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The application of virtual reality systems as a support of digital manufacturing and logistics

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Abstract. Modern trends in development of computer aided techniques are heading toward the integration of design competitive products and so-called "digital manufacturing and logistics", supported by computer simulation software. All phases of product lifecycle: starting from design of a new product, through planning and control of manufacturing, assembly, internal logistics and repairs, quality control, distribution to customers and after-sale service, up to its recycling or utilization should be aided and managed by advanced packages of product lifecycle management software. Important problems for providing the efficient flow of materials in supply chain management of whole product lifecycle, using computer simulation will be described on that paper. Authors will pay attention to the processes of acquiring relevant information and correct data, necessary for virtual modeling and computer simulation of integrated manufacturing and logistics systems. The article describes possibilities of use an applications of virtual reality software for modeling and simulation the production and logistics processes in enterprise in different aspects of product lifecycle management. The authors demonstrate effective method of creating computer simulations for digital manufacturing and logistics and show modeled and programmed examples and solutions. They pay attention to development trends and show options of the applications that go beyond enterprise.

1. Introduction

According to current trends of management the primary goal of any business is to manufacture products that meet customer needs in terms of usability, functionality and quality. Moreover the realization of logistics services related to efficient delivery of the product to customers and after-sales service are very important. Modern, automated and robotized production becomes one of the main subsystems of industrial logistics, which is located inside the integrated supply chain. In this sense, the supply chain includes all processes, activities and tasks associated with the flow of materials (raw materials, parts, semi-finished products, final products) in the direction from the supplier, through all the intermediate stages, to the client - classical logistics, and also the return paths (recyclable materials, packages, wastes) - reverse (eco)logistics. Providing the efficient flow of materials [1] requires the implementation of two-way flow of information between all participants in the supply chain (clients, traders, manufacturers, suppliers, transportation companies, warehouses and distribution centres, financial institutions). Additionally, in each stage of production and delivery it is necessary to make the right decisions in order to meet customer requirements and to provide the appropriate level of logistics services at acceptable cost and quality. Thus, the global and competitive market, forces managers to search for savings in every aspect of the company's activities, independently of the branch

in which it operates and the type of business. Aspiration to main goals of every enterprise are two things, first to satisfy the client needs and second to get an acceptable profit. These require quick response to clients' orders regarding to design and manufacture of new products and its delivery. In order to effectively production planning and enterprise managing in area of logistics (and even in a whole integrated supply chain) is to use a software, which helps to make proper logistics decisions, in various aspects of the enterprise activities, seems appropriate [2,3,4]. As examples, may be mentioned simulation software, dedicated to the production and logistics systems e.g.: Enterprise Dynamics - Logistic Suite, Flexsim, Roboguide, Process Simulate, Plant Simulation and other.

2. How to choose computer software to simulation of virtual production and logistics - problem of correct data acquisition for modelling and simulation

The computer simulation is an excellent method of representation a real system as a virtual reality model (e.g. manufacturing, internal or external logistics system etc. - please notice, that authors are trying to treat production system more widely, as a logistics system of the enterprise, sometimes even as a supply chain). The main goal of simulation is carrying out research and experiments on this model, in order to obtain some quantitative characteristics which describe the functioning of the system. The advantages of computer simulation in logistics are following: elimination of real hardware (equipment) during research, reduction of the research time in regard to the testing activities on a real object or system, repeatable conditions of the experiments, safety of the system during tests in extreme conditions, elimination of measurement errors associated with external factors, cost reduction and simplicity of parameters changes.

Applications of various simulation software can be used in autonomous, logistics systems management (e.g. educational production cells of technologically similar, typical parts, robotized rapid prototyping cell - micrologistics [2,3,5]; integrated stamping, painting and assembly line in automotive branch, cross-docking warehouse, conventional power plant - minilogistics [4]). Also, the same software, can be used in integrated supply chains management (e.g. exampled virtual enterprise, integrated "supply and delivery" transportation system, ecologistics systems - metalogistics /published in polish/; system of regional energy security, military logistics - macrologistics /not published own researches/). It affords the following opportunity:

- Analysis of manufacturing and logistics systems configuration options, conducting of experiments without the risk of bearing the real cost (besides software cost).
- Design, planning, (re)configuration and controlling of real business in virtual world.
- Widely understood optimization of any sized logistics system (from micro to macro logistics).
- Providing flexibility, repeatability and a high level of services in the solutions in the area of logistics activities in the supply chain.
- Minimization investment risk and reduction of the complex logistics costs.
- Predicting the working of the logistics system for future changes, disturbances and a new unknown challenges in supply chain.
- Using of simulation techniques and its results in lifelong learning of managers.
- Application of the computer simulations in other, untypical studies, depend only on the creativity of managers and researchers.

It is the undeniable true, of course, but we need required and correct information (data) which are concerned with the system which will be modelled [6,7]. It can be, more often, existing industrial logistics system (easier data acquisition - we know all important parameters of the system work, but we don't know all parameters of the future orders, however we have history of the orders – future orders can be similar). Rarely, it is a new logistics system which will be created in future (today designed factory, distribution centre, transportation enterprise, power plant, etc. - more difficult data acquisition, we know almost nothing. For example, it means that we weren't compete on the market, our logistics system wasn't automated as the implemented now etc.; so we have only prognosis of the customer market and only predictions about future work of the production system).

So, we need to collect all data connected with the similar products lifecycle from the past, in miscellaneous forms (e.g. using MIAS methodology [6]). Today, following the rules of computer integrated manufacturing and logistics - CIM/CIL and product lifecycle management - PLM, usually, we use the computer database files in standard format (CAD, CAE - engineering and assembly drawings, materials and strength parameters of the parts, static, kinematic, dynamic analysis of the product, etc.; CAM - technological operation sheets, instruction and worktime-estimating cards, CNC, PLC programs, etc.; PPC - customers orders with all parameters, bill of materials, available production staff, available technological machines, robots and manipulators, transportation devices, technological and assembly routings, realized production schedules [8], etc.; CAQ - number of wastes and defective products, down-times of technological processes (MTBF, MTTF, repairs staff and equipment), etc. and other data important to specific solution (e.g. financial data connected with costs of raw materials, tools, energy, fixed and variable cost of production, transportation, warehousing etc. and added value for every product, in simplified words - selling price).

But sometimes still, the data and information are saved in paper form or they are possessed as an unwritten knowledge of production staff and managers (unexpressed, unsaved know-how). Moreover, we try to make a predictions for future, take into account evidences of experiences of researches - e.g. hipotethical clients orders, technologies, projects of products, techniques of logistics services etc. We need to have all of the known data, unexpressed knowledge and uncertain information to create an efficient (correct) model of the logistics system. Of course, we have to extract the data (from all information we possessed) which we can to implement in specific simulation software, but sometimes we need to change form or unit of input data. Very often we must to create our own procedures or macros (e.g. agent based programming [9,10]) for description of specific solution in dedicated or high-level programming language (4DScript in Enterprise Dynamics, Flexscript in Flexim, C++, etc.) in simulation software. On Figure 1 the main steps of implementation digital manufacturing and logistics in real internal/external enterprise environment are presented.

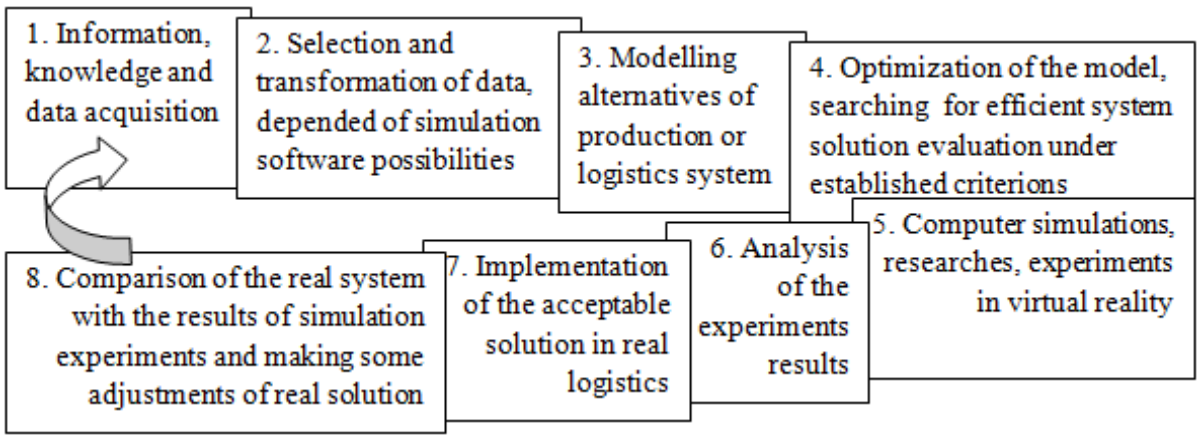

Figure 1. Implementation of digital manufacturing and logistics in enterprise.

During decision making process of buying computer simulation software oriented on logistics, it is necessary to consider the functionality of the packages, which may be different depending on the producer and the destination of the software. Additionally, everyone should be aware that the construction of an efficient (correct) model of the manufacturing or logistics system, is usually labour intensive and time-consuming, requires fluency in the simulation programming language, and often it is necessary to hire experts who know how the modelled systems operate (often from various fields, when the model of internal or external logistics system is created, e.g. product designer, technologist, production planning engineer, CNC machine and industrial robot programmer, logistician - supplier, contractor, warehouseman, deliverer, economist and others). The level of detail mapping will affect the quality of the model. An oversimplified model will generate the approximate results, imprecise and

not quite adequate to reality, but excessive detailing of parameters considerably increases costs and time of design process. Before the start of modelling a programmer should properly define the purpose of the simulation research (e.g. the study of the productivity of the logistics subsystem under the influence of disruptions, the study of the total costs of supply and distribution transport and warehouse subsystems etc.). In conclusion, it must be emphasized, that due to the high costs of simulation software (especially for commercial applications), in the case of modular solutions, user should select only those parts of the package that is necessary to model the logistics system and to precisely estimate the payback time for cost of purchase the software.

After building correct model of production or logistics system the experiments and researches (established at the beginning of system designing) should be conducted for optimization of received solutions. It is the last step before implementation the digital manufacturing and logistics in real environment of enterprise.

3. From virtual model, through simulation to real implementation - practical examples of application the selected simulation software in production and logistics processes

During their own researches authors used selected simulation software dedicated to manufacturing and logistics: Enterprise Dynamics 9 - Logistics Suite, Flexsim 7, Roboguide, Process Simulate.

Enterprise Dynamics 9 - Logistic Suite and Flexsim 7 are characterized by a large library of components that can be used in models of logistics systems. The typical devices which we can use in simulation models of real system are following: technological machines (classic CNC server, multi server, assembler, splitter, unpack, etc.); transport and storage devices (conveyors, forklift trucks, Automated Guided Vehicles - AGV, warehouse stacker cranes, high-bay warehouse); industrial robots (Scara type, portal, articulated), staff (teams of workers). In the software we can to model production and logistics system with taking into account important work parameters of devices and staff, routings, schedules, etc. but we can't create real CNC, PLC or industrial robot programs for true manufacturers (e.g. Fanuc).

Further development of simulation techniques, beyond: visualization in the virtual reality different manufacturing and logistics processes, testing the model (e.g. in relation to production planning, optimization of transportation routes, productivity tests), is intended to enable to design a new logistics system from the beginning, perform its' complete configuration and will give possibility for off-line programming of all devices inside automated factory. The use of advanced simulation software, like: Roboguide, Robcad, Plant Simulation, Process Simulate, etc. which cooperate together with PLC or autonomous control systems of CNC machines, robots, other automated devices, gives these possibility. In contrast to the Enterprise Dynamic and Flexsim, actual devices of industrial robot and machine producers (e.g. Fanuc, ABB, Kuka, Kawasaki) are available inside advanced simulation software libraries. They have a virtual control systems, programmable the same way as using operation panel (teach pendant) or high-level programming language (e.g. Karel, AS Language). In addition, there is possibility of import from the CAD software models of devices (e.g. machining centre, rotary table, conveyor), parts and details (e.g. car body, engine) and technological equipment (e.g. resistive welder, handle, gripper) even with their kinematics. Thus, it is possible to completely, detailed reproduction of the real production and logistics system. Other function, may be automatic collision detection of all moving parts of equipment in the virtual world. It significantly increases the safety during the installation of manufacturing cells, testing technological processes and production. It is quite common that construction of so-called "safe" production cells is the main standard and requirement for greater number of companies, especially in the automotive industry.

Examples of typical applications [2,3,4] created and implemented in real industries created in the described computer simulation software, during the scientific research were, among other things:

- Simulation of machining department and heat treatment for typical types of shaft, sleeve, frame, body, etc.
- Automated manufacturing system with quality control, sorting and palletizing (Figure 2).

- Simulation of manufacturing and assembly processes in the machine tool industry, with service of supply and storage systems.
- The internal transportation system in assembly department of automotive industry.
- External road transportation system, both for supply and distribution processes in the metallurgical branch.

Alternative, dedicated and unique applications including:

- Virtual model of rapid prototyping cell with use of industrial robot (Figure 2).
- Simulation of a conventional power plant with regard to aspects of ecologists.
- Model of cross-docking warehouse in regional distribution centre.
- Implementation of the compressor overhaul process with an external cooperation (virtual enterprise).
- Simulation of sales processes in the hypermarket.

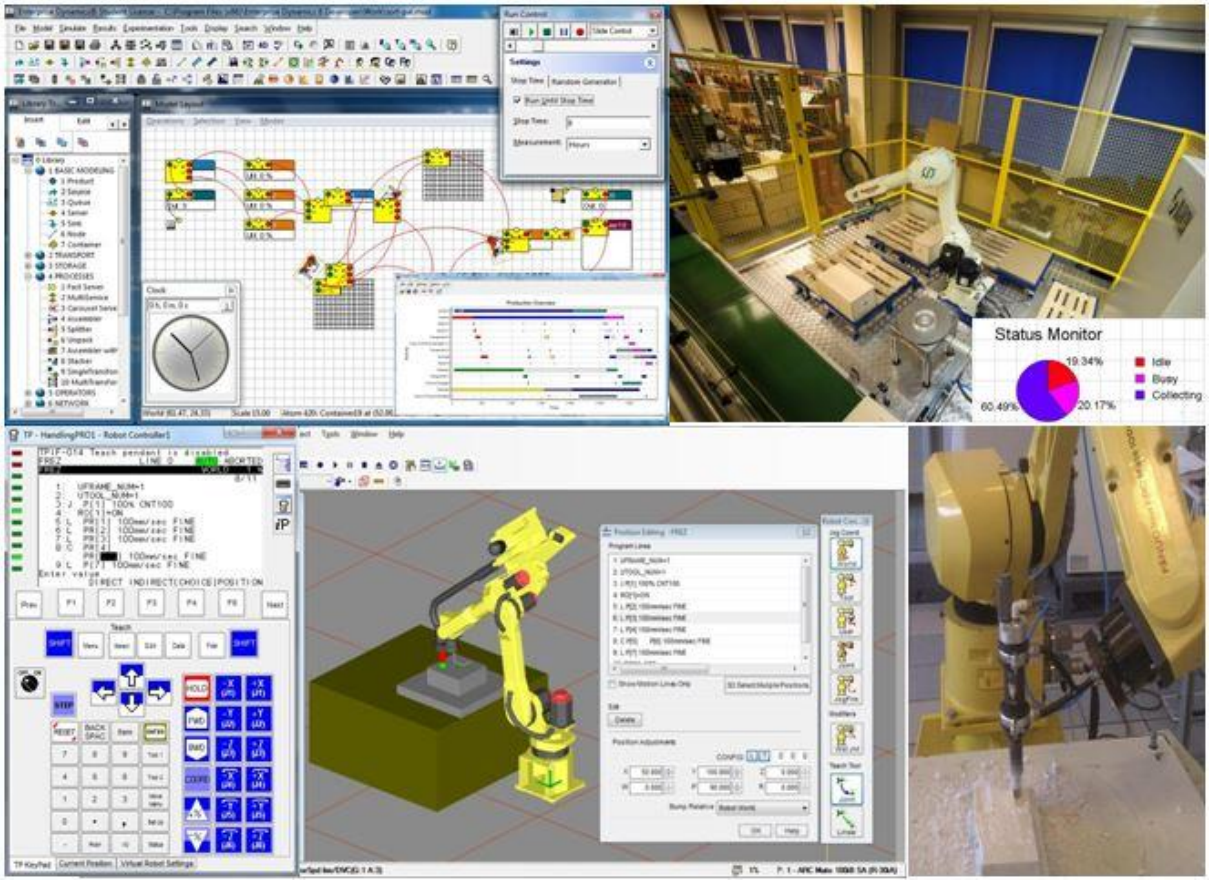

Figure 2. Example of created model and implemented solution after optimization in virtual simulation Enterprise Dynamics - Logistics Suite, Roboguide.

4. Conclusions

In conclusion, the development of computer-aided techniques is moving toward the integration of product design processes and the virtual reality (VR) and digital manufacturing (DM), in the form of so-called PLM software (Product Lifecycle Management). It includes all phases: from idea - conception of a new product, through design and manufacturing (CAD/CAE: DFMA,DFR /CAM /CAA/ - Computer Aided: Design/Engineering - For Manufacturing And Assembly, For Recycling /Manufacturing/Automation), to after-sales logistics servicing, recycling and utilization of used products (ecology). So, it gone beyond the autonomous, logistics system of production enterprise. The

software: Siemens PLM (Product Lifecycle Management) - Teamcenter, can be an example of future trends in production, logistics and enterprise management. It includes advanced CAD/CAM/CAE system (NX 10) and Tecnomatix software package, contains a large number of tools for modeling and simulation of production and logistics systems. It fills the gap between the design of a new product, its manufacture, service and recycling. These tools can be used for detailed modeling and simulation of individual workstations and production lines, in both automated and manually operated, also taking into account the principles of ergonomics (advanced models of the human body - Jack Human Modeling in Process Simulate). Of course, they can be use to the overall design and optimization of entire industrial plants (Plant Simulation). The virtual model, representing an accurate image of the planned production system allows programming of PLC and CNC machines, robots, transport and warehouse devices, while keeping the actual operating parameters and conditions. This allows for detailed simulation of production and validation of the whole processes (Virtual Commissioning). Thus prepared configuration and job control programs can be easily transferred to the newly built production system. It allows to significantly reduce the time of the system implementation. As a result, the enterprise may bring new products to the market earlier than the competition. The next integration step is implementation of the production real-time tracking systems MES (Manufacturing Execution Systems), which collect the production data during the work of the system. The data are important for the current production and quality management CAQ (Computer Aided Quality) and customer service (e.g. Teamcenter Service, including: maintenance, repair, and overhaul). It allows for efficient management of information flow in the enterprise and involves the entire product life cycle. Proposed, by Siemens, solution is very expanded and expensive, dedicated for large companies, but thanks to its modularity, to some extent, can be used also in medium and small enterprises. Modern trends and further development of simulation systems towards the direction of aiding logistics CAL (Computer Aided Logistics) and supply chain management is going to satisfy the assumptions of the concept of Computer Integrated Logistics (CIL).

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