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## Development and application of intelligent system modeling and simulation platform

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### ABSTRACT

As a common support of M&S (Modeling and Simulation) applications, M&S language and platform can effectively improve M&S capability for complex objects and systems. This paper proposes an Intelligent system Modeling and Simulation Language (IMSL) which integrates artificial intelligence theory and M&S technology to describe intelligent model structures, behaviors, facts, knowledge, and rules. Meanwhile, an M&S platform is implemented to provide a basic support for M&S of intelligent systems, featured as its convenience, efficiency and problem solving ability. Our research work has been focused on M&S methods and language specification of intelligence systems, intelligent simulation resource libraries and integrated development environment. As an application instance, M&S of a C3I (Command, Control, Communication and Information) system is conducted to evaluate the performance of IMSL and the IMSL platform. And the simulation result proves that IMSL can work effectively in solving practical problems.

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### 1. Introduction

System modeling and simulation is playing an important role in the modern field of M&S. With the development of computer technology and the increasing complexity of studied objects, different disciplines are involved and system simulation is tending to be more and more complex. The M&S of intelligent system is to apply intelligent theory and methodology to solve intelligent problems and is widely used in CIMS (Computer Integrated Manufacturing System), CGF (Computer Generated Forces), SBA (Simulation Based Acquisition), and so forth. With the development of artificial intelligent, many kinds of intelligent technologies (knowledge engineering, expert system, intelligent optimization algorithm, multi-agent technology, qualitative reasoning, neural network, etc.) have been widely used on the M&S of intelligent systems. M&S platform and language are aimed to provide a fundamental and universal support for M&S as well as promoting and improving the M&S capability of complex objects and systems. M&S languages are featured as providing the abilities of fast problem solving, convenient system applying and friendly user interface. Furthermore, M&S languages and platforms can free developers from messy work in building systems from scratch, accelerate the process of system development and improve the reuse of models and comparability of results. Therefore, it is important to develop a common and unified M&S platform for intelligent systems which can solve intelligent problems efficiently and reduce the user's workload.

This paper, in collaboration with applied theory and techniques of artificial intelligence, builds an Intelligent System M&S Platform and proposes an Intelligent system Modeling and Simulation Language (IMSL), which can help to solve M&S problems of intelligent systems. In the M&S process of intelligent systems, there often exists qualitative knowledge. Thus, qualitative and quantitative integration methodology is introduced in IMSL to make full use of qualitative and quantitative

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information. Another problem is how to improve simulation efficiency, especially for intelligent optimization algorithms which need iterative searching. That is the reason why multi-core environment are highly integrated in the platform. IMSL is defined to support the M&S of systems through describing intelligent model structures, behaviors, facts, knowledge and rules and can be applied to a wide range of systems. And IMSL is designed to tackle with knowledge engineering, expert system, qualitative reasoning and intelligent optimization problems efficiently. Besides, this platform has a user-friendly interface providing both text and graphic development environment and supports the simulation result display of intelligent behaviors.

Related key technologies of Intelligent System M&S Platform are described in detail. The remainder of this paper is organized as follows. Section 2 summarizes related research. Section 3 gives an overview of Intelligent System M&S Platform. Section 4 discusses design and integration of intelligent models. Section 5 presents some key techniques of implementing the integrated development environment, including the definition of IMSL, translating and compiling technology, and simulation engine technology. Section 6 implements a C3I application instance. The functions of IMSL and the platform are verified through the modeling of air force combat rule sets and the simulation of cooperative attack target allocation. Finally, the paper is concluded in Section 7.

## 2. Related work

The pertinent literature of this study mainly focuses on: (a) M&S language and platform; (b) solutions to intelligent systems; (c) intelligent optimization algorithms and application; (d) M&S of C3I system.

A lot of M&S languages and platforms have been developed and widely used in the whole community to support system simulation, such as Modelica, MATLAB, UML and SRML. Modelica is an object-oriented language for modeling the complex physical systems [1]. Models in Modelica are described by differential, algebraic and discrete equations [2]. It is suited for the modeling of multi-domain cooperative and continuous/discrete systems, and works almost perfectly on that kind of problem. Marco Lovera have conducted the M&S of satellite dynamics and obtained the results based on the Modelica language [3]. Victorino Sanz has developed a free Modelica library named DEVSLib to model discrete-event systems [4]. MATLAB is a language for technical computing with excellent performance [5] providing enriched toolboxes for continuous/discrete system modeling. It also provides different intelligent models and optimization algorithms in artificial intelligent toolbox. However, models in the artificial intelligent toolbox are not comprehensive to describe a complicated intelligent problem. For examples, MATLAB does not support qualitative modeling, knowledge based expert system, etc. UML is a comprehensive and universal modeling language [6]. Yves Vanderperren has applied UML to System-on-Chip and hardware-related embedded systems design and combined UML tools with well-known simulation environments [7]. Francesco Basile has used UML to formally express system's requirements, model the uncontrolled system and design the controlled one [8]. SRML is an XML application that can describe the behavior for distributed simulation models. Every SRML project builds a XML file defining the specification of typical elements, interactions and operating environment of simulation system, which makes it much flexible when modeling with SRML [9]. In addition, many scholars have analyzed related work of M&S and proposed new M&S platforms or framework. Tsai has proposed a service-oriented distributed modeling and simulation framework for the development and evaluation of large scale distributed systems. This framework offers specification for modeling via language specification, automated code generation, model checking and policy enforcement to allow different application architectures (layered, bus or peer-to-peer) to be simulated [10]. Among these M&S languages and platforms mentioned above, most are not suitable for M&S of intelligent systems or intelligent behaviors. Further application will be limited if a M&S language lacks a mature development environment for building simulation systems. And there needs massive developing work on simulation application if executable programs cannot be directly generated automatically.

The M&S of intelligent systems is to apply intelligent theory to solve intelligent problems on the base of M&S theory and method. The research scope of intelligent systems mainly includes expert systems, artificial neural network, evolutionary computing, knowledge engineering and data mining [11]. For solving these complex problems, artificial intelligent languages such as LISP, Prolog, Smalltalk, CLIPS, have been coming out one after another. LISP was originally specified in 1958 and created as a practical mathematical notation for computer programs [12]. And it quickly became the favored programming language for artificial intelligence research. Durand and Schwer have used LISP to describe the reasoning process about incomplete qualitative temporal information in artificial intelligence and natural language processing applications [13]. Prolog is a general purpose logic programming language associated with artificial intelligence and computational linguistics [14]. PY Zhao and XY Huang have carried out some experiments to present the realization of artificial intelligence in mathematic problem solving by using Prolog and found that artificial intelligence could be brought into mathematics through Prolog [15]. Smalltalk is first published in 1980 by Alan Kay to underpin the "new world" of computing exemplified by "human-computer symbiosis" [16]. CLIPS (C Language Integrated Production System) is written in "C language" by NASA in 1984 and is a public domain software tool for building expert systems which provides a complete environment for the construction of rule [17]. Furthermore, CLIPS provides interfaces for other high-level languages. Zhang has presents a knowledge-based system named "EFDEX" and used CLIPS 6.1 to perform intelligent functional design of engineering systems [18]. These languages can deal with most of intelligent problems, but problem still stands. These languages are mainly oriented at knowledge-based reasoning application and perform not quite well in optimization problems. Their capability of solving various intelligent problems is limited due to the lack of a unified modeling language.

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