COST 526 – Project *D1*

Final Report

Simulation-based optimization in sheet metal forming

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1. Introduction

Permanently increasing complexity of products and their manufacturing processes combined with the demand on high quality products lead to more and more use of simulation and optimization techniques in product and manufacturing process design. Due to the computational load caused by the solution especially of multistage manufacturing problems, sophisticated software systems from computational engineering are needed to adequately support product and process design optimization, shifting the focus in software engineering from stand-alone systems towards the integration of software and hardware resources in a distributed environment for high performance computing. Service-oriented architectures provide a promising approach for realizing such systems, no matter whether they reside on heterogeneous platforms of geographically distributed locations.

2. Goal of the project

In the course of this project, a prototype of a service-oriented distributed problem solving environment for the solution of simulation-based optimization problems in sheet-metal forming was to be designed and developed. As a prerequisite and in order to gain a comprehensive understanding of commercial as well as scientific aspects from simulation and optimization of sheet metal forming, an analysis of the business processes in small to medium enterprises (e.g. from sheet metal forming or casting industry) was required. Based on the results of this analysis, the formulation and analysis of relevant optimization processes and the design, implementation, and analysis of adequate solution strategies was envisaged.

3. Simulator, calibration, quality function and optimization algorithms, including assessment with respect to alternatives

During this project, various commercial simulation systems were evaluated concerning the quality/precision of the simulation results in relation to the necessary runtime and their adequacy for their integration into a distributed software system for simulation-based optimization. It became clear that different simulation systems are needed in different business processes along the product lifecycle. In its early stages (e.g. in bid engineering), yielding sufficiently precise simulation results in very short time (several minutes) is required. In the phase of actual designing a product and its manufacturing process high-precision simulation is needed in order to detect potential failures in production. Runtime for long-running high-precision simulation may be several days which is reasonable in later phases of the product lifecycle. Several benchmarks where made in the beginning of the project to determine the quality of different simulation systems [16].

Since the number of necessary simulation runs in the course of a sufficiently precise simulation-based optimization in sheet metal forming or casting implies an excessively long runtime, parallel and/or distributed solution approaches are inevitable to provide results in reasonable time. Hence, different optimization algorithms were evaluated considering solution quality, speed, and (parallel) speedup and efficiency [1]. To obtain preliminary results of these analyses, a test problem was formulated exhibiting several features of an actual optimization problem in multi-stage manufacturing [2].

4. Main scientific outcome

The problem formulation of a multi-stage manufacturing process with a variable number of stages (to be minimized) was derived from analyses of the actual manufacturing process. This formulation is essential for the further development of optimization strategies and their performance analysis (s.a. [1]). Since the solution of the actual simulation-based problem is a very long-running process, a test problem was defined for testing purposes. This test problem has similar mathematical characteristics compared to the original problem from manufacturing but its solution – using sequential as well as distributed optimization algorithms – is several orders of magnitudes faster than the solution of the original problem. Thus, it allows testing of various optimization strategies. A two-level optimization algorithm based on decomposition of product and process design was developed and is currently tested and analyzed.

From the software engineering point of view, bridging the gap between business processes in industry (in this case: product and manufacturing process design based on simulation and optimization) and the underlying IT infrastructure (hardware resources, software services, simulation/optimization codes) was in the focus of attention in the last phase of this project. Since mid-2004 a stable version of GLOBUS toolkit (GT) version 4 is available for implementation of software environments based on web/grid services. The previously designed and developed version of OpTiX (workbench for distributed solution of simulation-based optimization problems developed at the University of Siegen since end 1980s) was re-designed and re-implemented. Currently, a prototype of a service-based OpTiX is utilized as a test bed for software integration of simulation and optimization and for the newly developed optimization algorithms as well. For further research work on model-driven execution of business processes in engineering based on web services, the service-oriented version of OpTiX will be the platform to gain further insight into the specific problems in software engineering of distributed systems.

5. Main technical outcome

In order to validate the feasibility of a service-oriented approach for simulation-based optimization in sheet metal forming and casting, a software infrastructure was designed and partially implemented based on the de facto standard GLOBUS Toolkit V4. This prototype enables the secure remote usage of a simulation system (e.g. CASTS provided by COST 526 partner ACCESS) via a public network and a web portal. This infrastructure is currently in a test phase and preliminary results show the feasibility.

The infrastructure is currently deployed on the “Rubens” cluster system which was conceptually designed and configured by members of the Information Systems Institute and installed in the beginning of 2004. Since the cluster provides computational capacities not available for most of the SMEs in automotive supplier

industry as well as research institutions, such “easy to use” resources are crucial for business and research activities in engineering.

6. Collaboration within COST 526

Due to the participation in COST 526, an intensive collaboration with ACCESS e.V., RWTH Aachen, Germany was established. In this collaboration, complementing competencies in the simulation of casting and design as well as implementation of distributed software systems were combined. This lead to an integration of ACCESS’s simulation code CASTS into the software environment and to a prototype of remote, web-based, and secure access to resources across public networks between ACCESS, the Information Systems Institute in Siegen, and industrial partners in Northrhine-Westfalia, Germany.
On this topic, the joint research project MiGrid – funded by the state ministry for science and research in Northrhine-Westfalia – was successfully proposed which started in september 2004 (http://www.migrid.de). Furthermore, a project within the federal D-Grid Initiative was proposed together with ACCESS and several other partners and positively evaluated in 2005.
Additionally, further collaboration with Prof. J.L. Batoz and Dr. C. Knopf-Lenoire is planned based on the exchange of students between the organisations. Again, combining expertise in material science and software engineering is in the focus of thiese activities in order to enhance the software environment and to improve simulation as well as optimization algorithms.

7. Cooperation with industry

Within the MiGrid project, collaboration with COST 526-participants Dr. J. Jakumeit and Dr. F. Hediger from ACCESS e.V., Aachen, Germany and the following partners from automotive supplier industry was successfully established:

GEDIA Gebrüder Dingerkus GmbH, Röntgenstr. 2, 57439 Attendorn
Fischer & Kaufmann GmbH & Co. KG, Am Steinwerk 7, 57413
Egon Großhaus GmbH & Co. KG, Bonzelerhammer, 57368 Lennestadt
HMT Heldener Metall Technik GmbH, Biggen 12, 57439 Attendorn
Albert Hiby GmbH & Co. KG, Grünestrasse 32, 58840 Plettenberg

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INPRO Innovationsgesellschaft für fortgeschrittene Produktionssysteme in der Fahrzeugindustrie mbH, Hallerstr. 1, 10587 Berlin
GNS Gesellschaft für num. Simulation mbH, Am Gaußberg 2, 38114 Braunschweig
PROCAD GmbH & Co. KG, Vincenz Prießnitz-Str. 3, 76131 Karlsruhe
Co.Com Concurrent Computing GmbH, Am Eichenhang 50, 57076 Siegen

8. References

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