



Title:

**Integration of Virtual Reality in a Knowledge-based Engineering Approach for Preliminary Design and Quotation of Assembly Plants**

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Keywords:

Plant Configuration, Virtual Reality, KBE

DOI: 10.14733/cadconfP.2018.xxx-yyy

Introduction:

The worldwide market forces companies to deliver high quality quotation services to their potential customer. In fact, they should provide a range of different offers respecting tight lead-time. If the product to be marketed belongs to the so-called category of the “complex systems”, the bidding process may be challenging. The manufacturing plants are part of that class: their design involves many activities and results in the physical layout of the plant. In the last years, researchers put an increasing effort on Information and Communication Technology (ICT) tools for automatically designing, optimizing and giving quotes of manufacturing plant layout [2]. Knowledge based Engineering (KBE) oriented to automatic configuration of products is a powerful technology can tackle those issues [8]. In literature, many studies treat about advantages of KBE approach and its integration within several industrial environments. Usually, those applications deal with the automatic generation of technical documentation (reports, CAD model, simulation outputs, and so on) [5,9]. Nowadays, high bidding success rates go beyond the merely technical aspect.

Realistic visualizations (e.g. Virtual Reality) may increase success rate of the offer and improve the customer experience for any kind of product [1]. In fact, many companies make use of Virtual Reality (VR) in everyday product design process. For example, Volkswagen adopts VR for product design activities since 2008 [10], New Holland VR Laboratories employ immersive environment for further ergonomic evaluations such as reachability of handles within vehicle buck [7]. All those applications concern product design process enhancements. Also in academia, many studies focus on effectiveness of this technology in various design activities, like training for maintenance [3] and assembly tasks [4].

This paper aims at investigating the integration of virtual environments in a typical scenario of product configuration made by KBE tools. The focus is on automatic setup of VR scene starting from technical data to enhance engagement of customers through realistic walkthrough of plant building. The proposed approach is intended to encourage first-time-right configuration, reduce time for setup virtual environment and boost knowledge reuse up.

The paper is organized as follow: a description of the activities related to the quotation process as well as the framework and general architecture of the KBE system are depicted. Then, the generation of virtual environment based on standard libraries and its integration within KBE framework is presented. The proposed approach is applied to a case study regarding an assembly line layout visualization.

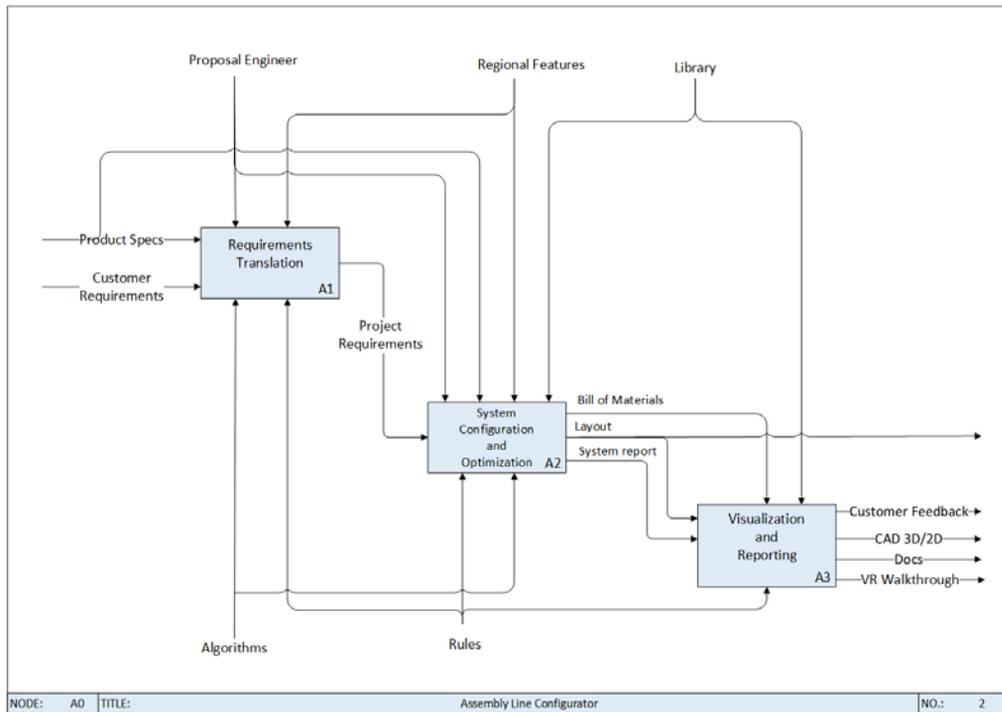


Fig.1: Schematic representation of KBE system implementation

#### KBE System:

A software prototype has been developed using KBE approach, then tested on a case study proposed by an industrial company leader in automated manufacturing systems. The application deals with the automatic configuration of assembly lines for automotive industry whose configuration process starts from a Request for Quotation (RFQ) provided by the customer. The goal is to provide to the customer a quotation that is as close as possible to the final product/system in a very limited time. This aim translates in providing a bunch of feasible project alternatives, ranging different bundles of cost, with a lead time as short as possible and with a high level of details. In Fig.1, an IDEF0 schema depicts the process performed by the KBE system. The process starts with the processing of the customer requirements: the RFQ contains, among the others, information about the location of the plant, target performances such as minimum throughput, technical efficiency, and so on. Furthermore, the characteristics about the products that has to be assembled (dimensions, weight, shape and so on), the available plant area (technical drawing, space constraints) are also available in that document. The parameters listed above are the input for the KBE system. Then, the logical design has to be carried out: these activities include the assembly tasks sequencing, the workload balancing of assembly jobs to different workstations (i.e. Assembly Line Balancing), the design of the layout within the plant. A detailed description of all those steps was provided in [7]. The company expert manages the input of the data as well as he/she starts the configuration and monitors its runtime. By means of the KBE system, the expert performs the whole configuration process. The output contains the 2D and 3D CAD model of the line, the list of machines with the estimated performance of the line and a technical description of the supplied equipment together with the cost estimation. The data are stored by means of a common repository: its function is to keep track of the data and information about the available modules and components for the plant design taking care of all the meaningful features of the current project.

Pushed by market requirements and by the fact that these kinds of technologies have an affordable cost, a new Virtual Reality module has been integrated in the KBE application. Hence, the paper is focused on the integration of VR module inside KBE system: customer can navigate the plants in an immersive

space exploring the proposed solution. This improvement allows the customers to evaluate the line inside the building in which it is going to be installed.

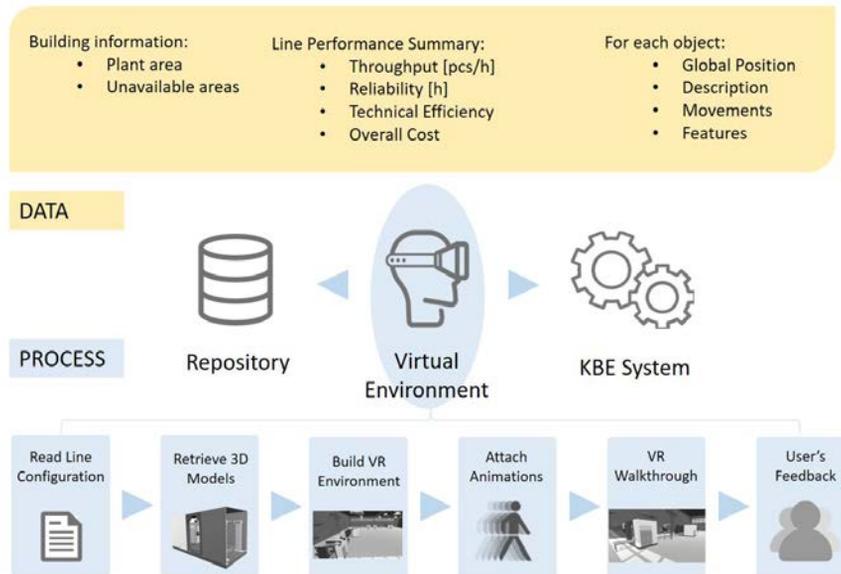


Fig. 2: Data and information exchange between repository and VR module.

#### Integration and development of virtual reality module:

This section discusses about the integration and implementation within the framework previously presented, emphasizing the automatic setup of the virtual environment. Virtual reality system must be coupled with a design and simulation system in order to create more realistic virtual environments. Information to build the visual modules are retrieved from the KBE system (Fig.1).

A subset of the whole amount of information related to plant layout previously designed are exchanged between repository and the VR module. These data are usually stored in company's PLM repository. Fig. 2 shows the information exchanged for VR environment setup as well as the process within VR environment module itself. The repository includes outcomes computed from logical design and optimization step (see node A2 in Fig.1) like components involved in building the assembly line, their positions as well as the performance estimated by simulating.

The outcomes of the logical design are based on a mathematical model that contains approximation: the "output generation" step allows the model to be refined taking into account detailed specifications like the dimension of the working areas, pillar positions and areas to be avoided. This step begins with sketching the 2D layout of the line with a user friendly and "drag & drop" based tool. In this way, the KBE system computes the coordinates of all the items composing the line with respect to the plant area. Usually, the repository already contains the whole library of 3D CAD models of workstations and the equipment that are necessary to build the virtual representation of the assembly line. Additionally, the same objects have also to be stored in a format able to be imported in the VR software (i.e; .fbx, or .obj) with the required colors, textures and material properties. In order to enhance the realism of the environment, many items (e.g. robot, pallet and so on) should mimic the real movements. The runtime computation of all the movements may be too heavy to have a fluent walkthrough. The simulation of the movement for each item are driven by a set prearranged motion equations. Those equations are in form of cubic splines whose coefficients have been previously computed and stored within the repository. All the above information are the ones useful to automatically build the VR environment.

As a test case, the integration between PLM repository and VR module, using Unity 3D Software, has been considered. Extensible Markup Language (XML) has been chosen as a standard communication language. The data from the XML file can be easily read by any VR software using XML parsing libraries.

Hence, the VR environment is generated automatically by retrieving the data from XML files and by loading the necessary 3D textured model; positional information with respect to a global reference system; spatial relationships between different product parts, sub-assemblies, and assemblies; and inter-part relationships from the model library in PLM.

All the project stakeholders can visualize and interact with the virtual environment through different visualization systems: immersive virtual reality environment like Cave Automatic Virtual Environment (CAVE) could be used if company is equipped with, otherwise Head Mounted Displays (HMDs) could be a valuable alternative. For multiple users, one person can wear the HMD, while others could watch the external display to understand what the HMD user was seeing. After looking for any Visual issues (aesthetic qualities and styling of the geometry) and functional issues (fit, form and function), customer proposes some changes or finalizes the commissioning of the line. In this way VR can help in reduction of cost, time, risk and improves quality and communication during commissioning of the line.

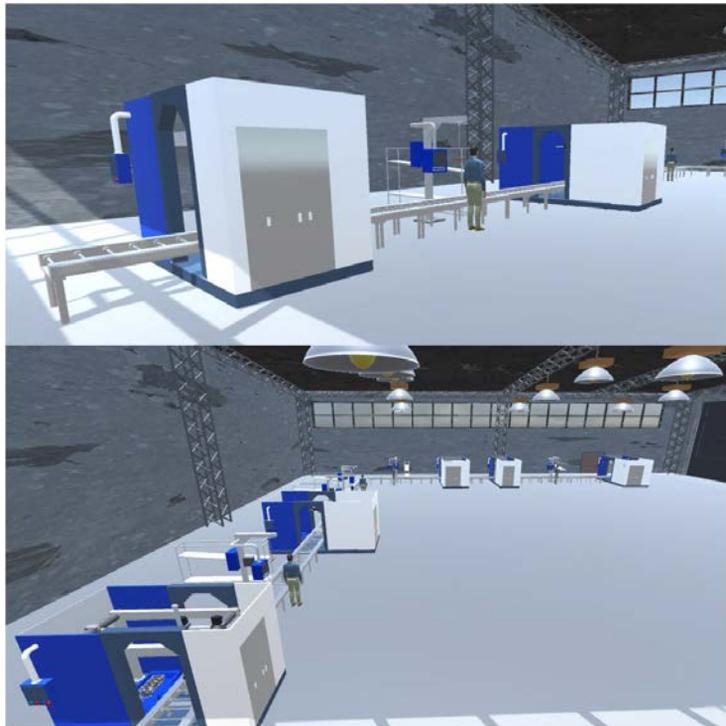


Fig. 3: Factory layout built in VR software (Unity 3D)

### Conclusions:

As the hardware becomes more reliable and the software more approachable, VR systems are becoming easier to operate. The overall objective of the solution described in this article is to provide the ways to create and test detailed replicas of assembly line and equipment in a 3D virtual environment-including PLCs, Human Machine Interfaces and robotic program. Since this project is based on the idea of Industry 4.0 and virtual reality can be considered as a very useful tool for design tasks causing effective costs and time reduction as well as improving the offers success rate. Virtual Simulation is a major enabler of speed-to-market by allowing manufacturing organizations to virtually validate manufacturing concepts upfront and throughout the lifecycle of new product introductions. The ability to leverage 3D data of products and resources facilitates virtual validation, optimization and commissioning of complex manufacturing processes, resulting in faster launch and higher production quality. By using advanced VR hardware and software, companies enhance engagement of customers through realistic walkthrough

of plant building during commissioning. Furthermore, they can go one step further for ergonomic studies, cycle time optimization, worker safety, maintenance, aesthetics checks as well as training the operators.

The integration of virtual environments in a typical scenario of product configuration made by KBE tools is a very important step to ensure its adoption in industry. Through the automatic setup of VR scene starting from technical data (i.e. 3D CAD model), the proposed approach is intended to encourage first-time-right configuration, reduce time for setup virtual environment and boost knowledge reuse up.

The integration of VR tools in the company environment is pursued through the automatic setup of the virtual scene as well as a deep integration with the ICT tools already available in the company. These aspects have to be stressed especially since VR is not considered as a merely conceptual design tool anymore but one of the means to pursue the process virtualization attempted by Industry of the Future.

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