MEMODULES as Tangible Shortcuts to Multimedia Information

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Abstract. Tangible User Interfaces (TUIs) are emerging as a new paradigm for facilitating user interaction with the digital world by providing intuitive means to link the physical and digital worlds. The MEMODULES project has the objective of developing, experimenting and evaluating the concept of tangible shortcuts (reminders), facilitating (a) the control of devices in the everyday life and also (b) the categorization of information in order to ease or improve information access and retrieval. The project aims at facilitating the user interaction with multimedia information by supporting both the creation and management of tangible links to digital content. Moreover, our research investigates the opportunity of a more complex, multi-sensorial combination of objects and multimedia information by combining multiple interaction modalities - such as voice and gesture - with interactive information visualizations. In order to address these issues we propose a user-oriented framework, called Memodules Framework, enabling end users to turn everyday objects into Memodules. The framework provides a single platform that combines end-user programming, tangible interaction, multimodality and personal information management issues. Memodules framework is built upon MemoML (Memodules Markup Language) and SMUIML (Synchronized Multimodal User Interaction Markup Language) models, which guarantee framework flexibility, extensibility and evolution over time.

1 Supporting Human Memory with Interactive Systems

Human memory is central in our daily life activities, not only to build relationships with friends, create our identity or reminisce about the past [50] but also to drive our attention towards the most important tasks to perform and to manage our lives [51]. Information overload, memory losses and attention lacks are crucial challenges to solve, not only for elderly people but also for the rest of the society. For these reasons, designing interactive systems that can support human memory has become critical to increase our wellness, using novel technologies and innovative human-machine interaction paradigms [52].

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Numerous elderly have memory and attention problems, without including Alzheimer disease [53], which hinder their daily lives. Not only do they have difficulties remembering appointments and tasks that need to be done, they might lose their glasses, or have trouble remembering people and places, which can result in unsafe situations and feelings of insecurity and melancholy.

Younger people also face memory problems, especially with the constant increase of information a person owns and handles. Not only the information amount is growing fast, it is dematerializing and thus, people are often feeling overwhelmed. Documents are multiplying in very large file hierarchies, pictures are no longer stored in photo-albums, music CDs are taking the form of mp3 files, movies are stored on hard-drives. Google and Microsoft recently tried to solve this issue by providing, respectively, a desktop search engine and a powerful email search engine, in attempt to minimize the effort needed by people to organize their documents and access them later by browsing. However, in order to find a file, one still has to remember a set of keywords or at least remember its "virtual" existence. If one does not remember having a certain document, browsing could be helpful, since it can reveal related keywords and documents. Those, in turn, can help you remember by association, like human memory does [51].

Memory retrieval happens in cycles, meaning that recollecting starts with a cue or a short memory description after which it cycles through different levels of detail of the autobiographical memory system until it matches the memory search [54]. A cue (or trigger) is a stimulus that can help someone to retrieve information from long-term memory. Anything can be a cue (a photo, a spoken word, a color, an action or a person), as long as there is a link between the cue and the to-be-remembered event. For example, when we see a picture of a place visited in our childhood the image may cue recollections associated to the content of the picture and trigger an emotional reaction simultaneously. This information is generally easier to retrieve if it is associated to a strong emotional experience [55] or when it is repeated often. This so-called rehearsal can be facilitated e.g. by having physical objects related to memories, such as souvenirs or photographs [56], [57], and in case these physical objects are linked to their digital counterparts such as photos and videos, these tangible interactions can support everyday human memory [58], [59], [52], [44]. Furthermore, it appears that people easily access and retrieve information when it is linked to other related information or objects [60], [61], either information or media, such as sounds, smells, images, which support the idea of cross-modal indexing [62].

Over the last couple of years, it has been demonstrated that Graspable, or Tangible User Interfaces (TUIs), a genre of human-computer interaction that uses physical objects as representations and controls for digital information [63], make up a promising alternative for the 'traditional' omnipresent graphical user interface (GUI). In a few projects such as Phenom [56], TUIs have been used to support people who are subject to the information overload problem, thanks to tangible reminders and shortcuts to access and control information. The Phenom souvenirs [56] are personal iconic tangibles embedded with RFID tags coupled to personal digital photo collections. Few systems have demonstrated the technical feasibility of associating digital media with tangible objects [64], [65], and generally remain stand-alone proof of concept prototypes or applications of limited functionality. More sophisticated combinations of multimedia and tangible interaction are only now emerging [66] [67]. Using personal objects that have ‘personal meaning to the user’ [59] in a TUI supports existing mental associations and media systems, reducing learning time. Examples of studies in this area include the souvenirs mentioned in [69], but also Rosebud [58], POEMs [68] and Passage [65]. These types of TUIs seem more suitable for novice users or elderly people and lend themselves better to the home environment as a place for personal belongings. Another important aspect of personal objects in a memory system is that often the objects’ original purpose is to remind people of its history and the (personal) stories attached [20].

The main goal of MEMODULES project is to investigate these aspects further in order to go beyond stand alone proof of concept prototypes towards more complete and general solutions combining tangible interaction with multimodality as well as multimedia information issues. Moreover we want to allow non-expert users to create their own TUI system with the ultimate goal of empowering people to easily and flexibly employ TUIs in the framework of upcoming smart environments. More specifically, MEMODULES project aims at developing, experimenting and evaluating the concept of tangible shortcuts (reminders), facilitating (a) the control of devices in the everyday life and also (b) the categorization of information order to improve information access and retrieval.

The chapter is structured as follows. Section 2 introduces the concept of Memodules and the main use-cases that have driven our research activities. Section 3 presents the user-centered design approach. Section 4 reviews relevant state-of-the-art within the domain of tangible user interaction, multimodality as well as information management. Section 5 presents the Memodules framework that allows end-user to easily turn everyday objects into tangible user interfaces by taking into account multimodality and personal information management issues. Section 6 concludes the chapter and presents futures works.

2 Memodules Concept

Memodules are tangible interfaces that link our memory to related digital information. Memodules are usually small or tiny-tagged physical objects containing a link towards information sources. They roost abstract information in the real world through tangible reminders. We consider the Memodules as tangible hypermarks, i.e. embedded hyperlinks to abstract information attached to everyday physical objects. Memodules do not only materialize information in the real world through tangible reminders, they also help controlling the dailylife devices accessing the information (CD player, TV, computer, etc.) or other devices (lamp, heater). The basic idea of this project is to associate three main entities: Humans, Memodules, and Devices, in order to launch a set of actions in a natural way in everyone’s everyday life:

Human + Memodules + Device = Action

Moreover the project will consider two complementary research approaches, i.e. user-centric and device-centric, in order to design, implement and evaluate Memodules, i.e. tangible shortcuts to multimedia information. In fact, information technology is transforming the way people interact among themselves and with objects around them. In particular, technology's focus is gradually shifting away from the computer as such, to the user. This change of paradigm aims at making communication and computer systems simple, collaborative and transparent to the user. Because both humans and machines are concerned in order to improve human-computer interaction, both should be carefully studied and taken into account when designing Memodules.

The following use-case illustrates one of the possible applications of Memodules in the domestic environment:

- Home use-case (Fig. 1): Sandra creates a folder full of pictures from her last vacations in Corsica. She glues an RFID (Radio Frequency Identification) on a nice seashell she brought back from Corsica and asks the system to associate it with the picture folder. One week later she wants to show her friends a slideshow of her vacation. She places the seashell, together with a "jazz" Memodule, in a little hole next to the plasma screen, which activates the show. Denis who enjoyed the evening and the pictures gives his calling card to Sandra. The following day, Sandra places Denis' calling card along with the seashell on top of the communicator and makes a brief special gesture to send everything.

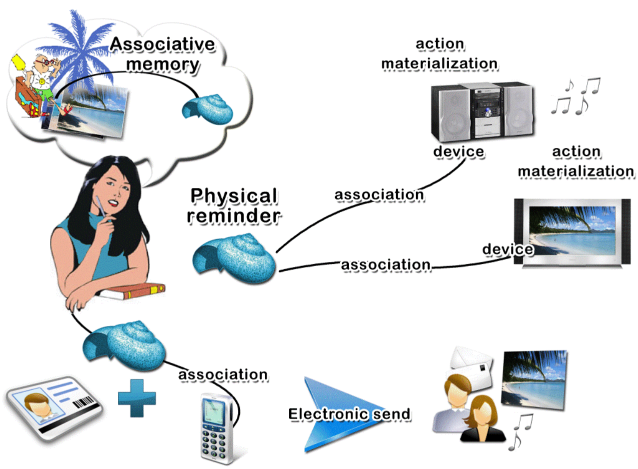

Fig. 1. Memodules Home use-case

Other application areas, such as business and library environments, have been envisaged and implemented as interesting Memodules use-cases:

- Business meeting use-case: Rolf missed a meeting. He places the printed agenda of this meeting, which is a tagged Memodule, next to a screen. The multimedia data recorded during the meeting, e.g. audio, video, documents, are immediately played on the same screen.
- Library use-case: Denis is at the library. He found two interesting books "Cooking for Dummies" and "Lonely Planet India", which he is planning to take home. He puts the two books next to a large display in the middle of the library and the system suggests to him various other books through an interactive visualization, books thematically realted, related by authors, or by references, or also those read by other users, who also selected the 2 books. He selects "The Art and Tradition

of Regional Indian Cooking" and the system indicates him the exact location of the book in the library on a map.

2.1 Memodules Approach

Based on the concept of associative memory, a physical object (the seashell in the example of Fig. 1) is associated to some digital information that is then materialized on a specific device through the user interaction (*Memodules interaction scenario*). As shown in Fig. 2 this approach, called here the Memodules approach, will be explored through two complementary fundamental and applied research axes:

- User centered design: study the user's needs and tasks they need to accomplish, in order to provide suitable and usable interfaces.
- Technology-driven design: improve human/computer physical interaction techniques and multimodal processing capabilities for a new generation of devices and environments (interaction techniques, in Fig. 2). This includes also considering issues related to information management such as how to classify, categorize, contextualize, visualize and personalize information according to user preferences and profiles (multimedia content, in Fig. 2).

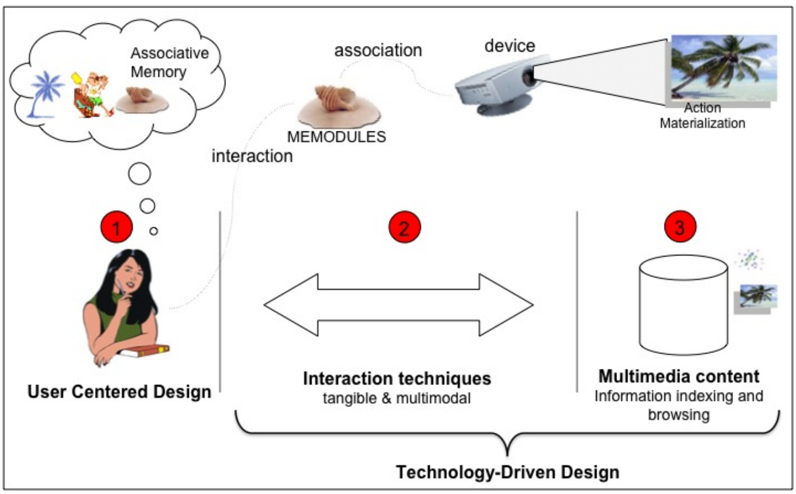

Fig. 2. Memodules approach

3 User Centered Design

The main goal of the user-centered design phase consisted of studying the activity of travelling in order to understand and point out: how personal objects and souvenirs are used and collected; how those objects are connected to memories and remind people; how we could combine those objects with multimedia content (digital photos, music etc.) to enhance recalling memories and storytelling.

User-centered design aims to explore travelling activities in order to elicit users needs and wishes to inform the design process. In order to explore and understand travel activity we conduct the user studies using different methodologies: focus group interview, the analysis of travel diaries (journal written during the travel) and an investigation of the most common habits on sharing travel memories through the Web (see Fig. 3). Relevant aspects outlined with aforementioned techniques drove succeeding brainstorming and concept generation activities as shown in Fig. 3 (the technology driven design was conducted as a parallel activity to study enabling technologies).

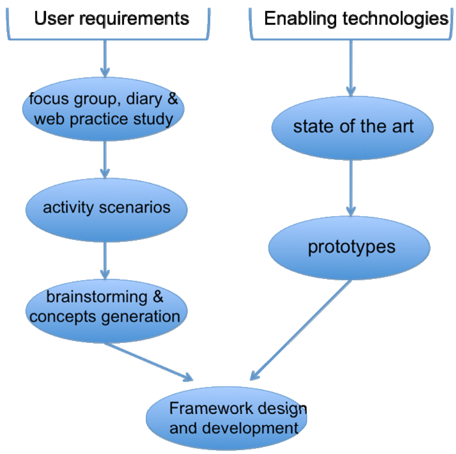

Fig. 3. User-centered process

The first investigation was conducted using focus group since it provides us with a great deal of data about current practices of tourists and helps us in understanding how to address the issue of traveling. We organized two different focus groups involving people who represent the users' class such as: independent travelers who arrange their own travel and activities, they are between 25 and 30 years old, with intermediate or advanced technology knowledge. They travel for pleasure for long and short period of time (from one week up to one month). Each focus group involved 6 persons. Focus groups investigated how users grasp souvenirs and collect information during the travel and how they use them after. For example the objects are grasped, organized, manipulated and consumed by the user in the attempt of fixing memory and remembering the experience of the voyage (Fig. 4).

Outcomes from these activities confirmed results achieved in the previous studies (such as [70], [69]) and clarified the basic features and some drawbacks of existing practices and tools that support travelling activities. For example planning a travel requires collecting information from several and different sources, and one of the most common ways to grasp information mostly regarding culture, habits and good tip is through personal contacts. Social relations have a key role on planning activity since people are one of the most important resources to gather information: friends, colleagues, relatives whom already have been there, natives, etc (more detailed information can be found in [49]).

Fig. 4. Some examples of souvenirs collected during the travel

The key findings that emerged from the focus group helped us to drive further investigation activities. Further study was oriented to elicit information regarding how people document the travel and which are the most common practices to publish and share multimedia data and travel stories. The analysis of travel diaries (journal written during the travel) and an investigation of the most common habits on sharing travel memories through the Web were then performed. Once again the results of these investigations elicited the importance for people to fix memories and share their experiences.

The whole user activity analysis provides us with many interesting elements and several scenarios (activity scenarios in Fig. 3) for guiding the design process. Among the several scenarios, we focused on few of them concerning the activity of sharing experience through story telling, collecting objects that evoke the travel and making personal reflection of the experience. According with the selected scenarios and related research works, some critical issues emerged:

- Users have difficulties in integrating different media (paper pictures, digital pictures, diary book, objects, etc…) and to exchange file and data,
- People use storytelling as the most natural way of narrate the experience,
- Souvenirs are important for travelers to retrieve events and circumstances; they are tangible cues to memories and good incipit for stories, Souvenir sometimes finish hidden somewhere inside the home and it is more and more difficult for people to find them as time passes by.

These issues guided our work in the successive step of the design process (more detailed information can be found in [34]). All along the phase of concept generation we explored the relationships of objects, collected and produced during the voyage, and how they can afford the recollection of memories and the sharing of experiences with others. Fig. 5 and Fig. 6 show two concepts developed as the result of aforementioned investigation activity. The first one explores the use of a mobile

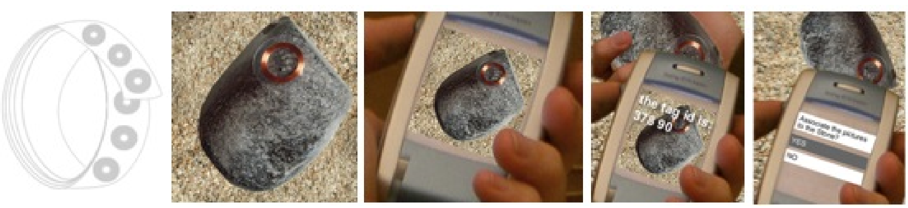

Fig. 5. Concept generation: linking a souvenir with digital picture

Fig. 6. Concept generation: augmented travelBook

phone as means to associate physical object to digital content (Fig. 5). The second one explores the use of tagged object to created augmented travel journal (Fig. 6). These concepts along with the results of the enabling technologies study (see Section 4) guided the design and the development of the Memodules framework presented in Section 5.

4 Technology Driven

This section presents the main investigation activities carried out within the technology-driven approach. According to the research approach schema presented in Fig. 2 three main research axes have been studied and are presented in the following: 1) Tangible User Interaction, 2) Multimodal Interaction and 3) Information Management. Even if these three main research axes are strongly related to each other (tangible interfaces are often combined with multimodality, multimodal interaction is habitually coupled with visualization, etc.) for the sake of clarity in the following we decided to present them one by one. Only projects which are most related to our work are presented, since some toolkits dedicated to creation of interfaces including tangible interaction and multiple modalities are covered in the survey chapter on "multimodal interfaces" at the beginning of this book.

4.1 Tangible User Interaction

Tangible User Interfaces (TUIs) are emerging as a new paradigm for facilitating user interaction with the digital world by providing an intuitive mean to link the physical and digital worlds [44]. Recently it has been demonstrated that personal objects and souvenirs can be used as tangible interfaces and ambient intelligent objects [20]. Users have a personal mental model of the links between their personal physical objects (souvenirs) and the related digital information, as a consequence those objects can be used as TUIs instead of developing new ones that have to be learned by the users. The innovative works of Wellner's DigitalDesk [47] and Ishii and Ullmer's Tangible Bits [22] have pioneered exploration of post-WIMP (Windows, Icons, Menus, Pointers) tangible interfaces. Ubiquitous computing applications have motivated these novel physical interfaces even more. However, tangible interfaces are difficult and time consuming to build, requiring a specific technological expertise that limits their widespread adoption. Several research efforts have been done during recent years to develop tools for prototyping tangible user interfaces and designing ubiquitous computing architectures. Some examples of those projects are: Smart-Its [18], Phidgets

[16], the iStuff [1] and iCAP [43]. These projects were mainly focusing on providing rich prototyping toolkits or programming languages for developing Tangible User Interfaces and ubiquitous devices from a developer point of view instead of focusing on end-users. Other examples of interesting projects focusing more on supporting non-expert in programming users to manage personal ubiquitous environments are Accord [21,39], Oxygen [40] and GAS [30]. All three projects have focused on giving end users the ability to construct or modify ubiquitous computing environments.

Our work has been inspired by the results achieved within the framework of those projects. However, some fundamental conceptual differences between those projects and our work exist: (1) our focus on personal objects and souvenirs as tangible interfaces instead of generic domestic objects and devices, and (2) our focus on memory recollection and sharing. Moreover our work is intended to support any type of user to use and combine augmented personal objects as a means for memory recollection and experience sharing and to support dynamic re-combination of those objects since personal memories associated to objects and events can change over time [19]. For this reason users should be provided with a mechanism for easily associating and reassociating multi-sensorial information to their personal objects.

4.2 Multimodal Interaction

In this section we present a state of the art of tools and frameworks dedicated to the rapid creation of tangible and multimodal interfaces. Both multimodal interaction and tangible interaction have seen extensive development in the last 20 years. Since the seminal works of Bolt [4] who worked on the "put-that-there" project, multimodal interaction practitioners extended multimodality towards new types of interaction modalities, semantically richer interaction, better fusion and integration of input modalities as well as finer fission of output modalities. This section is specifically targeted at covering toolkits geared toward the creation of multimodal interfaces (tangible or not).

Krahnstoever et al. [26] proposed a framework using speech and gesture to create a natural interface. The output of their framework was to be used on large screen displays enabling multi-user interaction. Cohen et al. [7] worked on Quickset, a speech/pen multimodal interface, based on Open Agent Architecture. Bourguet [6] endeavored in the creation of a multimodal toolkit in which multimodal scenarios could be modeled using finite state machines. This multimodal toolkit is composed of two components, a graphical user interface named IMBuilder which interfaces the multimodal framework itself, named MEngine. Multimodal interaction models created with IMBuilder are saved as a XML file. Flippo et al. [13] also worked on the design of a multimodal framework, geared toward direct integration into a multimodal application. The general framework architecture is based on agents, while the fusion technique itself uses meaning frames. Configuration of the fusion is done via a XML file, specifying for each frame a number of slots to be filled and direct link to actual resolvers implementations. Lastly, Bouchet et al. [5] proposed a component-based approach called ICARE. These components cover elementary tasks, modality-dependent tasks or generic tasks like fusion. The components-based approach of ICARE has been used to create a comprehensive open-source toolkit called OpenInterface [2].

On the side of tangible interaction, a number of toolkits for creating tangible and/or embedded applications have seen the light since the founding works of Ullmer and Ishii [22]. As shown by Mazalek [31], three main tendencies have been followed: hardware prototyping, groupware-focused and integrated application. Phidgets [16] and iStuff [1] are typical examples of the hardware prototyping approach, offering developers a set of hardware components and software drivers to use those components. Groupware-focused tools, such as SDGToolkit [17] offer tools allowing the creation of group-oriented applications. Finally, researchers have begun to work on a mid-way, integrated application toolkit approach; examples include Papier-Mâché [25] and Synlab API [31].

As interesting as these toolkits are, problems arise when you wish to mix them with other modalities such as speech: hardware components and groupware-oriented applications focus on their original tasks and generally do not provide opportunities to accept third party recognizers or an external data source. Hence, if we want to enrich tangible applications with other modalities, we need toolkits able to take into account data coming from very different sources, and still be able to fuse data coming from those sources.

4.3 Information Management

The main Memodules goal is to provide means to access and manipulate information easily using natural human communication channels. Nevertheless, for this interaction to be facilitated, the information itself needs to be somewhat organized. Furthermore links between similar pieces of information need to be drawn. Personal Information Management (PIM) techniques are of use to help presenting information in a way that the user can browse and search it with ease.

Popular desktop search engines like Google Desktop Search, Windows Desktop Search or Copernic Desktop Search are typically ports of Web searching technologies to the local desktop. They index files, emails, web history and offer free-text search queries as well as filters on type of document, location on the folder structure and other available metadata. Search results are presented in textual lists that may be ranked by relevance or sorted chronologically. *Stuff I've Seen* [10] can be considered the precursor of these engines, as it provides the same basic functionalities. A user evaluation on this tool revealed the importance of social and temporal cues for retrieving information. However the traditional Desktop Search tools provide no way of taking advantage of those contextual cues.

MyLifeBits [14] is a huge database system of personal resources. Its originality resides in the use of links that represent either user-created collections of resources or so-called transclusion (a resource cited or used by another one, e.g. a spreadsheet embedded in a textual document). As this database system provides an API, it can be interfaced. *FacetMap* [42] is an interface built on top of *MyLifeBits'* data store that offers a query-refinement mechanism based on properties of files, called facets. Therefore it allows browsing instead of free-text searching.

Forget-me-not [29] foresaw the importance of faceted browsing. Facets are metadata on information, like type of file (picture, document, and so one), size, or author for example. Faceted browsing is a browsing paradigm that allows exploring a dataset by sequentially querying facets in order to eventually find the documents of interest, instead of browsing a traditional folder hierarchy. The authors indeed suggest exploiting the human episodic memory, i.e. the ability we have to associate things to an episode in our memory. The location of an episode, the time when it happened and the people concerned are strong cues for recall. Similarly, *Milestones in time* [38] is a more recent work that tries to replace information in context, specifically in its temporal context, making use of episodes and temporal landmarks. As well, the *Time-Machine* environment featured in the latest MacOS X operating system leverages the seminal work done by Rekimoto [37] in order to exploit our ability to recall the approximate temporal period when a document was created or modified, thus emphasizing the importance of contextual cues and facets.

Apart from the actual PIM systems, a most interesting user-study of PIM strategies has been conducted in 2004 by Boardman [3]. He notably emphasizes the facts that: (1) Users generally prefer to browse instead of search through their personal information; (2) The personal email archive has a potential for being integrated with personal files, as relations are strong between personal files and filed emails.

Email is indeed one of the prominent sources of information overload, as a typical mailbox receives most of the personal information avalanche. Thus, email management is an important part of PIM. Indeed, since Whittaker and Sidner first studied user practices for managing email overload [48], numerous attempts have been made to produce complete clients or plugins to help manage mailboxes. Recent works like those of Dredze [9] or Cselle [8] successfully use machine-learning methods to classify emails into activities, helping to keep trace of current (but also possibly past) tasks. Some works use visualizations to help handle the current inbox and keep a synthetic view of tasks. *Thread Arcs* [24] for example, presents a novel visual approach that helps to understand threads of messages. In [45] the authors propose to visualize the ”conversational history” between the mailbox owner and a chosen contact during a certain period of time. Their *Themail* system is tailored for psycho-social practices analysis rather than for PIM. Perer and Shneiderman [36] visually explore relationships through past emails. Again, their system consists of an analytical tool rather than a management tool. All in all, few works really address the problem of managing and exploring an individual’s complete email archive.

Finally, semantic web technology, another approach to the problem of personal information management, has been considered. Semantic technology provides new powerful ways of handling data by adding semantic at the data level. This gives machines new possibilities to manipulate information, hence the capability of reasoning that will allow deducting new unstated information. In the context of PIM, an ontology provides a schema to structure the data. It is a description of a precise vocabulary that uses classes to identify the data and properties to link them together constituting a knowledge base. According to [35] most important reasons to develop an ontology are: To share common understanding of the structure of information among people or software agents; To enable reuse of domain knowledge; To make domain assumptions explicit; To separate domain knowledge from the operational knowledge; To analyze domain knowledge. As presented later on, in MEMODULES project we use ontologies to categorize information in order to facilitate information access and retrieval.

This short state-of-the-art underlines the major findings and unsolved issues in PIM: the importance of contextual cues, of semantic, browsing over searching, emails as a representative subset of personal information, information visualization as a solution to visual guidance and browsing.

5 Memodules Framework

This section presents the Memodules framework developed within the project. Memodules framework is a user-oriented framework enabling end users to turn everyday objects into Memodules. Turning a physical object into a Memodule means tagging the objects, linking it to the related multimedia information and describing how it interact with the surrounding environment to render the digital content. The framework provides a single platform that combines end-user programming, tangible interaction, multimodality and personal information management issues.

Memodules framework is built upon MemoML (Memodules Markup Language) and SMUIML (Synchronized Multimodal User Interaction Markup Language) models.

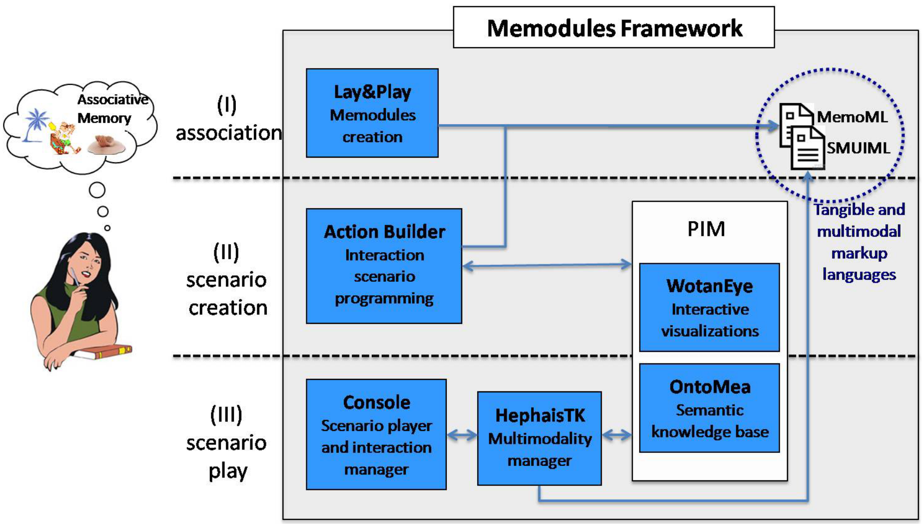

Fig. 7. Memodules Framework

As shown in Fig. 7, the framework is made of several components that allow users to create tangible user interfaces (*association*), to define how they interact with the devices (*scenario creation*) and to use them (*scenario play*). All the components are presented in the following sections. Eventually a light version of the framework, called Memobile, has been developed to run on standard mobile phones. Memobile, as the Memodules framework, is based on MemoML language (presented in the next section) and it is fully compliant with the main application. The added value of Memobile application is that users can bring it with them all the day long, wherever they are. Memodules framework is composed of the following components:

- Lay&Play, handles the creation of Memodules (tagged physical objects)
- Action Builder, allows users to define Memodules interaction scenarios (create association among Memodules, digital content and devices)
- WotanEye and OntoMea, facilitate multimedia information retrieval and visualization

- Console and HephaisTK, manage respectively the execution of interaction scenarios and multimodality issues
- MemoML and SMUIML, are the two markup languages the framework is built upon.

It is worth noting that all the components of the framework are fully operational, however since the project is not yet finished, so far only some of them have been completely integrated to each other.

5.1 Lay and Play, Memodules Creation

The Lay&Play system allows to easily turn everyday objects into Memodules (augmented personal objects) and to add them to the Memodules environment. A Memodules environment is defined as the collection of Memodules, related digital information and devices. The Lay&Play system is composed of a webcam and an RFID reader (Fig. 8) which allows simultaneously to take a picture of the object laying over the Lay&Play system and to read the ID of the RFID tag attached to the object. The digital counterpart of the physical object is created (Memodule creation) and added to the list of available Memodules objects displayed on the Action Builder editor (see next section).

5.2 Action Builder, Interaction Scenario Programming

Action Builder is the core of the application since it allows users to program the interaction of Memodules objects within a smart environment. The major design challenge for this component was to make possible for end-user (i.e. non expert users) to build their personalized smart environment. For this reason Action Builder provides an end-user programming approach: it is a visual editor based on the puzzle metaphor that handles the creation of interaction scenarios for Memodules. The choice of the puzzle metaphor was inspired by the results achieved within the framework of Accord project [37]. Action Builder uses the puzzle metaphor proposed by Accord and extends it in order to support more complex puzzle configurations combining parallel and sequential actions. Moreover, thanks to Lay&Play component, icons representing the digital counterparts of physical objects in our visual editor are created using the picture of the object itself, thus facilitating the user to link the physical object to its digital representation.

Action Builder allows users to create interaction scenarios that describe how Memodules interact with the surrounding environment and which devices are involved in the scenario. Scenarios are created using the puzzle metaphor: the user connects components through a series of left-to-right couplings of puzzle pieces, providing an easy to understand mechanism for connecting the different pieces. Moreover, constraining puzzle connections to be left to right also gives the illusion of a pipeline of information flow that creates a cause-effect relationship between the different components.

The puzzle editor is composed of a number of different panels (Fig. 8). The control panel (Fig. 8 on the top) contains the list of available puzzle pieces grouped in eight different categories (see below for more details about categories).

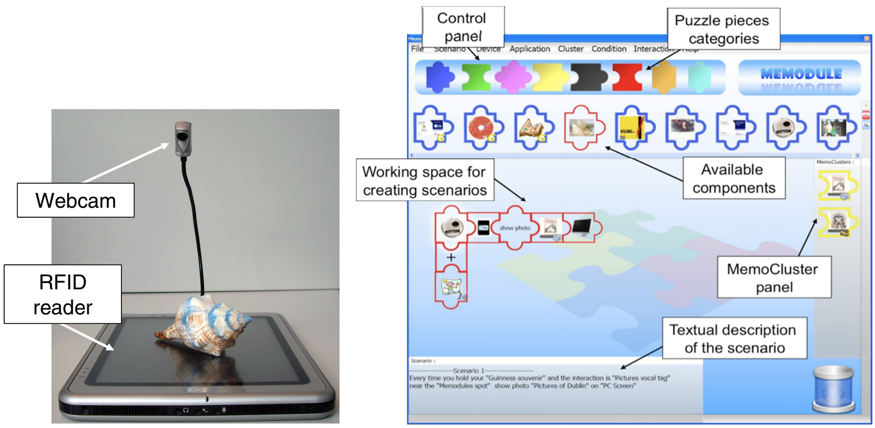

Fig. 8. MEMODULES Lay and Play (on the left) and the Action Builder (on the right)

Puzzle pieces can be dragged and dropped in the editing panel (or workspace) and assembled in order to create the scenarios. When a puzzle piece is dragged onto the workspace it clones itself and becomes a symbolic link. In order to remove pieces form the workspace they can be dragged to the trash can (on the bottom-right of the workspace). In order to connect puzzle pieces together it is necessary to drag a particular piece in the vicinity of a fitting target piece. If the two pieces are matching, visual feedback is provided to the user (the border of the puzzle pieces changes color). On the contrary if the user tries to connect two non-compatible pieces, the system will not allow their assembly. When a Memodule puzzle piece is selected the MemoCluster panel (on the right) displays information collections associated to that Memodule which have been created and used in previous scenarios. The creation of collections of information is facilitated by the use of personal information management techniques (see WotanEye and OntoMea modules in Section 5.7 and 5.8 respectively).

As the user connects the puzzle pieces the one by one, a textual description of the scenario that is being created is provided to facilitate user understanding (see Action Builder in Fig. 8, on the bottom left). Puzzle pieces are grouped into 8 different categories (see Fig. 9) and displayed with different colors. Their arrangement reflects the order in which pieces have to be connected; the first five categories are mandatory to create simple scenarios, while the last three categories can be optionally used to create more complex scenarios.

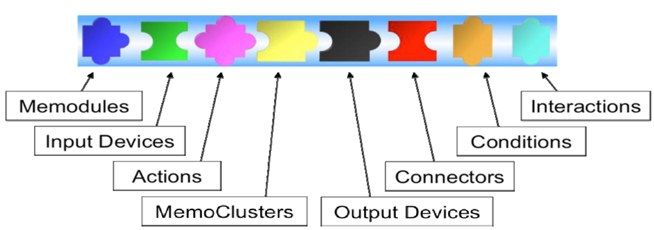

Fig. 9. Puzzle pieces categories

The blue pieces represent Memodules objects, the green ones regroup Input Devices (i.e. devices that can identify Memodules objects and start corresponding actions), the pink ones represent Actions to carry out (e.g. play music, show pictures, send an e-mail, etc.), the yellow ones stand for information that can be associated to Memodules objects (e.g. some photos, music, etc.). Digital content is grouped in "logical" clusters called MemoClusters. This means that information is browsed from everywhere in the PC using WotanEye and OntoMea modules, and grouped into logical collections. Black-colored pieces identify Output Devices, i.e. devices where the action is to be carried out (a TV for showing some photos, a Hi-fi stereo for playing some music, etc.). Red-colored pieces refer to Connectors that allow creating complex scenarios. At the time of writing two types of connectors have been implemented: the "AND" connector and "TIMER" connector. Finally light-orange and light-blue colored pieces refer respectively to Condition and Interaction. Conditions and Interaction are used along with Memodules pieces to create multimodal and context-aware scenarios. Conditions represent a set of variables (such as time, temperature, etc.) that are used to constrain the execution of the scenario (e.g. if the user adds a time condition to a scenario, the scenario is triggered only if the condition is validated). Interaction puzzle pieces allow the user to interact in a multimodal manner with the framework combining for instance tangible interaction (i.e. physical object) with voice-based interaction. Currently, two modalities are possible: voice and gesture.

The following three interaction scenarios illustrate what can be created using the Action Builder (Fig. 10). The first scenario (Fig. 10a) describes the following action: When Sabrina approaches the seashell (souvenir of some Greek holidays) to the Console (see next paragraph), the photos of that vacation are displayed on the PC screen and after 5 minutes the slideshow has terminated, a video of the Parthenon is played. The second scenario (Fig. 10b) describes the action: When Sabrina approaches the seashell and the business card of her friend to the Console the photos of that vacation are sent to the e-mail address of her friend via the PC. The third scenario (Fig. 10c) describes the action: When Sabrina approaches the seashell to the Console and gives the vocal command "pictures" the photos are showed on the screen while if she says "videos" the videos are played.

In order to manage the problem of losing a Memodule object (i.e. forgetting where it is placed), Action Builder integrates an RFID localization system that makes it

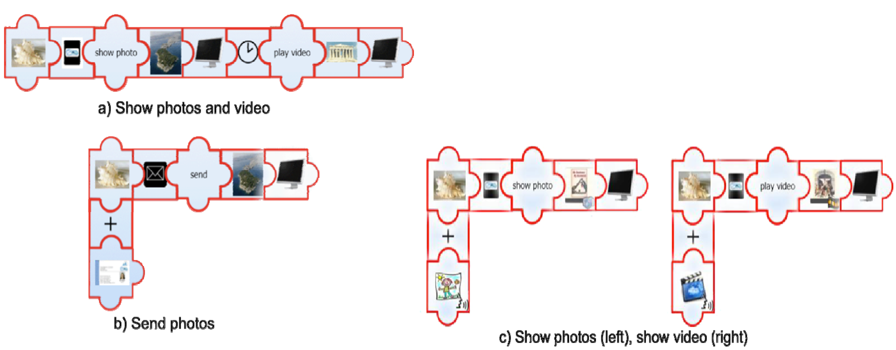

Fig. 10. Scenario examples

possible to find lost objects within a closed environment (a room). The localization system is made up of an RFID antenna that can detect the position of RFID-tagged object with an error of few centimeters. As show in Fig. 11, the user can activate the localization of a Memodule by simply selecting the puzzle piece representing the Memodule object in the Action Builder main interface and then clicking on the “find” menu item. This action starts the localization of the selected object and the result is displayed in real-time within Action Builder main windows, Fig. 11.

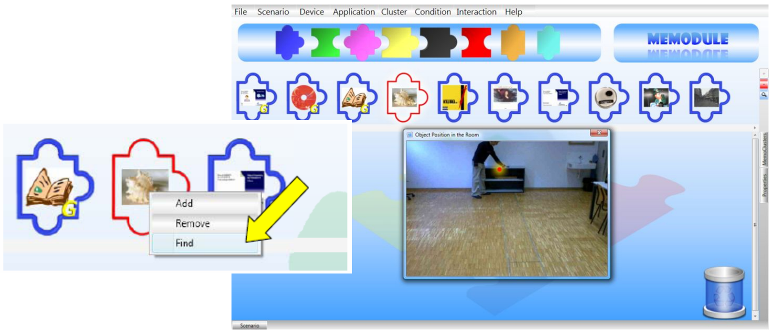

Fig. 11. Memodule localization using the Action Builder

5.3 MemoML Markup Language

MemoML (Memodules Markup Language) is one of the two technology-independent models upon which the framework is built [33] (the other model, SMUIML, is presented afterward). MemoML is an XML-based modeling language and it is based on the Document Engineering approach [15]. Document Engineering approach is emerging as a new discipline for specifying, designing, and implementing systems belonging to very different business domains by using XML technologies[1].

MemoML describes the components (Memodules, devices, communication protocols, actions, etc.) of a Memodules environment and how such components can be assembled to create interaction scenario using Action Builder. The components are the building blocks of the environment that can be combined together in order to define Memodules interaction scenarios. The model defines what a interaction scenario is, and the rules the interaction scenario has to undergo such as for instance the constraints associated to actions which restrain the types of information an action can operate upon (e.g. the action “play music” could not operate upon some photos). A more detailed description of MemoML model can be found in [33].

5.4 Console, Scenario Player and Interaction Manager

The Console is based on the Phidgets toolkit [16] and allows the user to start a scenario and to manage subsequent interactions with digital content. When a Memodule

[1] The choice of a declarative modeling approach allows us to describe what the framework is like, rather than how to create it, enabling system flexibility, reusability and portability over different implementation technologies.

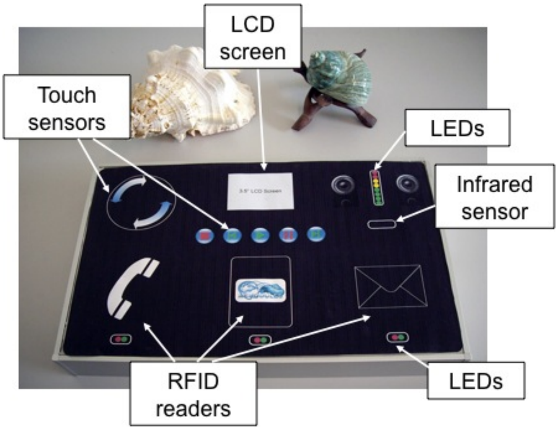

Fig. 12. Memodule Console

is approaching to one of the three RFID readers[2] of the Console (Fig. 12), the system identifies the Memodule object and retrieves the interaction scenario associated to it. In order to provide a visual feedback to the user, once the Memodule has been identified, the green LED associated to the RFID reader (see Fig. 12) lights on.

Once the scenario has been started the console allows managing actions execution. The Console is equipped with an infrared sensor, activated by the user's hand, which allows controlling the volume of sound when playing. At the same time some luminous LEDs give a visual feedback of the user's hand movements while adjusting the volume (Fig. 12).

Several touch sensors allow the user to interact with multimedia content while playing (play next, previous, stop, etc.). The LCD screen shows metadata information about the multimedia content that is played, while the circular touch (on the top left) allows the user to speed up or slow down the forward and the backward motion of some video or music playing. Scenarios can be executed just after they have been created with the visual editor, giving the possibility to the user to test whether the scenarios do what the user want.

The Lay&Play, the Action Builder and the Console have been fully integrated and some initial usability tests have been performed to evaluate the easiness of use of such integrated system. The tests involved around 7-8 persons, between 25 and 40 years old. After a short explication of the functioning of the three modules they were asked to perform the complete Memodule lifecycle, i.e. creation of a Memodules, definition of Memodules interaction scenario and play the scenario. The results of such tests provided good feedbacks about the system and gave also some interesting tips on how to improve the design of the system (see Memobile prototype in Section 5.9).

5.5 HephaisTK, Multimodality Manager

The main goal of HephaisTK toolkit is to allow developers to quickly develop and test interfaces mixing multimodal and tangible interaction. The HephaisTK toolkit

[2] The three readers represent three different devices (e.g. a TV, a PC and an interactive table) that for the sake of simplicity have been integrated into one Console in first version of the prototype.

served in the frame of the MEMODULES project to prototype a number of interfaces. The major objectives targeted by HephaisTK are modularity, extensibility, free use (via a GPL license) and usability. A modular architecture should allow the toolkit to be configured suiting the needs of the developer, so that unused components could be disabled. The extensibility is a common goal of any toolkit; its goal being to let developers plug easily into the toolkit custom human-computer communications means recognizers and synthesizers. Usability studies are also capital to make the toolkit easy to use, and should thus focus on the developer creating a multimodal interface; the toolkit should offer him with a scripting language comprehensible, yet powerful. HephaisTK has also been designed as a platform for testing new fusion and integration algorithms.

HephaisTK is designed to control various input recognizers, such as speech recognition or RFID tag readers, and the integration of their results. HephaisTK also helps controlling user-machine dialog and fusion of modalities. A developer wishing to use HephaisTK to develop a multimodal application will have to provide two components: his application and a SMUIML script. The developer's application (also called "client application" afterwards), written in Java, needs to import one class of HephaisTK. This class allows communication with the toolkit via listeners. The toolkit does not manage the actual content restitution, but sends messages or callbacks to the application describing the content to be restituted to the user. The SMUIML document (see next section) is used by the toolkit for a number of tasks: first, the definition of the messages that will transit from the toolkit to the developer's application; second, the events coming from the input recognizers that will have to be taken into account by the toolkit; last, description of the overall dialog management. The developer also has the possibility to add other input recognizers to HephaisTK toolkit. The toolkit provides compatibility with Sphinx [46] speech recognizer, ReacTIVision [23] computer vision framework and Phidgets [16] hardware building blocks, and manages any input devices emulating a mouse.

In order to account for the objective of modularity, the toolkit is built on a software agents framework, namely JADE. JADE was selected over other tools like, for example, Open Agent Architecture (OAA), because of its architecture not depending on a central facilitator, its neutral definition of agents, and its choice of Java as single programming language, allowing direct multi-platform compatibility, provided that a JVM (Java Virtual Machine) is present.

Agents are at the core of HephaisTK. The architecture of HephaisTK is shown in Fig. 13. For each input recognizer, an agent is responsible of reception, annotation and propagation of data transmitted by the recognizer. For instance, the agent responsible of a speech recognizer would propagate not only the speech meaning extracted, but also metadata such as a confidence score. Messages are then sent to the postman agent. This postman agent is in fact a central blackboard collecting data from the recognizers and storing them in a local database. Hence, all data coming from the different sources are standardized in a central place, where other interested agents can dig them at will. Another advantage of central blackboard architecture is to have one central authority that manages timestamps. The problem of synchronizing different timestamp sources is hence avoided, at the cost of a potential greater shift between the timestamp of the actual event and the recorded one. It is to be noted that this central agent does not act like a facilitator: only agents dealing with recognizers-wise

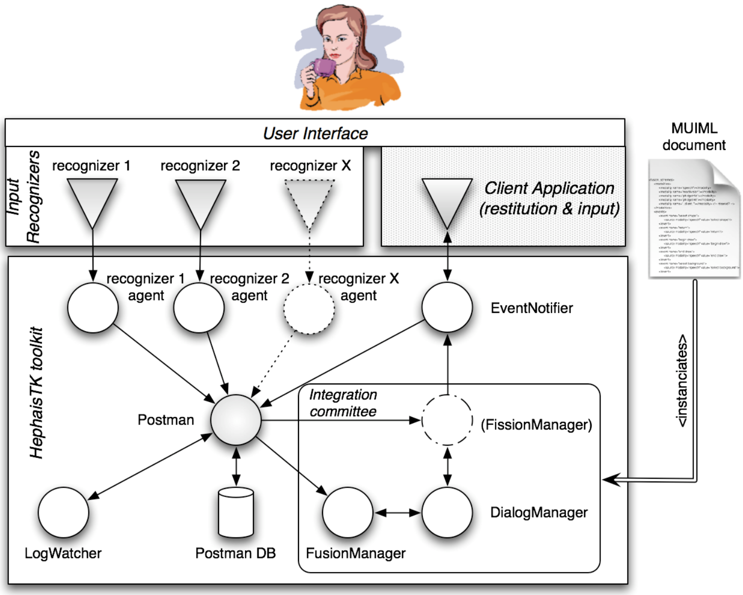

Fig. 13. Architecture of HephaisTK

data communicate with him. The agents within the integration committee communicate directly. Moreover, the postman agent also offers a mechanism of subscription to other agents: any agent can subscribe to events it is interested in. This mechanism of subscription allows for instance dynamic modifications or complete change of input modalities fusion method; a typical example would be an application using speech recognition that would be able to adapt on-the-fly to the native language of the user.

Three agents are currently responsible of the multimodal integration: the FusionManager, FissionManager and DialogManager. Those agents form the Integration Committee, responsible of meaning extraction from data coming from the different input recognizers. This Integration Committee is instantiated for a given client application by a SMUIML (*Synchronized Multimodal User Interaction Markup Language*) document. The Integration Committee sends all fusion results to an agent named EventNotifier, whose task is solely to let the client application interface easily with HephaisTK toolkit. The client application needs to implement a set of simple Java listeners in order to receive extracted information from the toolkit, which is a common implementation scheme in the Java language for GUI development. The EventNotifier is used by the client application to communicate with the toolkit and provide higher-level information, which could be used by the Integration Committee. HephaisTK hence sees the client application as its client, but also as another input source. As previously stated, the modular software agents-based architecture allows the toolkit to potentially offer a number of different fusion schemes, from rule-based to statistical to hybrid-based fusion schemes. At present, HephaisTK offers a rule-based approach, conceptually derived from artificial intelligence meaning frames.

The multimodal integration within the toolkit operates in an event-driven way: every time a new event is signaled to the integration committee (e.g. incoming input), it is matched against the possible frames of knowledge of the current context. Following the SMUIML script provided by the client application developer, the dialog manager indicates to the fusion manager in which state the application finds itself, and the fusion manager knows against which set of frames it will have to confront the incoming data. A typical frame of knowledge specifies a number of triggers needed to activate itself, as well as one or more actions to be taken when it activates. Typically, a frame would specify as an action a message to be sent to the client application, with potential data coming from the different input sources. Fig. 14 presents an example of frame in the context of an audio player application. This example is detailed later.

HephaisTK does not manage itself restitution to the user; instead, the Integration Committee informs the client application of the information extracted from the input recognizers. The actual restitution, by a standard GUI, text-to-speech or else, is up to the client application. Thus, communication with the client application is achieved through a set of messages. Those messages are predefined in the SMUIML script provided by the client application developer. To each message can be attached a set of variables, allowing for example to transfer to the client application the content extracted by a given input recognizer.

A first simple use case allowing control of a music player application via speech commands, standard WIMP interface elements and tangible RFID tagged objects has been implemented (Fig. 14). This application allowed simple interactions, such as "play", "pause", or "next track" commands, and offered different ways to express the commands. For example, a user could input the desired music with help of a tagged object while issuing a "play" command by voice.

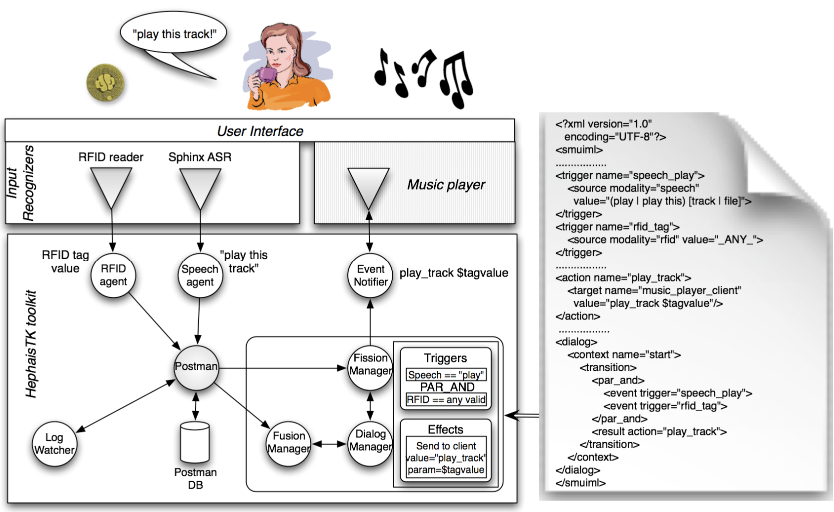

Fig. 14. An example application of a multimodal and tangible music player

A more complex use case followed in the form of the XPaint drawing table (Fig. 15). On this table, two physical artefacts (one of them can be seen in the hand of the user in Fig. 15) allow the users to draw on the table a set of shapes or tools selected by means of RFID-tagged tangible objects.

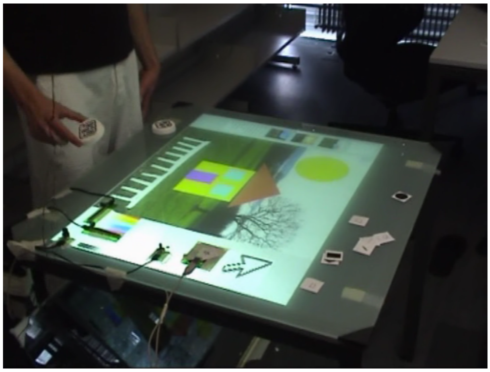

Fig. 15. The XPaint drawing table

Commands can also be selected by means of vocal commands, recognized with help of the Sphinx speech recognition toolkit [46]. Additionally, specific commands as selection of colour or line width are expressed through specific hardware input devices like Phidgets [16] sliders. Modelling the human-computer dialog for this application could be easely achieved with the SMUIML script, due to the level of abstraction provided by the HephaisTK scripting language. Another advantage stands in the fact that most of the existing XPaint application code could be re-used thanks to the clear application-HephaisTK separation.

5.6 SMUIML

The SMUIML document contains information about the dialog states (DialogManager), the events leading from one state to another (FusionManager) and the information communicated to the client application, given the current dialog state and context (FissionManager). The SMUIML markup language expresses in an easy-to-read and expressive way the modalities used, the recognizers attached to a given modality, the user-machine dialog, and the various triggers and actions associated to this dialog (see Fig. 16). More details about the SMUIML language and its structure can be found in [11].

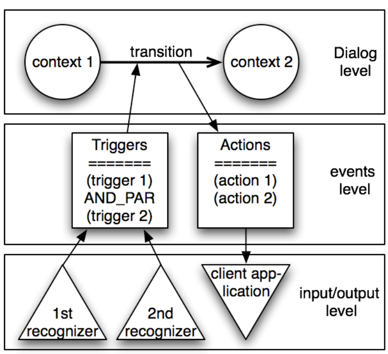

Fig. 16. The different levels of abstraction in the SMUIML language

5.7 WotanEye, Information Categorization

In order to tackle PIM (Personal Information Management) issues and following the ideas inspired from the state of the art presented in section 4.3, our prototype application, called WotanEye, tries to recover the natural context of information, focusing on finding similarities between different pieces of data along three facets, namely the temporal, social and thematic facets. Indeed, according to the study in [38], these are the three facets preferred by users looking for documents. More specifically, we explore the direction Boardman suggests and try to structure personal information around the structure of the email archive. Indeed, the email archive has potential for being taken as a core to which an important part of Personal Information (PI) can be connected: a single email inherently connects together people, topics and time. As such, a whole personal email archive thus contains invaluable thematic, temporal and social cues that other types of PI do not expose obviously. In emails, recipients of a message often know one another, so a social network can emerge, topics can be connected to particular groups of contacts, topics may also be time stamped, etc.

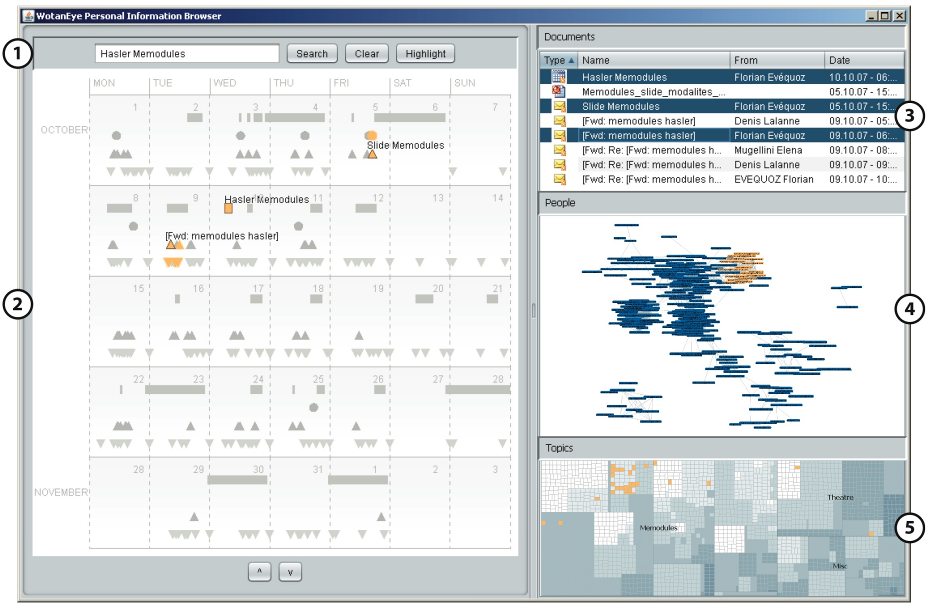

Fig. 17. Mockup of personal information management through interactive and visual cues (social cues on the upper left, thematic cues on the lower left and event- based cues on the right). See text below for more details.

Aiming to provide a unified access to the whole personal information and efficient search mechanisms, we leverage on an existing desktop search engine that performs an efficient indexing and a disposes of a powerful SQL-based API, namely Windows Desktop Search (WDS) [32]. The major drawback of using a desktop search engine is that the inverted index it generates is not accessible programmatically. Therefore, another method is needed to extract all the metadata required to build the temporal, social and thematic facets of PI. As the email archive is a representative subset of personal information, we developed a custom system that reads an email archive and extracts all the required metadata in a SQL-database. Therefore, we can build the temporal, social and thematic facets of PI. Moreover, using the email archive, similarities can be established between different facets data. For instance a certain group of people is likely to tackle a certain kind of topics at a particular time period.

Finally, we make use of information visualization techniques to present the user with its personal information along the different facets. Fig. 17 shows a partially implemented mockup of the browsing interface. The right part of the window displays a calendar-like view of documents (circles), emails (triangles) and appointments (squares). On the upper left part, the personal social network is shown with people pertaining to the monthly activity highlighted. On the bottom left, topics are arranged in a treemap view. At a glance, a user can visualize the main persons with who she/he has collaborated within the selected month, the distribution of the information exchanged within his thematic map, and the temporal distribution of this information within the month. Furthermore, this combination of views and dimensions support users in browsing through their preferred facet, depending on the way they memorized a piece of information. A user might remember that a document has been sent by a specific person, within a given month, in relation to a theme, or prior to a specific event. In this respect, WotanEye leverage on the biographic and social memories of users. A user can also select a specific theme, for instance "teaching", and visualize the concerned persons in her/his social network and the temporal allocation devoted to this theme within the month.

WotanEye provides novel interaction techniques for accessing multimedia data (documents, emails, audio/video recording, slideshows, etc.). Its benefit in this context is to be found in the assistance it can provide for browsing huge amounts of personal data. Indeed, the extracted PI structure may serve as a filter to help navigate through such data, and to assist in finding information thanks to similarity links that can be drawn between personal and professional information [28].

WotanEye can ease the creation of information collections to be associated to Memodules. In particular, during the creation of an interaction scenario it may be tedious to gather all the pertaining digital information that one want to associate to a specific object. The views that WotanEye provides exhibit a meaningful PI structure and may be used to facilitate the association task. If the emails, documents, pictures and other information about a common event are gathered and presented together, associating the whole episode to a physical object becomes easier. Reversely, physical objects already associated to digital information may serve as query parameters, or novel facets, to retrieve correlated pieces of PI.

5.8 OntoMea, Semantic Knowledge Base

The OntoMea prototype explores the opportunity of improving information indexing and categorization by the mean of ontology and semantic technologies. OntoMea is a semantic knowledge base engine allowing to store and exploit personal information ontologies. OntoMea can store semantic data, reason about them, infer new knowledge, and give full access to ontologies data. As shown in Fig. 18, OntoMea provides the structure that must be used to describe the data (based on different ontologies) and the architecture to query and update the data.

OntoMea is a java application, based on the Jena semantic web framework, which includes a light Jetty embedded web server. It maintains an RDF triple store, adding inferences to the basic data and allowing query through SPARQL queries (the standard semantic web query language) or predefined web services. Identifying data with URI, instead of database private keys, allow to uniquely identify them all over the world, facilitating the creation of connections between pieces of information. Such connections can be exploit to facilitate information retrieval tasks.

A small travel ontology containing some basic concept related to the travel activity (such as travel theme, visited place, persons, activity, etc.) has been developed. This far-from-being-exhaustive ontology allowed us to validate OntoMea prototype. Digital content, such as pictures, can be semantically annotated using concepts defined within the ontology. Such annotated data can be browsed and retrieved by exploiting the semantic relationships given by ontology facilitating information search activities.

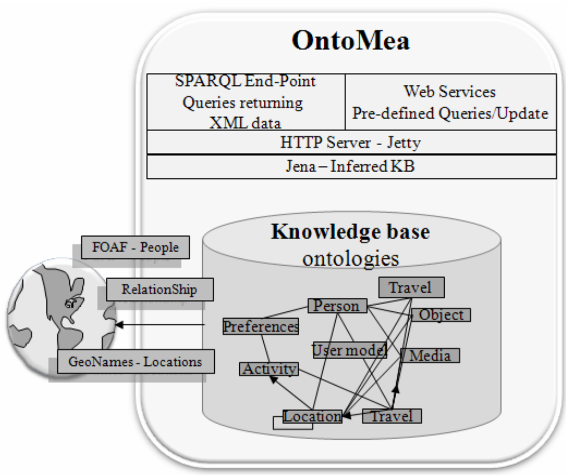

Fig. 18. Structural schema of OntoMea

Moreover OntoMea can handle links to any existing ontology (e.g., FOAF - Friend Of A Friend - ontology), making easier to improve our travel ontology.

5.9 Memobile, Mobile Framework

The Memobile is a mobile application that allows users to create association between physical objects and multimedia information wherever they are. The idea of developing a mobile version of the main application was suggested by the results of some user evaluations within the user-centered design approach that we conducted after the development of the main framework [34]. One important aspect emerged from the evaluation: the huge amount of physical objects and information collected and produced during the travel is too difficult to be accessed, retrieved and managed once back home. These issues guided our work in the successive step of the development process.

The goal of Memobile application is to give the user the possibility to tag physical objects and interact with them, associating multimedia content, at any moment and any place. Memodules framework and Memobile application are fully compliant, so once at home, the user can easily download all the information from the mobile phone to the main application as presented in the following. The Memobile application is based on a Fujitsu Siemens Pocket PC equipped with an RFID tag reader.

The application functions as described in the following. The user sticks a tag to the physical object and approaches with the object the mobile phone (step 1, Fig. 19). The mobile phone identifies the object and asks for a name (bookmark name steps 2 and 3, Fig. 19). The user can either select some media content (pictures, video, etc.) from his/her mobile phone or can produce new content and associate it to the previously created bookmark (steps 4,5,6 in Fig. 19).

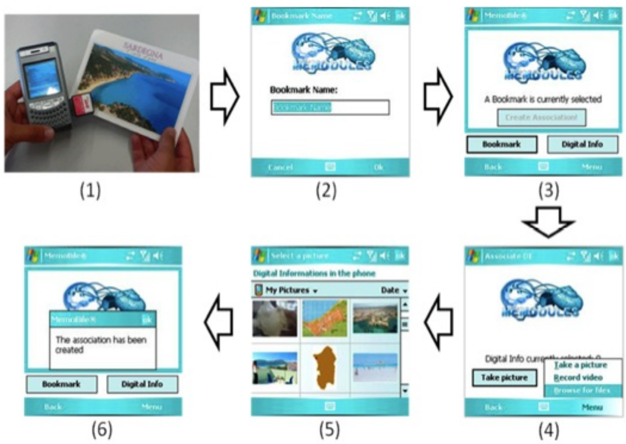

Fig. 19. Creation of an association between the souvenirs (postcard) and the digital content (some pictures)

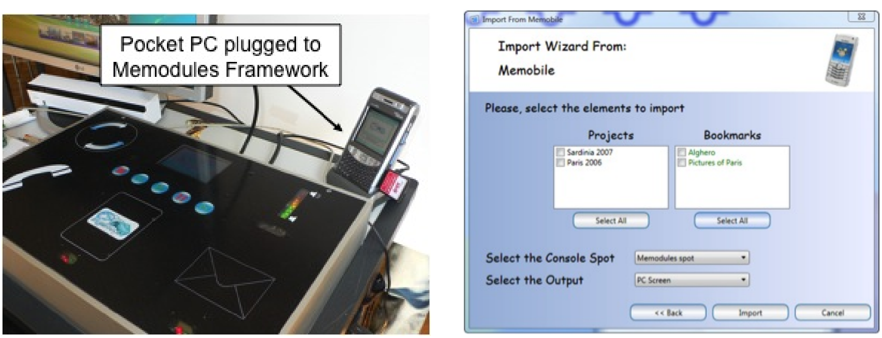

Fig. 20. Memobile plugged to the Console (left) and Import Wizard (right)

Once the association between the souvenir and some digital content has been created, the user can play the scenario simply approaching the souvenir to the mobile phone. In this case interaction scenarios are simpler since the input and output devices are fixed and predefined (the tag reader and Pocket PC screen respectively). Once back home the user can easily import the mobile scenarios into the main application by simply plugging-in the Pocket PC (Fig. 20).

6 Conclusion and Future Works

This paper presented the MEMODULES project dealing with tangible and multimodal user interfaces to support memory recollection and multimodal interaction within an intelligent environment. The project considered two complementary research approaches, i.e. user-centric and technology-driven, in order to design, implement and evaluate Memodules, i.e. tangible shortcuts to multimedia information. The article first presented the results of the user centered design process, i.e. the user requirements and needs through various studies such as focus groups. The article further presented the realization achieved during the first phase of the project, which consists of a Memodules framework that allows end-users to turn everyday objects into tangible user interfaces to access and manipulate digital content. The framework is composed of several modules, which address different issues such as tangible interaction, multimodal interaction and personal information management. Although the different modules presented in this article have received good feedbacks from users, which tends to prove the usefulness of Memodules approach, in the near future, we plan to combine them in a single framework and evaluate them with users within two complementary environments: the Smart Living Room and the Smart Meeting Room, to study user's interaction with Memodules in everyday life context in the first environment, and in the professional context in the second environment.

The Smart Living Room, installed at the University of Applied Science of Fribourg, aims at studying user interaction and technology integration in a home environment in order to personalize Memodules technologies according to the specific issues of domestic context. The Smart Living Room is equipped with furniture such as table, mirror, armchair, television and radio to replicate a usual home environment as well as a network of distributed sensors (for temperature, pressure, luminosity, noise, etc.), RFID readers and cameras to capture and analyze user interaction with and within the environment.

The Meeting Room installed at the University of Fribourg aims at recording meeting with audio/video devices, and further at analyzing the captured data in order to create indexes to retrieve interesting parts of meeting recordings. It is equipped with 10 cameras (8 close-ups, one per participant, 4 overviews), 8 microphones, a video projector, and a camera for the projection screen capture. It is further equipped with RFID readers for all seats to enable participants to register and bookmark meeting parts they want to index for further access. All the devices capture their streams in parallel and are synchronized which enable to further replay audio/video mosaics of meeting parts.

These two environments will be mainly used to run field studies and user evaluations to assess both usability and usefulness of the technologies developed. Further in the future we plan to study and test contextualization and personalization aspects within these two different contexts. Personalization issues target the adaptation of Memodules technologies to different categories of users: ageing people, young people, etc., whereas the contextualization targets the adaptation to the environment and task.

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