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CONCEPTION AN INTELLIGENT NODE ARCHITECTURE FOR INTRALOGISTICS

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Abstract: Intralogistics makes up an important part of the supply chains some call it the ‘heart of the logistics’. Lately the appearance of cyber-physical systems has been caused significant changes in this area, enabling not only a set of interconnected devices, but let new concepts to be implemented. This paper presents a novel control structure between the centralized and decentralized concepts – the so called intelligent node – which opens new possibilities for local control of intralogistics processes. The paper surveys possible connection of the intelligent node to the simulation based digital twin.

1 Introduction

Industrial companies witness in the recent years a large number of new concepts and solutions spreading across the world of production and logistics. Some call the effect of these changes fundamental, some say these are revolutionary. The most relevant issue here is the launch of Industry 4.0, which is a relevant project [1] from Germany on the application of Cyber-physical systems in the industry. It describes principles of production processes based on the tight integration and interconnection of physical and digital components. Networking is a decisive feature of this approach, the system components autonomously communicating with each other making decentral decisions along the value chain. Industry 4.0 takes also account of the increased computerization of the manufacturing industries where physical objects are seamlessly integrated into the information network.

Industry 4.0 supply however not only solutions but raises question and poses challenges as well. In [2] the author characterizes CPPS systems (cyber-physical production systems) as a composition of autonomous and cooperative elements and sub-systems that are getting into connection with each other in situation dependent ways, at various levels. Having such a complex structure the research focuses on the modelling, forecasting snd control of the systems operation. There are several important question in this context, like the level of autonomy, the cooperation, and tho possibilities for an optimization.

Complex systems’ control of Industry 4.0 requires facing and handling of the Big Data problem. Generally this is a term for large and complex data sets, for which conventional data processing techniques are not adequate. The Big Data problem addresses capture, analysis, searching, sharing, storage, transfer, visualization of data from various sources in different forms. Additionally the speed of the information flow is also challenging. In order to cope with this problem a common solution to decentralize the intelligent, decision-making functions. Internet of things (IOT) devices are necessary enablers for this. A typical application for the above is presented in [3], where development of a method for self-aware and self-maintenance machines is described.

Factory logistic systems of large production facilities also pose a big data problem. Production and logistic data come from different sources, such as the production planning, manufacturing machines, and human participants of various roles in the system. Size of the facility multiply the amount of data by the number of production and logistic segments.

These complex systems must be controlled in an adequate way. There are many different possibilities for an optimal control structure, the most common and relevant variants are described in Chapter 2. Our approach presents the so called „intelligent material flow” node and details its advantages and applicability in general and through an example. This paper is part of our research project „EPIC” that has received funding from the European Union's Horizon 2020 research and innovation programme.

2 Control architectures of factory logistics

This chapter describes the most common characteristics of factory logistic control. Most common and traditional system structures are built up using the centralized hierarchical concept shown in Figure 1. Here the materials handling system and warehouse management are integrated under the production control. This way all the logistic operations originate directly from the production, therefore separate optimization issues in the logistics are limited.

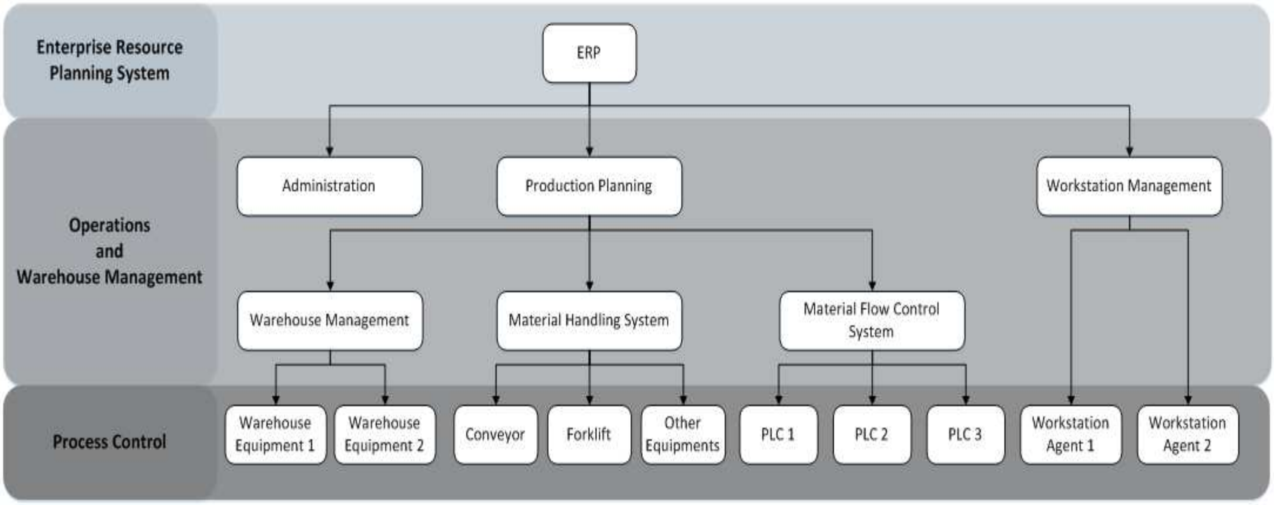

Figure 1 Centralized control

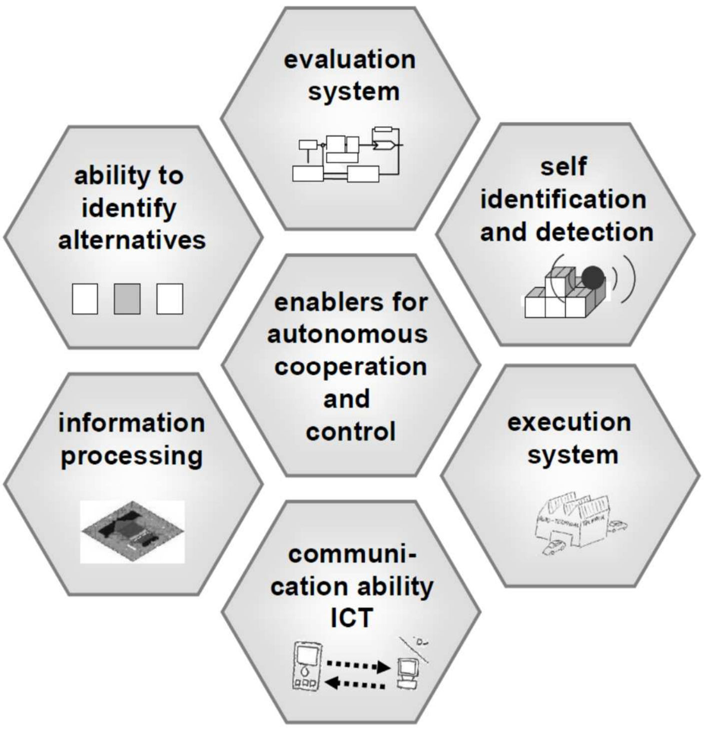

Figure 2 Enablers of autonomous cooperation and control [4]

Though using centralized systems there are possibilities for a broad, overall optimization, lately the need arose for more decentralized systems. This change of paradigm was caused by is increasing complexity in combination with a high incidence of potentially disruptive factors [4]. Further, the increasing number of product variants leads to a great number of possible combinations. This complexity cannot be managed by means of conventional, centralized control systems. In order to match to the above changed environment integration of new technologies and control methods has become inevitable.

The new requirements led to the appearance of highly decentralized, autonomously cooperating control system in the production and logistics. To create such a decentralized structure, several enablers from the system side must be met, like depicted in Figure 2.

Schumacher and Hummel in der publication [5] proposed a decentral event-based control structure. It consists of "system-"and "scenario-specific nodes" which provide agent-like decision-making. The connected modules are very versatile, starting from the conventional (Manufacturing Execution Systems - MES) system approaches for the modelling of special resources like collaborative robots.

Decentralized systems build up a strongly interconnected network of nodes, where intelligence, functionality, type and location of these nodes are diverse.

Between the central and decentral concepts partially distributed architectures also exist (see [6]), where an intelligent logistic object with appropriate micro- and macro view architecture is also depicted (see Figure 3).

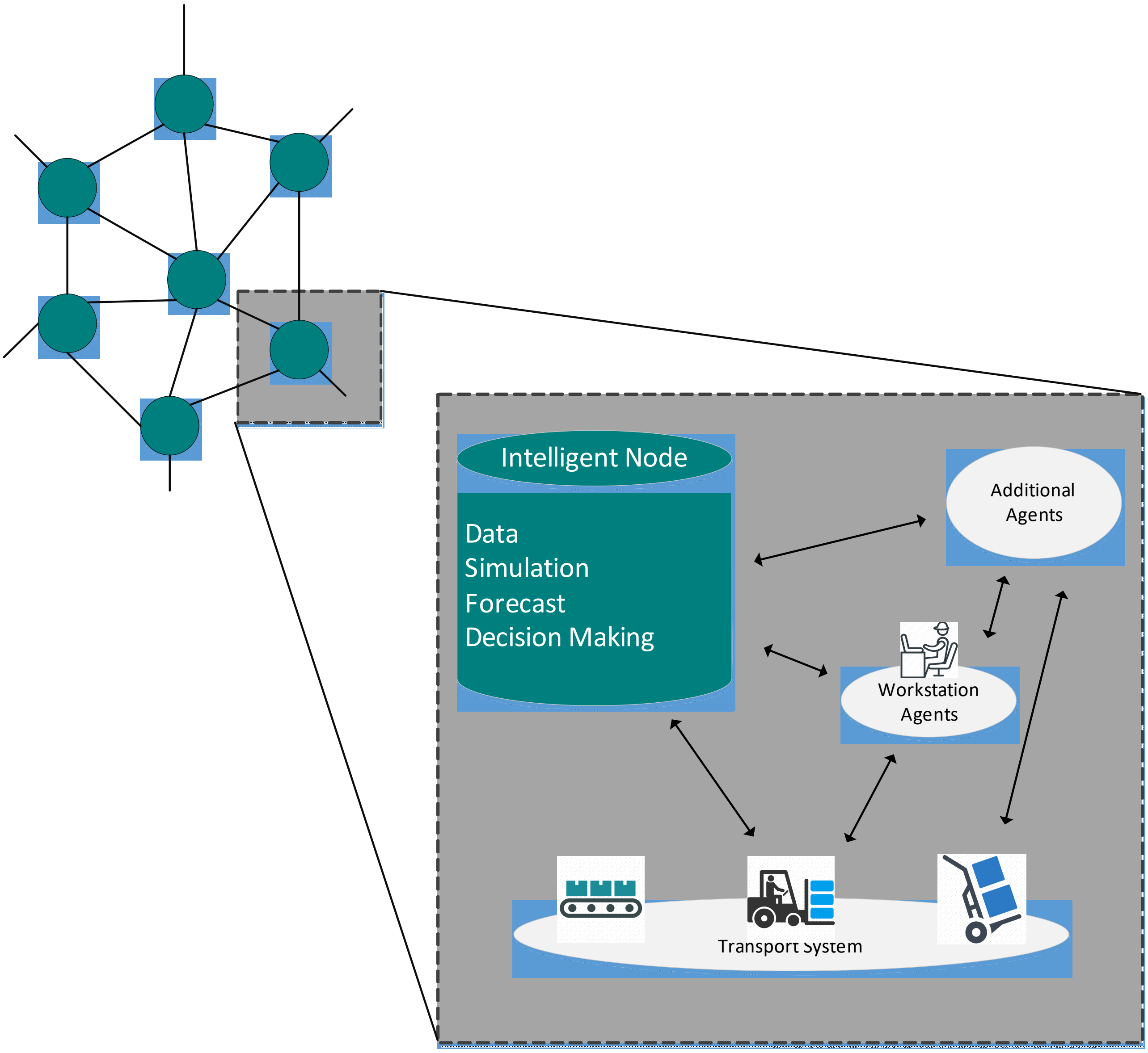

Figure 3 Concept of an intelligent logistic object wide a wide range of control functions [6]

The above paper describes that autonomous controlled logistic systems have several architectures which differ in the extent of ability transfer, the distribution of abilities and the representation of system elements. The higher the level of the first two aspects are, the bigger is the autonomy and complexity in the control system. The representation of a system is real, if logistic objects include control functionalities, otherwise it is virtual. The three main classes of architecture are Classical (Centralised) Production Planning and Control (PPC) Systems, Fully

Distributed Architectures with all the elements being intelligent logistic objects, and Partial Distributed Architectures where only a few clients have decision-making abilities. The concept of the intelligent node meets the requirements of a partial distributed control system architecture, as it is based on some complex information objects that collect information from other system elements, make decisions and transmit them back to the clients.

In production logistic systems continuous changes raise difficulties for the creation of the necessary control architecture. To match the structure to the continuously changing environment, manual tuning of the elements would require to excessive work. Therefore, self-adaptive features of the elements gain more and more importance. This is also related to the Big Data problems solution: this way a large amount of information can be transferred into knowledge via the adaptation process. In conventional systems central optimization was carried out. It should be remarked however that this is not feasible any more in large systems where the Big Data problem comes forward. Therefore, trends of decentralized adaptation come also forward.

Fully decentralized adaptation has however a backlash: the information remains decentral, there is no way to use it for other purposes. To cope with this problem (namely how to use the information generally) ontologies come into application. This is a good methodology to abstract and concentrate information. Originating from the computer and information technology, its excellent thinking pattern gets more and more applications in other areas as well.

The term "ontology" is originally a term from philosophy and indicates the discipline that deals with existence and the things that exist. In terms of informatics, "exist" means all the subjects which can be represented by data (see [7], [8]).

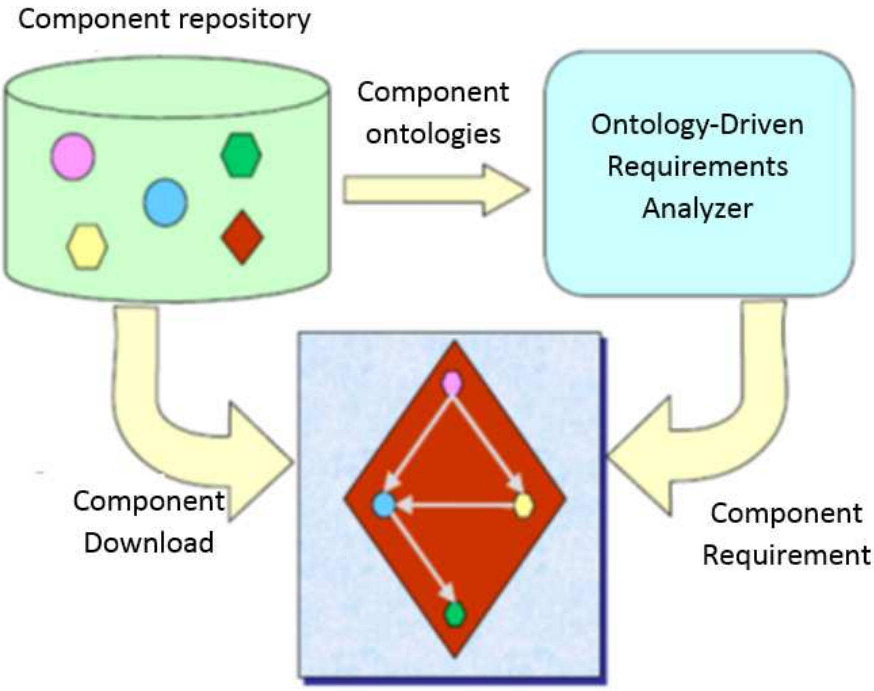

Figure 4 Concept of an intelligent logistic object with a wide range of control functions [9]

By translating the information into ontologies, adaptation of the systems can be carried out easier. Knowledge from earlier time periods can also be stored into repositories, from where these can be „taken" on demand, in the case of modelling altered processes. A good example for that can be found in the paper on Benjamin et al. [9]. Here the ontologies are stored in a virtual repository of components. Using this modelling and simulation, experts can easier identify the necessary elements, thus creating a more homogenous simulation model. The process itself is depicted in Figure 4.

Simulation aspects are very important in the control of logistic systems. The primary application area of them is to forecast the system's features. A general discussion of adaptability in logistic simulation modelling can be found in our previous work [10]. Therefore, we suggest an emphasized role for the simulation models.

Next, based upon the above considerations, definition of the proposed intelligent node architecture follows.

3 Structure of the proposed intelligent node for factory logistics

From the previous section we concluded that partially decentralized decision-making units can be advantageously applied for complex factory logistic systems. The necessary adaptive functionality can be achieved if the node is connected to the necessary sensors and other information sources and human supervisors as well.

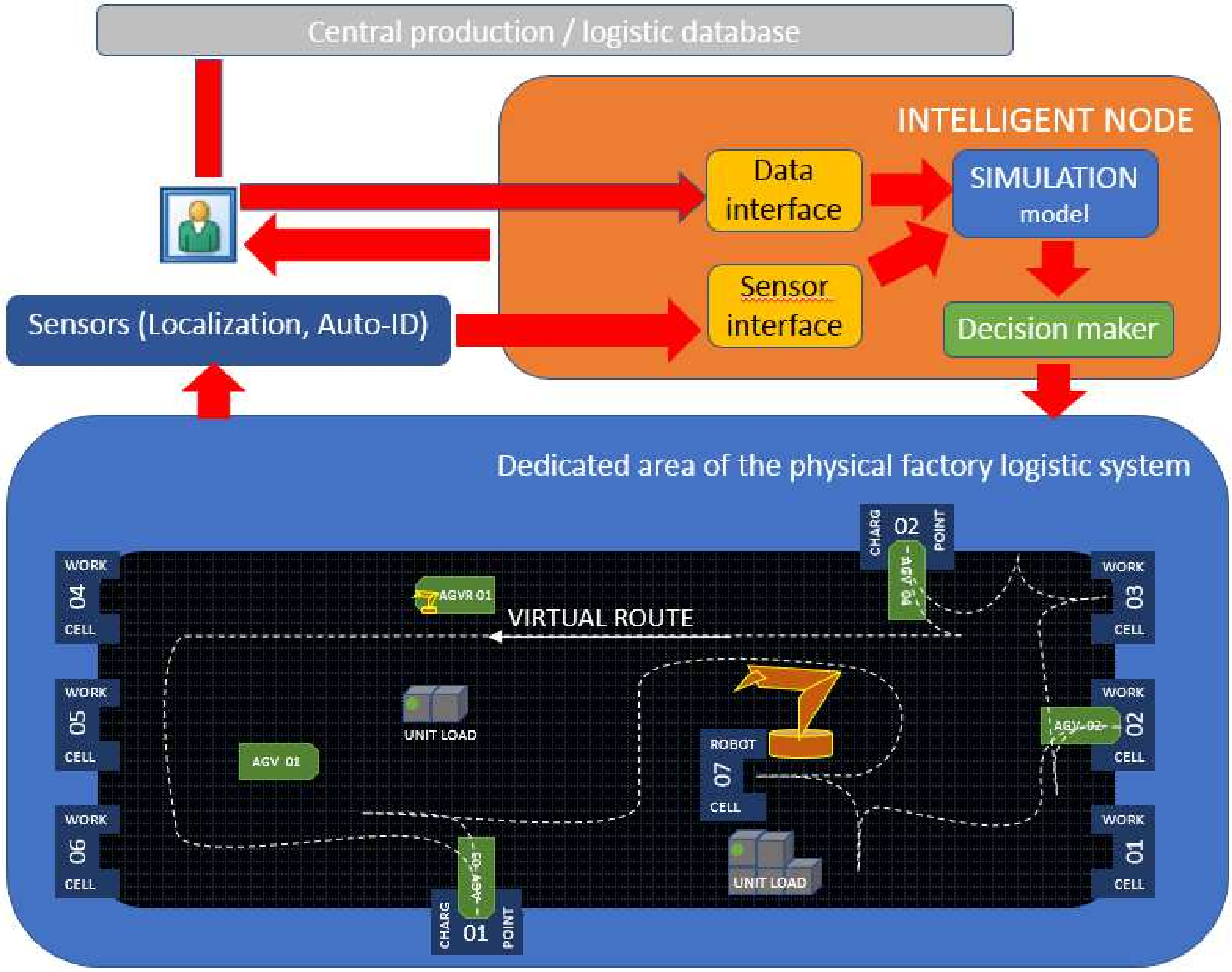

Figure 5 Concept of an intelligent node and its environment

Partially decomposition is done upon the spatial concept which means the nodes are distributed over the material flow area. This way local acting humans, sensors information sources are connected to this node. This approach differs from the functional one which would help decision-making in a certain problem over the whole system.

We preferred the spatial concept because it enables not only system adaptability but eases teaching of humans for the control's specialities, resulting in a bidirectional learning and adaptability between men and machines.

The proposed intelligent node's structure is explained via an example (see also Fig. 5.). Below the area of effect has been depicted (physical factory logistic system). It consists of in the example work cells from which some of them robotized. Among them the unit loads are transported using automatic guided vehicles (AGVs). The system is equipped with various sensors which are categorized into two categories. First a general localization system is necessary for the localization of material handling machines. Second, auto-ID sensors are installed as well, enabling measuring position and timestamp for various logistic objects (unit loads, tools etc.). It is expected that auto-ID information is automatically used for the determination of travel times in the simulation model. The intelligent node disposes of a data interface as well. Its functionality is detailed in the next section. Actually it enables transfer of the necessary information from the central production / logistic database into the simulation model. The information is filtered by human interaction. The simulation model is a digital twin which gives the necessary information for the decision maker module.

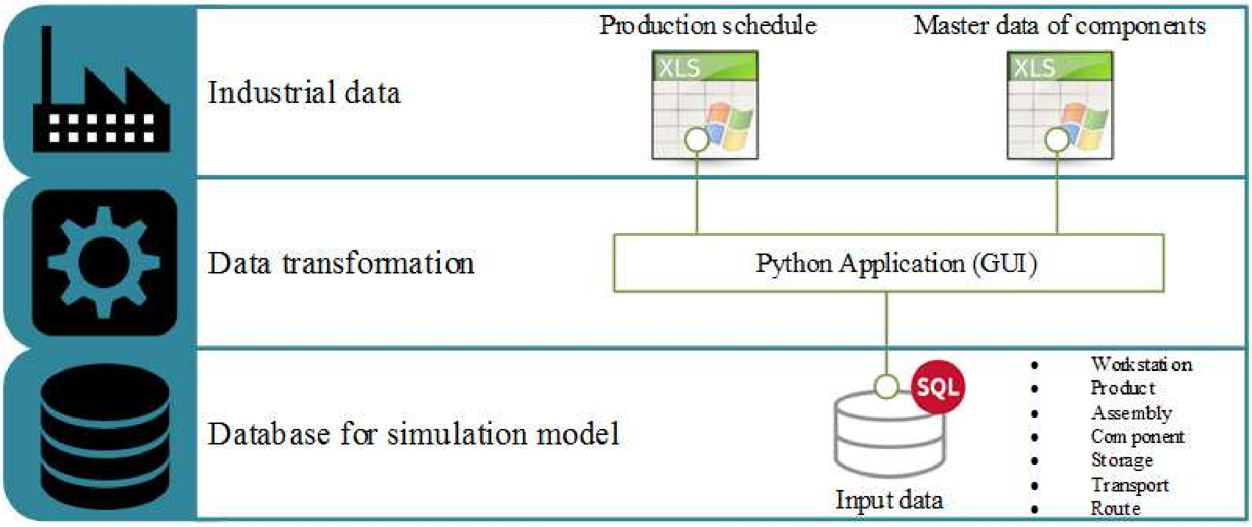

Figure 6 Data transfer into the simulation model

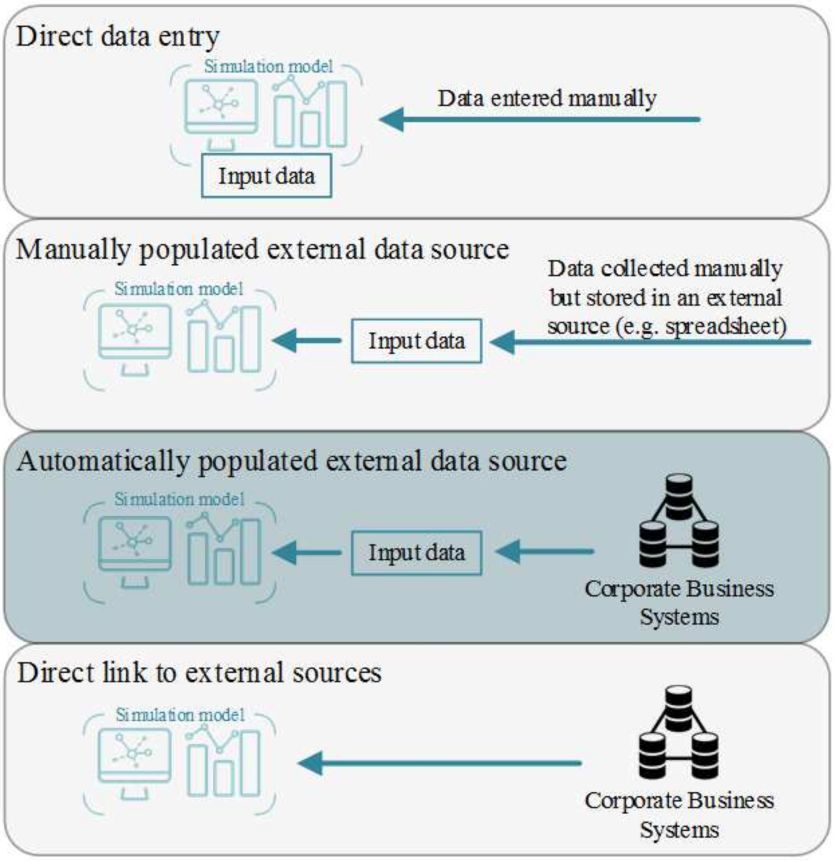

Figure 7 Data transfer into the simulation model

The intelligent node's functionality is to override the central control's decisions. For example, it is enough for the central control to send an AGV to a certain node the exact path and traffic control comes from the intelligent node. Its advantage comparing to the conventional AGV controls come from the flexibility as it can directly use various information sources. An important feature is the user interaction, so it can be easily adapted to unexpected changes as required by the concept of Industry 4.0.

4 Specialities of the data interface

The data interface module is a key component in the system. This is indispensable if continuous adaptivity is required, because there is no general solution for data conversion for the above specific task. Therefore we propose an interactive software, through which important material flow related data is transferred from central databases into the simulation model. It is indeed a two-steps process: first the necessary data is extracted from the central database, using a semi interactive method. Afterwards, the simulation model can be set up using automatic algorithms. The process flow is presented in Fig. 6. This semi-automatic methodology is not unknown for the generation of simulation data. Skoogh et al. in their paper [11] summarize methods for input data management in simulations and defined for the above four groups.

In the listing of Figure 7. we found that our methodology and automatically populated external data source are the most connected as in our intelligent node an automatic model generation is carried out

5 Conclusions

Above results belong to the foundational phase of our research work on the intelligent nodes. The overall goal of this topic is to verify that creating multifunctional intelligent nodes with defined circle of effect is a viable alternative against the fully decentral concept which increases intelligence at every available component. Next step of the research focuses on the transfer of these early results into industrial applications which increases acceptance.

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