Gamifcation in web based dynamical simulations - Trial in an undergraduate course in Paper Technology

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ABSTRACT

At Swedish universities future process engineers and process developers are educated in master programs targeting specific branches of the industry, e.g. pulp and paper. Learning the fundamental dynamics of both unit processes and larger process sections encounter in the industry are of high importance for the students. In an effort to further improve this aspect of the education and also highlight the important role of industrial process automation and control, simulations are a suitable tool. In this paper cloud based simulations inspired by the consumer game industry have been tested and evaluated in a master-level course in pulp and paper technology at Luleå University of Technology (LTU). The approach was well received by students and teachers, clearly encouraging students interest and understanding of process dynamics and automatic control.

INTRODUCTION

The application of process and control system simulations in educations are by no means a new approach. In some programs students build their own simulators from scratch and in others ready-to-use simulators are made available for the students. In this paper the target is set to improve user friendliness and user experience of ready-to-use simulators, i.e. the focus is on using simulations as a tool and complement in education rather than simulator designing. Traditionally these kind of simulators are installed on a set of dedicated student computers to which students are given access at specific time slots. Students are guided through the exercise (simulation) by instructions and questions normally documented on paper, very much like traditional laboratory exercises that many of us are familiar with.

The motivation of our work is to improve the pedagogical aspects of using simulators to gain knowledge of process and control system dynamics and how process design is affected by controller design/tuning and vice-versa. Simulations has the potential to further amplify curiosity and learning rate and we believe that gamification is one key enabler for that.

Our solution is based on Modelica® models and a cloud based simulation platform called Everysim®.

APPROACH

In this section fundamental platform requirements are described and our view of gamification is explained.

Requirements

A number of top-level user requirements where established at the beginning of the project:

- Clear definition and presentation of task/exercise and mission. The student should be able to start and run the game without much manual instructions.
- Possibility to start, pause and stop the game and vary simulation speed in order to manage real processes with very long time constants
- Possibility to run on many different devices, e.g. smart phones, PADs and PCs.
- Operating system independent.
- 24-7 access to simulations

In addition to these user requirements another important requirement in education is that the platform must facilitate interaction between the student and teacher where the minimum requirement is to provide means for the teacher to check student progress and understanding in order to give feed-back.

From a teacher perspective, administration must be minimized. Software updates like modifications of the simulation model and management of users may not take much time. For example, adding new students and checking on student progress must be very simple.

Gamification

In [1] gamification is defined as *the application of game design elements in non-game contexts* and the authors conclude that gamification is related to adding elements from game industry rather than developing full-fledged games. In the context of our work we have strived to enhance the normal user experience when working with simulators in education by adding gamification, key ingredients that where prioritized in this project are:

- Achieve short and long term user feedback in order to encourage strategical thinking (“think around the corner”) and keeping up the interest for the game.
- Define a story for the game. The story includes “what to learn” and “stages of learning”.
- Possibility to advance to new level when current task is completed - to evoke curiosity.
- Simple graphics to support understanding, e.g. levels and alarms.
- Simple questioner that is integrated in the game and further increases student-teacher interaction.

PROCESS

In the paper technology course at LTU studies of unit operations in paper production are in focus. Teachers have recognised that the students are struggling in understanding process dynamics that involve several unit operations. Especially how unit operations interact is difficult to explain. For example, how does an upstream change in beating energy affect the paper quality and properties of the long and short circulation. The process section chosen here range from a pulp storage to press section, i.e. a relatively complete stock preparation section as shown in Figure 1.

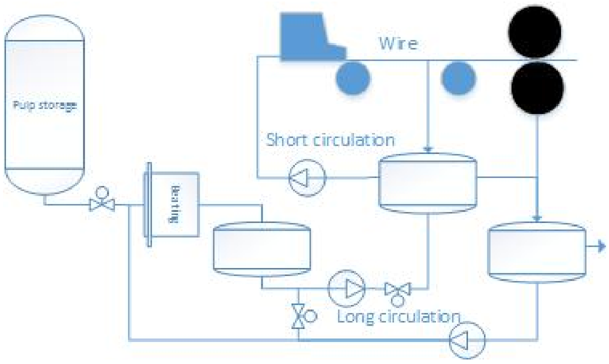

Figure 1, Stock preparation process to press section.

PROCESS MODEL

The dynamical process model is developed in Modelica [2] using Dymola [3] as simulator. Modelling components from the commercially available VISA [4] model library are used to build the model of the process in Figure 1. The model is composed by the following components:

- A pulp storage tank modelled as an infinite reservoir of pulp
- Pulp refiner
- Headbox and wire
- Press section
- Pumps and valves
- Controllers (LC, FC, QC)
- A pulp medium consisting of water, unbeaten fibre, beaten fibre and fines.

Pulp refiner model

The pulp refiner model refines the unbeaten fibre from the pulp storage tank into different components (unbeaten, beaten and fines). Students can change the refining by adjusting specific energy [kWh/tonnes] and Specific edge load (SEL) [J/m], the later corresponding to, for example, a change of refiner discs.

Generation of beaten fibre from unbeaten fibre is based on a beating factor and the beating factor is calculated as a function of refiner power and SEL. In a similar way the generation of fines from beaten fibre is calculated as a function of refiner power and SEL. No generation of fines occur directly from unbeaten fibre.

Calibration of the refiner model is done against measurement data using trends for specific refining energy vs tensile index at different specific edge load (SEL) [6], [7]. Furthermore, general trend of tensile index vs fines content [8] and specific energy vs. Schopper-Riegler [9] are used in the calibration phase.

WIRE MODEL

The wire model consists of a series of foil boxes that extracts the water from the pulp. In the current model the wire is represented with five foil boxes in series. Pulp drainability is quantified using the Schopper-Riegler number and the actual water leaving the wire foilbox to the short circulation is calculated and calibrated against measurement data.

In the visualization of the process shown in Figure 1 the dry line position is calculated and shown. The dry line (often also called the wet line) is the boundary between the reflecting and non-reflecting regions of the upper surface of the fibre mat on a wire.

CLOUD BASED SIMULATIONS - EVERYSIM

Everysim is an application that provides a framework for commissioning simulation based education to the web. Everysim supports six main functions that to a large extent fulfils the requirements outlined in chapter Requirements:

1, Using dynamical models

2, Graphical user interfaces (GUI)

3, Real time acceleration of simulations

4, Scenario based education setup and execution

5, Student follow-up and teacher student interaction

6, 24-7 access using a web browser on device of choice

Dynamical models are built in the Modelica language and compiled in Dymola. The graphical user interface (or operator interface) is built up in Inkscape™ mainly using a predefined graphical .svg object library that is supplied with everysim. This enables easy design of realistic user interfaces. A distributed shared memory, DSHM, [4] is used for data exchange between user-graphical interface-simulation model. DSHM also synchronises the simulation time with real time.

All files required to generate an everysim simulation are easily moved to the cloud using drag and drop from a local repository directly into the web browser. The built-in possibilities to design student training scenarios directly in the web browser in everysim enabled direct and easy transfer of requirements and ideas from the "story" into pedagogically designed tasks and missions.

When working with education the ability to check on student progress is an important feature. In everysim it is possible for the teacher, as administrator, to view the progress of each student. For example, the teacher can view time trends of process states (pressure, temperature etc) during a task, how long time the student needed to complete the task, and how well the student completed the task (e.g. threshold value compared with achieved value). In addition, it is possible to design a questioner to further test knowledge.

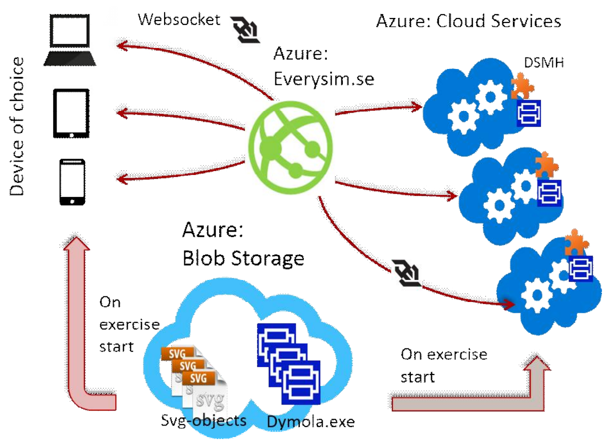

Figure 2, Overview of everysim architecture.

Everysim is a fully cloud-based application where the website, storage and cloud services are all placed in Microsoft Azure. Each user work through everysim.se and will get a dedicated cloud service (or instance) when an exercise is allocated. When an exercise starts the graphical objects (svg-files) will be uploaded on the client and the simulation model will be loaded into the dedicated cloud service.

The communication between the client and the cloud service uses Websocket in order to manage connection and enable interaction of up to several thousands of triggers in the simulation model. Communication speed is a crucial aspect of Everysim where real-time (or near real-time) simulations are required in order to achieve a realistic operator feedback.

Since Everysim is a web application scalability is inherent. Adding new users is very easy and fast and do not require hardware upgrades or software installations. Furthermore, all changes in the simulation solution are managed in one place and updates are pushed through the environment to all users at once.

STUDENT TRIAL AND RESULTS

Students were introduced to the subject in several theoretical lectures before entering the simulation. The simulation was performed in two double lectures with a 15 min break. These lectures were initiated by explaining implemented algorithms (models), regulatory options, visualisation of responses and assumptions made in the model as well login requirements.

The exercise was divided in different sections starting with a task to control the first refiner (task I). The students were asked to deliver two charts; paper strength (tensile index) and dewatering capacity vs specific refining energy at different SEL. Regulation was limited to specific refining energy (specifik energi, Figure 3) and different SEL (kantbelastning, Figure 3). The charts were made in excel and would then be used to manage later tasks in the simulation. This part of the simulation was ended by questions regarding refining and issues not implemented in the model.

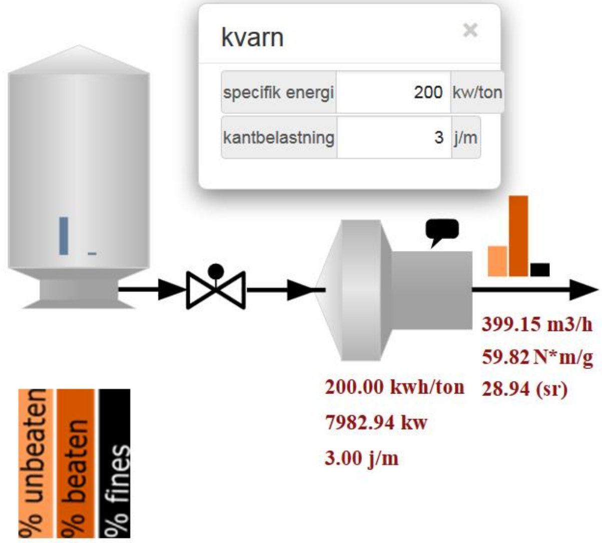

Figure 3 Refiner interface (kvarn in Swedish) with input dialog box open.

The following parts of the simulation utilized the full model and the question to be answered was; what production level can be reached with maximum paper strength at headbox concentration 0.3% (task IIa) and 0.2% (task IIb)? The regulatory option was to adjust the refiner, and the flow (FC004, Figure 4) to the headbox. After completing this task, an option to regulate an upstream pulp concentration (QC004, Figure 4) was introduced using a fixed headbox concentration of 0.3% (task IIc).

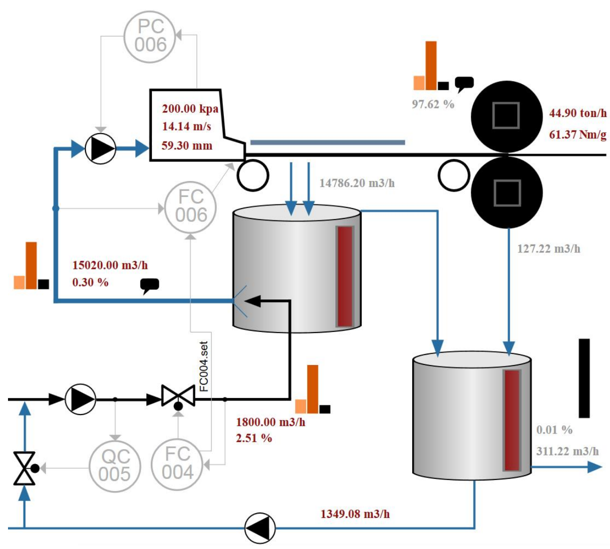

Figure 4 Graphical interface of stock preparation process to press section.

The intended learning outcome was; lowered dewatering requirement at higher concentrations give higher production. Maximum production was defined by the limitation in the dewatering capacity on the paper machine, illustrated by the “dry line” and when moved to close to the press section, terminating production. The termination was mimicking a break in paper production which can be restored with proper settings.

This section was also followed by questions related to drawbacks using high concentrations in headbox and during formation. In the last exercise, students were asked to optimize the production at a fixed refining energy (250 kWh/t) and a minimum required strength (70 Nm/g). Optimization was performed at two levels of retention 90% (taskIIIa) and 98% (taskIIIb). All regulatory options were available in this exercise.

It was challenging to moderate the simulation at the accelerated speed of 50 times real-time that most students selected to use. In the end all students submitted a report with results and reflections on the exercise.

The entire exercise excluding the “follow up” answers can be summarized in one plot, Figure 5. The plot shows the maximum production level achieved by individual students in the different tasks.

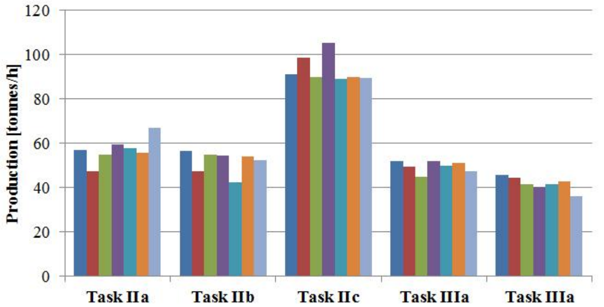

Figure 5, **Distribution of results from the production simulations (task II and III).**

Despite limited time to complete all tasks, students reached steady state with their selected settings using accelerated speed. The wide distribution of results is expected as the dynamic simulation will give different optima depending on how the optimization was made. Going from high to low setting on one parameter and the order and time of adjustments will give different results.

The realistic simulation requires a systematic approach using design of experiment to achieve less variation and higher production level. Further developments of the simulator would implement possibility to control and adjust retention-formation relationships and introduce graphical representation of pulp/stock and paper formation on the wire. These graphical representations would be simplified cross sections describing fibre distributions, fillers etc. as well as selected paper properties.

Finally, as teachers it was appreciated that no installations were required. A procedure normally requiring ordering of software installation to the IT-service, and thereafter, testing of the installed software in student computer labs.

CONCLUSIONS

In this study we can conclude that elements of gamification adds value to simulation based education. The response from students was encouraging requesting simulations as complement to more traditional teaching.

The students participating in this study had good insights in a variety of unit operations in the pulp and paper manufacturing but little or no experience of automatic control. Due to the design of tasks and exercises in everysim students were forced to adjust and run PID controllers in a factory-like interface (control faceplate). We believe this to be a valuable first introduction to automatic control on a very practical level and hope that it enlightens the importance of automatic control of dynamical processes.

We can also conclude that the adopted cloud based approach was essential in order to minimize administration of simulations and achieve high accessibility. Even though the implemented high level of accessibility was not fully explored from a user (student) perspective it was very much utilized in the implementation phase of the model and story.

ACKNOWLEDGMENT

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