iForgot

A Model of Forgetting in Robotic Memories

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***Abstract*—Much effort has focused in recent years on developing more life-like robots. In this paper we propose a model of memory for robots, based on human digital memories, though our model incorporates an element of forgetting to ensure that the robotic memory appears more human and therefore can address some of the challenges for human-robot interaction.**

Digital Memories; forgetting; robotics; life experiences

I. Introduction

The continual advancement in robot technology is creating increasingly more life-like robotic devices. Much of this research effort has gone into improving the nature of reactions to human input, where this reaction is based on the integration of sensor devices, for example touch, sound or vision sensors. It is our conjecture that to interact with humans in a more realistic manner, that a robotic device should not only move fluidly and react to stimulus, but also, that it should model a human-like memory to further aid robot-human interaction.

For humans, our memories define us as a person and allow us to converse and interact with other people in a meaningful manner. In this paper we motivate a prototype Robotic digital Memory (RM) that models human memory both for remembering, but also in that most human of traits, forgetting. Forgetting is an integral part of how human memory functions. By modeling forgetting, we can support a more realistic and natural digital illusion of life experience for a robotic device. In this work, we present a model of robotic memory of real-world interactions that can be generated by utilizing many of the same robotic sensors that are already employed to capture external stimulus. Following from this we present a first model of forgetting, which integrates temporal and spatial similarity, novelty, temporal distance and access-count as regulators of the forgetting process. These four inputs define how forgetting occurs in our model, a model which is based on extensive experience of gathering multi-year Human Digital Memories (HDMs) using wearable sensors.

II. Encoding and Retrieving Complete Digital Memories

Most research to date on digital memories has focused on maintaining HDMs for individuals, and we will now introduce this work, after a brief introduction to human memory.

A. Humans and our Memories

Human memory has been the subject of extensive research over many decades. We now understand a memory pipeline from sensory memory, through short-term memory and into long-term memory, with long-term memory being composed of three memory components; semantic memory for facts, procedural memory for actions and episodic memory for life experiences. However, human memory is inherently fallible; we forget events every day, for example, the names of people or the date an event occurred; however such forgetting is important for life, because maintaining a complete memory of every life experience would quickly overload a person.

It is believed that many factors influence the forgetting process for episodic memory, including natural temporal decay, how often we access the particular memory, the novelty of the experience and memory-merging based on interference from similar experiences. While forgetting may be an integral and important aspect of memory, it can have infuriating side effects, or in the case of memory-impaired individuals, seriously affect the quality of life. To help alleviate some of the downsides of forgetting, research has progressed in the area of maintaining digital surrogates of a human memory which capture all life experience digitally in a HDM archive.

B. Human Digital Memory Surrogates

HDM archives are automatic personal archives (in the spirit of the MEMEX [1]) which attempt to store many of a person's life experiences digitally, using various sensor devices, often including continuous image or video capture. The MyLifeBits [2] project at Microsoft Research is perhaps the most famous research effort in this area, in which Gordon Bell is capturing life experiences digitally, everything from books read, photos captured, home movies, emails, and other personal digital sources.

Related research at Dublin City University [3] has focused on the contextual gathering and organizing of HDM archives with an emphasis on visual capture of user's experiences and the employment of information retrieval techniques to automatically organize the HDM using content and context data. To enable the capture of everyday activities visually, Microsoft Research have developed a device known as the SenseCam, which is a small wearable device that passively captures a person's day-to-day activities as a series of photographs [4]. It is

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typically worn around the neck and is oriented towards the majority of activities which the user is engaged in. Doherty and Smeaton [3] are concerned with automatically organising daily streams of SenseCam photos and associated metadata (e.g. date/time, people & locations encountered) into a HDM of life events. Associated research in the area illustrates how employing SenseCam HDMs can aid individuals with memory impairments [5] by maintaining a visual archive of experiences that the person can review.

C. *Robotic Digital Memories*

Our conjecture is that, since capturing digital surrogate memories, using various sensor devices (including SenseCams), can aid humans with memory impairments, that similar technologies can support the maintenance of an RM (Robotic Memory), in which a robotic device's interactions with the real-world can be stored as if a memory and utilized to support more realistic everyday interactions with humans.

In our vision of robotic digital memories, various sensor outputs (including cameras, human interaction sensors, location and environmental sensors) are employed to build up an archive of real-world experiences which are stored as a densely-linked graph in which nodes model real-world experiences and the links reflect the degree of similarity among the nodes. In prior research [3] the segmented unit of experience is the 'event', for which a human encounters about 35 per day. We propose to model an *experience* for RMs that better reflects individual encounters with persons, locations, objects or any other sensor reading would be more suitable. These experiences can then be merged into events (e.g. meetings or parties) and in this way, a hierarchy from individual experiences to aggregated events is maintained.

Each experience is automatically annotated with metadata from the sensors and this metadata supports multi-layer linkage between nodes. The weighting of the links signify the degree of similarity between events. The more layers of sensory input, the higher the number of layers in the linkage graph. Finally there would be a number of ways to query or access the digital memory. For example, an encounter in the real-world (e.g. encountering a particular person) will generate sensor readings that can construct a query. Also, for any given experience, a list of similar experiences can be generated across any/all layers, thereby supporting the human memory trait of one recalled experience triggering the recall of other related experiences.

III. MODELLING FORGETTING

The challenges for maintaining a HDM differ from the challenges in maintaining our proposed RM. With a HDM, the challenge is in encoding and providing on-demand access to all life experiences. For RDMs, this challenge is extended to include an element of forgetting, thereby endowing the RM more human characteristics. Forgetting has been described by Bannon [6] as a 'necessary mental activity that helps us to filter the incoming sensory flood, and thus allows us to act in the world'. Our proposed model of forgetting operates as a first-access view of a full, interlinked, digital memory archive. This *forgetting view* is the first access point when trying to retrieve a memory, and the underlying complete digital memory is only accessed when necessity requires a complete RM scan. To enable this forgetting view, we propose that three (interlinked) computable factors of human forgetting need to be modeled in the RM. These factors influence the *recall probability* of an experience, which is a value that indicates how likely an individual experience is to be recalled. The three factors are:

- *Temporal Forgetting* of experiences based on the elapsed time since the experience was captured. The recall probability is reduced according to elapsed time.
- *Access-based Recall Enhancement*, where accessing an experience from the digital memory positively impacts the recall probability of an experience.
- *Novelty-based Recall Enhancement*, where more novel experiences (identified by inverse metadata similarity) maintain a higher recall value.

In addition to these forgetting factors, we propose to model the the concept of *Experience Merging*, where similar experiences that are not novel are merged together to create a single remembered experience. This can be achieved by examining experience similarity and an overall experience centroid (the average experience of the similar experiences) is presented to the user. This models the human memory trait that new memories will interfere with existing similar memories. This is the initial model that we propose of forgetting for RDMs.

IV. CONCLUSIONS

In conclusion, the proposed is a first model of forgetting in RMs, which does not replace the total recall that is possible with a digital memory, rather it is a view over the archive. We are working to evaluate this model using multi-year HDM archives. The model assumes a reasonable coverage of sensory input, and we do not attempt to model intelligence, emotions, or the vast complexity of what it means to be human, simply we propose a more human interface to a robotic memory.

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