Knowledge-driven Support for Reminiscence on Companion Robots

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Abstract. In this paper we present our work towards the development of an application for personalized reminiscence therapy in people with dementia. The reminiscence process aims at recalling personal memories by combining user-specific knowledge, dialogue-based human-robot interaction and multimedia content. The application is part of a robotic software framework for companion robots, investigated in the EU MARIO project and under evaluation in different dementia care settings.

1 Introduction

Dementia is a degenerative syndrome that affects the cognitive capabilities of an individual, causing a deterioration of memory, language and social behaviour. Among the cognitive rehabilitation interventions that complement pharmacological treatments, reminiscence therapy is based on verbal interactions that focus on recalling positive memories about people, past activities, experiences and personal events, often with the support of materials such as photos and videos that act as memory triggers. Reported positive effects range from increased socialisation to improvements in cognition and mood [9]. In recent years, the use of autonomous robots in dementia care has emerged as the main application field for socially assistive robotics [5]. Along this path, the H2020 European Project MARIO[4] is investigating the use of autonomous companion robots as cognitive stimulation tools for people with dementia (PWD). In this paper, we present an application for reminiscence therapy, as part of a larger framework where Semantic Web technologies and robotic solutions are combined to build an application ecosystem for companion robots. The application is designed to actively prompt the PWD and engage her in an interactive and personalised reminiscence process, where dialogue-based interaction patterns are complemented with multimedia content associated with relevant people, places and life events. The design of a system able to autonomously undertake reminiscence sessions poses several challenges. These range from the need to represent and acquire the heterogenous information that defines an individual's life history, to the exploitation of this data to engage the person in the reminiscence process. In this

[4] http://www.mario-project.eu/

respect, ontology-based knowledge representation techniques are at the heart of our approach, with a knowledge base (KB) that stores user-specific information and supports dialogue-based interaction tasks, from basic language generation to language understanding. Ontologies enable a formal definition and conceptualisation of domain knowledge. With respect to conventional database models, ontology models and their instantiation are independent of specific data modeling strategies or implementations, fostering reusability and interoperability across heterogeneous applications. In addition, reasoning techniques can be used to perform inference on both the schema and the data, so as to entail implicit information and derive new information from existing knowledge.

2 Related Work

As discussed in [7, 4], existing systems for supporting reminiscence aim at improving traditional practice and basically consist of software applications, deployed on desktop/laptop computers or tablets, that act as personalised multimedia systems for the storage and retrieval of digital reminiscence materials. The interaction is limited to the selection of digital items and access to the system is mediated by caregivers, who initiate and prompt conversation with the patient. Recent works have focused on conversational agents. In [1] the authors report on the positive feedbacks gathered from a pilot study, performed using a Wizard-of-Oz setup, where a natural language interface was used for reminiscence. Strongly related to our approach, Wilks et al. present a prototypical implementation of a dialogue system for reminiscing about images [8]. The system builds on a KB for storing images and related information, and relies on dialogue management for interacting with the user through a virtual companion avatar. Shi and Setchi focus on supporting reminiscence through ontology-based information retrieval [6]. The approach enables the retrieval of personalised life events using a query expansion algorithm over user-oriented ontologies and background knowledge.

3 Reminiscence Support

The reminiscence application, whose reference architectural model is shown in Fig. 1, aims at supporting so-called *simple reminiscence* [9], based on a conversational approach and highly focused memory triggers such as photographs.

Knowledge Base Support. Reminiscence relies on the availability of user-specific factual knowledge, gathered from family members and caregivers. To represent this heterogeneous information, specific ontology modules were designed as part of the MARIO Ontology Network (MON)[5], a set of interconnected OWL ontologies at the heart of the shared KB underlying the overall robotic applications ecosystem. Reminiscence ontology modules address the need of representing persons' biographic information, family/social relationships, life events and multimedia objects (e.g., digital images) along with their association with

[5] `http://www.ontologydesignpatterns.org/ont/mario/`

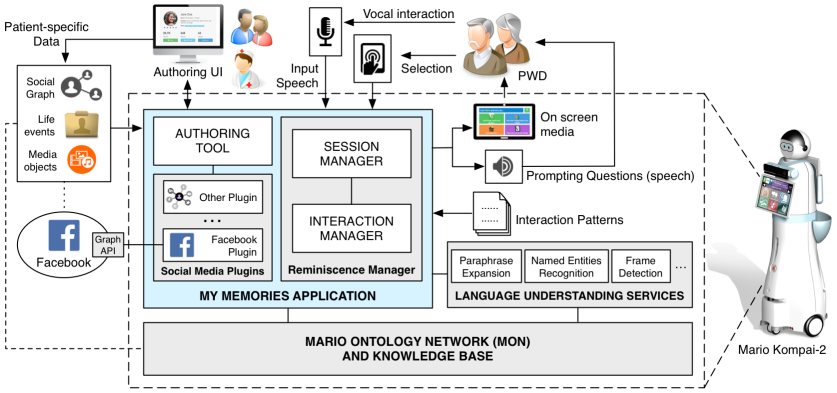

Fig. 1. Reminiscence application architectural model

persons, places and life events. While biographic information covers basic data (e.g., first/last name, birth date and hometown), family and social relationships enable the definition of a social graph for the PWD.

The definition of life events relies on the *time-indexed situation* ontology design pattern[6] and includes event participants, the location where the event took place, and a temporal dimension, to represent events that occurred in a specific date (e.g., a marriage) or over a period of time (e.g., attendance to college). Specific life events and their properties are explicitly modeled as *frames*, to cover typical domains including work and education (e.g., school attendance and working experiences), personal and family events (such as a marriage and the birth of a child), and living and travel experiences. A *frame* provides a schema for conceptualising the description of an event type and its participants in terms of *frame elements* or *semantic roles* [2]. For example, a marriage involves two persons participating as *partners*, and takes place in a specific *location* and *date*. Similarly, a birth event includes an *offspring* (the person that was born) and involves two persons as *mother* and *father*, along with the *birth place* and *date*.

The association between media objects and other entities relies on a semantic tagging approach, as defined in a *tagging* ontology module designed so that any object (including frames or even named graphs) can be used to categorise or describe the entity being tagged. This allows to define, for example, life events and persons as tags for an image, in addition to simple properties expressing where and when a photo was taken.

Authoring Tool. A Web-based *Authoring Tool* supports caregivers and family members in the process of building user-specific knowledge, centered around user's profile, family/social relationships and life events. It also enables the provision and tagging of multimedia objects, and is responsible for storing the gathered data in the knowledge base.

Reminiscence Sessions. The Reminiscence Manager is responsible for engaging the patient in the reminiscence process exploiting the available knowledge. A dialogue-based reminiscence session is driven by an extensible repertoire of

[6] `http://ontologydesignpatterns.org/wiki/Submissions:TimeIndexedSituation`

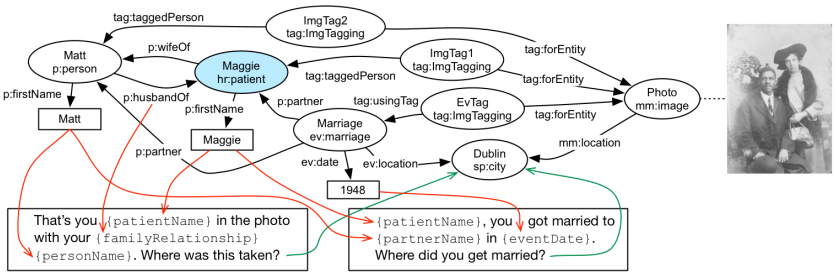

Fig. 2. Prompting questions examples and user-specific knowledge graph

interaction patterns, that allow prompting the user through specific questions, associated with media objects such as images that are contextually shown on the touchscreen available onboard the robot. An *interaction pattern* consists of: *(i)* a *precondition*, with constraints expressed as queries over the knowledge base, defining under which conditions the prompting question can be used; *(ii)* a parametric *prompting question* to be used for triggering reminiscence, represented as a partially-formulated question template containing variables to be instantiated; *(iii)* one or more queries over the knowledge base providing a binding for the variables in the prompting question. Targeted questions are defined to cover the aforementioned knowledge elements, including life event types, people and tagged media objects. As informally shown in Fig. 2, given a photo with information on where it was taken, and who appears in the picture, examples of parametric prompting questions that also exploit family/social relationships include *"Is that your* `{familyRelationship}` `{personName}` *in the photo with you?"* or *"That's you* `{patientName}` *in the photo with your* `{familyRelationship}` `{personName}`*. Where was this taken?"*. Similarly, the association between photos and life events can be exploited to formulate questions about the event. Assuming, for example, that there is a marriage event where the PWD is one of the partners, prompting questions such as *"*`{patientName}`*, you got married to* `{partnerName}` *in* `{eventDate}`*. Where did you get married?"* can be formulated.

Currently, prompting questions assume a specific, known answer, from a simple positive/negative answer to specific persons, places, dates or events. This constrains the language interpretation domain and understanding capabilities are exploited to check user's answer and then either providing the patient with intermediate hints or the expected answer, or moving to the next question. The selection of the interaction patterns is a dynamic process, driven either by patient's replies or by traversing the links in the knowledge graph on the basis of the dialogue context and history. So, for example, a question about when a photo was taken can be followed by a question concerning a person that appears in the picture, and then move to a life event where the person participated in, and so on, exploiting the properties in the represented entities and the semantic roles in the represented frames. The additional complexity coming from open-ended questions (e.g., *"How was your wedding day?"*) that aim at stimulating conversation is under investigation. In this case, the understanding capabilities focus on the recognition of named entities (e.g., mentioned people or places) and the

detection of frames matching with life events, exploiting the machine reading capabilities provided by FRED [3] and the linguistic resources made available by the Framester hub [2] and its integration with the MON and KB.

4 Conclusions and Future Work

The reminiscence application we presented will be deployed for validation as part of the MARIO software framework on eleven Kompaï-2 robots that are currently being trialled for acceptability with patients in different dementia care settings in Ireland, the UK and Italy. Initial validation steps, supervised by caregivers, aim at qualitatively evaluating the approach in real-world settings. Gathered feedbacks and trial results will drive the evolution of the application to enable the robot to undertake reminiscence sessions in an unsupervised and autonomous way. Ongoing and future work includes the ability to acquire factual knowledge from the conversational interaction with the user, as well as the introduction of sentiment analysis capabilities to assess emotional aspects and identify triggers generating positive feelings to be favoured in reminiscence.

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