initial state of a process.

State.  The state element contains the name of a state. All diagrams start and end with **state** elements. One process can start with the *start* element.

Input.  Input elements describe the kind of events that can be received by the process. All branches of a specific *state* start with an *Input* element, since an object changes its state only after a new event is received.

Create.  This element allows the creation of an agent.

Task.  This element allows the interpretation of informal texts or programming code.

Procedure call.  These elements perform a procedure call. A procedure can be defined in the last level of the SDL language.

Output.  Output elements describe the kind of signals to be sent, the parameters that the signal carries and the destination. If ambiguity about the signal destination exists, communication can be directed specifying destinations using a processing identity (PId) value, an agent name or using the sentence *via path*. If there is more than one path, and no specific output is defined, an arbitrary one is used. The destination value can be stored in a variable for later use [14]. Four PId expressions can be used:

- **self** an agent's own identity;
- **parent** the agent that created the agent (Null for initial agents).
- **offspring** the most recent agent created by the agent.
- **sender** the agent that sent the last signal input (null before any signal received).

Decision. ◇ These elements describe bifurcations. Their behavior depends on how the related question is answered.

In the next figure a process diagram is shown.

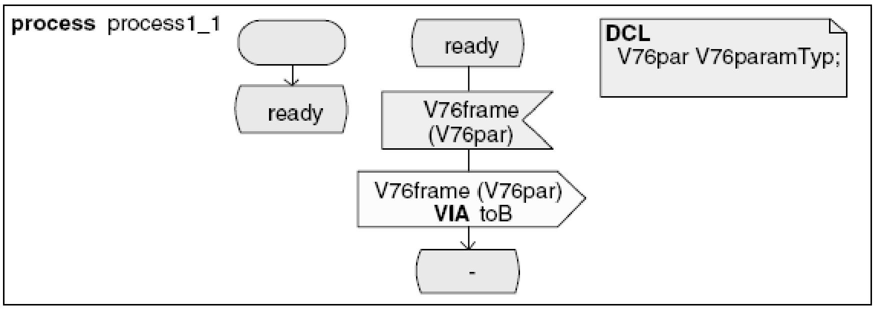


Fig. 8. SDL process diagram for the *ready* state of the process *process1_1* [18].

2.4. SDL procedures diagram

The last level of the SDL language allows the description of the procedures that can be used in the process diagrams through the procedure calls ▭. These diagrams are very similar to the process diagrams, with the exception that they don't need the states definition. The next figure shows an example of a procedure.

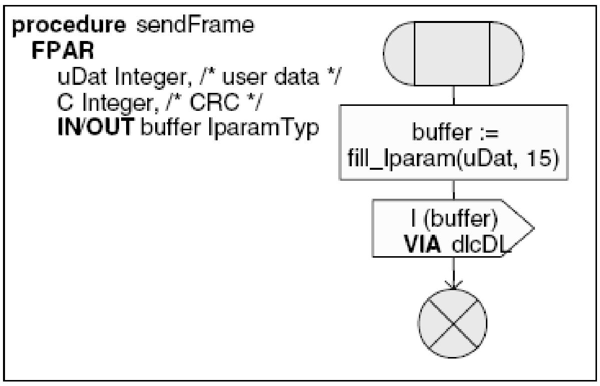


Fig. 9. Description of the procedure *sendFrame* [18].

3. Using SDL for the representation of social models

To use SDL to represent social models first is needed to understand the particularities that these models can have.

A system is a set of entities, (machines, people, etc), interacting with a common objective [19]. This objective can be explicit or implicit; hence, all system offers resistance to the change. In practical, the definition of what is and what is not a system depends on the object of study. To simplify the study of the system through the model the concept of *model state* is defined from a set of model variables. This set of variables allows the description of how the system is in a specific time instant. Analyzing the evolution of the variables that define the state of the model we can establish a first classification of the simulation models, continuous simulation models and discrete simulation models.

Models can also be classified depending on the evolution of the rules that defines its behavior. The models that modify its behavior during the execution of the simulation are evolutionary models; the models that never modify its rules are the interactive models [20]. In interactive models the results are obtained from the interaction of the different model elements[1].

Table 1. Systems classification depending on time and evolving rules usage [20].

	Static systems	Dynamic systems
Interactive	Static interactions. The only changes are in the composition. For instance, systems that are not modified over time. Through Monte Carlo simulations, an approximate value can be obtained.[2]	System interaction. Changes in the interactions between the different model components. For instance, an industrial plant.
Evolutionary	Evolutionary selection. Random acquisition of variations that change the composition of types.	Evolutionary system feedback that influences the supply of variation and the speed of evolution. Changes in type depend on the history of the system. For instance, the evolution of a society or wildfire with the interaction of an extinction model.

[1] "The interest of the interactionist perspective is usually focusing on the emergence of aggregated patterns of behavior and its effect in larger systems." [20].

[2] One example of an interactive static system is pi-calculus using Monte Carlo simulations. In this example, there is no time but the composition is modified during the simulation because the procedure produces an increasing number of points (with more points, the value is closer to the value of pi).

Models can also be classified depending on time variable. If the model is static (the time variable is not modified, or is not taken in consideration) or is dynamic (time is one of the variables that must be analyzed). Table 1 shows a classification of the models depending on the static/dynamic and interactive/evolutionist criteria. The classification of a system as interactive or evolutionary depends on the temporal scope of the problem being studied. For instance, if the lifetime of the simulation model is short in relation with the feedback derived from the entities behavior modifications (this feedback has no effects on the model execution), then an interactive model should suffice.

SDL has been used for years to represent interactive dynamic systems. In order to use it to represent social phenomenon SDL must be capable to represent an evolutionary system.

Evolutionary norms can be represented in different ways, but usually multi agent systems (MAS) allow the definition of models capable to implement some kind of evolution. Focusing the attention in the representation and the implementation of dynamic evolutionary models, different algorithms can be used, for instance [21] discuss the use of genetic algorithms, genetic programming and systems of classification to be used in social systems. The key in the evolutionary models is the capacity to learn. Different learning models exists [22], the evolutionary learning, learning along the live and cultural learning. Usually these learning methods can be implemented in two levels, in the individual level these methods can be represented with an approximation founded in the behavior based learning. In the population level can be represented using genetic algorithms [23].

Intelligent agents can implement procedures to allow knowledge acquisition, allowing a modification of its behavior. Since these procedures can belong to each agent, the specific learning methods of each agent are independent of the state of the whole agent colony. Also procedures managing a genetic pool can be defined, sharing information between all the agents of the colony. MAS are good candidates to represent an evolutionary and dynamic simulation model; hence the SDL language must be capable to represent intelligent agents. In a theoretical level, an intelligent agent can be represented like the next figure shows.

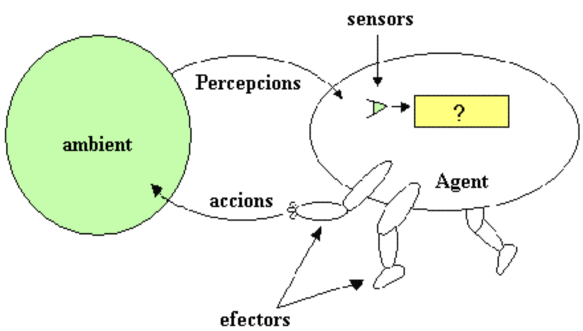


Fig. 10. Schematic representation of an intelligent agent.

An intelligent agent receives information using its sensors. According with the received information executes actions with the effectors or actuators. An intelligent agent adds evolutionary capacity to the whole model, since, as we said before, can implement algorithms to allow a learning capacity causing the modification of its behavior. Different intelligent agents exist depending on how the information is processed. Cortés et. alt. [24] proposes the next classification.

1. **Simple reflexive agents**: this kind of agents does not have states. Its actions are answers to the perceptions received. The connection between perceptions and actions are based in condition-action rules.

2. **Model based reflexive agents**: these agents have states. This allows the use of more information to give an answer. They are based in the idea that the sensors do not give all the information needed. The agent stores important information to complete the sensors information in order to perform the correct action.

3. **Goal based agents**: the agents have goals to be achieved. These goals allow the discrimination of the actions to be done.

4. **Utility based agents**: goals not guarantee that the agent conduct is useful. For that, the utility function is defined. This function allows choosing the actions that maximize this function.

The next figure shows a schema representing the simple reflexive agent.

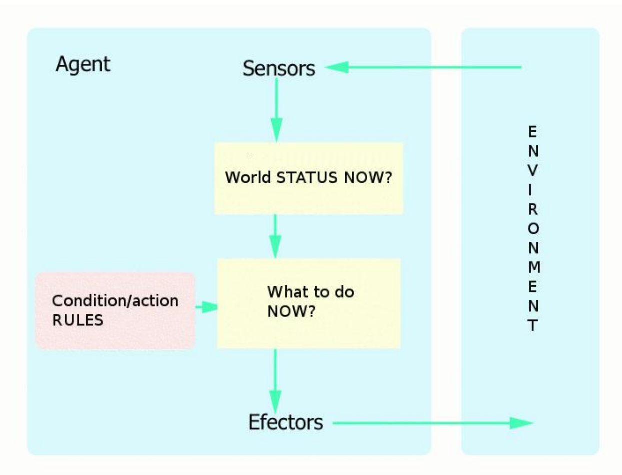


Fig. 11. Schematic representation of a simple reflexive agent.

The behavior of this agent can be summarized in the next steps:

1. The agent is waiting, until some information of the environment is received.
2. The agent process the environment information received and uses the condition/action rules to determine what to do.
3. The agent can initiate different actions to answer to the stimulus it receives. When all the actions have been done, the agent returns to the waiting state.

With these considerations in the next section, we propose a specification of a simple reflexive agent using the SDL language.

The representation of the other kind of agents can also be done using this language. Only to mention that we can also represent the agent goals or its utility functions, since SDL language allows the definition of procedures (in the last level of the language, as we can see in the section 2.4).

4. SDL simple reflexive intelligent agent representation

In a simulation model, the signals represent the events that rule the model evolution. Since the simulation engine is the structure that manages the delays of the model usually all the signals are send to this structure who decides what the next event to be processed is and what must be the element that process it. Since the delays are related to the signals the first problem is how we can represent this with SDL language. Delaying channels cannot be used, since the delay cannot be specified [15][3]. For that the channels used will be always non-delaying channels as we see in the section 2.1.

To solve the problem and allow the complete definition of the time related to the signals delays, all the signals must carry a parameter named *event*. This parameter (a structure represented in the Fig. 12) at least has three attributes (creation time, execution time and priority). Thanks to this parameter we can specify completely all the needed elements of the simulation model[4].

[3] Also the delays can be defined with timers, but this solution complicates the specification of the model.

[4] To implement this approximation different alternative exists, for instance the implementation of an event scheduling simulation engine.

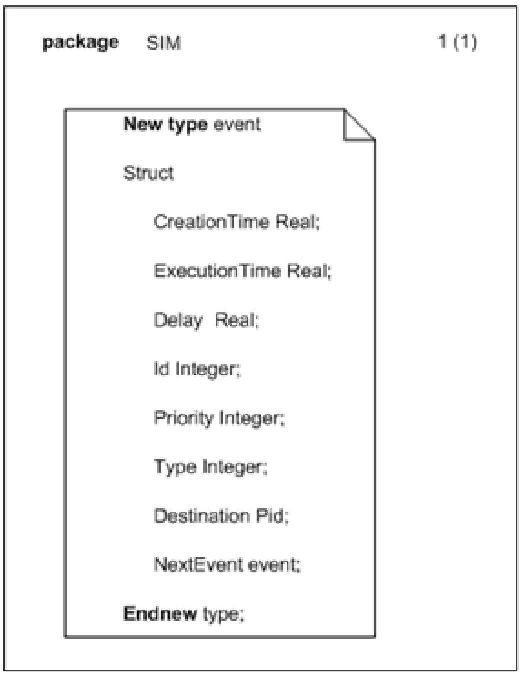


Fig. 12. SDL *SIM* package containing the structure *event*. Only *CreationTime*, *ExecutionTime* and *Priority* are always needed in order to define a simulation model. However other parameters can be contained in this structure as is shown in this figure.

With these considerations the formalization of a simple reflexive intelligent agent is shown in the next figures. The first level of the SDL diagram defines the blocks or process that composes the system. In this example only one typology of agents (in MAS sense) are used, enclosed in the *Population* block.

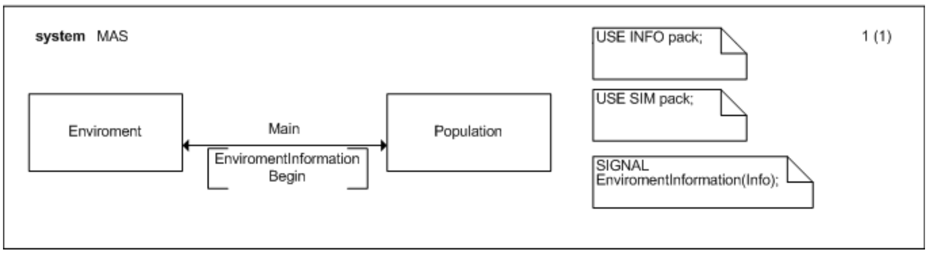


Fig. 13. System diagram of MAS model.

As is represented in the diagram, agents composing *Population* block receive only two kinds of events *EnviromentInformation* or *Begin*. *EnviromentInformation* signal have two parameters *event* (containing the information previously described) and *info*, a structure containing the information that can be perceived by the agents. In the next figure is shown an example of *INFO* package containing the structure *info* with the definition of the different environmental elements that can be perceived by the agent.

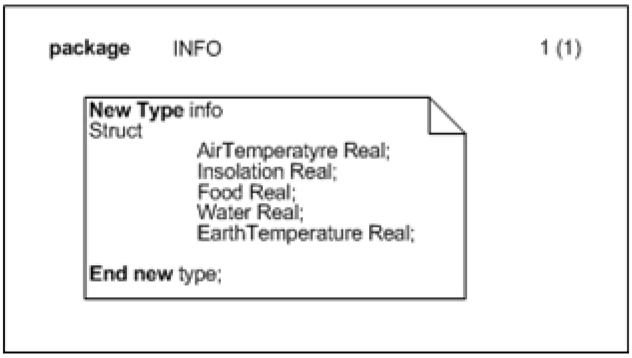


Fig. 14. Package “info”; this package is an example of environmental information that can be perceived by the agent (and representing what the agent can modify).

The great advantage of defining a package containing the *info* structure is again the modularity, since allows the definition of what can be perceiver and what can be modified in a single structure. This simplifies the validation and verification process.

As we can see, no behavior is defined yet in this first level of the model structure. To define the behavior of the model (hence the behavior of the agents), is needed to define the next levels of the SDL language.

Detailing the characterization of *Population* block, we define its hierarchical segmentation in the next diagram. Its composition is basically defined by a single process named *PSimpleRAgent*. The numbers (1,10) define the minimum number of agents (at the beginning of the model execution) and the maximum number of agents allowed in the model (usually created by a *create* operation).

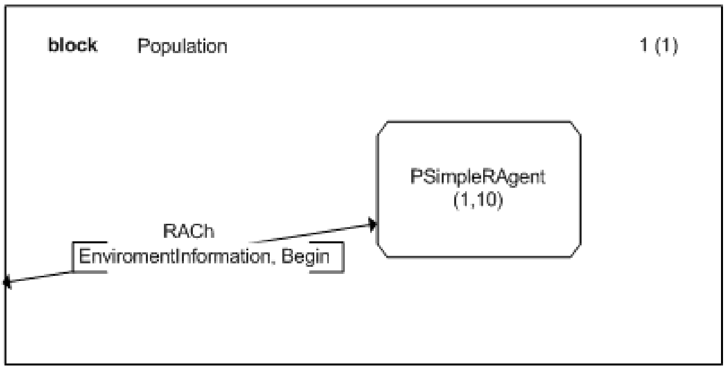


Fig. 15. The processes contained in the Population block are PSimpleRAgent process representing the intelligent agents.

At this point the structure of the *Population* block is fully defined, and we can start the definition of the model behavior through the *PSimpleRAgent* process diagram.

A simple reflexive agent reacts to the stimulus using its condition/action rules. However some ambiguities exists in the textual description we done in the previous section. As an example we don’t know what happens if an agent that is executing an action receives a new stimulus from the environment (can the agent execute both actions in parallel? Or the agent must wait to process the new stimulus until finish its action?. Or the agent must ignore the new stimulus?).

The next figures (Fig. 16, Fig. 17 and Fig. 18) details the SDL process diagram for a reflexive intelligent agent with the next assumptions about its behavior (assumptions that are represented in the diagrams).

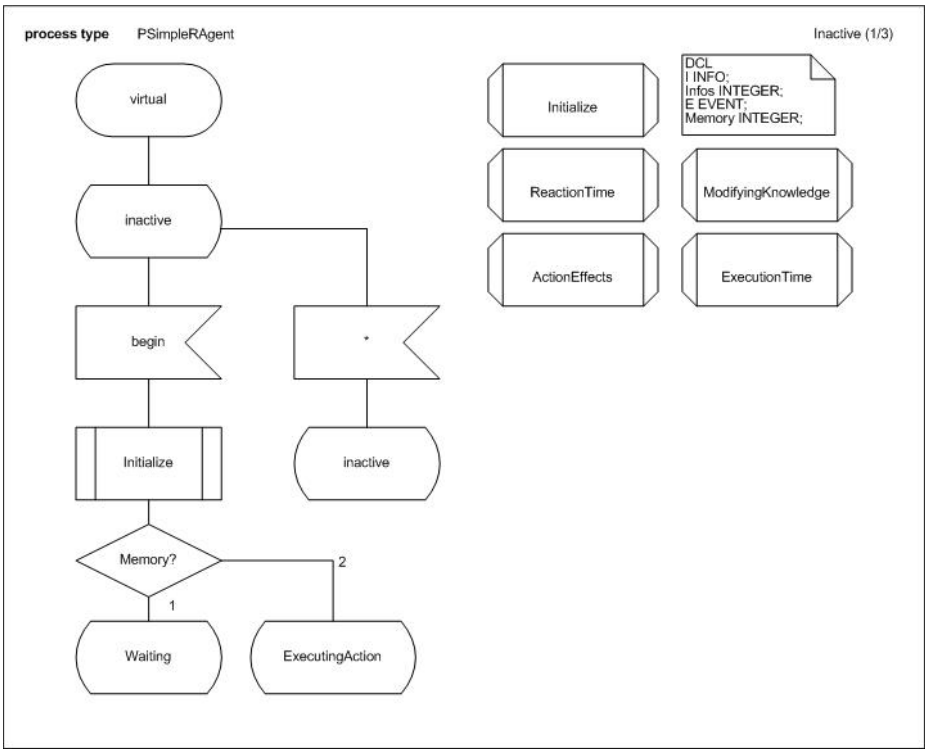


Fig. 16. Reflexive agent *Inactive* state process diagram. In *Inactive* state the agent ignores all the signals except *begin*.

First the agent is *Inactive*, ignoring the entire external stimulus until *begin* signal is received. When *begin* is received, the agent changes its state to *Waiting* or *ExecutingAction*, depending on its memory. This memory stores the state of the agent before become *Inactive*, (initialized *Waiting* by default in the Initialize procedure). When *EnviromentInformation* signal is received the agent starts to process this information, and changes the state to *ExecutingAction*. Once the information is processed, depending on the time defined in the procedure *ReactionTime* (defined in the last level of the SDL), the agent starts its actions (generating a new signal with the time defined in the procedure *ExecutionTime*).

As we can see this agent can perform different actions in parallel, since admits the reception of new *EnviromentInformation* signals when is in the state *ExecutingAction* (no *EnviromentInformation* signal is discarded). If this behavior is correct for more than one project we can reuse it and redefine only the last level of the SDL language defining the *ReactionTime* and *ExecutionTime* procedure. This allows the creation of simulation objects collections.

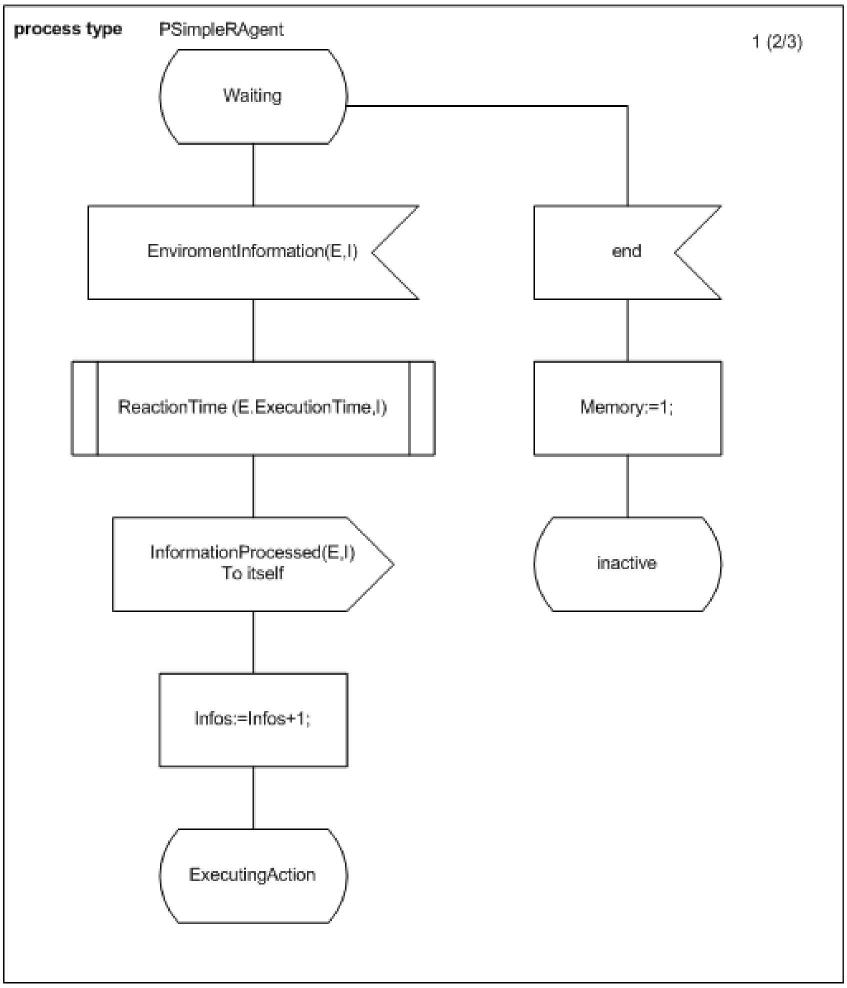


Fig. 17. Reflexive agent *Waiting* state process diagram. In the *Waiting* state, the intelligent agent is not performing any action. Only a new *EnvironmentInformation* event can modify its state (the agent is a s*imple reflexive agent*, only reacts to the environment stimulus, but do not make automatic actions). When a sensor obtains new information, the agent goes to the *ExecutingAction* state. The attribute *E.ExecutionTime* stores the time that the agent needs to process this information. Note that the function *ReactionTime* depends on the agent behavior and is specified on the fourth level of SDL language. An output event is produced and send to itself, *InformationProcessed*, with two parameters, the *event* structure E, and the *info* structure I that defines the information received by the sensor.

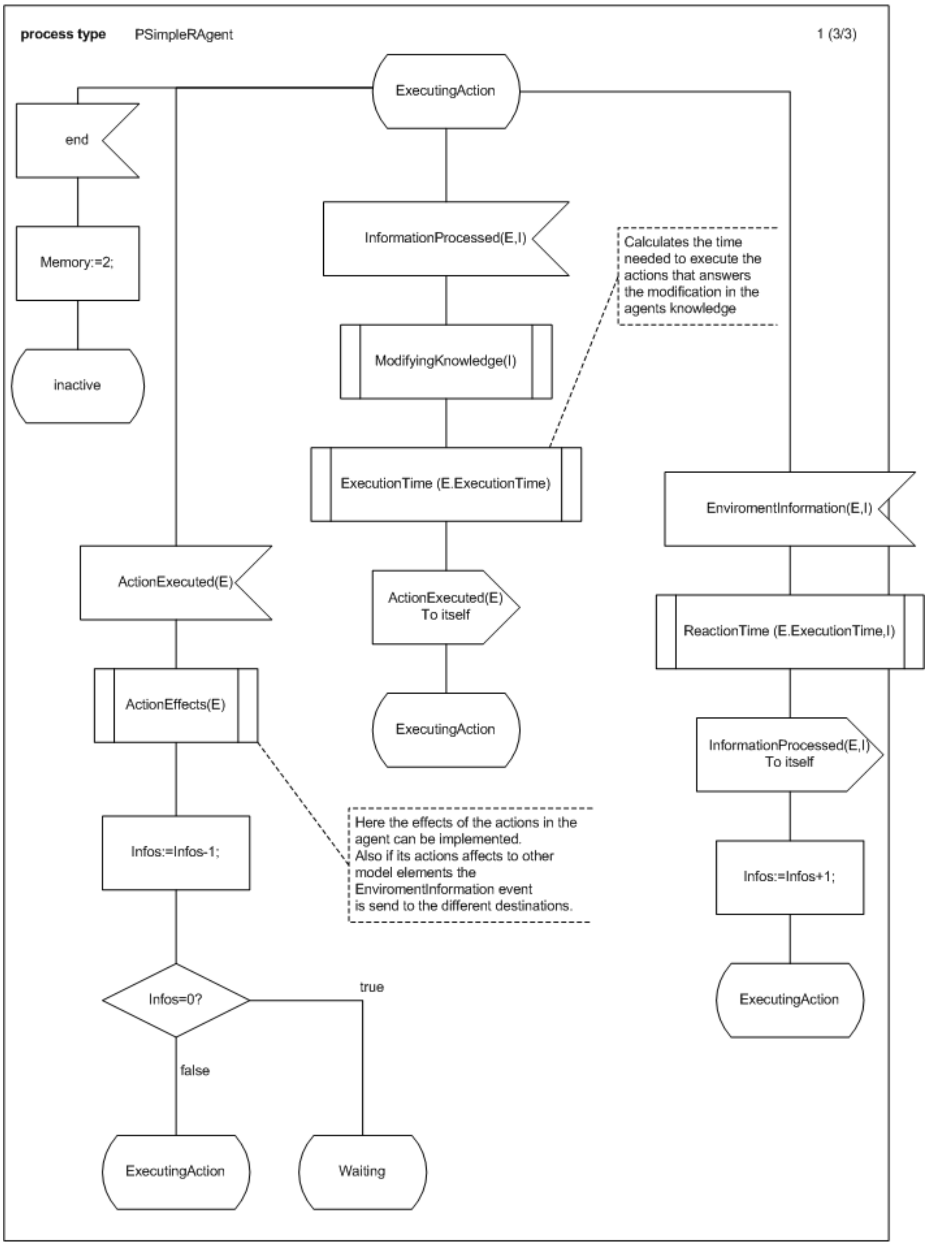


Fig. 18. Reflexive agent *ExecutingAction* state process diagram. For each *EnviromentInformation* signal received, the agent starts new actions, as we see in the previous diagrams. When the agent receives the *ActionExecuted* signal the agent has finish the action.

5. The procedures

Two main procedures exists in this example however we only shown, as an example, *ActionEffects* procedure (the structure of both is very similar). This procedure allows defining what are the actions that the agent do when a specific information is received from the environment. In this case the agent creates a new agent and sends an *EnviromentInformation* signal to the *Enviroment* block.

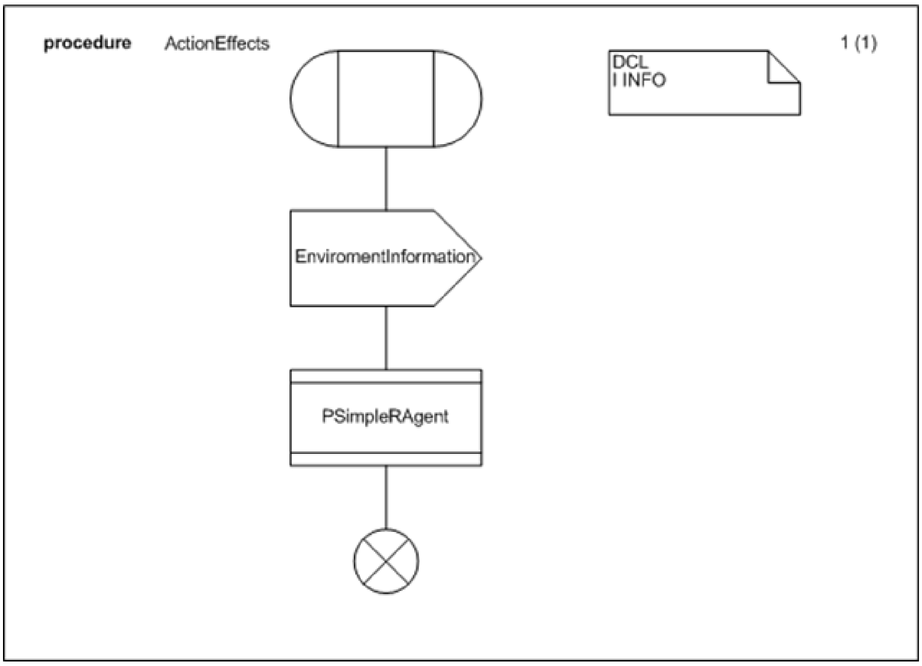


Fig. 19. SDL *ActionEffects* procedure diagram. In this example the action that the agent performs is the creation of a new agent.

Of course, depending on the specific behavior that the agent must have we can add code contained in a task block, decisions, or any other of the elements defined in the SDL language.

6. Concluding remarks

In this paper we describe the common benefits resulting from formalize a social simulation model and in particular, the benefits from use SDL as a formalization language. We propose the use of *event* structure to represent the time, and the *info* structure to define the environmental information perceived by the agent. Also we show a description of a simple reflexive intelligent agent using SDL.

The formalization of a simulation model is an important step that often is not done with the needed detail. Since social simulation is a discipline where different actors are related with the simulation model construction (with different formation and languages), this step will be a must. Formalization allows not only to acquire a deeper understanding of how the model behaves (and them how the system behaves), but helps in the reuse of simulation elements and in the validation and verification process. Also formalization helps to keep the model independent from the final tool selected to perform the implementation. This is a very interesting feature, since allows a complete understanding of the model without the need of know nothing about the tool used to perform the implementation. This helps in the separation of the roles involved in the model construction (the roles of the personnel involved in the model definition and the roles of the personnel involved in the model implementation). Also a formalism allows to establish a no ambiguous communication framework for the different personnel that are related with the construction of the model. Other interesting feature of formalization is the capacity to detect some problems related to the model (and maybe real system problems) before any implementation, this feature makes a formalization a product by itself.

Using SDL language to represent social systems has inherent advantages for the modelers, despite of the advantages reviewed before. First SDL is a standard, that means that a real consensus about its syntax exists allowing the understanding of the model for a wide range of professionals. Secondly, different tools understand SDL language, simplifying the implementation task. Some tools allow the automatic generation of code, and other allows the automatic simulation of the SDL models. As an example of tools that understand SDL language we can find ConTraSt [25], Cindarella (http://www.cinderella.dk/) or SDLPS [26] among others. Third, the graphical representation of SDL simplifies the understanding of the model (as we see, SDL also allow a textual representation). Fourth, SDL structure is based in different levels, with different diagrams allowing that the personnel focus its attention in the appropriate level of the description, without the need of understand the whole model. Following the example, in the first levels we are depicting the structure of the model (system, and the blocs and processes decomposition). In the next's levels we represent how the agents perform the actions (the process diagrams), and finally in the last level we detail what are the actions that the agent do (procedures diagrams). Five, since SDL can be used to represent interactive simulation models allows the interaction and integration of social models with other existing models easily. Finally, remark that since SDL allows representing the parallelism and synchronization concepts, helps in the distributed implementation of the model.

References

1. Brade, D.: Enhancing modeling and simulation accreditation by structuring verification and validation results. In : Winter Simulation Conference (2000)
2. Schmidt, Bernd: The Modelling of Human Behaviour. Erlangen: SCS Publications (2000)
3. Trencansky, Ivan, Cervenka, Radovan: Agent Modeling Language (AML): A Comprehensive Approach to Modeling MAS. Informatica 29, 391–400 (2005)
4. Epstein, Joshua: Why Model?'. Journal of Artificial Societies and Social Simulation 11(4), (2008)

5. Murata, T.: Petri nets: Properties, analysis and applications. In : Proceedings of the IEEE, pp.541-580 (1989)
6. Peterson, J.: Petri Net Theory and the Modeling of Systems. Prentice-Hall (1981)
7. Silva Suárez, Manuel: Las Redes de Petri: en la Automática y la Informática. Editorial AC, D.L., Madrid (1985)
8. Zeigler, b.p., Praehofer, h., Kim, d.: Theory of Modeling and Simulation. Academic Press (2000)
9. Ameghino, J, Tróccoli, A., Wainer, G.: Models of Complex Physical Systems using Cell-DEVS. In : Proceedings of the Annual Simulation Symposium, Seattle, Washington (2001)
10. Martelli m., mascardi: Specification and Simulation of Multi-Agent Systems in CaseLP. In : In Proc. of Appia--Gulp--Prode 1999, L'Aquila, Italy, p.http://citeseer.ist.psu.edu/martelli99specification.html (accessed 29 january 2006) (1999)
11. Sansores C., Pavón: Visual Modeling for Complex Agent-Based Simulation Systems. In : Sixth International Workshop on Multi-Agent-Based Simulation (MASB'05),Multi-Agent Systems and Agent-Based Simulation, LNAI 3891, 16 pp. (2006)
12. Hilaire, V, Koukam A., A., Gruer, P., Muller, J.: Formal Specification and Prototyping of Multi-Agent Systems. In : Engineering Societies in the Agents' World (ESAW'00) (2000) http://lia.deis.unibo.it/confs/ESAW00/pdf/ESAW11.pdf. (accessed 29 january 2006).
13. Faergemand, O.,: Introduction to SDL 92. Computer Networks and ISDN System. 26, 1143-1167 (1994)
14. Reed, Rick: SDL-2000 form New Millenium Systems. Telektronikk 4.2000, 20-35 (2000)
15. Telecommunication standardization sector of ITU: Specification and Description Language (SDL). In: Series Z: Languages and general software aspects for telecommunication systems. (Accessed 1999) Available at: http://www.itu.int/ITU-T/studygroups/com17/languages/index.html
16. SDL Tutorial. In: IEC International Enginyeriing Consortium. Available at: http://www.iec.org/online/tutorials/sdl/
17. Vangheluwe, Hans: DEVS as a Common Denominator for Multi-formalism Hybrid Systems Modelling. (2000)
18. Doldi, Lauren: Validation of Communications Systems with SDL: The Art of SDL Simulation and Reachability Analysis. Ed. Wiley. (2003)
19. Law, Averill, Kelton, W.: Simulation Modeling and Analysis. McGraw-Hill (2000)
20. Henning Reschke, Carl: Evolutionary perspectives on simulations of social systems. Journal of Artificial Societies and Social Simulation 4(4) (2001) http://jasss.soc.surrey.ac.uk/4/4/8.html.
21. Chattoe, Edmund: Just How (Un)realistic are Evolutionary Algorithms as

Representations of Social Processes? Journal of Artificial Societies and Social Simulation vol. 1, no. 3 1(3) (1998) http://www.soc.surrey.ac.uk/JASSS/1/3/2.html.

22. Curran, dara: Cultural Learning in a Dynamic Environment: an Analysis of Both Fitness and Diversity in Populations of Neural Network Agents. Journal of Artificial Societies and Social Simulation 10(4)3 10(4), (2007)
23. Fischer, Ilan: Evolutionary Development and Learning: Two Facets of Strategy Generation. Journal of Artificial Societies and Social Simulation 6(1) (January 2003) http://jasss.soc.surrey.ac.uk/6/1/7.html.
24. Cortés, U., Béjar, J, Moreno, A: Inteligencia Artificial. Edicions UPC, Barcelona (1994)
25. Fliege, Ingmar, Grammes, Rüdiger, Weber, Christian: ConTraST - A Configurable SDL Transpiler and Runtime Environment. In : System Analysis and Modeling: Language Profiles. Springer Berlin / Heidelberg (2006) 216-228 http://www.springerlink.com/content/a6n158217674q0gj/.
26. Fonseca i Casas, Pau: SDL distributed simulator. In : Winter Simulation Conference 2008, Miami (2008) http://wintersim.org/abstracts08/POS.htm#fonsecaicasasp84590.