The Process-Simulation.Center

Prototype of an Integrated Management System for Research, Lectures, and Practice

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***Abstract*—Sustainability and plurality continue to gain significance for society and companies. Thus, the consequences of management decisions on environment and people must be predicted and optimized. To this end, multiperspective simulations of various aspects of dynamic systems become more and more important. There is need for adequate tools, and for people to conduct this challenging modeling and simulation work. The Process-Simulation.Center is an Integrated Management System for company-wide documentation and simulation of (business) processes using Petri nets, process maps and organizational charts. It stores the models in a central database, the P-S.C Cloud, and allows all members of an organization to access the models according to an elaborated rights concept. To ensure regulatory requirements, the models run through an approval process. These aspects distinguishes the Process-Simulation.Center from other university projects to develop software for modeling and simulation, and enable new applications of the Petri net methodology. This article presents the current prototype and its application in research, lectures, and practice.**

***Keywords*—Prototype; Petri Nets; Process Map; Organigram; Integrated Management System.**

I. INTRODUCTION

Business information systems are build on the base of process, data, and organizational models and an integration of these perspectives. Processes are typically modeled using BPMN, as EPC, and rarely as flowcharts [1]. Petri nets are semantically richer. They facilitate analyses, complex simulations, and hence deep integration of the previously mentioned views. Surprisingly they are used more rarely. Probably there is a need to automatically enrich given other models to make this method more popular.

Illustrative teaching on Petri nets requires the use of software for modeling, simulation, and analysis. However, an evaluation of 91 Petri net tools published in [2] shows that these tools, typically developed at universities, are outdated or nor longer maintained. In [1], deficits in (also commercial) process management software with regard to resource-dependent simulation were also pointed out.

The works [3] and [4] explain how to teach basic Petri net modeling techniques, but exclude how to embed such models in Integrated Management Systems (IMS) and how to collaborate within such tools. A low-threshold offer for the use of an Integrated Management System based on Petri nets is missing so far.

This situation led to the development of the Process-Simulation.Center (*P-S.C*, [5]. It may be used free of charge by academic users. Other users can get a free trial access for three months. The *P-S.C* is currently denoted as a prototype following the notion of a prototype's definition [6]. It is used to test essential elements and functions of Highly Integrated Management Systems (HIMS), in particular cross-model and resource-dependent simulations, impossible with existing systems. As proposed during the presentation of [7] at the SIMUL 2021 conference, a multilingual user interface is also implemented.

Models are stored in the *P-S.C Cloud*. Users in the same mandators can edit their models together. The following functionalities have been implemented in the prototype, and are presented in more detail in this article:

1) The *P-S.C* features several products which allow for defining mandators for different target groups such as academics or companies.
2) Users of a mandator may have different authorization.
3) An approval workflow uses these different authorization concepts, thus, and models possess a life cycle. Changes to the models are tracked in a history.
4) Users may be grouped together.
5) The access to the models is controlled with the aid of user and group rights.

With the implementation of these concepts, the *P-S.C* now fulfills important requirements of Integrated Management Systems. Through this, also new teaching and learning content can be made tangible. The concrete technical and didactical implementation will be addressed in the following sections, inviting colleagues to also use the *P-S.C* in teaching and in their own projects.

The following Section II explains the development steps as well as the current status of the *P-S.C*. Then, the new mandator concept and the possibilities to organize users and models within a mandator are presented in Section III. Section IV explains the novel authorization concepts and the approval process. How to use the *P-S.C* on a daily basis is presented in Section V and how to gain the respective visualization for a simulated process is presented in Section VI. The paper closes with a conclusion and an outlook in Section VII.

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II. Development of the P-S.C

The *P-S.C* is a tool for modeling and simulation of the structural and process-oriented organization of companies. For several years, the prototype is already in use for research, teaching, and industry transfer projects at Worms University. The development process combines recommendations of the Design Science Research Guidelines [8] and evolutionary prototyping [9].

Figure 1 shows the development stages of the prototype over the years. The *P-S.C* is constantly being further developed. In the last 18 months, key functions have been introduced which are the core elements of Integrated Management Systems.

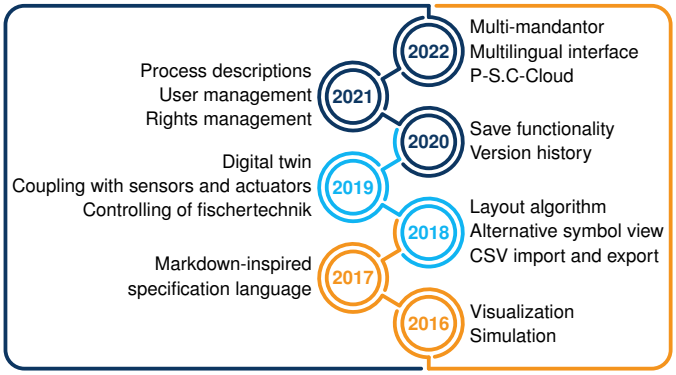

Figure 1. Milestones by Year.

The development of the *P-S.C* began in 2016 through the visualization of Petri nets in a web-based environment. In the first two years, the foundation for the later work was laid, in which Petri nets became simulatable and a markdown-inspired language for the specification of complex models was created. Meanwhile, the *P-S.C* is a tool for modeling and simulating simple and higher Petri nets with integration of swimlanes, for creating organizational charts, and for combining models using process maps (cf. [10]).

Since 2018, a layout algorithm accelerates the model development and makes it much faster compared to typical point-and-click UIs. Alternative symbols taken from the Font-awesome font set can be used to illustrate the models, and a CSV interface makes it easy to import data and export simulation results (cf. [11]).

Installed locally on a Raspberry Pi, the *P-S.C* has been able to access the GPIO interface of the Raspi since 2019. This way it may interact with external devices such as fischertechnik and can be used for plant control (cf. [12]) and as a digital twin. In addition to these techniques, case studies that explain how to create enterprise-wide process models, how to identify bottlenecks according to the Theory of Constraints, and how to simulate push and pull strategies in production processes have been integrated in the tool's internal tutorial.

Ever since the beginning of the development, this (internal) tutorial is constantly maintained and further developed. More than 80 examples explain how to use the tool, model with Petri nets, and solve challenging problems of dynamic systems with the aid of simulation.

The newly introduced *P-S.C Cloud* provides a simple way to store users' own models. In combination with the mandator concept, an authorization concept and an approval process have been implemented. Both are used extensively in teaching. Classes of students can be separated into groups. Exercises are assigned exclusively to the groups, and feedback is given using the approval process. Exercises, solutions, and feedback can be layouted with HTML5. Hence, techniques typically known from IMS are used to support learning processes.

In the meantime, more than 300 students have learned and worked using their own *P-S.C*-account. Their experiences and those gained through transfer projects with companies have been valuable sources for new requirements for the prototype.

The *P-S.C* has facilitated the development of new modeling and simulation techniques that have been presented on several international conferences. Especially at the SIMUL 2021, there was a request for a multilingual User Interface which has been fulfilled as of now. In addition to German, an English version of the *P-S.C* is available with the systems in place to support more.

To increase the visibility of this research work, the Group for Applied Process Simulation (GAPS) was founded at Worms University [13].

The most recently implemented milestones will be explained next in more detail in the course of this paper, and an outlook on the next steps will be given.

III. Mandators, Roles, Groups

The *P-S.C Cloud* is set up to serve different mandators simultaneously. As requested for a multi-mandator-capable system in [14], in the *P-S.C* the users of the different mandators can work without mutual insight into other peoples' data as if the environment were exclusively available to them.

The *P-S.C* supports various types of mandators for academic and professional purposes that account for different product categories. A first special (internal) mandator is *Tutorial*. A second special mandator is *Public*. It allows users to experience the possibilities of the *P-S.C* regarding modeling and simulation. Guests receive an account which is valid for three months and offers a limited number of own models separated from other users. They also have full access to the tutorial.

In all other mandators, several users can work together. Distinguished users with special roles can assign rights and duties and have the possibility to administrate their mandator as explained for mandator *Academic* next:

Mandator *Academic* establishes the roles *Admin*, *Lecturer* and *Student*: *Admin* users can add other users and define their roles. *Lecturer* users define learning groups and assign (other) users to them. They also create models or assign new modeling tasks in the descriptions of models that are assigned to the different groups. *Lecturer* users can also codify the user and group rights of models and, thus, their visibility within the mandator. Finally, they play a decisive role in the approval process. *Student* users have full access to the tutorial, work together in their groups, can submit solutions by requesting

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approval for their models, or take on specific responsibilities as process owners within their group.

The processes around enrollment and organization of learning groups are shown in Figure 2, where the *places* represent the information that arises, and the *transitions* represent the activities conducted according to the *swimlanes*: new users that register with the system initially receive a *Guest* role. If the registration mail address is related to an Academic mandate, an *Admin* user can enroll *Guest* users in the corresponding mandator and assign *Lecturer* or *Student* roles. *Lecturer* users then can define groups and assign *Student* users to them.

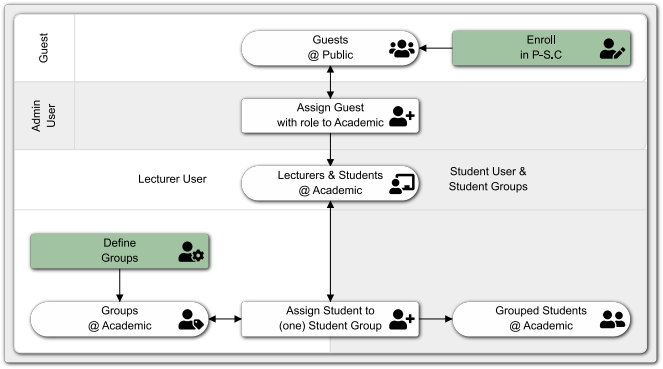

Figure 2. Petri Net Model: Enroll in Mandators and Organize Learning Groups (P-S.C export)

IV. Models, Rights, and Approval Process

Within a mandator, rights control which users may access which models. The following access modes are distinguished:

1) View a model without its specification.
2) Comment on a model.
3) See a model including its specification.
4) Simulate a model.
5) Change the working version of a model.
6) Ask for approval of a model.

In the current prototype, models cannot yet be commented.

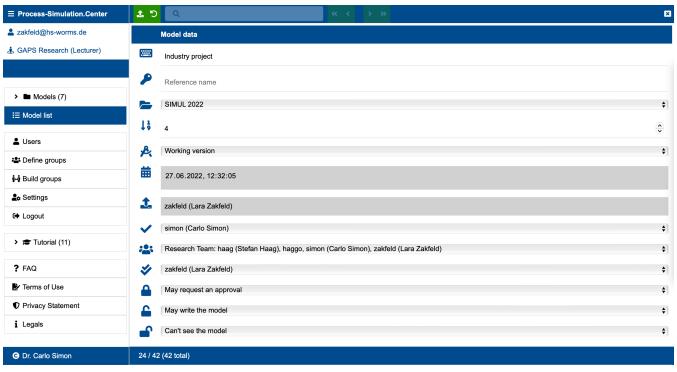

Figure 3. Rights Management of a Model (P-S.C Screenshot)

The *P-S.C*-screenshot in Figure 3 shows the possible settings per model. The rights can be defined separately for the process owner (🔒), users of the group (🔓) and all other users (🔓) where the opening of the lock symbolizes the extension of the numbers of users that might have access. The *P-S.C* adopts the most general right of a user that holds with respect to a specific model.

For all kinds of the aforementioned users, the different six rights are simply codified with the aid of drop-down menus. Also, other settings for each model can be made here.

Lecturer users can create new models, assign them to other users and groups, obligate a process owner, and also give permission to other interested members.

Models are initially created as *Working version*. When students have solved their modeling task, they release it for approval which is expressed by the state *Approval requested*. *Lecturer* users and the *Student* users can revoke the request for their own models, but *Lecturer* users also may accept the request and the model state changes to *Approved*. If a further working version is created for the model and the approval process is executed another time, formerly approved versions change their state to *Archived*. These models can still be read from the history log.

V. The Process-Simulation.Center Our Simulation Lab

The following insights in how the working group GAPS uses the tool might give a better comprehension of its possibilities. The tool is used for research, teaching and in first industrial projects. To separate these concerns from each other, each work focus has its own mandator. Currently, GAPS uses four active *P-S.C* mandators in parallel:

- The *GAPS* research mandator.
- *Academic* mandators for two different student groups.
- A mandator *Consulting* for an industry project.

Figure 4 shows a screenshot of the *P-S.C* with the (foldable) menu on the left side. The entire user interface and the settings are now available in German and English. Further languages can be added easily if required.

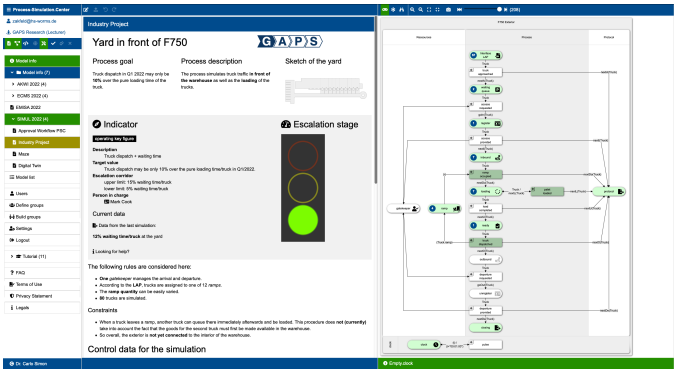

Figure 4. English user interface of the *P-S.C* (P-S.C Screenshot)

For each model, there are three views (from left to right):

- A model description.
- The model as a graph.

- The model specification codified in a special markdown language (not shown here).

This operating concept that differs from usual point-and-click interfaces, facilitates a rapid development of complex scenarios with a consistent visual appearance because of the implemented layout algorithms.

VI. From Model to Visualization

Modeling processes, running simulations, and presenting results in an appealing and helpful visualization outlines the entire journey along the simulation pipeline [15]. Due to the last development steps, this is fully possible in the *P-S.C*. Important functional elements of *P-S.C* coalesce. The CSV interface enables the use of externally provided simulation input data, tracking of the Petri net firing sequences, and an export of the markings of specific places. This data can then be visualized in external BI tools. One medium-term goal is a lively, automatically generated visualization based on the real data within the tool itself.

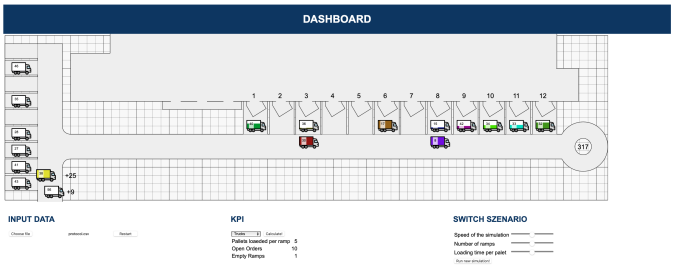

Figure 5. Dashboard Visualization of a Warehouse Front Yard

As an example, Figure 5 illustrates how to derive a visualization from a simulation model with a dashboard - in this case the yard of a warehouse (the model depicted in Figure 4). This approach enables people to see and understand data [16], offers a visual uniform representation and gives an active assistance to decision makers on the basis of current data [10].

What is represented here is the simplification of a real world example. A logistics provider simulates possible scenarios of an upcoming warehouse with the *P-S.C*. The Petri net of Figure 4 simulates all movements of trucks and protocols them on place *Protocol* at the right border. These series of numbers are exported and then translated into an animated dashboard where all truck movements can be observed. Due to the general nature of Petri nets, application to any other industries and processes are also possible.

An appealing visualization quickly awakens new ideas and user needs such as an interactive dashboard where input into the dashboard is looped back into the simulation. Likely, this will be a future requirement for the *P-S.C*. A short-term requirement for the tool that can be seen as a preparatory step is: having interactive elements for the description, for example a monitor for the current filling of a specific place.

VII. Conclusion

The development phases show a constantly evolving prototype. New features are evaluated in terms of their cost-benefit ratio in terms of new opportunities for users. Good examples are the multilingual user interface or the *P-S.C Cloud*, which facilitate the use of the tool for each group.

Such new features also enable students to use the *P-S.C* for intra-corporate theses. Some of the scenarios they have to model in their companies are also challenging from a research perspective, especially if they face multiperspective considerations and problems how to increase sustainability.

The working group observes that formerly separated activities merge and that in a next step this multidisciplinarity opens new fields of applications also for other industries.

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