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Scientific report for PICS 4334 cooperation by R. Olejnik

Title: New approaches for load balancing and scheduling in computational grids and embedded systems

The collaboration between partners from the University of Lille, the University of Grenoble and Polish Academy of Sciences (LIFL UMR CNRS & University of Lille I, LIG UMR CNRS & University of Grenoble, IPI PAN and IBS PAN), in the frame of the PICS project "Développement de méthodes heuristiques pour l'optimisation de l'exécution des programmes parallèles", took place from 2008 to 2010. This project aims at developing a methodology for structuring of programs in distributed systems, providing better use of resources and optimizing efficiency of execution of parallel programs. The new algorithms have been developed that determine an optimized distribution of programs and their components between processors, methods of observation and monitoring of program execution, and methods of task scheduling and load balancing of processors. Studies have also aimed at improving methods of communication in parallel systems based on "Systems on Chip" technology, and creation of high-level management structure in the Grid. The developed new methods are based on heuristic analysis and optimization employing a graph representation of programs.

The project results have been presented at international conferences and are intended for publication in scientific journals and conference materials. Furthermore, results concerning autonomous agent contract negotiations are in line, and of interest, to the EU COST Action IC0801 "Agreement Technology."

Cooperation in 2008

The first step of the PICS Working Program was to define a common platform for comparing and improving already developed methods of load balancing. During the next year of collaboration, a workshop on task scheduling in cluster and Grid have been organized in order to create a solid fundamental scientific bases for load balancing on Grids and embedded systems.

During 1 to 5 July, 2008, A. Goldman meets M. Tudruj and M. Paprzycki in Kraków, in order to set up an initial general cooperation framework.

During 21-28 July, 2008, M. Paprzycki, M. Ganzha and M. Drozdowicz from IBS PAN visited the LIFL laboratory of the Lille University 1. The Polish team met with R. Olejnik, Y. Alshabani and M. Taifour. During the visit an initial assessment of directions of collaborative research took place. Preliminary work, done within the framework of the PICS project, concerned utilization of software agents within the ADAJ architecture. During this visit different ideas for the development of agent-infused ADAJ (Adaptative Applications in Java) architecture were discussed. In particular, two levels of possible integration were suggested (within the ADAJ and "from the outside"). Completed work resulted in publication of a paper (1). Later, the LIFL team was involved in preparation of a new paper (2). Further works on ADAJ system with agent were carried on during the year 2009.



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During 1-13 September, 2008, M. Tudruj and E. Laskowski from IPI PAN visited the LIFL laboratory of the Lille University 1. The Polish scientists contacted the research group Paloma headed by Dr Richard Olejnik. During the visit common research works were done in the PICS project, concerned with the design of a new distributed Java program environment called SOAJA (Service Oriented Adaptive Applications in Java). It aimed at executing object Java programs according to the principles of DG-ADAJ (Desktop Grid ADAJ). The new SOAJA architecture was proposed, based on Web Services and the Service Oriented Architecture (SOA) approach. During this visit different ideas for the SOAJA software architecture were discussed. The subdivision of the system into modules and functions of different layers of the SOAJA system were agreed. Further work on the SOAJA system structure was carried on during the year 2009.

During 15-27 September, 2008, M. Tudruj and Ł. Masko from IPI PAN visited the LIG laboratory of the University of Grenoble. They contacted the MOAIS team headed by prof. Denis Trystram. Common research works were focused on the design of theoretical model of distributed applications, which corresponds to software concepts created by the team of the LIFL laboratory and the Polish partners from IPI PAN. This model included a heuristic algorithm for optimized initial placement of Java objects on virtual machines (JVMs), and metrics for a dynamic load balancing heuristic algorithm, including object migration performed during Java program execution. The proposed model was set as a base for further versions of load balancing algorithms for SOAJA, implemented in the frame of this PICS project and used on a platform provided by the team LIFL from Lille.

During 15 October to 1 November, 2008, a visit of R. Olejnik and Y. Alshabani from LIFL, France to IPI PAN, Warsaw, took place. During 23-26 October, 2008, a visit of P-F. Dutot and B. Videau from LIG, Grenoble to IPI PAN took place. The aim of these visits was to continue research on the design of the new software architecture of the SOAJA system based on Web Services and the Service Oriented Architecture concepts. During this visit, an initial model of application execution in the SOAJA system was further developed. Discussions were held on the possibility of using existing distributed programming tools for Java programs as a basis for layered implementation of the SOAJA system. Research was carried on technical aspects of implementation of data communication based on the remote method invocation model expressed by mechanism specific for Web Services-based environment.

On 24 October 2008 a working meeting of the PICS project took place in the IPI PAN site in Warsaw. During that meeting, 4 partners of the project participated, including 2 partners from France and 2 from Poland (the 2nd Polish partner team from the IPI PAN, headed by dr Marcin Paprzycki, attended). During the meeting, discussions were carried on the distributed computing model for Java programs developed for SOAJA as a result of IPI PAN-LIG-LIFL cooperation. The scope of further research work in the PICS project was discussed. Furthermore, organizational issues concerning organization of the workshop on Scheduling techniques for Grid that was to be organized in France (Cevennes) on the beginning of June 2009, with the participation of the partner teams of the PICS project, have been talked about

During 2008, the following common scientific papers were published:

- (1) M. Senobari, M. Drozdowicz, M. Paprzycki, W. Kuranowski, Maria Ganzha, R. Olejnik, I. Lirkov, Combining an JADE-agent-based Grid infrastructure with the Globus middleware—Initial Solution, Proceedings of the IAWTIC Conference.
- (2) M. Drozdowicz, M. Ganzha, W. Kuranowski, M. Paprzycki, I. Alshabani, R. Olejnik, M. Taifour, M. Senobari, I. Lirkov, Software Agents in ADAJ: Load Balancing in a



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Distributed Environment, in: M. Todorov (ed.), Applications of Mathematics in Engineering and Economics'34, American Institute of Physics, College Park, MD, 2008, 527-540

(3) R Olejnik, M Tudruj, B Toursel, I Alshabani, E Laskowski, Service Oriented Applications, Adaptive, International Multiconference on Computer Science and Information, Wisla, Poland, October 2008, pages 459 – 465

Cooperation in 2009

During the 2009 year, joint research work on heuristic scheduling algorithms for Java programs executed in distributed and Grid-type systems has been carried out. As a result, new algorithms based on a nature- inspired optimisation method (extremal optimization approach) for determining the initial allocation of objects among Java virtual machines deployed on clusters of workstations have been developed. The algorithm has been implemented for distributed programs in Java language, run under control of ProActive environment developed in INRIA. The results have been presented at the international conference ASTEC 2009 "Workshop on Algorithms and Techniques for Scheduling on Clusters and Grids", 1-5 June 2009, the Cevennes, France, in the following paper:

1. E. Laskowski, I. de Falco, M. Tudruj, R. Olejnik, "Using extremal optimization for the Java program of initial placement in clusters of JVMs.

These results were also next presented during the international conference "Cracow Grid Workshop '09", 12-15 October, 2009, in an article which has been published in the proceedings of this conference in early 2010

2. De Falco, E. Laskowski, R. Olejnik, U. Scafuri, E. Tarantino, M. Tudruj , "Initial Deployment of Distributed Java Programs in Cluster of JVMs through Extremal Optimization Approach, Cracow Grid Workshop '09 Proceedings", Editors: Marian Bubak, Michal Turala, Kazimierz Wiatr, Published by Academic Computer Centre CYFRONET AGH, Cracow, Poland, pp 44-54, February 2010

The JVM load measurement system used for the dynamic load balancing and the control of migration of application objects was presented in the article:

3. R. Olejnik, I. Alshabani B. Toursel, E. Laskowski, M. Tudruj, "Load Balancing Metrics for the SOAJA Framework", Scalable Computing: Practice and Experience Journal, pp 419–428, Vol 10, no. 4, December 2009

During the ASTEC 2009 conference, the results of cooperation between the IBS PAN, the LIFL laboratories, the IPI PAN, and the ID (University of Grenoble) were presented in the paper:

4. L. Masko M. Tudruj G. Mounié, D. Trystram, "The Comparison of Task Scheduling Algorithms for Dynamic SMP Clusters with Communication on the Fly".

This article presents a comparative analysis of two heuristic algorithms for task scheduling in systems based on dynamic clusters of processors. One is based on the list scheduling algorithm based on the ETF (Earliest Task First) heuristic, supported by a genetic algorithm. The second algorithm is based on clustering of nodes of the program graph, with the use of moldable tasks approach (developed in the French team).

Cooperation of the LIFL team with the IBS PAN team resulted, in 2009, in the following paper:

5. M. Senobari, M. Drozdowicz, M. Ganzha, M. Paprzycki, I. Lirkov, R. Olejnik, P. Telegin, "Job scheduling in agent-based Grid middleware"



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This paper presents results concerning: (1) available scheduling methods and their applicability to various scenarios involving utilization of software agents as intelligent high-level Grid middleware; and (2) existing Grid ontologies and their usability in the system under development. It was established that we would continue with focusing on extending and modifying the CORE Grid Ontology. In the next step, the adjusted ontology will be injected into an existing system. The results have also been summarized in 2 book chapters:

6. M. Drozdowicz, M. Ganzha, M. Paprzycki, R. Olejnik, I. Lirkov, P. Telegin and M. Senobari, Chapitre 7 : Ontologies, agents and the grid: an overview, in *Parallel Distributed and Grid Computing for Engineering*, B.H.V. Topping and P. Ivany (Editors), Saxe-Coburg Publications, pp 117-138, 2009. ISBN 978-1-874672-41-8

7. M. Senobari, M. Drozdowicz, M. Ganzha, M. Paprzycki, R. Olejnik, I. Lirkov, P. Telegin and N.M. Charkari, Chapitre 8 : Resource Management in Grids: Overview and a discussion of a possible approach for an Agent-Based Middleware, in *Parallel Distributed and Grid Computing for Engineering*, B.H.V. Topping and P. Ivany (Editors), Saxe-Coburg Publications, pp 141-162, ISBN 978-1-874672-41-8

The PICS members have set up a workshop on "Algorithms and Techniques for Scheduling on Clusters and Grids" (2 au 5 Juin 2009.-: Maison Clément, Centre CNRS "Les Plantiers", Gard, France). The PICS cooperation set between France and Poland, with the European Union sponsorship, has been strengthened by the participation of several of its members in the meeting. The presence of influential members of different national communities (from the CNRS' GdR RO, and GdR ASR) has fostered new connections on common topics. Tutorial sessions have been focused on young researchers.

The main scientific topic of the workshop was the scheduling and all its aspects, from theory to practice and implementation. A special emphasis was put on the following topics: multi-objective optimization, approximation algorithms, on-line algorithms, new computational paradigms, parallel tasks, work stealing, divisible load, Game theory, and uncertainties. About 50 people have participated in this workshop.

Cooperation in 2010

In the year 2010 we have continued works on the implementation of the new heuristic scheduling algorithms for distributed systems and embedded systems.

The extremal optimization algorithm for initial Java program placement on clusters of Java Virtual Machines (JVMs) was developed for JVMs implemented on multicore processors working under the ProActive Java execution framework. Java programs were represented as Directed Acyclic Graphs in which tasks corresponded to methods of distributed active Java objects that communicated using a RMI mechanism. The presented probabilistic extremal optimization approach was based on the local fitness function composed of two sub-functions in which elimination of delays of task execution after reception of required data and the imbalance of tasks execution in processors were used as heuristics for improvements of the extremal optimization solutions. The evolution of an extremal optimization solution was governed by task clustering, supported by identification of the dominant path in the graph. The applied task mapping was based on dynamic measurements of current loads of JVMs and inter-JVM communication link bandwidth. The JVM loads were approximated by observation of the average idle time that threads report to the OS. The current link bandwidth was determined by observation of the performed



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average number of RMI calls per second. The results of this research were presented in the following publication:

1. De Falco, E. Laskowski, R. Olejnik, U. Scafuri, E. Tarantino, M. Tudruj, "Extremal Optimization Approach Applied to Initial Mapping of Distributed Java Programs". Euro-Par (1) 2010, Lecture Notes in Computer Science, LNCS Vol. 6271, 2010, pp. 180-191

A new publication was prepared on the results of the analysis of scheduling algorithms of programs based on the notion of moldable tasks. These algorithms have been constructed for programs oriented towards execution in systems with dynamic processor clusters, and data communication on the fly. They have enlarged the scope of the research on moldable tasks on the analysis of their behaviour during execution on the new architecture. New estimations have been obtained of the quality of scheduling of moldable tasks in systems with dynamic structures. The algorithms have been implemented as a package of programs which define an optimised schedule of the target application programs in Java. Comparative experiments were performed concerning scheduling following different heuristics. These results were published in the following common paper issued in 2010:

2. Ł. Maśko, M. Tudruj, G. Mounie, D. Trystram, „Comparison of Program Graph Scheduling Algorithms for Dynamic SMP Clusters with Communication on the Fly”, 13-16 September 2009, Wrocław, Poland, LNCS 6068, Springer Verlag, 2010, pp. 31-41.

During the year 2010, the research was also focused on ontologies and semantic data processing. Here, on the basis of participation of IBS PAN team members (dr Ganzha and dr Paprzycki) in the MC of the EU COST Action IC0801 (“Agreement Technologies”) it became clear that use of software agents as autonomous entities that dynamically negotiate Service Level Agreement(s) is very much in line with the best state-of-the-art in development of adaptive system.

First, on the basis of literature analysis concerning SLA negotiations in the Grid and agent-Grid systems, we have modified and extended the CoreGRID ontology. Then, an interesting problem of constraint representation has been solved. The results of this work have been summarized in the following paper:

3. M. Paprzycki, M. Drozdowicz, M. Ganzha, K. Wasielewska, I. Lirkov, R. Olejnik, N. Attaoui: Utilization of Modified CoreGRID Ontology in an Agent-based Grid Resource Management System, proceedings of CATA 2010, pp 240-245

The final version of the ontology has been published in the Sourceforge repository at: <http://gridagents.svn.sourceforge.net/viewvc/gridagents/trunk/ontology/AiGOntology/>

and is being consulted with specialists in the field. First, it was presented to the authors of the original CoreGRID ontology, and received a positive response. Second, a research paper has been prepared that describes the ontology. When it is submitted for publication (and thus assuring that the "copyright" to the proposed ontology will be ensured), the information about the ontology will be distributed to a much broader audience, to be critically appraised and possibly further improved.

During this work, we have run into the issue of agent-agent communication that involves ontologies. One of the reasons for investigating this issue was the need to use ontological reasoners. In the original system design it was assumed that ontological processing will take place only via SPARQL querying of a Jena database. Currently a different system design is being evaluated. This new design is to use ontological reasoners directly. This being the case, agent-agent communication involving ontologies is needed. We have found out that existing approaches that involved ontology-Java-ontology translation are insufficient and/or associated with a



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specific commercial reasoner (Racer). This being the case we are in the final stages of creating our own solution to the agent-agent communication involving ontologies.

Finally, a comprehensive analysis of known approaches to agent-agent SLA negotiations was completed and on its base, and on the basis of the proposed ontology, our new approach to the SLA negotiations in our system will be completed (designed and implemented).

Results of this work will appear in the following papers (accepted for publication as book chapters by the PARENG 2011 conference):

4. M. Drozdowicz, K. Wasilewska, M. Ganzha, M. Paprzycki, N. Attaoui, I. Lirkov, R. Olejnik, D.Petcu, C.Badica Ontology for Contract Negotiations in an Agent-based Grid Resource Management System

5. K. Wasielewska, M. Ganzha, M. Paprzycki, M. Drozdowicz, D.Petcu, C.Badica, N. Attaoui, I. Lirkov, R. Olejnik, Negotiations in an Agent-based Grid Resource Brokering Systems

During 10-17, July, 2010, M. Paprzycki and M. Ganzha from the IBS PAN visited the LIFL Laboratory. During this visit the state of the research concerning the development of ontologies for the system and Service Level Agreement negotiations has been discussed. Furthermore, conceptually validated was the idea that with the two-pronged approach, the research taking place within the scope of the PICS project encompasses the complete software stack. From the low-level load balancing facilitated on the level of JVM's and management of Java objects, to the meta level, where load balancing is supported through autonomous negotiations between entities needing resources and entities representing them.

In November, 2010, the 10 day visit of R. Olejnik from LIFL took place to the IPI PAN and the IBS PAN. During this visit works on a common paper: Extremal Optimization Applied to Task Scheduling of Distributed Java Programs submitted to European Conference on Evolutionary Computations, EvoCOMNET 2011, April 2011, Torino, Italy were carried on. The paper presents a new extremal optimization heuristic approach to task scheduling problem which is combined with the initial task clustering according to the DSC (Dominant Sequence Clustering) method. The paper is expected to be published in the Lecture Notes in Computer Science series of Springer Verlag .

During November/December 2010 a one week visit of M. Tudruj and E. Laskowski from IPI PAN to LIG Grenoble took place. During this visit the research was focused on the subject of heuristics for multicriterial optimisation of parallel programs execution in systems based on processors with strong limitations of cache memory capacity. This subject will be developed in a further research.