PROJECT FINAL REPORT

PUBLIC INFORMATION

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1 Project Summary

The project developed the scientific and technological basis for the embedding of *proactive knowledge* into *smart products.*

Smart products are products which are able to proactively co-operate and communicate with humans and other products in an environment. A perquisite for such proactive behaviour is formally represented knowledge, encompassing knowledge about the product itself (features, functions, dependencies, usage, etc.), its embedding (physical & virtual environment), its users, and the specific context of use.

By focusing on the individual product, new forms of product-centred knowledge management become possible. Such concepts are urgently needed to deal with the challenges posed by the increasing complexity of products (more features and functions), the emerging diversity within products lines (customisation, variant management), the ever-growing amount of product-related content and data and the need for interoperability between products in open environments.

In contrast to static content, the knowledge in smart products is called *proactive*, as it comprises executable software and problem solving knowledge which enables the smart product to “talk”, “guide”, and “assist” its users. A schematic view of a smart product is depicted in Figure 1.

Figure 1: Smart Product with Proactive Knowledge

The project aimed at researching all aspects relevant to the acquisition, modeling, reasoning, management, and use of proactive knowledge.

Some proactive knowledge is co-constructed with the product, while other parts are gathered during the product lifecycle using embedded sensing and communication capabilities. A service-oriented SmartProducts platform with support for context integration and multimodal UIs has been developed and released. Widely re-usable concepts for smart products are implemented and evaluated in three industrial application scenarios. In addition, a socio-economic analysis has also been carried out, which evaluates the economic potential deriving from a massive deployment of smart products.

2 Overview of Results by Project Objectives

2.1 Objective 1: Development of integrated concepts and methods for proactive knowledge embedded in smart products

Realizing the vision of smart products requires an integrated conceptual framework covering all aspects of smart products. Such concepts must cover the whole proactive knowledge lifecycle, starting with the (automatic) creation over use, presentation and update to archiving. Although proactive knowledge comes in different formats and may come from a variety of different sources, a common modeling methodology is needed in order to process, integrate and present the proactive knowledge in a unified way. Semantic representations are necessary to search, retrieve, combine and present the relevant and appropriate content in an interactive, context-aware way. Likewise, the information about individual product itself, its environment, the tasks and interacting humans have to be represented and modeled using pre-defined template models and processed context information to influence how the content is presented and to influence the kind and the form of the interaction.

A set of ontologies and reasoning methods has been developed to characterise proactive knowledge and embed it into smart products in order to support context-aware interactions with a variety of users and other smart products. The project has delivered formal models for the three application domains (consumer appliances, aircraft manufacturing, smart vehicles) have been developed which are based on common upper-level ontologies. Additionally, a formal model of proactivity as such, i.e., how smart products collaborate with each other and humans to solve *tasks* has been developed. This conceptual framework builds on generic problem solving methods from knowledge-centric systems. These methods are integrated with static workflows and (physical) actuators in the SmartProducts platform.

2.2 Objective 2: Development of architectures and technologies for the creation, processing, management and distribution of self-aware, adaptive proactive knowledge

Based on the concepts and methods developed under Objective 1, a service-based software architecture as well as all necessary services are designed and implemented. This SmartProducts platform is based on OSGi, and includes a communication middleware, all essential services, a framework for the use of context information and support for multimodal UIs based on proactive knowledge. The architecture is scalable to deal with very large, distributed and heterogeneous data sets. This required the development, implementation and evaluation of storage, distribution and communication solutions for proactive knowledge. Corresponding technologies for the access (including security, privacy and reliability issues) and distribution (including update and maintenance issues) and of proactive knowledge have also been implemented. The platform implementation delivered by the project provides working implementations for all required services. These were refined and improved based on the results from the application trials and the evaluation.

2.3 Objective 3: Realisation of context-aware, personalised and multimodal human-product and product-environment interaction

The acceptance of smart products relies on the user experience provided. This is not just a technical problem but also has to take the environment and the task of the user into account. Human-product interaction should adapt to the user, his goals, the environment and the available devices and interaction channels. This requires a far more open approach to interaction design as usual. Using capabilities built into the product and the environment permits to create ambient intelligence like features, enabling immersive multimodal experiences. Based on provided or automatically learned task- and user models adaptation to each individual user and his personal tasks become possible. During the lifetime of the project, not only multimodal human-product interaction are implemented for specific smart products, but also a whole methodology (including corresponding tools) to create multimodal user interfaces based on proactive knowledge have been developed and implemented. At the dialogue level, the interaction between user and product are either guided by a workflow, or, in the future, guided by the interaction needs emerging from the application of problem solving methods. We have developed a model how multiple dialogues with the user can be conducted concurrently within the same environment, thereby sharing input and output devices. This model is based on speech act and language theory but awaits evaluation in experimental study.

Product-environment communication is based on the same intermediate layer as human-product interaction. This enables products to know which functionality from other products is available and how to use them. This is important for solving complex tasks involving several smart products. Each product can offer its knowledge or functionality for solving the task at hand. As a final resort the products refers to the human user to solve a task. By providing a unified abstraction for product-to-human and product-to-product interaction, the development complexity is reduced.

2.4 Objective 4: Product-centred knowledge management

Proactive knowledge offers a new way to the management and sharing of product-related knowledge. Turning structured or unstructured data into proactive knowledge makes it not only accessible for all kinds of purposes but allows for the proactive interaction between the knowledge and humans and thus giving actionable meaning to “dumb” data. Knowledge for smart products are organized around the concept of product and its lifecycle. This creates a knowledge lifecycle built around the product lifecycle. The whole knowledge lifecycle is based on a shared ontological view of the domain that is able to cover the whole lifecycle (common view). This has to be acquired and made available. However, while the product moves in its lifecycle, a number of communities will operate on it. Not all the knowledge used or collected by these communities will be relevant to the rest of the communities or even compatible with the rest of the lifecycle. Communities define their own ontological view of the domain. The role of the common view is knowledge sharing during the product lifecycle across communities and for future record, while the role of the community views empowers local communities to focus on their tasks. Knowledge captured based on both local and common views are exchangeable. Communities exchange knowledge with other communities either directly via their local views or via the common view.

Product-centered knowledge management requires the development, implementation and evaluation of storage, distribution and communication solutions for proactive knowledge. Corresponding technologies for the access (including security, privacy and reliability issues) and distribution (including update and maintenance issues) and of proactive knowledge have been implemented. The platform, thus, provides working implementations for all required services.

2.5 Objective 5: Socio-economic analysis of smart products and their application

Smart products are hybrids that merge tangible products with mobile information technologies. This opens up unprecedented opportunities for product designers and marketing manager for implementing adaptive and situation-aware product interfaces that generate dynamic communication behaviour with users during the whole lifecycle of a product. While the design and implementation of smart products poses a major challenge from a technological point of view, it also induces a number of economical and societal questions that have hardly been considered in prior research.

Firstly, the economical rationale, i.e. the business case, for the use of smart product is not fully understood.

Secondly, the success of the information and the services offered by a smart product depends on user acceptance of the new technology. For this reason, the project aims at doing empirical research of user perceptions and moderating factors, e.g., age, trust in technology, educational background, perceived usefulness, ease of use, and so on.

Thirdly, smart products may be regarded as technical artefacts that grant information systems ‘eyes and ears’, i.e. existing systems are provided with real-time information on the usage of physical products, but also about the activities of users. This implies several questions with regard to privacy, technology risks, and legislation. Therefore, this project seeks to shed light on the question how smart products should be designed to comply with existing privacy laws and the interests of various stakeholders on a political and a societal level.

2.6 Objective 6: Prototypic deployment and evaluation in three different scenarios

The consequent application and evaluation of industrial and consumer-focused application trials guarantees the applicability of the developed concepts and the software. The implementation of three pilot applications allows the evaluation of performance and scalability issues as well as the evaluation of user acceptance, flexibility and generality of concepts and implementations. The project considered three different application scenarios covering different industries and different parts of the product lifecycle to guarantee a broad applicability of the developed concepts, methods and technologies.

The first scenario, realized together with Philips, is focused towards the end user and smart products in the domestic appliances sector. The SmartProducts project concepts were integrated into the kitchen application domain, in which users will be guided with food planning, ingredients shopping, and the actual cooking itself. Figure 2 shows the Smart Chopping Board, one of the physical smart products developed within the project.

Figure 2: Smart Chopping Board

A second scenario looks at product lifecycle management of vehicles. The aim of Centro Ricerche Fiat is to develop and demonstrate a smart vehicle with embedded proactive knowledge in order to increase productivity and mobility during the product lifecycle. Figure 3 shows snow-chain mounting instructions from a “smart snowchain” being displayed on the dashboard display.

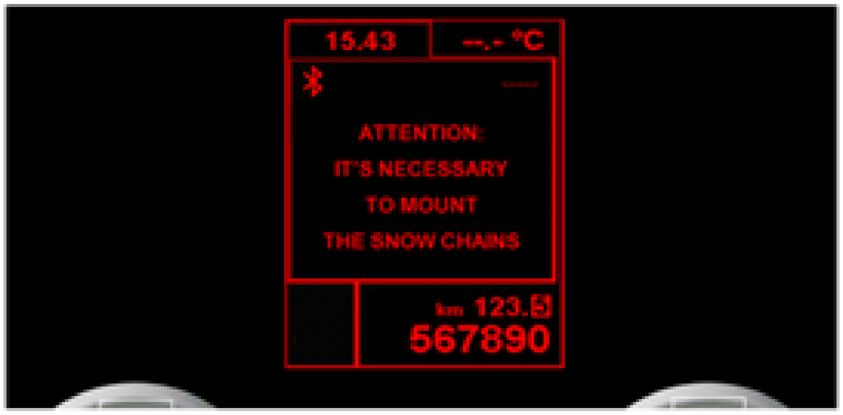

Figure 3: Snowchain mounting instructions

In the third application scenario, EADS focuses on the manufacturing phase and the co-construction of proactive knowledge in form of precise, annotated 3D models of individual airplanes. Figure 4 shows an overview over the smart products involved in this scenario. The top right part of the picture shows a part of an airplane, to which an electrical harness needs to be mounted together with a smart wrench. The lower right part shows a nomadic device, a smart product the operators use to receive instructions and work orders. The left screen shows the overview of the up-to-date 3D model generated based on information received from the smart wrench and nomadic device.

Figure 4: Implementation of the first two challenges in the demonstrators: DMU, Smart Tool and Nomadic device

3 Main S&T Results

The SmartProducts project aimed at researching all aspects relevant to the acquisition, modeling, reasoning, management, and use of proactive knowledge for smart products. This comprises the technological basis for embedding proactive knowledge into smart products and using it to communicate and co-operate with humans and other products in an environment. Laying the foundations for smart products based on proactive knowledge requires substantial scientific research in a number of scientific fields some of which have been partly unrelated up to now. Hence, the challenge is to achieve scientific advances in well-established scientific fields while ensuring a clear direction towards the required scientific basis for dealing with proactive knowledge and smart products. This requires an interdisciplinary and more holistic approach than the one used in previous research efforts.

Results on these topics have been published in more than 50 articles at workshops, conferences and journals, comprising top-level venues for each of the above mentioned fields such as ESWC, PerCom, EICS and CHI. Furthermore, the technology developed in the project has been applied in three integrated application trials, which comprehensively demonstrate the technology. In the following, we describe the main scientific results as well as the application trials to illustrate the developed technology.

3.1 Ubiquitous Computing Infrastructure

One tangible outcome of the SmartProducts project is a software and hardware platform for smart products (see Figure 5) which defines the major functional blocks of a smart product. Within the project reference implementations for all modules have been developed and most of them are available as open source via the project website. The architecture emphasizes a distributed, bottom-up approach towards ubiquitous computing, instead of the top-down design approach chosen in most research projects. The architecture has been evaluated internally, by applying it in the three case studies of the project and also externally be applying the methods from the Quamoco[2] research project.

One main component of the platform is the MundoCore communication middleware for ubiquitous computing. It is ideally suited for the needs of smart products, since it combines three different communication paradigms (publish/subscribe, streaming, remote method calls) in an integrated way. The middleware is available via the project website and also via its dedicated project page at www.mundocore.org.

[2] https://quamoco.in.tum.de/

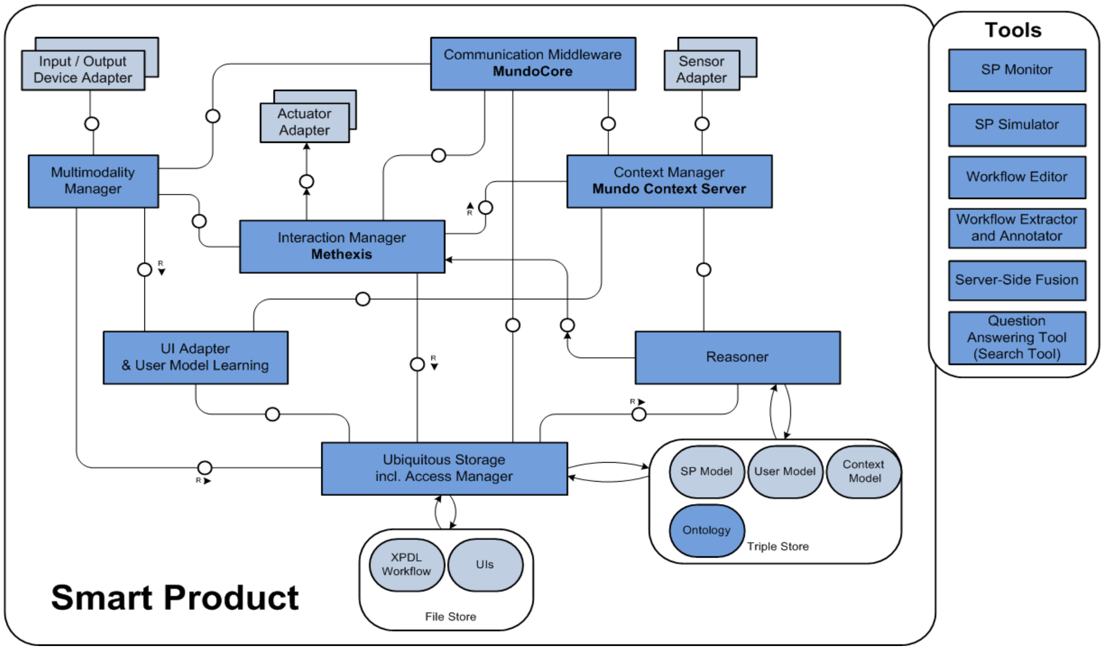

Figure 5: SmartProducts Software Architecture

Other available components support communication with Web services, connection to hardware sensors and actuators and the processing of context information. Further information on the components and their utilization can be found on the project website.

3.1.1 Selected Publications

Fernando Lyardet, Aristotelis Hadjakos, Diego Wong Szeto (2011). InSitu: An Approach for Dynamic Context Labeling Based on Product Usage and Sound Analysis, at the Activity Context Representation workshop at AIII 2011.

Daniel Schreiber, Andreas Göb, Erwin Aitenbichler, Max Mühlhäuser: Reducing User Perceived Latency with a Proactive Prefetching Middleware for Mobile SOA Access. Int. J. Web Service Res. 8(1): 68-85 (2011)

Daniel Schreiber, Erwin Aitenbichler, M Ständer, Melanie Hartman, S Z Ali, M Mühlhäuser: The Mundo Method—An Enhanced Bottom-Up Approach for Engineering Ubiquitous Computing Systems

Erwin Aitenbichler, Fernando Lyardet, Aristotelis Hadjakos, Max Mühlhäuser, Fine-grained Evaluation of Local Positioning Systems for Specific Target Applications, Ubiquitous Intelligence and Computing, volume 5585 of LNCS, Springer, 2009

Markus Miche, Daniel Schreiber, and Melanie Hartmann, Core Services for Smart Products, In: Smart Products: Building Blocks of Ambient Intelligence (AmI-Blocks'09), collocated with AmI'09, 2009.

Syed Zahid Ali, Zone-Based Ad-hoc Coupling of Smart Products in Open Environments, In: Smart Products: Building Blocks of Ambient Intelligence (AmI-Blocks'09), collocated with AmI'09, 2009.

3.2 Models for Domain and Problem Solving Knowledge

SmartProducts has developed domain models, e.g. for representing context information and interaction device properties. In this regard a modular, extensible approach to ontology design has been developed, as illustrated in Figure 6. The work in SmartProducts shed light on how reasoning and semantic web technologies can be used on resource constrained devices. One finding was that the main limiting factor is the available memory, and not the processing power. The domain models developed in SmartProducts were also considered in the future W3C standard for semantic sensor networks[3].

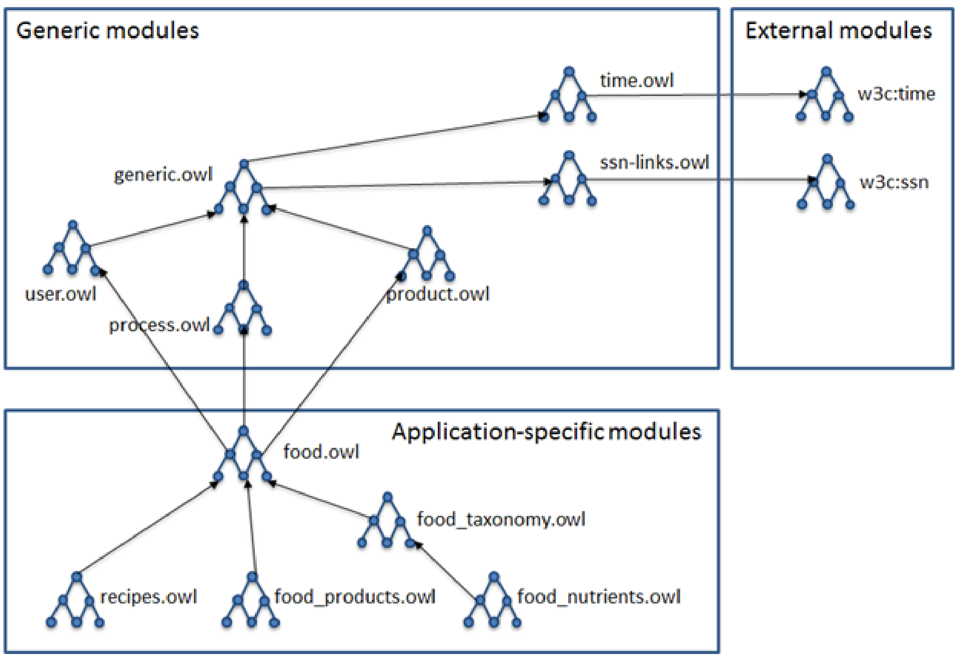

Figure 6: The SmartProducts network of ontologies (smart kitchen domain)

Of particular interest is the support developed for representing problem solving knowledge, Figure 7 shows part of the corresponding ontology. This approach allows smart products developers to describe generic problem-solving methods that tackle a whole class of problems (e.g., by constraint solving). The SmartProducts reasoning mechanism is able to enact these problem-solving methods in the real world, leading to truly proactive user support. The SPAPS framework and architecture which implements this approach towards real world problem solving is a major outcome of the project. It is tightly integrated with the SmartProducts platform and the MundoCore communication middleware in particular. SPAPS enables SmartProducts to exchange and collaborate on tasks defined in the ontology via the MundoCore middleware.

[3] The final report of the SSN Incubator Group has been published on 29/06/2011 and is available on the Web on http://www.w3.org/2005/Incubator/ssn/wiki/Incubator_Report

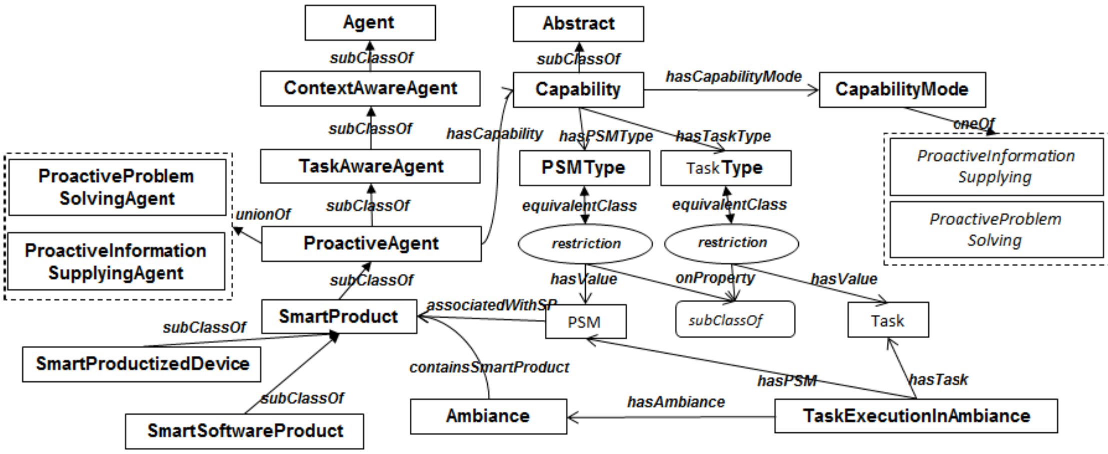

Figure 7: Main concepts of the problem-solving knowledge

Selected Publications

Nikolov, A., d'Aquin, M., Motta, E. (2012) Unsupervised Learning of Link Discovery Configuration (ESWC 2012)

Motta, E., Mulholland, P., Peroni, S., d'Aquin, M., Gomez-Perez, J., Mendez, V. and Zablith, F. (2011) A Novel Approach to Visualizing and Navigating Ontologies, ISWC 2011, Bonn

Nikolov, A., d'Aquin, M. and Motta, E. (2011) What should I link to? Identifying relevant sources and classes for data linking (JIST 2011)

Fernandez, M., Zhang, Z., Lopez, V., Uren, V., Motta, E. (2011) Ontology augmentation combining semantic web and text resources (K-CAP 2011)

d'Aquin, M., Nikolov, A., Motta, E. (2011). Building SPARQL-Enabled Applications with Android Devices. Demo (Demo Track) (ISWC 2011)

Motta, E., Peroni, S., d'Aquin, M. (2011). Latest Developments in KC-Viz (Demo Track) (ISWC 2011)

Mathieu d'Aquin, Andriy Nikolov, Enrico Motta (2011). Enabling Lightweight Semantic Sensor Networks on Android Devices (SSN 2011)

Nikolov, A., d'Aquin, M. (2011) Identifying Relevant Sources for Data Linking using a Semantic Web Index (LDOW 2011)

3.3 Tools for Extracting, Acquiring and Capturing Knowledge

Constructing the proactive knowledge required for a smart product manually is time-consuming and a severe barrier for the acceptance of knowledge-centric approaches in industry. Thus, one of the key results of the project are tools that facilitate this knowledge creation step at design time.

A particularly interesting result is the workflow extraction tool, which enables to automatically extract formal and machine readable workflows in XPDL format from unstructured text sources. The tool utilizes a number of processing steps, e.g., for identifying task descriptions using grammars, as shown in Figure

8. This tool is based on novel combinations of existing NLP approaches and a number of completely novel methods that have been developed within SmartProducts and published at international conferences.

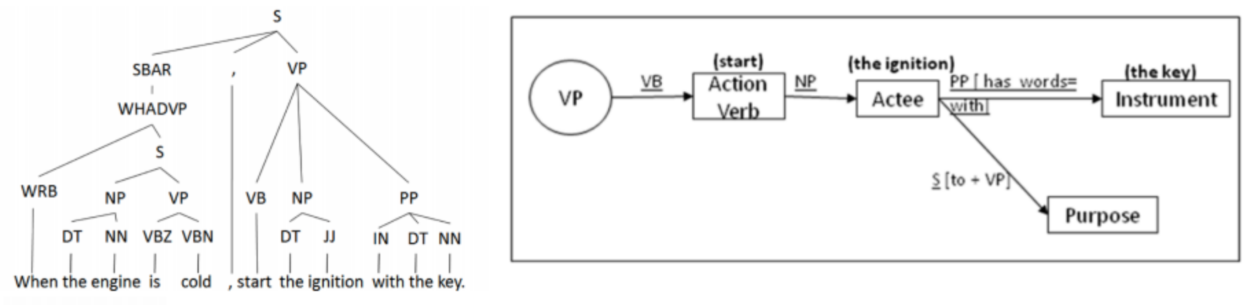

Figure 8: Parsing and identifying task descriptions

Other tools developed in the SmartProducts project comprise a workflow editor (see Figure 9), which allows to specify SmartProducts speficic extensions to the XPDL standard, tools for term extraction (JATE)[4] and a runtime monitor for SmartProducts (see Figure 10).

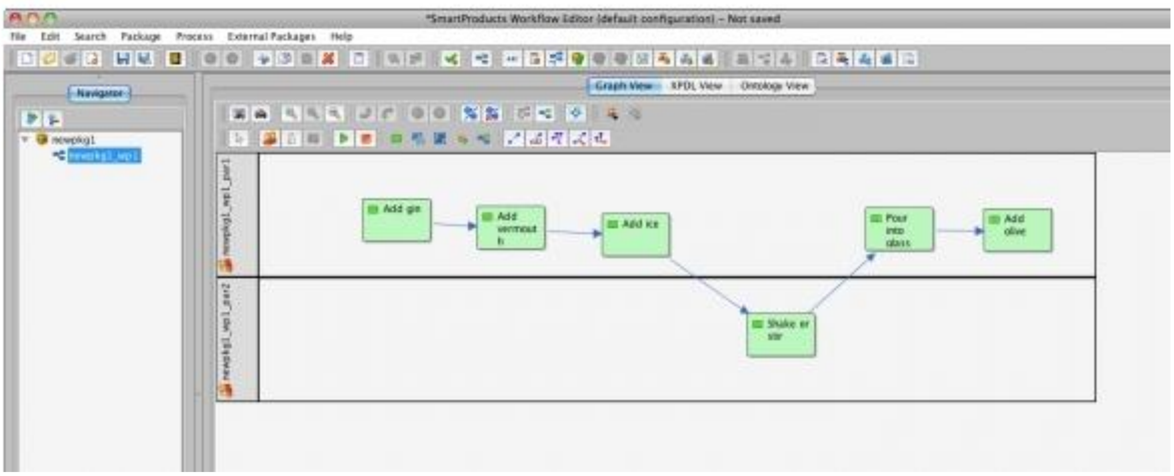

Figure 9: The workflow editor, based on the Together workflow editor

[4] http://code.google.com/p/jatetoolkit/

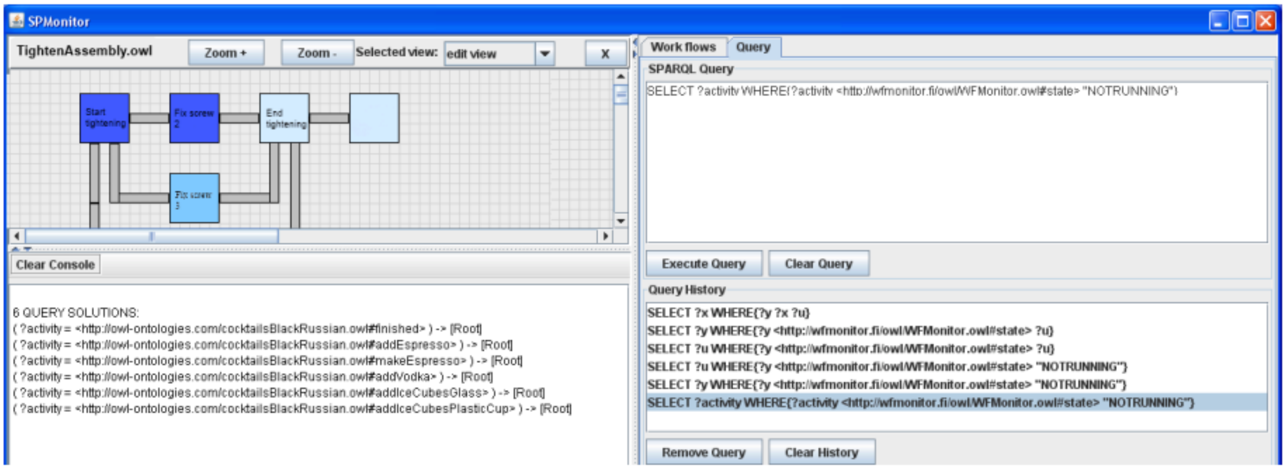

Figure 10: SmartProducts Monitor

Selected Publications

Dadzie, A.-S., Uren, V.S. & Ciravegna, F. (2011). Ontology-Based Knowledge Capture & Sharing in Enterprise Organisations. In Wong, W., Liu, W, Bennamoun, M. (eds.), Ontology Learning and Knowledge Discovery Using the Web: Challenges and Recent Advances, pp.200-225.

Dadzie, A.-S., Uren, V., Zhang, Z., Webster, P. (2011). An Integrated Environment for Semantic Knowledge Work, Proc., 20th ACM Conference on Information and Knowledge Management (CIKM'11), (Demo Track), pp.2529-2532.

Zhang. Z., Gentile, A., Ciravegna, F. (2011). Harnessing different knowledge sources to measure semantic relatedness under a uniform model. In Proceedings of the Fifteenth International Conference on Empirical Methods in Natural Language Processing (EMNLP2011).

Zhang, Z., Webster, P., Uren, V., Varga, A., Ciravegna. (2012) Automatically Extracting Procedural Knowledge from Instructional Texts using Natural Language Processing, (to be presented at) the International Conference on Language Resources and Evaluation (LREC 2012).

Fernandez, M., Zhang, Z., Lopez, V., Uren, V., Motta, E. (2011). Ontology augmentation combining semantic web and text resources. In Sixth International Conference on Knowledge Capture.

Dadzie, A.-S., Uren, V., Zhang, Z., Webster, P. (2011). An Integrated Environment for Semantic Knowledge Work, Proc., 20th ACM Conference on Information and Knowledge Management (CIKM'11), (Demo Track), pp.2529-2532.

Webster, P., Uren, V., Ständer, M., Shaken not Stirred: Mixing Semantics into XPDL, 5th International Workshop on Semantic Business Process Management at ESWC 2010.

Niskanen, I., Kantorovitch, J., Vildjiounaite, E. (2012) Towards the user confidence in sensor-rich interactive application scenarios, at the Workshop on Semantic Models for Adaptive Interactive Systems (SEMAIS 2011) at IUI 2011.

Lopez, V., Fernandez, M., Motta, E., Stieler, N. (Accepted 2011) PowerAqua: Supporting Users in Querying and Exploring the Semantic Web. (To appear in) the Semantic Web Journal.

Nikolov, A., d'Aquin, M., Motta, E. (2012) Unsupervised Learning of Link Discovery Configuration. (to be presented at) the 9th Extended Semantic Web Conference (ESWC 2012).

3.4 Distributed KnowledgeStore

The knowledge for smart products must obviously be stored. This can be done on the smart product itself, if the product is resource rich. However, in many cases the knowledge associated with a product surpasses the storage space that is available directly on the product. In this case the knowledge must be stored in the environment or in the back-end. Effectively distributing the knowledge is a key requisite for successfully deploying smart products on a large scale.

In the SmartProducts project a novel peer-to-peer storage and distribution framework has been developed that ideally addresses the unique storage requirements of smart products. It is based on the well-known Pastry system, however, extends it with knowledge about device classes and different content classes, such as content which needs to have high-availability vs. content that needs to be stored durable. This information is used by the system to intelligently and proactively place replicas in the network.

The approach has been evaluated using extensive simulations. The simulation parameters have been directly derived from an industry setting analyzed in cooperation with the SmartProducts partner EADS. This evaluation showed that the number of replicas is considerably lower with the novel approach compared to state of the art replica management schemes. This means that the novel approach is more efficient, since less storage space is needed. The average response time is not negatively affected by the advanced replica management strategies.

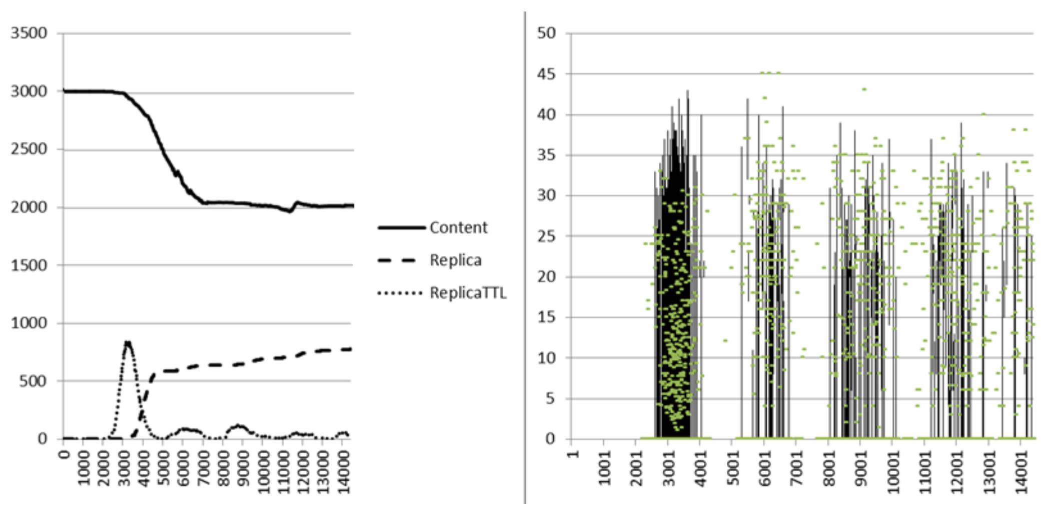

Figure 11: Numbers of Replicas and Average Response Times

To support distributed storage of semantic data a distributed SPARQL engine has been developed and tested. This fully working prove of concept allows one single SPARQL query to collect and combine results from multiple end-points. Two variants of this component exist. One is fully integrated with the

SmartProducts platform and uses MundoCore for communication, the other one uses standard HTTP for communication.

With respect to privacy and security of the stored data, a method for learning access rules has been developed and tested with end-users. We could show that the semi-automated approach led to a) better understandable and more concise access rule sets, and b) was able to speed up the rule creation process.

The storage format developed in the project was also picked up by the W3C standard on the object memory model[5].

Selected Publications

Miche, M; Kröner, A.; Haupert, J., "Analysis of Storage Infrastructures for Digital Objects Memories", ongoing activity out of W3C incubator group OMM-XG, publication planned in Q1/Q2 2012.

Beckerle, M., "Formal Definitions for Usable Access Control Rule Sets - From Requirements to Metrics", in SACMAT 2012, Rutgers University, Newark, USA, June 20-22, 2012.

Miche, M.; Baumann, K.; Golenzer, J.; Brogle, M., "A Simulation Model for Evaluating Distributed Storage Services for Smart Product Systems", in 8th International Conference on Mobile and Ubiquitous Systems (MobiQuitous 2011), Copenhagen, Denmark, 2011.

Miche, M.; Ständer, M. & Brogle, M. (2011), Leveraging Process Models to Optimize Content Placement - An Active Replication Strategy for Smart Products, in Marc Brogle; Xavi Masip; Torsten Braun & Geert Heijenk, ed., '5th ERCIM Workshop on eMobility (in conjunction with WWIC 2011)', pp. 1-12.

Kröner, A.; Haupert, J.; Brandherm, B.; Miche, M. & Barthel, R. (2011), Towards a Model of Object Memory Links, in 'International Workshop on Networking and Object Memories for the Internet of Things (in co-operation with Ubicomp 2011)', pp. 2.

Beckerle, M., "Interactive Rule Learning for Access Control: Concepts and Design", in International Journal On Advances in Intelligent Systems, vol. 4 no. 3&4, 2011.

3.5 Human-computer Interaction

Interaction with smart products is quite different from traditional human computer interaction. For one thing, the interaction resources are no longer built-in to the product, but because of space restrictions interaction resources from the environment must be reused. To this end, a flexible infrastructure for distributed interaction based on the MundoCore middleware has been developed within the project which is available as part of the SmartProducts platform.

One key scientific challenge addressed is the mediation of preferences between different interaction devices. For instance, the preferred font size of a user on a large screen tells you something about the

[5] http://www.w3.org/2005/Incubator/omm/XGR-omm-20111026/

preferred font size of this user on a smaller screen. However, the relation between these two settings is not straightforward. This topic was studied by analyzing and comparing settings for different preferences, applications and devices and a large number of user tests. The outcome is an empirically validated model for transferring preferences between devices. A result which will become increasingly important as the number of devices we use constantly increases.

Furthermore, concepts for defining robust and flexible human-computer dialogues based on workflows were developed. The problem addressed here is that normally workflows are too static to model interaction between user and system. Usually, users require more flexible approaches. To overcome this, algorithms and methods to restructure workflows on the fly, based on observed events have been developed. Figure 9 shows an example where a workflow is re-structured on the fly. In the example the workflow engine detects that step 4 has been performed out-of-order and adapts the remaining workflow accordingly. The system was implemented in the Methexis workflow engine, which is available through the project website.

Furthermore, Methexis seamlessly integrates with the SPAPS architecture, meaning tasks can be solved by workflows and workflows can expose tasks to the environment as part of their execution. This enables the developer to mix procedural and goal-based declarative style problem solving as appropriate.

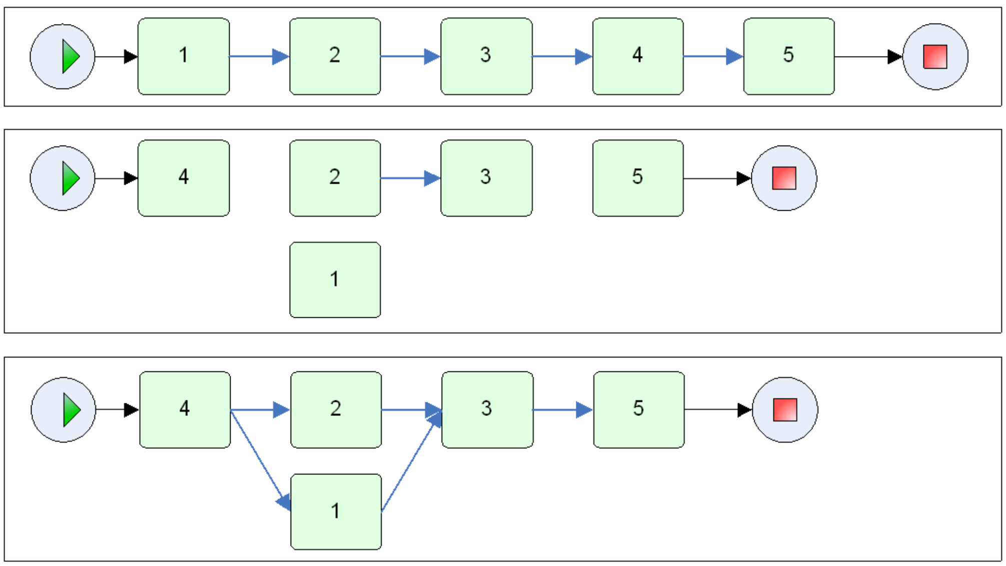

Figure 12: Example of changing workflow on the fly

Selected Publications

Felix Heinrichs, Daniel Schreiber, Jochen Huber and Max Mühlhäuser: "Toward a Theory of Interaction in Mobile Paper-Digital Ensembles", Proceedings of CHI 2012, ACM, 2012 (to appear).

Elena Vildjiounaite, Vesa Kyllönen, and Jani Mäntyjärvi. If their car talks to them, shall a kitchen talk too?: cross- context mediation of interaction preferences. In Proc., 3rd ACM SIGCHI symposium on Engineering interactive computing systems (EICS '11), 111-116.

Hartmann, M., Ständer, M., Uren, V. (2011) Adapting Workflows to Intelligent Environments, Intelligent Environments 2011

Vildjiounaite, E., Kantorovitch, J., Kyllönen, V., Niskanen, I., Hillukkala, M., Virtanen, K., Vuorinen, O., Mäkelä, S.-M., Keränen, T., Peltola, J., Mäntyjärvi, J., Tokmakoff, A., Designing Socially Acceptable Multimodal Interaction in Cooking Assistants, 2011 International Conference on Intelligent User Interfaces, Palo Alto, Feb. 2011

3.6 Smart Consumer Appliances Application Trial

This application trial investigated how smart products can be physically and socially embedded into our lives, with a particular focus on the kitchen context. A number of scenarios, conditions and embodiments have been chosen. In the kitchen environment domestic appliances are introduced which are aware of the usage context and help in choosing and preparing a meal. The smart products in the kitchen will (together) persuade the end-user in opting for healthy meal choices and influence the person's behaviour.

To realize, test and evaluate such a system using the SmartProducts platform a number of steps have been taken to define scenarios and requirements, to establish the user needs and user acceptance, to design the related functionality and to realize the smart products and related software. In a final step large parts of the system have been integrated and tested with end-users in the kitchen of Experience Lab in Philips Research.

Need and Acceptance

To evaluate the user acceptance a number of scenarios in the kitchen environment have been sketched: meal recommendation, interactive cooking guidance and ingredient shopping. Each of these scenarios describes how smart products can be used for a particular reason in a specific situation. By means of an online survey a total of 166 respondents expressed their attitude towards these scenarios. Most respondents indicate they enjoy cooking (67%) and cooking at home seems to be important (74%). 58% would like to have some assistance when cooking new dishes and also for suggesting new recipes. These results indicate a need for adding smartness to kitchen appliances.

Smart kitchen appliances, steamer, scale and chopping board

A number of smart products have created by adapting existing Philips kitchen equipment to enable the smart functionality e.g. a steamer, a blender and a scale. To really add functionality a new device has been designed: the chopping board. It is basically a scale adapted to be used as a chopping board which with extra functionality to let the user collect and store the amount of ingredients and the kind of ingredients (classified as vegetables, grain and meat; see Figure 2).

The evaluation of the concept and its functionality showed that motivated users liked the concept and it helped them to make healthy meals. The chopping board is running on the SmartProducts platform and communicates with the Smart Kitchen Assistant to help planning healthy meals.

Meal planning

The meal planning part provides ways to support people to make choices for a meal with easy to use colour coding which represents the nutritional values of the recipe, as shown in Figure 11. The colour green indicates a healthy recipe. The recommendations are provided with actionable advice, which is important to achieve a positive result. It enables planning for a whole week including making a shopping list. The system uses a nutritional knowledge base that contains professionally endorsed nutritional knowledge. The recipes used in the planner are from a database as used in the Netherlands Nutrition Centre (Stichting Voedingscentrum Nederland). All the recipes are in Dutch. The testing of the meal planning features have been carried out with Dutch participants.

Figure 13: Screenshot of recipe recommender with simple representation of nutritional value (in Dutch)

One of the results is that really simple ways of representation of the nutritional value of the meals has to be used. The greener the better is the message for the user and he can follow the consequences of his choice by looking at the squares in the upper right corner. This interaction scheme was tested with a number of potential users. The main result is that the interface should support adequate general information with goal setting included (i.e. work towards the green colour).

A special feature added in the Smart Kitchen Assistant is the combined information of the chopping board data and the meal planner to create a more precise history of the healthiness of the meals used. This feature was appreciated by the participants.

Persuasion

Persuasion was introduced as a technology to motivate the user to make healthy choices. From motivation theory it is known that social support and social interaction could be from great value to increase motivation; researchers also have looked at manners to involve social aspects recommendation applications. The predominant goal of this experimental research approach was to investigate the possibility to increase persuasive effectiveness by tailoring the persuasive messages to the personality of the user. The conclusion of this evaluation is that persuasive principles can be seen as a strong motivator and are able to affect (snacking) behaviour. In the context of choosing meals a questionnaire was conducted and the influence could not be confirmed. The technical engine for choosing persuasive messages is part of the SmartProducts platform.

Cooking guidance

In the context of the kitchen appliance application evaluation, the guidance feature is used to guide users through steps of a recipe, ultimately contributing to the healthy eating of the users. To evaluate the final version of the SmartProducts platform the Cooking Guide implementation was updated. The evaluation with users and real appliances has been carried out in the augmented kitchen of the Philips Research Experience Lab in Eindhoven. This evaluation was aimed at learning about the adaptivity of the user interface using a large screen in the kitchen (15") as well as a smart phone. A typical screen showing the sequence of steps is show in Figure 1412. These steps have been defined by analyzing the recipe and extract the appropriate steps for cooking the meal and are made available to the users.

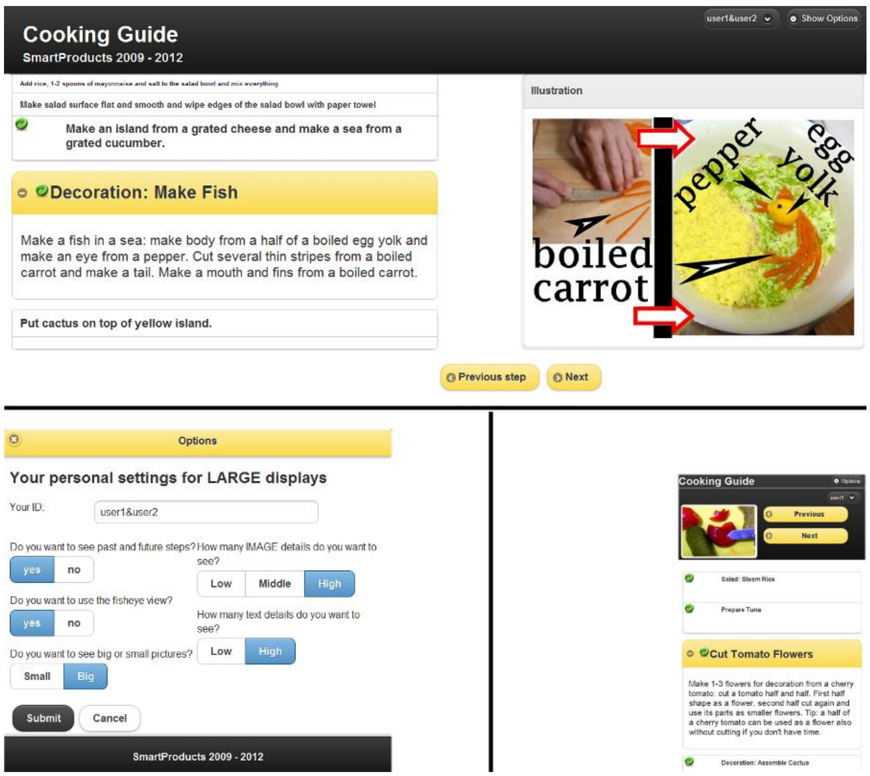

Figure 14: Cooking guidance instructions for preparing a salad

The evaluation showed that the users were confident to use the guidance application. The evaluation was conducted in 10 pairs of participants which worked together to complete the salad. The usability was tested with the SUS questionnaire and provided good scores of around 70. The user experience evaluation using the UEQ (User Experience Questionnaire) showed about 2.5 for attractiveness and 2.0 for efficiency. Moreover, it showed that the flexibility added by the Methexis engine in the SmartProducts platform is contributing to the appearance of the product to be "smart" and attractive.

Meal selection and shopping assistant

The meal selection function is also part of the Smart Kitchen Assistant. In case the user wants to adapt a recipe or define a new one this function is activated. The function enables choosing a suitable meal based on the user profile and additional relevant information provided by

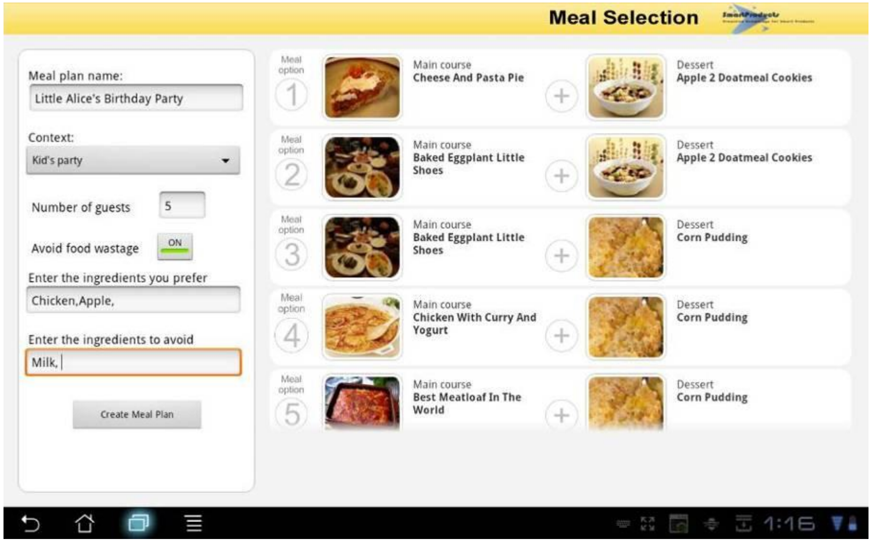

Figure 15: Meal options in the Meal Selection screen of the Smart Kitchen Assistant

different smart products (e.g., food items available in the fridge). This is an illustration of proactive problem solving in the context of smart products as executed using the SPAPS (SmartProducts Architecture for Proactive Problem Solving) for collaborative problem solving. Figure 13 shows how constraints for the meal planning task are added by the user through a UI. These are later combined with the constraints provided by other smart products in the environment.

Selected Publications

Kaptein, M., De Ruyter, B., Markopoulos, P., & Aarts, E. (2011). Tailored Persuasive Text Message to Reduce Snacking. (in press) ACM Transactions on Interactive Intelligent Systems (Special issue on Personalized Persuasion).

Youri van Pinxteren, Gijs Geleijnse and Paul Kamsteeg, Deriving a Recipe Similarity Measure for Recommending Healthful Meals, IUI ’11 Proceedings of the 16th international conference on Intelligent user interfaces, p 105-114 (2011)

Gijs Geleijnse, Peggy Nachtigall, Pim van Kaam and Lucienne Wijgergangs, Personalized Recipe Advice System to Promote Healthful Choices,IUI ’11 Proceedings of the 16th international conference on Intelligent user interfaces, p 437 – 438 (2011)

Toet, E., Meerbeek, B., Hoonhout, J. (2011). Supporting mindful eating: InBalance chopping board. In proc. INTERACT 2011 Workshop on Promoting and Supporting Healthy Living by Design, p49-52 (2011)

Andrew Tokmakoff, Xiaoming Zhou, Leszek Holenderski, Sjir van Loo, Alexander Sinitsyn, From lab to living-room: research challenges for AmI and Smart Products, In: Smart Products: Building Blocks of Ambient Intelligence (AmI-Blocks'09), collocated with AmI'09, 2009.

3.7 Product Lifecycle Management of Smart Vehicles Application Trial

The FIAT Group applications in the project investigate how to embed knowledge into smart products (vehicles, electronic devices, tools). The focus for FIAT, represented by its Research Centre, was on the communication and cooperation between humans, vehicles, smart phones, other intelligent products and the environment during the whole vehicle lifecycle.

The applications developed in the project achieved the following goals:

- easing the daily usage and maintenance of vehicle, by providing proactive help for using the vehicle and resolving problems during the usage. It takes the form of an adaptive personalized interactive handbook (see Figure 1716);

- helping vehicle owners in maintaining the vehicle value by controlling the status of the vehicle, understanding the relationship between wear-out and driving style and suggesting hints to improve it (see Figure 1717).

First application: adaptive handbook (eLUM)

The first time a new component is put inside the vehicle a new interactive workflow is downloaded from the eLUM server. Otherwise, a workflow expert is in charge of extracting and modifying a suitable workflow from existing material. In both cases the vehicle eLUM is updated as soon as the material is available.

During a normal trip several events can happen that make necessary to carry over some actions by the driver. Beyond the old paper vehicle handbook, an innovative adaptive eLUM has been realised. The eLUM is able to adapt itself to the specific car updating its initial structure with the components added to the vehicle during its life (i.e. children seat, snow chains etc). Each event detected via sensors like bad weather conditions activates an interactive procedure able to guide users step by step in the completion of complex tasks such as mounting snow chains. According to the context the user can benefit from the procedure from the most adapted device (chosen from the connected on board devices, iPAD, SmartPhones). Each of them shares the same knowledge and their status (e.g. the step of the procedure they are engaged in) is communicated in real-time to the other connected devices in the vehicle.

Figure 16: Support for mounting snow chains (on iPAD)

Second Application: Vehicle Status Monitoring (Deprecation Alert)

The driving behaviour is tracked using the SmartProducts platform in conjunction with the Blue&Me system (available in the vehicle) providing the interface to the vehicle sensors data. This data is refined and transferred to a backend and analysed. Depending on the user profile a certain persuasive strategy is chosen to convince the driver to drive more carefully. The driving feedback information and the persuasive messages are either actively accessed by the driver using a mobile device or a computer ("pull"), or are delivered to the driver by the system e.g. SMS ("push") to the mobile device.

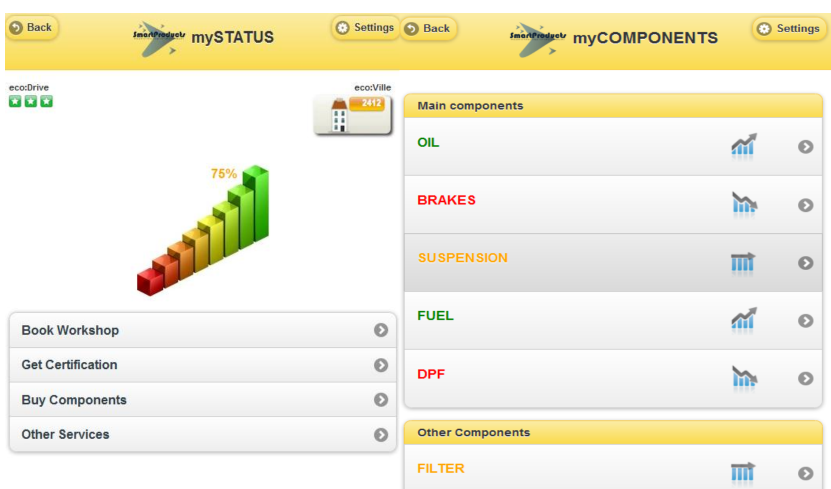

Figure 17: Monitoring the vehicle (left) and components (right) status

3.8 Aircraft Manufacturing

This application trial focuses on the implementation of SmartProducts concepts in an aeronautical manufacturing scenario. In this scenario, two workers have received a work order to tighten two electric harnesses onto an A350 aircraft panel. One worker is already an expert in this task while the second is still a trainee. Both work together simultaneously on the same work order, which contains several sub-tasks. They are equipped with tools, a nomadic device (that is, a ruggedized, mobile CP) and a smart tool. The nomadic device guides them through the work order and the smart tool is used to tighten assemblies.

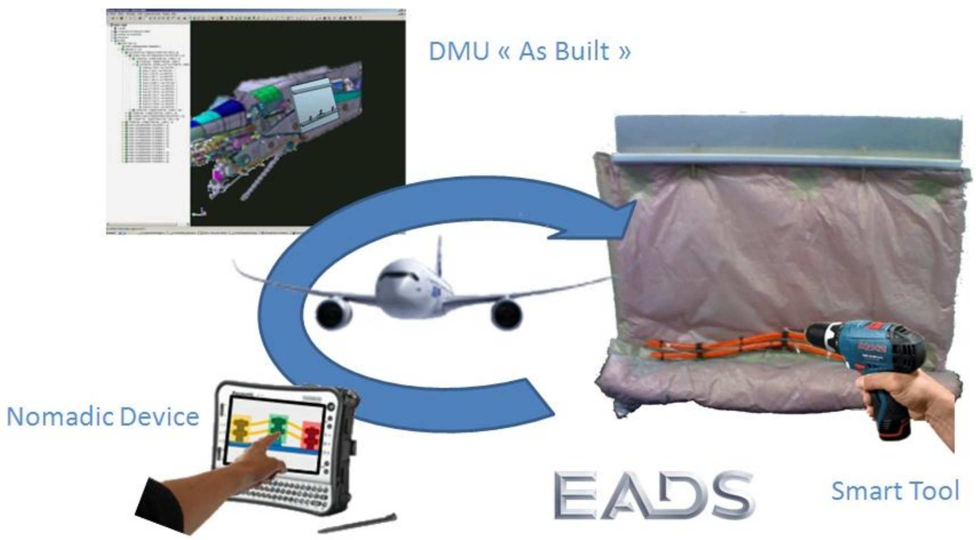

Figure 18: The main three elements of the Aircraft Manufacturing scenario: (1) a digital representation of a particular plane in its current (real-time) build state (Digital Mockup "As Built", DMU), (2) a Nomadic Device for viewing the DMU As-Built and displaying works instructions, and (3) the Smart Tool

This scenario is used to illustrate the 3 challenges which EADS is working on to cope with existing issues in the complex aircraft-manufacturing context. For each challenge, a demonstrator has been built and tested. The main target group of these demonstrations and trials are the end-users, who are the technicians supported in assembly tasks, and some managers, taking decisions on deployment of such technologies. Figure 18 presents an overview of the demonstrators and their relationship for the first two challenges.

The **first challenge** is the provisioning of knowledge specific to each aircraft. The objective is to integrate a manufacturing ecosystem of IT tools and all the data related to a single aircraft (product geometry, assembly processes, current manufacturing status, and manufacturing history) on a single data portal. This data is made available in the form of proactive knowledge that helps operators in manufacturing and maintenance to understand the status of the product with regard to its processes. Overcoming efficiently any event is easier when being aware of the installation status using real "As Is" data instead of "As Planned" data.

This is illustrated by a demonstrator of the As-Is Digital Mockup (DMU). The DMU has been defined and enriched by EADS to embed the links with the work orders and the work progress information.

The **second challenge** is to adapt the interaction between operators and aircrafts to environmental conditions and the user context. It aims at providing operators with the exact level of information to process their jobs without overwhelming them, so that

- they do not waste time manually retrieving the required pieces of information,
- the risk of processing errors is reduced, and
- the task duration decreases because of the reduction in the workers cognitive load.

The proposal solution includes a smart filtering mechanism and adapting the information delivered to workers based on

- operator profiles, taking into account their skill level and experience,
- available means and equipment to perform the task,
- real state of the plane, and
- actual working condition such as lighting.

A first demonstrator addressing this challenge was available end of 2010, showing how technicians accesses 3D documentation through a nomadic device. It also shows the use of a smart torque-wrench tool: the technician can select a torque program on the displayed DMU by pointing at the screw. This action remotely sets up the wrench. After the worker completes the task (that is, tightening an electrical harness) the DMU automatically records the task's completion and the actual torque values for each screw.

The demo also illustrates the use of the SP monitor (see Figure 19) to manage anomalies during the execution of tasks. Tests and demos have been organized at Airbus to collect feedback from potential end users, and facilitate future transfer from the research SmartProducts project to the aircraft industry.

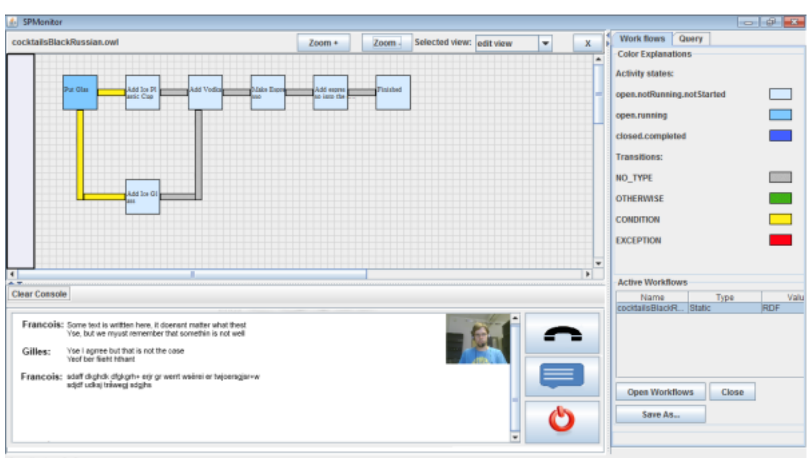

Figure 19: Communication through SP Monitor to solve anomalies

The **third challenge** is the data management required to address challenges 1 and 2. Data needs to be distributed among a central design location, multiple manufacturing sites of aircraft segments, and assembly locations. The difficulty increases drastically with the totally unpredictable location of the plane in service. Data management should also take into account problems of secure data storage, data distribution, and data synchronization while dealing with the coherency of huge amounts of data (e.g., the DMU).

The demonstrator for this challenge concerns the creation and distribution of the stored data in the scenario. Data are the Digital Mockup (DMU) from design office, work orders, "As Built" DMU and smart tool data. In parallel, it is planned to illustrate the Workflow extractor/Workflow Editor of on the Aircraft Assembly Procedure use case. The idea is to show the potential interest for people in charge of preparing procedures to use this kind of tools to be help in their daily work.

A more detailed description of the three challenges of aircraft manufacturing can be found in the SmartProduct whitepaper *A virtual plane to build and maintain real ones*, available on the SmartProducts homepage.

Selected Publications

Miche, M.; Baumann, K.; Golenzer, J. & Brogle, M. (2011), A Simulation Model for Evaluating Distributed Storage Services for Smart Product Systems, in '8th International ICST Conference on Mobile and Ubiquitous Systems'.

Pascale Hugues and Jerome Golenzer, A virtual plane to build and maintain real ones, SmartProducts Whitepaper

3.9 Summary of Results

The SmartProducts project integrated approaches from knowledge management and ubiquitous computing into one coherent overall conceptual framework. By successfully integrating results from these two fields, SmartProducts was able to open up new routes for scientific development.

In the project, this approach was applied to take a first step toward a paradigm shift on how people interact with products. Instead of needing to know a priori how one can interact with the product and what its functionalities are, or needing to read cumbersome manuals, the product guides the user and aid her. The following facts and figures underline the overall impact of the project:

- The project resulted in more than 50 scientific publications, including publications at international top-level venues and Journals.
- Two standards by the W3C have been influenced by the project and co-authored by project members
- Results from the project were exploited within the partner organizations of the project and partner organizations will go on to exploit project results after the project end. One start-up company was founded by former project members.
- SmartProducts disseminated and demonstrated results at both industrial (Sensing Technology, iTEC, etc.), Academic (AmI, etc.) and large European events (ICT 2010).
- SmartProducts results are used in teaching activities in the participating universities.