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Towards the Internet of Services: The THESEUS Research Program

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Foreword

Information and communication technologies (ICT) provide tremendous opportunities for business and society. This is linked to their ability to help create sustainable innovation, growth and employment. The new Internet protocol IPv6 is just one such technology that offers significant growth potential. It can be used to generate a virtually unlimited number of Internet addresses and to open up new fields of application right through to the linking of different objects. The result is a massive range of new business opportunities for Internet-based services, e.g., the linking, monitoring and control of industrial production processes (e.g., Industrie 4.0), as well as applications in the health and energy sectors (e.g., the Smart Grid). In order to simplify access to information, to link existing data to new knowledge and to explore the potential of the Internet, 60 research partners from science and business joined within the ICT research program THESEUS to successfully develop new technologies for the Internet of Services.

The year 2012 saw the conclusion of the THESEUS research program, which ran for a period of 5 years. The results that were generated by the ICT research program are extremely positive: THESEUS produced a multitude of new technologies for the Internet of Services, implemented 20 standardization activities, initiated 20 development partnerships, and successfully secured 39 follow-up projects. Over 50 patents and other protected results were registered within the framework of the research program. This was in addition to the development of over 130 prototypes and the publishing of more than 800 scientific papers. In total, more than 1,600 individual results were generated, of which around 1,100 can be accessed by the public in the THESEUS results catalogue, which is also available online.

THESEUS is one of the central areas within the government's ICT strategy "Germany Digital 2015", as well as in its "2020 High-Tech Strategy". The program received total funding of 200 million € – half of which was provided by the German Federal Ministry for Economic Affairs and Energy, the rest by program partners from the fields of industry and research. The key areas of research were defined as the development and testing of basic technologies, standards and promising applications for new Internet-based products and services. Through the work carried out in the THESEUS research program, Germany is taking on a pioneering and internationally admired role in the use of semantic technologies and the creation of new standards for the Internet of Services. This work has also served as the basis for the “Future Internet” program set up by the European Commission.

The research efforts focus on basic semantic technologies which collect, analyze, classify and link the meaning of content. Although standard search technologies are already able to provide good access to content on websites and in textual documents, automatic processing of visual, audio and audiovisual data content is much less successful. The knowledge contained in these types of data often remains hidden. Technologies from the THESEUS research program help to make this hidden knowledge usable. All companies and institutions that have to manage and structure large quantities of data can ultimately benefit from these technologies. Automatic indexing, for example, is useful for storing both doctor’s X-ray images as well as TV producer’s archive material. Bookkeepers need text recognition to scan their invoices, and librarians need this technology to read their index cards. The quick and automatic identification of well-known persons, places or events can assist an editor as he prepares his current news program, as well as a historian who needs to evaluate and link book contributions, newspaper articles and websites. The ability to find synonyms and similarities not only helps chemists with patent analysis, but also aids engineers who are looking to compare different bids.

THESEUS partners used this basic technology and went on to deliver tools and platforms for the development of new services and business models on the Internet. Individual software components and services were integrated with one another, and companies were able to link individual components using complex yet flexible solutions. A multitude of market players have been able to use online development platforms to develop and provide very simple web-enabled services. Conventional industrial companies have thereby become providers of web-based services. In this way, THESEUS has helped to turn the Internet into an ever greater basis for building ICT applications, infrastructure and services. Already, it is, for instance, possible to quickly find suitable services and to link these even more closely together. We also see increased use of cloud computing platforms which will not only offer software components, but also capacity and storage. Web-based services could even be used to tap potential in the area of traditional engineering and plant construction. In the publishing and media industries, web-based services can furthermore be seen as key factors for market growth. Art and cultural treasures can be preserved through digitization and can be processed to make them accessible in new environments. At hospitals, cloud computing technology can be used to help doctors compile information from a variety of different sources in a more efficient manner. In the future, the Internet of Services will provide both the general public and the economy with opportunities to develop new ideas.

In order to simplify the access of SME to technologies from the THESEUS research program, the German Federal Ministry for Economic Affairs and Energy launched the competition “THESEUS Mittelstand 2009” 3 years ago. The companies selected were given early access to the various technologies developed as part of THESEUS and were able to test and use them to create new products and processes. The work undertaken provided support for the development of services and business models and strengthened the competitiveness of small and medium-sized enterprises. The copying and replication of these achievements have served to strengthen growth and employment in Germany. The fact that five successful spin-offs were set up within the THESEUS research program shows how quickly it was possible to build bridges between research and commercial use.

Furthermore, the competition of ideas, "THESEUS Talents", offered young scientists, students and independent developers fresh opportunities to use their creativity and programming skills to contribute to THESEUS developments. Specific questions linked to the range of topics covered by the THESEUS research program have encouraged these groups to actively shape the research into semantic technologies. As it brought upcoming young talent into contact with scientific excellence and commercial potential, the project proved very successful in linking up pioneering research with broad-based training.

The THESEUS Innovation Center for the Internet of Services in Berlin hosts demonstrations and presents prototypes. Here, interested parties can test for themselves the new services and tools that have been developed as part of the research program since 2007. In the future, the Innovation Center is to become a Center of Excellence for the dissemination of THESEUS tools and THESEUS knowledge.

In addition, the THESEUS mobile tablet PC application provides information about the research program as a whole and allows users to view all of the results generated so far using the integrated catalogue of results of accompanying research. The intelligent research tool is in fact itself a product of THESEUS, using semantic technologies developed within the research program.

Only recently, the German Federal Government adopted ten forward-looking projects to implement the 2020 High-Tech Strategy. These forward-looking projects are to bring together the German Federal Government's research and innovation activities in especially promising fields of technology. The Internet is increasingly emerging as a hub for the supply and demand of services. German firms can go on to draw even greater benefit from this than they have done so far. The German Federal Ministry for Economic Affairs and Energy is therefore involved in the project "Internet-based Business Services", which is largely based on the results and findings from THESEUS. The research program will bring commerce and science together to work on the provision of new forms of high-value online services. The central focus will be on cloud computing.

The research program "THESEUS – New Technologies for the Internet of Services" provided significant impetus for further fields of research, e.g. in areas related to cloud computing and big data. This book provides detailed information on the THESEUS research program and the results generated, makes new connections, and looks ahead to the future. It is thus a source of information for both scientists and commercial users on the developments made within the THESEUS research program.

Berlin, Germany

Dr. Andreas Goerdeler
Deputy Director General Information Society, Media
German Federal Ministry for Economic Affairs and Energy

Preface

A book such as this one could obviously not be put together without the help and cooperation of many people.

I am particularly indebted to the authors who graciously made their contributions available in a timely fashion.

I would like to thank Dr. Anselm Blocher for his excellent editorial assistance and the production of the final camera-ready copy. Special praise goes to Mona El Hadidy and Renato Orsini for their assistance in formatting and copy-editing the book. Special thanks go to Ronan Nugent from Springer for his continuous publishing support.

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Saarbrücken, Germany

Wolfgang Wahlster
CEO of the German Research Center
for Artificial Intelligence (DFKI)

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Part I
Principal Challenges

Semantic Technologies for Mass Customization

Wolfgang Wahlster

Abstract We discuss the key role of semantic technologies for the mass customization of smart products, smart data, and smart services. It is shown that new semantic representation languages for the description of services and product memories like USDL and OMM provide the glue for integrating the Internet of Things, the Internet of Data, and the Internet of Services. Semantic service matchmaking in cyber-physical production systems is presented as a key enabler of the disruptive change in the production logic for Industrie 4.0. Finally, we discuss the platform stack for mass customization and show how a customized smart product can serve as a platform for personalized smart services that are based on smart data provided by the connected product.

1 Introduction

Semantic technologies are enabling mass customization for the delivery of goods and services that meet individual customers' needs and tastes with near mass production efficiency and reliability (Tseng and Jiao 2007). Mass customization creates a competitive advantage in the industrial economy, the service economy, and the emerging data economy. Mass customization leads to smart products, smart services, and smart data (see Fig. 1). The more they are customized, the smarter they get, since they are also adaptable to specific tasks, locations, situations, and contexts.

The Internet of Things, the Internet of Services (Heuser and Wahlster 2011), and the Internet of Data provide the technical infrastructure for the mass customization of products, services, and data. But only semantic technologies can provide

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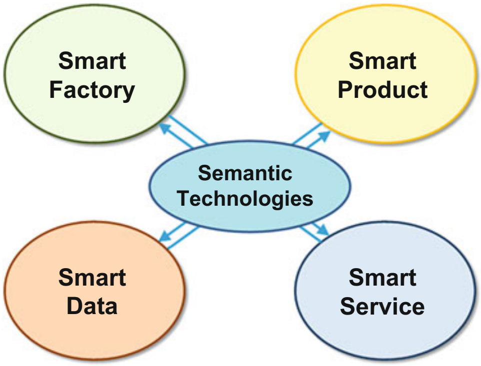

Fig. 1 Customization based on semantic technologies

the flexibility, adaptability, agility, and interoperability in manufacturing, service creation and delivery, as well as data analytics that are needed for the efficient customization of products, services, and big data sources. Semantic technologies allow us to describe, revise, and adapt the characteristics, functions, processes, and usage patterns of customization targets on the basis of a machine-understandable content representation that enables automated processing and information sharing between human and software agents (Fensel et al. 2003).

Smart Factories use cyber-physical production systems, semantic machine-to-machine (M2M) communication, and semantic product memories (Wahlster 2013a) to create smart products. These smart products are the basis for smart services that use them as a physical platform. Since smart products and smart factories include many sensors, the streams of sensor data collected by them can be fused and transformed into smart data that in turn can increase the efficiency of smart factories, smart products, and smart services.

Therefore, the results of the THESEUS research program described in this book, including methods, toolsets, and standards for semantic technologies together with insights gained into their application potential through the various use cases, form a solid basis for Industrie 4.0 and the fourth industrial revolution, the hybrid service economy, and the transformation of big data into useful smart data – as three major new R&D funding programs in Germany.

2 The Role of Semantic Product Memories for Mass Customization

Active semantic product memories will play a key role in the upcoming fourth industrial revolution based on cyber-physical production systems, which allow mass customization at an affordable prize. Industrial mass customization means lowvolume high-mix production. In the extreme case, this leads to a batch size of 1, but quite often custom products are manufactured in larger quantities for an individual customer. In addition, the volatility of markets and the ever-decreasing product life spans require multi-adaptive and multi-product factories with very short reconfiguration times.

Low-cost and compact digital storage, sensors and radio modules make it possible to embed a digital memory into a product for recording all relevant events throughout the entire lifecycle of the artifact. By capturing and interpreting ambient conditions and user actions, such computationally enhanced products have a data shadow and are able to perceive and control their environment, to analyze their observations, and to communicate with other smart objects and human users about their lifelog data.

Cyber-physical systems and the Internet of Things lead to a disruptive change in the production architecture: the workpiece, the emerging product or the product packing container navigate through a highly instrumented smart factory and try to find the production services that they need in order to meet their individual product specifications stored on the product memory. In contrast to the classical centralized production planning and manufacturing execution systems, this leads to a decentralized production logic, where the emerging product with its object memory is not only a central information container, but also an observer, a negotiator, and an agent in the production process. A semantic service architecture based on a production ontology and ubiquitous microweb servers realizes intelligent matchmaking processes between emerging products and production tools (see also Loskyll 2013; Loskyll et al. 2012).

Let us illustrate the principle of mass customization based on semantic product memories using a simple example from modern food production. The German company mymuesli[1] produces custom-mixed cereals. The customer can select from a variety of cereal base mixes and refine them in small steps down to 15 g, choosing between 80 ingredients like various nuts and fruits. Thus, more than 560 billion variants are offered by mymuesli via a web-based graphical configurator on the company's portal (see Fig. 2). The consumer's individual product specification is stored on a physical product memory tag. This enables the transfer from the Internet of Services, which is used for the B2C ordering and delivery processes, to the Internet of Things, which is used for manufacturing the individualized food product. Thus the virtual and the real world are integrated in the business model of mass customization at this point.

The machine-understandable product memory describing the particular mixture ordered by the customer is attached to the paper tube box that is used for shipping the muesli to the end consumer. The product memory is read by each of the 80 filling machines, as the tube box is moving along the row of machines. For example, it will pick up 35 g of cherries, skip the mangos, and then pick up 20 g of coconut chips from the next machine and so on, until the right amounts of all selected ingredients

[1] http://www.mymuesli.com

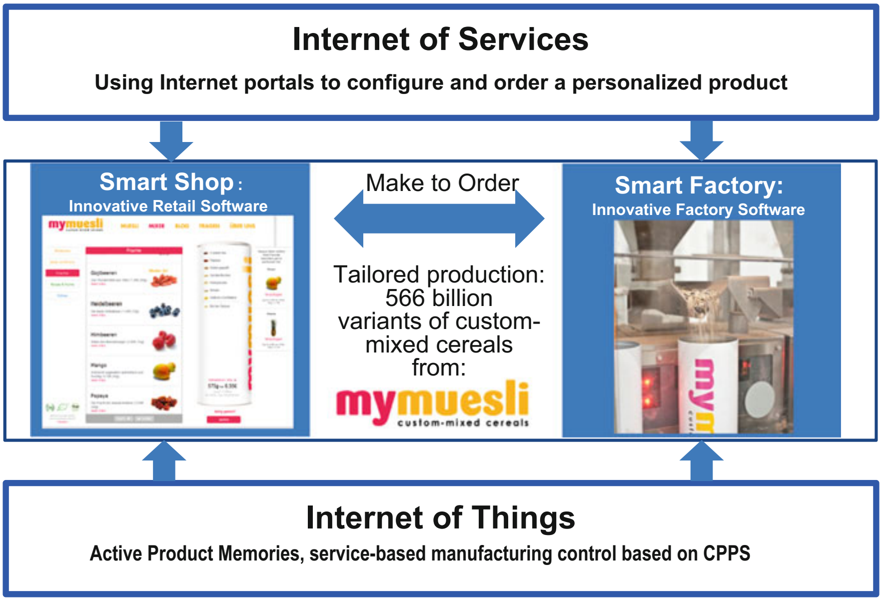

Fig. 2 Mass customization in food production

stored in the product memory are filled into the paper tube box. This means that the semantic product memory guides the flow across conveyor belts and filling stations in the smart factory (Wahlster 2013b).

By social media mining and information extraction from customer blogs big data can be collected about the customers' preferences for ingredients and their combination. Big data analytics transforms this customer data into smart data that can help to optimize the supply chain, so that always the right amount of ingredients is available in the warehouse for replenishing the filling machines. In addition, special marketing actions for selling ready-made mixtures can be launched, when a high demand can be predicted based on the smart data harvested for particular combinations. In addition, the production process could be optimized by such smart data analytics in real-time by the intelligent reordering of the sequence of filling machines, so that the average path length for the tube boxes is minimized.

The decentralized production control is also very useful, when a new filling station with a new ingredient is added due to market demands. The service-oriented architecture for smart factories in the Industrie 4.0 paradigm allows a very simple and fast solution. The new machine simply announces its service in the new row of filling stations, and as soon as the first tube box requesting the new ingredient is passing along, the machine is used in the reconfigurated factory. This illustrates the versatility and adaptability of this new factory paradigm, where new machines can be integrated in a plug-and-produce fashion minimizing manufacturing downtime.

3 Semantic Service Descriptions for Decentralized Production Control

As we have shown in the previous section, mass customization is achieved in smart factories organized like markets with many booths, where vendors advertise their goods and services. The emerging product can be viewed as a customer who is attracted to particular booths, since they offer goods and services that are on the customer's shopping list. The semantic representation languages used for the service description (see Fig. 3) allow for service discovery and selection, even in cases where no exact match is possible, but a subsumption relation can be established between the vendor's offer and the customer's needs, or a semantic equivalence relation between both descriptions can be established by automated reasoning based on the model-theoretic semantics of the markup-language. This means that the emerging product is no longer passive, but its active semantic memory and M2M communication bring it to life so that it can instruct the production machine as to how it should look. This is in sharp contrast to the traditional manufacturing paradigm where the product remained passive and all machines were centrally controlled by a manufacturing execution system (MES) generating a large programming overhead for every process change. The disruptive innovation in Industrie 4.0 is the inversion of the production logic based on semantic technologies: no longer does a MES dictate what happens with a workpiece, but the workpiece tells the machines what it expects from them.

As shown in Fig. 3, OWL-S is used as a semantic service description language in DFKI's smart factory installations. OWL-S is an ontology based on W3C's Ontology Web Language (OWL) that enables users and software agents to automatically discover, invoke, compose, and monitor Web resources offering services. Since OWL representations can be mapped automatically onto triples of the Resource Description Framework (RDF), there is a natural link to the Universal Service Description Language (USDL, see Oberle 2014) developed in the THESEUS research program as a building block of the Internet of Services. USDL focuses on the specification of various business aspects of services, like pricing, licensing, and service-level agreements and can also be mapped onto RDF, so that OWL-S and USDL can be easily connected to bridge service descriptions from the Internet of Things and the Internet of Services. Since RDF is also being viewed for big data analytics, it can be used as a kind of universal low-level assembly language of semantic technologies for smart factories, smart products, smart data, and smart services (see Fig. 1).

USDL 3.0 was described in the final report of the W3C incubator group in 2011. The Internet of Services requires a way of describing services as economic or social transactions within a broader context, including the price schemes, or the terms and conditions when consuming the service and paying for it. Also third-party intermediaries, such as brokers, or cloud providers are interested in the business and legal details as well as the functional details of a service in order to augment services and to monetize them.

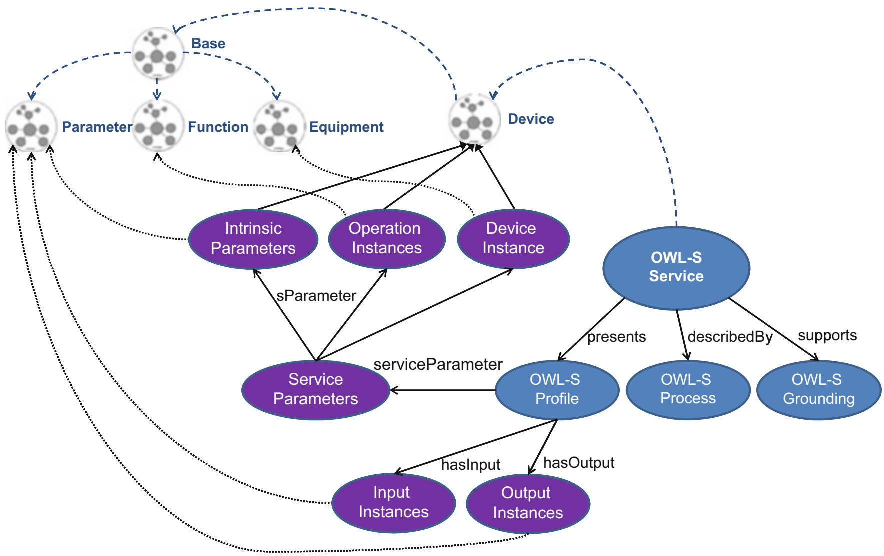

Fig. 3 Semantic service descriptions for the smart factory (Loskyll 2013)

USDL creates a kind of "commercial envelope" around a service, so that technical and functional service descriptions in OWL-S may be lifted to business services by adding USDL descriptions. As many services have a hybrid character with a digital and/or physical and/or a manual footprint, USDL can facilitate the combination and mash-up of such services. USDL has been expanded to a European scale in the context of the Future Internet PPP on the basis of the so-called Linked USDL, which is a remodeled version of USDL that builds upon the Linked Data principles. USDL also allows us to attach service offerings to sensor networks in smart factories, which can be used for internal accounting or selling sensor network services.

As mentioned above, active semantic object memories play a key role for connecting physical artifacts with smart data analytics and smart services. With the Object Memory Model (OMM) we have designed a generic framework in a W3C incubator group for implementing active semantic product memories (Kröner et al. 2013). OMM partitions a semantic product object memory into several blocks. Each block contains a specific information fragment and provides a set of metadata for search tasks in the memory. This list of blocks is supplemented with an optional table of contents and a header section. This header specifies the version of the OMM, a primary unique identifier for this object memory and an optional link to additional external block sources. Each object memory block contains information about a specific aspect or phase of the product's life. For the identification of relevant blocks by users and applications, a set of block metadata indicates the block's topic, which is stored in the block payload. If the block payload is not embedded directly into the

XML structure, then a link can be provided to indicate a relation to an outsourced block payload at any location in the cloud.

The block payload is the information container for the product memory entries and ideally is encoded in Semantic Web languages like RDF or OWL, so that a machine-understandable ontology and standardized epistemological primitives can be used for automatic processing. Semantic technologies embedded into OMM (Haupert 2013) guarantee interoperability of the product memory during the complete lifecycle of smart products and enable ubiquitous access by smart data analytics, smart services, and end users to the smart product's lifelog.

Thus, OWL-S, OMM, USDL and RDF provide the basic toolset to establish semantic technologies as the glue for integrating the Internet of Things, the Internet of Data, and the Internet of Services for Mass Customization.

4 Semantic Service Matchmaking in Cyber-Physical Production Systems

Of course, the semantic matchmaking techniques for cyber-physical production systems illustrated in Sect. 2 can be scaled to much more complex customized products that are produced on demand, like kitchens and cars. For example, the German kitchen manufacturer Nobilia automatically produces 2,800 customized kitchens per day allowing for 14 million variants. Every premium car of BMW is theoretically available in 10^{31} variants, and since there are close to 100 networked embedded systems in such a car, with frequent software updates, it is obvious that already today each car leaving the factory is a unique artifact.

Since the service descriptions for machines in a particular industrial domain are linked to ontologies (see Fig. 3) for the various production functions offered by the automation components (like adhere, weld, grasp), for the field devices that can be used to realize these functions (like sensor, drive, gripper), and for the parameters that are relevant for a particular process (like angle, velocity, force), the semantic descriptions can be easily reused, adapted and extended for new devices or new production systems in other domains.

As an example of cyber-physical production architectures with active semantic product memories, we have developed a production line for customized smart keyfinders in DFKI's smart factory within the framework of the Industrie 4.0 project RES-COM (Wahlster 2013b). The abstract production process specification is stored on the memory chip inside the backcover plastic frame (see Fig. 4). Using Bluetooth technology, the keyfinder will alert its owner any time his keys are more than 30 ft. away from his smartphone. The smart keyfinder is itself a simple example of a cyber-physical system, is produced in a smart factory, and provides various smart services. Please note that the massive amount of active product memories in a smart factory generates an enormous big data stream that can be harvested and analyzed for resource-efficient and high-quality production.

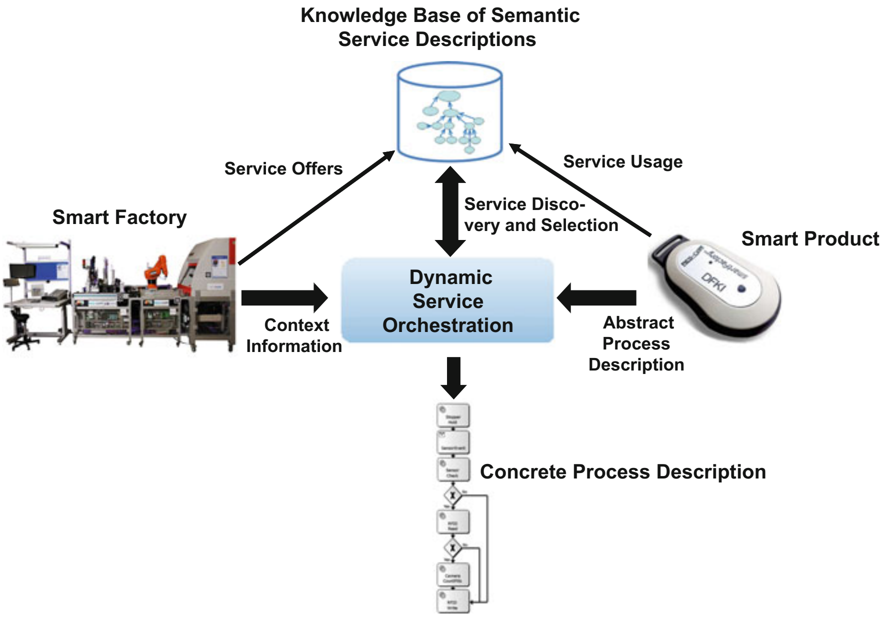

Fig. 4 Orchestration of Web services in the smart factory (Loskyll 2013)

5 From Connected Smart Products to Hybrid Smart Services

A car can be manufactured as a smart product in a cyber-physical production environment based on the specification stored on its semantic product memory that is attached as a black box to the car's chassis, before the assembly process is started. The semantic product memory not only drives the production flow, but also records all production steps, the resources, parts, and materials used. Since the semantic product memory is connected to the embedded systems and the various in-car bus systems, or in the near future to the IP-based in-car network, it can record all sensor and actuator signals of the car.

The logging data stored in the semantic product memory of the car can be used for various advanced services. Since cars are connected also with other vehicles and the road-side infrastructure via mobile Internet in Car2X networks, unimaginable volumes of anonymized traffic data can be created and stored in cloud-based mobility management systems. Since the cost of memory has declined by a factor of 500 million during the last 50 years and in-memory and massively parallel cloud computing is available, we can now analyze and respond to such big data streams in real time. This software-defined platform layer (see Fig. 5) is the basis for new service platforms that open up innovative business models based on mass customization.

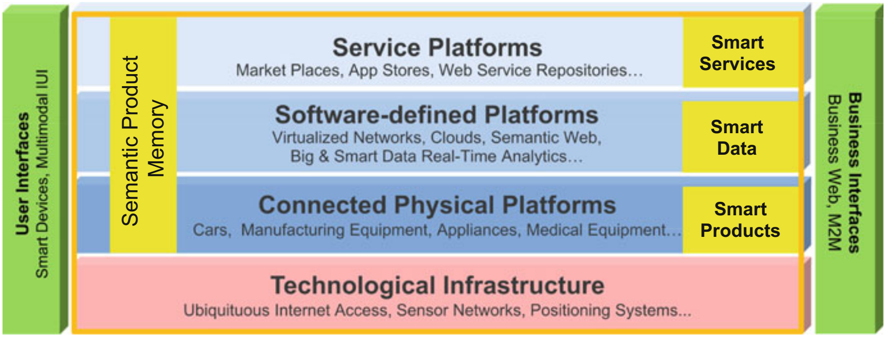

Fig. 5 Platform stack for customized smart products, data and services

Thus, the car as a connected physical platform can be used for various smart services. For example, the pay-how-you-drive functionality provided by auto insurance companies offers the driver lower fees or a bonus when they modify their driving behavior. The semantic product memory of the car provides real-time logging of the acceleration and braking behavior, the number of instances exceeding the speed limit, the number of night-time drives and other risk factors that are aggregated into a score that is delivered in a privacy-preserving trusted way to the insurance company, where the individual incentive is computed. This example shows clearly how a customized smart product can serve as a platform for personalized smart services that are based on smart data. It also illustrates the key contribution of semantic product memories to the mass customization of products as well as services.

The maturity of mobility with Internet connectivity being ubiquitous on a global scale and the consumerization of end-user devices including sensors and positioning systems that has driven the bring-your-own-device movement in workplaces characterizes the technological infrastructure for the path from smart products to smart services (see the first layer in Fig. 5).

End-user devices like smartphones, tablets, and wearables that are used in North America and Asia as connected physical platforms for services distributed via App stores are no longer produced in Germany. However, connected cars, connected factories, connected homes, and connected healthcare systems are physical platforms that are produced by Germany's export economy with the premium quality branding "Made in Germany" (see the second layer in Fig. 5).

The development of large-scale software-defined platforms, which support the mass adoption of trusted cloud computing as well as the storage and manipulation of big data streams enabling semantic analysis in real time, has accelerated the migration of value from hardware to software through virtualization, as hardware differentiation vanishes, submerged by low-margin commodity components manufactured at consumer scale (see the third layer in Fig. 5).

Market places for smart data and App stores or web service repositories for smart services constitute the fourth layer of service platforms on the platform stack (see Fig. 5).

Of course, the ultimate success of end-user applications depends to a large degree on the quality of the user interfaces. Intelligent multimodal interfaces based on semantic technologies were another important contribution of the THESEUS research program. SemVox[2] is one of the very successful spin-off companies of DFKI, that used results from THESEUS to integrate multimodal and spoken dialog systems into connected cars, homes, healthcare systems, and factories.

6 Conclusion

We have shown that in the era of Industrie 4.0, smart factories use cyber-physical production systems, semantic machine-to-machine communication, and semantic product memories to create smart products by mass customization. These smart products are the basis for smart services that use them as a physical platform. Since smart products and smart factories include many sensors, the streams of sensor data collected by them can be fused and transformed into smart data that in turn can improve the efficiency of smart factories, the functionality of smart products and the attractiveness of smart services. Therefore, the results the THESEUS research program described in this book, including methods, toolsets, and standards for semantic technologies, form a solid basis for Industrie 4.0 and the fourth industrial revolution, the hybrid service economy, and the transformation of big data into useful smart data for the emerging data economy.

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References

D. Fensel, J. Hendler, H. Lieberman, W. Wahlster, Introduction to the semantic web, in *Spinning the Semantic Web. Bringing the World Wide Web to Its Full Potential*, ed. by D. Fensel, J. Hendler, H. Lieberman, W. Wahlster (MIT, Cambridge, 2003), pp. 1–25

J. Haupert, DOMeMan: a framework for representation, management, and utilization of digital object memories, in *Proceedings of the 9th International Conference on Intelligent Environments*, Athens (IEEE Computer Society, 2013), pp. 84–91

L. Heuser, W. Wahlster (eds.), *Internet der Dienste* (Springer, Berlin/Heidelberg/New York, 2011)

[2]http://www.semvox.de

A. Kröner, J. Haupert, C. Hauck, M. Deru, S. Bergweiler, Fostering access to data collections in the internet of things, in *Proceedings of UBICOMM 2013, the Seventh International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies*, Porto, Sept 2013, ed. by W. Narzt, A. Gordon-Ross (IARIA, 2013), pp. 65–68

M. Loskyll, *Entwicklung einer Methodik zur dynamischen kontextbasierten Orchestrierung semantischer Feldgerätefunktionalitäten*. Doctoral dissertation, TU Kaiserslautern, May 2013

M. Loskyll, I. Dahmann, J. Schlick, M. Schwarz, Context-based orchestration for control of resource-efficient manufacturing processes. Future Internet **4**(3), 737–761, 8 (2012)

D. Oberle, A unified description language for the internet of services, in *Towards the Internet of Services: The THESEUS Research Program*, ed. by W. Wahlster, H.J. Grallert, S. Wess, H. Friedrich, T. Widenka (Springer, Berlin/Heidelberg/New York, 2014)

M.M. Tseng, J. Jiao, Mass customization, in *Handbook of Industrial Engineering: Technology and Operations Management*, 3rd edn., ed. by G. Salvendy (Wiley, New York, 2007)

W. Wahlster, Digitize your factory for smart products, in *The Digital Enterprise*, ed. by K.H. Streibich (Software AG, Darmstadt, 2013a), pp. 144–149

W. Wahlster, The semantic product memory: an interactive black box for smart objects, in *SemProM: Foundations of Semantic Product Memories for the Internet of Things*, ed. by W. Wahlster (Springer, Berlin/Heidelberg/New York, 2013b), pp. 3–21

Challenges of the Internet of Services

Stephan Fischer

Abstract The past decade was marked by a profound change in the business world. Globalization was already taking off in the 1990s, but it reached a new quality when people and companies got used to web-based collaboration across the globe. Started as a well-defined technical infrastructure, the Internet has become the world's encompassing communication infrastructure. Year by year, the network grew, more and more nodes were added, humans, machines, and businesses were linked, and finally the Internet boomed. It emerged into the world's business backbone.

1 Introduction

In 2005, Thomas L. Friedman coined the term of a "flat world" we are living in Friedman (2005). Since the 1990s, the globe has started to become flatter, caused by changes in the political landscape, business innovations, and web-based tools for collaboration. As these tools became mainstream, competition and collaboration became more equal on a global scale and hierarchies started to erode. A playing field was created that allowed for new forms of collaboration in real time, regardless of geography and distance. One of the well known results was outsourcing, which became a hot topic at this time. When Friedman revisited the topic in 2012, the narrative of a flat world seemed to have reached an ending point (Friedman 2012). Today's CEOs rarely talk about "outsourcing" anymore, says Friedman. The business world has become so integrated that products are engineered, built, and marketed through truly global supply chains using the most efficient resources wherever they are available in the world. More and more of today's products are "made in the world", as Friedman puts it.

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The growing importance of services will lead to a similar development in the service sector. In Germany, as in most industrial nations, the service sector is growing fast and will be a main source of further industrialization and globalization. In Germany, around 73 % of the economic value creation was generated from the service sector in 2009 (going up from 62 % in 1991). In the same year, around 73 % of all employees worked for the service sector (going up from 59 % in 1991).[1] This increase is accompanied by changes in the quality of services and their provisioning, and IT plays a critical role in making the change happen. More and more companies offer products combined with services such as monitoring or maintenance services. Some companies focus mainly on offering a service, e.g. renting out machine tools. It is a logical idea to offer these services through the Internet. This includes web services and other automated services as well as traditional business services.

We only see a very first glimpse of how the future of the web-based service economy will look like, but evidence matures that an Internet of Services is emerging. Enterprises will use the Internet to build and provide huge numbers of new kinds of services that go beyond booking flights or purchasing books. Services that are available on the Web separately will be combined and linked with one another resulting in aggregated value added services.[2] Using web technologies, services will become more widely and easily available. Enterprises will open their business processes to others to form value networks which will be, in the end, a necessity for success in most markets. The Internet of Services is expected to ensure profitability and further growth of the service sector. It is, so to say, *the* instrument of globalization of the upcoming decade.

However, the Internet of Services has not become reality yet – at least not in the full scale researchers have envisioned it. What challenges do we face regarding the rise of the web-based service economy? This paper will review this question from different angles: Research, daily life, IT trends as well as concrete projects that translate the Internet of Services vision into prototypes and field tests.

2 Landscapes of a Web-Based Service Economy

In 2005, Thomas L. Friedman felt that the Internet became the central globalization engine and foundation of the “flat world”. He then looked back and identified ten “flatteners”. These are innovations that helped to remove barriers for global collaboration. With regard to the emerging Internet of Services we might not know the exact flatteners of service-oriented challenges; however, we can use this idea to discuss areas where the new flatteners might come from.

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[1] http://www.bmwi.de/BMWi/Navigation/Wirtschaft/dienstleistungswirtschaft,did=239886.html

[2] This is the Internet of Services vision that lies behind the THESEUS research program and the TEXO use case that developed an integrated platform for providing, managing and combining Internet-based services; see http://www.theseus-program.de/en/about.php

When taking a bird's-eye view, the world of web-based services is not flat. It is rather structured along larger players that seem to dominate the business, complemented by larger ecosystems, loose networks, or smaller gated communities. It is a long known imperative to maintain openness and fairness in the Internet, politically as well as economically.[3] One challenge of the service sector is to ensure low entrance barriers with access to platforms, reliable and secure infrastructures, and standards. But there are several more areas that need to be looked at when discussing the Internet of Services.

We will review five landscapes that belong to the emerging world of web-based services or are tightly interconnected with it:

1. The scientific world that discovers the Internet and web-based services as appealing objects of research.
2. Our daily life that is penetrated with new technologies that will spread into the business world.
3. Today's IT trends that already contain traces of the upcoming world of web-based services.
4. The applied industrial research that builds on these trends and prepares the Internet of Services with prototypes, standards and platforms.
5. Innovation projects that translate research results into tangible software pilots for testing the market and evaluating first steps of a roadmap to the Internet of Services.

3 Research Focus

We started with the notion that today's Internet emerged from a well-designed infrastructure into something new and much more complex, namely a business platform and mission-critical infrastructure.[4] This development is mirrored by the research questions about the Internet. In the 1990s, most Internet research focused on technical artifacts such as new protocols and components.[5]

Around 2000, the notion changed. In his famous book "Linked", the physicist and network scientist Albert-László Barabási noted that a growing number of researchers asked a then unexpected question: What is it that we have created with the Internet (Barabási 2003)? Obviously the Internet went beyond the original scope it was designed for. This question caught the interest of researchers and is still a source of a growing body of knowledge about the Internet. New disciplines like Web Science or Network Science developed, with contributions from computer

[3]Most recently stated by Google's co-founder Sergej Brin who blamed Facebook for inhibiting innovation due to its closed networks (Katz 2012).

[4]Some authors use the term Societal Operation Platform (Couturier et al. 2011).

[5]This tradition is still followed by larger research programs working on advancements of the Future Internet.