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Graphical Layout Planning Module within a Semantic Web Framework for Modelling and Simulation

Modul zur graphischen Layoutplanung für eine Semantic-Web-Plattform zur Modellierung und Simulation

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Abstract: Based on an existing Semantic Web Framework for Modelling and Simulation the authors have developed a module to support the graphical layout planning of manufacturing systems in order to reduce the overall modelling and simulation effort. The benefit from the module is (a) to support the layout designer with the experience knowledge of other experts and project members that can be considered as constraints for the layout design and (b) therewith indirectly to consider the expert knowledge into the simulation model through the provision of the layout variants' results for the modelling and simulation.

1 Introduction

The process of design and development of manufacturing systems is characterized by the involvement of many project members who are utilising various software applications. When applying simulation to support these processes, the use of correct and accurate information is essential. Thus, an efficient and reliable link between the project members' applications and the simulation model is an extreme advantage, especially when different scenarios based on the variation of a parameter like product variants, technologies, production portfolio, or resource capacities have to be considered.

A core element of the manufacturing shop floor planning is the layout, as it depends on many parameters and allows for a very efficient communication among the project members. Unfortunately, in "real-world" planning projects, the constraints related to the layout design cannot be systematically used for capacity planning or material flow simulation, as they are not being formally documented. This leads to the risk that planning results do not match the prerequisites. In order to integrate the layout more closely with the planning information and to enable a flawless supply of the simulation experts with the updated information emerging from different layout variants, the Semantic Web Framework for Modelling and Simulation (SWFMS) developed by Fraunhofer IPK (RABE, GOCEV 2008a) has been extended with a module for Semantic Graphical Layout Planning (SGLP).

This paper is structured as follows: Chapter 2 gives a short overview of related work and the chapter 3 explains the SWFMS as the base for the plug-in development. The next two chapters define the functionalities of the graphical layout planning and their realisation within the SWFMS as a module for Semantic Graphical Layout Planning (SGLP).

2 State of the Art – Layout Planning and Constraints

The challenge during the preparation of a simulation study is to enable and support the project members in rapid development of layout variants in the early phase of the simulation project. Besides the material flow requirements, additional restrictions influence the spatial allocation of the layout objects like building, technical, economical, safety and legal issues (KETTNER, SCHMIDT, GREIM 1984, p. 239). The existing comprehensive solutions for layout planning as a part of the digital factory paradigm like Tecnomatix (SIEMENS 2010) and Delmia (3DS 2010) or CAD solutions like MicroStation (BENTLEY 2010) or JobDispo FAP (FAUSER 2010) focus on the constructive design process and thus on the development of detailed layout models necessary for later phases of factory planning. But, they hardly provide support for the formal and explicit modelling of the restrictions (constraints) that influence the layout design.

Most of the scientific methods for the facility layout problem are oriented towards the automated solution finding based on heuristic and meta-heuristic methods. A comprehensive overview of the available approaches like simulated annealing or genetic algorithms is given by (SING, SHARMA 2006). The biggest challenge of all these solutions is to provide a method for modelling the constraints which will be easy understandable and widely accepted by the human, but at the same time executable by machines.

The semantic web technologies (SW 2010) are addressing this gap by offering a possibility to model statements in the form of a triple subject-predicate-object. This construct, combined with the universal quantifier-$\forall$ and the existential quantifier-$\exists$ offers a base for modelling restrictions within an ontology that is understandable by human and executable by inference engines. Moreover, the semantic web technologies offer a modelling of rules in IF-THEN form upon which new triples can be generated, or constraints that can be evaluated on true or false. Still, no example has been found regarding the layout planning and material flow simulation. Referring to this, a solution for an interactive assistance system has been published which focuses on architectural design (HOFFMAN 2007). However, in the related implementation the available constraints are hard-coded and can thus not be adapted by the experts to specific requirements.

3 Semantic Web Framework for Modelling and Simulation

The Semantic Web Framework for Modelling and Simulation (SWFMS) is a set of ontologies that support the share and reuse of knowledge within the manufacturing domain. It is based on semantic web technologies like Resource Description Framework (RDF) and Web Ontology Language (OWL) and structured upon the widely accepted standard ISA-95 (2001). The platform offers a possibility to integrate information with different structures and notations within one company-specific Manufacturing Knowledge Base – MKB (RABE, GOCEV 2008b). Besides the possibility to model structures, concepts and instances of one particular manufacturing system, the semantic web technologies offer the possibility to explicitly describe the constraints that are characteristic for the manufacturing system. Therewith, multifaceted views for the project members and different roles can be obtained. Moreover, the SWFMS offers a basis for enrichment of the existing knowledge under the utilization of rules and deploying the predicate logic. As a result the project members are supported and enabled to generate the necessary information for the simulation of different scenarios in shorter time.

The core of the SWFMS is a manufacturing ontology (OWL-M). The classes and sub-classes are defined to structure the objects (e. g. process segments, products, machines, fixtures, etc.) as well as the work description. The relations between the instances are described as a triple subject-predicate-object.

4 Functionalities of a Layout Planning Module needed for Modelling and Simulation

A very common practice is to sketch the rough block-layout in the early phase of the project using a simple graphics application like MS Visio or MS PowerPoint. After finishing the layout planning; the simulation is provided with information about each layout variant. This includes e. g. the distances between machines and workstations, the areas around them for safety, handling and service, the assigned number of buffer places for the work in progress (WIP) as well as the maximum possible WIP area capacity. This information is usually delivered by the layout planner in additional spreadsheets which are neither explicitly related nor automatically updated with the changes on the particular layout. The information can be used by the simulation expert only after additional advice by the layout designer and other experts involved in the project. An even more critical issue is that the information acquired during the process of layout design and development, especially the gained experience about the constraints due to the layout, are documented implicitly and very often as casual statements within project documentations and team presentations. For example, the statement that two machines have to be placed at a minimum distance of 15 m is either kept by project members as experience knowledge or resides on some slide on a presentation from the project members meeting.

Summarizing, the following functionalities are required to be implemented within a SWFM:

- Modelling of an experience knowledge of experts that are not directly involved in the process of layout planning in form of constraints that could influence the layout design and development,
- Prompt alerting of the layout designer if constraints have been violated,
- Preparation of information from layout variants for the simulation.

These functionalities have been implemented as an extension of the Semantic Web Platform for Modelling and Simulation in the form of a module for Semantic Graphical Layout Planning.

5 Module for Semantic Graphical Layout Planning

5.1 Graphical User Interface and Reference Ontology

The module for Semantic Graphical Layout Planning (SGLP) is implemented in Java into the Eclipse environment and plugged-in to the SWFMS. It is developed for the support of layout planning in the early phase of a factory planning project and therewith depicts the planning area and the objects as simple textured rectangles only. The objects to be visualized on the layout are described within the MKB in the class of resources or in related sub-classes. The following manufacturing system elements can be visualized, manipulated, and positioned within the layout: Shop floor plan of the manufacturing area, machines, workstations, machine areas for handling and service, WIP buffer areas, material flow paths, as well as special areas and textual objects. In order to foster the visualisation, a picture of each resource can be attached to the objects and will then be displayed on the shop floor (Figure 1).

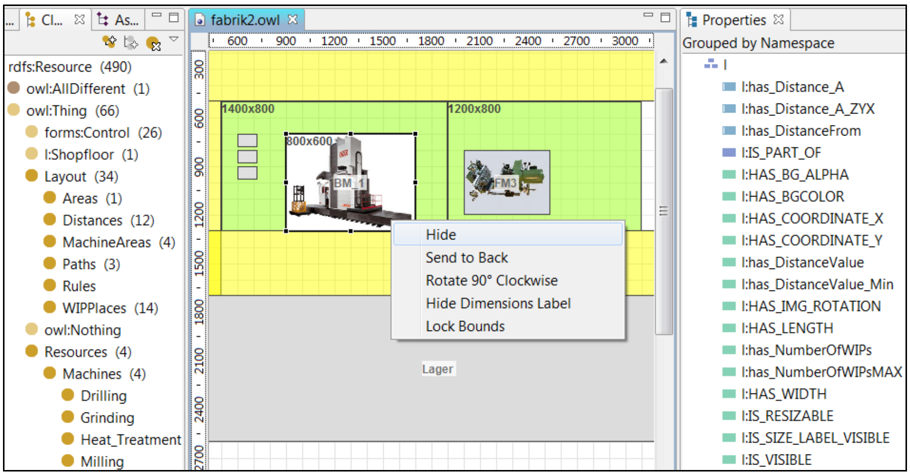

***Figure 1**: Semantic Graphical Layout Planning Module*

The relations between the resources to be displayed graphically and the module for SGLP are realised through the reference ontology *Fabriklayout.owl* which is imported into the MKB. Therewith the objects of the MKB are enriched by properties like the coordinates x and y, dimensions for length and width, rotation position expressing the angle related to the x-axle, colour defined as a standard RGB value, lock/unlock for ability to resize the object, etc. (Figure 2). Each machine belongs to a machine area that can also include other objects like WIP buffers or areas for transportation, handling and safety. The objects are related to the machine area with the property*: isPartOf*. As a result of any manipulation of the machine area on the layout like move and rotate, the actions are automatically assigned to the encapsulated objects and they are moved and rotated accordingly

The dimensions of the machine areas can be either calculated for each machine according to a given relation that considers the handling and service area needed around the machine, or can be arranged by the layout designer. If a buffer area is dedicated to the machine, the machine area has to be extended, too.

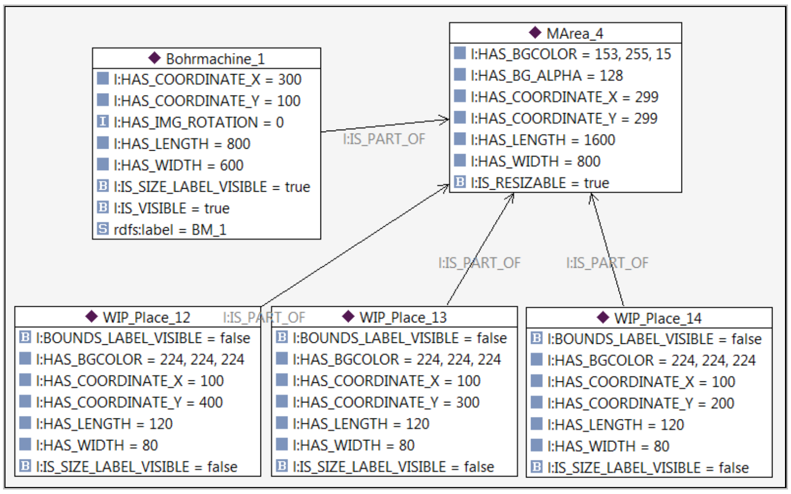

Figure 2*: Fabriklayout.owl – An example with an overview of the properties*

The requirement for functionalities as described in the Chapter 4 has triggered a development of other properties needed to describe additional relations between the objects. These properties are essential for modelling of the constraints like for the expression of minimum allowed distances between two machine areas, maximum possible WIP buffer places within a machine area, etc. Due to the standard language used for the ontology development, further constraints can be added, e.g. about the minimum width of transport areas, required accessibility of gantry cranes etc.

5.2 Constraint-based Layout Planning

A challenging issue within the modelling and simulation project is to grasp the experience knowledge of the experts and project members and to formalize this knowledge. Usually, this demands time-consuming iterations of the design and development steps, which are needed for an evaluation of the layout design with respect to consistency. Moreover, time consuming meetings are needed to check if the constraints that are not formally documented have been considered in the layout design and therewith in the simulation. In order to reduce these iterations and to decrease the overall project efforts, a method for constraints modelling and their active inclusion into the layout design has been developed. The realisation of the constraint modelling has been performed in two ways.

The first method is the direct hard-coding of the constraints into the Java code of the Module for Semantic Graphical Layout Planning. An example for this solution is that the user cannot move a machine out of the resource area related with the property *isPartOf*. This method can be deployed for general system constraints that are not dependable from the manufacturing system to be planned. The disadvantage is that the whole knowledge about the rules and the constraints is hard-coded and can be manipulated by the IT developer only.

The second method of constraint modelling is more flexible and scalable, allowing a definition of the relations and constraints directly into the MKB by the modeller. It has been realised in the SPARQL Protocol and RDF Query Language (SPARQL) utilising the basic query forms as IF-conditions including threshold values that should not be violated. These conditions are to be modelled by the experts of particular domain as experience knowledge, defining parameters like: safety distances around the machines, safety distances between some machines, allowed noise on particular area, etc. During the layout design in the module for SGLP an inference engine monitors the constraints and generates an alert when a particular one is violated through some reaction of the layout designer. An example for a constraint is the minimum allowed distance between two machines. If the layout designer places the machines in a distance less than the allowed one, the inference engine generates an alert. The warning has been implemented in two different ways. The first is directly in the Java code of the SGLP with a method upon which the user cannot move one machine area to another one closer than the minimum distance defined by the constraint rule. The disadvantage of this solution is that for each particular constraint the Java code has to be changed. The second possibility is to send a message to the layout designer with an overview of the constraint that has been violated and the instances which caused that (Figure 3). The context of the message can be defined by the expert who modelled the constraint, but at the moment does not include the value of failure. This is very flexible method as there is no necessity to change the developing environment and no additional structures from the ontology have to be modelled in the Java code.

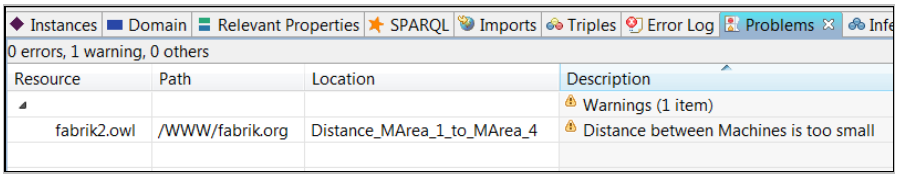

Figure 3: *A warning alert for constraint violation*

This set of properties and functionalities was found sufficient for a rapid development of block layout variants as a mean for communication within factory planning projects. The benefit from the module for Semantic Graphical Layout Planning is that any layout change is directly updated in the MKB, enabling:

- the decision and the information being in conformance with the numerous constraints entered in the MKB as experience knowledge, and
- updated information being available for the simulation.

5.3 Provision of the Information for Simulation

After the completion of the layout variants without alerts and non-conformances each layout element has a defined position and dimensions. The affiliation of the objects to a particular class of the MKB and the values for the coordinates and dimensions are used for calculation of the parameters needed for simulation. The computation of number of available machines, distances, path lengths, surface areas and WIP capacities is performed for each layout variant again by the inference engine based on the CONSTRUCT queries in SPARQL notation. Therewith, new statements in form of triples are generated which enrich the MKB and provide input values that can be directly read the simulation model.

6 Conclusions and Future Developments

The Semantic Web Platform for Modelling and Simulation has been extended with a Module for Semantic Graphical Layout Planning. With this module, the current and up-to-date values from the layout planning are automatically prepared for the simulation experiments. A method for constraint definition has been developed that enables to model the experience knowledge and expert information in the MKB. These constraints are used by the inference engine that infers upon the ontology and alerts the user if any constraints are violated. Therewith, the users without awareness on "small issues" that usually are kept by experienced experts, can properly, correctly, and quickly design and develop the layout variants. The prepared results from the layout planning about distances defined and available capacities are fed into the MKB. These are essential to perform simulation experiments upon the layout variants under consideration. The overall result is reduced effort and time for the simulation project and increased reliability of the simulation results.

The constraints can be related to all layout objects and can also be defined as a function of particular parameters as a part of the MKB. The change of those parameters is performed by the related domain experts and will always be considered when a new layout variant is planned.

The method developed and described in this paper is a first step in the development of factory planning advisors suitable not just for modelling and simulation but also for design and development of production and logistic systems in general. The future work will be focused on development of more complex constraints that can be used to define parts of the decision logic in the simulation model. Moreover, constraints related to the objects of product definition like bill of materials and process plans have to be studied. Additional developments are necessary to improve the clearness of communication to the user in case of constraint violation and the issues related to the update of the MKB by the domain experts.

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