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KIPPcolla - Knowledge Intensive Product and Production Management from Concept to Re-cycle in Virtual Collaborative Environment
Tekes Digital Product-Process Programme

D4.3 Final Report

Digitaalinen tuoteprosessi

Abstract
The present document summarizes and concludes the developments completed during the KIPPcolla project. Also envisioned future developments are discussed.

Revision History

Revision	Date	Comments
0.1	31.8.2011	Draft, not approved yet
0.2	2.9.2011	One publication added
0.3	5.9.2011	Publications added

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1. Introduction

Manufacturing-related business services that capitalize on information technology are expanding fast. The need for improvement and change comes from business, product development and manufacturing domains and is generally related to new value offerings, capacity adjustments, cost efficiency or technology. At the same time, innovative ideas and new concepts are emerging and new technologies are being developed. Fast adaptation to opportunities arising from innovative business models, products and production models and technologies and their synergies is the key in the competitive issue.

Manufacturing systems can be seen to emerge through evolutionary synthesis process simultaneously with business and product models rather than be planned according to a known set of parameters. This is due to the constant need of manufacturing domains to adapt to and to influence the developments within business processes and R&D. The successful emergence of sustainable system calls for effective co-operation with R&D, business and manufacturing domains.

The competitiveness of tomorrow's manufacturing enterprise lies in the operation of a digital representation of a factory in parallel with the physical one. Virtual factories exist, in theory, but the implementation into the companies' environment is not that ambient as it is promised in the vendor flyers. Enhancement of the virtual factory network by implementing the ontological definitions and semantic web technologies can eliminate the latency in the knowledge flow between the various tiers in the supply chain. The meaning of the content allows the development of new emerging manufacturing theorems to surface. One of these is a service oriented and holon-based production and production system design.

In order to reach level where the product and production knowledge is available a new set of tools, standards and methods for the Finnish industrial environment is required. This project offered a novel method to map the meaning to the content in different levels of abstraction in heterogeneous design environment, where different service agents can utilize the created and/or reasoned knowledge smoothly.

The high-level goal of the KIPPcolla project was to support adaptation of production systems in dynamic environment. In the project the production environment is seen as dynamic, thus evolving open complex system, where the communication and decision making is based on negotiation process between modular entities through well defined interfaces.

Two main goals or the project were:

1) Development of formal knowledge representation for product-process-system knowledge that allows the inclusion of meaning into the model; and
2) Paradigm proving of intelligent holon-based manufacturing, where the content is fitted to the context and thus providing the status of the operations environment and basis for reasoning and negotiation process between holons in order to find the best capable, available resources and routing.

This report will summarize the developments done during the project and give final conclusions and suggestions for future developments.

2. Main results achieved during the project

The main results achieved during the KIPPcolla project are shortly discussed here. Each of these results are described in detail in other deliverables, which are marked inside the parentheses within the text.

2.1. Background studies

In the beginning of the project following background studies were conducted:

- Overview to **standards for product, process and resource information presentation** and standards that draw the landscape of sustainability in manufacturing and enable information exchange between entities *(D1.1. Standards Landscape).*
- Review of the **current status of the adaptation and utilization of digital and virtual design and information management systems** in the industrial world *(D1.2. Virtuality Roadmap).*

2.2. Developed Concepts

During the project following concepts and methodologies were developed:

1. Holonic Operation Environment Concept

Definition of the **requirements for the dynamic holon-based environment** *(D 1.3. Requirements for holons, D3.1. Company specific case studies)* opens up the concept as a whole. The main characteristics of the system are that it is an open system and has characteristics of a complex system. The system itself is an adaptive system, where different services are needed depending on the evolution of the production system itself. The concept outlines following:

- Main characteristics and supporting theory base
- Comparison between static and dynamic environments
- Definition of modular components and interface requirements
- Information flow analysis and modeling
- Operation strategies in defined levels

2. Modular System – Modular ICT Concept

One of the main results was the development of **concept for modular and flexible information architecture and operation environment** *(D 2.1. Interoperability Strategies, D 2.2. Knowledge models and D 3.2. Operation Strategies).* The modular ICT approach is developed for a holonic manufacturing system (HMS). The concept developed here aims to enhance knowledge management and process control by facilitating the move from technology based solutions to configurable modular systems and processes where the digital models and modular knowledge management systems can be configured based on the need - not based on the closed legacy systems and fixed process planning. The developed modular ICT concept utilizes and extends the dynamic modularization ideology allowing new modules to be added or old ones to be removed throughout the system lifecycle, without disturbing the overall system. The principles of modularization, such as functionalities and interfaces, are used to deal with interactions of the full system. The approach taken here divides the knowledge management system into three separate layers: databases, semantic operation logic (the knowledge representation) and services that utilize the commonly available knowledge. Once the storing method is extracted from the logic and services, the new concepts (new service modules) can emerge.

3. Methodology for describing the capabilities and combined capabilities of resources

In a holonic system, resources need to describe their capabilities to other holons in order to organize the production. Automatic mapping of available resources against product requirements requires formalized and structured representation of the functional capabilities, properties and constraints of the resources. It is evident that digital representation of capabilities of systems and their components can significantly ease the system design, integration, adaptation and operation allowing automatic methods to find suitable system components and to build alternative scenarios during early phases of system design and adaptation planning. However, presenting a simple capability of an individual resource is not enough when designing or adapting complete systems and describing the capabilities of holarchies composed of multiple holons. Therefore a way to describe the combined capability of multiple co-operating resources is also desired. During the KIPPcolla project a **methodology to formally describe the capabilities of individual resources and combined capabilities of multiple co-operating resources** was developed and utilized in the pilot implementation *(D 2.1. Interoperability Strategies; D3.1. Company Specific Case Studies – Case Sonecta)*.

2.3. Company specific case studies

Four company specific case studies were conducted during the project. Each of the cases contributed to the overall goal of the project. These cases were *(D3.1. Company specific case studies)*:

2.3.1. Case Nokia

Case Nokia aimed to identify the knowledge intensive knots in the product and process information flows and draw a “knowledge landscape” of the selected areas in the organization. The case viewed the information flows in R&D and between R&D and production from different perspectives and identifies the challenges in the information flows on three levels – between humans, information systems and formats.

The results for Case Nokia:

- **For the company:** The study outlined the major challenges in information flow management between system users inside the company and among chosen suppliers. Based on the results a new project "Concept Piloting" was launched inside the company with the aid of researcher who was employed by the company.
- **For the science:** the study served as a starting point for the development of intelligent systems indicating the requirements for the information flows. The case study outlined the main challenges in information flows and human-machine interoperability. Case study outlined the importance of interfaces and cooperation through defined interfaces based on a holonic concept.

2.3.2.Case Finn-Power

Case Finn-Power concentrated on definition of modular entities. The development of product family was divided into five steps: setting of goals, developing a generic element model, analyzing the customer requirements, analyzing the minimum variation and describing the resulted product structure. In the fifth step a new description method, Product Structuring Blue Print (PSBP), for describing a product structure was developed. PSBP shows how items are related in assemblies, how modules include assemblies, how modules are realized, and what customer requirement is connected to each module. PSBP helps in creating the view of the significance of the product structure solution principles. PSPB gives also a response to how product structuring decisions have to be made.

The results for Case Finn-Power:

- **For the company:** The case resulted a full modularization project that was launched inside the company based on the research and development done during the modularization case.
- **For the science:** The case resulted different tools for evaluating the success (in financial terms) of the modularized product. The case outlined further the importance of interfaces.

2.3.3.Case Hollming Works

Case Hollming Works aimed to create a simulation method, which could give forecasts for production of a specific product class. The goal was to simulate the possible delivery time of each ordered product. In the simulation it should be possible to take into account current production load, type of orders and available recourses at current time. Also it would be desirable to get various kinds of information on how production behaves in different kind of situations with different workload.

The results for Case Hollming Works:

- **For the company:** The case resulted an operation schema for the production. The simulation showed how the resources and production load was developing within the timespan.
- **For the science:** The case demonstrated the actual requirements what the company needs from the simulation environment. The case had actual data and thus outlined what holonic simulation environment needs to represent by minimum demand and what can later on be added to the simulation. The case outlined the importance of holonic simulation environment where different scenarios can be created with minimal effort thus saving time. Also the case supported the developed “modular system - modular ICT” concept.

2.3.4.Case Sonecta

Case Sonecta focused on developing a modeling method to represent capabilities of resources and combined capabilities of multiple resources. The case included generic classification of capabilities based on resource functionalities and rules for managing the capabilities and combined capabilities. The developed capability description allows matching the product requirements with proper resources based on their capabilities and this way supports rapid design and adaptation of systems. It offers a way for the holons to advertise their own capabilities to other holons in the holonic system and dynamically allocate resources.

The results for Case Sonecta:

- **For the company:** The case tested the concept of ontological representation for the resource capabilities.
- **For the science:** The case served as fundamental part of the scientific part of the project. The holonic operation concepts and knowledge representation was formalized in cooperation with Sonecta (SurveyPal).

2.4. Pilot Implementation of Dynamic Operation Environment

During the project the following pilot implementations were completed and reported:

- **Holonic concept for dynamic operations environment – implementation** *(D 2.1. Interoperability Strategies and D 3.2 Operation Strategies)*:
    - Routing (order of operations) is based on availability and capability of the resource combinations.
    - Pilot implementation - first kind in the world - is based on Kademlia technology that is originally developed for peer-to-peer document sharing.

  - Each holon is seen in this implementation as node that can enter and leave the system without disturbing the systems overall coherence.
  - The control holon is responsible for distributing arriving orders to right locations.

- **Formal knowledge model for Product-Process-System information**
  - Core Ontology v30 *(D 2.2. Knowledge Models)*
  - Definitions for system capabilities *(D 2.1. Interoperability Strategies and D 3.1. Company specific case studies – Case Sonecta)*
  - Feature representation utilizing X3D (visualization) and corresponding XML/RDF fact file (non-geometrical feature information) *(D2.1. Interoperability Strategies & D 3.2. Operation Strategies)*

- **Feature Recognition - Pro-FMA Extended software** *(D 2.1. Interoperability Strategies and D 3.2 Operation Strategies)*
  - Extraction of manufacturing features from the case product
  - Profile extraction from revolution parts (beta testing)
  - Pre-process planning based on found features

- **Decision Making and Ordering tool - DeMO Tool** *(D 2.1. Interoperability Strategies and D 3.2 Operation Strategies)*
  - Fast overview of developed simulations, including fact sheet of the simulation (summaries of results)
  - Simulation follows the holonic concept --> routing is based on first available and suitable resource.
  - Viewing the resources on the factory floor, and showing their capabilities and combined capabilities.
  - Ordering the product manufacturing from the system → this tool launches the production.

- In cooperation with CSM hotel project:
  - Implementation of the laboratory environment
  - Simulation of the holonic environment

- **Implementation of the modular software system architecture**, see Figure 1 *(D 2.1. Interoperability Strategies and D 3.2 Operation Strategies)*
  - Integrates all the developed software and holons.
  - **Interoperation** of the software modules relies on **shared information model**, Core Ontology, and **web service** communication.
  - **Pro-FMA Extended** is used to recognize the **features** from the product model and to generate the **product requirements** in the form of a **pre-process plan.**
  - The **actual process plan** is created **"on the fly"** based on the **status** of the production system, as well as **capabilities** and **availability** of the resources.
  - **DEMO tool** is used to send the **requests** (i.e. product orders) to the holonic system through the **UI/Control holon.**

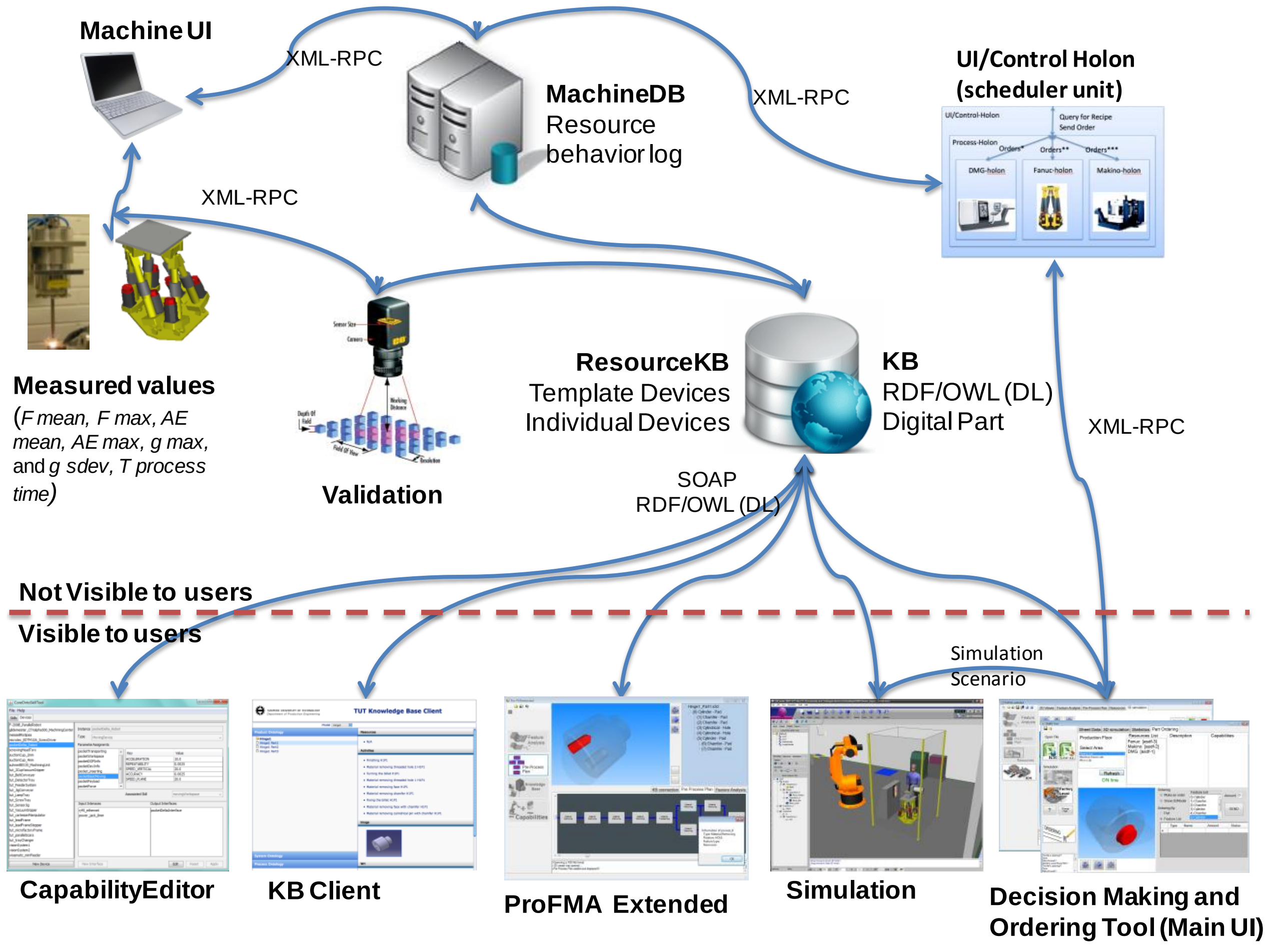

Figure 1. Modular ICT system architecture.

2.5. Scientific publications

Below is listed the most relevant scientific publications written during the project duration based on the achieved results. The publications can be found from the project Wiki. More publications about the final results are also expected after the project.

2.5.1. Doctoral Theses

- Lanz, M., 2010, Logical and Semantic Foundations of Knowledge Representation for Assembly and Manufacturing Processes, PhD thesis, Tampere University of Technology
- Järvenpää, E. Working title: Towards adaptation of production systems in dynamic environment. Estimated finishing time 3/2012.

2.5.2. Journals

- Nylund H, Andersson PH. 2010, Simulation of service-oriented and distributed manufacturing systems. Robot Comput Integr Manuf 26/6 (2010), pp. 622-628.
- Nylund H, Andersson PH. 2011, Framework for extended digital manufacturing systems, International Journal of Computer Integrated Manufacturing, 24/5, pp. 446-456.
- Nylund H, Lanz M, Ranta A, Ikkala K and Tuokko R, 2011, Viewpoints on Competitive and Sustainable Performance Metrics of an Intelligent Manufacturing Environment, Submitted to: Strojniški vestnik – Journal of Mechanical Engineering.

2.5.3. Conferences

- Nylund, H., Salminen, K. & Andersson, P.H. 2009. Framework for extended digital manufacturing systems. In: Huang, G. Q., Mak, K. L. & Maropoulos, P. G. (Eds.), Proceedings of the 6th CIRP-sponsored International Conference on Digital Enterprise Technology (DET 2009), pp. 1483-1500, December 14-16, Hong Kong, China, 2009.
- Lanz, M., Tuokko, R., 2009, Generic Reference Architecture For Digital, Virtual And Real Representations Of Manufacturing Systems, Indo-US Workshop on Designing Sustainable Products, Services and Manufacturing Systems, Bangalore 2009
- Lanz, M., Mani, M., Leong, S., Lyons, K., Ranta, A., Ikkala, K. & Bengtsson, N. 2010. Impact of energy measurements in machining operations. Proceeding of the ASME 2010 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2010, August 15-18, 2010, Montreal, Quebec, Canada 7 p.
- Lanz, M., Nylund, H., Ranta, A., Luostarinen, P. & Tuokko, R. 2010. Set-up and first steps on capturing of realistic resource characteristics of an intelligent manufacturing environment. Proceedings of the 20th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM 2010, July 12-14, 2010, California State University East Bay, USA. pp. 1028-1036.
- Järvenpää, E. & Tuokko, R. (2010). 'Towards Automatic Reconfiguration Planning of Changeable Assembly Systems'. Proceedings of the Post-Graduate Workshop on Intelligent Machines and Transport Systems, May 4-5, 2010, CERN, Switzerland, pp. 79-89.
- Järvenpää, E., Lanz, E., Mela, J. & Tuokko, R. 2010. Studying the Information Sources and Flows in a Company – Support for the Development of New Intelligent Systems. Proceedings of the 20th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2010, July 14-17, 2010 California, USA, 8 p.

- Nylund, H., Lanz, M., Ranta, A., Ikkala, K. and Tuokko, R. 2010, Developing Competitive and Sustainable Performance Metrics for an Intelligent Manufacturing Environment, Baric, G. & Dukic, G. (eds.). Proceedings of International Scientific Conference on Management of Technology - Step to Sustainable Production, MOTSP 2010, 2-4 June, 2010, Rovinj, Croatia, 8 p. **(Best paper award).**

- Nylund, H., Lanz, M., Tuokko, R. and Andersson P.H. 2011. A holistic view on modelling and simulation in the context of an intelligent manufacturing environment. International conference on Flexible automation and intelligent manufacturing, FAIM 2011, 26-29 July 2011, Taichung, Taiwan, pp. 801-808.

- Nylund, H., Salminen, K., Lanz, M., Järvenpää, E. and Tuokko, R. 2011, Concept and Roadmap for a CSM-Hotel Capability Management, Extended abstract submitted to: International conference on Concurrent Enterprising, ICE 2011.

- Järvenpää, E., Lanz, M., Siltala, N. & Tuokko, R. 2011. Activities and Corresponding Information Flows for Production System Adaptation Planning. Swedish Production Symposium, SPS11, 3-5 May 2011, Lund, Sweden.

- Lanz, M., Järvenpää, E., Luostarinen, P., Tenhunen, A., Tuokko, R. & Rodriguez, R. 2011. Formalising Connections between Products, Processes and Resources – Towards Semantic Knowledge Management System. Swedish Production Symposium, SPS11, 3-5 May 2011, Lund, Sweden.

- Järvenpää, E., Luostarinen, P., Lanz, M. & Tuokko, R. 2011. Presenting capabilities of resources and resource combinations to support production system adaptation. International Symposium of Assembly and Manufacturing (ISAM), 25-27 May 2011, Tampere, Finland.

- Järvenpää, E., Luostarinen, P., Lanz, M., Garcia, F. & Tuokko, R. 2011. Dynamic Operation Environment – Towards Intelligent Adaptive Production Systems. International Symposium of Assembly and Manufacturing (ISAM), 25-27 May 2011, Tampere, Finland.

- Garcia, F., Lanz, M. Järvenpää, E. & Tuokko, R. 2011. Process Planning Based on Feature Recognition Method. International Symposium of Assembly and Manufacturing (ISAM), 25-27 May 2011, Tampere, Finland.

- Lehtonen, T., Pakkanen, J., Järvenpää, J., Lanz, M. & Tuokko, R. 2011. Brownfield Process for Developing of Product Families. Proceedings of the 18th International Conference on Engineering Design, ICED11, 15-18 August 2011, Copenhagen, Denmark.

3. Why holons?

When discussing about our holonic concept with different people in seminars, workshops and conferences, a common comment/question has been: “Holonic manufacturing systems were developed 20-30 years ago and they didn’t work then. How could they work now?” Shortly put, the answer could be technological and methodological development of knowledge and information management. The holonic reasoning is relying on information and knowledge. Even though the concept of holonic manufacturing has remained similar throughout the years, the information technology has made huge leaps enabling the implementation of these concepts in a feasible way. The novel methods to manage and distribute knowledge, such as semantic web and web service technologies, as well as semantic knowledge management systems, have been paving the way for the successful implementation of holonic systems.

Other question often arisen in the discussions has been: “Why holons? What advantages we gain by implementing holonic architecture? The implementation seems to be a huge task.” Holons are autonomous, self-describing, entities having well defined interfaces and ability to communicate and co-operate with other holons. The modularity and self-organization ability enables the holonic systems to be extendable and adaptable. New holons, be it software system modules, new manufacturing resources or human workers, can enter and leave the system without disturbing the operation of the whole system. Each holon, module, knows its own purpose and the inputs and outputs, making the operation more transparent. In holonic system it is possible to make changes in individual modules without the need to change/re-program the whole system.

In the implemented holonic manufacturing environment, the self-description of the manufacturing resource holons is based on the developed capability descriptions. Capability descriptions allow the holons to advertise their capabilities to other holons in the system and enable the holons to autonomously organize the production based on the available capabilities.

It is true the implementation of the intelligent research environment to the TUT heavy machining laboratory has required a lot of effort. Probably the biggest challenge has been to modify the old machines into more intelligent system units that can have cooperation within each others. Each of the machine tools has been enhanced with several additional sensors and holonic interfaces, which both allow the feasible data collection and filtering procedures. The laboratory demonstration showed the basic requirements for an intelligent manufacturing system. Since the intelligence was built on top of existing devices it gave an impression of the sheer amount of work needed to make all systems communicate with each other.

Manufacturing is not the only domain, where the holonic architecture could be applied. Actually, it could be applied almost anywhere, like in medical and logistics domains. A good example can be found from city logistics. Cities and their design are not centrally controlled organized systems, but they are characterized by some level of chaos and continuous threat of the chaos to expand to other operational areas. This chaos is controlled by hierarchical control systems where the control is coming from the top. From this viewpoint the chaos is always considered as a negative element. This kind of systems need always be implemented as closed systems in order to prevent the chaos. The problem here is that innovations don’t happen in order and harmony, but the disruptive innovation always causes temporary chaos. Hierarchical control naturally strangles the innovation. Therefore we need a control system, for which chaos is not a matter of crisis, but a normal event, which can be handled in a flexible and efficient way. This kind of control system can be called as “chaordic system” (chaos + order). Chaordic system is self-organizing system which can always find a new equilibrium when the situation changes. The holonic control architecture can answer to the requirements of the chaordic system. This idea has been presented to the experts in the area of city logistics with very good feedback. The experts saw significant development potential for their business by implementing the holonic arcitecture following the “open system” principles.

4. Future work

In order to make the concept and operation of the dynamic operation environment more intelligent and autonomous, some future developments have been envisioned for the tools forming the environment. The following chapters will discuss about the future developments divided into two groups: Upper concepts and Developed services.

4.1. Future Work on Upper Concepts

Future work in the field of Modular ICT Systems:

- This implementation provided information of the content and context of a manufacturing and assembly system. However, for achieving intelligence and emerging behavior of a system, the past versus present status needs to be taken into consideration. This requires research actions towards a ”learning” factory.
- Development of new service concepts for knowledge-intensive product-process is needed. It is seen that once the tailored solutions are extracted form the PDM/PLM systems the solutions can be turned into evolvable services that utilize existing product data management system thus providing business intelligence outside the fixed PDM/PLM and ERP systems. This allows company to enhance and react upon changes in the business field.

Future Work in the field of Holonic System – Role Engine:

- What is not implemented yet in the previous research efforts are the actual negotiation procedures, definition of required roles and the utilization of the roles. These are needed for deliverable and workable intelligent system. The negotiation in higher level allows the assignment of roles for the holonic entities. In the lower level, the holonic entities are expected to negotiate of possible capability combinations that could fulfill the needs represented by the roles. The roles control the possibilities the system can adapt. In one hand the requirements are formed as roles or role- specifications, and in the other hand the roles are defined based on what combinations holonic entities can advertise. The role-definition needs to be iterative process that can utilize the contextual as well as content-specific information of the current state.
- Currently there is no platform for role definitions or role engines for guiding the adaptive open complex environment. The systems do not posses real context awareness without definition of roles and means for negotiation.

4.2. Future Work on Developed Services

Future developments for the Capability Editor:

- Currently the Capability Editor is used to manage only the device Blue Print information and the individual devices need to be created with the Protégé ontology editor. However, because Protégé is not an optimal tool for manipulating large amounts of data, this function will be later on implemented to the Capability Editor.
- In the future also the creation of resource combinations and manufacturing stations

will be handled with the Capability editor.

Future developments for the Pro-FMA Extended and capability mapping:

- Currently the pre-process plan defines only the very high level capability requirements, e.g material removing or material adding. In the future the algorithms for the pre-process planning will be further developed to enable more intelligent reasoning based on the recognized features and the additional user given information.
- Currently the steps in the pre-process plan are manually linked with the capability taxonomy. This will be automated in the future.
- Also the matching of the product requirements with the resource capabilities is done manually based on the taxonomy. However, when the taxonomy linking is automatized, also the requirement-capability matching can be done automatically.

Future developments for DeMO Tool:

- Currently the DeMO tool is retrieving the simple capabilities of the resources from the KB and making the reasoning with their input and output associations in order to define the combined capabilities of the manufacturing stations. In the future, the DeMO tool will use the web services to query this information directly from the KB without the need to make the reasoning by itself.
- Currently the DeMO tool shows only those device combinations that exist on the factory floor (i.e. those, which are created to the KB). Later on it should be possible to display all the possible device combinations having the required capability (also those, which are not existing currently on the factory floor).
  - ➔ If suitable capabilities don’t exist currently on the factory floor, new combinations of existing devices would be created and shown in the DeMO Tool.
  - ➔ The DeMO Tool would discuss with the UI/Control holon about the availability of the devices. Only available devices can make new combinations.

Future developments relating to the usage of history data:

- The history data collected by the Machine DB can be later on used by the UI/control holon e.g. to evaluate how well the resource performed in different situations. This information can then be utilized when resources for similar applications are needed.
- The history data can also be used for updating the capability information in the Resource KB, e.g. the accuracy.
- The history data should be handled by the role engine (discussed in the previous chapter), so that it could be associated with the specific roles that were used while collecting the data. This way the content and context information could be connected enabling knowledge to emerge. This knowledge can then be utilized for successful adaptation.

5. Conclusions

The operation and business environment changes rapidly. Ability to quickly adapt itself to new requirements has become a crucial enabler for the industry to gain operational flexibility. In order to achieve adaptability, companies and systems must be able to learn from the experience. The learning is achieved via gaining and understanding the feedback of change – its magnitude and direction. In order to understand the change, the company or system must be able to compare the past status with the new status of operations. Unfortunately, in the traditional operation environments the knowledge of neither the past nor the present status is in a computer interpretable and comparable form. It would require that the content, context and interaction between those is known. Without this content, context and their interaction information the adaptation to the changes in the environment is only a theoretical idea without real implementations. Until now, the adaptation has relied on human experience and knowledge, and has therefore been highly subjective.

Support for adaptation is required from all operation levels. A crucial enabler for this kind of dynamic operation environment is modular ICT architecture following the holonic principles. During the KIPPcolla project a concept and case implementation of a new kind of dynamic operation environment based on holonic framework was developed. Actually, the implementation was first of a kind in the whole world. The implementation included both the physical production resources (in co-operation with CSM-hotel project), as well as the modular ICT architecture. The developed approach enables the step towards more intelligent and adaptive production systems by applying four technical solutions: service oriented architecture allowing the customers to place their orders and resources to advertise their capabilities; open interfaces enabling interoperability; common language and structure for the communication based on the ontology; and holonic negotiation process allowing to make the match between requests and offerings and utilize other criteria for the final decision making.

The modular approach in ICT supports the need of adaptive production system, since the services can be added or removed based upon a need. It is seen also that the vendors can make new business openings based on modular system solutions and configuration of those instead of highly tailored solutions that cannot be re-used later on. This is seen as an asset for virtual collaboration environment for the small and medium sized enterprises that can offer services faster than a large scale company. The presented implementation of the dynamic operation environment provides information of the content and context of a manufacturing and assembly system. However, for achieving real intelligence and adaptivity, the past versus present status needs to be taken into consideration. In the current implementation this comparison is not yet done. More research actions towards a “learning factory” is required in the future. Also more development will be done for the tools forming the ICT architecture, in order to allow the system to operate more autonomously. These development actions were discussed in the chapter 4. Of course, new funding is needed to be able to implement the planned developments.