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MAY: my Memories Are Yours
An interactive companion that saves the user's memories

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To my family, who impatiently wait,
to João, who patiently listen

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Resumo

Durante os últimos anos, temos assistido a um novo impulso na área de agentes inteligentes aplicados a interação humano-computador. Em particular, estamos cada vez mais preocupados com questões relacionadas com o estabelecimento de relações sociais entre os agentes e os humanos e, em particular, na construção ao que chamamos de *"companheiros artificiais"*. Estes agentes têm como objectivo criar relações naturais e agradáveis com os utilizadores, por longos periodos de tempo.

Da interação humana e da psicologia, sabemos que o envolvimento e comunicação contínua pode ser estimulada pelo processo de *partilha de experiências*, fundamentado em aspectos cognitivos da memória. Da mesma forma, um agente dotado de tais características não só deve ser capaz de se adaptar melhor ao "mundo", mas também oferecer um desempenho mais eficiente num ambiente social, a fim de manter relacionamentos de longo prazo.

Como tal, desenvolvemos um sistema companheiro (MAY), que é capaz de guardar as memórias de experiências do utilizador. Propomos um modelo para a memória de um companheiro, que lida com as experiências compartilhadas entre o utilizador e o agente. Este modelo de memória está dividido em três níveis de abstração: períodos de vida, eventos gerais e os detalhes do evento. Esta estrutura modela eventos relevantes na vida do utilizador e permite manipular um modelo de dados sensíveis para inferência. Usando este modelo de memória, acreditamos que é possível melhorar alguns comportamentos sociais baseadas nas funcionalidades desta "memória compartilhada", como por exemplo, estar mais atentos aos objetivos do utilizadors, eventos comuns e acções futuras, com base em interações anteriores.

Foram realizados testes para avaliar a qualidade da relação que o nosso agente conversacional(MAY) pode estabelecer com os utilizadores. Os testes focaram-se na estrutura de memória e funções sociais que esta pode oferecer. Os resultados mostraram que o conhecimento sobre a vida do utilizador contribui uma classificação positiva por parte dos mesmos em duas dimensões da amizade: intimidade e companheirismo. Os resultados sugerem que se queremos criar agentes que desenvolvem algum grau de relação a longo prazo com os utilizadores de modo a manter o interesse pela interacção, estes devem, ser socialmente consciente e incluir elementos de experiências compartilhadas.

Abstract

During the past few years, we have witnessed a new boost in the area of intelligent agents applied to human-computer interaction. In particular, we are now more and more concerned with issues related to the establishment of social relations between these agents and humans, and in particular, in the construction of, what we call, "artificial *companions*". Not only do these agents aim at creating more pleasing and natural relationships with users, but also sustaining such relations over long periods of time.

From human interaction and psychology we know that engagement and continuous communication can be fostered by the process of *sharing experiences*, which is grounded in cognitive features of memory. Therefore, an agent that has a memory architecture to capture those shared experiences should offer not only an adaptability to the environment but also more efficient performance in a social environment in order to sustain long-term relationships.

As such, we developed a companion system (MAY) that is able to save the user's memories of experiences. We proposed a model for a companion's memory that handles the shared experiences and information between the user and the agent. This memory model is divided into three levels of abstraction: lifetime periods, general events and event's details. This structure shapes relevant events in the user's life and allows us to manipulate a cue sensitive data model for inference. Using this memory model we believe that is possible to enhance some social behaviours based on the functionalities of this "shared memory", such as for instance, being more attentive to the user's goals, common events and future actions, based on previous interactions.

We performed tests to evaluate the quality of the relationship that our conversational agent (MAY) can establish with users. The tests focused on the memory structure and the social functionalities that it can offer. The results showed that the acquaintance about the user's life contributes to the positive classification by users, in particular across two dimensions of friendship: the intimacy and companionship. The results therefore suggest that if we want to create agents that develop some degree of long term relation with users, they should, be socially aware and include elements of shared experiences to promote the engagement with the user.

Palavras Chave
Keywords

Palavras Chave

Companheiro Virtual
Memórias Partilhadas
Memórias de experiências
Memória Biográfica
Design centrado no utilizador

Keywords

Artificial Companion
Shared Memory
Memories of Experiences
Biographical Memory
User-centered Design

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Chapter 1

Introduction

> "A human being with no *daemon* was like someone without a face, or with their ribs laid open and their heart torn out: something unnatural and uncanny that belonged to the world of night-ghasts, not the waking world of sense."
>
> – *Philip Pullman, Northen Lights*

During the past few years, we have witnessed a new boost in the area of intelligent agents applied to human-computer interaction. In particular, we are now more and more concerned with issues related to the establishment of social relations between these agents and humans, and in particular, in the construction of, what we call, "artificial *companions*".

By envisioning new forms of interaction and creating this new types of agents that act as *companions*, we are trying to "turn interactions into relationships" (Benyon & Mival 2008). Embodied as robots, 3D synthetic creatures, or even interactive toys, an artificial companion should be able not only to promote more pleasing and natural relationships with users, but also to sustain such relations over long periods of time. But, companions, in general, must get to know the user's preferences and wishes (Catizone et al. 2008) , keep track of previous events with them, and make relations associated with their personal experiences.

Although many people would probably assume that this new idea is "stuff of science fiction" (Norman 1992), in reality, people already carry some kind of "companion" technology. For example, their PDA or mobile phone, which many of us seem not to be able to live without, illustrate this idea of a type of personal "assistant" that follows the human helping in his/her daily life, much in line with Pullman's imagination.

Motivated by these ideas, in the area of intelligent agents, some researchers have been focusing on the creation of "artifical companions" that have been designed to provide pleasing relationships, evoking social and emotional investment (Bradley et al. 2009). In fact, some researchers defend that such emotional investment is needed for the building of a relationship maintained over some period of time (Bradley et al. 2009). Others defend that this ability

for establishing alliances between users and agents is based on the use of empathetic and comforting behaviour, as Bickmore had demonstrated (Bickmore & Schulman 2006).

Yet, this focus on the establishment of the relationship with the user per se, may not be enough, as the agent should also be capable of maintaining such relation over multiple interactions. And one usual problem in recent companion systems is that the user's motivation for interaction decreases with time, as the companion increases the users' frustration with its repetitive and often pre-programmed behaviour (Ho et al. 2009).

On the other hand, language and speech technologies have improved considerably in the last few years and some researchers have focused on endowing companion systems with robust dialogue capabilities (Stahl et al. 2008). Even though those systems have some social "interaction" skills, often they lack in their believability, which again, may lead to a decrease in engagement. To overcome this barrier, researchers are now looking more closely at how people interact with each other and how *memory* is fundamental in natural scenarios and situations.

Indeed, in human interactions, memory is fundamental to hold up conversations and to sustain long-term relations. Without noticing, we constantly choose from our memories of experiences the best fit for the current situation, either to make a decision or to communicate with other people. People exchange facts of their personal experiences, commonsense or acquaintance of each other's lifes and such social behaviour has an impact in social environment (Hewstone & Stroebe 2001). Schank (Schank 1999) refers that the mind can be considered a "collection of stories or experiences one has already had". And, as stories of experiences constitute our knowledge, our intelligence is the ability to use that experience, and reminding is the process that make it all work together.

Accordingly, in order to build those *companions*, we should take the memory aspect into consideration. A 'human-like' memory would allow them to compreend the world and select relevant information for the current situation, and also be capable of taking more informed decisions about future events (Lim et al. 2009). Motivated by that fact, many researchers have recently focused on agents' memory architectures and their relation to long-term believability. In artificial companions systems, particularly episodic memory based architectures, are believed to be essential (Tecuci & Porter 2007; Laird & Derbinsky 2009; Ho et al. 2009; Magnenat-Thalmann 2009), as they aim to reflect the agents' experiences.

But taking the human memory comparison even further, peoples' knowledge is not just about their personal experiences. They retain acquaintance about the others lifes as well. It is this process of *sharing personal memories*, available by autobiographical remembering, that makes a conversation seem more truthful, believable and increases the interaction's engagement (Bluck 2003). Consequently, an agent's memory constituted only by its experiences might not be adequate for maintaining a long-term relationship.

In the area of intelligent agents some memories architectures have been

tested, and Ho (Ho et al. 2007) emphazised the importance of Autobiographical Memory(AM) in increasing believability of intelligent agents, and in promoting the agents' adaptability to the environment or new situations.

This suggests that if we want to create more believable long term agents, capable of carrying on with more engaging interactions and consequently maintain a relationship for a longer period of time, we need to consider the memory aspect and its sharing aspect.

1.1 The Problem

This dissertation discusses the integration of a model of *shared memories* into a companion system to sustain long-term interactions with users. This integration is associated with a quite large as perhaps general objective that is:

> *How can we build a socially enabled agent that acts as a companion, and is capable of participating in the process of 'sharing experiences' with a user, and at the same time, lead to the development of a long term relation?*

To handle with this problem we will focus mainly on the relevance of the memory to attain such large goal. However, we are not going to mimic human memory but rather create mechanisms that can assist humans in a specific task based on shared memories. We want to develop an illustrative case of a companion system focusing the companion's capability to record the user's *memories of experiences* in a social interaction. We are particularly concerned in how to represent and identify relevant events of user's life that worth to be saved and simulate agent responsiveness based on the acquired knowledge. Thus, regarding our problem the hypothesis that we will try to prove is:

> *If the companion uses a model for "shared memories", inspired in some aspects of human memory, and is capable of indexing user's experiences and use that temporally grounded information in a social interaction, users will establish a stronger companionship relation with the agent based on what the agent knows.*

In order to support our hypothesis we will investigate how human memory works, in particular the major social functions of memory. Then, we will formulate a memory model capable of indexing user's experiences and flexible enough for rapid access during interaction. After that, a conceptual model will be integrated into a companion's architecture, which was developed using a user centered design during the process. To conclude, we will perform an evaluation to validate our hypothesis.

1.2 Document Outline

To better understand the state-of-art on companion systems and record mechanisms of everyday life in *Chapter 2* we provide a small survey of the work

developed in three areas: systems with automatic diary generation, companion systems and memory architectures for intelligent agents. This chapter ends with a comparative assessment of the presented and discussed systems. This review takes into account primarily the characteristics and domains that may be useful for our goal.

Following this first analysis, in the next chapter (*Chapter 3*) we investigate the human memory's anatomy in order to find out relevant mechanisms that could be computationally interesting for creating a companion capable of retaining *shared experiences*. We start by describing the divisions of memory, following a comparison of autobiographical and episodic memory. Next, we review some theoretical functions of autobiographical memory and finally we go through the steps of the remembering process.

It is inspired on the human characteristics of memory that we propose a model for shared memories in *Chapter 4*. We describe a memory model in three levels of abstraction for the memory representation of the companion system.

At this point of our work, and recognizing the importance of user's presence in the design process, we conducted a 2 user centered studies that are described in *Chapter 5*. There, we explain the conducted probe study and show its results, as well as, the Wizard of Oz experiment with users for validation of the initial interface.

The gathered data from the prospective users was then used for the construction of our agent's (MAY's) architecture presented in*Chapter 6*. In this chapter, we show how the previous model of memory was integrated with all other defined models that constitute MAY.

Finally, in *Chapter 7* we describe the experiment conducted for validation of our research question, followed by some conclusions (*Chapter 8*), where we summarize the developed work an some future work is presented.

Chapter 2

Related Work

Our main aim is to develop an interactive companion that can sustain a long-term interaction with a user assisting him or her to keep memories of their everyday life. As such, while studying the related work we had to investigate three different areas, which we have structured here in three sections (see their main contributions for the overall goal in fig. 2.1).

First, we describe systems that use proximity with the user to infer important moments in user's life and also augment his/her memory with sensed data organized in a diary (research area 1 in fig.2.1). In the following section, relevant social agents' systems (research area 2) and different perspectives in the construction of such applications are presented. Next, we emphasize the importance of memory in companion systems and we describe recent research on memory architectures (research area 3). Finally, we briefly discuss the features in each system and approach that are relevant to the design of an interactive companion capable of of handling a relationship.

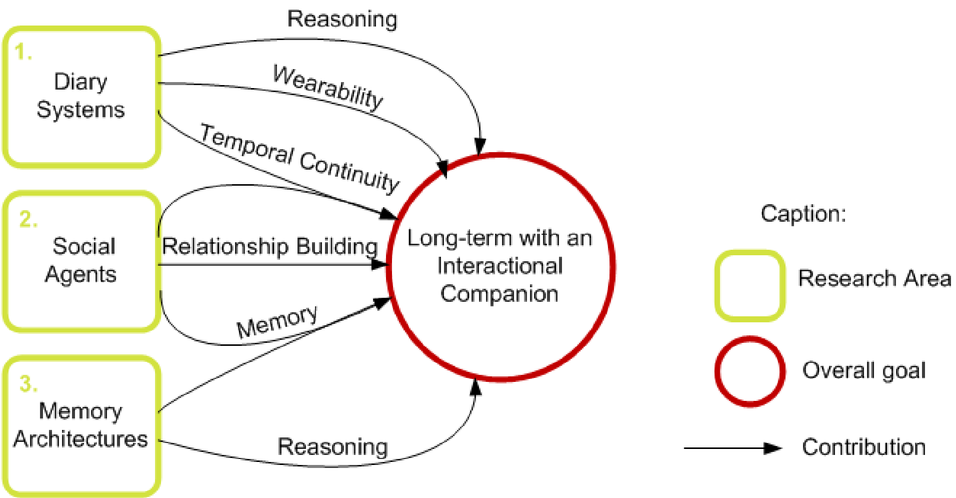

Figure 2.1: Main contributions for each research area surveyed in this chapter

2.1 Systems with automatic diary generation

Novel applications are now more and more designed in a user centered way. Using knowledge about a user's day in an non obtrusive way, is a hot research topic which is guiding the development of recent systems. We surveyed some systems that exploit ways of acquiring that knowledge about user's personal lives and show how that is applied in different perspectives.

In this section we describe systems that use proximity with the user to infer important moments in user's life and also augment his/her memory with sensor data organized in a diary.

2.1.1 Affective Diary

The ***Affective diary*** project (Lindström et al. 2006; Höök et al. 2008) is a personal logging system (with characteristics of a diary), which uses sensor data from physiological responses picked up from users' bodies, inviting people to further explore their bodily reactions experienced during the day. Not only does the system demand exploration of emotions, but it also allows the user to remember and reflect on their embodied emotional experiences.

The system uses two different types of sensors: the ones that allow the measurement of movement and the Galvanic Skin Response (GSR) sensors (Picard 2000). The movement activity is registered by a pedometer and accelerometers placed in the sensor armband, around the user's wrist. GSR measures the arousal in users, due to skin conductivity being highly sensitive to emotions in some people.

Besides the sensor data, the system captures various activities on the mobile phone (text messages, photo, etc.) and all the information can be transferred into the user's *Affective diary* when he/she gets home. The collected data is presented in a time line, as an abstract ambiguously shape, which represents arousal and movement activity, during the day.

The amount of activity acquired by the movement sensors is reflected in how upright the abstract shape is. That mapping is a simple, straightforward one. Lack of movement captured by sensors leads to a laid down shape and a high level of movement is mirrored in an upright figure(see Fig. 2.2). Further, different levels of arousal are represented with colors.

However the mapping between color and emotion is not evident as it is highly subjective and cultural-dependent. In this way, the color is expressed as energy through a color scale, starting with red and ending with blue. Typically, red is often seen as a high energy color and blue as contain less amount of energy, which is comparative with high and lower galvanic response.

The mobile data, as well as the sensor data, is time stamped and presented above the characters (shapes), to help users to reflect upon their daily experiences. The system also enables to relate the physical reaction to diary-notes, letting the user scribble something and manipulate photographs and other data attached to the moments picked up by the sensors.

The aim of this system is not to classify user's emotions and tell them what

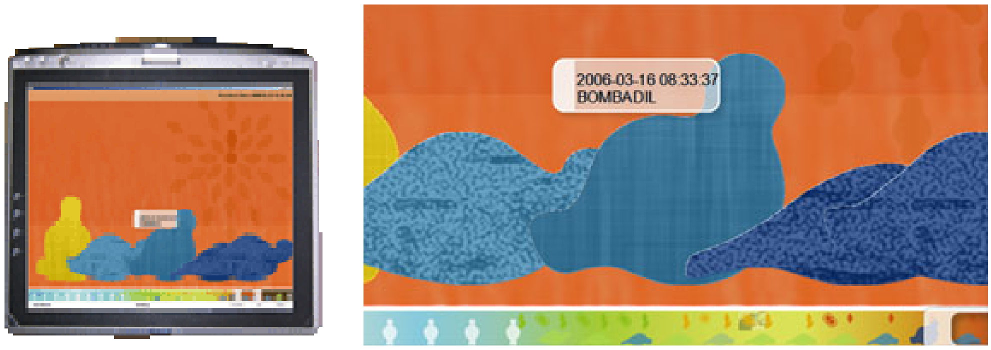

Figure 2.2: Affective Diary

they have experienced, but rather the interactional design approach allowing users to reflect on the present data and give them the power of relate the visual data to specific moments of the day in a subjective way. The authors expected that, by recognizing their bodily reactions, users would probably learn about themselves.

2.1.2 AniDiary

AniDiary-Anywhere Diary (Cho et al. 2007; Cho et al. 2007) proposes to summarize the user's daily life in a cartoon style, using information collected from the user's mobile device (see fig.2.3). The procedure of the AniDiary generation comprises 4 steps: information logging, pre-processing, landmark detection and cartoon generation.

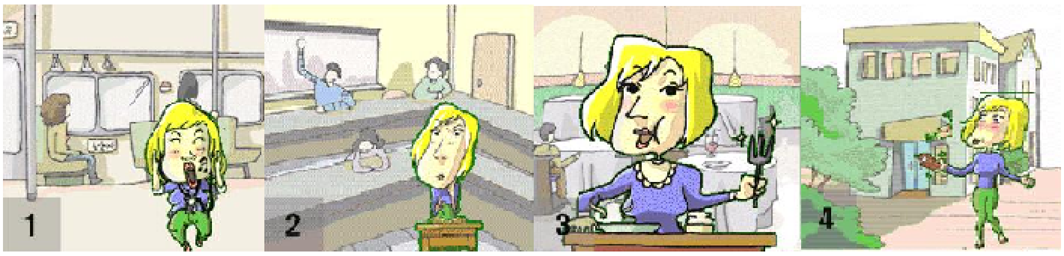

Figure 2.3: Story generation of landmark events

In the logging stage, data from sensors and the web is collected and stored into a file system. The logging system runs on Windows CE with a small GPS receiver attached to the device, which allows the system to infer the user's current position. The logging system also stores information about the usage of photo viewer, MP3 player, calls log, SMS and retrieved weather information from a Korean Meteorological website.

In the pre-processing stage the system employs standard statistical analyses to extract significant information, because raw data is not always meaningful. The raw information is labelled with pre-stored semantic information about

GPS locations (“My Home”, “My Office”, etc). Some statistical techniques, like average or frequency over the time domain, help to find discrete information about the use of SMS, call logs, photos and MP3.

Detection of landmark events is used and important moments of one’s life as ’episodes’ are stored. A number of Bayesian networks (BNs) is used to address event indexing problems and identification of memorable events. The system uses SMILE (Structural Modelling, Inference, and Learning Engine), an engine to implement BNs in mobile devices. Because a network based on daily life can involve a large amount of information, capable of causing real-time errors, the system comprises multiple BNs each one specialized in one activity. There are four kinds of BNs: Place-activity, Emotional/conditional, Circumstantial/situational, Events. A total of 39 BNs are used. The modular cooperation between BNs is done is two stages, first each BN output is calculated and in second stage those outputs are input evidences for the other BNs.

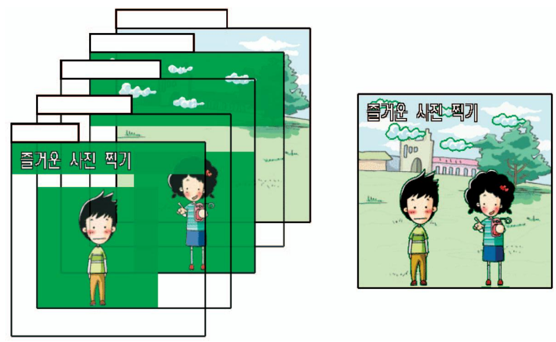

Figure 2.4: Cartoons’ composition

The cartoon-representation is a useful way of present detailed information of such wide domain as one’s daily life. A cartoon generation module selects cartoon cuts (text, sub character, main character, sub background and main background) that are most appropriate given the similarity between images and landmarks (fig.2.4). This similarity is calculated based on pre-defined annotations on images and probability of the landmark event. After the cuts selected, they are organized in a story stream using consistency ontology to make a plausible cartoon story.

2.1.3 The Familiar

The Familiar (Clarkson et al. 2001) is a system that captures patterns from camera, microphone and accelerometers to allow a user to keep a diary of his daily memories. These sensors are in a doll and into clothing, objects that are correlated with the user’s activities. The microphones are used for speech detection and the accelerometers for gesture classification. With these modules the system can learn features of user’s life – in particular long-term patterns.

Sensors are integrated with a small computer, HDD and data mining algorithms (clustering), which allow that similar segments of data are grouped

together, needed to be labeled by the user. The cluster methods developed allow extraction of patterns automatically as Hidden Markov Models (HMM). To each cluster could be added some memorabilia (photos, audio and text) by the user.

The system generates an automatic diary in a time-line with identified patterns (context recognition system) but interaction is still necessary with the user in the form of a diary. It identifies routine and special events.

2.2 Social agents as companions

In the domain of intelligent agents that act as companions, we can see a fast growth of research and development as new interactive and intelligence based technologies are appearing. In this section, some relevant companion systems are presented together with some different perspectives in the construction of such applications. We will mostly focus on the COMPANIONS project and Bickmore's work as we believe they are the most representative of this area.

The COMPANIONS project has the challenging goal of developing autonomous, persistent, affective and personal multimodal interfaces with robust dialogue capabilities (Stahl et al. 2008). In COMPANIONS, conversation with characters is the central part of interaction, as it is initially from conversation that relationships are formed. The project has now two completed prototypes: the *Health and Fitness Companion*, and the *Senior Companion*. Both prototypes highlight an advanced spoken dialogue system in the establishment of long term realtions with users.

Differently, in Bickmore's work, we can find a different perspective. Bickmore et al. (Bickmore & Picard 2005) argue that maintaining relationships involves managing expectations, attitudes and intentions. Relationships are supported by emotional interaction, and as such, the emotional aspects need to be carefully considered in a companion. Those techniques are studied with a created relational agent named *Laura*.

2.2.1 Health and Fitness Companion

The ***Health and Fitness Companion*** (HFC) acts as a conversational partner, which overall aim is to build a long-term relationship with the user (Hakulinen et al. 2008; Cavazza et al. 2007; Stahl et al. 2008). The companion has a stationary component situated in the user's home and a mobile component, where the interaction is made through a mobile phone or device. The HFC stationary embodiment uses a Nabaztag device (fig.2.5), a physical plastic rabbit-like artifact that uses wireless technology. To express itself, the rabbit uses speech, mobile rotating ears and various patterns given by the four colored lights (Cavazza et al. 2007). The commercial version meets all requirements for any-time interaction with spontaneity.

The HFC stationary component accounts for the major part of the user interaction (Stahl et al. 2008) and holds sophisticated knowledge about nutrition and exercise physiology (fig.2.6). The system is not a virtual therapist,

Figure 2.5: Nabaztag device

but provides advice and guidance throughout the day about lifestyle and combinations of diet and exercise. The main operation of the system comprises, not only, planning the day, looking for user's well-being, but also including the user's tastes and preferences. The plan for the day is dictated by the context in which conversation takes place, that is, the time of the day and the user's intended activities. Planning the day becomes a compromise between the user and the system and is constructed through dialogue. Those generated plans are then available in XML format in the internet and can be downloaded whenever the user wants.

Figure 2.6: Interaction with the HFC

When the mobile component starts, the companion asks the user if it should connect to the home system in order to download the current plan (generated in a former interaction). If he/she accepts, the plan can be downloaded via a HTTP call and from it, pertinent information for exercise activities is extracted. The mobile companion runs in a PDA and is used during physical exercise. A GPS device is used to track the user's position, speed and distance. Previous exercises can also be used to be compared with actual real time data. After an exercise, the session data can be uploaded to the home system (fig.2.7) for the user to access in the dialogue with the robotic component.

The interaction mode used in both components is speech. The mobile component also contains button presses and stylus interactions as ways of receiving input whenever needed, such as during an exercise or any other situation where

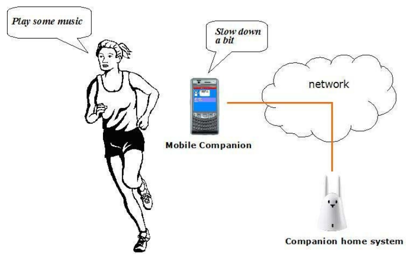

Figure 2.7: HFC architecture

voice input cannot be used. The system responds via speech or text messages. The mobile companion is based on a stand-alone, speaker-independent solution, making it fairly unique among mobile spoken dialogue systems (Stahl et al. 2008).

The goal of the system is to act as a companion rather than a real personal trainer, taking a persistent role in the user's everyday life. Besides mobile capabilities, the feeling of communicating with the same companion is given by the use of a character with the same visual representation as the physical rabbit used as home system. The TTS voice is also the same.

The HFC model separates cognitive modeling from dialogue management and enables their flexible interoperability. The cognitive model processes domain-level information and generates dialogue plans (Hakulinen et al. 2008), that is, it decides which information in the user's speech is important and what suggestions should be given. The dialogue manager takes care of confirmations, initiative and turn-taking.

2.2.2 Senior Companion

The ***Senior Companion***(SC) (Catizone et al. 2008; Cavazza et al. 2007) allows elderly people to annotate photographs in order to build up a narrative of their life. This application gives them the opportunity to show to a friend (the virtual companion), images of their family and friends (fig.2.8).

During each session the companion prompts the user to describe the photos and through conversation the user reminisces about life memories: where the photo was taken and when, people in the photo and their relationship with the user. People in the photo are recognized using a recognition software (OpenCV), which enable the discussion about the photo properties (person on the left, right, center, etc).

To annotate the photos it is necessary to understand what the user says. There is a natural language understanding module, which extracts meaning from the user utterances, such as people's name, locations, family relations and dates. That knowledge is then associated with photo annotations and represented with particular concepts in an ontology. With respect to family, an ontology is needed to represent the family relations. Close to this idea, there is also a possibility to represent people and their relations to events (Baptism, Wedding, etc.). For that, another ontology was used. To annotate location in

Figure 2.8: Senior companion interface

images, a geocoder API available in a website is used, enforcing pre-processing to disambiguate places, and enabling the system to show pictures based on a location cue. The integration of these types of data (places, people and events) allows the annotation module to create knowledge that can be used by the dialogue manager in an intelligent way. The dialogue is focused on a specific topic and uses ATNs (Augmented Transition Networks), which intend to express the dialogue activity associated with each topic. The identification and recognition of faces and other items in the image are a source of user satisfaction, because during interactions the user watches the system learning about his/her life, and constructing knowledge about it. That process is executed by the system and the recognition done by the user contributes to a development of a close relationship.

2.2.3 Laura

Laura (Bickmore & Picard 2005) is an agent integrated on an application (MIT FitTrack) that aims to motivate users to do physical exercise. *Laura* was perhaps one of the first interactive embodied conversational agents designed for use in home computers. The embodied agent supports multiple interactions that contributes to a persistent construction of a relationship. *Laura* is able to remember things about the user and refer back to previous interactions. The system is based on dyad models, this is, the relationship does not reside in either of a partner, but in the interaction between each other (fig.2.9).

Language is crucial to maintain human relationships, although other types of relationships can be constructed without language, human-pet relationship, for example (Bickmore et al. 2005). The system interaction consisted entirely on relationship-building dialogue, with scripts using an augmented transition network (ATN) in a pushing conversation way. The user uses a mouse to select one of multiple-choice-inputs, dynamically adapted during each turn of the conversation, while *Laura* speaks using synthesized speech. This choice from a set of options can be quite restrictive, because the user is limited to them.

In face to face interaction the emotional display is very important, and Laura has a quite advanced set of non-verbal behaviour associated with the

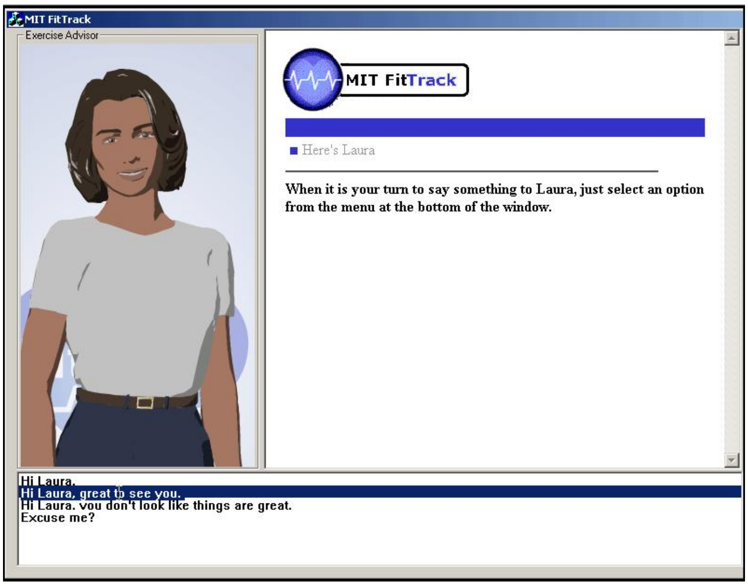

Figure 2.9: MIT FitTrack application. Example of dialogue between Laura and the user.

verbal communication, including: hand gestures, gazing, raising and lowering eyebrows, head nods and walking on and off the screen. This behaviours are automatically generated at compile time using BEAT (Cassell et al. 2001). This animation toolkit allows not only the mapping from text in embodied expressive behaviours, but also to tweak the intonation and other speech parameters to adapt to the written text.

The relational model used in FitTrack System considers that initial relations are distant and professional, but gradually become more personal over time. That approach enables a continuously change of behaviour to respond to user expectations. The key element of the system is the modeling of the agent-user relationship, and that consists on using the relational behaviour, particularly empathy. By empathy it is mean the process of understanding, and responding to another person's expression of emotion (E.g. user: "I'm not feeling so great." Agent: "I'm sorry to hear that.").

Later on, and developded by the same team, Louise (Bickmore & Schulman 2007) is an agent that expresses itself using the same features as Laura (synthesized speech and synchronized nonverbal behaviour), but users rather than use the mouse to select what they want to say, they speak the chosen utterance. This study investigated whether empathic accuracy or user expressivity conducts to increasing user-agent social-bonds. Two versions of Louise were explored, in the empathic approach the user is restricted to the way he can express himself and, in expressive approach user can freely express their feelings conducting to imperfect empathic responses. The results of the study showed that an agent with empathic accuracy is more efficacious in comforting users, even if the user's way of expression is restricted.

Further, one crucial element is the system persistent memory. Memory is

represented as an episodic store of all (or key) past interactions with the user. That includes remembering task oriented information, like the name of walking buddy or the favourite place to exercise, as well as task facts like favourite television programs or where the user will go next weekend. The FitTrack also records facts indexed to specific conversations, providing knowledge about user mood for the last four interactions (Bickmore et al. 2005).

To maintain engagement over long periods of time the system uses a straightforward approach to implement variability in the agent's behaviour. An utterance, of many, is selected randomly at runtime, which provides some variability in both verbal and non-verbal interaction. The use of facts stored in memory also contributes to several options for speech generation.

2.3 Memory architectures for social agents

As described in the previous section, most companion systems have focused on capturing the user's attention by endowing the agent with empathetic behaviour (Bickmore et al. 2008) and robust dialogue capabilities (Stahl et al. 2008). However, there is a persistent problem in sustaining long-term relationships, due to the repetitive behaviour of the agent (Ho et al. 2009).

To surpass this problem, researchers have recently focused in developing more robust memory architectures to increase agents' believability. In this section we present some of those systems, with a focus on Ho (Ho et al. 2009) work and a different approach taken by Mei Yii Lim (Lim et al. 2009).

2.3.1 Artificial Life

The concept of an autobiographical agent was first introduce by Dautenhahn (Dautenhahn 1996) and she defined it as "an embodied agent which dynamically reconstructs its individual 'history' during its life-time". Autobiographic memory (AM) in humans empower the integration of the past into the future, the knowledge about past experiences, spread through a narrative network in our minds, allowing for more informed decisions. Likewise, it has been suggested that in agents this could help them to communicate and form social relationships.

Some memory architectures for Artificial Life scenarios have been previously developed and evaluated by Ho et al (Ho et al. 2006; Ho et al. 2008). The architectures are based on theorectical models from research in psychology: Short-Term Memory (STM), Long-Term Memory (LTM), Purely Reactive (PR) agents (agents that do not remember past experiences) and also LTM with significant events, which are classified positively or negatively. The argument behind the last model is that positive and negative events should guide the agent to meet or avoid some internal states.

They created a dynamic and complex 'nature-like' VRML and Java virtual environment to test their approach to model autobiographical memories. The agents were designed with a finite lifespan and with some needs to fulfill, using the resources in the world. The world also had obstacles dynamically

distributed throughout it. The simulation done encompassed the comparison of the different referred models and showed that autobiographical memories outperform PR memory models, and also that LTM with significant events improved the agents' performance and chances to survive in a dynamic environment.

Later research, done by the same authors, addresses the question of how the inclusion of autobiographical memory structure in an agent and how its own emotions can increase the believability through an interaction with a user (Ho et al. 2007). They define AMIA (Autobiographical Memory for Intelligent Agents) framework - an autobiographical knowledge base of significant events sensed by the agent (Ho et al. 2007; Ho & Watson 2006). It does not try to copy an adult AM, but rather captures essential features from some psychological models suggested by M.A. Conway (Conway 2005).

They propose an implementable computational model, divided in Life Periods, Themes, Episodes, Events and Action, with different models that can be linked and yet evaluated separately. Themes and Life Periods are the highest levels of abstraction and probably they are not applicable to agents solve quick problems, but still can be useful to decrease the search space of an agent. An event is set of actions that can be grouped together and have some basic indexing components as time, location, agents involved in the event, etc. Events are also organized by goals and they can encapsulate all necessary knowledge for a particular object or situation. They represent highly specific experiences and a central feature of AM.

Inspired in this framework, Ho et al. (Ho et al. 2007) integrated a simplified AM (based only on episodes) into an agent architecture capable of experience emotions. That architecture was used in FearNot! application – an educational anti-bullying software. This AM stores the captured actions (refined in what, whom, how) with their emotional impact and creates a temporal perception between just occurred events and those that happened some time before. This means that the agent can respond to both external and internal stimulus based on knowledge continually acquired. Preliminary results of this ongoing study showed that the agents are capable now of converting the memory contents into agents' 'life story' (Ho & Dautenhahn 2008).

In (Ho et al. 2009), Ho et al refer that this network of events constructed over multiple interaction with the agents' environment can extend the agents' capabilities to plan and guide future behaviour. It will be possible to the agent to choose an action (or a set of actions) that will lead to a specific outcome, based on some episode attached to a previous interaction.

2.3.2 Generic memory for a social companion

Some research emphasizes the need to develop generic memory architectures capable of dealing with complexity, independent of the use the system may have in the future (Tecuci & Porter 2007). Generic memory systems should encompass the retrieval of relevant facts for the current situation (accuracy), collect a large number of events without performance decreasing (scalabil-

ity), efficient storage and recall (efficiency), memories addressable by content (content addressability) and finally enable partial matching of events (flexible matching) (Tecuci & Porter 2007).

Mei Yii Lim et al present an initial prototype for a social companion generic memory. The aim is to create mechanisms reflecting human memory characteristics to allow companions identify, characterize and distinguish experiences (Ho et al. 2009).

This was built on top of the emotional model FAtiMA (Dias et al. 2007), which incorporates reactive and deliberative appraisal components for agents' decision making (Lim et al. 2009). Their approach try to accomplish the maintenance of a long-term interactions focusing on adaptability to preferences and to the environment. Therefore, with memory mechanisms, they intend to capture every day routines and acquire knowledge about the environment to achieve formulation and consummation (Ho et al. 2009) of goals in a dynamic context.

The memory architecture is composed of a Short Term Memory(STM), responsible for gathering the active information relevant for the agent's processing; and a Long Term Memory (LTM) to ensure that the companion learns and adapts to the situations over the long-term (Ho et al. 2009). Encapsulated in the LTM there is the active goals structure (GER) organized according to the current goal activity and responsible for fusion of data that comes from STM and elaborate appropriate reactions to the circumstances.

The actions stored in LTM are then selected by its emotional impact and relation to a goal. Indexing is then done by time, location, participants and objects. It is worth notice that not everything is stored. Reducing the quantity of information leads to a more coherent behaviour. Additionally, the model includes forgetting mechanisms, not only to discard information no longer useful, but also to address privacy issues, this is, retaining information that cannot be said/showed in some specific circumstances. That process is done using the decay theory, where the information is 'scored' based on use and then, when it falls on disuse, it is selected to removal (somehow starts to fade away in less technical terms).

This memory system is being used in the context of a buddy companion being developed to be used in an office setting. The "companion" interacts with workers in the office and keeps information (private or public) about common events and situations there arising.

2.4 Comparative assessment

In the previous subsections some relevant systems were described according to different properties associated with companion systems. Together, such properties, combine a set of features that we think to be important in a companion system. This includes:

- **Wearability** – it is implicit, mobility and use of sensors.

- **Reasoning** – ways of extracting knowledge from the acquired data and make inferences about that.
- **Temporal Continuity** – capacity of organize the data in a temporal line representative of the user's everyday activities.
- **Relationship Building** – refers to agents' ability to communicate with the user and then establish a relationship.
- **Memory** – how information is orgazined and what kind of information the system retains. Memory archictectures based on episodic memory (EM) and autobiographical memory (AM)

2.4.1 Mobility and Wearability

Currently, applications that do not make use of context are losing ground, since users and consumers are increasingly demanding towards the mobility issue. New applications should predict the user's needs. By context, we mean environmental information that is part of an application's operating environment and that can be sensed by the application.

Any companion system "in all its bits" must be aware of contextual information, and the best way to do that is being always present in the user's company. However, it should be present is a less intrusive way as possible.

Laura is the one of two systems that is not wearable, and that decreases it efficacy in motivating users. The user must introduce data in the computer to update the information relative to physical exercises. If the agent was integrated into a mobile device, it could receive real time information about user's performance and motivating him/her when required, such as the mobile fitness companion operates. In the case of mobility the *Senior Companion* would benefit if the system could sense locations and recognize them as places where photos were taken and show them to the user. This behaviour could be relevant for the maintenance of the relationship.

The *Affective diary* wants to capture physiological responses, as well as, quantity of movement. It also captures activities in the mobile phone and attaches them to an arousal moment, which is left to user interpretation. *AniDiary*, as well, captures activities from the mobile phone. That device has a built in GPS which is very useful to infer location and motion. The emotion of the cartoon character is defined by settle assumptions. *The Mobile Fitness Companion* uses GPS as the only way of sensing. However, it would be useful if it could have integrated another kind of sensors to monitor physical activity. *The Familiar* system, differently, uses cameras and microphones as a different perspective of sensing the environment, it aims to record the maximum as possible.

2.4.2 Reasoning

AniDiary and *The Familiar* use data mining algorithms, Bayesian networks and cluster analysis, respectively, to extract knowledge and identify patterns

in the sensed data.

A Bayesian Network (BN) is a statistical classifier that can predict whether a given tuple belongs to a particular class or not. It uses probabilistic dependencies between variables to achieve a result, and despite being computationally intensive, it has high accuracy and speed when applied to large databases. Due to the BN explicit representation, it is possible to add prior knowledge to the training process which will improve the learning rate (Han & Kamber 2006).

On the other hand, clustering proceeds in reverse direction: first similar data are grouped into clusters and then are assigned labels to a small number of groups, comparatively to amount of initial data. Cluster is also used for outlier detection, this is, values that are 'far way' of any cluster, which is interesting for detection of landmark events (Han & Kamber 2006).

In both applications the used data mining methods are suitable for each application. In *The Familiar*, images with the same characteristics are grouped together and organized in a timeline with the user's help. It is dificult to use only a BN, since all data must be annotated first. In *AniDiary*, the data comes from specific events that occur in the mobile phone, and the activity identification depends on a probabilistic model, as well as, the recognition of landmark events. It is not absolutely necessary to have user interaction with the system in order to classify any period at the timeline.

In a different perspective, endowing agent's with more robust memory architectures based on human characteristics, was proved to be efficient. Setting aside time consuming methods for reasoning skills, the new models for memory architectures offer accuracy for operating in real time situations.

2.4.3 Temporal Continuity

Gathering events in timeline allows the creation of stories about the user and his/her life and, in addition, enables the search for specific events.

AniDiary creates a story with the recognized activities and the systems like *Affective Diary* and *The Familiar* provide a path to a chronological day description. Jointly with memorabilia and user annotations, a story can be organized and constructed.

Comparatively to the *Affective Diary*, the *AniDiary*, defines which were the important moments in one's day and generates a story with comic cartoons. That is, without a doubt, a good starting point to seek for detailed information. On the other hand, it does not give the user the opportunity of built his/her own story. Finally, the *Affective Diary* empowers the user to interpret the presented data with personal assumptions. There is no rule to determine that certain physiological response value corresponds to a stated emotion but people can write in the diary their interpretation.

Although companion systems do not have explicitly a feature of story generation, we could probably say that they maintain a story about the user. At last, information about the user's past interactions can be organized chronologically in the system. The *Senior Companion*, with all information it can

gathers also has sufficient knowledge to elaborate a story about user's life, but at the moment the system do not include that feature.

2.4.4 Relationship Building

The three systems surveyed in section 2.2 implement this component in two different perspectives. The systems developed in COMPANIONS project base their relationship building on dialogue. They can show that what user says is understood and the agents are able to keep a conversation. Their relationship with the user also relies on what they know about him/her and such knowledge is acquired through dialogue.

A relational agent must use social dialogue, verbal and nonverbal expressions of empathy, adressing the user by the name and explicitly valuing the relationship (Bickmore et al. 2008). This relational behavior is not present in the COMPANIONS project (except with the use of small talk). Differently *Laura* relies on this kind of interaction and her emotional display is correlated with user responses, as well as, her dialogue. The objective is make the user feel that someone is there for him/her and cares for him/her. Studies (Bickmore & Schulman 2007)done with Laura, proved that users prefer systems with appropriate empathic feedback.

In *Laura*, besides the mobility feature, what decreases its success is the multiple choice interaction. On the other hand, the COMPANIONS systems use speech recognition software allowing for a much more natural type of interaction.

Otherwise, the diary generation systems do not have built-in this ability in establishing a relationship due to their lack of agency.

2.4.5 Memory

The described diary generation systems do not make use of any memory architecture. They have a memory for gathering information about the user, but, they retain everything they can to be analysed later.

On the other hand, the companions systems reviewed have a memory system capable of retain facts about past interactions and some elements of user's life to increase proximity (HFC and Laura). The SC for example, has a kind of autobiographical memory system only based on episodes due to its capability of knowing one's life story based on the information given with the photographs. But very roughly speaking it is a set of characteristics 'what', 'who', and 'where' linked to an object, which in general represent no more than a singular episode.

As discussed in section 2.3 memory is an important component in companion systems to maintain relationships over time. The mentioned autobiographical mechanisms have showed several improvements in intelligent agents, yet they have not been tested in conversational companions systems, in which AM dynamics might improve reasoning skills in real-time. Besides, none of the these systems considers the creation of a *shared memory* element, but

concentrates more on the agents' autobiographical memory.

		Affective Diary	Ani Diary	The Familiar	HFC	SC	Laura
Wearability		Yes	Yes	Yes	Yes	No	No
Reasoning		No	Yes	Yes	No	No	No
Temporal Continuity		Yes	Yes	Yes	No	Yes	No
Relationship Building		No	No	No	Yes	Yes	Yes
Memory	**EM**	No	No	No	Yes	Yes	Yes
	AM	No	No	No	No	Yes	No

Table 2.1: Systems comparison

2.5 Concluding Remarks

According to Picard (Picard 2000), an emotional experience refers to all we consciously perceive of our own emotional state. Although physiological responses could give us hints about an emotional change, like *Affective Diary* does, but the personal description or the concrete knowledge about surrounding context is still missing.

Looking at the reviewed companion systems, they offer two different approaches for maintaining long-term relations: either endowing companions with robust dialogue capabilities or relational ability. We believe that together they play an important role on creating companions believability. Those components adding to the flexible nature of autobiographical memory, would also increase companion's adaptability and changing its repetitive behaviour.

Based on this missing links, we will develop MAY (my Memories are Yours), a conversational *companion* that saves user's memories in a diary form. The companion will be created to assist a teenager user on self-reflection and daily companionship about what happens in his/her life. This system should preserve the user's expressivity as traditional diary can provide. On the other hand, to try to achieve that goal it is necessary to take into account that language is the currency of most human social processes (Chung & Pennebaker 2007), so we will base the interaction on that issue. Our focus will be on agent's memory, in particular autobiographical memory, which we believe will lead to improvements in intelligent agents and have not been tested in conversational companions.

Chapter 3

Memory's Anatomy

Remembering is the capacity of recall when required. That means to bring the past into the present and relive it. It is the human ability to travel back in time with one's own mind, and memory is the mental capability that makes it possible.

Usually we say that memory is the mental faculty of retaining information about stimuli of some sort when those stimuli are no longer present. Memory is also used to refer the contents of a storage system rather than the system it self (O'Hara et al. 2006). Oppositely to what we are tempted to think, human memory is not just one system. Humans have multiple memory systems that respond differently to diverse kinds of information and give the illusion of a single mechanism.

In this chapter we examine the human's memory, summarizing its principal components in a top-down approach. We discuss how humans store in memory relevant events in one's life and how that information is used through life. Thus, we will pay special attention at autobiographical memory, the component responsible for making this information last, and its connection with episodic memory, identifying its components and functions.

As was reviewed in the previous chapter, agents' memory architectures based on autobiographical mechanisms showed several improvements on adapting to new environments and situations. We would like to explore how a 'human-like' autobiographical memory works and which essential features are useful to be embedded in an agent's memory architecture, which aim at participating in the *sharing memories* process.

3.1 From Top to Bottom

There is a strong evidence that memory can be divided into discrete processes (Dolan 2002). The most obvious is the separation in two systems, short and long-term memory, based upon temporal duration of retaining information in memory. Functionally, these two different systems can be described as memory that guides behaviour and latent memory activated by cues and accessible to on-going situations (Dolan 2002), respectively.

It is also accepted that long-term memory can be distinguished between explicit (or declarative) and implicit (or non-declarative) memory (Baddeley 2002). Implicit memory refers to inherent skills, for example ride a bike, drive a car or simply talk. Things that we learn along life, forms of procedural knowledge that are embedded into the behavioural expression systems of which they are part (O'Hara et al. 2006), do not imply conscious awareness to perform. Explicit memory can be divided into two separate systems as Tulving (Tulving 1993; Tulving 2002) proposed, *episodic* and *semantic* memory.

Semantic memory registers and stores information about the world and makes it available for retrieval. It enables individuals to operate in situations, objects, and relations that are not present to the senses (Tulving 1993; Baddeley 2002). The domain of semantic memory comprises knowledge about the society and the way it functions. For example, knowing that Lisbon is the capital of Portugal or the spicy taste of a chilli pepper.

Episodic memory is oriented to the past and, is the only memory system that allows people to re-experience past experiences, travel back in time, like Tulving suggests (Tulving 2002). Very roughly speaking, remembering is 'what' happened 'where' and 'when'. A memory system for personally experienced events in a subjective space and time. Makes possible for a person to be conscious of an earlier experience as well as transporting him/her self into the future through the use of semantic knowledge (Tulving 2002; Tulving 1993; Tulving 2001).

Initially, Tulving (Tulving 1993) proposed that these two systems have a hierarchical relationship where episodic memory depended, in some operations, on the semantic memory. Later, he developed an idea that episodic and semantic memory differ fundamentally in the 'feeling of remembering' (Tulving 1993). That is, not only does an individual know that an event happened, but also he has total conscious awareness along with the capacity of re-experience it. Imagine someone that is conscious about the world and himself, and knows that back during the last summer, he went to Paris, and knows that Paris is the capital of France. Yet, he cannot remember a single moment passed in Paris. We can say that his episodic memory is dysfunctional due to his inability to consciously re-experience any of his earlier experiences in subjective space and time.

This sets a barrier between remembering and knowing facts of our lives or experiencing events oppositely to have factual memories of them. Contradictorily, we nearly always interpret new events based on available knowledge about the world and about ourselves – *autobiographical memory.*

In this issue M.A. Conway (Conway 2001) refined the concept of episodic memory (EM) and autobiographical memory (AM), drawing a contrast between them, which limits were somehow blurred.

3.2 A perspective on autobiographical and episodic memory

In Conway's (Conway 2001) view (see Table.3.1 for a resume), episodic memory is seen as a system which contains sensory-perceptual details of recent experiences, an experience-near approach where those memories last for very short periods of time. These memories are only retained in memory when linked to a more permanent type of memory – *autobiographical memory* (AM). AM persists over long time periods and retains knowledge of the self at different levels of abstraction.

In his perspective episodic memories can form abstractions, which coupled with beliefs and attitudes of the working self, form conceptual autobiographical knowledge. In other words, autobiographical memory can be seen as semantic knowledge about one's life, retaining knowledge about progress of personal goals, but does not allow re-experience.

According to (Conway 2001), that "semantic knowledge" has three levels of specificity:

- **Lifetime Periods** can be seen has temporal and thematic knowledge. Often those periods last for years, for example "When I was at school", and can be grouped by themes. Themes consist in outstanding situations in a higher abstraction view, such as "relationships" or "work".
- **General events** are linked to life time periods and cover single events that could last for few days or months, for example, "vacations in Italy" or "study for algebra exam".
- Detailed information concerned with a single event refers to **Event-Specific Knowledge** (ESK). They are often accompanied by "images that pop into mind" and have the duration of seconds or hours.

This hierarchical representation gives a temporal sequence within the episodes remembered (Nelson 2003) and enables the organization of the self from some point in the past through the future. This raises an interesting relevant question, the function of memory is only to allow us to remember past experiences?

Normally it is assumed that memory is about the past, but actually it is also about the future (Nelson 2003). Any individual gathers in memory common and valuable events and later uses them to take an action in the present envisioning a future effect. Memory, most precisely AM, serves this purpose and many others. In the next section, we describe one in particular, the social component of AM.

3.3 Functions of AM

Recent studies on memory focused on its functional approach (Bluck 2003; Bluck et al. 2005; Pillemer 2003; Nelson 2003), particularly on the use of AM. That is, understand why people recall information the way they do (Bluck

	Autobiographical Memory	Episodic Memory
Functions	Define a self course; Place constraints on what goals could be maintained and pursed (help in decision making)	Keep track of progress on active goals as plans are executed
Knowledge	Comprises others, activities locations and evaluations to a period as a whole. A period is denoted by 'When I was fifteen" and contains generic information. It is divided in lifetime periods and general events.	Event-specific, every step in an action like a recipe.

Table 3.1: Resume of Conway perspective for autobiographical and episodic memory

2003). They are concerned not about how well people remember mundane facts of their lives, but why that information is retained in memory for a long time (Bluck et al. 2005).

Theoretically AM has three functions *self*, *social* and *directive* (Bluck 2003; Bluck et al. 2005).

Self function is an essential element in personal identity. It is hypothesized that it provides continuity of the self across time from the past to the future (Nelson 2003), as well as, coherence about 'what we are'. It is also argued its contribution to self-enhancement. People frequently compare their past selves to their current one to find positive differences in what they were and what they are now (Nelson 2003).

Directive function. Pillemer (Pillemer 2003) argues its importance to guide future behaviour and choice of actions in particular situations. Either common experiences of everyday life or traumatic episodes kept in memory are important to move an individual away from constant error. It helps in problem solving and development of opinions or attitudes (Bluck et al. 2005). An individual can predict his and others future actions based on past events. This function clearly explains Nelson's (Nelson 2003) message of using the past to serve future decisions, as mentioned earlier.

The *Social function* is claimed by Neisser (Neisser 1988) as the most fundamental function of AM. Nelson (Nelson 1993) suggests that autobiographical memory has high significance on sharing memory with other people. *Sharing memories* contributes to develop intimacy and maintain relationships, due to its capacity of providing material to conversations, making them more realistic and persuasive (Nelson 2003).

Individuals always talk about the past and share their experiences when others are not present at the original event (Alea & Bluck 2003). How much and what is remembered during conversations rely on similarity or familiarity with the listener (Alea & Bluck 2003). It is evident that people recall more information when talking to a friend. Sharing emotional and personal

information leads to the development of social bonds, thereby establishing and maintaining intimate relationships (Hymann 1994).

The memory-sharing (Alea & Bluck 2003) process is infuenced by responsiveness, that is, listeners make empathetic and contextually grounded responses to what the speaker is saying. Not only does memory-sharing enhance believability of conversations, but also serve engagement and intimacy in relations (Bluck 2003) in an enjoyable two-way interaction. Talking about the past (*sharing*) it is the process by which autobiographical memories are socially constructed (Pasupathi et al. 1998).

3.4 The process of remembering

Finally, these memory structures are used in processes, such as remembering and forgetting. The action of remembering is a complex process. Theoretically it can be described in three phases: encoding, storage and retrieval (Baddeley 2002; Tulving et al. 1983) that were experimentally analysed.

Encoding is the process whereby information is registered (Baddeley 2002). It involves representing a sequence of linked scenes that occur over a short period of time, associated with different kinds of information. Using semantic knowledge, events are interpreted automatically in a meaningfully way and it does not matter how spatial and temporal information are represented. Attention plays an important role in the amount of the episode that will get into the memory (Mayes & Roberts 2001).

Storage or consolidation refers to the maintenance of information over time (Baddeley 2002). Few experienced episodes are put in long-term memory storage and, only part of those is later retrievable (Mayes & Roberts 2001). Episodic memory is strengthened by emotional arousal and arousal generally, and even that starts to fade away in the first hour. In addiction to emotions, the brain's 'decision' about whether to detain or lose information depends on the quickness with which an event occurs. Other later events may occur and remark that earlier information as important, irrelevant or misleading, the system will wait until de body is in a state of quiescence (O'Hara et al. 2006).

Retrieval is the process of accessing to information by recognition or recall (Baddeley 2002). Recall is normally an intentional process but can occur automatically when some perception – cue – triggers some experienced event (Mayes & Roberts 2001). A cue is a stimulus that can help someone to retrieve information from long-term memory (van den Hoven & Eggen 2008). Anything can be a cue, photos, smells, text labels, spoken word, a color, an action, a person, as long as there is a link between a cue and an event.

Access to episodic memory, like autobiographical memory, is undoubtedly highly cue-sensitive, and is determined by encoding and retrieval environment (Tulving et al. 1983). However, episodic memory has a unique characteristic: allow to travel back in time without depending on memory content, in a very recent past. For example the question 'What I was doing this morning?', a cue is present (*this morning*) but is not specific enough to correspond an episodic

memory content.

3.5 Concluding Remarks

In this chapter we visited the memory hierarchical systems in a top-down approach. We mostly focused on describing M.A. Conway proposal for memory subdivision in episodic an autobiographical memories. He suggests that a autobiographical memory can be seen as semantic knowledge about one's life, retaining knowledge about progress of personal goals, but does not allow re-experience like episodic memory. He highlights that autobiographical memory encapsulates episodes in a three layer structure that gives us temporal continuity and context for episodes of our lives. The referred semantic knowledge can be specified in: *Lifetime Periods*, *General Events* and *Event-Specif Knowledge.*

Adding to this characteristics autobiographical memory plays an important role in our existence and we discussed some research that define three theoretical functions for it: *self*, *directive* and *social.* To conclude, we review the stages of the remembering process aiming at using these models as a starting point to create a computational model for a memory that is *shared* between user and agent.

Chapter 4

A Model for Shared Memories

As discussed in the previous chapter, autobiographical memories can be seen as mental constructions generated from an underlying knowledge base (or regions), which are sensitive to cues, and patterns of activation. Autobiographical memories contain knowledge at three levels of specificity: *Event-Specific Knowledge (ESK)*, *General Events* and *Lifetime Periods*.

While *lifetime periods* identify thematic and temporal knowledge, *general events* are related to actions, happenings and situations in one's life. *ESK*'s details are contextualized within a general event that in turn is associated with one or more lifetime periods, linking self autobiographical memory as a whole (see Fig.4.2).

In this chapter, we explain how we have mapped these concepts onto a virtual companion's memory system as a way to capture factual and emotional events experienced by the user.

4.1 Structure of the knowledge base

The proposed memory's architecture can be seen as a small ontology of semantic relations, which describe the main cues for triggering one's memories. As Conway (Conway 2001) and others researches refer, anything can be a cue. In our model we will only consider cues that could be represented by text and syntactically inferred from it.

Based on theoretical concepts (Conway 2001), the memory is constructed in three independent levels, using RDF (Resource Description Framework)[1].

The underlying structure of this framework is a collection of triples, each consisting of $< subject, predicate, object >$. These triples are organized in graphs, allowing simple data model for inference. The triple is illustrated in figure 4.1. The subject and object are nodes in the graph both linked by an edge. This edge represents the predicate, which establishes the relation between the two nodes.

[1]RDF provides an infrastructure for describing knowledge about the resources, and supports a richer data integration that helps machines to understand the information. It also has a query language with the ability of querying very large datasets with excellent performance (Ianni et al. 2009).

Figure 4.1: Knowledge base triple.

Taking into account the human memory structure, the knowledge base consists of 3 subgraphs, each one representing one level of specificity (Figure 4.2)- lifetime periods, general events and ESKs. They act as specific views the in knowledge base and all graphs(levels) are interconnected, yet can be accessed separately.

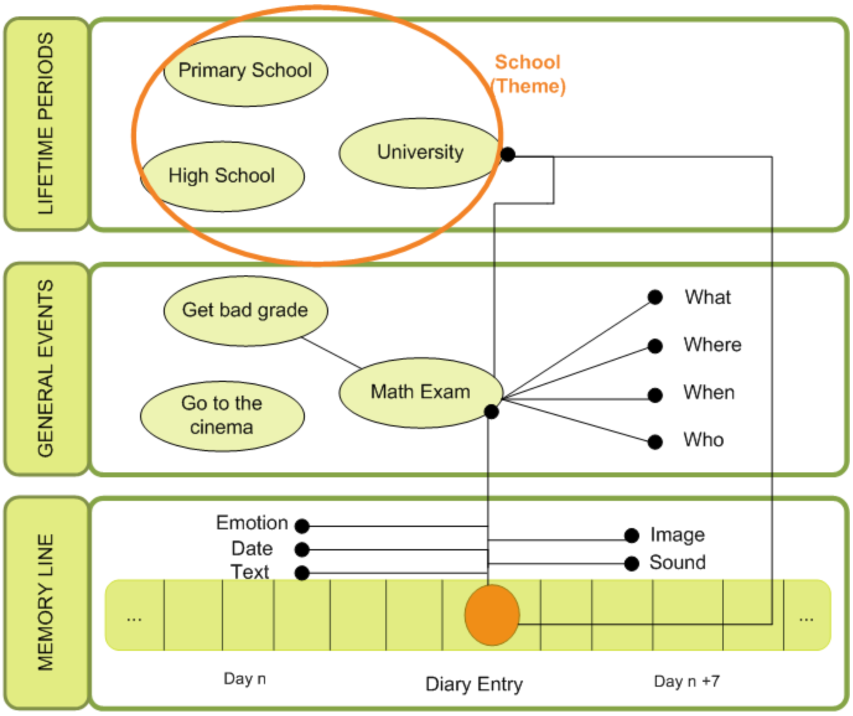

Figure 4.2: Agent's Memory System

Base level – memory line This level tries to represent Events Specific Knowledge (ESKs). The main idea is to capture a timeline over which the details of memories are stored. In other words, for each chronological position we have a node linked by a predicate to text objects, which represent details of the memory. The predicates are associated with date, text (the personal description of the experience), image, and sound, and they allow the retrieval of one memory at the less abstract level.

Middle level – general event General events capture the main action of one memory and allow the retrieval by small pieces of text, which are syntactic inferred from the textual input. They are associated 'what',

'where', 'when' and 'who'. The edge 'when' links to a different and more detailed object than the predicate 'date' (which is in the level below). For example, it could have a string related to the time of the day. Further, a general event can be within one or more lifetime periods, and as such an edge should be included into this feature. For instance, the event "Holiday in Rome with Sam" can be linked to the lifetime period "Year 2008" and at the same time "Relationship with Sam", because it was an event that happenned during these periods of life.
By definition, general events can be linked to other general events creating mini-stories. In this model, this view of memory will be represented by linking events that have the same context. For instance, the general event "Holiday in Rome" (master event) can be connected to other events like "Visit to the coliseum" or "Lunch in Vatican".

Top level – lifetime period For any given chronological period there may be a number of lifetime periods, which probably overlap in time. That is why, as M.A. Conway describes, thematic knowledge is associated with temporal knowledge to index different parts of the memory and fix the overlap problem. The lifetime period graph is organized by context, or theme, that is, a generic concept that specifies the content of a lifetime period. For example, the theme "School" may comprise lifetime periods like "primary school", "high school" and "university". Each node in the graph is a lifetime period inserted into a context, which have a bidirectional link to a general event.

4.2 Shared Memory

A shared memory is a memory of an experience that one had had and told to the agent. Roughly speaking is an event that occured in the user's life. Here a *shared memory* or *event*, *sm*, is defined by the tuple $< L, G, E >$, where:

- **L** – refers to one or more lifetime periods, which contextualize in a broad period of time an event.
- **G** – defines the main part of a shared memory, that is the action or event.
- **E** – specifies the details of one event.

4.2.1 Lifetime Period - L

A lifetime period can be divided in two categories:

- **FL** – Fixed lifetime periods. Those refer to periods that are common in everyones' life. For example, the current year and the user's age.
- **SL** – When we refer to a specific time in our lives we use particular words that possibly only make sense for us. According to this idea, lifetime

periods can be subjective, and cannot be defined *apriori*. Therefore, new LTPs will be created dynamically whenever it is needed.

We consider that a LTP can be recognized when a sentence starts[2] with the temporal adverb followed (or not) by the nominative singular pronoun and finally the verb: $QUANDO\,(+SUBJECT)\ +VERB$. For instance, "When I was in highschool..." or "When I worked in Lisbon ..."

4.2.2 General Event - G

A general event is a tuple with 6 characteristics $< A, Wo, We, Wn, Wt, Ev, Sub >$, where:

- **A** (action) – infinitive of the main verb indentified in the shared memory.
- **Wo** (who) – participants that had taken part in the event
- **We** (where) – specific place where the event occurred
- **Wn** (when) – specific time when the event occurred
- **Wt** (what) – any other complement of the shared memory that not fits in the other characteristics.
- **Ev** (event) – refers to the event itself. The event is generated by linking the action to one of the inferred characteristics: $A + \{Wo, We, Wn, Wt\}$. That link is based on the underlying semantic of the verb. For example, if the verb indicates movement, such as "go" or "go out", it links to where. Thus, the event is given by $A + We$.
- **Sub** (subevent) – link to a related G element.

4.2.3 Memory Line - E

The details of an event (G) refers to the surrouding context of it and the emotional details that user may have added. This element is defined by the tuple $< T, D, Em, I, S >$, where:

- **T** (text) - sentence or set of sentences that describe the event and add personal details to it. It describes a personal view of the facts and its emotional connotation.
- **D**(date) - date object extracted from the *Wn* characteristic of the event. It corresponds to an instant (a specific day) or a interval with a settled begin and end.
- **Em** (emotion) - emotional state in T. The system is capable to work with this variable (and others that we might want to add), but at this stage of implementation the emotional stage is not inferred from T.

[2] We took into account the grammar rules for Portuguese

- **I** (image) - image that one can use to better describe the event.

- **S** (sound) - sound that could add some personal detail and sufficient to bring the event to one's mind.

4.3 Access to the knowledge base structure

As mentioned in the previous chapter, remembering is a complex process and is theoretically divided in three phases *Encoding*, *Storage*, *Retrieval*. We based the access to our knowledge base on these three stages which are described in the following subsections.

4.3.1 Encoding process

Figure 4.3 depicts the encoding process for a written text as input. A main event (G1) is extracted from the set of sentences and subevent (G2) is attached to it. To each one the general events, the components of a shared memory (*sm*) are extracted and after used as cues for memory triggering.

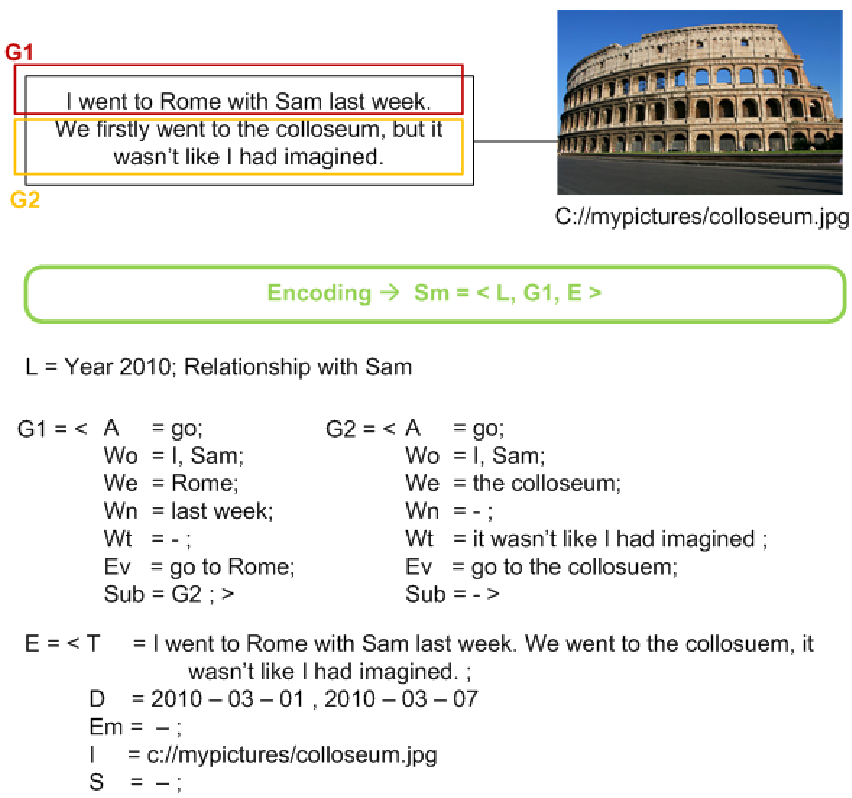

Figure 4.3: Encoding process

4.3.2 Storage

The storage phase is responsible for maintaining information over time. In human memory only relevant and important events are retained in one's memory. Thus, as we are concerned with an agent that gathers meaningful information about the user, we have to apply a filter to guarantee that only relevant events are stored in memory.

In humans, the importance of a memory can be strengthen by any emotional feature attached to it. However, an action that is present in a memory also plays an important role. Weighing verbs as *"to eat"* or *"to go"*, we can easily reject *to eat* as a unforgettable action, oppositely, the verb *to go* that indicates movement and perhaps an important change on the user's state. Thus, a *sm* is only stored in the agent's memory if the event (based on its action) adds relevant information about the user.

At this stage, it is also of our concern the process that allows the events to fade away from the agent's memory. Forgetting, as well as remembering, is a complex process that we will not consider directly. However, with this memory structure we can simulate the loss of information without actually losing it, making the data inaccessible whenever necessary. The lifetime periods and themes in this memory division may not be useful for daily problems, but they define whether an 'area' in the agent's memory is accessible or not for information search.

4.3.3 Retrieval

The retrieval process, as mentioned before, is a complex process and is this case we will simplify the access to the agent's memory. As Hoven et al. (van den Hoven & Eggen 2008) refer, everything can be a cue for memory triggering, as long as it is linked to an event. Using this memory structure, everything is a cue due to their link to the general event triple (G).

Therefore, any element at any level of the memory can be retrieved, as long as, a reference to the general event is present. So to retrieve any element from memory three elements should be present $O =< G, Lv, Wr >$, where:

- **G** – reference to the specific event (SUBJECT)
- **Lv** – level in the database or graph where the search should be performed (context)
- **Wr** – what to retrieve from the performed search. Note that this element represents and edge in the graph, more precisely a relation between two nodes. (PREDICATE)
- **O** – obtained element (OBJECT)

To get any event based on information from any of the other levels, it is only necessary to perform the inverse process $G =< Wr, Lv, O >$.

4.4 Concluding Remarks

In this section we specified a model for shared memories between agent and user. This model is divided in three levels of abstraction based on Conway's perspective for autobiographical memory. This preserves a cue sensitive structure where every element can be a cue for memory triggering.

Inspired by Conway's view we described the structure of the object that can be stored in the knowledge base or agent's memory. We emphasized that a general event (G) is the main characteristic and the other two contextualize and add personal details to it.

We also described how the three stages of remembering can be performed using this memory structure. The events are indexed in memory based on the characteristics of the three levels and those indices will be later considered as cues for memory triggering either of events or any detail associated.

Chapter 5

Companion Prototyping

Envisioning and implementing new systems, in our particular case companion systems, requires more than a virtual design in one's mind. One of the most common problems when designing applications is to have expectations about how people think and behave, and how we might like them to. Designers are frequently drawn to developing more attractive interfaces without taking into account usability and user satisfaction (Kramer et al. 2000). However, to yield satisfaction, not only should the user accomplish his goal easily, but also the interface should be appealing and usable.

During the design process, it is essential to "give value to the user" (Kramer et al. 2000), mostly in companion systems where interaction must be more than just a mechanical relation between a person and a machine (Nardi 2006), the design must undoubtly involve potential users. This requires an iterative process in which users can experiment in early stages of design (Iacucci et al. 2002). As such, with the aim of building a memory companion we initialized the design process through participatory design methods to better serve user's needs and pleasure demands. The design process carried out comprised two phases: *Probing Daily Life* and *Looking for Error*. The results obtained allowed us to create the agent MAY that we will present along this thesis.

5.1 Probing Daily Life

Our initial purpose was to uncover the practices through which people experience memory sharing and discover how they perform activities that the system tries to assist. But how to analyse 'real life' without losing personal expressivity? To achieve a 'close view' of daily life without blurring the essential aspects (the one's that we had not thought of) we moved away from the controlled environment found in a lab, sending a probe to potential users and waiting for its return.

Cultural probes are an interesting collecting process, in which people are agreeable in sharing personal aspects of their lives. The probe exercise gives necessary detachment from the designer, and provides information about how people use the given materials to express themselves in an unobtrusive way (Dix et al. 2004). Probes do not directly lead to designs, as we could experi-

ence, but make us aware of details, which are valuable in inspiring design ideas (Gaver et al. 1999). We used this approach as a starting point to satisfy our intentions.

Our experiment was focused on teenagers, mainly ones that have just started their academic life in the university or were about to start it. We wanted to disclose what they are willing to tell to a companion, which things are important in their life and which are of their concern. How ‘stories’ of their life are told, and consequently organized in words, and which are their routines. Further, we wanted to analyse how people used the provided materials.

Figure 5.1: Probe’s materials

5.1.1 Experiment and Returns

At this point, we gave them an envelope (Fig. 5.1) containing ten tasks to perform, a blue pen, coloured pens, post-its, stickers with emotions and a notebook - their ’companion’. Each task had clear instructions of what was needed to do, yet not restrictive about how to perform them. The first task aimed at creating a first bond with the companion requiring an image of it/she/he. The following tasks, tried to ‘extract’ ways of interaction and sharing experiences (memories) process.

People had liberty do deal with the requests as they preferred. The 14 participants (seven boys and seven girls) from ages 16 to 18 were first-year students of Instituto Superior Técnico, Universidade do Minho and high school finalists. They took the probes and returned them 3 weeks later.

Probes should not be used to produce scientific analysable data (Gaver et al. 2004), therefore, it is common to give participants ambiguous and absurd tasks to create detachment from preconceived definitions of the world.

Although our designed tasks (see Appendix A) were relatively straightforward, they called for subjective interpretation from us and a deeper thought from the participants. The collected answers revealed to be an insight of each participant and its combination brought up a “conceptual model” of the prospective group of users and how the system should behave.

Companion's Image

The first task (Fig. 5.2) tried to connect the user to the whole experience, constructing the illusory image of a notebook as a companion. The participants had to scratch or glue elements that together represented an image of their companion of choice. All the following tasks they had to do would afterwards be performed with that image in mind.

Figure 5.2: Shape me! (Task 1)

The obtained results were not works of art, but they definitely drew the picture of what potential users expect from a companion. Its image emerged as various characters and it was clear the need for the character convey each individual's personality. For example, a person glued elements which she identified the most, like ballet shoes and ritmic gymnastics objects, while another one refered to the companion as "a character to his style, which would like to have fun".

As a final task of the sequence, we challenged participants to draw a new image of the companion. We wanted to uncover if the tasks performed in the meantime, influenced their opinion about how a companion should look like or act. The answers were interesting. The sex of the character emerged as the same of the volunteer, as one explains: "I think MAY would be a girl now, just because I realised that I would tell a girl more easily the things I talked about in the tasks". Finally and surprisingly, one participant gummed a cartoon cut of the cricket from Pinocchio story. Perhaps, suggesting that a companion assisting them in their daily lives could act as his/her conscience.

What is important to users

Most of the participants did not spare the details (Fig.5.3) and have used the given stickers representative of emotions, as well as, the colored markers to illustrate the text. However, nothing stood out, or lead to

new ideas that could add value to the functionality of the companion system.

Figure 5.3: What have you been doing? (Task 2) and One day at school/University (Task 9)

Focusing on content and regardless of personal tastes, there are some interests and concerns that are common in all probes, apart from its position in a scale of preferences. Tasks confirmed four important dimensions in younger's life: love, sport, leisure and school.

Further, when asked about the main problems that teenagers face, one girl referred the exams as "a big issue" in her life and the pressure to succeed. Adding to this, she referred "we always have to worry about our physical appearance", what could suggest latent lack of confidence in teenagers nowadays. A male 'probed' pointed out the conciliation of personal life and studies as the main problem.

A companion system should be prepared to respond promptly to these subjects and provide emotional support when needed. It should encompass strategies to encourage the user and congratulate when she/he do the things well.

How are memories described

From the literature presented, we already know that people structure their memories in three levels of abstraction. But how are events recollected? We designed a task (Fig. 5.4) in which participants had to choose among a set of pictures, one in particular that triggers an important memory and describe it. It is possible to observe a pattern in their written text as this task is described. They established a broad period in their lives, which cannot always be mapped into a date. Then, they specified an event and after that started describing its details.

They described memories that they share with their friends, highlighting that their social relations have an important role in their lives.

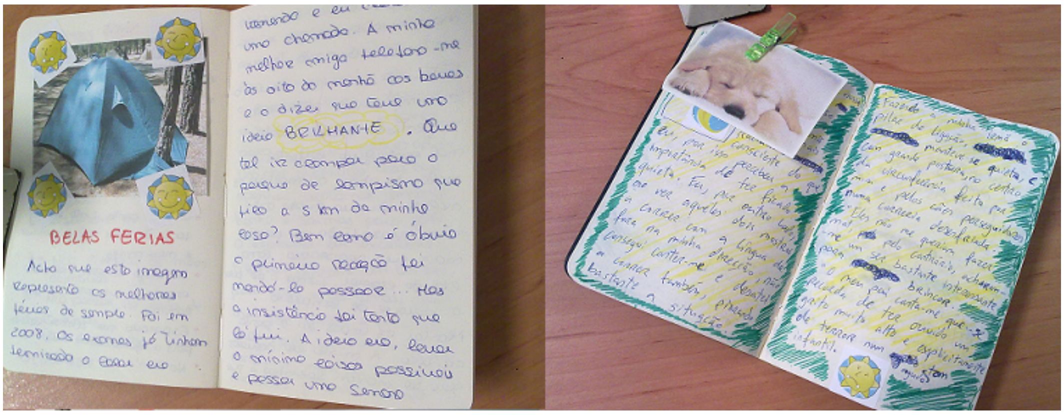

Figure 5.4: I remember . . . (Task 6)

5.1.2 What was probed?

This experiment provided an engagement with the participants, allowing us a ‘close view’ of their lives. The ‘storytelling tone’ was constant in their responses, as they literally wrote a diary. However, a direct interaction with a companion was not left out, and during the experiment some subjects really ‘talked’ to MAY. In the light of this, we established that the communication between user and companion would be by text to preserve the expressivity we found in the data. Then, the central point of the interaction would be dialogue, which facilitates the sharing of knowledge and individual’s information.

Moreover, the probes enhanced a conversational behaviour as suggested by (Dunbar et al. 1997). There is a focus on talking about personal experiences and relationships, as well as the emotional responses involved in those interactions. The personal experiences fit in one of the four important dimensions of younger’s life: love, sport, leisure and school.

The way how the given materials were used did not surprise us, but stood out the necessity of a feature to enable attaching objects, like images or sounds, to the written text. Still, the probes oriented the design of the interface and a first prototype was modelled.

5.2 Persona

A relatively new design technique for interactive applications is the use of *Personas*. *Personas* are an archetype of actual users with well defined characteristics and it was first introduced in HCI community by Cooper (Cooper 2004).

It aims at helping designers focus on the prospective user of a system or interface, taking into account his/her needs and goals (Chang et al. 2008). Despite being conceptually simple, Cooper claims that *personas* are powerful and effective in every cases. Yet these imaginary characters must be defined with precision and rigor, after some initial investigation of the target user. *Personas* have various attributes, such name, age, gender, educational

achievements, profession, possessions, likenesses, family, occupation, friends, pets, tasks, life stories, goals and so forth (Grudin & Pruitt 2002). They are "imaginary" users that designers consider in their design process.

This technique arises from the difficulty of working closely with potential users on a possible new product, specially in large organizations (Grudin & Pruitt 2002). User-centered design based on *personas* increases user focus and awareness. They are specific assumptions about a set of people and make the decision criteria explicit (Grudin & Pruitt 2002; Pruitt & Grudin 2003).

Some studies (Chang et al. 2008; Pruitt & Grudin 2003) were performed to evaluate if the presence of the factor *persona* have a positive effect on the final design comparatively to the absence of it. Their studies enhanced that the use of *persona* helped designers on picturing the user and get to a consensus. However, *personas* should be used for a particular effort and should not substitute other techniques for participatory design. Instead, they should complement them and enhance user focus. On the whole, this is a good approach for complement and guide not only the design process, but the test phase as Grudin (Grudin & Pruitt 2002) suggested.

5.2.1 Amy

Following this persona design technique, we created a fictional user, named Amy (see its description is on appendix A). The data extracted from one probe was our starting point to create that fictional person, which behaviour was interactively built based on real data from the rest of the potential users, who have participated on the probe study. The created character aggregated a set of characteristics from several persons (participants in the probe study) and not from just one.

Our aim at creating Amy was to guide the companion's design both its interface and implementation. Further, we would like to extend the use of personas to help us surpass the long-term issue, based on the engagement that this tool can provide. More details on this matter are explained on *Evaluation* section (section 7).

The *persona* Amy is 18 years old and is on her first year of Computer Science in Instituto Superior Técnico. She likes summer time and being with her friends whenever is possible. April is her best friend, and they usually go to the cinema together and out for dinner once in a while. As many teenagers one of her goals is passing the driving test and of course be succefull in her studies at the university. Further details are on appendix A.

5.3 Looking for Error

> "The Wizard? But nobody can see the Great Oz! Nobody's ever seen the Great Oz! Even I've never seen him!"
>
> – *Wizard of Oz (1900)*

The revised work in chapter 2 highlighted some interesting points to conduct this research. With this idea in mind and designing for the target user, we created an inicial prototype for the interface of the companion system. To validate it and discover its problems, we conducted an early evaluation process using the *Wizard of Oz*(WOZ) technique. WOZ method simulates an human-computer interaction while a human, known as the wizard, acting like a computer and simulating its 'intelligence'. The aim is to pretend the computer side sufficiently well to fool the subjects for most of the time (Fraser & Gilbert 1991).

Most WOZ experiments are used to examine the viability of an interface and also for research on natural human-computer dialogue systems. Similarly, in this phase of design, we wanted to explore the usability of the interface and the relevance of its features, as well as, if the natural language dialogue converged to a speech pattern (Maulsby et al. 1993).

The first prototype had a standardized layout. We decided to use a chat like interface to simulate the communication with someone in 'the other side', like many other dialogue systems. The interface (see fig.5.5) also have some buttons to better serve the user in his task accomplishment. The user could indicate to the system his/her mood (button 1), the theme of the conversation (button 2), change the system mode to recover past information (button 3) and also attach a image or a sound (button 4 and 5) to some written sentence.

Figure 5.5: Initial interface prototype. *Zone 1* is activated by clicking on *button 2*; *Zone 2* changes its display when the recovery mode is activated (*button 3*); and *button 1* allows the user select an emotional state, which is displayed in *Zone 3*

5.3.1 Wizard Experiment

As said before, the subject could type text and click on the functional buttons to interact with the system. On the other hand, the wizard communicated with the user by typed text.

To fulfill the requirements of a WOZ simulation (Fraser & Gilbert 1991) and correctly simulate the system according to its future behaviour, the wizard responses were according to each sentence or instruction, one at a time, in the sequential order they appeared. For that reason, wizard's responses pretend to be mechanical without looking to the dialogue as a whole.

Experimental Setup

Each one of the 9 participants were sat at a computer running the client side of our application. The person responsible for the experiment sat next to them, not only to ensure that was a genuine test, but also to check if there were problems during interaction. After introducing their name, they started interacting with the wizard. The wizard was sat in another room at a computer running the server side of the application.

The experiment started with a introductory sentence to explain the whole aim of the experiment to the participants and to help them start the interaction:

"Hi < username >, my name is MAY. I like to talk about several subjects and your mood. If you would like, you can share with me images, sounds or even your memories. Do you need any help with the interface?"

Before starting they were informed that the task was to talk with the companion MAY about their day. What they had done or what they were supposed to do. To accomplish that they should use all the functionalities offered by the interface to be better understood by the system.

Observations

Some of the participants started their session with the system (wizard) by using the chat interface, as the only way of interacting with the system. The buttons were not seen as an auxiliary mechanism for communication, but as other functionalities of the system. As result, they were explored during the interaction, introducing some noise. The resultant interaction was not continuous as we expected.

Figures 5.6 and 5.7 show two brief examples of dialogues extracted from the experiment.

In the first dialogue (fig. 5.6) the user clicked on a button to select the *leisure* theme. System future's behaviour should automatically prepare a response according to that choice and the wizard simulated that.

However, in most interactions only the chat was used and the buttons were randomly clicked. The dialogue shown in figure 5.7 is an example of that and the result was a very confuse dialogue.

S: Olá
S: [Lazer] **(*)**
MAY: Olá
MAY: O que gostas de fazer nos tempos livres?**(**)**
S: ir ao cinema.
MAY: gosto de cinema. Qual o teu filme favorito?

Figure 5.6: (*) the user clicked on a button of the interface to chose a theme of conversation; (**) wizard response according to the selected theme of conversation

MAY: Tens planos para hoje?
R: jogar futebol
R: [ESTOU Preguiçoso] **(*)**
MAY: Vais jogar futebol?
R: sim
MAY: Porque é que estás preguiçoso? **(**)**
R: porque já estamos no fim do dia
MAY: Eu adoro futebol. Qual é o teu clube favorito?

Figure 5.7: (*) Mood option was selected and the information sent to MAY (wizard). (**) Response relative to the mood selected

5.3.2 Problems found

Daily, teenagers interact with their friends using Instant Messaging. Therefore, with a chat like interface we were exploiting a model recognized by all, needless of instructions or explanations. The buttons were chosen to smooth the interaction and at the same time enable the system to respond more accurately.

However, instead of helpful, we found that the buttons were a bit useless. The familiarity with a text based dialogue interaction distracted users from the rest of the functionalities. However, the same familiarity brought also a problem. Users are used to write their sentences in more than one line. That is, they click the *return* button on their keyboard before the utterance ends. The system's responses can be influenced by this way of dialogue, but eventually the user will learn how to overcome such problems and will find the best way for interacting.

Dialog patterns were particularly difficult to found. Actually, the scope of the idealized system is large enough to hamper our task of recognizing a general way of speaking/writing, especially when it is in Portuguese.

In light of such results, we decide to support the communication with the agent on the technology, as will explain in the next chapter.

As a result, the interface suffered some modifications that we believe to be

necessary. We verified that the chat diverted users attention from the other mechanisms for interaction. Yet, as we intent to preserve the user's expressivity during a friendly dialogue, in which the process of sharing memories of experiences could happen, that is an essential feature that should be maintained.

The resultant prototype is in figure 5.8. It is a much simpler interface, leaving off more space for showing information related to the stored memories. The buttons for adding image and sound objects were left in.

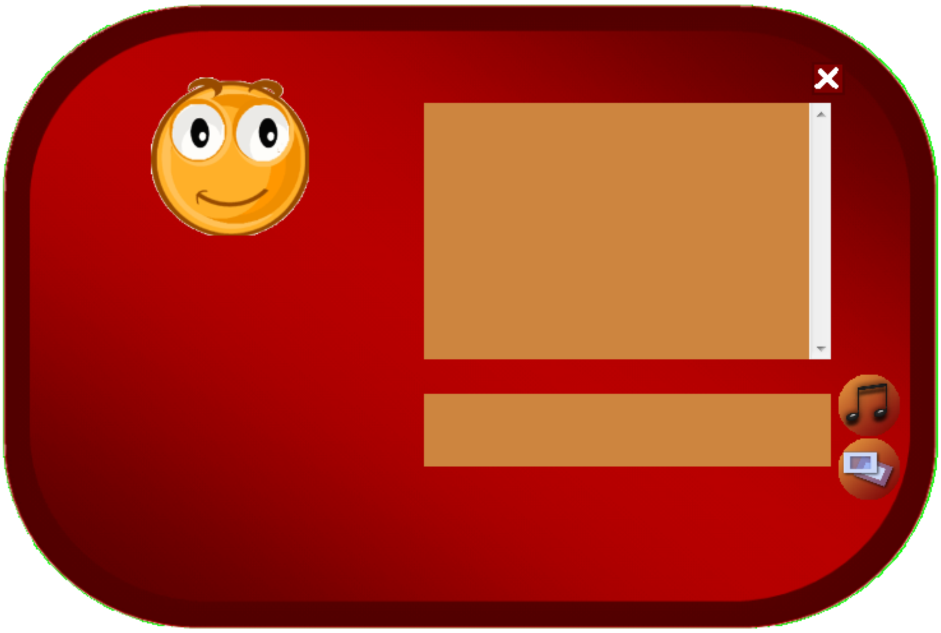

Figure 5.8: Resultant interface prototype after the WOZ.

5.4 Concluding Remarks

Introducing the user in early stages of design was found very useful.

We described how we designed the probe study, and which information was possible to extract from them. From that information we created Amy, who guided the design process, helping us focusing on specific user. Following that we conducted a Wizard of Oz to test the viability of an initial interface design and also to try to identify patterns of communication, between a user and a chat like agent.

Chapter 6

Setting-up MAY

Using the model proposed for memory sharing and the results of the design experiments, this chapter describes the implementation of a virtual companion system personified by MAY (my Memories Are Yours). MAY is an agent created to assist a teenager user on self-reflection and daily companionship about what happens in his/her life. The communication between the agent and the user is done through dialogue by which the *shared memories* are collected and saved in a diary form (or timeline).

Our intention is to use this shared knowledge, which refers to important events in one's life, in an useful way for relationship building between an agent and the user. We use the memory model for *shared memories* explained in chapter 4; recent technology, such as ConceptNet3 (Havasi et al. 2007) and A.L.I.C.E. (Wallace 2008); and some natural language tools responsible for unifying the system and ensure the communication. As such, we first provide a general overview of the system, then we describe the used supporting tools follow by each one of the components of MAY's architecture and how they are linked together.

6.1 General Overview of MAY

In this section we provide a general overview of MAY's architecture, by describing genericaly the main components and processes of the system.

6.1.1 How it flows

MAY's architecture, broadly speaking, works in the following way (see fig.6.1): the agent perceives new sentences introduced in the chat interface as a response to the dialogue. When this happens the system will operate in two steps. First, the input is processed. Then it works on providing a convenient reply. The process will flow as described below:

1. Processing input

    - Every sentence will be analyzed using the Natural Language Module (described in section 6.2.1). Relevant events and their elements are

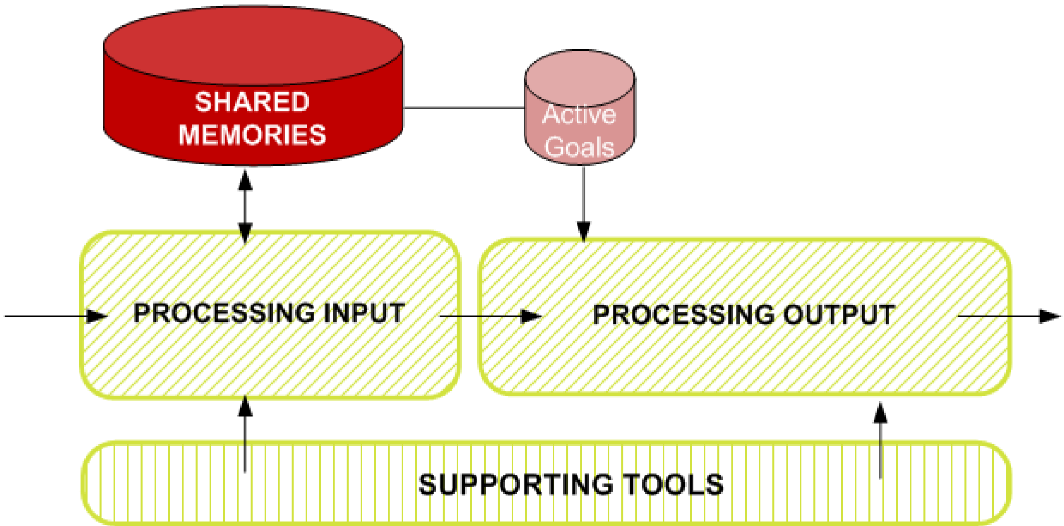

Figure 6.1: Abstract representation of System's Architecture, showing how information flows

searched in each sentence based on the action identified by the verb.

- The shared memory base and active goals are updated with every new relevant "sensed" event. The latter accounts for events that have not happened yet. The former stores all relevant past events in user's life that the agent knows.

2. Processing Output

- If the agent has nothing more relevant to say the dialogue is supported to a great extent by A.L.I.C.E[1] (section 6.2.4) and, as such, will generate a response by pattern matching. Otherwise, a response is carefully built using the information from the next step.
- To produce an adequate response, the agent starts by searching its memory for anything appropriate to say. It looks for active goals, past events with some relevant information for the current situation or even go beyond the present and infer future plans. As another option the CNET support module (section 6.2.3) can step in to produce a more accurate response. With that refinement, an answer is given to the user.

In the next sections, we sumarize each module and its involment in the whole process. Starting by processing the input and then processing the correspondent output.

6.1.2 How it works

The system architecture is depicted in Fig.6.2. This model is composed by four main modules: *Autobiographical Memories*, *Data Analyser*, *Agent's cognitive*

[1] http://alicebot.org/

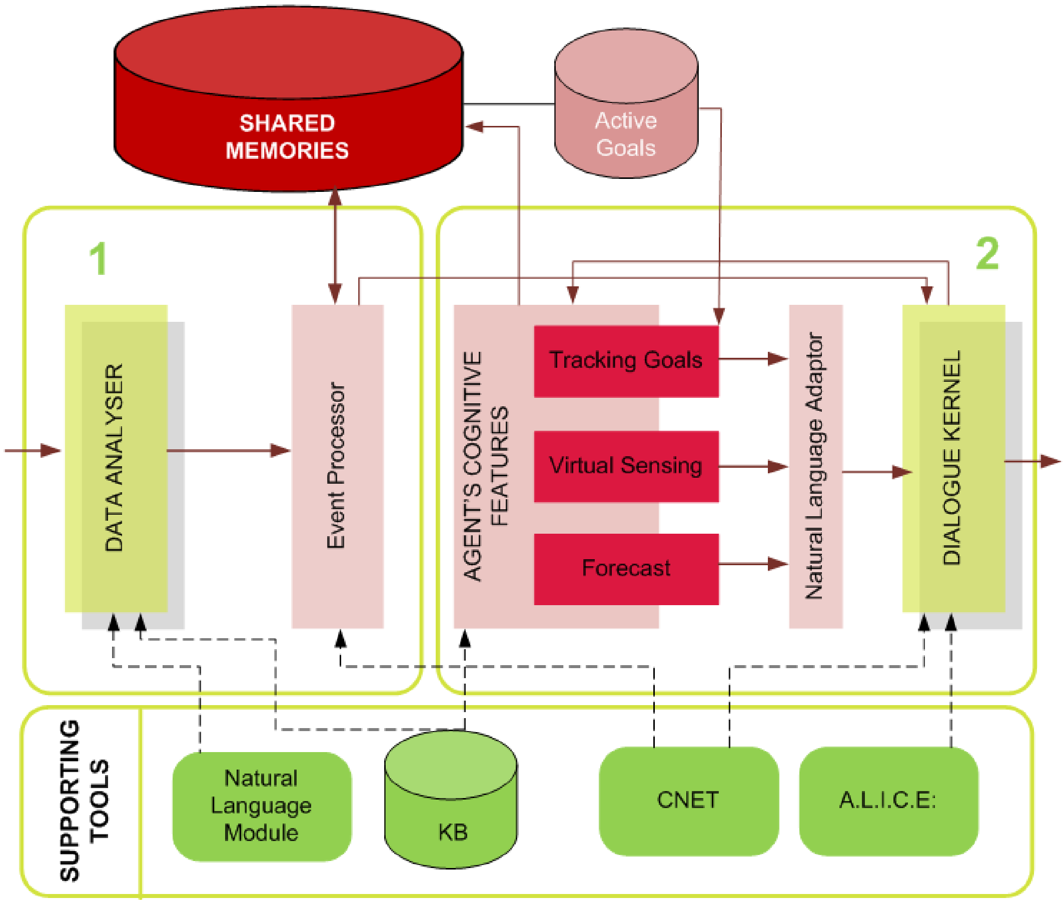

Figure 6.2: System's components and information flow. 1 - *Processing Input*; 2 - *Processing Output*

features and *Dialogue Kernel*.

The *Shared Memories* module accounts for the shared memories between agent and user (detailed in chapter 4). It is worth noticing, however, the sub-model - active goals. It refers to the future events that the user sets as a possibility or a scheduled event in his/her life.

As the user writes a sentence it is given to the *Data Analyser*, responsible for extracting the event descriptors - what, when, where, who - and the event itself. This work is accomplished using a *Natural Language Module* and a *Knowledge Base*, which up to now, have tools to map human-time into a normalized form. The normalized data is then transferred to the *Event Processor* responsible for saving relevant events into the *Shared Memories* module respecting its hierarchy levels. If the event takes place in the future, it is saved with the same structure, into the *active goals* set.

When an event is created, the *Agent's Cognitive* module 'senses' if any internal stimulus arouse a pattern in the data. This is, if any pattern was activated by one of the possible cues attached to the events. It enables three data views that will be explained in detail in section 6.3.

The *Dialogue Kernel* uses a modified version of A.L.I.C.E, an engine that

uses AIML (Artificial Intelligence Markup Language) to create responses to questions and inputs. The dialogue is pro-active and adapted to the main goals of a teenager user – school, love and play. To preserve situations of which the agent does not have an appropriate answer, we use ConceptNet (Liu & Singh 2004) to endow the system with dynamical capabilities to adapt to unpredictable input.

6.1.3 How it looks

For interacting with MAY the user has to use the interface shown in figure 6.3. In this image it is possible to see four highlighted regions, which are four distinct areas, with different functions that allow the communication.

Figure 6.3: Interface for interaction

Region 1 and 2 refer to the dialogue. The former, shows the utterances from both user and agent in dialogue form according to that interaction. The latter, is the area reserved for the user to write his/her sentences and thus carrying the communication with the agent. These two areas are no more than a familiar interface, like the Instant Messaging.

On the right of region 2, the two buttons allow the user to add images or sounds to the written text. The yellow circle in region 1, exemplifies the use of the image button.

The other regions in the interface are related to the retrieval of information. At the bottom of the interface (region 4) there is the "memory line", which represents the base level of memory as explained in chapter 4. The 'clouds'

along that line are clickable objects that allow the user to access to a specific day of memories of experiences.

By clicking in one those 'clouds' the region 3 appears, showing a list of events associated to that specific date. Each event on the list is clickable, allowing the visualization of the event's details.

6.2 Supporting Tools

There has been a research boost in extracting knowledge from textual data, identifing entities and enabling the computer to "understand" what we are really trying to say. Plus, in agents, this feature can improve their credibility by endowing them with capabilities for classifying information about what the users say.

In this section, we describe the supporting natural language tools to help dissect the input as text and also how we applied and integrated new techonologies like ConceptNet 3 and A.L.I.C.E in our system.

6.2.1 Natural Language Processing

Our aim in developing this kind of tools is (1) to be able to identify a sentence's verbal tense and to separate future from past events (2) to identify the *event* (action) and its characteristics: *when* it happened, *who* participated and *where* it took place. Those components are responsible for memory indexing that MAY uses.

We use a quite simple approach avoiding time consuming implementations, like the commonly used probabilistic models, for tagging and entities recognition. We preferred this semantic approach because it allows for rapid prototyping. Further, as we had done some design experiments we had data and structured information, allowing us for semantically develop a tool adapted to our goals. Our approach takes advantages of the relation between words, carefully extracted from a Portuguese grammar (Borregana 1997). The process is divided into five steps and works as follows:

1. Sentences are split into clauses

   To avoid errors we split each sentence by their conjunctions to obtain clauses. With this approach it is easier to identify the words relations. After, all punctuation is removed.

2. Word pre-tagging

   Each word is tagged with the morphosyntactic specifications for portuguese used for *subcorpus PAROLE*[2]. We used a pre-tagged corpus to classify each non verb or non substantive.

3. Rules

[2] http://www.elda.org/catalogue/en/text/W0024.html

Verbs and substantives are classified according to a rule system that identifies relations between words.

4. Verb tense

   To verify if the classification was correct we used a Stemmer(Snowball-Porter[3]) to remove inflections from words, not only to identify regular and irregular verbs, but to identify the tense. The tense was computed according to all the adjacent verbs.

5. 4W - who, when, where, what

   The event and its characteristics were computed using the clause's verb as reference and according to words classification, as well as the rules that determine which set of words represent which entity. This extraction is independent of sentence construction.

To evaluate the described process we extracted 36 sentences from the probes and ran the morphosyntactic classification and entity extraction. From 393 words it failed the classification of 2. The solution found suited our intention and we consider it to be sufficient for extracting the event and the indexing characteristics that we needed. We believe that in an informal conversation this algorithm will succeed most of the times.

6.2.2 The Time Reasoner

Knowing when an event took place or is going to take place is of extreme importance. However, users have at their disposal several ways of describing a period of time because the system allows free text in name of expressivity. Then, it is essential to convert temporal expressions into a normalized form for accurate database management. In the previous section, we explained how the extraction process of temporal expressions was done, here we describe our approach to normalize those expressions.

Temporal Entity

In (Hagège et al. 2008) a general directive for time in Portuguese is proposed. We followed their approach and adjusted to our goals defining a *Temporal Entity* as follows [4]: a specific *Instant* of time or an *Interval* within two limits. The former represent an absolute date, for example "2010-5-1" or relative dates given by a temporal expression as "ontem" (yesterday) or "no dia anterior" (on the day before). They are relative due to the need to point out a reference to compute the correspondent date. The latter is composed by two instants that together are just one entity. Each one of the instants corresponds to a temporal limit, for instance "Entre Janeiro e Abril" (Between January and April).

[3]http://snowball.tartarus.org/

[4]Notice that for the purpose of this work, the small unit that we work with is day. That is, we not consider hours, minutes and seconds

Normalization

The main difficulty in building this type of automatic systems is the variety of ways that people use to express time (Childs & Cassel 1996). Therefore, instead of thinking in advance in all the possible temporal expressions we implemented an expression independent temporal reasoner, following an arithmetic approach to compute a date. We use a small ontology[5] for time (see Appendix C). The idea is not that each temporal expression has a correspondent function to compute the respective date as (Childs & Cassel 1996) and (Craveiro et al. 2008) suggest, but rather to have a common representation for each different set of words. Any modification in the ontology, following the standards, will automatically produce an output without code modifications. We set three divisions for data months, weeks and words.

- **Month.** When the input corresponds to a month, it is possible to get the correspondent number and the max number of days that the month has. For February the max number of days is computed by a rule.
- **Week.** We set that a weekday corresponds to a number from 0 to 6. A weekend is defined by two weekdays and consequently by an *interval*.
- **Words**. This set represents temporal words usualy used on temporal expressions. Those words intend to increment or decrement the current date. Yet, other words (that were not considered) can be included in this set. They may represent timed feasts (moveable – Carnival, Easter or immovable–Christmas) or even words that designate the unit we are working on: year, month or day. That can be applicable when we say "No ano passado (. . .)".

The normalization process works as follows:

1. *Word tagging*

   For each word a code is given based on what was extracted from the ontology presented in appendix C.

   Example: ***Temporal expression***: **"natal do ano passado"**

natal	do	ano	passado
function_call: *create_date*	/	interval: 365	operation: -1

   To the word 'natal' a code relative to a function is associated. The word 'ano' was tagged as an internal, and finally the word 'passado' was stamped as an operation. Those codes are transformed into numbers, which will be used in the next step.

[5]We focused the development of ontologies in RDF because is technological more advantageous for our project.

2. *Arithmetic functions*

   The base date for calculations is Christmas of the current year, by default is the current date. Over that date are applied the operations, if they exist. In this case, it should be a decrement of one unit of time. The interval variable indicates the unit in which the decrement should be computed.

   When we identify the word *Monday*, for example, the verb sentence helps us decide whether it refers to *next* or *last Monday*. It also covers months across years, that is, an interval of time that starts in September of 2009 and ends at April of 2010.

This time reasoner is not exhaustive for all combinations of temporal expressions and simple arithmetic operations over a timeline might not be enough. However, we believe that during a friendly conversation this module can be sufficient and compute the time of an event accurately. For more details of the covered combinations see section C.2.

6.2.3 ConceptNet 3

ConceptNet (CNET) is the largest, freely available, machine-useable commonsense resource (Liu & Singh 2004). It aims to create a network of relations, which represent the facts that each one of us knows about the world (Havasi et al. 2007). For example, "a pen can be used to write" or "one of the things you do when you read a magazine is turn the pages".

This "explanation of the world" is provided by the Open Mind Common Sense (OMCS) project, an initiative of MIT Media Lab[6]. They collect statements from untrained volunteers on their website by asking questions based on analogies to fill gaps in a sentence. That process allows them to teach the database new facts and make the existing knowledge more strongly connected.

CNET is a semantic network where concepts are the nodes and the edges are predicates expressing the relationship between two nodes (Fig.6.4). The concepts are semi-structured natural language fragments extracted from complete sentences. Regarding to the former sentence in the previous example, *pen* and *write* are the concepts and the relation linking them is *Used for*. In the second statement, *read a magazine* and *turn the pages* are the concepts and the predicate that makes the connection is *HasSubevent* (that means, what do you do to accomplish it).

One of the strengths of CNET is its multilanguage knowledge collection. The API is flexible enough with its natural language tools to build ConceptNets for multiple languages and synthesize them into the same database (Havasi et al. 2007). That simplicity allowed the creation of a Portuguese Corpus, collected by the OMCS in Brazil.

CNET also offers tools for reasoning, using computational resources to infer relations between concepts: context finding, inference chaining and conceptual analogy (Liu & Singh 2004).

[6]http://commons.media.mit.edu/en

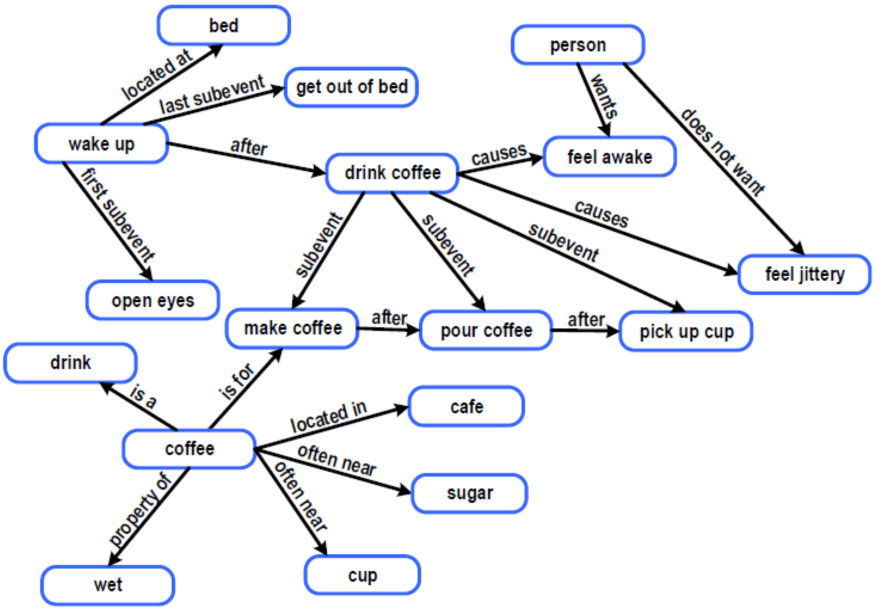

Figure 6.4: An excerpt from ConceptNet's semantic network of commonsense knowledge (Liu & Singh 2004)

In our system CNET was used for practical commonsense reasoning for conceptual analogies, in particular: (1) to find out if two sentences are related, that is, if both sentences belong to the same subject and (2) get knowledge about a concept when dialogue scripts cannot provide an answer.

1. **Finding Relations.** We illustrate below the application of CNET in MAY as a way of finding out if two sentences are related.

   Sentence 1: Foi bom. [Fui ao cinema com o Lyam].
   Sentence 2: [O filme foi muito bom.]
   O Leonardo DiCaprio desempenha um grande papel.

   (a) First, the sentences in brackets in blue are split into concepts.

   Concepts of sentence 1: $< Concept :< pt : cinem >>$
   Concepts of sentence 2: $< Concept :< pt : film >>$,
   $< Concept :< pt : bom >>$

   (b) Then, we verify if there is a relation between pairwise of concepts.

   CNET has a module responsible for describing a relation between two concepts – *assertion.objects.filter(concept1, concetp2)*, if any exists. Further, if a relation is verified it must have a high score. A score is a cached value that represents the reliability of an assertion. Notice that assertions are obtained from OMCS and the score is

computed by the number of people who support the assertion minus the number of people who oppose it. Due to the (low) size of the database in Portuguese and the correspondent extent of relations between concepts, we established that an assertion is reliable when $score > 3$.
The following *assertion* satisfies that condition and establishes a relation between the twwo concepts, which is the predicate *AtLocation*.

Relations: $< Assertion : AtLocation(film, cinem) >$

2. **Get conceptual relations.** The relations between concepts become relevant to us when we try to enrich the dialogue. When a input pattern does not match with a previously defined script in the dialogue database, the system tries to compute a response that can be valuable to carry on with the dialogue. That is done using again the assertion module.

   (a) First we extract the concepts.
   Sentence: Vou ao ginásio fazer um pouco de exercicio.
   Extracted concepts: $< Concept :< pt : vou >>$,
   $< Concept :< pt : faz\ exercici >>$,
   $< Concept :< pt : pouc >>, < Concept :< pt : exercici >>$

   At this point, a concept is selected from the set randomly. However it could be applicable to opt for the most relevant using natural language techniques.

   (b) After randomly select a concept we compute in which raw assertions it will take part. A 'raw assertion' connects a concept to its natural language representation.

   Selected concept: $< Concept :< pt : faz\ exercici >>$
   Raw assertion: $< RawAssertion : pt : ('fazer\ exercicios'$
   $MotivatedByGoal\ 'desejam\ manter\ a\ saúde')s = 2 >$

   (c) Corresponding to each relation described in CNET (see appendix B for more information) we have several sentence prototypes. Those sentences have gaps where the two concepts that belong to the referred relation can fit. For example:

   Concept 1: $'fazer\ exercicios'$
   Relation: $MotivatedByGoal$
   Concept 2: $'desejam\ manter\ a\ saúde'$
   Example of gapped sentece for correspondent relation:
   $Quando\ queremos\ < concept1 >\ é\ porque\ < concept2 >\ ?$

One of the drawbacks of CNET is the Portuguese database derived from the Brazilian Portuguese that is not always appropriate to use in a European Por-

tuguese context. In addition, it does not have any filter to separate what is a concept from what is not, before the entries in the database became permanent. Further, many of the functions to operate over the database do not work properly for other languages than English. This problem imposed us to fill that gap and create some of the necessary functions. On the other hand, it offered us a net of semantic relations carefully defined and very useful in the scope of our project.

6.2.4 A.L.I.C.E.

A.L.I.C.E. (Wallace 2008) is an engine that uses AIML (Artificial Intelligence Markup Language) to create responses to natural language inputs. The inital aim of A.L.I.C.E was to create an agent that would pass the "Turing Test". This chat-robot was inspired by the old ELIZA (Kuipers et al. 1976) psychiatrist program but, in contrast, it has more than 40 000 categories of knowledge whereas the original ELIZA had only 200.

AIML derivates from XML (Extensible Markup Language) and its aim is to be easy to use by novices and offer interoperability with XML. AIML elements encapsulate patterns to stimulus, responses to those patterns, and other elements to be parsed by the AIML interpreter. One of its strengths is its modular implementation that allows extensibility of the interpreter.

The AIML pattern language is simple and efficient. It consists only on words and wildcard symbols, such as _ and *, and all the objects are stored in a tree allowing a compact memory representation and efficient matching. It supports recursion, representation of context, predicates and pronoun swapping substitution. An object in AIML is made up of units called categories. Each category corresponds to a possible input, a "template", which corresponds to the robot response, and an optional context "that" or "topic" (Wallace 2008). See the example below.

```
<category>
<pattern>HELLO< /pattern>
 <template>HI THERE!< /template>
< /category>
```

We have chosen A.L.I.C.E to support our dialogue system because it is a simple tool based on pattern matching that allows extensibility with a huge corpus of text. Yet, it was fundamental to make some modifications: (1) we translated from English to Portuguese the indispensable files so that it covers the main phrases and most common inputs; (2) we included other functions in the AIML interpreter to enable the comunication with the agent during dialogue.

1. **Translation** of the corpus from English to Portuguese was not a straight forward process. The formalism of the English language makes the task of finding default categories to introduce in A.L.I.C.E. corpus easier. The system do not make distinction between a declarative sentence and a

question. In fact, in English there is no need to do this separation of data, and thus, this model favor languages with a unique model for questions.

Translation to Portuguese was a challenge. We had to surpass the absence of gender, take into account the null subject, establish difference between questions and sentences, and be aware that in Portuguese there is more fluctuation of words within a sentence. The most obvious solution and with less cost was to multiply the category objects to match our language needs.

Still, in informal discourse a question is only a question because it ends with a question mark and nothing else in its structure implies that. Certainly, is not a set of innumerous input patterns that will surpass our problem. However, A.L.I.C.E. does not have any inherent goal to achieve, so it has several patterns for general questions which people, probably, find as the most natural way of interacting.

2. **Extending AIML**. Extensibility of AIML and its modular structure smoothed our task towards building the dialogue function of our system. We introduced another tag, $< function >$, to be recognized by the AIML interpreter which provides the interoperability of the remaining modules.

   Whenever the dialogue needs some external information, this tag is activated. That may occur in several occasions:

   (a) *CNET support*

   When the dialogue does not recognise an input, it automatically returns a response acknowledging that fact. To decrease the number of times that such situation occurs we used CNET to help the system producing replies within the context, for a pattern that was not thought of before or that is not so common. How that is accomplished was described in section 6.2.3.

   (b) *Agent's cognitive features*

   Internal stimulus are constantly being activated and suffer some processing. When suitable, it will release the correspondent output that should be placed onto a sentence.

   (c) *Access to memory*

   If a question concerning some information that the agent may have in memory is recognized, a function is called to promptly respond to that input. In that case, the social component of the system is never lost, since it never changes to another mode of interaction to proceed with such request.

If needed, one would easily add any other function without effort. The main requirement is that an implementation must be assured to handle that function.

6.3 Modules

To better describe each module and its function in the whole system, regard the following excerpt of dialogue between Amy and MAY. Amy used to interact with MAY frequently, so the agent already knows her and detains information for linking events and define her life story.

```
MAY >> Olá Amy! Está tudo bem?
Amy >> Está tudo bem:)
MAY >> Como foi o teu dia?
Amy >> Foi normal. Fui ao cinema com o Lyam.
MAY >> E que tal?
Amy >> O filme foi muito bom! O Leonardo DiCaprio
    desempenha um grande papel.
```

Same dialogue translated to English:

```
MAY >> Hi Amy! How are you?
Amy >> I'm fine:)
MAY >> How was your day?
Amy >> Was normal. I went to the cinema with Lyam.
MAY >> And how it was?
Amy >> The film was great! Leonardo DiCaprio
    plays a great role.
```

Data Analyser

The interaction is text-based and all the information extracted is syntactically inferred from it. The *Data Analyser* module receives sentences as input and processes them using the *Natural Language Module*, which uses the natural language tools referred in the previous section. This module extracts from each sentence in input the 6-tuple $< A, Wo, We, Wn, Wt, Ev >$, described in the conceptual model chapter. Table 6.1 shows the tuple parameters extracted from a sentence.

Sentence : *Fui ao cinema com o Lyam.*	
Parameter	**Words**
Action (A)	ir
Who(Wo)	eu, Lyam
Where (We)	ao cinema
When (Wn)	hoje
What (Wt)	--
Event (Ev)	ir ao cinema

Table 6.1: Data Analyser output

Shared Memories Module

This module allows for the representation and processing of the *shared memories* between agent and user, according to the conceptual formulation explained in detail in chapter 4. The module has a sub-module – *Active Goals*, which has the same internal structure as the main module. It refers to the future events that the user has set as a possibility or a scheduled event in his/her life. Future and past events are split using the natural language tools described in section 6.2.1.

Using the information that comes from the *Data Analyser*, relevant events are selected and archived in the agent's memory. The selection process is performed by the *Event Processor Module*, responsible for choosing and creating the objects to be stored.

How it determines whether an event is relevant or not is established by the action (A) in the tuple. Important or relevant actions (A), directly extracted from the probes[7], can be indicators of important events in a teenager's life and consequently worth being saved.

If the event is relevant, the system starts the encoding process. The *Event Processor Module* uses information in *Knowledge Base*, which accounts for the time reasoner described in section 6.2.2 to calculate the exact interval of time, in which the event (G) occurred or is going to occur. Adding to this, the event (G) needs to be contextualized in a period of the user's life. This event is encompassed in three overlapped *Life Time Periods*(LTP) – *a) namorar Lyam*; *b) 18 anos*; and *c) 2010*. The last two are included in the category of fixed periods, more general and broad periods of time that are common in memories' division in people. The first LTP is personally meaningful and activated by the participants (who) in the event.

Once again, taking a look at the example: "*Fui ao cinema com o Lyam*". The verb "ir" is considered relevant. Then, the shared memory object is created and the memory will have the following RDF description:

```
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF
   xmlns:genEvent="http://generalevents.com#"
   xmlns:lifePeriod="http://lifetimeperiods.com#"
   xmlns:memoryLine="http://memoryline.com#"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#">

<rdf:Description rdf:nodeID="xwkGezvP4">
  <lifePeriod:memory rdf:nodeID="xwkGezvP2"/>
  <lifePeriod:genEvent rdf:nodeID="xwkGezvP3"/>
  <lifePeriod:period rdf:datatype="string">18 anos</lifePeriod:where>
  <lifePeriod:period rdf:datatype="string">2010</lifePeriod:where>
</rdf:Description>

<rdf:Description rdf:nodeID="xwkGezvP3">
```

[7] ir, fazer, sair, vir, ter, acabar, chumbar, passar, dar, ser, desister, estudar, partir

```
  <genEvent:lifePeriod rdf:nodeID="xwkGezvP4"/>
  <genEvent:memory rdf:nodeID="xwkGezvP2"/>
  <genEvent:event rdf:datatype="string">ir ao cinema</genEvent:where>
  <genEvent:where rdf:datatype="string">cinema</genEvent:where>
  <genEvent:when rdf:datatype="string">hoje</genEvent:when>
  <genEvent:who rdf:datatype="string">eu</genEvent:who>
  <genEvent:who rdf:datatype="string">Lyam</genEvent:who>
  <genEvent:what rdf:datatype="string"></genEvent:what>
</rdf:Description>

<rdf:Description rdf:nodeID="xwkGezvP2">
  <memoryLine:lifePeriod rdf:nodeID="xwkGezvP4"/>
  <memoryLine:generalEvent rdf:nodeID="xwkGezvP3"/>
  <memoryLine:date rdf:datatype="date">
    datetime.date(2010,3,11)</memoryLine:date>
  <memoryLine:text rdf:datatype="string">
    Fui ao cinema com o Lyam.</memoryLine:text>
  <memoryLine:image rdf:datatype="string">
    c://mypictures/poster.gif</memoryLine:image>
</rdf:Description>
</rdf:RDF>
```

The relation between sentences is determined by some factors including CNET tools previously described in section 6.2.3. Those tools are used by the *Event Processor* to complete a memory with more details or create a new sub-event in memory.

In this particular example the second phrase, "O filme foi muito bom! O Leonardo DiCaprio desempenha um grande papel.", is related to the previous sentence, because it concerns to the same subject. However, neither the verb "ser" nor verb "desempenhar" is relevant to create a new shared memory object. Therefore, the memory level of the previously created shared memory has to be updated. Below is shown an extract of the RDF database where the parameter text has been updated. Graphically the database view of this specific shared memory, can be illustrated as showed in figure 6.5.

```
<rdf:Description rdf:nodeID="xwkGezvP2">
  <memoryLine:lifePeriod rdf:nodeID="xwkGezvP4"/>
  <memoryLine:generalEvent rdf:nodeID="xwkGezvP3"/>
  <memoryLine:date rdf:datatype="date">
    datetime.date(2010,3,11)</memoryLine:date>
  <memoryLine:text rdf:datatype="string">
    Fui ao cinema com o Lyam. O filme foi muito bom!
    O Leonardo DiCaprio desempenha um grande papel.</memoryLine:text>
  <memoryLine:image rdf:datatype="string">
    c://mypictures/poster.gif</memoryLine:image>
</rdf:Description>
</rdf:RDF>
```

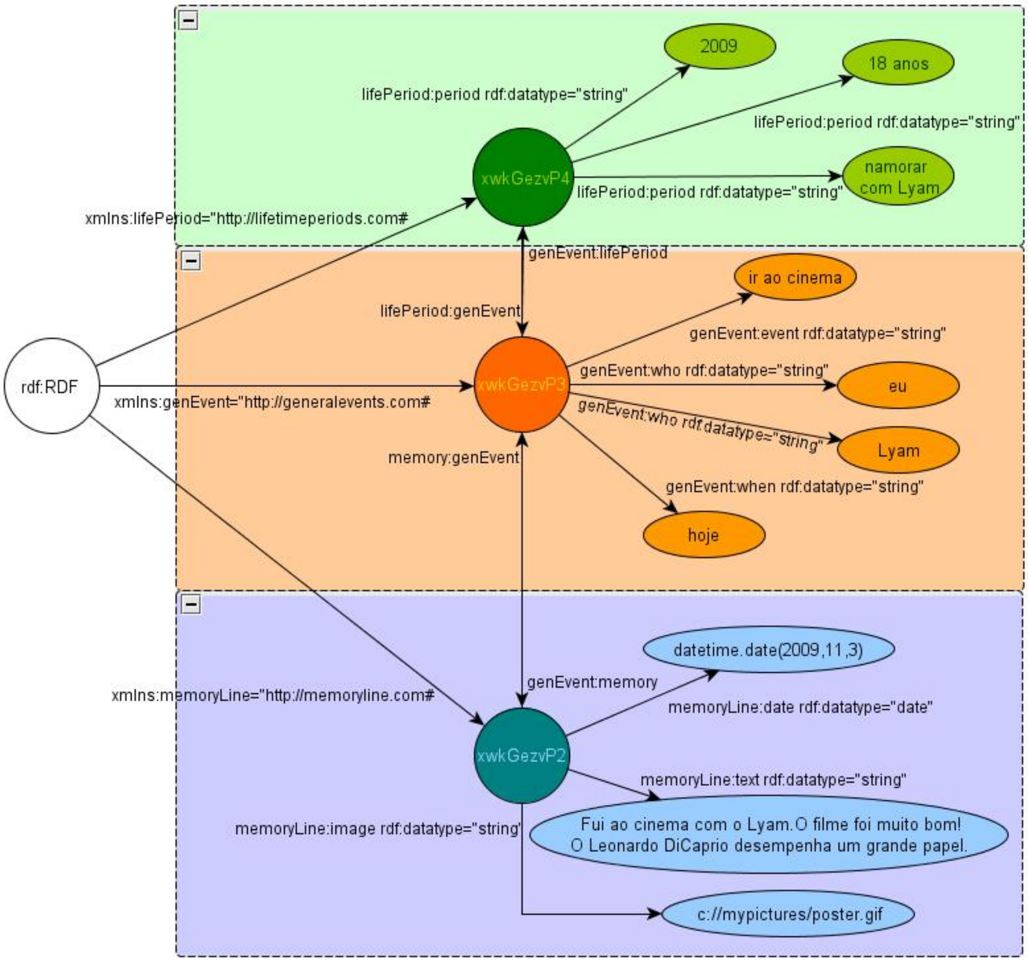

Figure 6.5: Graphical example of the RDF memory description

Dialogue Kernel

The dialogue is a central part of this system because its mechanisms deal with the whole interaction progress. The goal is to let the user talk about his/her day allowing for self reflection. But the user does not have to perform this task alone. The dialogue is a mixed iniciative one to help the conversation flow, although, the user, at any time, can change the subject and lead the conversation. The dialogue has five internal states as shown in Fig. 6.6.

A object *State* is parameterized by the variables in table 6.2.

Each one of these variables controls how and when to switch states. The boolean *complete* controls if the state has to be visited in another cycle of dialog and the *time out* variable warns when the system has stayed in a state for too long. The idea is to carry on the conversation as smoothly as possible.

Notice that the transition between states takes into consideration if the previous input was a question. If that is true it will wait for an answer before it proceeds. To clarify each state's goal, we provide their brief description:

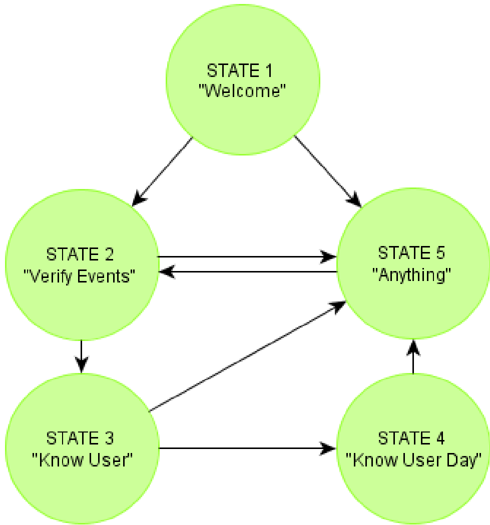

Figure 6.6: Pro-active dialogue cycle in five states

Parameter	**Description**
Id	An integer that identifies the state
Next State	Id of the next state
Previous State	Id of the previous state
Complete	A bollean that indicates if the goal of the state was achieved
Time out	An integer that saves the number of dialog cycles in that state

Table 6.2: Dialogue state's description

- **State One** refers to the inicial greeting in any social conversation. When the agent recognizes that the state has ended it will switch automatically to state two.

- **State Two** is responsible for verifying if there is any active event in the active goals' database. If there is any pendent event, the agent brings it to the 'conversation' to actualize the user's memories of experiences.

  The information retrieved from the active goals is transferred to the *Natural Language Adapter* to be adapted to its correct form, changing the pronouns and the verb tense. After transformed, the data is used to complete the gaps existent in an prebuilt sentence.

- **State Three** aims at obtain from the user information that is relevant for future interactions. Here the agent asks the user several questions about his/her tastes, activities and personal information. Those questions are progressively asked along the interaction.

  In order to be natural, the system asks questions progressively as it gets to know the user. The number of questions vary according to the equation 6.1. The main idea is to determine the number of questions to be asked

in the current interaction, according to how many are left and how many were asked in the previous sessions.

In initial interactions the agent is keen to be familiar with the user and consequently asks more about him/her. Over time, the agent must continue showing interest about the user, but the questions decrease in quantity per interaction.

When all questions for the current session/interaction were asked, the flag *complete* is activated and the system does not return to this state again.

$$\left\lceil \frac{questions\_left \times questions\_previous\_interaction}{questions\_previously\_left} \right\rceil \tag{6.1}$$

- **State Four** focus on encouraging the user to talk about his/her day, seeking for memories of experiences. By asking simple questions, such as "How was your day?", "What are you doing now?" or "What or plans for this weekend?". Those questions are adquadely asked taking into account the time of day and the day of the week. This state has three goals to achieve: *a) ask about the past*, if the user does not interact for some time; *b) ask about present*; and *c) ask about future arrangements.* It also considers for how long the user have been away and provides a empathetic response accordingly.

  When this state is complete, the agent suggests the user some other activity like make doing some exercise, enjoy the rest of the day, or take a walk.

- **State Five** is present when the dialogue reaches a point of atomic patterns that do not belong specifically to any topic of conversation, but at same time, can fit any of them. That is the reason why all states have a link to this one, because eventually at some point the conversation will fall in this category.

  This state occurs in situations when the user starts talking about a parallel topic or when there is a miss pattern and the system does not understand the user.

  One common problem is to be stuck on this state in a cycle. To recover from that, if the agent does not understand the user after a certain time, a variable *time out* indicates that is time to move on.

To exemplify how the cycle works, please consider the following example (please see its translation on appendix D):

```
1          Amy >> Ola
2          MAY >> Ola Amy! Como estás?
```

```
3         Amy >> Está tudo bem
4         MAY >> Óptimo! Fico contente por saber.
5         Amy >> E tu?
6         MAY >> E eu?
7         Amy >> Como estás?
8         MAY >> Estou a correr dentro dos parametros normais.
9         Amy >> Bom saber.
10        MAY >> Ainda bem que forneço informação útil.
11        MAY >> Como foi ir ao concerto dos Cranberries ontem?
12        Amy >> Foi um espectáculo!
13           Ela cantou as músicas todas!
14        MAY >> Isso deve ter sido muito fixe.
15        Amy >> pois foi
16        MAY >> Eu também acho.
17           Está a ser um dia cheio de trabalho?        ...
```

State one operates from lines 1 to 5. After that, the dialogue jumps to **state 5** (lines 6 to 10) to carry out the dialogue without talking about something in particular. When the time is up the dialogue switches to **state 2**, where the agent verifies pending events. From one previous interaction the agent knows that on the previous day Amy was supposed to have been at the Cranberries' concert, so the agent asks about it (line 11). If the answer is negative the event is ignored. On contrary, if the event really happened the event is copied to the shared memories database.

From lines 12 to 16 we can see the small talk provided by **state 5**. After that, the system jumps to **state 3** that is permanently completed and starts by inquiring the user about the present (**state 4**). The interaction moves on until **state 4** is completed.

Agent's Cognitive Features

The function of this module is to 'sense' if any internal stimulus lead to a pattern identified in data, after a memory had been created or assist dialogue either in state 2 or 4. It enables three views of the data 1. *Tracking Goals*; 2. *Virtual Sensing*; and 3. *Forecast.* These three functions grounded on data in the agent's memory allows for the creation of the agent's responsiveness.

1. **Tracking Goals** refers to the function of state 2 in the dialogue cycle of each interaction. During stage 2 the agent accesses to the active goals database to extract some event that needs to be stored permanently or simply eliminated. This is an interactive process because the agent needs user's feedback to do the operation.

   After extracting the desired information, if this exists, the *Natural Language Adaptor* is responsable to adequate time expression and verb tense to the gaps in a defined sentence in question form.

2. **Virtual Sensing** is concerned with the agent's ability to sense that something is missing in the told event. Elements that can be missing are the place, the participants, or even the time.

   This feature of the system can work in different situations. If there is information in the database about the referred event, the question about what is missing uses that information. Otherwise, it can simply ask the user "Onde é que (+auxiliary verb) $<$ *action* $>$?", "Com quem é (+auxiliary verb) $<$ *action* $>$?"

   To clarify this issue, let's look at the following excerpt of dialogue:

```
1           ...
2           Amy >> Daqui a pouco vou passear o Teddy.
3                  (In a while I'm going to walk Teddy.)
4           MAY >> Vais ao parque?
5                  (Are you going to the park?)
6           ...
```

   In line 2, Amy says that she is going to walk her dog, Teddy. The event "passear Teddy" is frequent in Amy's life and the agent recognises it. In her sentence the element 'where' is missing, so the agent combines two things that it knows: most of the times the event "passear Teddy" happens is in the park and 'where' is missing in this sentence. Then, the agent conclude that this time that could also be true.

   When this search in the database is performed, we compute a view of the events that match the criterion of the event introduced. We set that it the agent would be confident in believing that some fact is true if that fact occurs at least 51% of the time in proportion with the number of events in memory. Otherwise, the agent is not sure and consequently, does not introduce the fact in a question form during the dialogue.

3. **Forecast** normally refers to future, but in this case it refers to anything that the agent does not actually know but still can be inferred using the data in memory. The aim of this feature is particularly useful in diversifying the conversation when the system asks about yesterday or tomorrow in state 4 of the dialogue cycle.

   In contrast with the previous feature, this takes in account the day of the week to make a prediction. At some point of state 4, when the agent should ask something about future arrangements, the question could be formulated as "Amanhã vais correr para o estádio?" (Are you going jogging to the Stadium, tomorrow?). The agent knows that several times in the past the user told it that at Saturdays he/she used to going jogging to the stadium.

All the functions that this module provides make use of a very cue sensitive database, which facilitates building the social bond. It is easier for the agent to recall the exact episode accessing to any level of the RDF structure.

Furthermore, such structure provides views of the database given by the lifetime periods, events or dates, which decreases the space of search. It is also this social process of showing acquaintance and interest in user's life, that we believe will make the difference.

Although, this agent does not forgets, it does not consider all events in memory to make its forecasts. People change over time and the agent tries to keep up. Once again, lifetime periods have an important role in reducing the space where the agent looks for information.

6.3.1 Memories Retrieval

In the previous section, we referred three different situations in which the agent can access intentionally to memory. Yet, the user can ask for his/her own thoughts in two different ways: (1) asking directly to the agent; and (2) clicking on the interface buttons.

- **Access to memory in dialogue**

  We took advantage of the technology embedding this functionality in A.L.I.C.E. scripts. We assumed that when people ask for some information, they start their question by using one of the following interrogative pronouns: *Quando*, *Onde*, *Que*, *Quem*, allowing the user access time, location, action or participants, respectively, of any event in memory. Any other fluctuation of the words in the sentence is not considered due to being so unpredictable and could occur any change of meaning. Below is an example of the processing instructions for an input started by "Onde é que ...":

  ```
  <category>
  <pattern>ONDE É QUE *</pattern>
  <template>
  <think><star/></think>
  <function>findWhere</function>
  <condition name='responseValid'>
  <li value='1'>Resposta: <get name='actionLocation'/></li>
  <li value='0'>Nao tenho informacao sobre: Onde é que <star/></li>
  </condition>
  </template>
  </category>
  ```

  This process is performed in three steps:

  1. Pattern matching – The user intention is recognized by matching the input to one of the scripts.

     ```
     <pattern>ONDE É QUE *</pattern>
     ```

2. Access to agent's memory – The *template* tag sets out the response and it can encompass several instructions to be performed before the agent prints it.

   (a) Initially, the request is saved:

   ```
   <think><star/></think>
   ```

   (b) Next, the request is decomposed in elements: *who*, *what*, *when* and the *event*.

   (c) With that information, the correspodent procedure is called

   ```
   <function>findWhere</function>
   ```

   This function uses the RDF's query language – SPARQL, to perform the request to the database. It will take the form: $O =< G, \ Lv, \ Wr \ >$, where Lv is the general events' level and Wr is Where.

3. Response – Finally, it is verified if the agent 'reminded', in this case, the place where some action happened. A control variable indicates whether the information is known or not.

```
<condition name='responseValid'>
<li value='1'>Resposta: <get name='actionLocation'/></li>
<li value='0'>Nao tenho informacao sobre: Onde é que <star/></li>
</condition>
```

- **Access by click**

  This functionality allows direct access to the information by clicking on the interface buttons. In the bottom of the interface there is the Memory Line, which stands for the base level of the memory hierarchy. Each cloud represents an entry in the 'diary', which is identified by a day (fig.6.7).

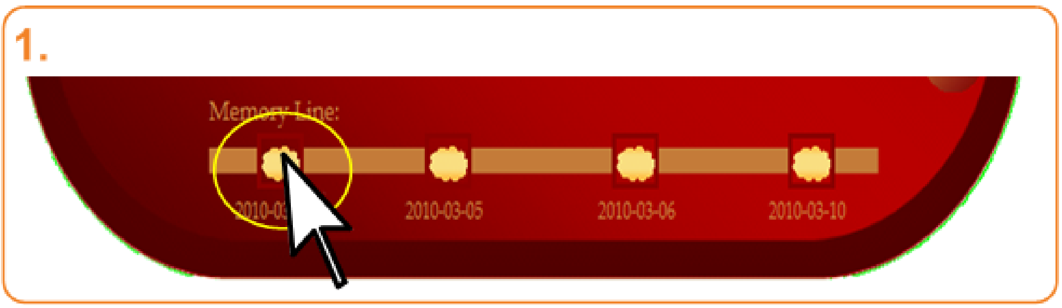

Figure 6.7: Stage one of retrieval using the interface buttons

By clicking in one of the clouds a list of events for that specific day is presented, as shown in Fig.6.8 (stage 2). The retrieval process is activated when a day is selected and an event is expected as a final result. So, the final event (G) in stage 3 of fig.6.8 is obtained by questioning the database $G =< Wr, \ Lv, \ O >$, with the following parameters Wr = generalEvent; Lv = memoryLevel; O = 2010-03-02. Notice that, for each day, there is

Figure 6.8: Stage two and three of retrieval using the interface buttons

a list of retrieved events. By selecting one of the events the user can see its description.

The musical note and the frame in the figure, are two clickable items that allow to listen a sound or to see an image that were previously added to memory, respectively.

6.4 Concluding remarks

The purpose of this chapter was to describe all the components in the companion system, as well as, how the conceptual model for memory is integrated in the whole system. This chapter started with a description of the supporting tools essential to the functioning of the system how their functionalities were used to achieve our purpose. Next, the architecture for the companion MAY was presented and all modules described. We focused on showing how the encoding process works and how the input is modeled to fit in memory.

We tried to transmit that the data shared with the agent is used in a social relationship building and that those little things that we remember about our friends, where he likes to go jogging, what he used to do on Friday nights, contribute to maintain the relationships over time.

Chapter 7

Evaluation

This chapter describes two different experiments performed with MAY. The first one was a preliminary test that was needed to verify how acceptable the agent's dialogue was. The second one, which we will detail here, consisted in a between subjects evaluation to answer the major research question stated in the Introduction. In that evaluation we tried to verify if the presence of *shared memories* enabled the development of specific relations between user and the system, in comparison with the absent of such element.

7.1 Preliminary Tests

As stated before, the dialogue is a central piece of the system due to its proactive behaviour. It is the dialogue that somehow commands the whole interaction from begin to end. The core of our dialogue system is the A.L.I.C.E engine and its correspondent scripts, which were translated into Portuguese. Plus, some scripts had to be modified and the corpus improved to better respond to what concerns teenagers.

Although A.L.I.C.E is a robust system, the accuracy of the agent's actualized scripts and how they cover the scope of the dialogue had to be tested in a real situation. As such, the dialogue component was subjected to pre-tests involving the user.

To do that, we created a console application consisting only of the agent's dialogue. It maintained an internal state, knowing the user's name and the attained state in the dialogue cycle. Purposely, the memories' detection was not present. The application had to be installed on the user's computer and it maintained a log of all the dialogues, which would be analysed at the end of the experiment.

This application was given to eight people (ages between 22-25) that had to interact with the system daily, for some period of time (about 2 weeks). To those participants, instructions were given on how MAY performs, letting them know that MAY's offers support in one's everyday life, being capable of talking about any subject that might concern teenagers. Our aim with this experiment was to extract information, from different contexts containing

a wide diversify of agent responses and making it more capable of finding a response for many types of situations.

Some of the subjects were aware of the kind of behaviour an automatic systems could achieve, and indeed we verified that their lines in the dialogue were brief and concise. Yet, other not so familiarized users write long sentences, with more than one topic in each sentence, interacting with MAY as if it were a real person. However, given that this is the type of effect that we want to achieve with our companion, their contribution was very good from out perspective. On the other hand, as the introduced some noise in the input data, that confused the agent and contributed to a frustrating experiment for those participants. During the tests we also noticed that the input frequently did not match the patterns in scripts, what added some difficulty to this task.

With the logs obtained, some patterns of writing were extracted at the end which contributed to increase our corpus of patterns. We introduced some common assertions and we chose to respond to events according to their verb, as a simple solution to our problem. With these changes incoorporated in a new version of MAY, we were then able to perform some more focused evaluation of the system.

7.2 Evaluating Memories in the Memory

After testing and improving the dialogue system, we focused on the main evaluation phase. We wanted to find out if users were capable of recognising some social capabilities on MAY's discourse, as well as, capable of identifying those capabilities as temporally grounded. We wanted to see if users perceive the agent as intentional, based on the result of previous interactions stored in a timeline.

Yet, at this phase, we should take into account a key issue related to long term evaluation. A system, as MAY, that gathers the user's memories should stay with him/her for a long period of time, to give the opportunity for the agent to collect those memories of experiences. However, that was an unaffordable task to be performed during the duration of this dissertation. Further, finding a considerable set of people (teenagers) available and that agree on participating in such long study revealed quite difficult at this stage.

As such, in this section, we start by explaining how we have introduced a possible element for simulating long term interactions, in particular through the adaptation of the Persona design method carried out into the evaluation phase. As such, we will next describe the goal of the overall experience, as well as, its methodology and results.

7.2.1 Simulate long-term

The use of *personas* has recently become popular worldwide as a design method and was used for the development of MSN Explorer products (Pruitt & Grudin 2003), for example. Its success is due to its power in engaging the designers during the prototyping phase. Researchers argue that people easily remember

stories and narratives than a technical report, and as such personas with their stories can be very powerful. Further, *personas* act as a mechanism to enhance memory, attention and help on the organization of data (Grudin & Pruitt 2002) carried out during the design phase.

This idea is also prevalent even in the design of TV series. It is frequent to see people believe that the characters are real and their life realistic. At the same time, people are keen in discussing details and make predictions about characters behaviour according to a set of characteristics, which they have gathered from few episodes. On the other side, the actor builds his character and exercises a history where the character may fit. Certainly, the actor adds some details to help him behave more naturally (Grudin & Pruitt 2002), as well as, the designers make assumptions about the created *persona*.

So, we brought the concept of *persona* into the evaluation stage in order to assess MAY's memory performance in a long term interaction. As such, we created a persona, called Amy (already described in Chapter 5) To simulate the long-term issue, we previously interacted with the system as Amy, giving it the opportunity of gathering enough information to perform in a real situation. We introduced memories of experiences into the system, taking into account the life story we had created for Amy, supported by the idea that models of fictional people can be engaging as real people (Grudin 2006).

This idea was supported by the belief that if the *persona* is efficient in engaging designers to focus on users, it should be equally effective on engaging users, when they perform tests with some system or interface. That issue was already raised by (Gomes et al. 2008) and they used *personas* to test the usability of a web prototype.

7.2.2 Objective of the experiment

With this experiment we wanted to validate the raised hypothesis introduced at the begining of this dissertation.

> *If the companion uses a model for "shared memories", inspired in some aspects of human memory, and is capable of indexing user's experiences and use that temporally grounded information in a social interaction, users will establish a stronger companionship relation with the agent based on what the agent knows.*

To support our hypothesis we developed a companion architecture using a model of autobiographical memory for shared memories between agent and user. We explored the social function of autobiographical memory and we created MAY capable of making use of some of these social capabilities during interaction. Its aim was to develop the relationship with the user and create some proximity between them.

7.2.3 Procedure

A total of 90 participants (72 male, 18 female, aged 18-24) took part in the experiment. All of them were undergraduate students from IST (Technical

University of Lisbon) and the study was available through an online questionnaire.

The questionnaire conducted the participants through three stages (see fig. 7.1). In the first two stages the subjects had to witness an interaction between Amy and MAY, which they should observe carefully. After each interaction they would be asked about MAY's behaviour. The last stage aimed at measuring how MAY's attitudes induce the relationship between Amy and MAY, for that we applied an established friendship questionnaire.

In each stage, when inquired, the subjects had to classify statements in agreement with a five-point Likert scale (1 - I strongly disagree; 3 - I don't agree or disagree; 5 - I totally agree), coupled with a justification to validate the response.

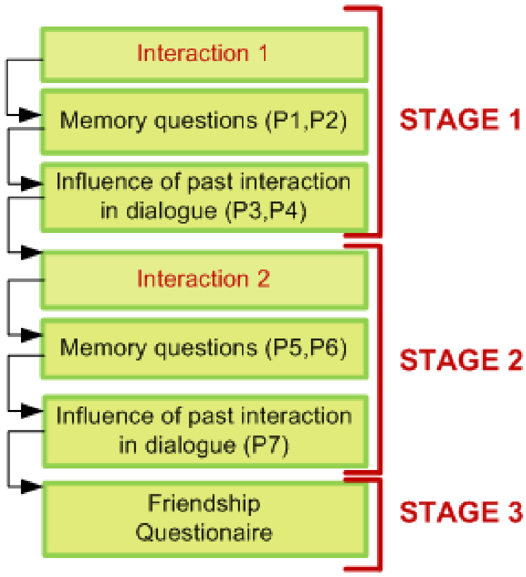

Figure 7.1: Evaluation's stages

Notice that none of the subjects knew what the system did, neither if it should act as a companion or an agent that saves personal facts about the user through shared memories. Plus, the interactions between Amy and MAY reflected some of the agent's capabilities of using the *memories of experiences* collected during previous interactions with the system.

The full questionnaire and interactions between Amy and MAY are presented in Appendix D.

7.2.4 Manipulation

We conducted a between-groups experiment to evaluate the raised hypothesis. Thus, one group of participants was exposed to the *memory* condiditon and the other group to the *no memory* condition. The online questionnaire automatically randomized the participants to one of the conditions, which express the following situations:

- *memory* – there is no modification in MAY's architecture. There is a link to the *Agent's Cognitive Features Module*. This module is responsible for bringing back relevant information for the current situation.

- *no memory* – MAY's architecture was manipulated and there is no access to the *Agent's Cognitive Features Module*.

  However, in this condition, MAY still knows the user's name and maintains the pro-active behaviour based on the design of the dialogue system. That is, it still 'cares' about the user by asking intentionally generic questions to get information about user's day.

7.2.5 Results

The collected data was analysed using the Mann-Whitney test to compare the differences between the two conditions.

Stage1

In the first stage of the experiment the users whatched an interaction between Amy and MAY, where the agent shows that he knows some predefined goals in Amy's life. Below are some examples of the type of interaction (*memory* condition)[1]:

```
11        MAY >> How was the Cranberries concert last night?
12        Amy >> It was awesome!
             She sang all the songs!
13
...
25        MAY >> I'll be waiting.
                 Did you go out for dinner two days ago?
26
27        Amy >> Yes. It was my sister's birthday.    ...
```

Rather, in *no memory* condition such acquaintance is not verified, but the agent displays an empathetic behaviour embedded in the dialogue system:

```
11        MAY >> How was your day yesterday?
12        Amy >> It was awesome!
              I went to Cranberries' concert.
...
25        MAY >> I'll be waiting.
                 Tell me your last and important memories?
26
27        Amy >> Saturday I went out for dinner.
              It was my sisters' birthday.
          ...
```

Table 7.1 depicts a summary of the results obtained for the different questions at this stage of evaluation and exhibit the clear differences between the

[1]The full interaction is on appendix D both in English and Portuguese

two conditions (see also fig.7.2 for a graphical visualization of the descriptive statistics of Table 7.1).

As the results show, users recognised the presence of knowledge about goals (Q1, Q2) and the results between conditions were significant ($p < 0.001$). Further, the user recognised that knowledge as result of previous interactions of Amy with MAY (Q3 and Q4). As displayed in Table 7.1 the effect of Q3 ($r = -0.68$) accounts for 46% of the variance, showing that the agent behaviour was recognized as temporally grounded.

Cognitive Features	Id	Question Statement	Descriptive Statistics *memory (N=46)*	*no memory(N=44)*	Mann-Whitney differences between conditions
			Mdn[Quartiles]	Mdn[Quartiles]	
Tracking Goals	Q1	MAY knew about the event "go to the cranberries' concert"	5[4,5]	2[1,3]	U = 129.000 $p < 0.001$ r = -0.777
	Q2	MAY knew about the event "go out have dinner"	4.5[4,5]	2[1,3]	U = 232.500 $p < 0.001$ r = -0.68
Influence of past Interactions	Q3	MAY knew about the event "go out have dinner" because Amy had told it in any past interaction	5[4,5]	1[1,3]	U = 248.500 $p < 0.001$ r = -0.679
	Q4	Past interactions have influenced the current one	5[4,5]	3.5[1,5]	U = 527.500 $p < 0.001$ r = -0.452

Table 7.1: Mann-Whitney statistics for the first set of questions

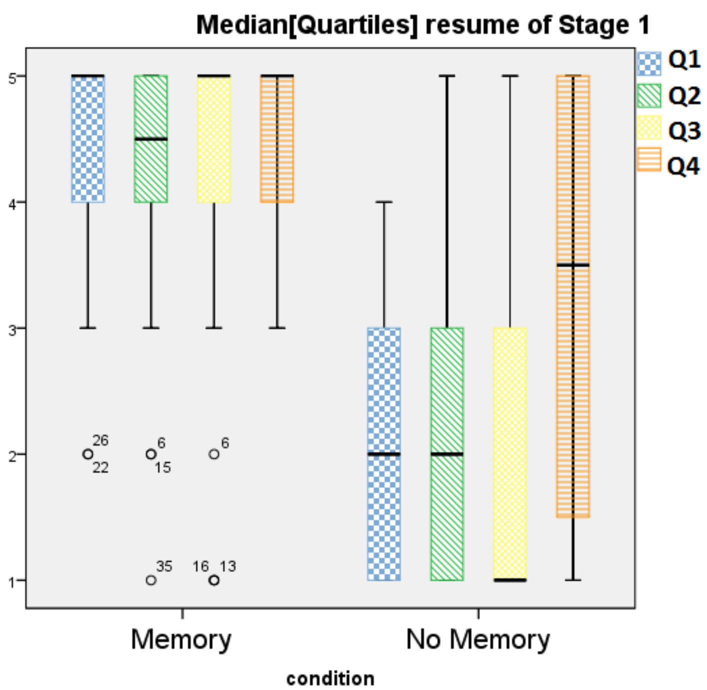

Figure 7.2: Descriptives Statistics for Stage 1

However, *no memory* condition had a wide discrepancy of opinions that ranged within the five points (Mdn[Quartiles]=3.5[1,5]), when the participants

were asked about the influence of the past (Q4). This dispersion of values is due to the agent knowing the user's name. For some participants that fact was a sufficient (in the absence of other) for the existence of prior interactions. As one user justified "MAY knew to whom was speaking, as she referred as Amy".

Stage2

In the interaction portraied in the second phase of the evaluation, the *memory* condition enhanced the agent's acquaintance about some details of common or regular events in Amy's life.

```
12        Amy >> Yes. In a while I'm going to walk Teddy.
13        MAY >> Are you going to the park?
...
16        Amy >> This evening I'm going to the cinema
17        MAY >> Are you going with April, Amy?
          ...
```

Oppositely, in *no memory* condition the agent keeps answering to Amy with general sentences that could fit in most situations, using the pattern-matching mechanism offered by the dialogue system.

```
12        Amy >> Yes. In a while I'm going to walk Teddy.
13        MAY >> Sounds good to me.
  ...
16        Amy >> This evening I'm going to the cinema
17        MAY >> I would like to go too...
...
```

Cognitive Features	Id	Question Statement	Descriptive Statistics *memory (N=46)*	*no memory(N=44)*	Mann-Whitney differences between conditions
Virtual Sensing	Q5	MAY knew something about the action "walk Teddy"	4[3,5]	3[1,4]	U = 589,000 $p < 0.001$ r = -0.370
	Q6	MAY knew something about the action "go to the cinema"	4[3,5]	4[2,4]	U = 722.500 $p < 0,05$ r = -0.256
Influence of past Interactions	Q7	Past interactions have influenced the current one	5[4,5]	4[4,5]	U = 797,500 $p < 0.051$ r = -0.206

Table 7.2: Mann-Whitney statistics for the second set of questions.

Although, in this stage of the experiment the differences were not clear (Table 7.2 and fig.7.3 as a graphical representation), the results were interesting. one can see that the two conditions are somehow quite close. These results may have happened for two reasons: 1) the agent's replies may have lead to a misunderstanding by the users. The responses make them feel that the agent 'knew' something about some characteristics of the activity; 2) by watching the previous interaction at stage one.

The participants probably had expectations about the second interaction, which make them think that the agent took conclusions similar to their own assumptions. According to user's justifications "MAY recognizes cinema as a fun activity because he replied that he would like to go"(referring to his answer to Q6).

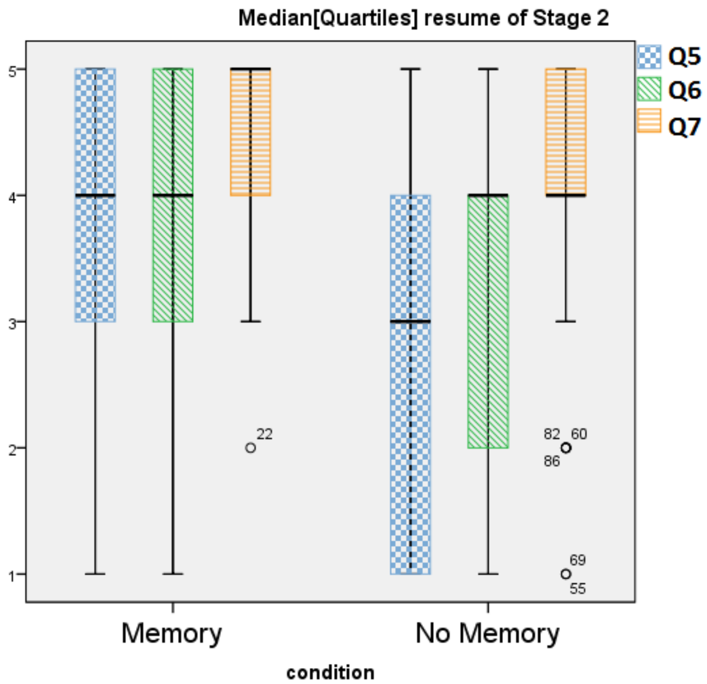

Figure 7.3: Descriptives Statistics for Stage 2

Stage3

Measures

One of the aspects that we were interested right from the begining was to identify if the social mechanisms of memory used in this companion system lead to some level of companionship between user and agent. With MAY we wanted to build a companion that stays with the user for a very long time, developing a relationship and getting to 'know' the user's preferences and wishes (Catizone et al. 2008).

In human relationships it is possible identify a type of relationship that fits in this definition – *friendship*. Therefore, we employed the McGill Friendship Questionnaire (MFQ) (Mendelson 2009), which measures six dimensions of friendship between people. We used this questionnaire to classify the relation between MAY and user. Mendelson has identified six different functions of friendship conceptually distinct:

(1) *Stimulating Companionship* – engagement in enjoyable, fun and exciting activities;

(2) *Help* – guidance, aid and other types of help:

(3) *Intimacy* – being attentive to other's states and needs and open to honest expressions about thoughts, feelings and personal information;

(4) *Reliable Alliance* – keeping available and loyal;

(5) *Self-validation* – comfort, encourage and help the friend on keeping positive confidence in himself; and

(6) *Emotional Security* – providing comfort and confidence in novel or threatening situations.

According to Allan (Allan 1989) friendship is "a relational term which signifies something about the quality and character of the relationship involved". Similarly, we wanted to measure the type of the relationship that the agent is capable of developing with the user based on what it knows about the him/her. With MFQ we can somehow get a glimpse of the qualify the relationship between Amy and MAY. In particular, we were interested to examine if positive aspects of the relationship (de Souza 2006) prevail in *memory* condition in comparison with the *no memory* condition.

The used assertions of MFQ were manipulated to fit into our experiment. That adaptation was based on the results obtained by (Leite et al. 2010) in a online survey, in which the users had to associate a set of assertions with the dimensions of MFQ. Our experiment and interactions within both conditions are presented in appendix D.

Notice that the *Emotional Security* dimension was not measured in this study. The main reason resides in the fact that in order to recognise this dimension one needs much more than two interactions for the users to understand how MAY can provide comfort to them, as Leite et al (Leite et al. 2010) pointed in their study. Plus, the agent is only prepared to recognise situations that need a concerned response at the initial state of the dialogue and does not recognize emotional states during the interaction.

Results

At this stage of the evaluation, we applied the MFQ to measure the quality and the characteristics of the relationship. The dimensions *Intimacy* (fig. 7.4) and *Companionship* (fig. 7.5) were the ones that differ significantly ($p < 0.001$) in the extent of both conditions.

The dimensions *Help*, *Self-Validation*, *Reliable Alliance* are embedded in the dialogue structure, so the pro-active feature or 'attitude' of the agent contributes to the high level of agreement with the correspondent statements, in both versions of the questionnaire. The agent encourages the user, gives

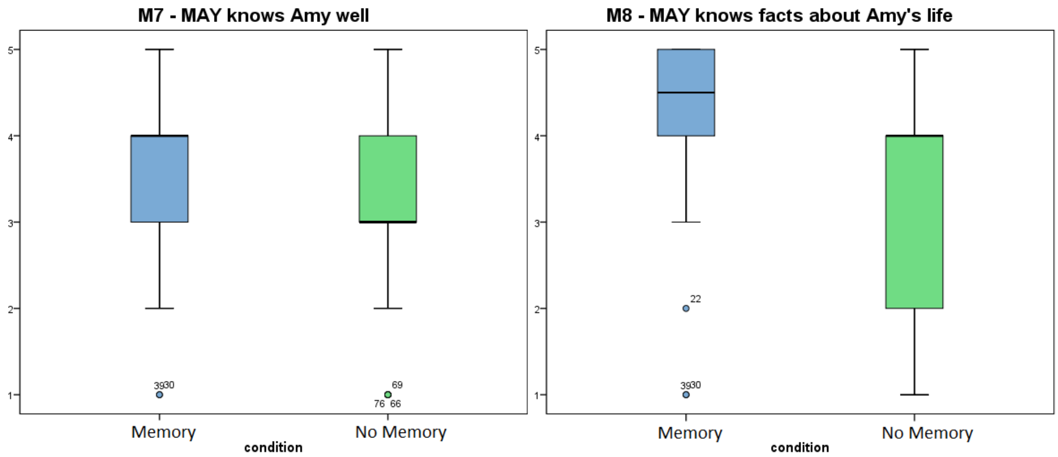

Figure 7.4: The two bloxplots show the differences between the two conditions relative to the *intimacy* dimension

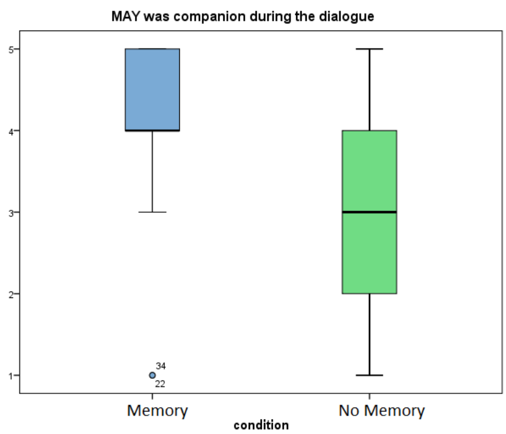

Figure 7.5: The bloxplot shows the differences in the *companionship* dimension

advices and has an empathetic behaviour that helps in the maintenance of the relationship.

As Table 7.2 shows, that differences were not significant for those conditions. However, looking at the participants justifications was evident that they understood the agent's notion of time and that events talked about were theme of conversation between Amy and MAY in some past interaction(s). For example, some users' justifications were "Probably that information was mentioned before"; "Amy told MAY before"; "MAY knew that Amy usually goes to the cinema with April"; "MAY thought that Amy was going with April".

Intimacy and *Companionship* account for 11% to 26% of the variance, respectively, what suggests a wide effect of our experimental condition in these two dimensions, which we believe to be equally important in the maintenance of a relationship and enough to satisfy our hypotheses. Some studies, such as (de Souza 2006) verified that when friends are seen as a primary source of social support, companionship and intimacy are quite important factors that

Friendship Dimensions	Id	Question Statement	Descriptive Statistics memory (N=46)	no memory (N=44)	Mann-Whitney differences between conditions
			Mdn[Qaurtiles]	Mdn[Quartiles]	
Companionship	M1	MAY is friendly	5[4,5]	5[4,5]	U = 842.000 $p < 0.05$(1-tailed) r = -0.17
	M2	MAY was companion during interaction	4[4,5]	3[2,4]	U = 433.500 $p < 0,001$ r = -0.512
Help	M3	MAY's comments are useful	3[2,4]	3[2,4]	U = 955.500 *ns*
Self-Validation	M4	MAY does Amy feel that she can do things well	4[3,4]	4[3,4]	U = 975.500 *ns*
	M5	MAY encourage Amy	5[4,5]	5[4,5]	U = 995.500 *ns*
Intimacy	M6	MAY have interest about Amy's life	5[4,5]	5[4,5]	U = 949.000 *ns*
	M7	MAY knows Amy well	4[3,4]	3[3,4]	U = 639.000 $p < 0.05$ r = -0.332
	M8	MAY knows facts about Amy's life	4.5[4,5]	4[2,4]	U = 582.000 $p < 0.001$ r = -0.383
Reliable Alliance	M9	MAY woul still Amy's friend even if a month pass	5[4,5]	5[4,5]	U = 982.500 *ns*

Table 7.3: Mann-Whitney statistics for the agent's characteristics

make those relationships endure.

7.3 Concluding Remarks

In this chapter we described two evaluation studies done on our companion's architecture. The overall goal was to measure the user's perception of the relationship that the system might develop with the user based on its memory functions. The experiment was done in three stages using the persona Amy. Users had to classify the relationship between Amy and MAY, after the agent showing some knowledge about her life. This classification was based on five of six dimensions of friendship.

The manipulation of our experiment maintains constant the dimensions *Help*, *Self-Validation*, *Reliable Alliance*, which are embedded on the dialogue feature common to both conditions - *memory* and *no memory*. The results are in agreement with this initial specification, showing no difference in both conditions.

It is on the *Intimacy* and *Companionship* dimensions that our experimental condition has expression. The results for questions M7 and M8 were significant ($p < 0.05 \, and \, p < 0.001$) showing that introducing the shared memory factor on companion system can contribute to enhance the quality of a relationship between the user and the entity. The results emphasised the need for not only the ability to remember, but also the capacity to remember events, and details of events, previously shared. Also, the results for M2 suggest that agent's responsiveness, showing that it has been listening, is more enjoyable and capable of simulating some proximity.

Yet, the results for questions M1 and M6 are probably the most interesting. These questions are encompassed in *Companionship* and *Intimacy* dimensions, respectively, and there is no significant difference within both conditions for (only) these two questions.

These results may have been influenced by the interaction on stage 2, where differences were not very clear. In fact, responses like "I would like to go" are more closely related to a friendly relationship that just simply shows acquaintance about the person with whom Amy used to go to the cinema. A more careful choice of neutral replies for the agent may influence positively the overall results.

However, it was clear that the agent's responsiveness as a result of its memory structure had a positive effect on the experiment. Furthermore, the outcomes corroborate the Nelson's argument about how the social function of memory, the *sharing memories* process, contributes to develop intimacy, which is essential to maintain a relationship.

Although, the memory model has not been directly tested, the results are based on what the system is able to do with the data in the *Autobiographical Memory Module* and *Active Goals*. It was enhanced in the performed tests so the way how data is indexed can provided a prompt and natural response by the agent, and as one participant noted "the memory contributes to a more real dialogue". Moreover, using the *persona* factor in our experimental scenario we intend to take advantage of its engagement effect and expect that users perceive the social interaction with it as real.

Chapter 8

Conclusion

Artificial companions aim at providing pleasing and interesting experiences for users in some task accomplishment over multiple interactions. They envisage a change in the way interactions take placebetween humans and machines, tryin to turn them into relationships. However, so far, most of the companion systems lack in certain mechanisms which leads to repetitive behaviour, decreasing the users' engagement over multiple interactions.

To overcome this issue, researchers have started exploring memory architectures in virtual agents, which have become an important component when we try to improve agents' interactive performance. Still, to create relationships that last for long time, agents should not concentrate in the agent's autobiographical memory and start to include users experiences, as well.

With this dissertation we wanted to address the following problem:

> *How can we build a socially enabled agent that acts as a companion, and is capable of participating in the process of 'sharing experiences' with a user, and at the same time more, lead to the development of a long term relation?*

To try to solve this problem we formulated the hypothesis:

> *If the companion uses a model for "shared memories", inspired in some aspects of human memory, and is capable of indexing user's experiences and use that temporally grounded information in a social interaction, users will establish a stronger companionship relation with the agent based on what the agent knows.*

In order to prove the aforementioned hypothesis we investigated how human memory works and how the process of sharing memories of personal experiences is available by autobiographical remembering. Using a model in three layers for the agents memory we tried to accomplish a very cue sensitive memory structure, in which all levels are accessible allowing memory triggering at any layer. It also allows the agent to get from the memory the best fit for the current situation. That memory model was then introduced in a companion agent, MAY, which was built including the user in the design process.

To evaluate how this model of shared memories contributes to the development of companionship, we have conducted a between users experiment to classify the relationship that can be achieved with such memory structure. We exposed the participants in the study to one of two conditions *memory* and *no memory*. The latter accounts for the companion system without access to shared memory module and consequently, incapable of performing with its full capacities. The former, refers to the agent as it was designed.

The experiment had three phases. The first two intended to capture if the user perceived the agent's intention and recognizds the elements in the dialogues as temporally grounded an effect of previous interactions. The results shown that users have clearly perceived that the agent has knowledge about Amy's life, when the information is temporally well defined. On the other hand, when the MAY refers to specific details of common events, their relation to the agents' memory is somehow blurred. Personal assumptions about how some activities are performed added some noise to our sample. Yet, statistical differences between the two conditions were verified.

The third phase of the experiment intended to classify a kind of relationship that MAY can develop using the functionalities that the participants had opportunity to experience. This classification was based on McGill Friendship Questionnaire (MFQ). We obtained positive results for two dimensions of friendship, *intimacy* and *companionship*, which account for 11% to 26% of the variance, respectively. These were interesting results for this first prototype which corroborate Nelson's argument about how the social function of the sharing process contributes to development of intimacy, and consequently, the maintenance of a relationship.

This companion prototype enhances some social aspects that is possible to achieve with such memory structure capable of indexing user's memories of experiences. Hence, its functionalities and the efficiency on retrieval gives it the ability to perform in a social environment. We explored how acquaintance about one's life can influence positively a relationship and we introduced such characteristic into a conversational companion. Yet, this memory structure may offer many others possibilities that can be explored in future work.

8.1 Future Work

Although the results achieved seem encouraging, MAY still has many limitations that should be addressed in order to achieve a state of the art prototype to be tested by many users, at home for a long period of time. As such, we can see many directions to pursue regarding this memory structure, as well as some improvements of this companion prototype. They are as follows:

- First, it would be important to perform a direct evaluation with the system. We are now planning to extend the use of the created persona so that users can play a role and interact with the system as Amy. Using the persona effect as an engagement technique, we expect that users believe that she is real as they start interact as her through a "roleplay"

type of evaluation. This may surpass long-term evaluation issue, privacy issues, which are important at this stage and allow us to control of the environment where this experiment is performed.

- Also, in the performed evaluation study we verified that women's classification of the sentences did not deviate from the median for each question. Some psychological studies (de Souza & Hutz 2007) verified that differences in gender influence perception of quality of relationships. Although this may be also true in our case, our study was not very uniform in gender, so we cannot take any conclusion base on the data we have. So, it should be interesting to conduct a study with more females in the sample and compare the results.

- When we compared some related work, we stressed that wearability would be an important feature in any companion system. We argue that any companion should be present in any occasion and step in when the user asked for it. A system as MAY, would benefit of such integration in a mobile device. At first, the natural language processing will take less effort because people tend to restrict what they say to less words. Plus, the system would take advantage of the mobility to have some contextual information for an enjoyable and perhaps more realistic interaction.

- Finally, there are interesting possibilities for a system that saves so valuable data as the important or relevant events in one's life. We believe that a correct use of this information will enable the system to help the user to reflect about different situations based on some emotional characteristics, thus enabling some informed self-reflection. Further, it can allow us to explore the directive function of autobiographical memory and guide the user in future behaviour and choice of actions in real life situations. Yet, those are not trivial issues, but at same time they offer an interesting challenge.

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Appendix A

Cultural Probes

A.1 Tasks

Description of the asked task to perform during the probe experince.

Task 1 - Shape me! Shape MAY. Imagine a character with whom you would like to talk frequently and with whom you will be willing to tell daily matters. Use the first page of the provided note-book to draw or gum one or some images which characterize the character you imagined.

Task 2 - What have you been doing? Imagine that MAY is your friend and tell him how your day was. Where have you been, what you were supposed to do and you didn't, what you like, what you love, what annoyed you, what you hate. Do not forget the materials you have at your disposal. Mark the text with emotions.

Task 3 - Top ten Make a list of your 10 major interests (1 is the biggest). You can write what you want, a name, a sentence, a descriptive text. Don't think much write what comes to your mind. Once again make a list of your 10 major concerns (1 is the biggest). You can write what you want, a name, a sentence, a descriptive text. Don't think much write what comes to your mind.

Task 4 - Play with me What is your favorite computer game? Imagine you have a virtual companion (virtual character) which helps you to move forward in the game.

- What would you like him to do for you?
- What would be his strengths?
- If something went wrong what would be his reaction?
- And when you achieve a high score?
- And when you lose?

Task 5 - Write me Write a mail to may@gaips.inesc-id.pt, answering to the following question: "Which are the main problems of the young people

(you and your friends) nowadays and what kind of risk behaviours they are involved with? Which are their main goals?"

Task 6 - I remember Pick an image in the envelope that triggers a memory. Describe that memory, like you were describing it to a friend, like you are tell him/her a past story that he/she is anxious for knowing. In that way the general lines of the memory are not enough. Mark the situations with emotions.

Task 7 - That special night Imagine you are telling a friend one of your last night outs. Pick one memory of one amazing night. Tell him the fun moments, where you went and what you do until you arrive home. Probably getting home was fun too, don't you think?

Task 8 - My best friend Answer to:

- How is your best friend like(not only physical characteristics)?
- What you used to do together? How often?
- How is your relationship?

Task 9 - One day at school In this envelop there is a draw which represents a path. Mark in it, as you like, activities, relationship with your colleagues, professors and employees, during a school day.

Task 10 - Draw me again After performing all tasks, the image of MAY probably changed. So, draw him again!

A.2 Persona

The *persona* Amy is desbribed in the next page.

Persona

Name	AMY
Age	18
Gender	Female
Socioeconomic Status	Middle class
University	Instituto Superior Técnico
Course	First year of Computer Science

Persona Details

Family	Amy lives with her parents and sister. She always have fun with them and they are always there to back her up.
Friends	Friends are important in Amy's life, and them are in her list of concerns. Her best friend is April, they used to go to the cinema, to go shopping or have dinner/lunch once in a while. They try see each other every Tuesday or Friday.
Pets	She has a dog to take care.
Sport	Every time she plays volleyball, she plays with her heart. She totally loves it and for her it's a great escape from school.
Likes	Amy is a summer person. She also likes listening music, travelling, camping, school (why not), eat good food, going out at night with friends. She prefers places like hard rock café, but Bairro Alto is one of her choices too.
Dislikes	Wake up early, public transports (school-home), domestic tasks at home.
Goals	Pass the driving test, get good grades at university subjects, to be in good shape, wake up on time for school
Tasks	Take care of the dog; at Tuesdays and Fridays is her turn to clean up the kitchen; clean up her room weekly; go to volleyball practices; go to drive lessons

Life Stories

"In Summer 2008 I went on a camping trip to Açores with some people from school. Against all odds it rained a lot! The worse came later… At the middle of the night some tents collapsed and we have to go our 'neighbors' tens to spend the night. In the morning all campsite had been flooded and our clothes and stuff were soaking."

"Today is my 16 birthday and I got my first car – a Microcar. I am so happy and excited. It is like a dream come true. I cannot wait to show it to all my friends."

"Today was a normal day at school. Slightly boring… don't really want to work. But I went to one beach for lunch with friends, really good moreover."

Appendix B

Relations in ConceptNet 3

B.1 Relations Description

Relations express relations between concepts. At this moment, set comprises the following relations (Havasi et al. 2007):

ID	Name	Description
0	IsA	What kind of thing is it?
1	HasA	What does it possess?
2	PartOf	What is it part of?
3	UsedFor	What do you use it for?
4	AtLocation	Where would you find it?
5	CapableOf	What can it do?
6	MadeOf	What is it made of?
7	CreatedBy	How do you bring it into existence?
8	HasSubevent	What do you do to accomplish it?
9	HasFirstSubevent	What do you do first to accomplish it?
10	HasLastSubevent	What do you do last to accomplish it?
11	HasPrerequisite	What do you need to do first?
12	MotivatedByGoal	Why would you do it?
13	Causes	What does it make happen?
14	Desires	What does it want?
15	CausesDesire	What does it make you want to do?
16	HasProperty	What properties does it have?
17	ReceivesAction	What can you do to it?
18	DefinedAs	How do you define it?
19	SymbolOf	What does it represent?
20	LocatedNear	What is it typically near?
21	ObstructedBy	What would prevent it from happening?
22	ConceptuallyRelatedTo	What is related to it in an unknown way?

Appendix C

Natural Language Tools

C.1 A RDF (small)ontology for time in MAY

The image represents an extract from the original ontology.

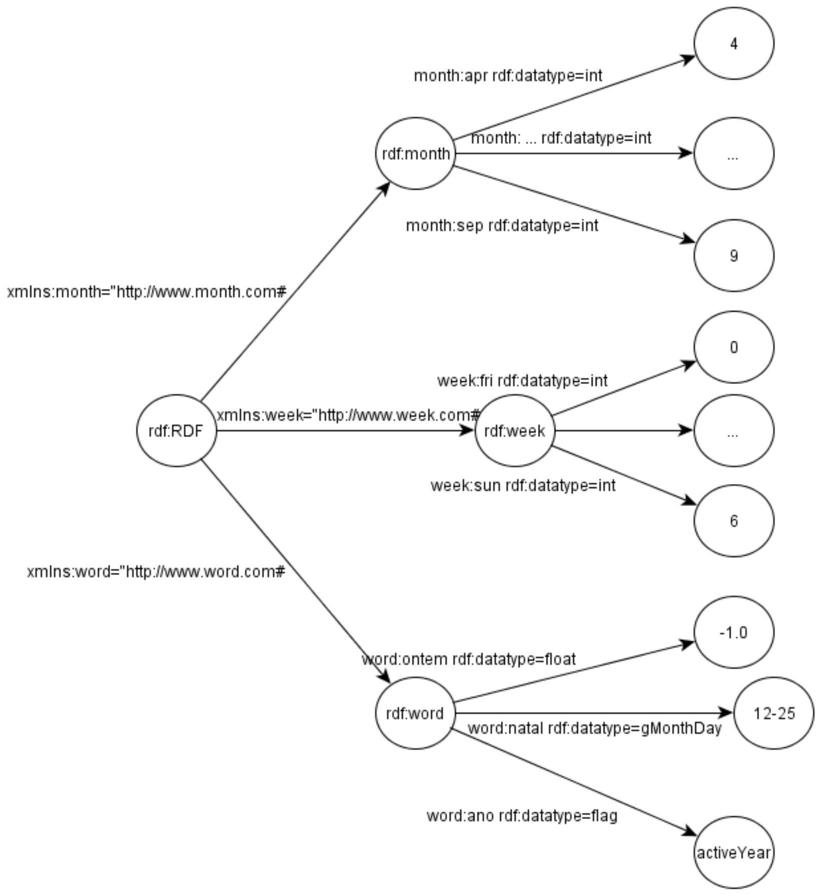

Figure C.1: A RDF (small)ontology for time

C.2 From expression to date

Caugh Temporal Expressions (for Portuguese):

	Rule	Examples
1	S|T - N - S - H - S* - N*	Em 29 de Abril de 2010 A 29 de Abril
2	S - N - S* - RT	Em 1986 Às 6 da tarde Por volta das 6
3	S - Z* - S* - N* - S* - H	No ano de 1986 No dia 6 de Abril No dia 6, no mês 4, no ano 2010
4	S - Z|RT - RQ* - RT	À noite De manhã cedo De manhã muito cedo Na véspera de natal
5	S* - H - S|C - H	De Junho a Abril
6	S* - P. - Z	Este mês, este ano, esta semana Nos meus anos
7	S - Z - S - P.* - B+	Nos anos da Rita Nos anos da minha amiga Rita
8	S - W	Na quarta-feira No fim-de-semana
9	S* - RT|Z - S* - (Z|RT)*	Ontem Na véspera de natal
10	S - T - O|W	Durante a semana, durante a Primavera, no Inverno

The next table depicts examples of the transformation of temporal expressions into temporal entities.

As explained in the respective chapter the small unit of time considered is day. So, temporal expressions referent to smaller units are not contemplated.

[1]Concatenation of two intervals
[2]January belongs to the following year
[3]Referent to the actual month
[4]Same for year and week
[5]immovable time feast
[6]movable time feast

Natural Language Expressions	Instant	Interval
Em Junho		2009-06-01 2009-06-30
De Junho a Setembro[1]		2009-06-01 2009-09-30
De Setembro a Janeiro[2]		2009-09-30 2010-01-31
No dia 6	2009-12-06[3]	
No dia 6 de Janeiro	2010-01-06	
No ano de 1986/Em 1986		1986-01-01 1986-12-31
No mês passado/anterior[4]		2009-11-01 2010-11-30
No mês seguinte/próximo[4]		2010-01-01 2010-01-31
Na segunda-feira	2009-11-30	
No fim-de-semana		2009-12-05 2010-12-06
Depois de amanhã	2009-12-07	
Na véspera de Natal[5]	2009-12-24	
Na Páscoa[6]	2010-04-04	

Appendix D

Experimental Evaluation

D.1 Interactions

In this section we present the interactions between Amy and MAY, which were shown to the participants in the experiment. The participants were randomized to one of the two conditions *memory* and *no memory*. Both are displayed in the next subsection in Portuguese as the experiment took place and also translated to English.

D.1.1 Condition: *memory*

First Stage - Dialogue 1

```
Amy >> Ola
MAY >> Ola Amy! Como estás?
Amy >> Está tudo bem
MAY >> Óptimo! Fico contente por saber.
Amy >> E tu?
MAY >> E eu?
Amy >> Como estás?
MAY >> Estou a correr dentro dos parametros normais.
Amy >> Bom saber.
MAY >> Ainda bem que forneço informação útil.
MAY >> Como foi ir ao concerto dos Cranberries ontem?
Amy >> Foi um espectáculo!
       Ela cantou as músicas todas!
MAY >> Isso deve ter sido muito fixe.
Amy >> pois foi
MAY >> Eu também acho.
       Está a ser um dia cheio de trabalho?
Amy >> Estou a estudar.
MAY >> O que estudas?
Amy >> Análise. Percebes alguma coisa de análise?
MAY >> hummm... Acho que não. Conta-me mais!
Amy >> Eu também :( Tenho teste de análise no Sábado.
```

```
MAY >> Pois. Precisas de estudar. Força!
Amy >> vou tentar.
MAY >> Fico à espera.
       Sempre foste jantar fora há dois dias?
Amy >> Sim. foram os anos da minha irmã.
MAY >> Conta-me mais. Compraste algum presente.
Amy >> Claro!! Comprei-lhe um vestido lindo!
MAY >> Não vou contrariar tanta certeza.
       Parece-me uma boa compra.
Amy >> Obrigada.
MAY >> Não tens de quê.
       Conta-me os teus planos para o resto da semana.
```

Translated to English:

```
Amy >> Hi
MAY >> Hi Amy! How are you?
Amy >> I'm fine
MAY >> Great! Glad to know.
Amy >> And you?
MAY >> And me?
Amy >> How are you?
MAY >> I am running in the normal parameters.
Amy >> Good to know.
MAY >> Glad for giving you useful information.
MAY >> How was the Cranberries concert last night?
Amy >> It was awesome!
   She sang all the songs!
MAY >> That must had been very cool.
Amy >> yes, it was.
MAY >> I agree.
   Are you working hard today?
Amy >> I'm studying.
MAY >> What are you studying?
Amy >> Math. Do you know anything about math?
MAY >> hummm... I don't think so. Tell me more!
Amy >> Me neither :( I have a math test on Saturday.
MAY >> I see. You need to study. Go go!
Amy >> I'll try.
MAY >> I'll be waiting.
       Did you go out for dinner two days ago?
Amy >> Yes. It was my sister's birthday.
MAY >> Tell me more. Did you get her a present?
Amy >> Of course!! I bought her a beautiful dress!
MAY >> If tou have so sure. It seams like a good buy.
Amy >> Thank you.
MAY >> You're welcome.
```

33 Tell me more about your plans
34 for the rest of the week.

Second Stage - Dialogue 2

1 Amy >> Ola
2 MAY >> Boa! Vieste hoje também!
3 Tudo bem?
4 Amy >> estou cheia de sono
5 MAY >> Porque é que estás cheia de sono?
6 Amy >> Não dormi muito bem ontem.
7 MAY >> Tens que regular melhor o teu horário
8 para dormires 8 horas por noite.
9 Que estás a fazer?
10 Amy >> Nada de especial
11 MAY >> Mesmo nada?
12 Amy >> Sim. Daqui a pouco vou passear o Teddy.
13 MAY >> Vais ao parque?
14 Amy >> Sim é a nossa rotina.
15 MAY >> Compreendo.
16 Amy >> Logo à noite vou ao cinema
17 MAY >> Vais com a April, Amy?
18 Amy >> Desta vez vou com o Lyam:)
19 MAY >> É bom fazer coisas diferentes do normal.
20 Amy >> Sim também acho
21 MAY >> Hoje tivemos uma boa conversa.
22 Amanhã voltas?
23 Amy >> Sim vou tentar
24 MAY >> Fico à espera.
25 Amy >> Adeus MAY
26 MAY >> Gostei de falar contigo Amy.

Translated to English:

1 Amy >> Hi
2 MAY >> Hey! You also came today!
3 Everything allright?
4 Amy >> I'm sleepy
5 MAY >> Porque é que estás cheia de sono?
6 Amy >> I didn't sleep well last night.
7 MAY >> You should make arrangements to sleep
8 about 8 hours a night
9 What are you doing?
10 Amy >> Nothing.
11 MAY >> Really nothing?
12 Amy >> Yes. In a while I'm going to walk Teddy.
13 MAY >> Are you going to the park?

```
14        Amy >> Yes, that's our routine.
15        MAY >> I see.
16        Amy >> This evening I'm going to the cinema
17        MAY >> Are you going with April, Amy?
18        Amy >> This time I'm going with Lyam:)
19        MAY >> Is good to do things out of normal.
20        Amy >> I agree
21        MAY >> We had a good talk today.
22               Are you coming back tomorrow?
23        Amy >> I'll try
24        MAY >> I'll be waiting.
25        Amy >> Bye MAY
26        MAY >> Nice talk to you Amy.
```

D.1.2 Condition: *no memory*

The dialogues for this condition were the same, except for critical situations related the memory. Only those changes are presented here.

First Stage - Dialogue 1

```
11        MAY >> Como foi o teu dia ontem?
12        Amy >> Foi um espectáculo!
 Fui ao concerto dos Cranberries.
...
25        MAY >> Fico à espera.
26               Conta-me as tuas últimas e
                 importantes memórias?
27        Amy >> No sábado fui jantar fora.
                 Eram os anos da minha irmã.
```

Translated to English:

```
11        MAY >> How was your day yesterday?
12        Amy >> It was awesome!
                 I went to Cranberries' concert.
...
25        MAY >> I'll be waiting.
26               Tell me yout last and important memories?
27        Amy >> Saturday I went out for dinner.
                 It was my sisters' birthday.
```

Second Stage - Dialogue 2

```
12        Amy >> Sim. Daqui a pouco vou passear o Teddy.
13        MAY >> Parece-me bem.
...
```

```
16        Amy >> Logo à noite vou ao cinema
17        MAY >> Também gostava de ir...
18        Amy >> Não vai dar. Vou com o Lyam:)
```

Translated to English:

```
12        Amy >> Yes. In a while I'm going to walk Teddy.
13        MAY >> Sounds good to me.
 ...
16        Amy >> This evening I'm going to the cinema
17        MAY >> I would like to go too...
18        Amy >> Not going to happen. This time I'm going with Lyam:)
```

D.2 Questionnaire

The full questionnaire is displayed in the following page. Where is video 1 and 2, consider the dialogues in the previous section. Some questions (variables) were ignored during the results analysis process.

The analised variables translated to English, for both conditions, were:

Stage 1

Q1 – MAY knew about the event "go to the cranberries' concert"
Q2 – MAY knew about the event "go out have dinner"
Q3 – MAY knew about the event "go out have dinner" because Amy had told it in any past interaction
Q4 – Past interactions have influenced the current one

Stage 2

Q5 – MAY knew something about the action "walk Teddy"
Q6 – MAY knew something about the action "go to the cinema"
Q7 – Past interactions have influenced the current one

Stage 3

M1 – MAY is friendly
M2 – MAY was companion during interaction
M3 – MAY's comments are useful
M4 – MAY does Amy feel that she can do things well
M5 – MAY encourage Amy
M6 – MAY have interest about Amy's life
M7 – MAY knows Amy well
M8 – MAY knows facts about Amy's life
M9 – MAY woul still Amy's friend even if a month pass

groupMode: 2.00

Interagindo com MAY

Esta experiência é anónima e demora cerca de 10 minutos

Introdução

Imagine um sistema que lhe permite falar com uma personagem virtual sobre aquilo que acontece na sua vida.
A imagem à esquerda representa essa personagem. O seu nome é MAY.

É possível interagir com essa personagem através de uma interface usando diálogo.

Nesta experiência serão mostrados alguns videos sobre uma interacção de Amy com MAY.
Amy é uma estudante universitária e usa algum do seu tempo a falar com MAY.

Video 1

Clique no link em baixo para assitir ao primeiro video. Veja-o atentamente e preste atenção ao conteúdo do dialogo.
Video

DEPOIS de assistir ao video e de acordo com o que VIU no video, por favor indique o nível de concordância com cada uma das seguintes frases, usando a escala indicada em baixo.

(1 :Eu discordo completamente da frase; 3 : Eu não concordo nem discordo; 5 : Eu concordo plenamente com a frase)

Amy já tinha interagido com o sistema *	1 2 3 4 5
MAY tinha informação sobre a acção 'ir ao concerto dos cranberries'	1 2 3 4 5
Justifique (em poucas palavras) a resposta anterior *	
MAY sabia que 'ir ao concerto dos cranberries' era um acontecimento frequente *	1 2 3 4 5
MAY sabia que 'ir jantar fora' poderia ter acontecido *	1 2 3 4 5
Justifique (em poucas palavras) a resposta anterior *	
MAY sabia que 'ir jantar fora' poderia ter acontecido porque a Amy lhe disse em alguma interacção anterior *	1 2 3 4 5
Interacções passadas influenciaram o dialogo *	1 2 3 4 5
Justifique (em poucas palavras) a sua resposta *	

Video 2

Clique no link em baixo para assitir ao primeiro video. Veja-o atentamente e preste atenção ao conteúdo do dialogo.
Video

DEPOIS de assistir ao video e de acordo com o que VIU no video, por favor indique o nível de concordância com cada uma das seguintes frases, usando a escala indicada em baixo.

(1 :Eu discordo completamente da frase; 3 : Eu não concordo nem discordo; 5 : Eu concordo plenamente com a frase)

Amy já tinha interagido com o sistema *	1 2 3 4 5
MAY sabia algo sobre a acção 'ir passear o Teddy'	1 2 3 4 5
Justifique (em poucas palavras) a resposta anterior *	
MAY tinha informação sobre a acção 'ir ao cinema'	1 2 3 4 5
Justifique (em poucas palavras) a resposta anterior *	
May sabia que 'ir ao cinema' é um acontecimento frequente *	1 2 3 4 5
Justifique (em poucas palavras) a resposta anterior *	
Interacções passadas influenciaram o dialogo *	1 2 3 4 5
Justifique (em poucas palavras) a resposta anterior *	

Questões finais

De acordo com o que viu nos videos, por favor indique o nível de concordância com cada uma das seguintes frases, usando a escala indicada em baixo.

(1 :Eu discordo completamente da frase; 3 : Eu não concordo nem discordo; 5 : Eu concordo plenamente com a frase)

MAY é amigavel *	1 2 3 4 5
MAY interessa-se pela vida de Amy *	1 2 3 4 5
MAY conhece bem Amy *	1 2 3 4 5
MAY foi companheiro durante o dialogo *	1 2 3 4 5
Os comentários de MAY são uteis *	1 2 3 4 5
MAY faz Amy sentir que pode fazer bem as coisas *	1 2 3 4 5
MAY tem conhecimento sobre factos da vida de Amy *	1 2 3 4 5
MAY encoraja Amy *	1 2 3 4 5
MAY continuaria a ser amigo de Amy mesmo que não a visse durante alguns meses *	1 2 3 4 5

Sexo * — Masculino / Feminino

Idade
- Menos de 14
- Entre 14 e 18
- Entre 19 e 23
- Entre 24 e 28
- Entre 29 e 38
- Entre 39 e 48
- Mais de 49

Se quiser deixar algum comentário utilize a caixa em baixo

* = Input is required