A Multi-user-collaboration Platform Concept for Managing Simulation-Based Optimization of Virtual Tooling as Big Data Exchange Service

An Implementation as Proof of Concept Based on Different Human-Machine-Interfaces

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Abstract. Intelligent connected systems for the successfully implementation of collaborative work systems in the areas such as Internet of things/Industry 4.0 require a knowledge management system which offers opportunities to work on one task with different organizations on the same time. Cooperative work in the field of setup preparation for production systems is one challenge for an efficiency and infallibly work preparation. One example is the validation and optimization process for NC-programs, which is offered by CAD/CAM interfaces as well as the experiences of the worker uses the machine. Planned production processes are simulated by the CAD/CAM-programs. Optimized setup data are provided to the worker using the setup. The challenge is to provide a service to handle the dataset of job information, optimization information and setup information for many users in order to manage databases and data sets. The approach deals with a system concept of an implementation of a production optimization tool embedded by a collaborative platform containing access by a Multi-User-Agent to manage setup parameters direct from the simulation to the machine as well as proved job management workflows.

Keywords: Simulation-based optimization · Collaborative platform · Multi-user-agent · Knowledge management · Virtual tooling · NC-program · Data exchange

1 Introduction

Intelligent linked systems are an important condition in order to implement research activities and manufacturing jobs in the area of “internet of things” – in Germany often called “Industry 4.0”. Thus a qualified knowledge management system is required which offers opportunities to work synchronously and cooperatively on one task on the same time independent from the workplace location. The goal is to reach a productive and sustainable manufacturing process which offers also the opportunity to learn from experience and data from the past.

Thus a Multi-User-Agent based approach is pursued which provides work preparation processes in the area of virtual tooling as part of the digital factory. In addition,

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cooperative work is also provided using a collaborative platform. With support of a combination of several systems and approaches, a service platforms is developed and will be presented in this contribution. For that knowledge, production and setup data sets are provided for several users. Especially for the generation of job and order data, production details, setup information for workflows and tooling machine setups as well as the machine-generated sensor data offers new challenges for process analysis and data processing. A detailed problem description is given in Sect. 2. Section 3 presents the related work for the basic research project as well as collaborative systems. Section 4 offers the current concept and the architecture of the total work preparation system. Section 5 closes the contribution with a conclusion.

2 Problem Description and Motivation

In order to provide for each user $u_m \in \{u_1 \ldots u_M\}$ inside and outside of several organizations $o_n \in \{o_1 \ldots o_N\}$, every manufacturing job are defined as $j_k \in \{j_1 \ldots j_K\}$. As cloud and collaborative application, these set would rapidly lead to high data variants that have to be evaluated by optimization and simulation runs as well as job scheduling queues. Each job contains at least one workpiece. The job information are provided as instructed data which are saved in a database. These data are processed in a structured data format, the so called VMDE. VMDE stands for virtual machine data exchange and is defined as an XML-based data format (see Fig. 1) which provides the definition of a job for the tooling machine simulation. The XML-based data contains tool information, workpiece geometry information, workpiece clamp information, position information, encoded NC-programs as well as control information. The NC-program, control information and position information defines the setup information that can be optimized by the "setup optimizer".

```
<VMDE>
    <Head />
    <Project>
    <Tool id="T1000">
    <Clamp>
    <!—Geometry content -->
    <Blade>
    <!—Geometry content -->
    <Holder>
    <!—Geometry content -->
    </Holder>
    </Blade>
    </Clamp>
    </Tool>
    ……..
<WorkpieceClamp id="WC1000" />
        <Workpiece id="1" name =”square”>
        <zeropoint id=”1” location=”-70 30
        25”/>
        ……..
        </Workpiece>
        <Programs id=”26”/>
        </Project>
</VMDE>
```

Fig. 1. Example interface data for communication between simulation and work preparation platform

Clamp and workpiece geometry (CAD-data) depends on the design process of the organization. The problem for these circumstance is that one production step can be defined as one manufacturing job it and can contain one and/or more VMDE-data. These configurations lead to a data processing overhead. In order to provide a processing method to define jobs, VMDE contents in a cloud-based collaborative environment, a process system is striven by this contribution. For that a standardized workflow is required to organize collaboration between the organizations and their jobs.

A rough example structure of the communication interface (VMDE) between work preparation platform and simulation is shown in Fig. 1.

In order to provide the manufacturing job configuration (implemented as VMDE-data) which contains always a simulation job as available for lower system performance, a subdivision of the data in smaller string-snippets are required. Then the data process is provided as well running system using the cloud architecture. The snippets are saved in the provided individual user database. Figure 2 shows a database condition for a simple simulation job in order to simulate primitive geometry. For more complex jobs, the data number will be rapidly increase which requires high data processing procedures. For one simple job which contains only one simulation job-data in order to communicate with the simulation model, the number of snippets amount 20094 strings.

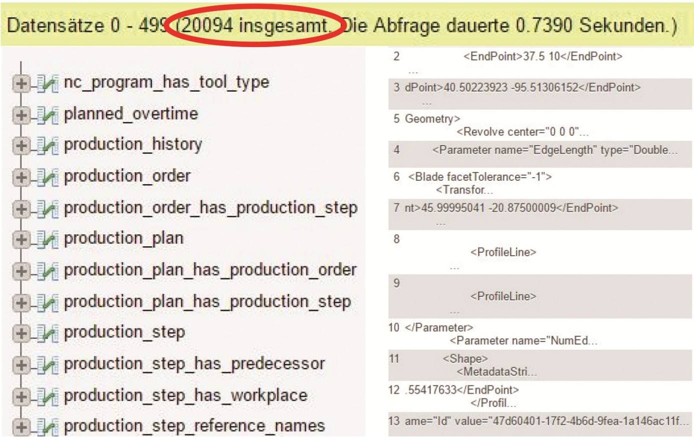

Fig. 2. Section from one user database containing simulation job information and string-snippets

3 Related Work

3.1 Related Work of the Development Process of the Work Preparation Platform

The basic research project in order to improve work preparation-processes in the area of manufacturing processes especially cutting machines named by "*InVorMa*" is supported by the German Ministry of Education and Research. The research goal is to develop a service platform in order to optimize machine and job setups based on virtual tooling using a simulation model of a milling machine. The research project contains sub-projects which handle the setup optimization processes as well as the knowledge management system. The result is an optimal job schedule of manufacturing and simulation jobs, providing valid setup parameters, suitable machine selection and a suitable data processing.

For that there arose several approaches to decrease the simulation and computational effort. The computational process occurs because of the high number of variants of the machine setup and production parameter setup. The optimization would generate many parameter sets for each product and each machine which has to be simulated. The idea to parallelize the simulation would imply a linear time decreasing situation which offers useful improvements for low number of datasets.

The optimization component of the production and machine setup is given by a metaheuristic called particle-swarm optimization (PSO) (see [1]) which is tested as asynchronous, synchronous, and grouped-asynchronous extension in order to manage stochastic node failures and parallelize optimization runs [2]. A shrank process time using asynchronous PSO is shown in this contribution. In combination with an additional calculation program called "*NC-parser*" as fitness component the processing time decreases on several seconds. The NC-parser approximates the tool paths and estimates the production time using a real NC-program. In combination with the PSO-algorithm minimal workpiece positions are identifiable which leads minimal production time. In the contribution of Weber [3] zeropoint optimization of the workpiece setup in order to reach minimal production time is presented.

In order to concern the problem of high simulation effort cluster algorithms are tested in combination with the PSO-NC-Parser-combination. The contributions [4–6] offer a useful solution in order to optimize workpiece and clamp position for the machine setup to determine positions without unintentional collisions during the production processes. The collected positions information are also saved back in the user data bases which are managed by a multi-user-agent.

3.2 Related Work to Collaborative Platforms and Conceptual Overview

For systems which offer integrated and collaborative work for several participants, for example customer and business partners, collaborative systems are defined as "computer based systems for group oriented support of decisions support and problem solutions, flexible information link and exchange, rapid dialogues including absence of participants, electronic conferences and worldwide multi-media communication [7]." This kind of systems represents no new approaches, but due to the research in order to implement support opportunities for cooperative teams using information and communication technologies, the research idea arose in the early 1980s as "*Computer Supported Cooperative Work (CSCW)*." It is represented as interdisciplinary research area in order to improve team work providing and usage suitable information and communication systems [7]. Collaborative systems gain increasing importance caused by the provided internet connection, networks in companies, and the development of new devices though to the current system landscape today [8]. With support of web services and defined interfaces, organizations can disclose, receive, and share information with their cooperative units. CSCW is designated as predecessor of Social Software/Social Media [9, 10]. A conceptual map is presented in the contribution of Martensen [9].

4 Concept and System Architecture

4.1 System Architecture

The work preparation platform considers five subsystems in order to provide optimal tooling jobs and machine setup. The usability is realized by a multi-user-login structure which is controlled by a web-based interface and also by a collaborative platform. Figure 3 presents the sub-systems embedded in a cloud-architecture including the interfaces between users, system, and manufacturing part.

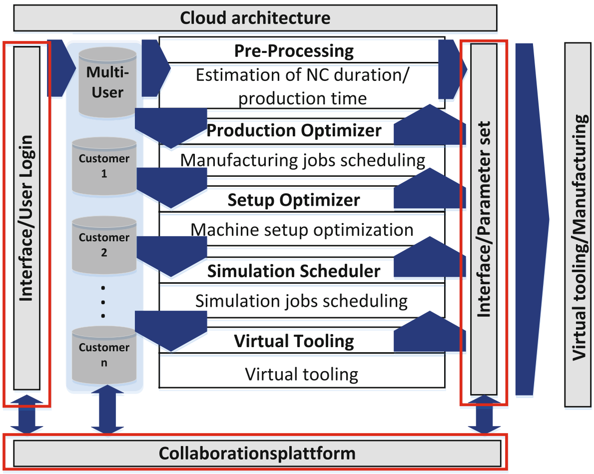

Fig. 3. System architecture of the work preparation platform

The user gets their individual database connection by a user log-in so that their have access to their own system resource. With support of the web-based interface as well as the collaborative platform, there are opportunities to define the manufacturing jobs with meta-data such as deadlines, costs, setup costs, selections of workpiece geometries, workpiece clamps as workpiece fixtures in the tooling machine, the used machine, chosen NC-programs and trigger of simulation and optimization of their schedule and machine setup.

The pre-processing part uses the *NC-parser* application, a program which read in the NC-commands and approximates the tool paths and calculate the production time, and in combination with an ontology system a suitable machine can be chosen taking into account the workpiece size, tool paths as boundary box, and the workspace size of the potential tooling machine.

The production optimizer calculates a manufacturing job schedule taking into account the restrictions such as machine capacities, human resources, job and machine failures, time tables and delivery deadlines.

The setup optimizer uses a meta-heuristic as optimization part which is combined with a cluster algorithm (see [2, 3, 5]) in order to decrease the calculation effort and the number of simulation runs when all potential solutions have to be evaluated by the simulation programs. The goal of the setup optimizer is to find a best position and orientation of workpiece and clamps in the machine workspace. The potential solution candidates from the setup optimizer system are distributed as simulation jobs to computer resources by the simulation scheduler. Then the solution candidates are evaluated by the virtual tooling system which contains the simulation model of a real tooling machine. There, the workpiece position candidates are investigated in order to prevent unintentional collisions as well as circumstantial tool paths.

The results of the optimization systems are given back to the user by the web-interface as well as the collaborative platform and the results are also stored in the database device where the user has access for future processes.

4.2 Multi-user-agent and Interface Concept

As described in Sect. 3.1 the work preparation platform consists of several parts which are joined together and interact with many users in- and outside of organizations. The focus of this contribution is the user interface by collaborative platform and web-interface provided by database resources and multi-user-agent. A detailed content of the subsystems of the work preparation platform is given by the references in Sect. 2.

Figure 4 gives an overview about the interaction of the subsystems as well as the part of the user log-in and the interfaces to the collaborative platform.

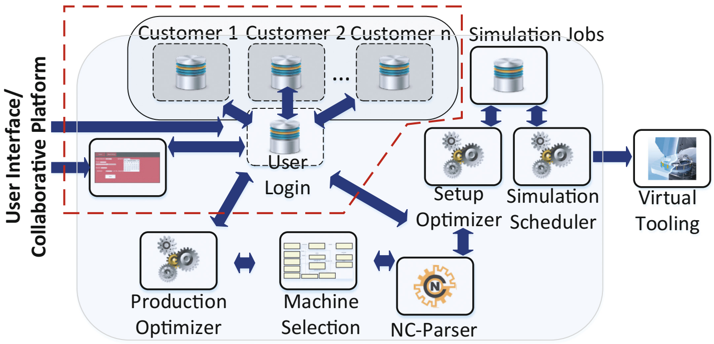

Fig. 4. System interactions and embedded multi-user-agent and collaborative platform (Color figure online)

The red marked field in Fig. 4 presents the system overview which communicate with the user database where the user access is provided. The multi-user-agent communicates with the sub-systems of the work preparation platform depending on the intention of the user (optimization, job-scheduling, simulation). The data sets of the user which are inserted in the interfaces lead to a selected machine, a production plan and an individual machine setup. Every user uses different tooling machines which are provided as simulation model. The optimization can be calculated in their assigned network using assigned computer resources or are provided by a cloud architecture.

The virtual tooling data exchange process is controlled by the simulation scheduler as well as the remaining systems using the cloud architecture which is presented in Sect. 4.1. The size of the exchange data volume depends on the number of users, complexity of the workpieces and the total number of simulation jobs and can determine a range size from several Megabytes to several Gigabytes for each job.

The multi-user-agent consists of a so called customer-pool database where all user names, passwords and related server access are saved. In order to ensure the personal user-data, the entries are encoded as "base64" containing ASCII characters. The entries are additionally secured by secure-hash-algorithm *("sha 512")* which process cryptology hash functions. In order to manage the multi-user-agent and the databases as well as the total number of jobs, there is a workflow management system required which is realized by a HMI (human machine interface) provided as web interface as well as collaborative platform. As use case the commercial platform Microsoft SharePoint is used. The web interface is programmed by the standard-tools HTML 5 and the database connection is managed by PHP 5. The features of the interface is realized by JavaScript. The data bases are implemented as SQL-database, but alternative database implementation opportunities are conceivable.

4.3 Workflow as Online Solution to Define Simulation Jobs and Production Information in Order to Manage Work Preparation

Figure 5 presents the workflow that is necessary in order to define full simulation and production jobs by the web interface and by the collaborative platform. Every user uses

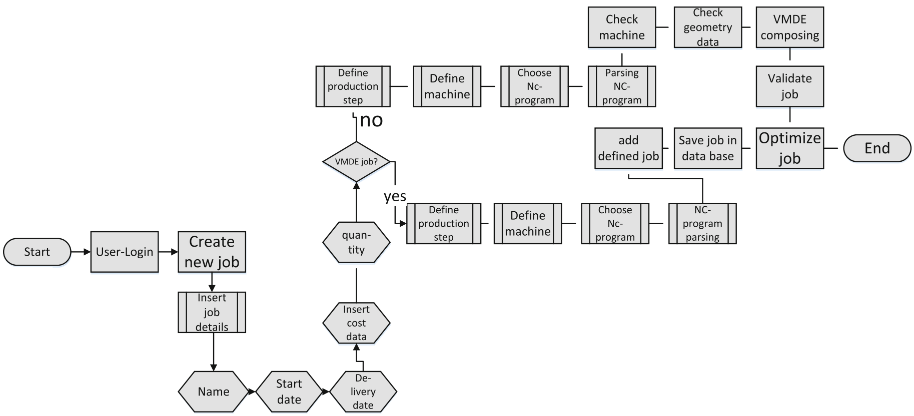

Fig. 5. Workflow of the data management process using web interfaces as well as collaborative platform

his database connection and the services behind the optimization as well as the setup check. The VMDE-composing process is also implemented as a work preparation platform. The Optimization and the composer processes in order to manage the big data problem caused by the VMDE-snippets are independent.

4.4 Online Solution Using Collaborative Platform

The web interface, presented in Sect. 4.3 is recreated as collaborative platform for MS SharePoint. The user can define simulation jobs, manage production information as well as organize the setup of the work preparation issues. The database is also linked with the provided server architecture. In order to run optimization processes the collaborative platform is less well suitable because the optimization executed data has to be saved on the local system of the user. But for the workflow management and for the data management in order to provide simulation jobs and resource management, the platform offers its useful features from different log-in locations. The interface design is shown in Fig. 6.

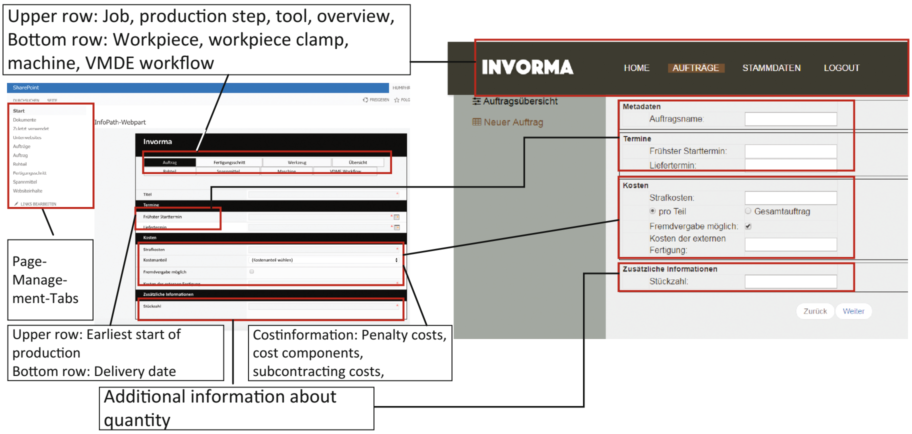

Fig. 6. Collaborative interface using MS SharePoint as use case and proof of concept

The data set is stored in lists and as entries in the database and it can be read-out by standard SQL-commands. Behind the detailed information about the job, there are entities such as name and quantity. Production steps contains the information about technology such as milling, drilling or turning or a combination as well as additional activities such as assembly, painting or deburring.

The input mask "tool" defines the tool geometry and the tool type. Information about workpiece and clamp contain material type, names and definitions and geometry data. The VMDE workflow contains additional information that are required to use a composer application in order to create the VMDE data required for the data exchange with the virtual tooling machine, for example a milling machine simulation model. The collaboration platform also manages the delivery dates, production dates and shift schedules for the worker and the combined costs. A decision support function is also possible through the information about the subcontract information as well as the external processing costs.

5 Conclusion and Outlook

This contribution represents a symbiosis of technical opportunities to combine and to synchronize a web-based multi-user-interface and a collaborative platform for work preparation management of many generated optimization data provided by the tooling machines (sensor data), production optimizer as well as setup optimizer and the virtual tooling machine data exchange process (VMDE). Especially the high number of data exchange snippets (VMDE-snippets) in combination with sensor data cause a bottle neck in order to manage the data set for the o_n organizations that contains u_m users and j_k jobs. The provided platform shows a high potential of usability and guarantees an overview about the simulation jobs and organize the validation and optimization runs in order to control the cloud architecture presented in Sect. 4.

As future work the development will continue in order to synchronize optimization runs in the collaborative platform and web-interface independent of the login-location. The goal is to use the collaborative platform without execute the optimization runs on local hard drives or other hardware.

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