Model-based Collaborative Virtual Engineering in Textile Machinery Industry: Living Lab Case Study

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Abstract

Client demand for on-of-a-kind products and services is leading to a paradigm shift in the way organisations, and especially SMEs collaborate to design, customise, configure, and manage specialised products and services. This paper presents the findings from a living lab case study of a textile machinery manufacturing SME that uses the concept of model-based collaborative virtual engineering and supporting tools in the form of a mashed-up model-server environment to support the needs of its mobile engineers. Initial findings reveal that use of such an environment provides real-time (on the finger-tips) access to relevant data through a single interface, reduces re-work, provides real-time updates, supports on-the-move interactive collaboration, decreases meeting times, and allows for better response to and satisfaction of client needs.

Keywords

Model-based collaboration, collaborative virtual engineering, model-server, textile machinery, living lab

1 Introduction

Organisations, both large and small, require a set of easily configurable tools to deliver one-of-a-kind customised products and services to demanding clients. These tools should support on-demand engineering, configuration, assembly and management of such products and services within collaborative settings. The typical operational norm of organisations delivering one-of-a-kind customisable products and services is that of the virtual enterprise (also referred to as smart organisation, virtual organisation, etc.) [Browne, Sackett, Wortmann: 1994; Charbuck, Young: 1992; Camarinha-Matos, Afsarmanesh, Garita, Lima: 1998; Walton, Whicker: 1996; Kazi, Hannus: 2003; Kürümlüoglu, Nøstdal, Karvonen: 2007].

Client demands for one-of-a-kind customisable products and services leads to a paradigm shift in how smart SMEs operate which provide limited and yet customisable products and services. For example, for textile machine manufacturing, the norm in the past has been using machine drawings (preferably in the form of 3-D) with supporting documentation. However, this is difficult to sustain in a global marketplace where on-demand customisation is becoming the norm. Especially with several organisations being involved, such on-demand customisation requires the use of innovative solutions such as tools and applications built around model servers to support the design, engineering, and management of products and services [Kazi, Ristimaki, Balkan, Kürümlüoglu, Eichert, Finger: 2008].

This paper presents some of the recent work undertaken in the CoVES (Collaborative Virtual Engineering for SMEs) [CoVES: 2009] project from the context of one end-user, Balkan Textile Machinery and their use of model-server based tools (as defined in [Kazi, Ristimaki, Balkan, Kürümlüoglu, Eichert, Finger: 2008]) combined with Finite Element and collaboration tools (phpCollab) to support its operations for collaborative virtual engineering. The work presented is based on testing the solutions within a living lab setting in accordance with Loeh: 2008.

2 Industrial Context

2.1 Overview

Balkan Textile Machinery is a Turkish SME specialising in Textile Machinery and Cotton Ginning Machinery. The company designs parts by using CAD and manufactures by using universal, CNC and cold forming machines. More then 50% of its products are exported.

Two important and frequent processes of Balkan are offer making and order fulfilment process. For a coordinated and traceable offering process, a centralised system for managing data and documents is important. Already during the offering process product models and many describing documents are created in a team. Integrated project management and collaboration functionalities are necessary for the communication of the involved people at Balkan. With these applications offer making will be faster and better coordinated.

With foreign customers and their needs for customised textile machinery, the need for different interactive collaboration mechanisms has risen significantly. While in the past, machine drawings with support documentation sufficed, this is not the case especially with new (foreign) sub-contractors and/or distributors, clients, and mainly needs for on-demand customisation of machine design to suit the requirements of new clients.

For the order fulfilment process, many people are involved in such a project. They need a collaboration platform where they manage their projects and documents. It is essential for the daily work to find the necessary documents and models with the most actual version, even if more people work in the same area. Therefore, the possible document managing functionality supports the process in versioning and direct linking to projects and tasks. The communication and collaboration aspects of the CoVES platform help team members to organise their meeting dates and enables discussions, even if people work at different locations and at different times. FE (Finite Element) web calculations will provide better insight into the design of critical components. Using analytical formulas for classical machine engineering is often quite limited since they exist only for certain types of geometry and load cases. Therefore, the FE method will allow more flexibility in the design process as well as optimisation of the design with respect to chosen objective. This will reflect in better capability of order fulfilment.

2.2 Challenges

Potential customers of Balkan are distributed world-wide Balkans managers as well as sales representatives worldwide on the move (e.g. on trade fairs, exhibition, directly at potential customers etc.) for selling machinery for offer making. Only a minor percentage of the sold Balkan machines are standard machines: Balkan offers engineering-intensive, modular structured and customised machineries.

Therefore, main challenges for the offer making process of the machinery (e.g. product catalogues, drawings, etc.) are information, communication and data exchange with engineers, technicians or managers (assembly team) at the customer site as well as data access from outside.

Furthermore, decision making on technical solutions (e.g. technical feasibility checks) between worldwide distributed people of Balkan is always a challenge which needs discussions, collaboration and technical facts.

In particular the following problems emerge during the offer making:

- Lack of mechanisms for efficient data exchange
- Data and document provision is a problem (i.e. to find or to collect the right data on the file system)
- Lack of tool to discuss technical requests/problems directly on a drawing to solve the problem
- Direct access on engineering services, e.g. FE calculations
- Order and project monitoring possibilities for the managers on the move

Moreover, information and communication, data exchange and access to documents of the assembly teams at the customer site for assembly and the ramp-up phase of the machinery cause several problems:

- Lack of mechanisms for efficient data exchange
- Data provision is a problem e.g. master data, order, drawings and product information (i.e. to find or to collect the right data on the file system)
- Lack of a tool to discuss and solve technical problems occurred during the assembly and ramp up phase of the machinery: Short-term request by the customer for changes causes many troubles and rework and therefore Balkan has to be very flexible, especially in foreign countries (long distances) (Build-to-Order (BTO)/ Job-shop production of customised machinery) (change management functionalities)

2.3 Industrial Requirements

Balkan has interest in having an optimal tool for communication and collaboration to support offer making processes and the ramp up phase of the machinery at the customer site. Hereby one key element is the collaboration for engineering problem solving (technical feasibility). Balkan also wants to achieve effective and efficient communication and collaboration between managers, engineers, sales representatives and customers at different locations (also on the move) combined with reduced time and costs for additional travelling. These are the key elements of working in the CoVES Living Lab. In summary, the ideal solution for Balkan is Smart phone or laptop using CoVES:

- Easy to use and practical
- Appropriate for managers, engineers and technicians (different profiles and rights)
- Full access to all company data and information (e.g. calculation data, status, figures, reports, CAD-Files) while being on the move as well as options for making comments and marks
- Possibility for sharing and exchanging data and information with a shared desktop for simultaneous viewing
- Documentation of drawings of parts and modules (in the sense of change, version management functionalities, e.g. for cabling, piping, etc.) and history functionality to track changes
- Basic knowledge management functionalities
- Support of communication and collaboration (i.e. day-to-day work coordination, engineering problem solving, decision making, conflict management) with headquarters during sales and order fulfilment process (including engineering process).

3 Model-based Collaborative Virtual Engineering

3.1 Overview

Within the CoVES project [CoVES: 2009], product design, customisation, configuration, and management is promoted using a "model-based collaborative virtual engineering" concept. The main underlying facet of this concept is a product (or service) model that is the main shared container of all relevant product (or service) data (geometry, material, components, etc.) and corresponding information (assembly manuals, quality lists, contact persons, configurability options, etc.). This model is hosted in a model server that provides different design, customisation, configuration, management, real-time collaboration and visualisation functionalities. The model serves as the basis for collaboration and any changes in a part of the model lead to real-time updates that are communicated to all relevant stakeholders.

3.2 CoVES Model Server Environment

The main component of the CoVES model server environment is the CoVES model server that is developed by Enterprixe and is based on their Enterprixe Model Server for Building Construction [Enterprixe: 2008]. This offers offline/online model creation, editing, browsing, and online interactive model-based collaboration functionality in addition to many other features [Kazi, Ristimaki, Balkan, Kürümlüoglu, Eichert, Finger: 2008] such as:

- Model Sharing: Unlimited number of simultaneous users can access over the Internet the Model Server and create, modify, update and review a 3D/4D product model of the machinery using different kind of client modules.
- Hybrid Model: Related drawings and other documents (stored, e.g., in phpCollab or any other document/content/product data management system) can be linked to the appropriate parts and components in the model. This allows for easy search and retrieval of relevant documents/information related to a particular clicked part/object within the model.
- Integrated Messenger: Using the Model Pointer concept users can have text based (Instant Messenger type) model related collaboration communication related to a selected part/object of the model.

To complete the CoVES model server environment, the CoVES model server is supported through two additional components:

- CoVES finite element service: supporting service through mathematical simulations and analysis of model components (e.g. calculation of temperature distribution due to frictional heat generation within rubber roll which is rotating at high speed and it is in contact with the steel knife which removes the material from roll surface)
- phpCollab: Groupware solution featuring calendaring, document management, contact management, Skype, mobile environment, etc.

All three components of the CoVES model server environment: CoVES model server, CoVES finite element service, and phpCollab are connected together through mash-up (for more details, refer to the CoVES technical architecture [Dryndos, Kazi, Langenberg, Loeh, Stark: 2008].

4 Living Lab Use Case

4.1 Overview

The living-lab approach in the CoVES project is conducted in a few steps as shown in Figure 1 and further detailed in Loeh: 2008. To first prepare the experiment, a business analysis has to be carried out at selected living-lab cases. Followed by extensive technology, demonstrations and discussions have resulted in first ideas and feedback for improvements. In parallel, specific experimentation projects and processes were identified and prepared for real-life experimentation.

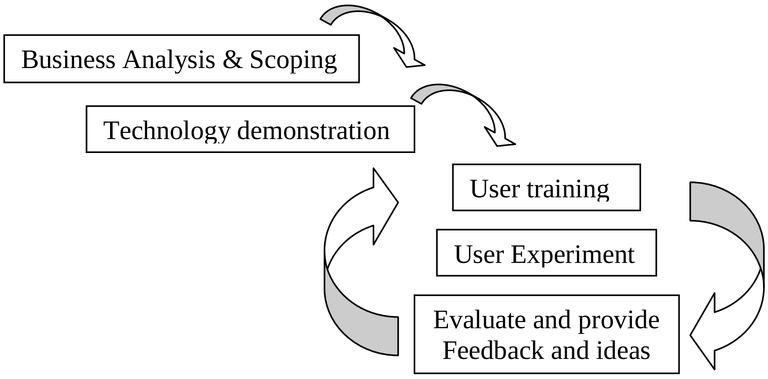

Figure 1: CoVES Living Lab approach

In the living labs the CoVES project collaboration solutions were introduced to the end-users. User trainings and training materials were also provided before and during the experiment phases. Therefore, constant feedback for improvement was collected and transformed into the requirement list for further improvement of both collaboration solutions. The evaluation and feedback will now be taken up by technology providers for the following experimentation cycle.

To evaluate the outcomes of first living-lab experimentation cycle, different indicators have been identified and used to compare the different cases.

- Critical incidents and cause-effect analysis: The cause-effect analysis will allow the identification of problems in adoption of collaboration solutions.
- Changes in collaboration routines: Routines represent the interaction patterns between different stakeholders who are collaborating together. Therefore, indentifying the changes in routines will show how technologies are influencing collaborations.
- Performance and other quantitative indicators: Identifying the key performance indicators will enable the effectiveness of the collaboration solutions to be evaluated and compared across different cycles of the living-lab experiment.
- Key ideas for functionalities and improvement: Through collecting new ideas, new improved functional features will be introduced to further enhance the collaborations.

4.2 Living Lab Set-up and Use Case

The Enterprixe model server has been installed in conjunction with phpCollab directly inside of the Balkan company (the FE service was offered as a hosted service on a remote computational server). This was necessary because it is planned to do the test with real production and confidential data. Therefore, a server in the Balkan company network was preferred. Beside this security issue, the company server has better availability of a faster network connection inside of the company. Balkan started to use phpCollab as a working environment during the offer making and parts of the order fulfilment process. Nevertheless, the project in phpCollab covers the whole process from requirement specification to after sales services. So the main tasks are:

- Requirement specification and machine identification
- Field study
- Engineering
- Creation of final offer
- Manufacturing
- Installation
- After sales service

The base used toolset consists of group management and collaboration platform based on phpCollab and model based collaboration. Furthermore, a Finite Element service is offered to users as a web application for entering the process and design parameters and retrieves analysis results (Figure 2).

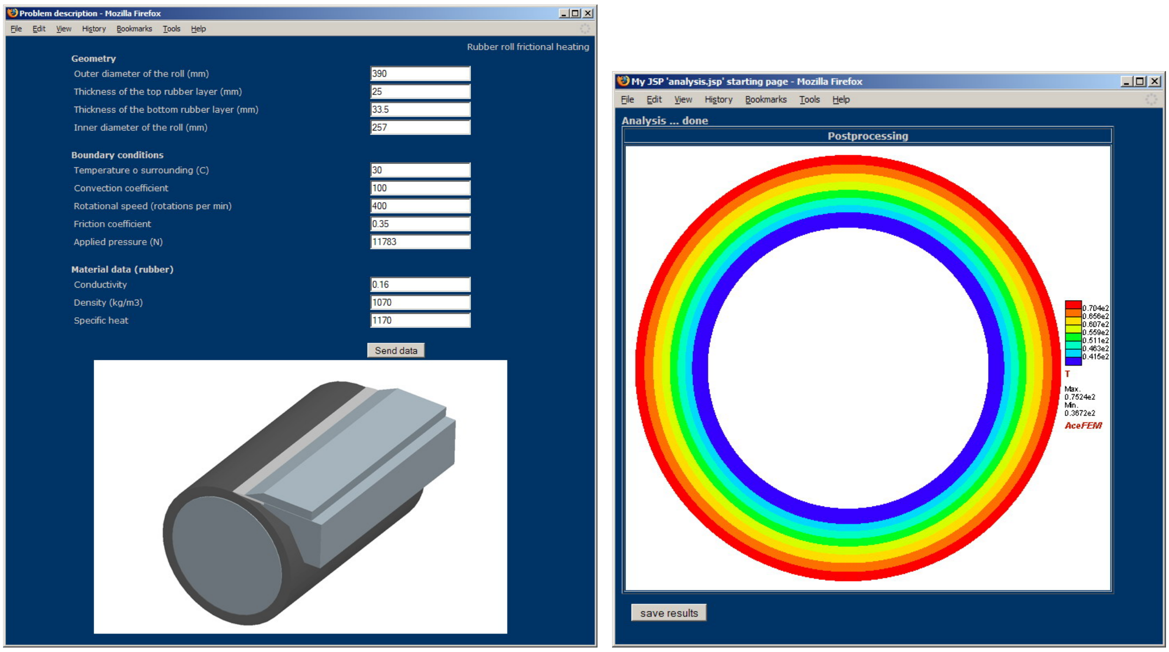

Figure 2: GUI of the rubber roll FE web application: data input form, result post-processing

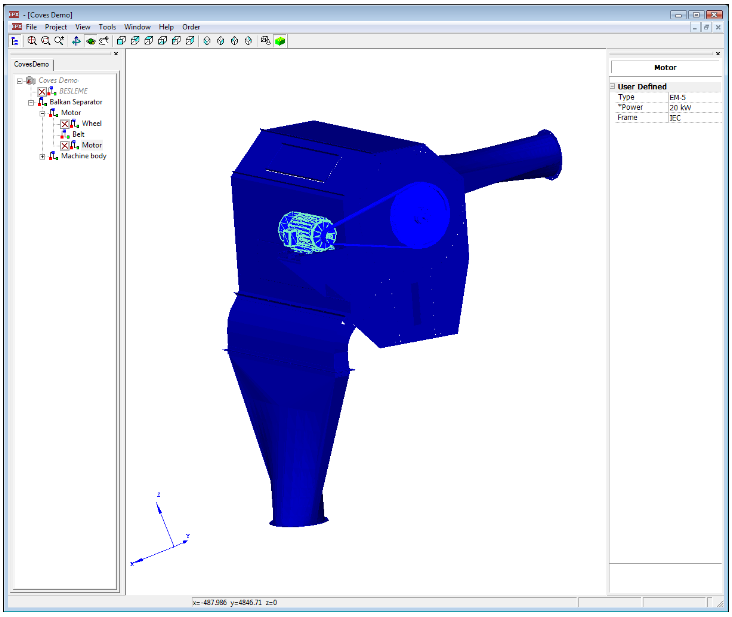

Figure 3: Balkan Condenser on Enterprixe Explorer

As a real test case for evaluation and experimentation of collaboration, data and document exchange as well as engineering services the Unloading Separator of Balkan already have been selected (see Figure 3).

phpCollab is the main collaboration platform in this living lab. Most documents are managed in this system, only the CAD data are part of the Model Server.

In the following table three process steps of the Balkan order fulfilment process represent exemplary the scenario/workflow defined in the initial phase of the living lab activities. It describes the workflow including day to day work coordination, conflict management, product customisation, engineering changes/problem solving, decision making.

Table 1: Three exemplary process steps of the Balkan order fulfilment process

Process step (description)	Input	Output	Tools/Clients/ Software	Organisation/ Actors	Requirements
Prepare a meeting with the customer for specification	• Products drawings/models (CAD-files, models) • Price list (doc) • Movies (mpeg) • Samples (hardware) • Catalogues (paperbased and pdf)	• Prepared stuff	• **Model Server** (for preparing CAD-files/drawings) • phpCollab (data, documents)	@Balkan or on the move: • Manager	
Base identification and selection of the machine or a machine line/plant	• Customer requirements (capacity, wanted production volume, specs of the machinery, size of building/customers-factory, etc.)		• Balkan catalogue(s) • **Model Server**	@customer site • Sales • plant manager • Customer	• Manager on business trip
Field study at customers site (planned factory) done together by managers, engineers	• Customer requirements • Technical drawing/ drawings (Inventor, Autocad) • Factory layout plans	• Machinery layout planning • Revision from customer (based on 2D or 3D-Models delivered to the customer without any details)	• Model Server for presentation of the machine model • Data on mobile device (phpCollab and documents)	@customer site • Customer • Engineers • Managers	

5 Analysis of Key Findings

From the user experiments and iterations there are a number of interesting findings:

- The mashup concept of integrating different data and applications into one environment creates significant value, as especially the Balkan case shows. The user gets "at his fingertips" direct access to the models, FEM calculations, files, project management and communication support. All are linked together in a very short time. Through this the order process becomes much faster and integrated.

To improve model-based collaboration within Balkan in the future, the following actions will be taken:

- **3D models from Balkan**. For being able to properly test the model-based collaboration environment, more 3D models of Balkan machinery would be needed.
- **Configuring a machinery line**. The possibility of configuring the machinery line from the machinery components using the Model Server Client would be very interesting for the users.
- **Web based viewing of the model.** Based on the test use experience a request was expressed for a possibility to view the model by using a web browser only.
- **Tree view of model hierarchy into phpCollab.** A request was expressed also for being able to explore the alpha-numeric properties (without the graphics of the model) of the machinery in phpCollab.

Besides the positive impacts of the model-based collaboration critical incidents occurred. The following table represents the problems and a cause-effect analysis.

Table 2: Critical incidents and cause-effect analysis

Event	Cause	Effect/outcome
Problems with synchronisation of the mobile client with the main database	Has to be evaluated. Error occurred only on one notebook.	Mobile application was downloaded, but the data was not synchronised correctly. The application hangs up.
Model imported in Model Server is mainly a geometry model (does not include product data).	In initial modelling, using modelling system, any product data (attributes) are not defined.	Define relevant product data in initial modelling (in form of attributes/ properties) and transfer them to attributes in Model Server.
Model imported in Model Server does not have an internal structure.	In initial modelling, using modelling system, any internal structure is not defined.	Define internal structure in initial modelling (by using, e.g., layers) and transfer it to hierarchy in Model Server.

Concerning the collaboration platform, the exchange of files between team members gets easier by using a central collaboration platform with document management. Also versioning helped the involved users to find the most recent version of documents. Furthermore, a better overview about the current status of the process workflow/phases (see Balkan workflow) is given. This reduces communication efforts/costs while being on the move. Additionally, the platform facilitates a very fast access to contact data (e.g. client data in phpCollab and further data of project members with Skype and Model Server online status information) as well as relevant documents.

Furthermore, the performance and other quantitative indicators describe the key findings of the Balkan experimentation. As first indicators the following are given:

- The possibility for remote collaboration sessions based on the single, common 3D product model of the machinery substantially decreases the need for physical meetings and for travelling.
- Possible modifications due to customer requirements, e.g. during sales negotiations at the customer's premises, can be immediately communicated with the design and production at Balkan factory.

6 Conclusions

Collaborative virtual engineering is the preferred mode of operation especially for SMEs that provide specialised one-of-a-kind products and services to demanding clients. This paper presented a living lab case of a textile machinery manufacturing SME and its experience in using the concept of model-based collaborative virtual engineering and supporting tools in the form of a mashed-up model-server environment. The model-server environment was based on the CoVES model server, CoVES finite element service, and phpCollab all integrated together using mash-up. In the living lab environment, three main organisational processes were explored: preparing for a meeting for client need specification, base identification and selection of machine or a machine line/plant, and field study at client location (planned factory). Findings from the living lab case study revealed that integration of different components of the model-server environment through mash-up provided significant value through its ease of set-up and configuration. Furthermore, this allowed for finger-tip access to models, finite element analysis calculations, files, project management, communication support, and real-time access and collaboration to configure the machine on-the-fly as per client needs and specifications.

During the living lab test environment, the following aspects were noted to be relevant for further enhancing the benefits of the model-server environment: it was necessary to populate the model server with more rich models of the machinery (more than simple geometry), develop a capability to configure not only one machine but a complete line of machinery, allow simple web-browser based access to model and supporting data/information, have a tree view of model hierarchy replicated in phpCollab to allow for better exploration of different alpha-numeric parameters of the model, and the need to support model access on mobile devices (especially for managers on the move and at client locations [e.g. factories]).

It was observed that use of a model-based collaborative virtual engineering through a mashed-up model-based environment provides real-time (on the finger-tips) access to relevant data through a single interface, reduces re-work, provides real-time updates, supports on-the-move interactive collaboration, decreases meeting times, and allows for better response to and satisfaction of client needs.

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