# Augmenting Human Memory using Personal Lifelogs

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## ABSTRACT
Memory is a key human facility to support life activities, including social interactions, life management and problem solving. Unfortunately, our memory is not perfect. Normal individuals will have occasional memory problems which can be frustrating, while those with memory impairments can often experience a greatly reduced quality of life. Augmenting memory has the potential to make normal individuals more effective, and those with significant memory problems to have a higher general quality of life. Current technologies are now making it possible to automatically capture and store daily life experiences over an extended period, potentially even over a lifetime. This type of data collection, often referred to as a personal life log (PLL), can include data such as continuously captured pictures or videos from a first person perspective, scanned copies of archival material such as books, electronic documents read or created, and emails and SMS messages sent and received, along with context data of time of capture and access and location via GPS sensors. PLLs offer the potential for memory augmentation. Existing work on PLLs has focused on the technologies of data capture and retrieval, but little work has been done to explore how these captured data and retrieval techniques can be applied to actual use by normal people in supporting their memory. In this paper, we explore the needs for augmenting human memory from normal people based on the psychology literature on mechanisms about memory problems, and discuss the possible functions that PLLs can provide to support these memory augmentation needs. Based on this, we also suggest guidelines for data for capture, retrieval needs and computer-based interface design. Finally we introduce our work-in-process prototype PLL search system in the iCLIPS project to give an example of augmenting human memory with PLLs and computer based interfaces.

## Categories and Subject Descriptors
H.3.3 **[Information Search and Retrieval]**: Search and Retrieval - Search process, Query formulation, H.5.2 **[User Interfaces (D.2.2, H.1.2, I.3.6)]**: Graphical user interfaces (GUI), Prototyping, User-centered design


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## General Terms
Algorithms, Design, Human Factors.

## Keywords
Augmented Human Memory, Context-Aware Retrieval, Lifelogs, Personal Information Archives

## 1. INTRODUCTION
Memory is a key human facility inextricably integrated in our ability to function as humans. Our functioning as humans is dependent to a very significant extent on our ability to recall information relevant to our current context, be it a casual chat with a friend, remembering where you put something, the time of the next train or some complex theory you need to solve a problem in the laboratory. Our effectiveness at performing many tasks relies on our efficiency and accuracy in reliably recalling the relevant information. Unfortunately humans are frequently unable to reliably recall the correct information when needed. People with significant memory problems (e.g. amnesic patients) usually face considerable difficulty in functioning as happy integrated members of society. Other people, although having much less noticeable memory problems compared with the amnesic patients, may also experience some degree of difficulties in learning and retrieving information from their memory for various reasons. In this paper, we use the phrase normal people to refer to individuals with normal memory and normal lifestyles, as opposed to amnesic or mentally impaired patients. The desirability of a reliable and effective memory means that augmenting memory is a potentially valuable technology for many classes of people.

Normal individuals might use a memory augmentation tool to look up partially remembered details from events from their life in many private, social or work situations. The augmented memory application itself might proactively monitor their context and bring to their attention information from their previous life experiences which may be of assistance or interest to their current situation. Details from these experiences could be integrated into personal narratives for use either in self reflection or to enable experiences to be shared with friends [1]. Sufficiently powerful augmented memories could not just support their users, but actually extend the user's capabilities to enable them to perform new tasks or existing tasks more efficiently or faster.

In order to provide augmented memory applications however we need some means to capture, store and then access personal information from a person's life experiences to form an augmented memory. The emerging area of digital life logging is beginning to provide the technologies needed to support these applications. Personal lifelogs (PLLs) aim to digitally record and store many features of an individual's life experiences. These can include details of visual and audio experiences, documents created or read, the user's location, etc. While lifelog technologies fall short of genuinely mimicking the complexities and processes of human memory, they are already offering the promise of life enhancing human augmentation, especially for episodic memory impaired patients, that is people who have problems remembering their daily experiences [2].

Existing studies in lifelogs have concentrated primarily on the physical capture and storage of data. One of the major activities in this area which has explored this topic in detail relates to Gordon Bell's experiences of digitizing his life described in [3]. Bell explores the topic of "e-memories" and "Total Recall" technologies related through this own experiences of digitizing his life. While his work provides significant insights into the potential and issues or digital memories, it focuses very much on the technologies of capture and storage, and potential applications. Our work in the iCLIPS project in the Centre for Digital Video Processing (CDVP) at Dublin City University[1] is exploring capture and search of personal information archives looking not just at data capture, but also the development of effective content indexing and search, and importantly in relation to this paper, that we are looking at the processes of human memory, the form and impact of memory failures and how these might be overcome using search of PLLs. In our work, we are concentrating on memory failures typically encountered by normal people, and using these to guide the development of a prototype interface to access a PLL as an augmented memory.

The remainder of this paper is organised as follows. In section 2 we examine PLLs and related works on digital memory aid tools in a little more detail, Section 3 then looks at theoretical models of memory from the psychology literature, reviews some existing empirical studies regarding normal people's memory problems and memory supports needs in their daily life, and discuss the possible function that PLLs may be able to provide for augmenting human memory In section 4 we postulate the guidelines for developing PLLs systems to augment human memory, giving suggestions on computer based interface designing, types of data to be capture, and retrieval techniques required. And finally section 5 we introduce the iCLIPS project and our prototype application.

# 2. BACKGROUND

## 2.1 Personal Lifelogs (PLLs)

PLLs are typically captured using a range of software and hardware devices. A separate lifelog is captured for each individual. In our work we use software applications to log all activity on the individual's desktop and laptop computers. This involves recording files created, edited and opened, logging web pages accessed, and archiving emails sent and received. Peripheral devices are used to continuously record other potentially significant data streams. These include visual information recorded using a wearable camera, in our case the Microsoft SenseCam[2], or camcorders, some projects also use audio recording to record conversations, the most important source of our conventional daily communication. Due to privacy concerns related to continuous capture of audio data, we do not capture audio data in our work. However, other communications sources such as SMS messages and Twitter feeds can be monitored and included in a PLL. In addition there is a wide range of context information that can also be recorded. For example, location can be monitored using GPS sensors which then look up named locations in gazetteers, individuals present can often be inferred by monitoring nearby Bluetooth enabled devices, date and time are often easily be captured, and are very powerful context data for search of information. Another interesting source of data is biometrics. Research has shown a correlation between measurable biometric responses such as heart rate and skin conductance and temperature, personal arousal and memorability of events [4]. Thus capturing these biometric features can potentially be used to help locate events in a PLL of potential personal significance to its owner.

## 2.2 Related Works

There have been a number of studies on developing memory-supporting applications. But most of current research claiming to use PLL data in supporting human memory is limited to presenting streams of captured episodes (e.g. video or audio records of certain episode) to the user, to have them "re-experience" the past, to look up required information or "re-encode" information encountered during that period and consolidate memory of it (e.g.[2, 5, 6]). While these applications appear to have promising results in clinical psychology studies with severe amnesic patients, that is, people who suffer from serious memory disorders (e.g. [2]), such applications may not be equally useful for people who have normal memory abilities. For example, in the study of [2], the subject (patient) can hardly recall anything that happened to her even after one day's delay. Therefore, a simple review and consolidation of past events can be very helpful for them to maintain necessary episodic memory. A patient's lifestyle can be very different from that of normal working people, in that they have enough time to review their experiences day by day. Therefore the "rehearsal" type memory aid (e.g. [5, 6]) is less likely to be favoured by normal people, unless it contains some important information which is difficult to remember or if there is some specific information they can't recall. For example, it is not unusual that we need to find an object or a document but don't remember where it is, or we meet someone we saw before but can't recall the person's name. Ubiquitous Memories [7] is a tool designed to automatically retrieve video clips which were captured when an object was previously presented. The developers also argue it to be a tool to help people find physical objects. VAM [8] was designed to automatically retrieve personal information such as the name of a currently encountered person by automatically detecting the face of the person. Audio life logs such as iRemember [9] are usually used to recover information one learned from audio conversations. Forget-Me-Not [10] helps people find documents by searching for actions in which the document is involved. The cues it presents to trigger memories of the target document related action also include other actions in the day which are presented

[1] http://www.cdvp.dcu.ie/iCLIPS

[2] http://research.microsoft.com/en-us/um/cambridge/projects/sensecam

by iconized attributes, including people, location, actions on documents and time stamps, then allow filtering/searching for an action on the document.

Most work in PLL capture to date has focused on short term studies of a few days or a week or two of data. To support research exploring technologies to truly augment human memory it is our belief that much longer term PLLs archives are needed for research. As should be obvious, capturing PLLs using current technologies requires a considerable investment by the subject capturing their own PLL. Software must be monitored and data carefully archived, more demandingly though the batteries on peripheral devices must be charged regularly and important data uploaded to secure reliable storage locations. The iCLIPS project has so far gathered PLLs of 20 months duration from 3 subjects. Our experiences in capturing and archiving this data are described in detail in [11].

# 3. MEMORY SUPPORT NEEDS

Since people will only turn to use memory aid tools when they feel unconfident or incapable of retrieving a piece of information from their memory, we believe that a sound understanding of the memory problems people usually encounter in their daily life will provide a guide of the functionality of memory aid tools.

In this section we first explain memory problems and the mechanisms which cause problems based on psychology research, we then review existing studies in exploring normal people's memory failures and needs for memory aid tools in daily life, and finally we discuss the possible functions that PLLs may be able to provide for augmenting human memory.

## 3.1 Theoretical Review

Memory is a cognitive ability to encode, store and retrieve information. Encoding is the process of converting sensors received external stimuli into signals which the neuron system in the brain can interpret, and then absorbing the newly received information into long term storage, termed *long term memory* (LTM). Retrieval is the process of bringing back information from the LTM storage. Different types of retrieval approaches are used for different types of memory. The two basic categories of memory systems are *procedural memory* and *declarative memory*. Procedural memory is also called *implicit memory*, meaning that it is usually retrieved without explicit awareness or mental effort. Examples include memory of motor skills, oral language, and memory of some types of routines. Procedural memory usually requires minimum cognitive resource and is very durable. It has been found that even people with serious global memory impairments have preserved procedural memory. For this reason, memory aids for procedural memory are not explored in this paper. Declarative memory as opposed to procedural memory, usually involves explicit awareness during encoding and retrieval. There are two major types of declarative memory: *semantic memory*, meaning memory of facts, and *episodic memory,* referring to the memory of experiences, which is usually related to temporal context. Most of our memory problems are declarative memory problems.

Although most memory problems can only be observed during retrieval, since current techniques are not advanced enough to know what's happening in the human mind, failures at any stage can cause problems in memory. For example, failure to encode encountered information makes the information unavailable in one's memory. In the Seven Sins of Memory [12], Schacter characterizes seven daily memory problems including: transience, absent-mindedness, blocking, misattribution, suggestibility, bias, and persistence. These sins can generally fall into three categories of memory problems namely: forgetting (transience, absent-mindedness, blocking), false memory (misattribution, suggestibility, bias), and the inability of forgetting (persistence). In the remainder of this section, we explain the mechanisms for these memory sins (problems), and discuss the possible solutions that PLLs can offer.

**Table 1. Seven Sins of Memory**

| Sins | Meaning |
|---|---|
| **transience** | the gradual loss of memory overtime |
| **absent-mindedness** | incapability to retrieve memory due to the lack of attention while encoding the information. |
| **blocking** | the failure of retrieving encoded information form memory due to the interference of similar information retrieved or encoded before (proactive) or after this (retroactive) |
| **misattribution** | remembering information without correctly recollecting where this information is from |
| **suggestibility** | reconstructing a set of information with false elements, which are from the suggested cues at the time of retrieval |
| **bias** | people's current retrieved or reconstructed memory is influenced by current emotions or knowledge |
| **persistence** | inability to forget things which one wants to forget |

Encoding newly encountered information or thoughts needs to process them in a short term memory (STM) system, which is called working memory (WM). The WM system is comprised of subsystems including separate short term storage channels for visual spatial and acoustic (sound) information, and an episodic buffer which links newly incoming information with what is already in long term storage. WM also has a central executive module which assigns cognitive resource (especially attention) to the channels [13, 14]. Thus the absence of attention can reduce the encoding efficiency or even cause encoding failure of some information input at that time (this is the so-called "absent-mindedness" in the seven sins of memory). And information which was paid more attention to is more likely to be better encoded and therefore more likely to be better remembered. It has been suggested that emotion can often influence attention at encoding, and therefore influence the memory of items.

Regarding LTM, it has been argued that information in human memory exists in an associative network, the activation of one piece of information (by external output, e.g. presenting that information again) can trigger the memory of its linked nodes [15]. The stronger the link, the more likely the trigger is going to happen. This is why recall is easier when a cue is presented (cued recall) than when there is not (free recall). It has been suggested by many psychology studies that it is the lack of proper links to information, rather than the loss of the memory of information itself that cause "forgetting". Since one node of memory may be linked to several other nodes, it is important that only the required information be triggered. Thus, inhibition is an important function of human memory. However, it may also induce 'blocking'. A classic example is the 'tip of the tongue' (TOT) phenomenon, where one is unable to recall the name of some well remembered information, feeling that the memory is being temporarily blocked.

False memory, meaning memory errors or inaccurate recollection, also arises due to the structure of the associative memory network. According to Loftus [16], every time a piece of memory is retrieved, it is actually reconstructed with associated small nodes of information. False memories can bring various problems in daily life. For example, "Misattribution" of witnesses can cause serious legal problems if a witness does not know whether the source is from reality or was in a dream or on TV or even imagined.

As for the sin of persistence, this is actually a problem of mental well-being and cognitive problems with memory. The reason for persistence is that unwanted and sometimes even traumatic memories are so well encoded, rehearsed and consolidated, that they may not be buried or erased. According to theories of forgetting, these memories can be "blocked" if the external cues can form strong link with memories of other experiences, ideally happy experiences. Therefore, having people rehearsing more happy memories may find these helpful to replace their memories of traumatic experiences. The question of which pieces of happy memory to present is beyond the scope of our work, and is left to clinical psychologists.

In summary, there are two main reasons for difficulty in retrieving a memory, namely: absence of the memory due to failure at encoding, or the lack of proper and strong cues to link to and access the correct pieces of memory. For memory problems arising from both causes, PLLs may have the potential to provide supplements. Data in PLLs can provide some details which one failed to encode due to "Absent-mindedness", or which have faded in one's memory over time. It can also provide cues for memories which have been "blocked".

## 3.2 Empirical Studies

In this section, we further explore the needs for memory aids though some documented empirical studies, and use the results of this work to focus our investigation.

In [17], Elsweiler et al explored people's daily memory problems with a diary study in working settings with 25 participants from various backgrounds. They concluded that the participants' diary inputs can be split into 3 categories of memory problem: Retrospective Memory problems (47% in their data entry), Prospective Memory (29%), and Action Slips (24%), which are also a type of prospective memory failure caused by firmly routine actions rooted in procedural memory. Since prospective memory failure and action slips usually happen before the person is made aware of them by experiencing the consequent error caused by the problem, it is unlikely that people will actively seek help from memory aids in these cases, unless the memory aid is proactive and intelligent enough to understand what is going on.

Lamming et al [18] also did a diary study to explore possible memory problems during work, and found that the most frequently occurring memory problems include: forgetting one's name, forgetting a paper document's location, and forgetting a word or phrase. Prospective memory problems were also found to be frequent and usually severe.

The diary study by Hayes et al [19] took a more direct approach and explored the situations in which people wanted to use their memory aid tool, a mobile audio recoding device called Audio Loop, to recollect the recorded past. The questions in their diary study not only included memory failures, but also how much time the participants would be willing to spend on recalling such content. Their results showed that for neural events, people would spend an average of 336 seconds ($\sigma = 172$) to find the required information from voice records. 62% of the reported reasons for returning to an audio recoding were because of "cannot remember", 33% out of 62% was *transience* type retrieval failure, while 29% out of 62% were due to failure of encoding (e.g. absent-mindedness). Another 26% of their reasons for searching recorded audio were to present the records themselves to other people. And finally 12% of recordings were marked as important before recording. While the reasons for rehearsing these predicted important records were not described, these results indicate that important events are likely to be reviewed, and that people may want to "rehearse" recoding of important parts to consolidate their memory of information encountered during the period. Due to limitations of the information they record (selective audio recording), and the specific tool they use, the scenarios in which people may need memory aids might be limited. For example, when the experience is largely made of visual memory, audio records may not be helpful and not be desired.

## 3.3 Summary

While all of the above studies successfully discovered some daily memory problems, the non-monitored self-reporting approach is limited in that the people can only report their needs for memory support when they are aware of a difficulty in retrieving a memory. While it is true that people may only seek help for specific parts of their memory when they realize that they have problem in recollecting these pieces of information from their memory, they are not always very clear as to what they actually want to retrieve until they bring back the piece of memory. For example, sometimes people just want to review (mentally) some past episodes for fun or because of nostalgia. They usually look at some photos or objects which are related to past events, and which bring them more vivid memories of past experiences. Due to the richness of data, lifelogs can provide more details about the past than any physical mementos can do.

In short, lifelogs are a good resource for supporting retrospective memory problems, including those we have gradually forgotten, distorted, or we missed while encoding. Consolidating memory of useful information cam also can also be used to provide digital copies of episodes (e.g. when we need to give a video record of a meeting to some one who failed to attend), or provide memory cues to trigger a person's organic memory about the original information, experiences, emotion, or even thoughts. Lifelogs might also be able to improve a subject's memory capability by training them to elaborate or associate pieces of information.

Indeed, supporting people's memory is not only a matter of finding the missing or mistaken parts of memory for them but also improving their long term memory capabilities. It has been argued that the better memory is often related to the ability to associate things, and make decisions of which information to retrieve. For example, older people usually have less elaborated memory [20].

In the study by [21], psychologists found a tendency for people with highly elaborated daily schemas to recall more activities from last week better than people with poorly elaborated schemas. Therefore, memory-supporting tools may be able to assist people to associate things in order to elaborate and consolidate their memories, and which can facilitate retrieval by strengthening the links between memories and the cues that life logs systems can provide, and potentially enhancing their efficiency at performing various tasks.

# 4. GUIDELINE FOR DEVELOPING LIFE LOG APPLICATIONS

Based on the previous sections, lifelogs should be able to provide the following:

- Memory cues, rather than external copies of episodic memory.
- Information or items themselves: semantic memory support, when one needs to exact details about previous encountered information, or when one needs the original digital item, e.g. a document.

Whether it is the information itself which is needed, or the target triggered memory, it is important that these items or this information can be retrieved when needed, and that relevant retrieved results can be recognized by the user. Indeed, what to retrieve and even what to capture and store in life logs depends on what needs to be presented to the user to serve the desired memory aid functions.

## 4.1 Presenting

There are basically two rules for presenting information:

**1. Provide useful information as memory cues**

When items are presented to the user, it is desirable that the information shown can be recognized by the user as what they want, and that if the retrieval targets are cues that are expected to be useful to triggers to the user's own memory about something, e.g. experiences which cannot be copied digitally, it is also essential that the retrieved targets are good memory cues for the memory that the user wants to recall, e.g. the memory of an experience.

Lamming et al. [18] suggested that memory supporting tools should not only provide episodes or information one forgets, but also episodic cues including other episodes with the temporal relationships among them, together with information about the characteristics of these episodes. It is suggested in [8] that the features usually visible in episodic memory cues are: who (a face, any people in the background), where (a room, objects and landmarks in the environment), when (time stamped, light conditions, season, clothing and hair styles), and what (any visible actions, the whether, etc.)

**2. Avoid information overload**

It is also necessary to avoid information overload when presenting material as a memory aid. In [22], it was found that when unnecessary information is reduced and important parts of information are played more slowly, their memory aid application achieved its best results. We suggest that text or static images which can be used as a summary of events, can also be good at reducing information overload compared to viewing videos (e.g.[10]). This requires that the system either to detect important parts, or digitize and textualize describable features of physical world entities or events should be digitized to facilitate retrieval. The term digitalize in this paper means represent the existence of physical world entity as digital items, e.g. an image or a line of data in the database. These can be searched directly using certain features (cues), rather than with the features of episodes in which such information is encountered, e.g. features of a person and a corresponding profile. Overall appropriate cues really depend on what people tend to remember. Therefore it is important to explore the question of what people usually remember about the target.

## 4.2 Data Capture

In principle, the more information that is captured and stored in lifelogs, the greater will be the chance that the required information can be found in the data collection. However, the more data that is collected the more the noise level may also increase and impose a greater burden on the life logger. In order for a PLL to support the above memory augmenting functions, the following data channels are needed:

**1. Visual**

For the majority of individuals, most of our information is inputted via our eyes, therefore it is important that encountered visual information be captured. While video can capture almost every moment when it is recording, watching video streams is a heavy information load. However, browsing static images or photos can be much easier job. Some automatic capturing cameras have been proved to provide rich memory cues [23]. The Microsoft SenseCam is one such wearable camera which automatically captures images throughout the wearer's day. It takes VGA quality images at up to 10 images per minute. The images taken can either be triggered by a sensed change in environment or by fixed timeout. Other examples include the Eye Tap [24] and the other Brother [25].

**2. Speech**

Another important source of information in daily life comes from audio. For example, much useful information comes from conversations. However, as mentioned previously continuous audio recording has been argued to be intrusive and unacceptable to surrounding people. For this reason, it is difficult to carry out continuous audio recording. Some existing studies, such as [9] discussed early, record audio for limited significant periods, however we chose not to do this since this requires active decisions of when to begin and end capture and careful choice of when to do this to avoid privacy problems. We preferred to continuous and passive capture modes which are non-intrusive. An alternative source of much of the information traditionally conveyed in spoken conversation is now appearing in digital text communications as described in the next section.

**3. Textual (especially from digital born items):**

Nowadays, we communicate more and more with digital messages (email, instant message, and text message). These content sources contain an increasing portion of the information used in daily life which used to come from spoken conversations.

These digital resources, usually in the form of text, have less noise from surrounding environment and irrelevant people, and therefore have less likelihood of intruding on a third person's privacy. Text extracted from communication records (e.g. emails, text messages) can be even used to assist narrative events and represent computer activities to trigger related episodic memory (e.g. [10]).

**4. Context**

As mentioned earlier, context information such as location and people presented can provide important memory cues for events [26]. Therefore they are both important for presenting events and can be useful for retrieving items related to events.

## 4.3 Retrieval

The final and possibly most challenging component of an augmented memory application built on a PLL is retrieval. It is essential that useful information be retrieved efficiently and accurately from a PLL archive in response to the user's current information needs. In order to be used most efficiently by the user, retrieval must have a high level of precision so as not to overload the user's working memory. It is recognized that a key feature of good problem solving is the ability of an individual to retrieve highly relevant information so that they do not have to expend effort on selecting pertinent information from among related information which is not of direct use in the current situation. Being able to filter non-relevant information is an important feature of good problem solving.

Finding relevant information in such enormous data collections to serve a user's needs is very challenging. The characteristics of PLLs mean that they provide a number of challenges for retrieval which are different to those in more familiar search scenarios such as search of the World Wide Web. Among these features are that: items will often not have formal textual descriptions; many items will be very similar, repeatedly covering common features of the user's life; related items will often not be joined by links; and the archive will contain much non-useful data that the user will never wish to retrieve. The complex and heterogeneous natures of these archives means that we can consider them to be a labyrinth of partially connected related information [27]. The challenge for PLL search is to guide the owner to elements which are pertinent to their current context, in the same way as their own biological memory does in a more in complex and integrated fashion. Traditional retrieval methods require users to generate a search query to seek the desired information. Thus they rely on the user's memory to recall information related to the target in order to form a suitable search query. Often however the user may have a very poor recollection of the item from their past that they wish to locate. In this case, the system should provide search options of features that people tend to remember. For example, the location and people attending an event may be well remembered, thus the search engine should enable search using this information. In fact, the user may not even be aware of or remember that an item was captured and is available for retrieval, or even that a particular event occurred at all, so they won't even look for this item without assistance.

We can illustrate some of the challenges posed by PLLs retrieval using an example. Consider a scenario where someone is looking for a particular photo from her PLL archive. All she remembers about the picture is that last time she viewed it, the sun was glaring in the window and she was talking on the phone to her friend Jack. Conventional search techniques would not be capable of retrieving the correct photo based on these context criteria that are unrelated to its contents. Use of the remembered context would enable her to search for pictures viewed while speaking with Jack while the weather was sunny. The notion of using context to aid retrieval in this and other domains is not new. Context is a crucial component of memory for recollection of items we wish to retrieve from a PLL. In previous work we examined the use of forms of context data, or combinations of them, for retrieval from a PLL [28]. This work illustrated that in some situations a user can remember context features such as time and location, much better than the exact content of a search item, and that incorporating this information in the search process can improve retrieval accuracy when looking for partially remembered items.

Ideally, as argued by Rhodes [29], a memory augmentation system should provide information proactively according to the user's needs in their current situation. Many studies on ubiquitous computing have been devoted to research into detecting events. For example, retrieving an object related to a recording when someone touches an object for which the sensor information is passed to the retrieval system as a query. Another system called Ubiquitous memories [7] automatically retrieves target objects related to a video recoding which automatically tagged when touching the object. Face detection techniques are used in [8] to tag a person related to a memory, and enable automatic retrieval of personal information triggered by detecting of the face.

Satisfying the need for high precision retrieval from PLLs discussed earlier requires search queries to be as rich as possible by including as much information as possible about the user's information need, and then to exploit this information to achieve the highest possible effectiveness in the search process. Our underlying search system is based on the BM25F extension to the standard Okapi probabilistic information retrieval model [30]. BM25F is designed to most effectively combine multiple fields from documents (content and context) in a theoretically well motivated way for improved retrieval accuracy; BM25F was originally developed for search of web type documents which, as outlined above, are very different to the characteristics of a life log. Thus we are also interested in work such as [31] which explores ways of combining multiple fields for retrieval in the domain of desktop search. Our current research is extending our earlier work, e.g. [28], to investigate retrieval behaviour using our experimental PLL collections to explore new retrieval models specifically developed for this data. In addition, PLL search can also include features such as biometric measures to help in location of highly relevant information [4].

# 5. iCLIPS - A PROTOTYPE PLL SEARCH SYSTEM

The iCLIPS project at DCU is developing technologies for effective search of PLLs. To support this research, three researchers are carrying out long term lifelog data collection. As outlined in Section 2, these collections already include 20 months of data, including visual capture of the physical world events with Microsoft SenseCams [32], full indexing of accessed information on computers and mobiles phones, and context data including location via GPS and people with Bluetooth. The Microsoft

SenseCam also captures sensor information such as light status and movements (accelerometer). Our system indexes every computer activity and SenseCam image with time stamps and context data including location, people, and weather. It enables search of these files by textual content and above context such. Part of our work continues to focus on the development of novel effective search algorithms to best exploit content and context for PLL search. The other focus of the project is the development of a prototype system to explore user interaction with a PLL to satisfy their desire for information derived from their previous life experiences.

One of the reasons for the success of popular established search engines such as *Google* is that their interface is simple to use. Once a few concepts have been understood users are able to use these search engines to support their information search activities. However, simple interfaces to existing collections work well to a large extent due to the features of the data being searched and the background of the users. In the case of web search engines the domain knowledge, search experiences and technical background of searchers is very varied. However, the size of the collection being searched with its inherent redundancy of data with information often repeated in different forms in multiple documents meaning that pieces of information are accessible from different sources using a wide range of queries from users with differing linguistic sophistication and knowledge of the domain. Additionally in the case of the web link structures generated by the community of web authors can be exploited to direct searchers to authoritative or popular pages. In the case of specialised collections such as medical or legal collections, users are typically domain experts who will use a vocabulary well matched to that in documents in the collection. As outlined in Section 5.3 the characteristics of PLL collections are quite different to conventional search collections. An interface to search a PLL collection requires that the user can enter queries using a range of content and context features. The memory association between partially remembered life events means that more sophisticated interfaces supported browsing of the PLLs using different facets are likely to be needed to support the satisfaction of user information needs. Essentially users need an interface to enable them to explore the labyrinth of their memory using different recalled facets of their experiences.

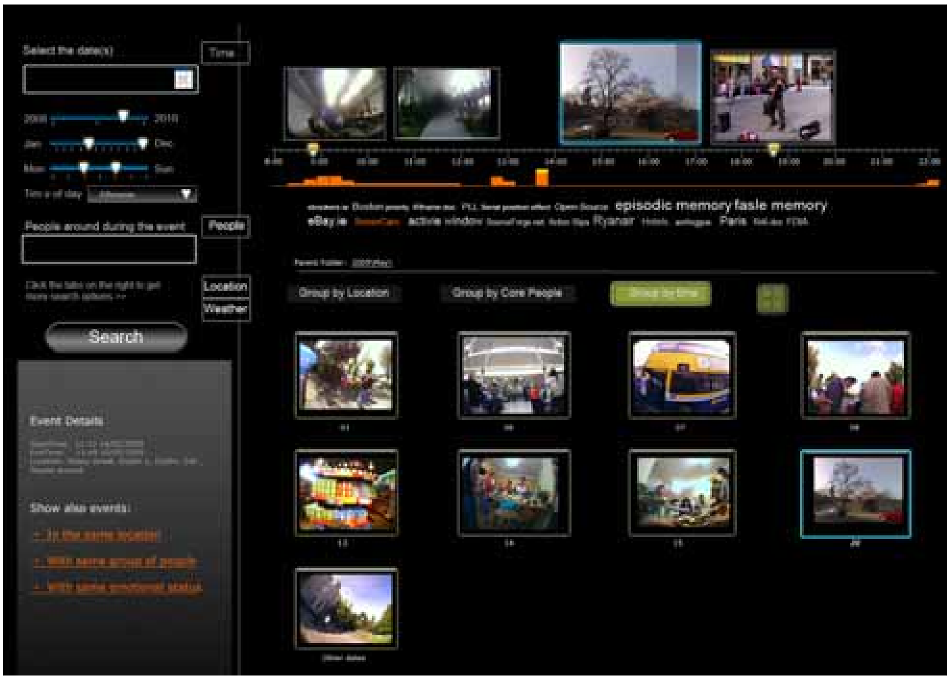


**Figure 1. Sample iCLIPS interface**

Figure 1 shows our prototype interface for use of a PLL as a daily memory aid for normal people. In particular, it aims to serve the functions of: providing specific information or digital items to supplement the parts of memory which are not available to be retrieved; providing cues of specific episodes to assist the user to rehearse experiences during that period. It also seeks to assist users in improving memory capability though repeatedly associating events or information. This interface requires user effort to look for or choose the information to be presented, thus both searching and browsing panels are included.

**Search**

The interface provides a range of search options to cater for the different types of information people may be able to recall about the episodes or items, such as location, people present, weather conditions and date/time. We understand the burden of trying to recall and enter all of these details for a single search, so we adopt the virtues of navigation, and put more weight on the presentation and browsing of results. This is particularly important in cases where over general search queries may bring too many results for easy presentation. For example, sometimes people just want to have a look at what happened during certain periods, e.g. when they were in middle school, and enter a time-based query: year 1998, this may result in huge amount of result data being retrieved which must then be explored by the user.

**Navigation**

To avoid information overload when there are a large number of items as results, and provide instant memory cues for each small step, we adopt the advantages of location-based hierarchical folder structures to let users navigate and browse search results which are grouped either temporally or by attributes such as location or core people attended. Based on psychology literature, we believe that when, where and who are well remembered features of episodes, therefore grouping items based on these features makes it easier for users to remember and know where there target is. It also enables them to jump to other results which have similar attributes (e.g. in the same location, with same group of people). By doing so we also expect the system to help people remember more context data for each event or item, generating more useful associations in their memory and elaborating them.

**Presenting results**

While presenting the results, we provide context cues to help people recognize their target and related folders more easily. Since temporally adjacent activities are argued to be good episodic memory cues, the system enables preview of folders by presenting landmark events or computer activities (if there are any) on a timeline. A “term cloud” (a group of selected keywords, similar to a conventional “tag cloud”) of the computer activities is also presented in the form of text below the timeline, by clicking a word, its frequency of appearance is displayed. Again this is designed to provide more memory cues for recalling what the user was doing with documents which contain such keywords. For example, one may remember that the target needed was previously encountered during the period when he/she read a lot about “SenseCam”. The name of the location and the people are also included in the term clouds for the same reason.

Due to the complex functions provided in the interface, it is not suitable for portable or wearable devices. Thus it is not aimed at solving memory problems which need solution urgently while the person is away from computers. Alternative interfaces potentially automatically taking account of current user context (location, associates nearby, and time) would be needed for mobile interaction is planned to a part of our further study.

We are currently undertaking user studies to evaluate the prototype system. These evaluations include the reliability with which episodes in the results can be recognized from the features presented to the searcher, whether they feel that it is easy to recall at least one piece of information required by the search fields, and the effectiveness of the retrieval algorithms. If these functions are fully working, we can explore how the life loggers prefer to use these data in supporting their memory, and what functions they may want to use in different situations, with our system and our data collection.

# 6. CONCLUSIONS AND FURTHER WORK

In conclusion, developments in digital collection and storage technologies are enabling the collection of very large long term personal information archives in the form of PLLs storing details of an individual’s life experiences. Combining these with effective tools for retrieval and presentation provides the potential for memory aid tools as part of the augmented human.

Effective solutions will enable user’s to confirm partially remembered facts from their past, and be reminded of things they have forgotten about. Applications include recreational and social situations (e.g. sharing details of a life event), being reminded of information in a work situation (e.g. previous meetings with an individual, being provided with materials encountered in the past), and potentially for more effective problem solving. Integrating these technologies to really support and augment humans requires that we understand how memory is used (and how it fails), and to identify opportunities for supporting individuals in their life activities via memory aids. The iCLIPS project is seeking to address these issues by developing technologies and protocols for collection and management, and for effective search and interaction with PLLs.

Our current work is concentrated on completing our prototype system to explore memory augmentation using long-term PLL archives. Going forward we are seeking methods for closer integration between PLLs, the search process and human use of memory, possibly involving mobile applications and presentation of using emerging display technologies such as head up displays and augmented reality.

# 7. ACKNOWLEDGMENTS

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