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PICKING LINES MODELING

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Industrial settings like picking lines are confronted to the challenge of increasing the efficiency with automate detection systems, robots and optimization algorithms. In this context, there is a general necessity to represent their structure and behavior in an abstract way, in order to integrate data and to execute various simulations. The paper analyzes several paradigms used for modeling picking lines and it proposes an object-oriented environment based on concepts that are specific to distribution centers and picking lines, which constitute the abstract syntax of a new modeling language. They were used for configuring a model editor and creating models that may be interpreted for further processing and adaptation needed by the automation elements. An example of model is given for a pharmaceutical warehouse with a conveyor-based picking line featured with magnetic, optic, position and weighting sensors.

1. INTRODUCTION

One of the key issues for an efficient supply chain is to reduce the time a product stays in the warehouse, as well as the time required for its assignment to a customer order, including its picking and packaging. Stock keeping units (SKU's) may be distributed to fixed, dedicated locations, randomly or based on classes. The picking procedures can also be differentiated as: discrete collecting of orders one after another, assignment to certain zones of the warehouse, picking batches composed of multiple orders, or waves that depend on the shipping schedule [1]. The routes of the SKUs and of the pickers are very important for the optimization of a distribution center, often based on heuristic solutions [2].

Automation has a big contribution to the current solutions, using diverse technologies like: identification based on bar codes scanned and transmitted via a local network, picking directed by the workers' voice, lights that illuminate the next item to be picked, carts used for batch picking and distributing them according to multiple orders, conveyors that transport picking containers, horizontal carousels that increase the operations' speed, vertical carousels and lift modules meant to deal with a high density storage, automated storage and retrieval systems (ASRS) completely controlled by computers, or parcel sortation systems that indicate the correct destination area of the warehouse [3].

Another possibility is to replace the manual picking with a robotic arm, increasing both precision and speed with a three axial control. This may be especially useful for pick and place of extremely small parts, which otherwise need to be handled through a microscope [4]; such tasks need highly trained operators and may cause them vision and wrists problems.

Order picking consumes more than half of a warehouse expenses, due to the current trend to increase customization of products and the volume of individual distribution centers but, at the same time, due to the requirement of reducing the lot sizes and the distribution cycles. Therefore, these are objectives that compete to each other and the optimization problems become more complex.

Currently, besides the range of typical solutions adopted by industry, there are also academic studies that are mainly oriented towards procedural aspects, like routing, batching and zoning. However, the underlying structure of the distribution center is modeled non-homogenously and with ad-hoc defined models, as focus is given to the adaptation and optimization methods. We investigate in this article how object-oriented modeling based on a specific language may be used as a modeling paradigm that could be further interpreted and used as a foundation for applying and comparing various procedural solutions.

Chapter 2 analyzes several modeling paradigms applied for picking lines, including agent-based modeling, graphs, mathematical models, genetic algorithms, stochastic models etc. Chapter 3 describes the proposed object-oriented paradigm and the way it was formally defined as a full-feathered modeling language, with the correspondent editor and the possibility of integration with other processing tools. Chapter 4 applies this software for representing the model of a real life pharmaceutical warehouse, adding technical details for its automation units. Starting from the visual model we annotated each element with precise information extracted from the technical specifications and then we generated a description of the picking line in a standard interchangeable format, which is generally used for transmitting information between software applications.

2. MODELING PARADIGMS

Generally, the picking lines are not automated, but they have to be designed for optimizing the manual treatment of a large variety of orders. One possible approach is to assimilate the people working together to autonomous agents who make decisions and influence each other's behaviors. The cost and time of packaging may be considerably reduced by an appropriate distribution of the SKU, by an optimal assignment of the number of pickers and by avoiding congestions. Hagspihl and Visagie proposed the application of agent based modeling and simulation (ABMS) and for validation they use real-life data obtained from video recordings and time stamps [5]. The analyzed results were: the total packaging completion time, the critical limit of congestion, and a combination of them considered in the marginal analysis method. They used Java and XJ Techno-

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logies for simulations. Agent-based modeling assumes that humans or robots are autonomous agents that are capable to interact to each other within a well-defined environment, and who develop a behavior that influences the group. The applications are very diverse, from supply chains to organisms' cells or to the evolution of civilizations [6]. The software support applied for ABMS consists of spreadsheets, computational systems like MATLAB or Mathematica, general programming languages, but also specialized tools and geographical information systems (GIS).

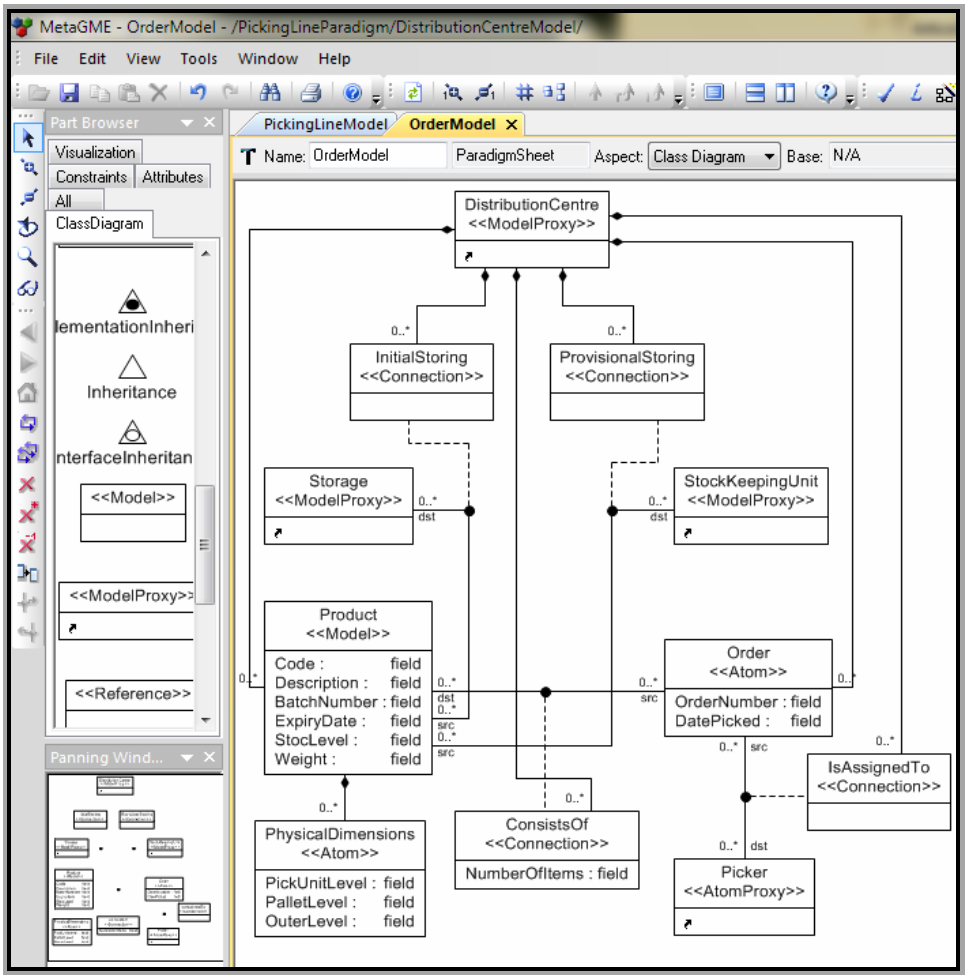

Fig. 1 – The order model paradigm sheet.

Renaud *et al*. modeled a conveyor belt system as a graph whose nodes were represented by the storage locations and the arcs indicated the distance between them [1]. Based on this model and a shortest path algorithm, they determined the optimum product location and several sorting rules.

Vonolfen *et al.* used multiple models for simulating a material handling scenario in a large production plant [7]. The storage optimization was based on a mathematical model for estimating the pick frequency / part affinity (PF/PA) score in respect with the provisional storage areas, and the distance between individual locations. The picking process was simulated using a discrete deterministic model implemented with AnyLogic^{TM}, considering the workers and the forklifts operated by them, whose routing was optimized within a simulation environment based on HeuristicLab. The transportation from the warehouse to the workstations was treated dynamically; it took into account distances and available resources as optimization constraints, but it could be improved with a stochastic model [8]. The route optimization was performed with a genetic algorithm that is similar to the dynamic Pickup and delivery problem with time windows (PDPTW).

A stochastic model of the order stream was applied in [9], considering the probability of a pick occurring at a given location and the space between locations. Thus, one estimated the walk distance for three design configurations: single-depot, dual-depots with conveyors and no-depot with conveyor and radio-frequency identification (RFID). Their simulations proved that a decision of technology investment has to take into account the picks density and homogeneity.

In this context, we investigated the advantages offered by the object-oriented orientation, as a generic possibility to formally define the underlying structure of a picking line and to use it for further modeling and simulation of its behavior.

3. OBJECT-ORIENTED MODELING PARADIGM

A general modeling language that is very well known is unified modeling language (UML), because it is also an adopted standard. It is based on concepts like classes, attributes, associations, generalizations – well-known by software engineers but quite far from the terminology currently used in application domains. That is why there is a new trend, to define domain specific languages that employ concepts familiar to domain experts and easy to understand and work with.

In our case, the purpose was to create a language that allows one to represent distribution centers and their picking lines in particular. For this purpose, we identified the main elements that should be used within the abstract representations, provided that they are domain specific, yet general enough to have a variety of individual instantiation forms. For example, an *order* can consist of several *products* and it has a specific *number* and a *date* when they are picked up. The typical attributes of a *product* are: *code, description, batch number / expiry date, physical dimensions, weight* and *stock levels* [10]. Therefore, these elements should be present in the abstract syntax of the modeling language as data types. Figure 1 illustrates how we represent the abstract syntax with the language editor of general modeling environment (GME) [11]. GME modeling elements are considered models composed of atomic, indivisible parts, and are represented as rectangles that may also contain a second compartment, including their main properties, called attributes. Besides, these elements may be related to each other. For example, a picker may be assigned to treat an order; therefore there is a connection between the *Order* and *Picker* concepts, as depicted in Fig. 1.

The proposed modeling language contains three important parts, formalized in what GME calls paradigm sheets and represented as distinct diagrams:

- *OrderModel* – a paradigm sheet for describing the above explained order treatment (see Fig. 1);
- *PickingLineModel* – a paradigm sheet for modeling the picking lines (see Fig. 2);
- *Instruments* – an existing paradigm imported and reused within this project.

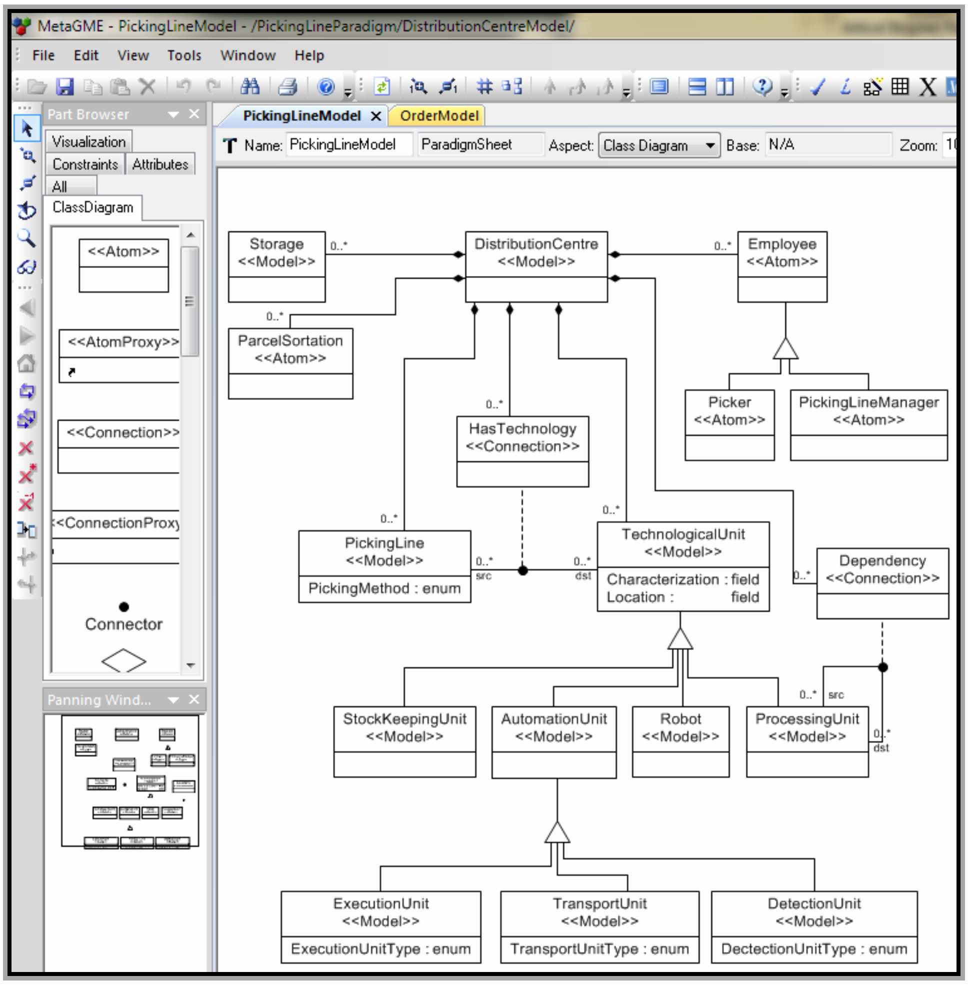

Fig. 2 – The picking line paradigm sheet.

The second paradigm contains a hierarchy of elements for modeling various technological units that accompany this part of the data center, like: detection units (which are the abstract representation of sensors, barcode scanners or RFID readers) or execution units (electrical engines, actuators, printers, sealing machines).

The third paradigm represents a generic characterization of measuring instruments and systems, and it was previously used in a data integration environment called EquiLAB, described in [12]. Its purpose was to create a library of models that may be used for parsing data acquired from non-homogeneous sources and integrate them into a common database for further processing. Apart from that, the visual models were also used for creating study materials for engineering students. The integration and reuse of the *Instruments* paradigm in the context of picking lines allows one to represent them from the point of view of their data model, but also to generate inputs for the existing data integration environment, *i.e.* for EquiLAB.

The ensemble of these paradigms was interpreted in

GME for generating a model editor that may be used not only for representing various picking lines, but also for generating a text file expressing their structure in an interchangeable format, available for being processed by other simulation algorithms. The editor notations were configured specifically for this application domain.

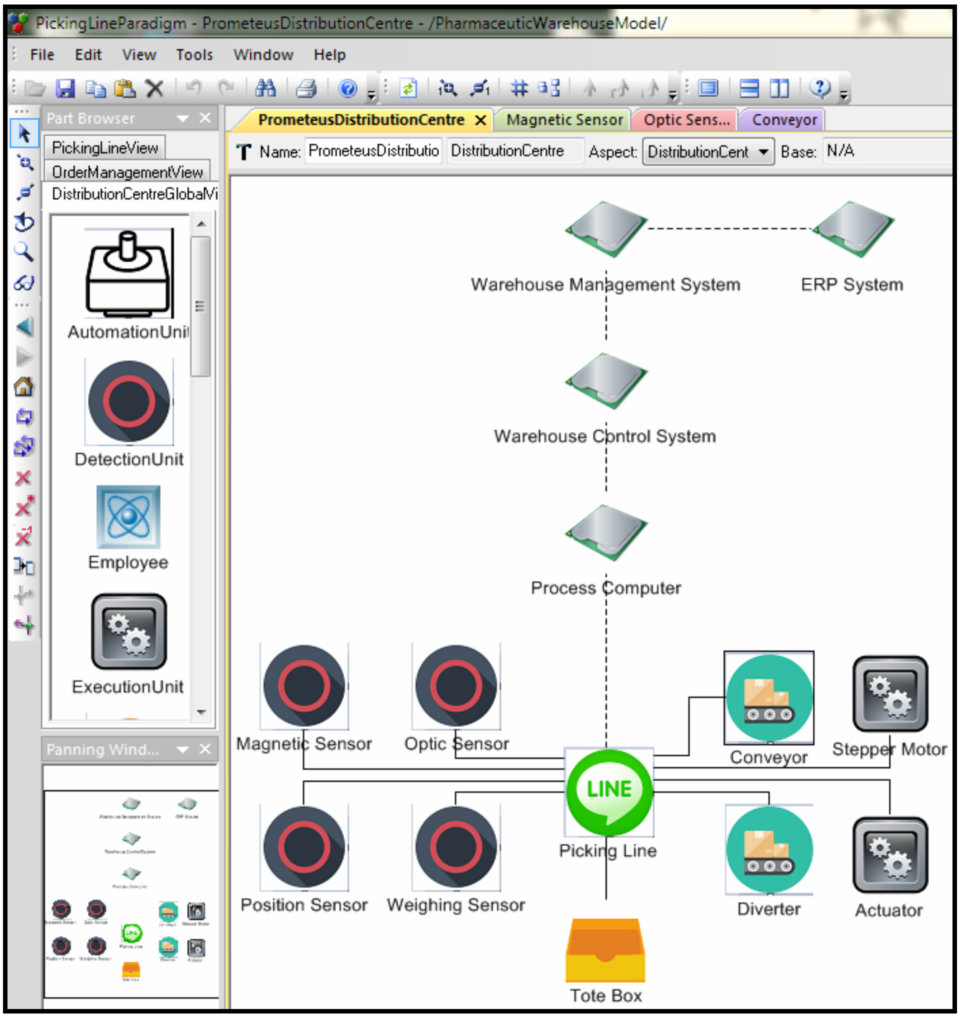

Fig. 3 – The main diagram of the pharmaceutical warehouse model.

4. PHARMACEUTICAL WAREHOUSE MODEL

The object-oriented modeling paradigm and its associated editor were used for representing an existing pharmaceutical warehouse, with its centralized software control and its distributed automation facilities. The system has a layered architecture, modeled in Fig. 3, which is composed of:

- a warehouse management upper-level, for establishing the picking, packaging and shipping processes; it is integrated with a general enterprise resource planning (ERP) system that takes over the customer orders;
- a system that controls the regular automation functionalities of the warehouse and the emergency situations;
- a process computer layer that ensures the interface between the upper information system and the lower hardware elements;
- command and control devices for implementing the picking line process, *i.e.* magnetic, optic, position and weighting sensors [13], stepper motors for conveyor operation, diverters, actuators etc.

We obtained a visual representation of the warehouse system, whose complexity led us to a collection of interrelated diagrams. Thus, starting from the model illustrated in Fig. 3 (where one used the concepts from the picking line paradigm sheet) we added particular representations based on the *Instruments* paradigm for the automation, transport, storage and execution units, according to their technical specifications (*e.g.* [14]) and to their capabilities to acquire data or to adapt in respect with various settings. A good illustration of this approach is represented on Fig. 4 that concerns the case of a magnetic sensor, frequently used in the conception and practical configuration of a pharmaceutical warehouse.

In the pharmaceutical warehouse there are various types of sensors, but magnetic sensors are used with priority. One of the main uses of these sensors is in the automotive system for sensing the position and the product box distance. There are two types of magnetic sensors, according to the physical effect that represents the basis of their operation: Reed sensors and Hall effect sensors. Although they are both magnetic proximity sensors, they are significantly different in the way they work. A Hall effect sensor is a three-wire, solid-state device, whose output changes when exposed to a magnetic field. A Reed sensor is a switch from the electrical point of view, with tiny contacts that open or close in the absence or presence of a magnetic field. In many applications either device could be used, but there are also some situations where one technology is preferable over the other. Reed sensors generally have very long life compared to other electromechanical devices, but they cannot match the virtually infinite life of a Hall effect sensor.

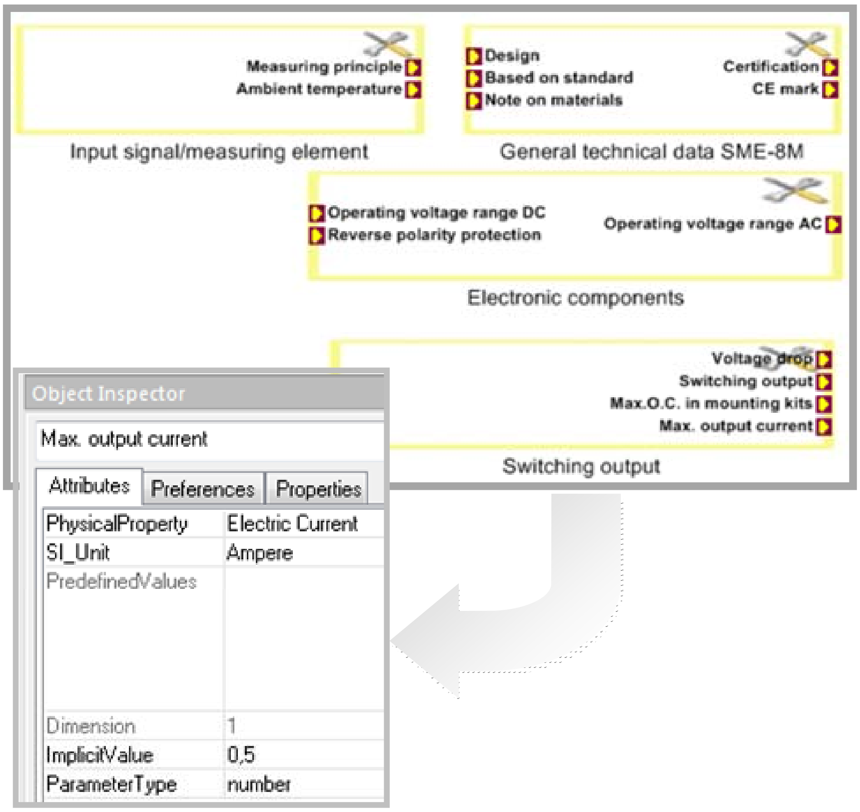

Fig. 4 – Technical details for the magnetic sensor.

Fig. 5 – Example of XML code generated from the GME model.

The editor also supports the generation of a hypertext description, by exporting all the diagrams to a single extensible markup language (XML) file (see a selection of print screens in Fig. 5). This facility is important for further integration with other tools, like EquiLAB for data integration, but also with systems that optimize the configuration of the picking line automation units.

5. CONCLUSION

A formal representation of warehouse architecture is essential for real-time monitoring of the numerous devices that control its operation, for early detection of errors and further analysis of logs in order to improve the processes and the overall quality of the system. The analysis of various paradigms applied for picking lines modeling and optimization, especially in academic approaches, shows that there is a clear need of a common description of the structural aspects, which may be obtained with the specific object-oriented language proposed in this paper.

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