Gentelligent® Parts: A Decentralized Information System for Enterprises

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Abstract. Gentelligent® Parts are components that function as storage mediums. They can record information, save it, process it and communicate it. Due to these characteristics, Gentelligent® Parts can serve as decentralized Enterprise Information System (EIS). It follows that along the product's evolutionary process and during the utilization phase extensive potential for improving the logistic and technical processes results. This article provides insight into both the principle of Gentelligent® Parts as well as the corresponding data structure and targeted process improvements.

Keywords: *EIS for manufacturing sector, Inter-and Intra-organizational information systems, Supply chain management (SCM), Supply chain planning and execution, Production planning and controlling, Logistics operations*

I. INTRODUCTION

In addition to the price and product quality, a high logistic efficiency, implicated through short delivery times and high delivery reliability, is an increasingly significant factor for a company's success [1-3]. Logistics is thus a key factor in global competition. This is not the least due to businesses concentrating on their core competences and trying to design factories accordingly. Through the intensive outsourcing of secondary processes and the complete outsourcing of modules that are to be manufactured to system suppliers, the vertical integration is radically reduced. Subsequently within an enterprise there is a shifting of complexity. Externally seen, this means that the performance demanded by the customer has to be produced from clearly longer and complexer value adding chains [4]. Adequately providing information is increasingly significant for managing these extended value adding chains.

In order to stand up to the globalized markets steadily increasing stress of competition, enterprises have to constantly increase their efficiency along their internal value adding chain as well as along those links reaching beyond them. This concerns both logistic and technical processes. Efficient management requires that economical decisions are made on every hierarchical level and at every link of the supply chain throughout the entire product evolutionary process. Adequately supplying the right information to the right person and the right process at the right time is therefore essential [5]. In the future, information, its availability and its usefulness will be core competences for a successful company [6].

2. CURRENT AND FUTURE INFORMATION PROCESSING

Up until recently the talk was about “Economy of Speed”. The focus was on optimizing the production factor “time” in the sense of production and delivery time. Now, at the start of the “Economy of Information”, more and more factors such as uniqueness, innovatability and the ability to learn stand in the foreground. The paradigm of “individual production” will dominate production technology for a long time and is already reflected in decisive tendencies [7]. In order to realize an “individual production” customer specific information for each product has to be backed up by corresponding information technology.

Production companies are already developing enormous logistic potential through currently available information technology such as RFID or barcodes. Nevertheless, with this technology information about parts or processes along the value adding chain can not be completely provided. Moreover, due to the physical separation of the parts and information (cf. Figure 1) it can not occur in real time.

Currently, parts and their related information are a single unit only in the form of a virtual component during the development phase, that is during the first phase of the products evolution. Further in the lifecycle (production, utilization, disposal) the information is generally separated from the physical part. The production date, production history, quality information, materials, state of change, product model and additional information are no longer directly available. In order to be able to access the information of an individual component, the serial number – as long as a unique one exists – has to be read out and subsequently accessed from a databank located elsewhere. Usually though, individual part information is not maintained or is maintained only for a short time span in a databank. At best, the information for a series of parts can be accessed. Direct access of information about a component has thus been impossible up until now.

The RFID technology can help to reduce the lack of information about the real world in the virtual “planning world” [8]. Due to the new possibilities for applying RFID technology in order to combine products and product information for example shown by ten Hompel [9], this technology exhibits a trend for exponential growth. However, as a result of the materials limited durability and their physical constraints there are boundaries to the application of RFID technology, particularly in production processes.

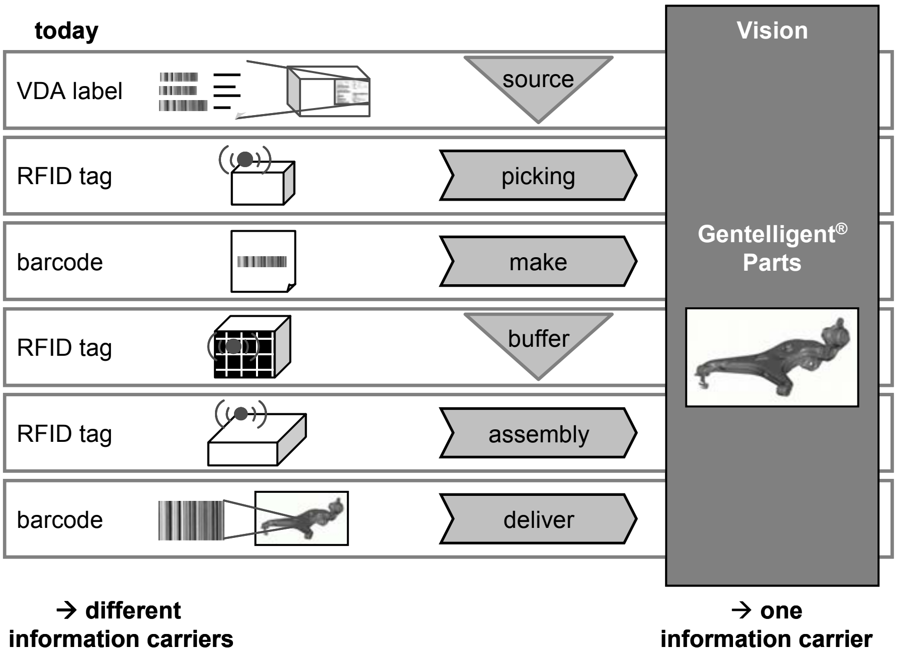

Figure 1. Part Relevant Information Storage: Today and in the Future

As a study from Seliger and Reichl [10] demonstrated, there is however a high demand for cost efficient information systems in production enterprises. These information systems should for example, as embedded systems, be able to be used flexibly for different technical systems and applications. With information systems that accompany the production, the continuous monitoring of standard units during the utilization phase should for example be possible in order to punctually arrange adaption processes such as maintenance and repairs. Such fundamental changes to the provision of information, not only impact the information in the production, but also open up both new potential and requirements for machines. Production systems will have to communicate and organize themselves in the future [11].

3. GENTELLIGENT® PARTS

In order to fulfil the abovementioned conditions, the foundation for a changing the paradigm in production technology will be created within the collaborative research centre (SFB) 653 "Gentelligent® Parts in the Lifecycle" (which is being conducted at the Leibniz Universitaet Hannover. The longterm goal of SFB 653 is the abolition of the physical separation of components and the information relevant to them. This will be accomplished through the development and utilization of a new type of components, the so called Gentelligent® Parts. These are characterized by their ability to record information, store it on the part and process it. The information is maintained throughout the lifecycle and can thus also be inherited by a future generation of parts. The components are thus genetic and intelligent (GI), or simply "Gentelligent®"

In order to realize this vision of Gentelligent® Parts a variety of technologies will be developed. For example foreign objects will be inserted in sinter parts. Through the existence and the size of foreign particles in a matrix array, information such as an identification number can be directly and irreversibly stored in the part [12].

However, there will also be methods developed which allow saved information to be changed. As Bach et al. [13] and Wu et al. [14] pointed out information can be saved, deleted and re-written similarly to on a harddrive through the introduction of magnetized magnesium under a keeper layer on the component.

Furthermore, the Gentelligent® Parts will be equipped with sensor functions, so that information from their surroundings can be recorded and saved. An example of this is the production of mechanical stress sensors through the placement of local strains. According to Behrens et al. [15] through this it is possible to record the load on a part over its lifecycle.

4. GENTELLIGENT® PARTS AS A DECENTRALIZED INFORMATION SYSTEM

Through the new component properties outlined above, the conditions for an Enterprise Information System (EIS) based on decentralized information stored on parts are met. Above all, the available decentralized information generates potential for the implementation in logistic processes, since these processes are characterized by a great amount of data. The goal is to reduce external storage mediums and to store a large portion of all the part relevant information – created through the production and utilization of the part – on the part directly. The use of additional data carriers such as externally placed RFID tags or barcodes will be refrained from. Through this alone, mistakes on error prone interfaces between the frequently different data carriers should be avoided, because no duplication or loss of data can occur here.

4.1 The Concept of Data for Gentelligent® Parts

Planning and Controlling logistic and technological production processes during the manufacturing of parts is based on information management. Which information should be decentrally stored on a component when – that is for conducting which processes – is thus critical for the development of information systems based on Gentelligent® Technology (GI Technology). In order to determine this, information, which on the one hand flowed into processes as input information and on the other hand flowed out of processes as output information, was collected from generic processing models such as the Supply Chain Operations Reference Model published by the Supply Chain Council [16].

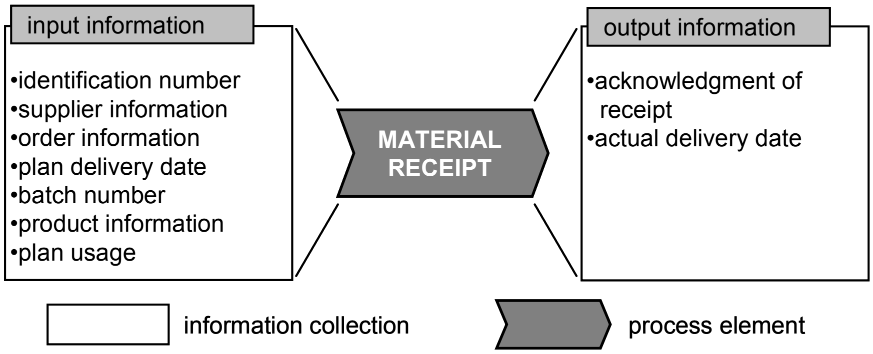

Figure 2. Input and Output Information for the "Material Receipt" Process

This is illustrated in Figure 2, using the example of the process element "material receipt". The "material receipt" process result in the confirmation of the goods input and the booking of them in a materials management system. The actual delivery date is also recorded, so that a supplier control can be conducted.

First to be noted as input information for this process, are the identification of the part and the supplier. Together with information regarding the ordering and the planned delivery dates (in some circumstance also the batch number), the correctness of the delivery can be determined. Information about the product and the planned usage is also helpful for the more expedient forwarding of goods, quality control and direct disposal of them onto the line.

As exemplarily presented here, the processes for procurement, production, assembly, distribution and return were analyzed with their process elements. Based on this matrix it could be identified which information could be advantageously stored decentrally on the part. Once the data model is developed, it will structure the information that is required and/or created during the production processes of Gentelligent® Parts (and is to be stored on the components) in a process oriented way. This model is a requirement for the consistent and redundancy-free processing of information.

The storage capacity of Gentelligent® Parts is – at least according to current technology – limited, however it will continue to be expanded in the future. The concept of the data model has to reflect this. The plan therefore is to gradually extend the data to be stored on the part, depending on the storage capacity of the Gentelligent® Parts. An excerpt from the data model is presented in Figure 3. The central information of a Gentelligent® Parts is without a doubt its identification. It thus forms the first step of the data model. This distinct, part specific, information already facilitates a number of process simplifications and reduces the process' susceptibly to errors. In a second step, information documenting the production process is to be stored on the Gentelligent® Parts. Included in this are data for clearly identifying all the links in the supply chain, as well as all the batch numbers along the evolutionary process. The part is thus unmistakably traceable. At the same time, through the uniqueness of the combination of different information a protection against plagiarism is implemented on the component.

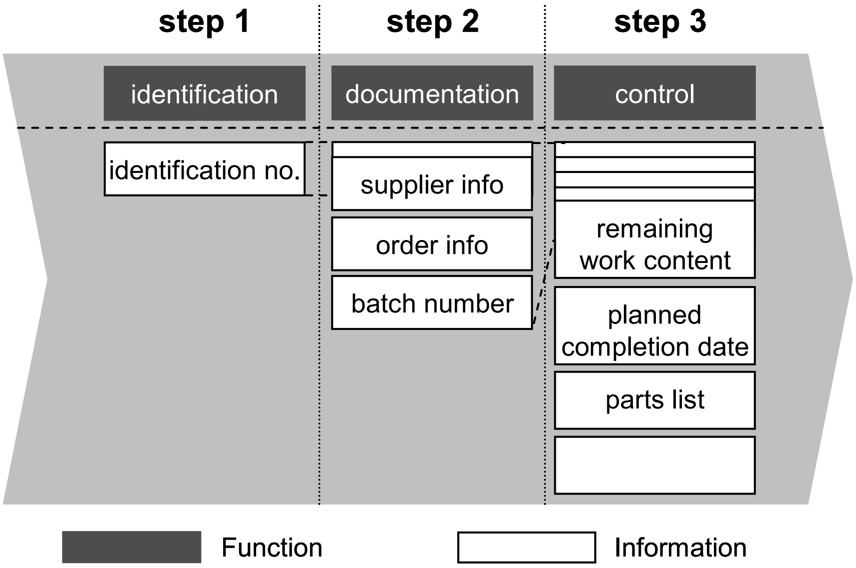

Figure 3. Excerpt from the Data Model for Gentelligent® Parts

In a third stage of development, the available data model is supplemented by further data. Here, information which enables a desired function of the Gentelligent® Parts is to be saved. If for example, a real time capable, part driven control of the assembly area is to be realized, then static information such as a part list of the components which are to be mounted can on the one hand be stored. On the other hand, dynamic information such as remaining work content (in planned hours) or the desired and realizable completion dates for an order can also be saved. Furthermore, the information part list stored on a key part enables a part driven picking to prepare an assembly process. The worker can identify the parts to be picked for assembly with the help of the Gentelligent® Key Part. Accordingly information relevant to other utilizations of Gentelligent® Parts can also be stored.

4.2 Utilizing a Decentralized Information System in Production Processes

GI Technology makes it possible to design simpler, leaner and more error resistant processes. In order to elucidate this, the application of GI Technology on a number of processes will be exemplarily presented here. The procurement process will be considered first. It is outlined in Figure 4, on the third level of the SCOR model using the five process elements: “scheduling material delivery”, “material receipt”, “material testing”, “material transport” and “release of supplier payment”.

As indicated in Figure 4, GI Technology almost affects all five process elements. The scheduling of the material delivery can be activated through Gentelligent® Parts. They log out of the store when they are used and activate a new order operation when a minimal stock level is breached. A quasi GI Kanban is thus implemented.

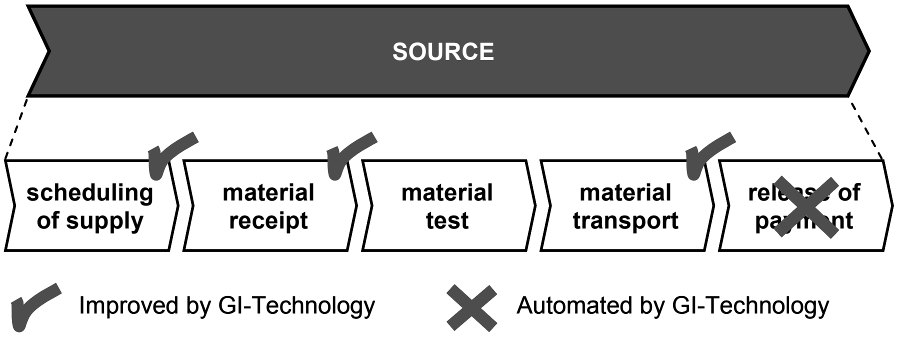

Figure 4. Process Improving the Procurement Process through GI Technology

Through the GI Technology the subprocess “material receipt” including verifying the identity can be simplified when the delivered materials are simple and clearly identifiable.

This is the case, when an identification number is directly written on the part and can be identified error-free through an active or – depending on the type of GI Technology implemented – passive scanner. Personal expenditures and costs due to errors caused by mistakes on both the receiver’s and deliverer’s side can be avoided, because whether or not the delivered part is correct can be determined by directly comparing the part and system data.

The material transport from the receipt of the goods to a downstream stocking echelon can also be simplified: By clearly identifying the part, a storage location will be assigned to it through the EDP system and if applicable directly written on the Gentelligent® Parts. The risk of mistakes during storage is thus minimized.

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Furthermore, it is plausible that the release of the suppliers’ payment could be automated by activating it with GI Technology. By exactly identifying the number of received parts, the payment process would be initiated based on the components. It can be activated either directly after the receipt of materials or when applicable, after they have been tested. All of the parts, which meet the standards for the technical quality, are registered after they have passed through the process elements “material receipt” or “material testing”. The value deposited in the EDP system, will be credited to the supplier, whose identification is also stored on the part. These accounts will then be settled in a specific cycle e.g., weekly or monthly. It is also conceivable that this application could be extended by storing the price of the part directly on it, so that the billing can be conducted through decentrally accumulated, part specific information. This billing data then only has to be collected in the form of credit accounts in the EDP system.

Within the frame of the production process, a part driven control of assembly parts will also be implemented. Of the four production control tasks, identified by Lödding [17] – order creation, order release, sequencing and controlling capacities – this method will regulate the order release and sequencing. However, it will also have an impact on controlling the capacities.

For each of the groups which are to be assembled, a key part will be determined, which can communicate with the remaining components in its group. The key part knows from the start of the manufacturing what the target completion date for the group is. Based on the inter-operation time which remains to the target completion date, the components will decide amongst themselves the sequencing of the processing on the workstations. Thus if a part falls behind, and others have enough time to wait, a decentralized order sequencing change will be carried out. The goal of the algorithm that this is based on is to maintain the given targeted completion date and ensure that all parts in a group arrive at an assembly workstation simultaneously. As soon as all of the parts to be manufactured and assembled have passed through the production, the key part will trigger the picking of the remaining parts from the stores based on the deposited part list for the assembly order. This method should increase the scheduling reliability and reduce both the WIP as well as the handling effort required during the assembly.

Since the remaining work content and the completion date for the individual operation are deposited on each of the parts, existing back logs on any of the workstations can be decentrally reacted to by increasing capacities as long as a corresponding flexibility of capacities is permitted.

As demonstrated here based on the example of procurement, process simplifications can be identified throughout the complete production process. A number of these simplifications are so extensive that the process elements can almost be automated.

4.3 Utilizing a Decentralized Information System during the Product Evolutionary Process

Further important utilization aspects of GI Technology can be identified outside of the production process. An example of this is the documentation of the evolutionary process of Gentelligent® Parts. Every link of a supply chain irreversibly encodes and writes its identification and where applicable the batch number on the corresponding part. Through this, the evolutionary process of the Gentelligent® Parts is continuously written. This can protect enterprises from claims for recourse in relation to parts which are not produced by them, but are rather copied. Moreover, the traceability of products, which is already demanded in many industrial sectors, is easily ensured.

The intelligence of Gentelligent® Parts arises through its technical ability to compile, process and store information during the utilization phase such as influencing forces, accelerations, and temperatures. This occurs through suitable materials and sensors, which are integrated in or linked to the part. The entirety of information that is stored on the Gentelligent® Parts can as required be communicated to the user of the part or read out during its removal/replacement.

The information recorded during its implementation should be applied to determine causes of failures and based on that the probability of failure and the length of remaining life, as well as for determining dynamic maintenance intervals. The information gained is passed back to the company through the maintenance process or through a return process, so that the information can be passed down to the next generation of parts. New parts can therefore be designed with the help of real load profiles, which are determined during the utilization phase of the previous parts.

5. SUMMARY

A decentralized Enterprise Information System based on Gentelligent® Parts offers an enormous potential for making improvements and for avoiding errors in the logistic and technical production processes, particularly with regards to the supply chain which extends beyond the enterprise. This potential was tentatively outlined in both production processes and utilization phases. In order to realize this potential, a corresponding data model, which is oriented on the Gentelligent® Parts' still small but steadily growing storage capacity, was discussed in detail. Through this, errors at interfaces between companies and at interfaces between firms and information systems can be avoided.

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