Sharing Memories of Smart Products and their Consumers in Instrumented Environments

Austausch digitaler Gedächtnisse von Produkten und Konsumenten in instrumentierten Umgebungen

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Summary Intelligent assistants need precise knowledge about activity sequences and the habits of their users so as to support them in an adequate manner. The following contribution addresses an approach to user support, which takes advantage of the object centred nature of many day-to-day activities. By means of application examples from the everyday, we illustrate how a combination of smart items and digital memories allows for realizing innovative support mechanisms, which take into account static knowledge about objects as well as situational observations and historical data. Here, we devote special attention to applications originating from the sharing of data gathered this way between users and systems. ►►► **Zusammenfassung** Intelligente Assistenten benötigen präzises Wissen über Handlungsabläufe und Gewohnheiten ihres Benutzers, um diesen in adäquater Weise unterstützen zu können. Der folgende Beitrag behandelt einen Ansatz zur Benutzerunterstützung, der sich die objektzentrierte Natur vieler Alltagshandlungen zu Nutze macht. Wir illustrieren anhand von Anwendungsbeispielen, wie durch die Kombination von Smart Items und digitalen Gedächtnissen innovative Formen der Benutzerunterstützung möglich werden, die statisches Wissen über Objekte mit dynamischen Informationen und historischen Daten kombinieren. Besondere Aufmerksamkeit widmen wir hierbei Anwendungsmöglichkeiten, die aus dem Austausch der so gewonnenen Daten zwischen Benutzern und Systemen entstehen.

KEYWORDS I.2 [Computing Methodologies: Artificial Intelligence]; J.7 [Computer Applications: Computers in other Systems]

1 Introduction

On the way to the disappearing computer (see, e. g., [11]) considerable research efforts have been taken in order to support the communication between user and environment. One major trend are smart objects, whose tracking allows for inferring the user's intention and providing user support (for an overview see [1]). This trend is accompanied by an increasing interest in research on building and exploiting digital memories, whose potential is illustrated by a broad range of applications such as communication [12], health care [6], assisted living [9], or shopping [8].

We argue that a combination of these trends could yield new forms of user support. In the following, we report on ongoing research concerning the sharing of digital memories, which is conducted in SharedLife (BMBF grant 01 IW F03) and BAIR (DFG SFB 378 "Resource-Adaptive Cognitive Processes"), and involves identification technology, environmental sensors, digital memories, and social network services.

2 Scenario

In the following example, smart objects and digital memories are used to assist a user in the preparation of a dish for a dinner with friends (see Fig. 1). An analysis of the user's social network enables a personal assistant to suggest a recipe matching the guests' food preferences. It transfers digital memories concern-

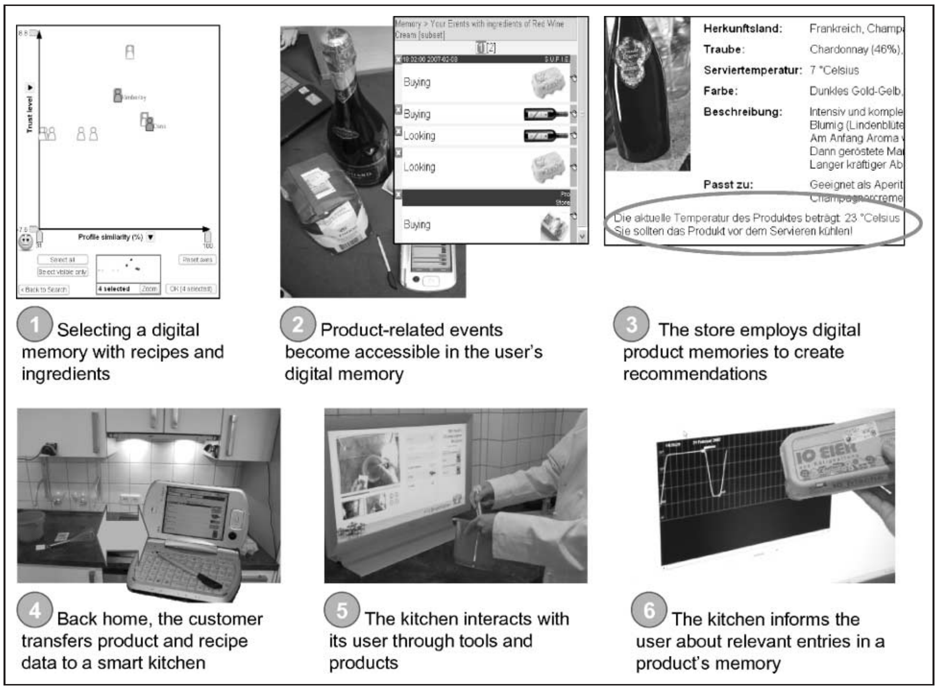

Figure 1 User support from smart objects and digital memories when choosing a recipe, shopping ingredients, and cooking.

ing the recipe and its ingredients from a socially close cooking expert (1) to the user's digital memory, which she may consult during grocery shopping (2). Additional support is provided by the store itself. It tracks the user's interaction with products, and exploits this data to generate product comparisons and recommendations, which are displayed on a display attached to the shopping cart. This information offer is combined with data from the products' digital memories. Thus, the store may suggest not only other dishes which could be prepared with an ingredient at hand, but also report on conditions the product was recently exposed to in order to emphasize its quality (3).

Back home, the personal assistant transfers the recipe to a smart kitchen (4), which acquires based on the user's contact preferences related information provided by other users, e. g., an interactive video. Once the user starts to prepare the dish, the kitchen displays sequences from the video (5) matching tools and ingredients on the working surface, which allows the user to benefit from personal assistance without being interrupted in his interaction with ingredients and tools. This presentation is enriched with the ingredients' digital memories (6); for instance, the kitchen may inform the user that a sensible product was exposed to heat and should be consumed soon. Finally, once the cooking process is finished, the user may share her individual cooking procedure with friends – because all of her actions have been automatically recorded in her personal digital cookbook.

3 Sharable Digital Memories

This scenario is grounded on digital memories, either in the form of a diary-like personal memory, or the one of a product memory bound to some physical object. Their value for user support greatly depends on the amount and the quality of stored data. Automated capturing via sensors provides a way to deal with the former issue – however, without aggregation and abstraction the resulting records will often stay meaningless.

Therefore, we proposed in [5] a multi-level approach for transferring low-level sensory information into semantically rich memory entries. Fig. 2 shows a schematic view of the involved processes. Environmental perceptions are initially stored in a short-term memory as a stream of raw sensor data. After these perceptions have been filtered for duplicates, an abstraction process is applied to create a symbolic representation of the observed information. The symbolic representation is then forwarded to the long-term memory. Here, all information is stored in a *context log*. Additionally, related observations are combined into entries of a *personal journal*. While the context log contains a fine-grained, data-centric representation of recorded perceptions, the personal journal provides a condensed, user-centric view of the memory.

While a user's digital memory is typically hosted on a personal device that the user trusts, an object's memory is stored on some server in the infrastructure. In order to associate a physical object with its digital memory, the object is tagged with a unique URL, under which the object's memory can be accessed. This tagging can be implemented through a multitude of technologies, ranging from 2D barcodes over RFID transponder to wireless sensor network nodes.

The resulting digital memories are encoded in RDF/OWL in order

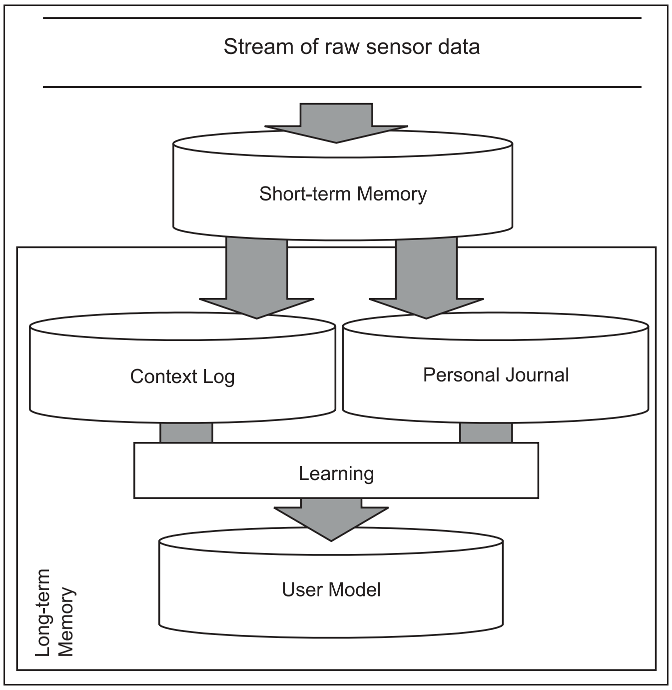

Figure 2 Components involved in the building of digital memories.

to facilitate their processing through automated reasoning processes. The ontology used in our implementation is expressed in the Web Ontology Language (OWL) and is based on the IEEE Suggested Upper Merged Ontology (SUMO) [7]. This agreement on a common representation supports the interoperability of digital memories – and therefore enables their sharing between users and systems as envisioned in our scenario.

SharedLife addresses this idea with a peer-to-peer client, which allows a user to communicate information from the digital long-term memory, in particular, personal journal entries (cf. [13]), to other users and environment services. Here, memory sharing is grounded on the assumption that memories are only submitted to external parties on the user's demand. Similar to email, once submitted revealed information cannot be taken back or modified. On this basis, the system exploits the user's digital memory and smart items in order to support various actions related to memory sharing.

In order to provide assistance in judging and selecting sharing partners, the system takes into account public available information (e. g., social network information from http://bakespace.com) as well as available memories about other users. The latter ones include previously shared profile information (e. g., about food preferences) and experiences (e. g., shared cooking instructions). These data are combined in a graphical selection dialog consisting of several interaction layers (cf. [4]).

Once the user has confirmed one or more sharing partners, requests may be issued to these users. SharedLife's user interface supports this process with pre-authored queries, which are attached to the ontological description of physical objects in the user's environment (e. g., tools and ingredients in the kitchen). A proactive support component exploits this knowledge in order to suggest automatically queries related to objects the user is interacting with.

For handling incoming requests, our prototype provides several mechanisms chosen with respect to the outcome of a user study concerning manual and automated sharing mechanisms (cf. [2]). One option is to inspect the requested memories, exclude selected entries, and then reply manually. This is in compliance with comments obtained in the study expressing the need for making exceptions from automated response behavior, either to protect certain data without ignoring a request completely, or to eliminate irrelevant information.[1] Alternatively, the user may instruct the system to construct a rule in order to automate the handling of similar requests in the future. Its precondition consists of contextual features such as location and action type, which are extracted from the requested memories. The user may then edit these features and control their impact on a potential response (see Fig. 3).

Figure 3 Defining a sharing rule from a given request.

All sharing actions are automatically recorded in the involved users' digital memories. This allows them to evaluate and control requests and responses – feedback, which is exploited by the system to support future actions.

4 Exploiting Digital Memories

4.1 The Smart Store

As illustrated before, one potential application for digital memories is shopping assistance. We de-

[1] As pointed out in [3], if people are willing to share information, then they are usually interested in providing information which is useful for the questioner.

ployed our prototype in an existing intelligent environment, the *DFKI Smart Store*. This environment assists a customer with product information, product comparisons, and personalized advertisements either on a wall mounted plasma display or a tablet PC mounted on the handle of a shopping cart. Furthermore, in the case of the grocery scenario, the application suggests recipes based on amount and kind of goods already placed in the shopping cart.

The user communicates with the store by means of a multi-modal interface (cf. [14]) and by interacting with the offered products. Actions such as taking a product from a shelf, putting it back, or storing it in the shopping cart are captured by *RFID*. Other sensors, e. g., for sensing light, temperature, sound, acceleration, and magnetism, are attached directly to the products. Here, RFID is used to locate and identify a product – and to associate information gathered by the remaining sensors with it. This combination enables the store to monitor interactions with the product's wrapping, which is then exploited to offer value-added services. For instance, a rotation of the product may indicate the user's interest in some product. If it is put back to the shelf, then the store may compile a personalized product flyer handed out to the user at the end of the shopping trip.

Thus, regular products become smart items. Recording their sensors' perceptions in product-specific digital memories enables further applications that exploit the temporal nature of certain occurrences. Thus, the store may access a temperature curve of a pack of eggs to validate its quality or may inform the user that a bottle of champagne has recently been shaken.

This information and the related services can be further combined with the user's personal digital memory. For instance, the user may share a planned recipe with the store in order to improve the store's recommendations, or exploit recommendations of friends in order to complement the store's anonymous support. Vice versa, adopting the store's recommendations (such as the mentioned flyer) allows the user to enrich the personal memory with information valuable not only for later shopping trips, but also for other contexts.

4.2 The Smart Kitchen

The cooking domain provides rich opportunities to test and evaluate methods related to the construction, sharing, and exploitation of digital memories. Since all times, cooking-related knowledge has been recorded in the form of written recipes and has been subject of exchange with relatives, friends, or foreign visitors. However, the manual recording of recipes has significant drawbacks: Besides being cumbersome, it prevents the sharing of ad-lib food creations or spontaneous variations of existing recipes.

In this section we present the Smart Kitchen, an instrumented environment that supports the automated capturing, sharing, and exploitation of cooking experiences through the user's digital memory (cf. [10]). It is able to observe smart items and the user's cooking process through a combination of different types of sensors (cf. Fig. 4):

a) Multiple *video cameras* record an audio/video stream of the cooking session. The video is used to capture spoken instructions, as well as preparation steps that we are not able to observe with our sensors. The cameras are placed above key locations like the stove, the countertop, or the basin. A motion detection algorithm automatically switches to the camera that currently shows the most activity.

b) *Radio frequency identification* equipment identifies and locates ingredients and objects. Each movable object in the kitchen is tagged with a passive RFID transponder, which holds a URL. This URL allows to uniquely identify the object and to access its memory. RFID antennas are mounted discretely at various locations (like in the fridge or under the countertop) and allow for detecting if an ingredient or tool is placed on or removed from such a location.

c) An *electronic scale* measures the amount of used ingredients. The identity of the object that is measured is determined via RFID.

d) *Networked kitchen appliances* report about their state and usage via a powerline interface: The stove monitors the power level of each individual hot plate and checks, if cookware is present on the plates. The oven provides the operation settings chosen by the user (like air circulation, timer settings, etc.) as well as the current temperature. The fridge and the freezer report their current temperature and tell, if the door is opened or closed.

The kitchen can be run in two modes: Recording mode and playback mode. In recording mode, a multi-angle video stream show-

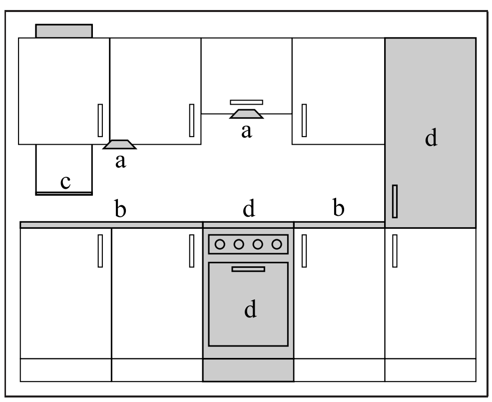

Figure 4 The components of the Smart Kitchen.

ing the cooking process is captured on the kitchen server. Timestamped information about the kind and amount of used ingredients and kitchen utensils is stored in the user's memory and linked to the video stream, as information about the use of kitchen appliances is. The recorded information can then be shared locally with other users of the same kitchen, or globally with arbitrary users over the Internet.

In playback mode, a textual list of required ingredients and their amount is constructed from the memory and displayed together with the recorded video. In parallel, the current state of the environment is continuously compared with the state of the environment at recording time, and the playback is synchronized accordingly. If for instance some ingredient is missing, the playback is paused until the problem is resolved. During both modes, helpful information about the currently handled objects is shown on the kitchen display. Such information includes object-related experiences fetched from the user's personal journal, or general information from product memories such as the current temperature of a bottle of wine, or instructions on how to use a given kitchen utensil.

5 Conclusions

The ongoing instrumentation of every-day environments and objects with sensors and microelectronics allows to capture a broad range of observations about the state and behaviour of the user, the environment, and the contained objects. In this article we showed, how the utility of such information can be taken to a new quality by combining it with historic knowledge. We presented examples of this idea in a consumer shopping and food preparation scenario and described, how such digital histories can be automatically constructed, either in the form of a user-centered personal journal or an item-centered object memory. We illustrated how additional benefit can be generated by sharing digital memories between different users, and how the actual sharing process can be supported by an automated system.

Whenever personal information is collected and shared, privacy is a strong issue. Future work will have to focus on this topic, for instance by considering cryptographic methods like anonymization and digital rights management to ensure the users' privacy and informational self-determination. Thereby, the issue of privacy applies to the sharing of memories but also to the observation of the user through the environment.

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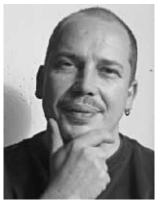
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