# KNOWLEDGE BASED SERVICES FOR DEVICES IN AUTOMATION

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Abstract: The integration of manufacturing design and production processes around aggregated shared knowledge improves production efficiency. In this paper, planning level faults on the assembly lines or conflicts in product design are identified and picked up in real time via the use of integrated knowledge based services. Issues with the supply chain can also be fed into the model by linking the services to Enterprise Resource Planning (ERP) systems. In the production process, errors and/or faults are fed back into the knowledge base system to aid confident future planning. This approach allows more targeted alerts and reports of failures, empowering the production operative and allowing more problems to be solved at the source of origination.

## 1 INTRODUCTION

Service Oriented Architecture (SOA) has emerged as a reliable distributed computing method. Web services are considered the best implementation method of SOA as they are loosely coupled and platform independent. Nevertheless to construct machine processable 'XML' in a complex product manufacturing enterprise, a higher level of semantics is required which is provided by ontology. An ontology is commonly defined as: a formal, explicit specification of a shared conceptualization (Gruber, 1993). More specifically, an ontology is an engineering artifact composed (i) of a vocabulary specific to a domain of discourse, and (ii) of a set of explicit assumptions regarding the intended meaning of the terms in the vocabulary for that domain.

In the manufacturing domain, the relationship between the design phase of a product and its creation on a production line is vital for manufacturing efficiency. Errors in the design or failure to create an assembly line that suits the product design can create delays in the process as re-design or re-configuration occurs. These revisions have impacts on both the supply chain and overall manufacturing/assembly output.

The Loughborough University in collaboration with Ford UK have been investigating how ontologies and SWSs could be used to improve Ford production output. These investigations lead to the development of a software framework, which will facilitate the integration of product design and production line configuration. This framework builds on existing web services developed during projects such as SOCRADES (Kirkham, 2008).

## 2 RELATED WORK

The research work on ontologies and the semantic web has started intruding into real industrial problems from pure academia work. SOA and its implementation using Web Services (WS) have raised significant interest as a technology facilitator for encapsulating industrial devices as loosely coupled and interoperable units (Jammes, 2005). Semantic web is based upon ontology which provides semantics and reasoning support for intelligent retrieval and discovery of manufacturing resources (Ming, 2003).

The use of ontologies in the manufacturing domain to form intelligent semantic web services to improve productivity are emerging (Lukibanov, 2005); (Ajit et al, 2004). These ontologies are applied to a variety of points in the manufacturing lifecycle ranging from design and production phases.

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These innovations are significant for companies like the Ford Motor Company which is currently facing challenges in maintaining competitive advantage when faced with competitors who can produce products on a large scale and lower cost from less developed economies. To counter this, western manufacturing has looked towards innovation in manufacturing process embracing movements such as agile manufacturing (Yusuf et al., 1999). The enablement of high quality and customized production through agile manufacturing requires changes in production process. Central to the production line is the ability for it to support change and reconfiguration (Harrison et al., 2006). Time saved during this process has a direct impact on the efficiency of an organization and is a key focus of research.

To date re-configuration and assembly line flexibility has been managed in a variety of ways. Ford's Powertrain manufacturing/assembly follows this pattern with assembly lines consisting of a variety of vendor specific machinery and control software. Thus integration of machines and lines is a challenge and integration with enterprise management such as ERP software is rarely achieved.

## 3 DEVICE LEVEL SERVICES

By encapsulating the functionality of devices as a service, new systems can be created by composing simple services into complex applications with a minimum of programming efforts (Lastra et al., 2006). Semantic Web is a very strong and flexible knowledge representation method which can express entity structure, properties and the causal link between entities explicitly and concisely (Zhihong, 2002). Semantic web services can foster the integration of heterogeneous production devices and of a mix of architectures in systems which would be chaotic from an ICT perspective (Lastra et al., 2005).

Embedded web services have developed around the initial innovation presented by tools such as the GSOAP toolkit (Engelen and Gallivan, 2002) to a more detailed and defined toolkit in the form of DPWS (OASIS, 2009); (Schlimmer, 2010). This web service toolkit although largely based on GSOAP, presents support for standards to enable 'eventing', subscription and notification of events enabling a more efficient lower layer of device based communication. The ability for services to be present a manufacturing device level allows the use of semantic web services at real time production level. This semantic management will impact the management of the line by injecting the ability to link the data from the line along with its behaviour into knowledge based services.

This greater level of management and knowledge based reasoning on the line will enhance wider production processes. For example, device level service behaviour can be factored into ERP and supply chain management services to help plan production output.

## 4 CONFIGURATION MANAGEMENT

In order to support the execution of services on the assembly line, supporting services need to be in place before, during and after device level execution. In order to make this process dynamic and transferable, knowledge of service design and functionality is required. In the BDA project ontologies were developed to serve this specific requirement using semantic web services.

Machine, line, component and product data has been captured into ontologies using Protégé and OWL (Knublauch et al., 2004); (Martin, 2004). Ontologies are a key part of a broader range of semantics based technologies and automated inference that arose within the Artificial Intelligence community. Many different representation formalisms have been explored and reasoning engines developed. There are different kinds of ontologies, the ontologies developed for the current research can be classified as domain ontology as well as task ontology. Task ontology is developed for a specific task within a certain domain.

Creating ontology for a domain provides an opportunity to analyse domain knowledge, make domain assumptions explicit, separate domain knowledge from operational knowledge, provide common understanding of the information structure and enable reuse of domain knowledge.

The ontologies in the current research represent how the Powertrain assembly line is constructed and example ontology of a production task on an assembly line can be seen in Figure 1.

A visualization of a simple ontology to represent a typical assembly task is illustrated in Figure 1. An ontology in the manufacturing domain is used for controlled vocabulary, consistency in data quality and navigation through disparate information sources through mediation. Ontology is an intensional formal semantic structure which encodes the implicit rules constraining the structure of a piece of reality (Bachimont, 2000).

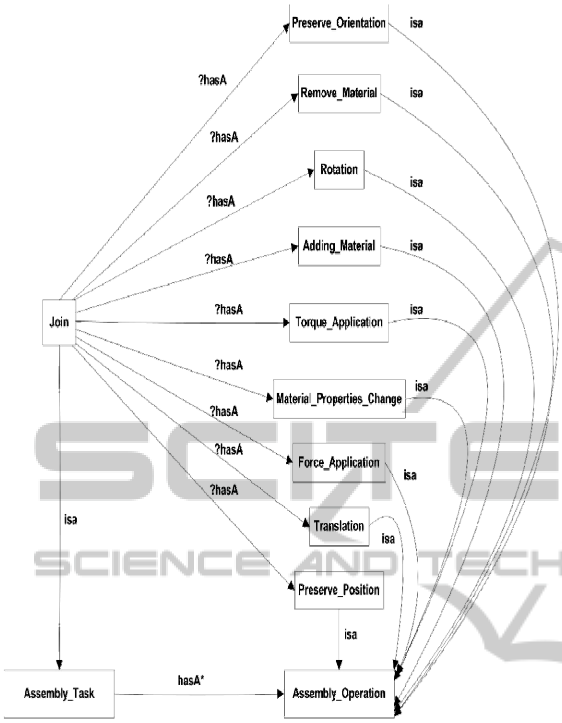


Figure 1: Ontology for a production line task.

An ontology is seen as a meta-level specification of a logical theory, in the sense that it specifies the ‘architectural components‘ or ‘primitives‘ used within a particular domain theory (Wielinga, 1994). Therefore an ontology is a representation of components and their allowed interactions, with the purpose of providing an explicit framework in which to elaborate the rest of the system. Ontologies overcome data heterogeneity. Data sources can be heterogeneous in syntax, schema, or semantics, thus making data interoperation a difficult task. Syntactic heterogeneity is caused by the use of different models or languages. Schematic heterogeneity results from structural differences. Semantic heterogeneity is caused by different meanings or interpretations of data in various contexts. To achieve data interoperability, the issues posed by data heterogeneity need to be eliminated. Currently, the basic ontology model is defined along three axes: relationships, hierarchy, and abstraction, as shown in Figure 2.

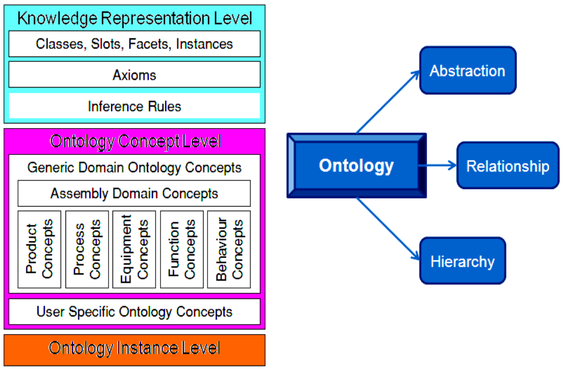


Figure 2: Ontology structure outline for PPR domains.

On the ontology level all the specific domain concepts, attributes, constraints, and rules are defined for the related entities i.e. products, processes and resources (PPR). Ontologies expose implicit knowledge that has been previously hidden in domain assumptions or in the implementation of an application. Figure 3 describes 04 major functions of an ontology.



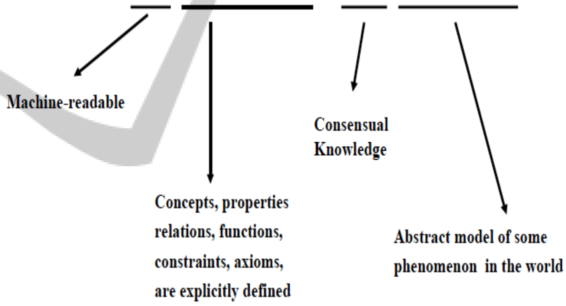


Figure 3: Ontology functions.

To support the decision making, an ontology model is proposed that include three representation levels: the underlying knowledge representation level, the ontology concept level and the instantiation level. The domain ontologies are divided into generic and user specific concepts. For example, a library of physical models may be represented with the help of an ontology. To each component in the library, information is attached that describes the function of the component (for example, an engine has the function “generate power”). If this information is represented explicitly, an engineer may be able to search the library for component models that fulfill a certain function, rather then designing a new one. In the ontology-based approach, domain specific ontologies are modeled to specify semantics of terminology systems in a well-defined and unambiguous manner. A model is a simplified representation of a system intended to enhance our ability to understand, predict and control the behavior of a system. Based upon the presented categorisation, ontology of the complete assembly line was modeled and an example of the abstract concepts is shown below in Figure 4.

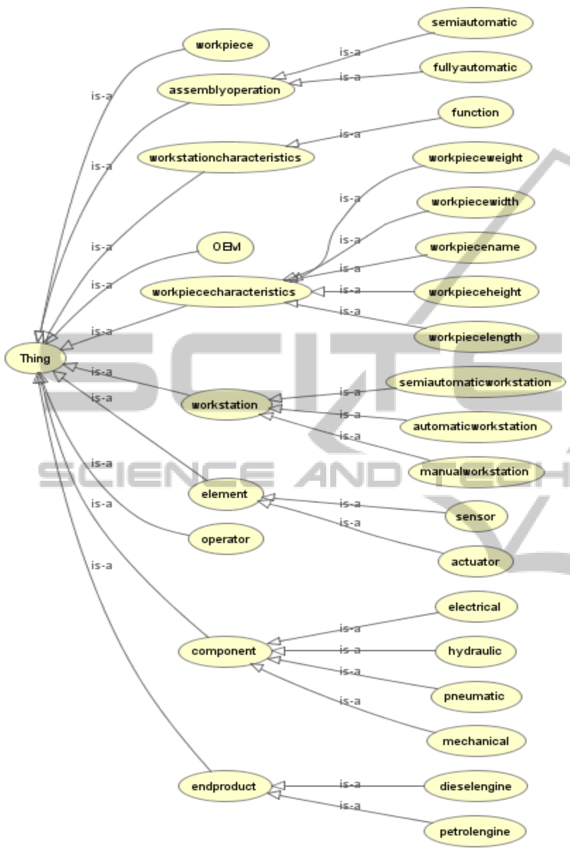


Figure 4: Ontology for a production line - snapshot of line in Protégé 4.0.

Key concepts introduced into the ontology are work piece, work piece characteristics, workstation, workstation characteristics, assembly operation, operator and end product. Based upon these concepts, relations among products, processes and resources are established into the ontology which constitutes manufacturing backbone. The current assembly line reconfiguration approach is largely based on the skill and knowledge of engineers rather than the actual process involved. Whenever there is any change in the product it is then essentially engineer's responsibility to examine the needs of the reconfigured system to support the new product (Raza et al., 2011).

Current automation systems fail to meet business requirements (Raza and Harrison, 2011). The assembly lines, such as powertrain assembly line for automotive engine, have a limited capacity to produce variety of products (engines). The built in capability to deal with variety has to be limited to justify investment and is a trade-off between the inevitable but unpredictable changes and the increased cost of flexibility (Raza and Harrison, 2011). One of the main reasons for automation systems and especially the assembly automation systems in automotive sector not fulfilling the business requirements is that the relational knowledge base among products, processes and resources is either non-existent or not properly designed / used. There is a genuine industrial requirement to establish relationships among PPR domains to readily assimilate the requisite information for any change in product at any time (Raza and Harrison, 2011).

Therefore it is imperative to create a knowledge base among PPR domains to fully utilise the available knowledge. Ontologies are not only useful for helping solving the information overload problem, but can be used for a variety of different applications, such as sharing explicit knowledge, increase communication, and help in natural language understanding. With the help of practical knowledge in ontology, a quick evaluation of many potential resource configurations is possible as well as the best suited one for a changed product (Raza and Harrison, 2011). There are no platform independent application tools available for modelling the PPR information explicitly neither does any tool exist to link PPR relational information unequivocally (Raza and Harrison, 2011).

Ontology assists the mapping of data from a variety of vendors and sources that constitute a production line. This enables a layer of knowledge to exist over the distributed data sources that are needed to help configure, support and run the production process / assembly line. For example a breakdown on the line can be followed up by a detailed report on faulty components based on line data and distributed component design records from various vendors. This information could aid the recovery and repair time for the line as shown below:

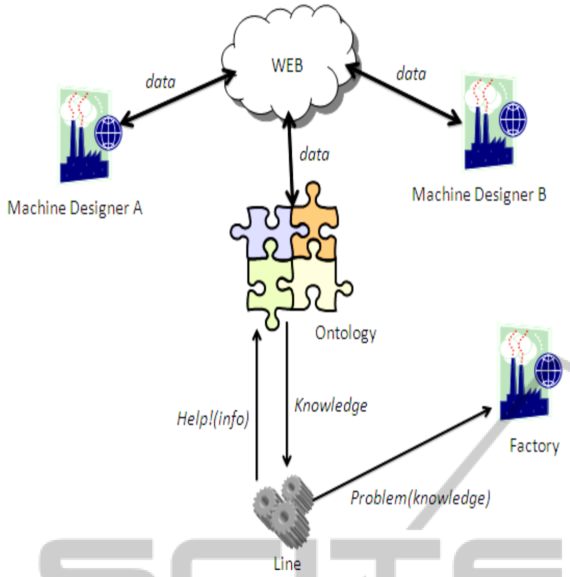


Figure 5: Knowledge based service use in assembly line management.

Thus a layer of distributed knowledge is wrapped and exposed as semantic web services as shown in Figure 5. These services abridge knowledge to data to be represented in web service processes thus aiding re-configurations of lines. Another example is the integration of new product specifications in existing line designs. Here the new specification can be accessed using web service calls and compared using an OWL ontology against the existing line. To automate (fairly) the task of assembly line configuration / reconfiguration, product and resource (line) link points need to be defined at early stages of design and made available easily to be searched, analysed and implemented on 'when and where required' basis (Raza et al, 2011). This will enable automated comparison of new products against existing line data also expressed as ontologies. This method will ensure conflicts in the product design with the line can be found and picked up at earlier program stages. It provides a broad encompassing structure of the domains that is handy and practical, a knowledge based support on every engineer's desk for making intrigue calculations and quick relational constraints. As a result, a PPR domains can be modelled realistically and constitute a complete knowledge management cycle of the automotive domain for the assembly line design activity, as depicted in Figure 6.

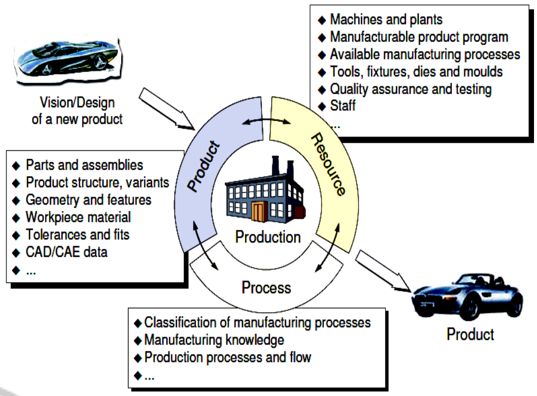


Figure 6: Product, Process and Resource integration constitute manufacturing knowledge backbone.

## 5 CONCLUSIONS AND FUTURE WORK

In this paper we explored a methodology that incorporates and improves distributed intelligence at the shop floor level. Currently the ontologies are used to aid the re-configuration of the assembly lines for new products. Live use of the ontologies has been limited to a few basic error conditions. As the development and use of the knowledge based services evolve they will be used as support in the entire production lifecycle. However, to make it a reality the data has to be captured or represented into ontologies from a wide variety of proprietary and legacy data sources throughout Ford, UK.

Using knowledge based services a new layer of manufacturing management can be envisaged that will help the entire production lifecycle. This layer is enhanced by the use of device level web services which will enable the live use of knowledge in automated decision making on assembly lines. To date, the use of knowledge based services has been limited to the design phase of machines. By using the technology in SOCRADES and BDA projects this approach can be widened out to encompass the whole process. This will standardise production management and responses to errors that will reduce cost and improve manufacturing efficiency.

The recently started AESOP (ArchitEcture for Service Oriented Process Monitoring and Control) project EU FP7 (AESOP, 2011) is now extending the application of the approach in the process control domain. AESOP deals with several key challenges that arise such as real-time web services, interoperability, plug and play, self-adaptation, reliability, cost-effectiveness, energy-awareness, high-level cross-layer integration and cooperation, event propagation, aggregation and management.

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