SharedLife: Towards Selective Sharing of Augmented Personal Memories

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Abstract. The rapid deployment of low-cost ubiquitous sensing devices – including RFID tags and readers, global positioning systems, wireless audio, video, and bio sensors – makes it possible to create instrumented environments and to capture the physical and communicative interaction of an individual with these environments in a digital register. One of the grand challenges of current AI research is to process this multimodal and massive data stream, to recognize, classify, and represent its digital content in a context-sensitive way, and finally to integrate behavior understanding with reasoning and learning about the individual's day by day experiences. This augmented personal memory is always accessible to its owner through an Internet-enabled smartphone using high-speed wireless communication technologies. In this contribution, we discuss how such an augmented personal memory can be built and applied for providing the user with context-related reminders and recommendations in a shopping scenario. With the ultimate goal of supporting communication between individuals and learning from the experiences of others, we apply this novel methods as the basis for a specific way of exploiting memories — the sharing of augmented personal memories in a way that doesn't conflict with privacy constraints.

1 Introduction

The rapid deployment of low-cost ubiquitous sensing devices – including RFID tags and readers, global positioning systems, wireless audio, video, and bio sensors – makes it possible to create instrumented environments and to capture the physical and communicative interaction of an individual with these environments in a digital register. One of the grand challenges of current AI research is to process this multimodal and massive data stream, to recognize, classify, and represent its digital content in a context-sensitive way, and finally to integrate behavior understanding with reasoning and learning about the individual's day by day experiences. If we add the clickstream history, bookmarks, digital photo archives, email folders, calendar, blog and wiki entries of an individual, we can compile a comprehensive infrastructure that can serve as his augmented memory. This personal memory is always accessible to its owner through an

Internet-enabled smartphone using high-speed wireless communication technologies. We have realized a broad range of augmented memory services in our system SPECTER (see, for instance, [1], [2], [3], [4], and [5]).

Ever since ancient times, storytelling has been a way of passing on personal experiences. The selective sharing of personal augmented memories is the modern counterpart of storytelling in the era of mobile and pervasive internet technology. In our SHAREDLIFE project, we are creating augmented episodic memories that are personal and sharable. The memory model does not aim at a simulation of human memory. Instead we are realizing an augmented memory in an unintrusive way, that may contain perceptions noticed by SPECTER but not by the user.

Although some researchers believe that it is feasible to store a whole human lifetime permanently, we are currently concentrating on a less ambitious task. We try to record and understand an individual's shopping behavior for a few days and share relevant experiences with others in a way that doesn't conflict with his privacy constraints. Dealing with shopping experiences is a limited, but meaningful task against which we can measure progress on our augmented memory research.

2 Related Work on Augmented Memories and Knowledge Sharing

The building of augmented personal memories in instrumented environments for the purpose of extending the user's perception and recall has been studied for more than 10 years (see, e.g., [6]; [7]). While this research has focused on user interface design for the retrieval of memories (among others, [8]; [9]), other research has looked into ways of processing the contents of such memories so as to increase their accessibility to their owner (see, e.g., [10]; [11]).

The exploitation of augmented memories has been researched for diverse scenarios. For instance, work conducted in the E-NIGHTINGALE project shows how automatically created nursing records may help to avoid medical accidents in hospitals (cf. [12]). How RFID technology and Web mining can be applied to support the user with everyday activities is discussed in [13]. In the project LIVING MEMORY [14], records of people's activities and access to community-related information are automatically processed in support of community-related behavior in relatively complex ways. An example of how memories can support social matching is offered by the system AGENTSALON (see, e.g., [15]). The system uses experience logs of participants in an academic conference in order to stimulate conversation via rather extraordinary means, involving animated characters.

3 Personalized Assistance in Mixed-Reality Shopping

Today, the retail industry introduces sensor networks based on RFID technology for advanced logistics, supply chain event management, digital product

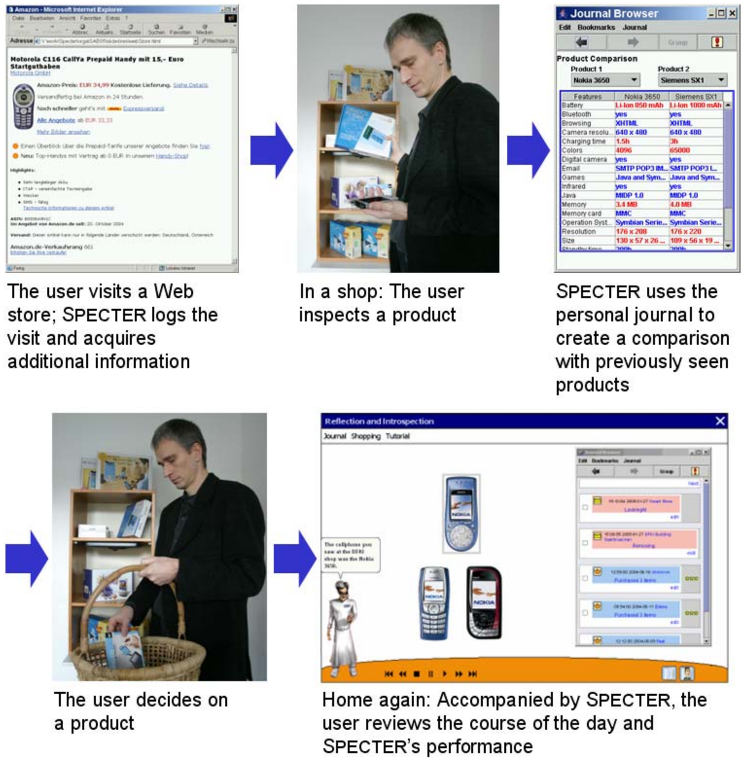

Fig. 1. A typical action sequence from a shopping scenario explored in SPECTER.

memories, innovative payment systems, and smart customer tracking, so that shops turn into instrumented environments providing ambient intelligence. Instrumented shopping environments like the METRO future store or the experimental DFKI Cybershopping mall support mixed-reality shopping, which augments the usual physical shopping experience with personalized virtual shopping assistance known from some online shops. Currently, our DFKI installation includes three small shops with instrumented shelves: a grocery store, a camera and phone shop, and a CD shop.

Up to now, such instrumented shopping environments provide more benefits to the supplier than to the customer. Our research is aimed at exploiting the networked infrastructure for more personalized shopping assistance like digital shopping list support, automatic comparison shopping, cross- and up-selling, proactive product information, and in-shop navigation. The combination of advanced plan-recognition techniques with augmented memory retrieval is a prerequisite for the generation of user-adaptive cross-selling and up-selling recommendations. For example, the system, recognizing that the customer is picking up the usual ingredients for lasagna, may recommend a discounted Italian red wine from Tuscany — a wine similar to one the customer enjoyed some time before but has since forgotten. Such personalized services make sure that shoppers get the best value. In this way, they are compensated for the risk of losing some privacy in instrumented shops.

Fig. 1 illustrates the use of augmented memory functions for automatic comparison shopping in a mixed-reality environment. The user wants to buy a new cell phone. At home, he searches the internet for new models. Our augmented memory service tracks the user's browsing behavior and stores the result in his personal journal. When the user decides to check the physical look and feel of the selected phone in a real shop, he can exploit various augmented memory functions using his internet-enabled PDA. As soon as he grasps a phone from the instrumented shopping shelf, SPECTER generates a comparison table of the features for this particular phone and the best-rated phone that the user found during his preparatory internet search. This is a typical instance of mixed-reality shopping, since the tangible experience with physical products is related to virtual shopping experiences through web browsing. When the user decides to buy a cell phone and puts it in the instrumented shopping basket, this event is recorded in the personal journal together with temporal and spatial information. Later at home, the user of SPECTER can review his digital diary and reflect about his shopping behavior, including entries about which products he has found on the web, which products he has checked in the instrumented shop without buying them, and which products were compared with each other.

The user of the DFKI Cybershopping mall can also look for audio CDs, in particular for soundtracks. People come in contact with soundtracks through various situations — e.g., in a cinema with the family, while watching a DVD at home, or while browsing an Internet store. Sometimes they have a precise idea of the music in question, and sometimes, they have never heard it. This background serves as the scenario in which a user exploits augmented memories by means of SPECTER in order to learn more about soundtracks that might be of interest.

The left side of Fig. 2 shows the user looking at a RFID-tagged CD, which she has grasped from the instrumented rack. The right side shows a screenshot from her PDA, which she is holding in her left hand to access the augmented memory services. SPECTER's personal journal shows that "The Lion King" has been explicitly evaluated by the user (the journal entry is labeled "Classifying") leading to the highest possible rating, visualized on the PDA screen as two thumbs up. For the "Stallion of the Cimarron" SPECTER notes that the user has grasped this CD and then checked a weblink that is automatically offered on the PDA to provide proactively additional product information (the journal entry is labeled "Looking in detail").

In order to actively acquire information about the soundtracks, our user can first browse the Web pages of an Internet store. SPECTER unobtrusively records these actions and assigns to each CD examined by the user a subjective rating based on the user's attention (for more details, see Fig. 8). While shopping, the system provides a listing of services related to the CDs being considered based on situational preferences. For instance, if she is in her favorite shop and has

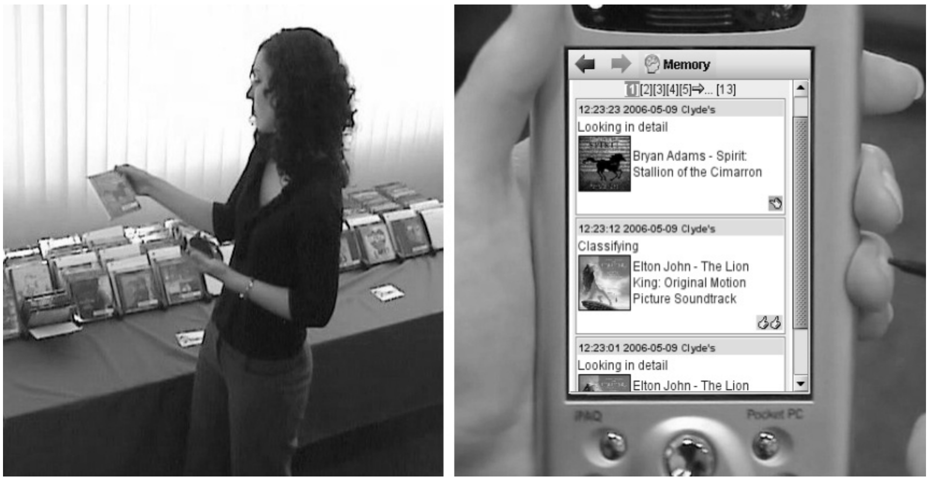

Fig. 2. Creating a personal journal in Specter.

spare time, the system may inform her of special offers on similar CDs. The user may exploit her augmented memories in several additional ways. For instance, if a CD is unknown to the user, the system may provide a list of similar CDs known by means of augmented memories, and thus provide a clue about its content. The other way around, the user can tell Specter to provide to the shop some examples of CDs she likes in order for them to suggest similar CDs as yet unfamiliar to her. All these actions contribute to her augmented memories and may therefore later become the subject of reflection and introspection.

Humans have memories filled with their experiences. But as an alternative to acquiring experiences on their own, humans often share memories with others (e.g. actively by telling stories or, more modernly, by blogging, passively by watching movies or reading autobiographies and test reports). Given augmented memories created on the basis of observations in instrumented environments and given several users with such memories based on our Specter software, the key research question of our SharedLife project is: can we reproduce the natural exchange of memories to some degree to enrich the memories of individuals and support their activities?

Fig. 3 illustrates a first version of the SharedLife system used in our instrumented CD shop. The user's behavior, his ratings and past choices are captured in his augmented memory (see step 1 in Fig. 3). This personal memory can be used for a combination of reminding and recommendation, which we call "recomindation" (see step 2 in Fig. 3). The system reminds the user that he had listened to the soundtrack of "Toy Story" while he was watching the DVD with friends on the 1st of March 2005 at noon. In addition, it recommends to buy the CD, since the augmented memory includes a very favorable personal rating of this soundtrack. The user can publish parts of this shared memory after entering it in his ubiquitous user model (see step 3 in Fig. 3). He can specify privacy

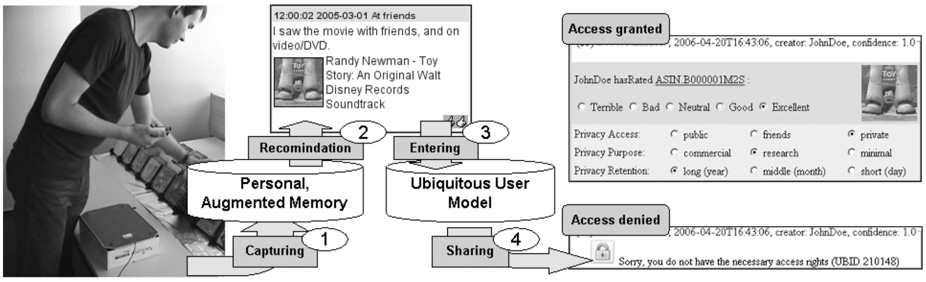

Fig. 3. Sharing augmented personal memories.

constraints, so that a selective sharing of the augmented memories becomes possible. For instance, the access to the excellent rating of this soundtrack by the user may be denied for commercial use, but granted for research purposes only (see step 4 in Fig. 3).

4 From Sensor Data to Memories

The first step towards the creation of augmented memories is the automated recording of contextual information as perceived from various types of sensors. In our example scenario, each CD is an RFID-tagged smart object, which allows tracking its presence within the store areas (shelf, basket, cashier). Optionally, these objects may be anthropomorphized in order to facilitate the human-environment communication (cf. [2]). The user's location may be determined using IR, RFID, and/or GPS (see [16]). Biosensors (e.g., electrocardiogram (ECG) electromyogram (EMG), electrodermal activity (EDA), and acceleration (ACC) sensors) provide further information about the user's state, which is applied for choosing an appropriate communication channel and for automatically evaluating events (cf. [17]). Finally, Web services allow the system to acquire rich context information (e.g., the current weather or important events from RSS feeds), which may later on serve as an access key to the memory. In addition, such services are used to realize certain domain-specific features within the user's environment. For instance, Specter assists its user with services implemented by [18], such as a similarity search for CDs.

Each of these input sources is linked to a so-called *RDF store* (see [3]). Such a store provides an RDF-based interface to a sensor-specific memory, which is decoupled from the user's augmented memories. Two advantages provide the rationale for this separation:

Efficiency: sensor memories are not bound to Specter's RDF-based implementation of the augmented memory. This is of special interest due to the diversity of the perceived data, which may range from raw mass data of biosensors to rich information retrieved from Web services. For the same reason, sensors may implement their own abstraction methods — e.g., a simple mapping is performed in order to translate GPS coordinates into semantically meaningful

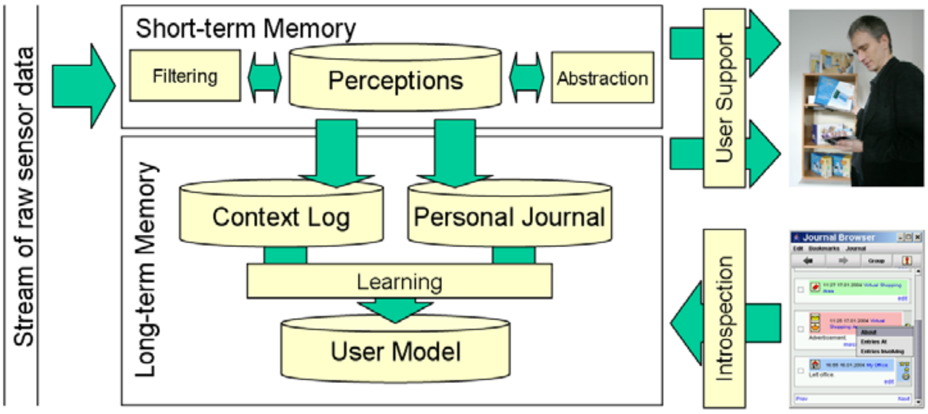

Fig. 4. Building memories from perceptions in SPECTER.

locations, whereas input from biosensors is processed on a mobile system by means of dynamic Bayesian networks.

Flexibility: for various reasons, the connection between the augmented memory and some sensors may sometimes be lost (e.g., technical issues, trust issues). In such a case, the user should be allowed to complete the augmented memories at a later time using records from the sensors' memories.

4.1 Modeling Perceptions

Sensors provide the system with *perceptions*; their RDF-encoded content contains simple statements such as "user reaching shelf" or "user holding CD". At any given point of time, the set of all available sensors' latest perceptions defines the *context* of an event in SPECTER.

Information contained in perceptions references an ontology based on the IEEE SUMO and MILO [19]. The user's state is modeled using the general user model ontology (GUMO, cf. [20]), a mid-level ontology which provides applications with a shared vocabulary for expressing statements about users. Furthermore, in order to facilitate the exchange of GUMO statements between different applications, the ontology provides a means of combining such statements with meta statements, e.g., about privacy, trust, and expiry issues. GUMO statements reference a variety of dimensions that describe user properties. Their basic dimensions include `contact information`, `personality`, and `emotional state`. These concepts are the topmost level of a broad range of specialized concepts. The complete ontology can be reviewed and edited online with an ontology browser provided at `http://www.gumo.org/`.

4.2 The Abstraction Pipeline of SPECTER

In order to describe how perceptions are processed and stored we have developed a *memory model* (see Fig. 4). In this model, incoming perceptions are stored in

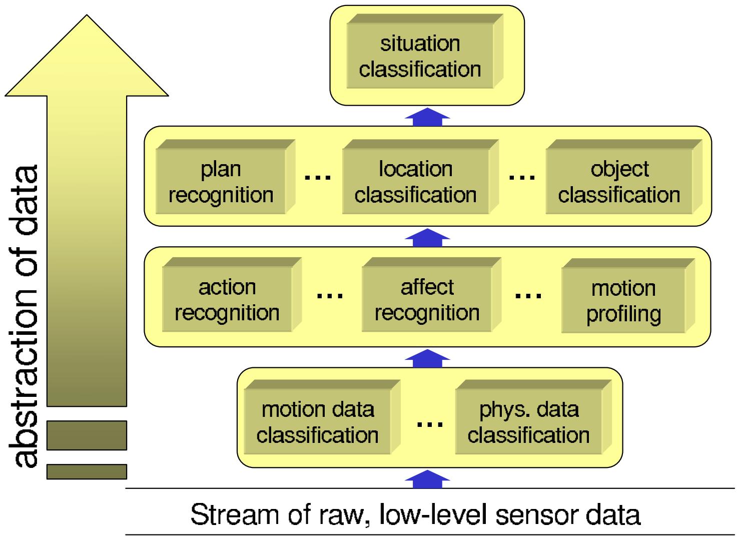

Fig. 5. An abstraction process is performed in order to gain symbolic information from raw sensor data.

a short-term memory, which serves two main purposes. First, it is of special relevance for the recognition of situations and thus situated user support. The facts stored in the short-term memory model the user's current context; a BDI planner (JAM, cf. [21]) matches this context against patterns of service bindings specified in the user model (more about this in the next section). The second purpose of the short-term memory is to trigger, based on events and event chains, the construction of episodes in the long-term memory.

Our approach to a long-term memory for intelligent environments is two-fold. First of all, perceptions are stored in a *context log* without further change. This log works primarily as the system's memory. It is linked to the *personal journal*, which consists of entries representing episodes created from one or more perceptions. For instance, the perceptions "user holding A" and "user holding B" can be combined to the episode "user comparing A and B". The creation of journal entries is an abstraction process, which is performed using pre-authored rules expressing commonsense knowledge and domain knowledge.

Fig. 5 illustrates the abstraction pipeline realized in SPECTER. The stream of raw level sensor data is first classified, so that basic motion data can be derived (compare the bottom of Fig. 5). The results of RFID readers can be abstracted to the observation that a certain product has been removed from a particular shopping shelf and put into an instrumented shopping basket. This can be further abstracted to an intended purchase of this product. If the shopper has already put pasta sheets, chopped tomatoes, and beef in his basket then the plan recognition mechanism of SPECTER will generate the hypothesis that the user wants to prepare a lasagne. When an additional plan for preparing tiramisu is recognized and a 12-bottle box of Chianti wine is bought, SPECTER may classify the situation on the highest level of abstraction as "shopping for an Italian dinner party" (compare the top of Fig. 5).

The grocery shopping scenario involves complex constraints on cooking for a particular dinner guest, such as availability, food allergies, dietary rules, and religious food preferences. Thus, shopping tips and shared cooking experiences are most welcome and SHAREDLIFE may grant limited access to the augmented memory of friends and family members with cooking expertise.

5 Exploiting Memories

We focused in the previously described shopping scenario on a specific way of exploiting augmented memories. Depending on the user's current context, the system offered recommendations and reminders related to that context with the goal of putting information about past experiences relevant for the current situation into the user's mind. For instance, if the user is inspecting some CD in a shop, the system might come up with cheaper offers previously seen, or with recommendations of similar CDs in this shop. In order to describe such processes we coined the notion *recomindation*; a study with 20 subjects showed that a number of aspects of this paradigm tend to be recognized not only as appropriate and effective in supporting the user's shopping experience, but also as *enjoyable* (cf. [4]).

5.1 Reflection and Introspection

A crucial factor for the quality of such support is information about the relevance of the numerous events recorded over time for a given situation. The relevance is determined by several factors, and one of them is explicit or implicit user feedback. Feedback is represented by ratings, which may be attached to personal journal entries. We experimented with various rating dimensions including *evaluation* (a general quality judgement of objects referenced by the entry), *importance* (how important is the entry with respect to the user's current goals), and *urgency* (how urgent is the entry with respect to the user's goals). Ratings are assigned either explicitly by the user (cf. the left-hand side of Fig. 8) or implicitly based on feedback from biosensors and domain-specific heuristics.

Ratings assigned by the system may differ from the user's perception, e.g., due to noise within the sensor data or inappropriate heuristics. Furthermore, especially in the case of an "untrained" system, the mapping of situations to services might require an adaptation to the user's personal needs as well. The user may address such issues by performing an *introspection* of her augmented memories.

We think of introspection as *"...a process of inward attention or reflection, so as to examine the contents of the mind..."* (cf. [22]). In the case of our approach to augmented personal memories, introspection consists of processes in which the user and/or the system explore the long-term memory in order to learn about

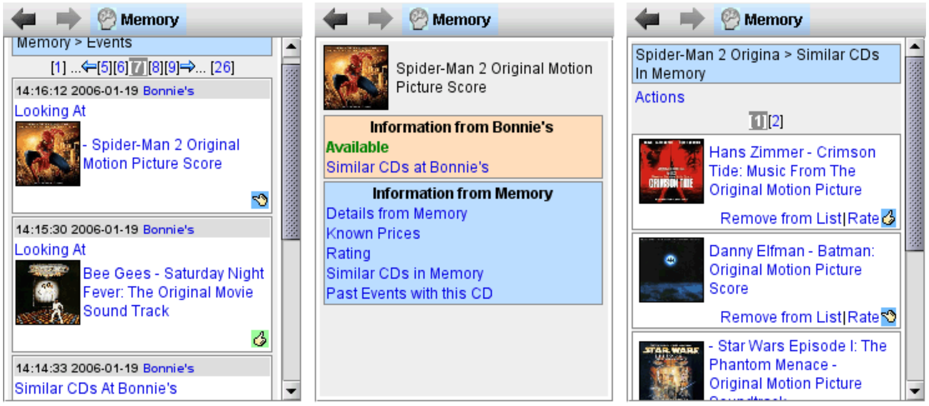

Fig. 6. Views on augmented memories: events, functions, and objects (from the left to the right).

the course of events. From the user's point of view this includes the option to explore and to rate journal entries, including those produced in response to system actions. From the system's point of view introspection is an opportunity to refine, collaboratively with the user, the user model.

Feedback from our test user group indicated that an introspection should be possible in a mobile setting (in order to make use of spare time, e.g., during a train ride) as well as in a desktop setting. This is reflected in SPECTER's user interface to augmented memories, which consists of two major components.

On a mobile device, a *journal browser* lets the user explore and evaluate memories. It provides the user with diverse views on her augmented memories. Fig. 6 illustrates three of these views:

– *Events:* For each event, this view provides information about its context (e.g., location and time), a summary of actions observed by SPECTER, and ratings assigned by system and user. Additional filters may constrain the list of shown events.
– *Functions:* This view lists services related to some object contained in the augmented memory, which can be applied by the user in the current context. Here, the user interface distinguishes environment- and memory-related functions. In our example, the current location is the CD store "Bonnie's", which allows the user to ask for similar CDs on sale ("Similar CDs at Bonnies"). Other functions such as a price comparison ("Known Prices") make use of the augmented memory in order to look up known instances of the CD.
– *Objects:* At many opportunities an object-centered view is applied by the system in order to focus specific sets of information from the memory, such as the outcome of a retrieval process. This view presents a list of objects (here: audio CDs), which can be exploited by the user in diverse ways, for instance, to specify example-based queries to memory and environment.

These views are typically triggered by interactions between user and environment. Complex interactions often involve several views; in our example, the user starts from an event referring the "Spider-Man 2" soundtrack and uses the memory-related function "Similar CDs in Memory" in order to retrieve an object list of similar CDs seen so far.

Other functions of the journal browser are not directly related to the memory, but to the system configuration. These include top-level manipulation of system services (e.g., switching off some support), bookmarking of views, and so-called *reminder points*, which indicate the need for a close review of the current situation.

Such reflection and introspection can be performed on a regular desktop PC using an *introspection environment*. It provides a rich user interface which enables in combination with the planner already mentioned a collaborative introspection of augmented memories (see [5] for a detailed description). If the user is exploring the memory, then the system assists by offering event summaries as well as details and links to the memory and the Web. The latter point to external resources and services, and thus provide another means for retrieving and adding information to the memory.

These activities usually require the user's initiative. The system also proactively checks the memory for situations where clarification might help to improve the user model; examples of such situations are reminder points and user feedback obtained during the execution of some supporting service. When such situations are detected, the user is asked to enter the collaborative process described below.

5.2 Collaborative Critique of Situated User Support

If the user is not confident with the system's suggestions, or wants to set up a new service binding, there is a component explicitly designed for mapping situations to services. This component is described in detail in [23]; at this point we will only summarize its features and focus on its role within the introspection process.

The purpose of this component is to provide a scrutable and easy-to-use interface that allows the user to interact with complex machine-learning processes without the need to deal with the technical subtleties of feature selection or data encoding. The key to our approach is to combine the system's capability to deal with the statistical relevance of a situation's features with the user's ability to name semantically meaningful concepts that can and should be used to describe the characteristics of a situation.

The result of our ongoing effort is a user interface which provides several interaction layers of varying complexity for combining services and situations. Especially relevant for a critique of a situation's features (and thus for configuring the execution of linked services) is the screen shown on the left-hand side of Fig. 7. This shows a list of features, which have been extracted using statistical methods from the memory, as it is presented to the user.

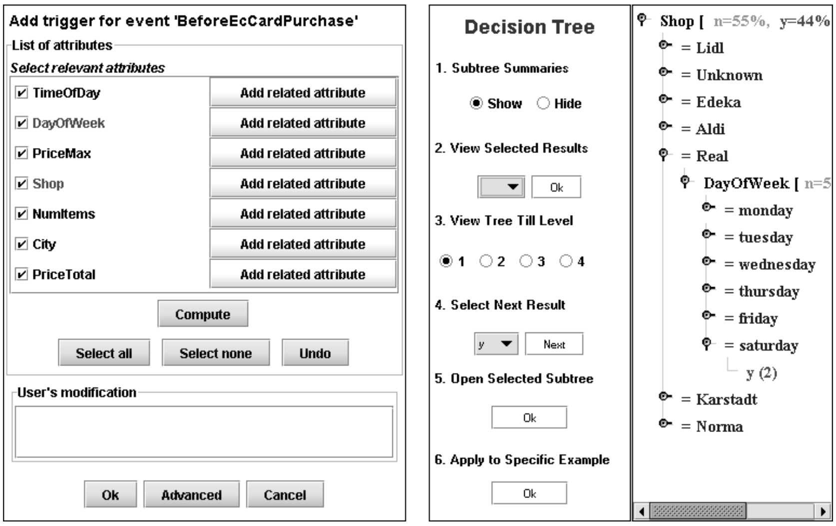

Fig. 7. A user interface for critiquing situational features (left-hand side) and inspecting decision trees generated from these features (right-hand side).

The user may critique this set by deselecting features, or by navigating in their semantic neighborhood using a graphical interface to the underlying ontology. In our example scenario, the user might want to inform the system that recommendations should only be retrieved in certain kinds of shops. A way to achieve this goal is to inspect the list of features and then to refine the shop's features, e.g., by replacing the general shop by a more specific branch.

The system applies the adjusted feature set for computing a decision tree. It becomes connected to the short-term memory; from now on it is used to classify the system's observations and thus to decide if the service chosen by the user should be triggered. In order to make this mechanism transparent to the user, the decision tree can be inspected by means of the graphical user interface shown on the right-hand side of Fig. 7. This interface provides various ways of navigating the decision tree, and offers additional information about the relevance of the selected nodes based on the number of positive and negative examples taken from the personal journal.

6 Selective Memory Sharing

So far we focused on personal use of augmented memories. However, there is often the need to communicate personal memories with the environment: for instance, the user may select items from the memory and provide these as examples to the environment in order to personalize services offered there. Of course, these applications may exploit such data for building their own model of the user.

This way of *sharing* personal augmented memories matches the idea of ubiquitous user modeling, which can be described as *"...ongoing modeling and exploitation of user behavior with a variety of systems that share their user models..."* (see [24]). In the following, we will illustrate how by means of a platform for ubiquitous user modeling, namely U2M (cf. `www.u2m.org`), such sharing mechanisms can be realized.

Within U2M, the concept of *sharing* is split up into *exchanging* and *integrating* statements about users. The former is realized by a user model server that provides a service-based architecture for distributed storage and retrieval of statements about users. The integration of statements is achieved with the accretion model according to [25] together with a multilevel conflict resolution method described in [24], which also solves the problem of contradictory information.

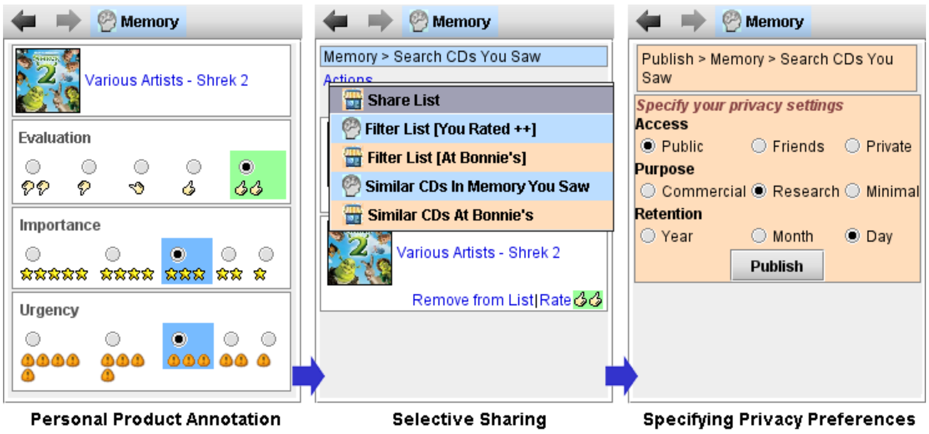

Fig. 8. Selective memory sharing with privacy constraints.

What statements can be retrieved and how they are integrated depends on several layers of metadata attached to the statements by means of reification. From the outermost to the innermost layer, these are: `administration`, `privacy`, `explanation`, and `situation`. They establish a sequence of access constraints which have to be met in order to obtain the reified statement. The privacy layer in this sequence is of special interest. It implements the following privacy attributes: `key`, `owner`, `access`, `purpose`, and `retention`. The user model server checks these attributes in order to deliver as much information as possible without violating the user's preferences. Combined with the other layers, complex situational access constraints can be established, such as "friends only & at my home & for personal purposes".

Fig. 8 depicts how this technology allows for sharing information extracted from an augmented personal memory. In our example, the user evaluated the

CD “Shrek 2” very positively (two thumbs up, left-hand side of Fig. 8). Since no specific situational context is provided for this evaluation, the ratings for importance and urgency have been set by the system to a neutral default value. A context menu allows the user to initiate a sharing process at any time for lists of objects – here: audio CDs – retrieved from the augmented memory. The middle of Fig. 8 shows that the user has selected a list including the CD “Shrek 2”. The user may specify privacy-related preferences (here: about access, purpose, and retention) explicitly for the current sharing process (right-hand side of Fig. 8) or rely on U2M’s default reasoning which derives privacy preferences from personal defaults set in the ubiquitous user model. Once submitted, U2M makes the data accessible to other users with respect to the user’s privacy preferences.

7 Conclusions

One of the grand challenges of current AI research is to create instrumented environments and to capture the physical and communicative interaction of an individual with these environments, to process this multimodal and massive data stream, to recognize, classify, and represent its digital content in a context-sensitive way, and finally to integrate behavior understanding with reasoning and learning about the individual’s day by day experiences.

We presented our SharedLife project, in which we are creating augmented episodic memories that are personal and sharable. We described the experimental DFKI Cybershopping mall, which supports mixed-reality shopping and which augments the usual physical shopping experience with personalized virtual shopping assistance known from some online shops. Our research is aimed at exploiting the networked infrastructure for more personalized shopping assistance like digital shopping list support, automatic comparison shopping, cross- and up-selling, proactive product information, and in-shop navigation. In the technical core of the paper, we described in detail the abstraction pipeline and the first implementation of the memory sharing mechanism of SharedLife, which is based on a ubiquitous user modeling server.

Our future work on SharedLife will address the question of how the sharing of augmented memories can contribute to the communication within small, potentially ad-hoc formed groups. We want to provide mechanisms for automated and semi-automated memory sharing. Such mechanisms must not only take into account situated access constraints on privacy and trust (e.g., in order to distinguish between situations of everyday life and emergency cases), but also the structure of the group (e.g., to define experts or opinion leaders).

8 Acknowledgements

This research was supported by the German Ministry of Education and Research (BMBF) under grant 524-40001-01 IW C03 (project Specter) and under grant 01 IW F03 (project SharedLife). Furthermore, the German Research Foundation (DFG) supported this research in its Collaborative Research Center on

Resource-Adaptive Cognitive Processes, SFB 378, Project EM 4, Bair. Finally, we would like to thank all project members for their valuable contributions.

References

1. Kröner, A., Heckmann, D., Wahlster, W.: SPECTER: Building, exploiting, and sharing augmented memories. In Kogure, K., ed.: Workshop on Knowledge Sharing for Everyday Life 2006 (KSEL06), Kyoto, Japan, ATR Media Information Science Laboratories (2006) 9–16 Invited talk.
2. Wasinger, R., Wahlster, W.: The anthropomorphized product shelf: Symmetric multimodal interaction with instrumented environments. In Aarts, E., Encarnação, J., eds.: True Visions: The Emergence of Ambient Intelligence. Springer, Heidelberg, Berlin, New York (2006)
3. Schneider, M.: RDF:Stores – a lightweight approach on managing shared knowledge. In Ma, J., Jin, H., Yang, L.T., Tsai, J.J.P., eds.: Proceedings of the 3rd International Conference on Ubiquitous Intelligence and Computing (UIC 2006), Springer (2006)
4. Plate, C., Basselin, N., Kröner, A., Schneider, M., Baldes, S., Dimitrova, V., Jameson, A.: Recomindation: New functions for augmented memories. In Wade, V., Ashman, H., eds.: Adaptive hypermedia and adaptive web-based systems: Proceedings of AH 2006, Berlin, Springer (2006)
5. Baldes, S., Kröner, A., Bauer, M.: Configuration and introspection of situated user support. In: LWA 2005, Lernen Wissensentdeckung Adaptivität, Saarland University, Saarbrücken, Germany (2005) 3–7
6. Lamming, M., Flynn, M.: "Forget-Me-Not": Intimate computing in support of human memory. In: Proceedings of FRIEND21, the 1994 International Symposium on Next Generation Human Interface, Meguro Gajoen, Japan, Meguro Gajoen, Japan (1994)
7. Gemmell, J., Williams, L., Wood, K., Lueder, R., Bell, G.: Passive Capture and Ensuing Issues for a Personal Lifetime Store. In: Proceedings of The First ACM Workshop on Continuous Archival and Retrieval of Personal Experiences (CARPE '04), New York, USA (2004) 48–55
8. Dumais, S., Cutrell, E., Cadiz, J., Jancke, G., Sarin, R., Robbins, D.C.: Stuff i've seen: a system for personal information retrieval and re-use. In: SIGIR '03: Proceedings of the 26th annual international ACM SIGIR conference on Research and development in informaion retrieval, ACM Press (2003) 72–79
9. Aizawa, K., Tancharoen, D., Kawasaki, S., Yamasaki, T.: Efficient retrieval of life log based on context and content. In: CARPE'04: Proceedings of the the 1st ACM workshop on Continuous archival and retrieval of personal experiences, New York, NY, USA, ACM Press (2004) 22–31
10. Horvitz, E., Dumais, S., Koch, P.: Learning predictive models of memory landmarks. In: Proceedings of the CogSci 2004: 26th Annual Meeting of the Cognitive Science Society, Chicago, USA (2004)
11. Clarkson, B.: Life Patterns: structure from wearable sensors. PhD thesis, School of Architecture and Planning, Massachusetts Institute of Technology, Cambridge, MA (2002)
12. Kuwahara, N., Noma, H., Kogure, K., Hagita, N., Tetsutani, N., Iseki, H.: Wearable auto-event-recording of medical nursing. In: Proceedings of the Ninth IFIP TC13 International Conference on Human-Computer Interaction (INTERACT 2003). (2003)

13. Philipose, M., Fishkin, K.P., Perkowitz, M., Patterson, D., Hähnel, D.: The probabilistic activity toolkit: Towards enabling activity-aware computer interfaces. Technical Report IRS-TR-03-013, Intel Research Seattle, Seattle, WA 98115, USA (2003)
14. Stathis, K., de Bruijn, O., Macedo, S.: Living memory: agent-based information management for connected local communities. Interacting with Computers **14**(6) (2002) 663–688
15. Sumi, Y., Mase, K.: Supporting awareness of shared interests and experiences in community. International Journal of Human-Computer Studies **56**(1) (2002) 127–146
16. Brandherm, B., Schwartz, T.: Geo referenced dynamic Bayesian networks for user positioning on mobile systems. In Strang, T., Linnhoff-Popien, C., eds.: Proceedings of the International Workshop on Location- and Context-Awareness (LoCA), LNCS 3479, Munich, Germany, Springer-Verlag Berlin Heidelberg (2005) 223–234
17. Brandherm, B., Schultheis, H., von Wilamowitz-Moellendorff, M., Schwartz, T., Schmitz, M.: Using physiological signals in a user-adaptive personal assistant. In: Proceedings of the 11th International Conference on Human-Computer Interaction (HCII-2005), Las Vegas, Nevada, USA (2005)
18. Amazon Inc.: Amazon e-commerce service (2005) http://www.amazon.com-/gp/aws/landing.html.
19. Niles, I., Pease, A.: Towards a standard upper ontology. In: FOIS '01: Proceedings of the international conference on Formal Ontology in Information Systems, ACM Press (2001) 2–9
20. Heckmann, D., Brandherm, B., Schmitz, M., Schwartz, T., von Wilamowitz-Moellendorf, B.M.: GUMO - the general user model ontology. In: Proceedings of the 10th International Conference on User Modeling, Edinburgh, Scotland, LNAI 3538: Springer, Berlin Heidelberg (2005) 428–432
21. Huber, M.J.: JAM: a BDI-theoretic mobile agent architecture. In: AGENTS '99: Proceedings of the third annual conference on Autonomous Agents, New York, NY, USA, ACM Press (1999) 236–243
22. Sharples, M., Hogg, D., Hutchinson, C., Torrance, S.: Computers and Thought: A Practical Introduction to Artificial Intelligence. Bradford Book (1989)
23. Bauer, M., Baldes, S.: An Ontology-Based Interface for Machine Learning. In Riedl, J., Jameson, A., Billsus, D., Lau, T., eds.: IUI 2005: International Conference on Intelligent User Interfaces, New York, ACM (2005) 314–316
24. Heckmann, D.: Ubiquitous User Modeling. PhD thesis, Department of Computer Science, Saarland University, Germany (2005)
25. Kay, J., Kummerfeld, B., Lauder, P.: Personis: A server for user models. In de Bra, P., Brusilovsky, P., Conejo, R., eds.: Proceedings of the Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems. LNCS 2347, Springer-Verlag Berlin Heidelberg (2002) 203–212