Using Google Glass and Machine Learning to Assist People with Memory Deficiencies

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Abstract – *Memory deficiencies may occur naturally with age and for a variety of reasons including Alzheimer's disease, depression, side-effects of drug use, stroke, and traumatic brain injury. Because memory loss can significantly interferes with daily life, many external memory aids have been developed, though most use a passive approach. In this paper, we report on the design and prototype development of a dynamic, wearable system, called ELEPHANT, to assist those with memory deficiencies. Our design uses the Google Glass platform and a machine learning approach to intelligently retrieve stored photographic "memories" annotated with location, date, time, and activity information to enhance the memory of the user. Motivating background, system design philosophy, results of an initial prototype implementation and plans for future enhancements are presented.*

Keywords: Machine learning, Google Glass, memory deficiency, wearable technology, assistive technology.

1 Introduction

Our memories define who we are. Memory deficiencies affect people of any age and are associated with Alzheimer's disease, depression, side-effects of drug use, stroke, and traumatic brain injury, including the resulting side-effects of playing in the NFL, and a variety of other causes [2]. Memory loss significantly interferes with daily life, robbing a person of his or her independence, happiness and sense of self. Over the years, many external memory aids have been developed to assist those with memory loss, from low-tech note cards to a variety of high-tech electronic devices [3,8,10,14,15], though most use a passive approach requiring that they be checked periodically.

Fig. 1. Imagined use of ELEPHANT memory assistive system for elephants with memory deficiencies.

For people with memory loss, not being able to remember to check a notebook or electronic device for information can itself be a barrier to the very assistance that is needed. Recently, research has reinforced past results and demonstrated that using active reminders that automatically notify the user via television assisted prompting [12] and even Google Calendar [13] can successfully help to compensate for memory loss. The successful demonstration of an active approach based on television display or Google Calendar opens up an intriguing line of research and development possibilities, and neatly points at a Google Glass solution.

Rather than requiring manual entry of items into Google Calendar, a system that can automatically prompt entry of reminders could provide a valuable alternative for those with memory deficiency. Our proposed design, the Electronic Localization, Elucidation and PHotographic Assistive Notification Technology system, or ELEPHANT, has the goal of detecting or discovering new events and supporting the prompted, visual learning of an individual's daily routine. Using machine learning techniques, an assistive memory store of annotated visual data is gathered and analyzed for later retrieval and use, providing dynamic reminders and general memory assistance. Annotated photographic information has been demonstrated to provide effective memory assistance to amnesiacs and Alzheimer's patients [7,15,16], with benefits such as improved memory accuracy, the ability to carry on a conversation, and increased quality of social interactions with others.

In this paper, an approach that uses machine learning techniques on the Google Glass platform is presented and discussed. First, motivations from a healthcare needs perspective is shown and the suitability of wearable technology to support those needs is given. Next, justification for our proposed update to the "memory wallet" concept [7] is provided to support the approach and as a foundation for the initial ELEPHANT prototype application. Finally, our plans for continued development and future work are presented.

2 Healthcare Needs

According to a recent survey of adults in the U.S. aged 60 or over, 12.7% of respondent's self-reported increased confusion or memory loss in the preceding 12 months [1]. Of these respondents, 35.2% reported functional difficulties as a result of these issues, resulting in significant negative impact to their normal activities and social interactions.

As of 2011, over 16 million in the U.S. were suffering from some form of cognitive impairment [21], with an estimated 5.1 million of those over the age of 65 suffering from Alzheimer's disease, resulting in more than 10 million family members providing assistive care. By 2014, over 20 million in the U.S. were affected by some similar form of significant cognitive decline [6]

Thus, the challenges and costs to affected individuals, families and caregivers are substantial. However, adopting a technological solution can reduce costs and improve outcomes for those affected [11], and it is long-established that technology can be used to successfully assist people with cognitive impairment [8].

3 Wearable Technology in Healthcare

Wearable technology, wearable devices, or simply "wearables," refer to electronic devices that are incorporated into clothing or accessories worn on the body [19], and are increasing in mainstream popularity [18]. Wearable devices appear to have the potential to improve care for a variety of patients while reducing costs for healthcare organizations [17]. There also appears to be large and underserved market among the chronically ill who could benefit from wearable devices [9], and there is an increasingly widespread belief that wearable devices will become commonplace and perform such helpful tasks as automatic facial recognition to assist with remembering names [17]. Thus, it appears wearable technology has a place in healthcare in general, and in memory assistance specifically.

Fig. 2. Google Glass™. [5]

One device that may serve in that capacity is Google Glass, a type of "smart" glasses. Glass is composed of a frame that holds a computer, battery and a high resolution display [5]. It is equipped with, Bluetooth and Wi-Fi connectivity, a bone conducting transducer for audio I/O, 12 GB of memory, a rechargeable battery, and a camera that can take pictures and videos. Software applications designed to use Glass are called "Glassware," and make use of APIs for the local device and web-based interactions [4]. Some initial trials of using Google Glass in the healthcare industry are underway to assist with patient care, with indications that wearable computing increasingly will have a role in healthcare [17].

4 System Design

The overall design (Fig. 3) of our Google Glass based, machine learning, assistive memory system consists of five principle components: the Recollection Triggers module manages user interactions and queries, a Classification Filter manages the memory database, the Memory Item Database where memories are stored, a Recall Evaluator that assesses query results and guides the user to further actions as needed, and the Prism Display which includes all Google Glass display, I/O and networking support.

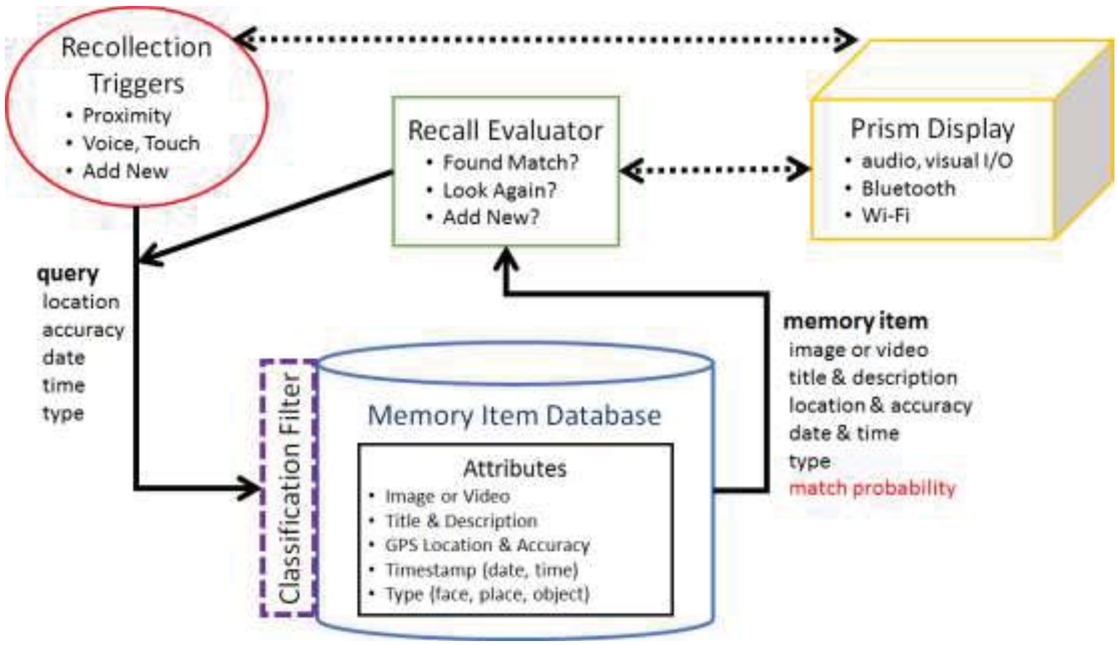


Fig. 3. Diagram of memory assistive, machine learning system for Google Glass.

4.1 Modules

The **Recollection Triggers** are responsible for detecting a noticeable change of location or proximity to a familiar or previously visited location, a direct voice, touch or programmatic command to initiate a query to look-up and add a memory item. The frequency of automatic monitor of GPS location must be balanced with meaningful granularity of location and with battery life as GPS support is known to consume battery power rapidly.

The **Classification Filter** implements multiple machine learning classifiers that are used to perform Memory Item Database look-ups. These classifiers each use one or more of the **Memory Item Attributes** to classify a new query item based on previous memory items. Each classifier reports a probability that a given existing memory item matches the current query so that a most likely memory item match can be found for the current query.

The **Memory Item Database** contains all stored memory items, each of which is an image, textual title and description of that image, the GPS location, GPS measurement accuracy, date and time reported at the time the image was recorded, and an image type as determined using simple image type detection (face, place, object, etc.) or input manually by the user along with the title and description.

The **Recall Evaluator** determines whether the match probability result reported by the Classification Filter and returned with retrieved memory item is a suitable match for the current location. Suitability is determined by the user confirming a correct match. If the match is unsuitable as determined by the user, the Memory Item Database is queried again for the next best match. If no suitable match exists, the user is given the option to add a new memory item to the Memory Item Database.

The **Prism Display** represents the hands-free, Google Glass visual display along with the corresponding hardware that supports audio input and output and both Bluetooth and Wi-Fi network connectivity.

4.2 Automated Learning Extensibility

The opportunity exists to enhance the Recollection Triggers and Recall Evaluator to attempt to identify a title and description for a new memory item and add it automatically to the Memory Item Database. This can be accomplished using the Google Glass Mirror API to perform a Google web query to find a best match for a current location.

ELEPHANT

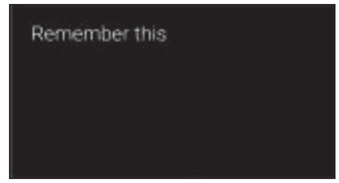
As a proof of concept, a simplified, prototype version of the ELEPHANT system for Google Glass was developed. This prototype application is comprised of two main parts: memory creation and memory display. The memory creation portion guides a user through a series of tasks to capture relevant environmental data about a subject. The memory display portion uses this captured information to create digital, rich media flashcards of the subjects (memories) that are then presented on the high resolution display. Using simple gestures, a user can navigate through these flashcards to review captured information about the subjects. A user can also select any of the flashcards in order to receive additional, more in-depth information about its subject. The hope is that browsing these memories will aid the user with recognition of the subjects captured. Note that the source code is available for this prototype system by contacting the authors, and will be referenced in some detail below for clarity.

4.3 Motivation for Prototype Design

The purpose of developing ELEPHANT was to provide a versatile application that could assist people with a variety of memory deficiencies. While there are many other external memory aids available, Google Glass presents a unique way to easily capture and deliver a wide range of relevant information (visual, audible, and textual) about important subjects in a relatively discreet manner. As a wearable technology, it supplies the means to perform these functions without encumbering users unnecessarily.

4.4 Description

To start ELEPHANT, users can say “ok glass, remember this” from the Glass clock screen, or they can use the touch menu to select the card containing the plus icon and the word “Remember”. Once selected, ElephantService starts. This service owns and displays a LiveCard containing the title “Elephant” and the words “Never Forget,” managed by the RePopulateUIActivity.

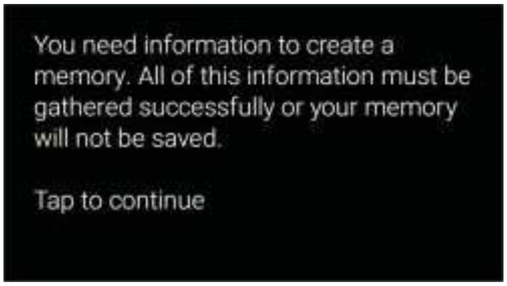


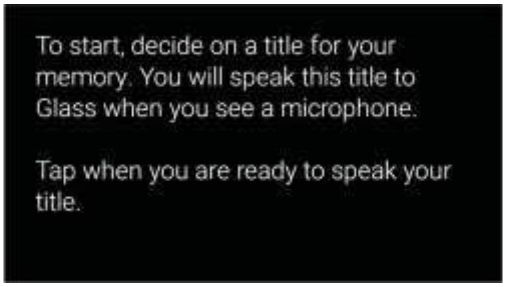
The action provided by this LiveCard is MenuActivity. When tapped, MenuActivity starts and displays a menu with options to “Create Memory”, “Browse Memories”, “Delete Memories”, or “Quit.” Swiping navigates through these options. Tapping chooses an option. Once an option is chosen, the corresponding Runnable is created and run to execute the appropriate set of functionality. This functionality varies with each option.

When “Create Memory” is chosen, date and time information is gathered and stored using a method from the FileOperations class. In addition, a number of Activities are set up for sequential execution. These include Activities for providing instructions on how to gather environmental data about a subject as well as Activities for gathering the data. The sequence of execution is:

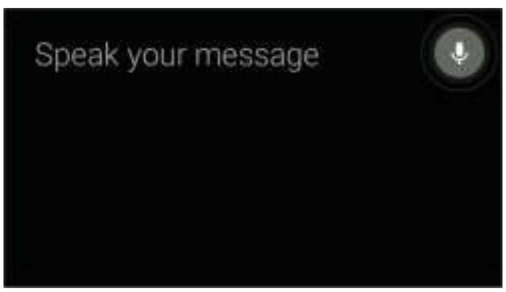
- IntroInstructionsActivity,
- SpeechRecognitionActivity,
- PictureInstructionsActivity,
- PictureActivity,
- VideoInstructionsActivity,
- VideoActivity,
- RePopulateUIActivity, and finally
- FileOperationsWriteActivity.

These instructions are written in a direct, colloquial style. They are designed in such a way that users proceed only when they are ready to do so. They focus on providing only the information necessary to perform the next task in the memory creation, review, or deletion processes. By incorporating these features, users with limited technical experience are enabled to successfully use this application.



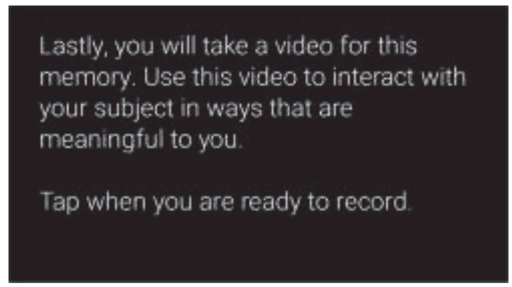


The SpeechRecognitionActivity uses Google's speech recognition technology to create a title for the memory using voice to text.

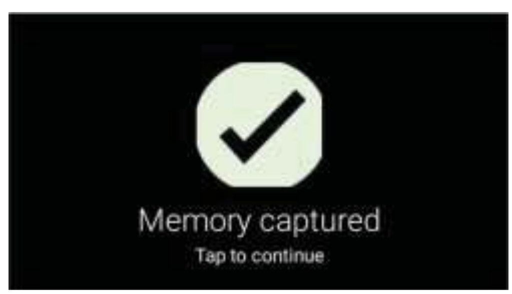


PictureActivity uses Glass's camera to take a photo of the subject.

VideoActivity also uses the camera to capture a "meaningful" interaction with the subject in the form of a video.



The textual title for the memory, and the file paths to the picture and video on the local disk are stored using methods in the FileOperations class. The FileOperationsWriteActivity stores all of this information in the local database so that it can be easily retrieved and accessed as a single "memory" of the subject.



In similar fashion to the "Create Memory" option, three activities are set up for sequential execution when "Browse Memories" is chosen.

In order, these are: MemoryScroll-ActivityInstructions, MemoryScrollActivity, and Re-PopulateUIActivity. The MemoryScrollActivity-Instructions educates users on how to review the stored memories. The RePopulateUIActivity is the same activity that was previously described.

The core functionality within the "Browse Memories" option lies in MemoryScrollActivity. When this activity is started, all information about each of the memories is obtained from the database. If no memories are found, a card is displayed alerting the user that memories should be created.

If memories are found, a Runnable is created on the main UI thread to periodically check on the status of the JpgToBmpTask. The JpgToBmpTask, (an AsyncTask), is then executed in parallel on a background thread to create bitmaps from the jpg images of the subjects that are stored on the disk. (This is necessary so that the UI thread does not become unresponsive, and so that the images can be displayed on cards.) Throughout this process, cards are shown to users to update them on the task's progress.

Once the bitmaps are ready, the Runnable from the main UI thread is stopped. Next, cards are created for each memory and added to a CardScrollView so that users can navigate through them by swiping. Each card contains the title, date, time, and picture for the memory's subject. A video is also associated with each memory. If users tap on a memory's card, Google Glass's video player presents additional information about that memory by playing the appropriate video from the disk. Once the video is finished, users are returned to the CardScrollView to browse additional memories, if desired. Per the MemoryScroll-ActivityInstructions, users swipe down from the CardScrollView to return to the card containing "Elephant" and "Never Forget."

When "Delete Memories" is chosen, the Delete-MemoriesActivity is setup for execution, followed by the RePopulateUIActivity mentioned previously. The DeleteMemoriesActivity presents users with a card warning them that they are about to delete all memories. Per that card's instructions, swiping down will cancel this activity, while tapping will cause deletion to proceed. Swiping down returns users to the card containing "Elephant" and "Never Forget." Tapping causes all information about each of the memories to be deleted from the database by calling a method from FileOperations. It also causes a card to be displayed notifying users that deletion was successful.

When "Quit" is chosen, a request is made to stop ElephantService. This causes ELEPHANT to terminate.

5 Conclusions

There is a definite utility to providing tremor-reduction in software form, as it can apply even as hardware technology and pointing device technology continues rapidly to evolve. A smoother and less jumpy pointer can help eliminate a distraction for an audience during a presentation and provide a presenter who has a tremor of some form with a more comfortable and effective presentation experience. Pointing devices using tremor-reduction software can help those with natural tremors such as Essential Tremor or those with medical conditions that cause other mild to severe tremors. In fact, an approach to tremor filtering may be more widely applicable and useful to a general user, as the tendency to become nervous, and therefore have some mild hand tremor, when making a presentation before an audience is a natural tendency for many speakers.

6 Future Work

Using wearable technologies to aid those with memory deficiencies holds significant promise for improving patient outcomes and reducing the cost of care in the future. Since there is already evidence that some with cognitive impairments prefer electronic memory aids to mnemonic strategies, it seems natural to pursue improving the capabilities of electronic devices [7]. In particular, a sophisticated wearable such as Google Glass may have the potential to provide a wide range of assistive functions that are not possible with other devices currently available.

The ELEPHANT prototype system creates digital, rich media flashcards of subjects (memories) that are then shown to a user on Glass's high resolution display. This is helpful as an external memory aid. However, this application has the potential to be used as a memory training platform as well. One way that this could be accomplished is by incorporating logic into the application that implements the “vanishing cues” learning technique to elicit responses from users about each memory. For some with cognitive impairment, this “vanishing cues” learning technique proved to be an effective way to acquire new information [15].

Delivering more targeted memory reminders has proven to be beneficial to memory enhancement [20]. This targeted approach will be implemented as part of our overall system design that incorporates richer cues that include GPS location, date, time and memory item type, filtering using machine learning classification techniques. Some experimentation will be needed to identify the most appropriate and effective machine learning approaches, although the authors suspect that Logistical Regression, SVMs or Naive Bayes hold the greatest promise.

7 Acknowledgements

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