Aspects of designing testbed for radiocommunication systems

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Aspects of Designing Testbed for Radiocommunication Systems

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Abstract. This article presents the method for implementing a hardware & software testbed for a radiocommunications suite intelligent control system using virtual models. It also describes the main advantages of the testbed, which allow designing, testing and exploring the possibilities of algorithms for interaction between subsystems of the suite being designed and its control system in real time and real communication lines. One of the main advantages of this testbed is the ability to accurately reproduce the functionality of communication interfaces of real devices included in the radiocommunications suite, which is necessary for solving research problems and compiling load characteristics. The article provides a multi-level structural and functional diagram of the testbed. The proposed solution increases the cost-effectiveness of designing complex radio-engineering suites and allows to speed the development and debugging of embedded software up by several times.

INTRODUCTION

Designing Intelligent Control Systems (ICS) that are part of any complex suite requires development and design support tools, design process automation tools that will allow you to effectively manage the ICS operation, detect malfunctions, and evaluate qualitative and quantitative performance indicators of the radio-engineering suite as a whole. The expanding range of hardware interfaces and the desire to implement Automatic algorithms for the functioning of products create the steady trend of increasing the automation level of designing complex radio-engineering suites, which leads to the creation of increasingly complex testbed structures.

At the same time, the hardware and software architecture of modern radio suites aimed at ensuring functioning in any application conditions is implemented in the form of a complex hierarchical structure. Undoubtedly, such a structure, which provides means for controlling the process of obtaining information and processing it by adaptively changing operating modes of the ICS itself and its subsystems, will improve the quality and characteristics of the suite operation. This actualizes the consideration of practical aspects of designing and implementing the ICS testbed, which allows implementing methods and algorithms for designing and subsequent testing of products.

TESTBED OVERVIEW

Currently, various control system testbeds and simulators are very popular and in demand. Below is an overview of testbeds and systems designed for testing and designing complex engineering suites.

Paper [1] presents the design and configuration of the testbed designed to develop and test algorithms for controlling and servicing vehicles on orbit. The testbed allows emulating the contact dynamics for rendezvous and docking on models of docking adapters. Obviously, the described testbed is impractical due to budget constraints, since the tests re-quire rather cumbersome full-scale models. In addition, such a hardware structure does not scale for research needs.

Papers [2, 3] present the hardware and software architecture of testbed emulation of a wire-less RF channel. The device provides a study of the bandwidth of communication channels, including phenomena associated with multi-path effects, which is necessary for the study and verification of various radio-engineering systems. However, there

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are limitations in the operation of testbed, which is due to the limited capabilities of the testbed hardware in certain ranges.

Paper [4] presents the mechatronic engineering concept of a control system for the design of cyber-physical production modular machines and systems. The presented system allows you to test machines or production systems for compliance with customer requirements even before setting up a real machine. It is emphasized that modularity is one of the most important requirements for such systems, since it allows you to dynamically adapt to the requirements of the customer. In addition, there is a need to use virtualization technologies to simulate the behavior of a real production system or machine in order to test the basic functions and security requirements. This approach reduces the time required for acceptance testing and commissioning of complex technical systems.

Paper [5] presents the hardware & software testbed intended to design orthogonal frequency-division multiplexing (OFDM) systems. The testbed provides the ability to evaluate the execution of algorithms and check the functional correctness of modules based on the field-programmable gate array, which is part of OFDM systems. The hardware implementation is checked by software processing in real time, and software modeling is performed over real wireless channels, which makes fault localization more efficient. However, the proposed software implementation cannot fully account for violations occurring in a realistic environment, so the actual performance of implemented algorithms cannot be guaranteed. Disadvantages of the hardware implementation are the high operational complexity and the complexity of fault localization.

Paper [6] proposes an approach to the implementation of the testbed hardware and software platform, the main purpose of which is to experiment with cognitive radio devices, in particular, with Dynamic Spectrum Allocation algorithms. The design of testbed is mainly aimed at providing adequate support for experiments on the application of cognitive principles. The software is built based on user scenarios. It also emphasizes the need to apply the principles of modularity, multithreading, and object-oriented capabilities in the design of the testbed software.

Recently, network testbeds have become very popular, which are an environment for developing wireless devices and protocols. The design of testbed for reproducing network behavior is based on two popular solutions: using only software solutions (for example, in EmuLab), which gives insufficient insight into reality; or using the real Internet (for example, in PlanetLab), which gives fewer opportunities to reproduce various critical scenarios. Some testbeds allow you to select and mix both possibilities as desired by the researcher [7]. However, the known solutions focus mainly on network protocols and packet exchange algorithms, and not on the implementation of simulators taking into account the capabilities of real technical devices.

Further, the generalized requirements for designing an ICS testbed, which supports the ICS functionality research by radiocommunications suites in a network environment, are formulated, and the implementation of the ICS testbed requirements is described.

REQUIREMENTS FOR ICS TESTBED

Scalability

The system scalability lies in the ability to increase its performance by integrating additional structural units that implement similar functionality.

The ICS testbed is built from unified functionally complete modules of the same type of structure, due to which the system can be expanded by simply adding new modules.

Distributed Management

Distributed management in this context involves the implementation of the following basic principles:

- decentralization of data processing, parallel execution of management processes, deferred synchronization;
- physical distribution of information resources between system objects (modules) with the unity of their logical representation;
- support for the principles of automatic configuration of modules connected to the system, including without stopping the simulation processes.

From the technical perspective, all modules connected to the ICS testbed are equal. Each module with appropriate permissions can perform system service functions, which increases the overall reliability of the system. The available memory space is used dynamically, which allows you to have many sets of functioning diagrams and periodically update (change) the current implementation of the script in accordance with the current target function.

Multi-functionality

Multi-functionality involves the implementation of the principle of universality, based on a set of functional interfaces. The modules that are part of the ICS testbed are functionally separate information objects that have a set of unified interaction interfaces.

Multi-technology Support

Multi-technology support consists in ensuring the interaction of modules using all available communication technologies, which is critical for the ability to quickly reconfigure the system without stopping its operation.

The transmission of information is carried out in the form of unified data packets, regardless of the specific content of this information, which can be arbitrary and modified as necessary. This achieves multi-technological support for communication channels.

Modularity

Modularity is a property that assumes the grouping of functionally related parts into complete groups (modules of higher order). It is used to reduce the apparent complexity of the system by encapsulating the functionality inside the modules, which leads to hiding the complexity.

The design of the ICS testbed modular structure assumes a multi-level hierarchy, which is typical for large complex systems. In addition, modularity allows you to implement data transfer from the source module to the consumer module along a dynamic route, which includes necessary transit modules. When replacing one of the modules, data transmission can be implemented through other modules that have a similar communication protocol in structure and command.

ARCHITECTURE OF ICS TESTBED

Therefore, we propose to implement the ICS testbed structure based on a combined approach, including methods of automatic control theory and fuzzy control.

Figure 1 presents the generalized Intelligent Control System testbed diagram containing a Control Unit, a Fuzzy Controller, a Decision Unit, an Input Interconnection Matrix and an Output Interconnection Matrix, with the mandatory presence of a feedback circuit.

The main unit is the Fuzzy Controller unit, which implements adaptive control functions. It contains a Proportional Unit, the required number of Integrating-Differentiating Clusters (IDC), each of which contains several Integrating Units, several Differentiating Units, and a lookup table (LUT). Figure 2 presents the diagram of a single Integrating-Differentiating Cluster.

The Control Unit receives and transmits commands of the information exchange network, controlling the flow of data between the testbed modules. In addition, the Control Unit takes into account the current, predicted and earlier states of the ICS inputs and outputs, time change coefficients, emergent and critical states, etc. The input data arrays converted into control actions are fed to the Fuzzy Controller PID units, Interconnection Matrixes, and Fuzzy Controller.

The Fuzzy Controller consists of four main units: a Fuzzification Unit, a Defuzzification Unit, a Fuzzy Rules Storage, and an Engine Interface. The Fuzzy Rules Storage contains information in the form of a set of system management statements. The Engine Interface provides the formation of a logical solution based on fuzzy rules. The Fuzzification Unit and Defuzzification Unit provide the transformation of the outputs and inputs of the mechanism into signals that are understandable to the managed object. The Fuzzy Controller decision-making process is based on observing the control error or output value of a controlled object, which form quality indicator value based on a pre-selected criterion. For more information about the operation of Fuzzy Controllers, see [8-10].

The Input Interconnection Matrix and Output Interconnection Matrix allow organizing series-parallel (cascading) connections of IDUs. The number and location of testbed communication channels with a controlled device is designed depending on the controlled object's structure and purpose complexity, since such objects are usually built as multi-level and multi-circuit. LUTs are used to store expert data and may have the form of specialized storage devices, which currently widely used in the field of computer technology.

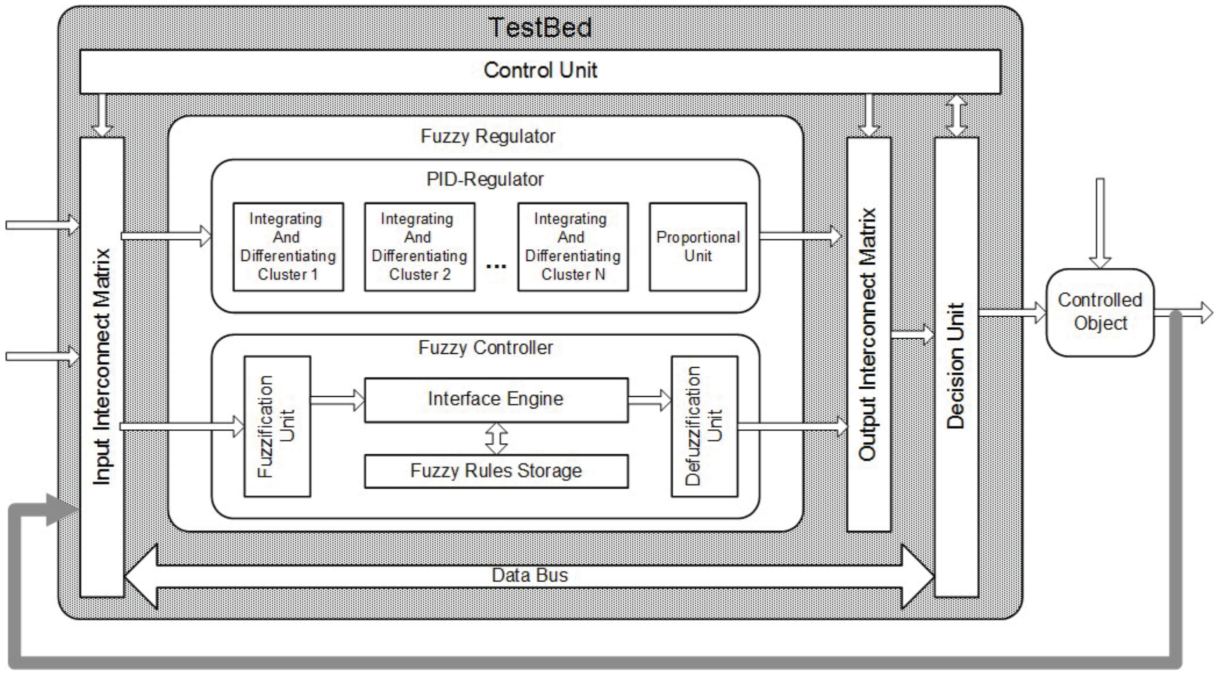

FIGURE 1. Intelligent control system testbed.

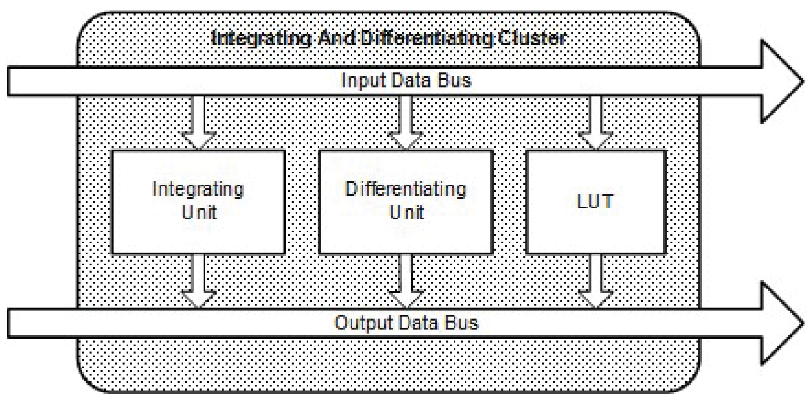

FIGURE 2. IDC block diagram.

LUTs are used in the following cases:

- PID regulation does not give a positive result or is unproductive when values of analyzed parameters are beyond acceptable limits;
- PID regulation has low efficiency, which leads to an increase in the adaptation time and, as a result, the probability of violating the steady-state operation of the controlled device.

During the control process simulation, the IDC and Fuzzy Controller are implemented in the form of virtual models, the information interaction between which occurs through transactions via virtual communication channels that simulate real means of communication in the control system under study. Papers [11-12] address the aspects of using virtual models in the process of designing complex control systems.

Obviously, the number and structure of IDUs and interactions may vary dynamically within the existing task and hardware configuration. Figure 3 presents the IDC configuration options obtained using the Input Interconnection Matrix and Output Interconnection Matrix.

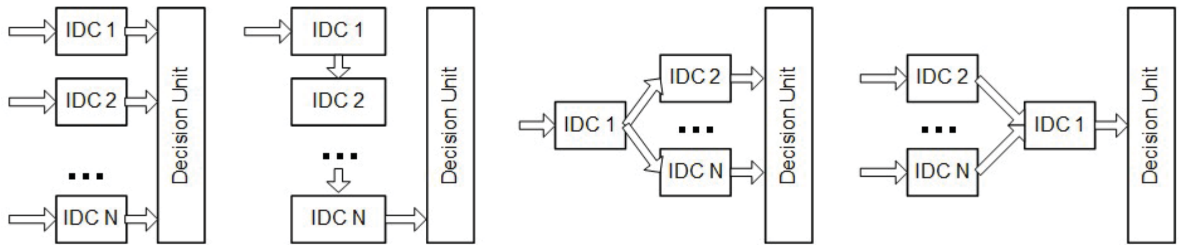

FIGURE 3. IDC configuration options.

Several important advantages of the proposed solution:

- flexibility of forming a topology taking into account access control to modules;
- control of the distribution of software resources;
- software capabilities that allow forming fairly complex control and control signals;
- control of the behaviour of modules, each of which can function in different time frames.

CONCLUSION

The proposed testbed architecture hardware and software solution provides a new level of design capabilities. This solution is based on the optimal combination of reliability, speed and functionality parameters, which increases the efficiency of developing and studying control processes of radiocommunications systems, as well as algorithms and protocols of their operation in relation to specific operating conditions. The operation principles and hardware & software solutions are patented [13, 14], which confirms the success of the proposed technology.

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