Agent-based Prototype of the Dynamic Engineering Design Process Performance Management System (DEDP-PMS).

V.Samoylov[2], Prof. V.Gorodetsky[2], V.Ermolayev[3],
E.Jentzsch[1], O.Karsayev[2], N.Keberle[3], W.-E.Matzke[1], R.Sohinus[1]

[1]Cadence Design Systems, GmbH, Mozart str., 2, 85622, Feldkirchen, Germany
{jentzsch, rsohnius}@cadence.com
[2]SPIIRAS, 39, 14-th Liniya, St. Petersburg, 199178, Russia
{gor, ok, samovl}@mail.iias.spb.su
[3]Zaporozhye National Univ., 66, Zhukovskogo st., 69063, Zaporozhye, Ukraine
{eva, kenga}@zsu.zp.ua

Summary. The software prototype of intelligent agent-based DEDP–PMS to be demonstrated results from collective efforts of academic and industrial organizations involved in the PSI[1] project. The main intended capability of the developed prototype is to assist project managers in optimal planning and scheduling constrained by the given human resource allocation. The prototype is applied to dynamic engineering design processes (DEDP) in semiconductor and electronic systems domain. Another intended functionality of the developed software is simulation-based evaluation of DEDPs using the metrics accounting for the uncertainty of efforts spent by different designers. This uncertainty arises because different designers may have various capabilities to execute different design activities. DEDP-PMS is developed as an intelligent multi-agent system using rather detailed and semantically rich family of ontologies. These domain ontologies shape out the system knowledge base DEDP-PMS implements: the planner which automatically generates work breakdown structures of DEDPs; the scheduler providing optimal human resource allocation; the simulator supporting "what if" analysis; the graphical user interface; the means to export the results of planning and scheduling to Microsoft Project.

Technical Content of the Demo

"Design – a signature of human intelligence – was always a great challenge for artificial intelligence (AI) research" (cf. [8]). Observations of how humans act in design inspired several fundamental ideas in AI, e.g., automated problem solving and reasoning. In return, AI community has attacked the problems of design domain by attempting to engineer systems and infrastructures that are capable of supporting humans in accomplishing intelligent tasks.

Engineering design processes are far from being fully automated yet in a satisfactory way, though some attempts have been undertaken. These attempts have used agents to create intelligent software systems to support design processes performed by designer teams and comprising contributions from various disciplines ([1], [2], [6], [7], etc.). The state of the art is discussed in [3]. These attempts revealed the fact that automating a design process is a challenging task of high complexity.

The software prototype of the intelligent agent-based dynamic engineering design process performance management system (DEDP-PMS) to be demonstrated results from collective efforts of academic and industrial organizations involved in the PSI project of Cadence Design Systems GmbH. DEDP-PMS is not supposed to fully automate a design process. The approach is to provide the set of intelligent capabilities to design project managers. These intelligent capabilities are implemented using the ideas, the frameworks, and the technologies borrowed from the DAI domain.

DEDP-PMS is an intelligent multi-agent system using rather detailed and semantically rich family of ontologies. These domain ontologies shape out the system knowledge base ,DEDP-PMS implements: the planner which automatically generates work breakdown structures of DEDPs; the scheduler providing optimal human resource allocation; the simulator supporting "what if" analysis taking into account the uncertainty induced by the human factor; the graphical user interface; the means to export the results of planning and scheduling to Microsoft Project

The following functionalities of multi-agent DEDP-PMS software prototype will be demonstrated:

1. Knowledge–based automatic generation of the project Work Breakdown Structure (WBS)

Work Breakdown Structure is generated using

    (a) Knowledge base, with the rich carefully designed ontology at the top of it, generalizing experience of the experts in the *dynamic engineering design processes* of the system knowledge base;

    (b) Specification of the design artifact for which the design process plan and schedule is to be developed; this specification includes decomposition of the design artifact into functional blocks, their types, complexities, etc. defined by Project Manager using Graphical User Interface (GUI);

    (c) Specification of human resources available in design process, i.e. the design team and the profiles of the team members (designers), which specify designers' skills, capabilities to execute various types of activities, their availability functions, etc. recorded in the DEDP-PMS data base; this specification is done by Project manager using the GUI;

    Automatically generated WBS is then exported to MS Project and presented to the Project Manager in the convenient and habitual style.

2. Optimization of the human resources allocation to partially ordered activities composing WBS and scheduling

The following information constitute the input of this optimization algorithm

    (a) Specification of designers' profiles;

    (b) Actual (current) availability functions of the designers, alteration of designers' availability functions due to involvement into other projects, occurrence of urgent unpredictable activities, etc.

Optimization algorithm is heuristic–based. The heuristics were carefully selected based on the study of the related publications and on the extended simulation–based experimental study of the optimization power of various heuristics. The peculiarity of the scheduling algorithm is its ability, except order relation over activities given in WBS, to take also into account some specific relationships given over the subsets of activities, e.g. parallelism relations.

The resulting activity allocation and the schedule are exported to MS Project for visualization and the analysis by Project Manager.

3. Simulation of the resulting resource allocation and schedule

The objective of the developed design process simulation is the deeper study and validation of the design process plan and schedule through the assessment of the values of a number of metrics reflecting various aspects of the resulting design process quality. Simulator is an event-driven statistical simulation subsystem taking into account the uncertainty implied by the human factor The uncertainty is implied by the fact that the effort to be spent by each particular designer to execute this or that activity has the random value. For the specification of this uncertainty the β –probability distribution specific for each designer in regard to each particular type of activity and its difficulty is used.

Simulation subsystem records the simulation log which contains exhaustive information concerning schedule performance in various experiments thus making it possible to compute the necessary statistical characteristics and metrics of the developed plan and schedule of the particular design process.

Based on the statistical characteristics and the metrics resulting from simulation procedure it is possible to fully and exhaustively evaluate the expected properties of developed design process (distribution of the design process makespan, robustness, cost-related attributes, etc.)

4. What –If analysis

DEDP-PMS prototype supports different options of "*What –If"* analysis*. A* project manager is supplied with the capability to build several alternative variants of a design process plan (WBS) and schedule, to study the influence of some "disturbing" factors (the late changes in the specifications and requirements, the changes in the availability functions of the designers, unpredictable delays, the emergence of unexpected activities to be performed urgently, etc.). Each such situation can be studied in depth: for each of them a project manager can compute all the metrics specifying the quality of the design process. These functionalities of DEDP-PMS will be demonstrated.

Additional Information

The design and development of DEDP-PMS multi-agent software prototype is based on the agent-based simulation framework developed in PSI project [5]. The prototype was designed and implemented using the platform of the Multi Agent System Development Kit (MASDK) [4] based on the Gaia methodology [9]. The main agent classes of DEDP-PMS are Project Manager assistant and Designer. The latter are replicated within the particular application according to the number of designers composing the certain design team.

The user interface of a Project Manager is implemented as MS Windows application and it is shared by the multi-agent system core. The visualization of a design process plan and a schedule is done using MS Project 2003. Information exchange between the GUI and the multi-agent system core is implemented using the standard TCP-IP socket. The export of data from the multi-agent system core to MS Project 2003 is implemented using standard COM interface.

References

1. Balasubramanian, S. and Norrie, D. H.: A multi-agent intelligent design system integrating manufacturing and shop-floor control. In: Proc. First Int. Conf. on Multi-Agent Syst., San Francisco3-9, 1995
2. Cutkosky, M.R. et al: PACT: An Experiment in Integrating Concurrent Engineering Systems. *IEEE Computer* 26(1), p. 28-38, 1993
3. Ermolayev, V.: The State of the Art in Agent-Based Modeling and Simulation of Design Processes. TR-PSI-2-2004. Cadence Design Systems, GmbH, 25 p., 2004.
4. Gorodetsky,V., Karsaev, O., Samoylov, V., Konushy, V., Mankov, E., and Malyshev, A.: Multi Agent System Development Kit. Chapter in book R.Unland, M.Klusch, M.Calisti (Eds.) Software Agent-Based Applications, Platforms and Development Kits. Whitestein Publishers, 2005.
5. Gorodetsky, V., Ermolayev, V., Matzke, W.-E., Jentzsch, E., Karsayev, O., Keberle, N., Samoylov, V.: Agent-Based Framework for Simulation and Support of Dynamic Engineering Design Processes in PSI. In: Pechouchek, M., Petta, P., Varga, L. Z. (Eds.) Proc. 4th Int. Central and Eastern European Conf. on Multi-Agent Systems (CEEMAS'05), 15-17 September 2005, Budapest, Hungary, LNAI 3690, pp. 511-520, 2005.
6. Parunak, H.V.D. et al: The RAPPID Project: Symbiosis between Industrial Requirements and MAS Research. *Autonomous Agents and Multi-Agent Systems* 2: 111-140, 1999.
7. Shen W. and Barthes J.-P.: An Experimental Multi-Agent Environment for Engineering Design, *Int. J. of Cooperative Information Systems*, 5(2-3), 131-151, 1996
8. Vancza, J.: Artificial Intelligence Support in Design: A Survey. Keynote paper at the *1999 International CIRP Design Seminar*, Kluwer, 1999.
9. Wooldridge, M. Jennings, N. R. and Kinny, D.: The Gaia Methodology for Agent-Oriented Analysis and Design. *Journal of Autonomous Agents and Multi-Agent Systems*, 3(3), 285-312, 2000.

Hardware and software requirements

Prototype will be present on notebooks, which we bring ourselves, so we have not got any requirements to hardware and software. We will need just power connectors 220 V 50 Hz.

URL for a demo storyboard

http://space.iias.spb.su/ai/publications/ASP.ppt