Modeling and Simulation of Dynamic Engineering Design Processes

A tutorial proposal for ER'05

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Design – a signature of human intelligence – was always a great challenge for researches in various disciplines. For example, observations of how humans act in design produced several fundamental ideas in AI and DAI – automated problem solving and reasoning [Simon, 1969]. In return, the researchers as the broad community attacked the problems of design domain by attempting to engineer systems and infrastructures that are capable of supporting humans in accomplishing tasks that require intelligence. Quite a big piece of this stake is of course the challenge of designing the concepts and the models of different aspects in design. Moreover, from data and knowledge engineering perspective the problems of Conceptual Modeling are design problems per se: the problem of designing intelligent artifacts [Ginsberg, 1993], or exploring the design space of intelligence [Sloman, 1994; Davis, 1998].

The complete process of design has not been fully automated yet in a satisfactory way. For example, agents or other "smart" software systems still do not design artifacts as humans do. Some attempts, however, have been undertaken. Some of these attempts have used agents (an engineering sub-area of DAI) to create intelligent software infrastructures for supporting engineering design processes performed by distributed teams and comprising contributions from various disciplines. The models of Engineering Design Processes produced in these developments are based on the paradigms of an Agent and an Agency.

The tutorial will survey these attempts in the period of the last 10-12 years structuring them alone the dimensions of complexity in Integrated Product Design as well as alone the time axis. We shall focus on how these dimensions of complexity affected the developed conceptual models. Some of the dimensions of complexity are: the boundaries between disciplines in multidisciplinary design, conflicting goals among the design team members, big chunks in design process, counter-intuitive behavior of the designers, etc. The time axis is divided into three topical periods: the "Antique" period, the "Middle Ages", and the "Renaissance". The Antique period is characterized by the substantial growth in interest in agent-based approaches to engineering design automation. The constellation of research projects undertaken at that time were raised by big, even romantic, expectations of a breakthrough, of a so called silver bullet in the field. We shall overview several of the most influential "Antique" projects: PACT+SHADE, ACDS, ABCDE, DIDE, SHARE, SiFA. These expectations, however, have not been fully backed up with the appropriately sound results. The tutorial analyses the reasons behind this. It is concluded that the main problem was the lack of the maturity in fundamental theories, basic frameworks, and underlying models, methodologies, and technologies. The tutorial then switches to the survey of the second historical period of "Middle Ages" which main focus was on the development of these basic theories, models, methodologies, and technologies like for example Dynamic Design Process Models (RAPPID project), Dynamic Distributed Planning and Coordination Mechanisms (ADN project). The developments of the

"Middle Ages" formed what may be called a critical mass leading to the "Renaissance". Examples of several projects are given and analyzed in order to determine the realistic focus in engineering design automation activities which emerge in recent times. Recently launched projects and their accomplishments are overviewed in this part of the tutorial. Special attention is paid to the descriptions of the goals, the problems attacked, and the approaches to solutions.

In the upcoming part of the tutorial the Productivity Simulation Initiative (PSI) of Cadence Design Systems, Inc. is presented in detail. This presentation is structured as follows:

- PSI Goals and objectives
- PSI Dynamic Engineering Design Process (DEDP) agent-based modeling framework: mechanisms and knowledge models
- PSI DEDP-MAS architecture, implementation methodology (Gaia), and MAS DK as the rapid prototyping toolkit
- Use cases, the testbed, and simulation experiments performed with PSI DEDP-MAS

PSI related part of the tutorial will demonstrate how agent-based models, principles, methodologies may be used for the intelligent support of dynamic, weakly defined engineering design processes in Semiconductor and Electronic Systems (SES) design domain providing for the increase in their productivity. Industrial opportunities of using multi-agent design process simulation tool will be outlined.

The concluding part of the tutorial will present the general picture of the state of the art in agent-based engineering design automation as well as some future trends. The main question which will be proposed to the audience is: Are agent-based models of Engineering Design Processes really a kind of a silver bullet for engineering design automation? In the context of our PSI project this question may be reformulated as follows: Is there a chance to expect the order of magnitude increase in design productivity through employing agent-based models and simulation mechanisms? Some answers will be given based on the experience of the PSI project.

The **objectives** of the tutorial are:

- To survey the role of agent-based approaches in modeling dynamic, weakly defined processes in engineering design

- To outline the realistic focus, or the niche for agent-based approaches and solutions in managing engineering design

- To report how this focus has been addressed by the current accomplishments in PSI project of Cadence Design Systems

- To stimulate the audience to discuss if there might be a Silver Bullet in Engineering Design automation both in the broad sense and in some specific application areas like SES design

Expected audience. We expect a broad audience of researchers and practitioners interested in modeling dynamic weakly structured processes and specifically engineering design processes, in the applications of agents and multi-agent systems in different domains and specifically in engineering design management. The main purpose of the tutorial is to provide the overview picture which will be balanced for the attendees from academia and industry.

References

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Biographical sketches of the authors

Vadim Ermolayev, PhD

Prof. Vadim Ermolayev (http://eva.zsu.zp.ua/) is the head of Intelligent Systems Research Group and the Associate Professor at the Department of IT of Zaporozhye National University (ZNU), Ukraine. He had received his MSci from Dnepropetrovsk State University, Ukraine in 1984 and his PhD from Zaporozhye State University in 1994. Since 1997 he is affiliated as an Associate Professor at the Department of IT of Zaporozhye University. Prof. Ermolayev worked at various research and management positions both in academy and industry. Since 1991 he took part in several research and RTD projects funded by European frameworks, National programs, industry. He was the committee member of several National professional bodies, like, for example, Ukrainian Research and Education Network (URAN). He is also the registered expert of EU Sixth Research Framework Program. He serves as the international editorial board member of several National and international research journals and as a program committee member for various international conferences.

Prof. Ermolayev's current research interests comprise: intelligent software agents and multi-agent systems, intelligent information retrieval, agent-enabled e-business, ontologies, Semantic Web, Semantic Web services, evolution and adaptability in intelligent software systems.

Vladimir Gorodetski, PhD, DSci

Prof. Vladimir Gorodetski (http://space.iias.spb.su/ai/gorodetski/) is the head of Intelligent Systems Laboratory of St. Petersburg Institute for Informatics and Automation of the Russian Academy of Science. He received his MSci from the Military Air Force Engineer Academy in St. Petersburg in 1960 and from the Mathematical and Mechanical Department of the St. Petersburg State University (1970). Prof. Gorodetski received his Ph.D. degree (1967) and Doctor of Technical Sciences degree (1973) in the domain of Optimal Space Vehicle Control. His professional interests and publications are in Optimal Control System Theory, Space Mechanics, Applied Statistics, Planning, Pattern Recognition and Artificial Intelligence, Knowledge Discovery from Databases, Data and Information Fusion, Digital Image Steganography, Computer Network Security.

Currently in the agents domain Prof. Gorodetski and his research group work on the multi-agent systems theory and implementation methodology, software tools for multi-agent systems design, development of applied multi-agent systems in logistics, network security, engineering design. The group also works in some closely relevant fields: data and information fusion for situation assessment, distributed intelligent data mining and distributed decision making.

Eyck Jentzsch

Eyck Jentzsch has received his Dipl.-Ing. degree in information technology from the Technical University of Ilmenau, Thuringia, Germany in 1994.

He is currently as Staff Services Engineer with Cadence Design Systems, Inc., the world's largest supplier of electronic design technologies and engineering services (http://www.cadence.com/), and the head of Cadence's VCAD Virtual Laboratory (VLab). One of the main professional concerns and duties of Mr. Jentzsch is to envision and to analyze the possible impact of today's and emergent technologies on engineering design and adopt them accordingly.

Mr. Jentzsch has over 10 years of engineering and business management experience in the knowledge-intensive semiconductor and electronic design automation (EDA) industries. He worked as a design engineer at various groups within the Siemens AG in Germany where he was engaged in design engineering and the development of novel semiconductor devices and very large scale integrated (VLSI) CAD systems. In 1998 he joined Cadence Design Systems GmbH, Munich.

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Wolf-Ekkehard Matzke has received his Dipl.-Ing. degree in Theoretical Electrical Engineering (summa cum laude) from the Technical University of Ilmenau, Thuringia, Germany in 1984.

He is currently a Fellow with Cadence Design Systems, Inc., the world's largest supplier of electronic design technologies and engineering services (http://www.cadence.com/), and the head of Cadence's European Virtual Integrated Computer Aided Design (VCAD) business. One of the main professional concerns and duties of Mr. Matzke is to envision, to predict, and to analyze the possible impact of today's and emergent IT and knowledge-based technologies on engineering design performance management.

Mr. Matzke has over 20 years of research, engineering and business management experience in the knowledge-intensive semiconductor and electronic design automation (EDA) industries. He was a Scientist at the Institute of Semiconductor Physics, Academy of Sciences (GDR), Frankfurt (Oder), Germany, from 1984 to 1991, where he was engaged in design engineering, novel semiconductor devices, numeric modeling and simulation techniques, and very large scale integrated (VLSI) CAD systems. In 1992 he joined Cadence Design Systems GmbH, Munich, Germany, where he worked in several management positions. He is the architect of the VCAD collaboration model to manage dyadic B2B relationships in high-tech market conditions, characterized by extreme challenging requirements for flexibility, agility, and adaptability, such as in the EDA-Semiconductor setting, where the model develops rapidly towards a de-facto standard. He serves as a member of Scientific Advisory Boards of several companies and is a member of the Steering Committee of the edacentrum, a German industry association supported by the German Ministry of Education and Research. Mr. Matzke is the author or the co-author of many publications and patents. He is the member of ACM, AIS, IEEE, and INCOSE.

His current research and development interests include integrated circuit (IC) design technology, technology management, knowledge management and transfer in technology-driven industry settings, design science, design productivity and performance research, and virtual enterprise concepts.