Challenges and Opportunities within Personal Life Archives

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ABSTRACT

Nowadays, almost everyone holds some form or other of a personal life archive. Automatically maintaining such an archive is an activity that is becoming increasingly common, because without automatic support the users will quickly be overwhelmed by the volume of data and will miss out on the potential benefits that lifelogs provide. In this paper we give an overview of the current status of lifelog research and propose a concept for exploring these archives. We motivate the need for new methodologies for indexing data, organizing content and supporting information access. Finally we will describe challenges to be addressed and give an overview of initial steps that have to be taken, to address the challenges of organising and searching personal life archives.

CCS CONCEPTS

• **Information systems → Digital libraries and archives**; **Personalization**; *Users and interactive retrieval*; *Evaluation of retrieval results*;

KEYWORDS

Search Engine, Lifelogging, Personal Life Archive

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1 INTRODUCTION

New devices such as mobiles, tablets, wearables, in addition to the various social media platforms such as Facebook, Instagram or Snapchat, have became a normal part of everyday life. Consequently, users end up passively collecting large volumes of data about themselves (typically non-indexed) in their own personal life archives, which are currently spread across multiple devices and services. These personal life archives can contain information about every activity an individual participates in, such as where they go, how they get there, who they speak with, what they see and what information they access. In effect, a multi-source, detailed, digital life diary is being generated for every individual who chooses to do use such technologies. The key enabling technology is the ready availability of power-efficient sensing devices, which are embedded in the modern cell-phones and wearables. It is our conjecture that it is only a short step to move from sensing life to searching through the resultant personal life archives.

Furthermore, we believe that there is a clear coverage-gap between the indexed online content and the non-indexed personal life archive content. While conventional search engines provide retrieval facilities over online data, the integration of personal data in the search process has not yet occurred, apart from some limited personalisation of search results (which is more limiting than helpful). It is our conjecture that a new generation of search engine should be able to “zoom" in and out to give users information based on their friends and families (i.e., via social network platforms, from people having the same habits, etc.), and continue to go deeper and must give the insights from the users themselves (from the quantified-self information). Given the right capture technologies, coupled with a new generation of data organisation techniques and semantic multimedia annotation, new ways of interacting with our own personal life archives will emerge and change the way we view ourselves and our activities.

What is needed as a next step of development and to unlock the potential of these data, are new ways of organizing, annotating, indexing and interacting with personal life archives. Being able to interact with the collected data with the same ease as one executes a Google search nowadays, will enable a new level of insight for the users that helps them to get a complete picture of their data and information. This can happen on different granularities such as a phone number, a location, an entire event in great multimedia detail, or even perform an analysis of lifestyle trends over many years.

Providing insights from personal life archives can help to improve healthcare, working lives, education and social activities [5] and can give new levels of self-awareness. Some obvious benefits for the users can be for example, an easy way of sharing natural life experiences, prospective memory feedback to enhance productivity, personalised wellness feedback, better understanding the

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functioning of the human memory system, and a better understanding of the associations between lifestyle, environmental context and mortality.

Nevertheless, there are many challenges to be overcome like optimised, semantically rich data capture, efficient data mining, knowledge extraction and retrieval tools and the provision of appropriate interaction methodologies. In this work we focus on identifying the opportunity and the challenges and then suggesting the mix of technologies that have the most potential to tackle these challenges in the future.

Consequently, the aims of this paper are:

- To provide an overview of past efforts to capture personal life archives in the research community;
- To inspire and motivate researchers in the multimedia community to use their know-how in this new emerging and societal important area;
- To propose how future personal life archive data should be stored and organised, and therefore made easy for a user to access via an appropriate search mechanism;
- To discuss the challenges in providing retrieval and access to personal life archives;

In the rest of this paper we will briefly describe the overall challenges before discussing the particular requirements for data capture, organisation, retrieval and presentation. Finally we will motivate the benefits of personal life archives and introduce our implementations to address these challenges .

2 CURRENT STATE AND PERSONAL LIFE ARCHIVES

In the 1940s Vannevar Bush introduced the world to the Memex, a life knowledge organisation hypermedia system operating as a desk-based device [7]. Memex introduced new concepts such as information links or trails which are created by the individual or by others. Memex was described as an *"enlarged intimate supplement to ones memory"*. In these words, Bush had identified some of the key issues for maintaining personal life archives, that they be enlarged (store as much information as feasible), intimate (private to the owner) and supplemental (working in synergy with ones memory). The Memex provided an inspiration for the Xanadu system [35] by Ted Nelson which introduced the terms hypertext and hypermedia and was a precursor to the WWW, though with different aims and goals. In 2006, Bell and Gemmel's work on developing the MyLifeBits [21] personal life experience archiving tool digital memories [4, 5], and their book Total Recall [5] introduced the public to the concept of maintaining personal life archives of all information encountered and developed the first database focused retrieval technologies.

Lifelogging has appeared to be an extreme activity carried out only by a small number of pioneering enthusiasts e.g., Steve Mann [33], Gordon Bell [4], and Cathal Gurrin [15, 27]. If one explores the reasons why only few pioneers had gathered these personal life archives automatically are many and varied and pose a set of challenges for the community to consider. One of the most important challenges is the privacy and ethical concerns [14, 36]. It is our conjecture that personal life archives are likely to follow the experiences of cell phone cameras, social networking sites, and location tracking services. Once the personalised experience, wellness, and memory capture and sharing provide a wide range of benefits to end users; these concerns become of secondary importance. In other words, society develops an acceptable usage policy and embraces a new technology as the benefits become apparent. Another challenge comes with the overwhelming amounts of data [42] that personal life archives naturally generate. Research has indicated that lifelog data can be summarised into useful knowledge through i) segmenting it into a series of distinct events or activities [16], ii) automatically labelling those events from both the content [15] and context [30], iii) automatically detecting faces and event novelty to identify those events that are more interesting to reflect on [17], iv) presenting segments of this personal life archive to the user as required and v) analysing this data to provide new knowledge to the user.

Another challenge is that personal life archives attract life activity data at varying degrees of fidelity. A single sensor (e.g., an odometer or pedometer) operates at a very low-fidelity whereas the wearable video technique moves towards high-fidelity total capture which digitises a much richer snapshot of life activities. All such data has sometimes been referred to as memories, yet this should not be considered as an actual memory capture technique, rather a multimedia sampling of a representation of a life activity, which, when located and presented by appropriate software to a user would help to trigger wet-ware memory recall.

Consequently, and in agreement with Bush's vision of the 'enlarged intimate supplement to ones memory', we refer to these lifelogs or e-memories as Personal Life Archives of sampled life experience data that can be analysed in real-time and work with the person's memory to enhance life experience. *Personal*, in the sense that they are intensely private archives that are gathered by the individual for the individual, though of course they may be stored and processed remotely and aspects of the archive may be shared with other people or organisations. *Life* in the sense that they are enlarged archives of life activity data and as such should aim for the target of total capture of life experience. *Archives* in that they will be historically stored and analysed throughout the life of the individual and potentially even longer. While real-time access will provide for life enriching contextual access to past activities (in synergy with the individual's natural memory), there is also enormous potential for long-term analysis and understanding of the life archive data.

3 CHALLENGES

Search and ranking is only one aspect of the challenge that information retrieval systems have to tackle. When we are developing retrieval systems, whether for personal life archives or simply for WWW pages, to find a starting point, we need to understand how the personal life archive will be accessed. To begin our consideration, contemplate how people access their own digital photo or video archives. For sufficiently small archives, a browsing mechanism (manually or automatic organisation into clusters based on folders or events) is acceptable, where the selection of an axis of browsing results in the generation of a manageable set of result documents. Consider browsing a photo archive using date or location. However, when the archives become larger and less organised, a search or search/browse metaphor is normally chosen to support fast and effective access.

Contemplating personal life archives, the sheer scale of these multi-year or multi-decade archives suggests that a browsing methodology is not sufficient from the outset. The initial (and the only) experiments into multi-year multimodal personal life archive search suggests that even a basic search methodology increases the possibility of a user locating desired content by a factor of three in a third of the time [17]. When considering search, there are a number of alternative search methodologies that could be considered. Firstly keyword based search can be processed over textual narratives generated from the sampled life experience. Another alternative approach is to support the user in generating a new type of multi-axes query in an efficient manner; for example, I know that my friends Paul and Jack were there, it was a Sunday evening, and we were in Barcelona watching a football game in a bar. A third option is the real-time context-driven automatic querying that is somewhat of a holy grail of this research area. The realtime sampling of life experience can trigger contextual queries to support recollection, retrieval of information and remembering intentions, which, if presented to the user in a suitable manner, can provide for truly novel and currently unknown applications for personal life archives. Applications that can remind you that the person you have just met is having a birthday today or that the last time you bought this type of soup, you felt ill the following day.

While there has been an explosion in the amount of consumer-sensed and -generated data now being created, stored and shared, the ability to organize and provide useful retrieval facilities over this data is still limited. There are many domain-specific solutions for uses such as sensing the level of exercise or sharing a user's location, however, there are still few attempts to fully grasp the full potential of sensing the person, the quantified self [34]. As we progress towards more enhanced sensing of the person (total capture), this coming world of personal life archives will pose new challenges for the areas of multimedia contextual sensor capture, multimedia data organisation, multimedia search and retrieval as well as the human factors that define how we can interact with these personal life archives, not to mention the outstanding issues such as privacy, security of data and supporting the important human need to forget.

We can point out that the key challenges are to gather rich archives in real-time in a non-intrusive manner, to organise these archives into meaningful experiences and generate descriptive metadata, to provide retrieval and recommendation facilities and to support omnipresence of access.

In order to more clearly define the interaction challenges and help to articulate our vision, let us again refer to the five R's of memory access from Sellen & Whittaker [42]. The five R's are recollecting, reminiscing, retrieving, reflecting and remembering intentions. Each of the five Rs define a different reason why people access their memories, and by inference, why people would wish to access their personal life archives. Since each R defines a different way that people are able to interact with their memories, and until such time as we have sufficient numbers of people maintaining personal life archives to get real-world usage data, they serve as a the only source of different proposed interaction scenarios available.

- *Recollecting* is concerned with reliving past experiences for various reasons. For example, we may want to recall who was at an event, or where we parked the car.
- *Reminiscing*, which is a form of recollecting, is about reliving past experiences for emotional or sentimental reasons. It is often concerned with story-telling or sharing of life experiences with others.
- *Retrieving (information)*, is a more specific form of recollecting in which we seek to retrieve specific information from the personal life archive, such as an address, a document or a piece of information.
- *Reflecting*, is a form of quantified self-analysis over the life archive data to discover knowledge and insights that may not be immediately obvious.
- *Remembering Intentions*, which is more about prospective (remembering plans) memory than episodic memory (past experiences). This is a form of planning future activities which is a life activity that everyone engages in.

These provide valuable clues how to develop the organisation, search and presentation elements of Personal Life archives and will be the focus of the remainder of this paper.

3.1 Life Archive Capture & Storage

The starting point in generating personal life archives is gathering the data in a non-intrusive manner. Prior work [42] has suggested that focused capture of only the information that the individual needs at a point in time is the best approach for supporting human memory; however we suggest that such an approach is not in keeping with the Memex vision and would significantly limit the potential of Personal Life Archives. The idea of 'total capture' [21], sampling life experience in high-fidelity, is that all life experience, whether considered important or useful at the time would be captured. This will provide for a more useful, future-proof and flexible personal life archive. As an analogy, WWW search engines index all the WWW; a search engine that selectively indexes only the important or popular content would fail to catch trends, hot-topics or the long-tail of user queries. Total capture of every aspect and moment of life experience, whether it is every heart beat, our locations and motion, or everything we see and do, provides us with new and potentially valuable information about ourselves.

Inspired by the work of Gurrin et al. in [22], we list different categories of life archiving tools which can be applied at the time of writing:

- Passive visual capture. Utilising wearable devices such as Narrative Clip [1], the Microsoft SenseCam [28], or first-generation Augmented Reality glasses, will allow for the continuous and automatic capture of life activities as a visual sequence of digital images.
- Passive audio capture. Audio capture could allow for the identification of events or identification people who was speaking. It is normally can be done via any smartphone.
- Personal biometrics. Sensing devices are becoming more common and widely used by the quantified self community, which allow wearer monitor their sleep duration, distance traveled, caloric output, and other biometrics information.

[1] http://getnarrative.com

- Mobile device context. This refers to using the phone to continuously and passively capture the users context (e.g., location, movement, or acceleration), coupled with smart watches, these devices are able to capture much of the activities of life.
- Communication activities. This refers to the phone or PC passively logs messages, emails, phone calls, or other contents of communications.
- Data creation/access activities. Logging data consumed and created, for example, the words typed, web pages visited, videos watched and so on.
- Environmental context and media. According to [22], lifelogging is mostly, but not exclusively about recording using wearable technology, they could be logged (and accessed) by other sensors, such as surveillance cameras.
- Manual logging life activities. This refers to the indirect or direct logging of activity that is initiated by the user, for example, video recording, personal logs and diary.

Once sensed data has been captured, it needs to be stored, which is one of the key challenges that needs to be addressed. In order to support any of the five R's (especially reflection) the personal life archive should not be time-limited, i.e., should extend back indefinitely and life experiences (unless expressly requested by the user) should not be deleted for reasons of storage capacity or processing overhead. However some form of summarisation may be necessary.

A typical lifelogging camera wearer will generate about 1TB of data per year. For an individual, this is reasonable to assume storage on a single computer and the assumption of Kryder's law, that hard drive densities will continue to increase, should see the storage capacity keep pace with data storage requirements. However, storage capacity that is sufficient for periodic photo capture will not necessarily keep pace with continuous video capture, which will require many tens of TBs per year. Notwithstanding the relatively low cost of digital storage, once data services scale to thousands or millions of people, then local storage solutions would tend to be replaced by cloud-hosting. However in the case of the data storage requirements of personal life archives, (at current pricing models) the data storage cost for cloud-hosting is likely to be prohibitive. An alternative solution needs to be found that merges the convenience and data security of a cloud-hosting service with the low cost of individual storage solutions.

Over the coming sections we will describe our current technique to automatically organise personal life archives.

3.2 Life Archive Organisation

The human memory system has evolved over thousands of years to store autobiographical memories, and we believe that personal digital archives needs to mimic how the human mind operates. Past literature has motivated that the human mind stores information in distinct events or episodes, that similar episodes are associated with each other, and that more important episodes are more strongly remembered [17]. However in addition to this, given the range of data streams associated with a given important episode of interest, a short descriptive summary narrative of that episode is required. As a starting point, the personal digital archive information could be arranged as follows:

- *Raw data should be hierarchically arranged and stored:* Typically in information retrieval (IR), there is a single basic unit for indexing and retrieval, typically called the document. For many IR tasks, this basic unit is the preferred as unit of retrieval and choosing the basic unit is usually trivial. With lifelog data, it is not trivial to decide what the basic unit is since the lifelogs are multimodal with different modes captured at different frequencies (1 second to potentially 1 day, or longer) [14]. In order to deal with this problem, we followed the study in [14] that sort the data by chronological order, and use the minute as the basic units.
  Building up from the basic unit, we organize the data at higher level with can be turned into more useful information. Typically, in a full day, we know that a person encounters anything upwards of 20 individual *episodes or events*, with each lasting on average about 30 minutes, though there is a lot of variety [18, 31]. Prior work on episode segmentation analyses sensor streams from wearable cameras to segment of life-experience into events, post-capture [16], however this poses a problem. The human memory operates in real-time, so any personal life archive, that is designed to work in synergy with human memory should also work in real-time. Hence, we propose that processing should occur in real-time and that this entails data analysis on both the smartphone, wearable devices and a cloud-based server, to operate in real-time and upload *events* to the personal life archive as they happen. We have extensively evaluated many such event segmentation techniques on uploaded data [16]. However future challenges remain in developing real-time episode segmentation on the devices.
- *Episodes should be semantically described:* To support both post-hoc review and real-time analysis of episodes, both server-side and device-based semantic analysis tools are needed. These act as software sensors to enrich the raw sensor streams with semantically meaningful annotations; such software sensors are multi-layered to allow for additional derivations to be minded from existing sensor outputs the personal life archives. For example, raw accelerometer values on a smartphone can identify the physical activities of a user [3], bluetooth and GPS sensors or audio allow us to determine where and with whom people are with [9], while using automatic detection of concepts is possible from images [15]. These user activities combined with and event ontologies help infer higher-level semantics on the lifestyle of individuals. We currently utilise the following virtual sensors in our personal digital archiving system; semantic date/time, meaningful location, personal physical activity, social interactions (via bluetooth), environmental context (via GPS and crowd-sourcing of relevant tags [20]), semantic visual concepts automatically identified from the photos and personal context of the user's life pattern. Together, these generate a detailed description of user activities. In addition the relative importance or potential memorability of each episode can be determined via a combination of image face detection and bluetooth people recognition, in conjunction with the relative uniqueness of the situation the user is in (relative to their normal lifestyle) [19].
- *A simple narrative summary of each episode should be generated:* Individuals desire quick and simple episode summaries that are easy to understand. For example, Xu explains why such simple summaries are desired on a cognitive functioning level [46], "*The*

mental representation or situation model clearly depends upon interactions between the language system and complementary, extra-linguistic cognitive processes … the situation model is created by connecting the text with knowledge derived from the reader's long-term memory, and involves additional demands upon attention (e.g., the ability to shift points of view and parse sequences of events), working memory (the ability to retain longer term, anaphoric references), and the contribution of emotional knowledge, visual imagery, empathy, and abstraction" [46]. Concise narratives are an important building block for personal life archives in that they are shown to produce emotional responses to autobiographical memories and help support many of the 5 Rs of memory access. This therefore motivates the needs to summarise the range of sensor stream semantic annotations into a meaningful and engaging descriptive narrative. A secondary benefit of such narrative generation is that the textual narratives can also be used to support keyword text search [39].

3.3 Life Archive Indexing and Annotation

To be able to retrieve life experiences for search or recommendation from personal life archive, either later or in real-time, the experiences and their annotations need to be indexed. An initial assumption would be to employ state-of-the-art techniques from artificial intelligence, database search and information retrieval to scalably index the life-experience events and provide omnipresent access via keyword/database search, ranking, recommending and presenting the multimedia rich life experience archive through multimodal interfaces. However, we contend that to better understand how to develop lifelogging solutions and how to support effective access to these data, it becomes necessary not simply to view this as a new form of multimedia retrieval challenge. Rather, it is important to understand how people will use and access their life archives. As a starting point, we turn again to the five R's of memory access from Sellen & Whittaker [42]. Each of the five Rs define a different reason why people want to access their memories, and by inference, their personal life archives. They provide valuable clues as to how to develop the organisation, search and presentation elements of Personal Life archives.

- Recollecting is concerned with reliving past experiences for various reasons. To take an analogy from cognitive science, Recollecting is concerned with accessing episodic memories. Recollecting will require highly accurate search engines that semantically rank content and extract just the nugget of information that is most pertinent to the user and represent this event in as much detail as possible to as to aid recollection. This will require conventional information retrieval, coupled with query-specific experience segmentation (somewhat similar to the Shot Boundary Detection [43] of digital video. This in itself is a motivation for 'total capture'.
- Reminiscing, which is a form of recollecting, is about reliving past experiences for emotional or sentimental reasons, sometimes alone, often with others. From information Retrieval, it will require new techniques for narrative generation [10], storytelling [8], topic detection and tracking [1] and novelty detection [47] from single (and potentially from multiple individual's archives), all operating in conjunction with conventional multimedia document ranking techniques, as required for Retrieving (below).
- Retrieving (information), is a more specific form of recollecting in which we seek to retrieve specific nuggets of information from the personal life archive. Retrieval will require highly accurate text, multimedia and sensor data search engines that semantically rank content and extract just the nugget of information that is most pertinent to the user. The conventional Information Retrieval concept of top N ranked lists does not successfully operate for personal life archives (unless N = 1); after all, there is marginal benefit in a system that provides a ranked list of locations for where the car has been left. The query will define the type of knowledge that is required; it is unlikely that a whole document would be expected in response to a query, as is the norm for WWW search. Rather the personal life archive is more akin to question answering in Wolfram Alpha than to whole document retrieval in Google.
- Reflecting, is a form of quantified self analysis over the life archive data to discover knowledge and insights. It includes information summarisation from lifelog streams [37], event detection [20] and various forms of data analysis to infer and evaluate the importance of new semantic knowledge [9, 15, 38, 44] from the personal life archive. Typically such data analysis approaches rely on artificial intelligence, machine learning and various forms of statistical analysis and should proactively recommend new knowledge, not solely relying on a human information need as input, due to the fact that reflecting from a personal life archive brings the potential for new knowledge discovery.
- Remembering Intentions, is a form of planning future activities which is a life activity that everyone engages in. This assists people to remind or prompt them on tasks they would like to do (*e.g. post that letter*), or real-time prompts on who they are talking to (*e.g. this is Paul*), or giving prompts on conversation cues (*e.g. last time here together, you had just come away from seeing the new Batman film*). Past lifelogging efforts were exclusively focused on episodic memory as it was always a post-hoc analysis (i.e. constrained by technology); however now with real-time technology available we can now consider situational awareness (and past history of user) to provide prospective memory prompts.

Taking the five Rs as a guide, we need to identify how to develop efficient methods that can effectively provide insights from the life archive, not simply in response to an explicit user query, but also in response to real-time contextual cues.

4 POTENTIAL APPLICATIONS

Getting insights from personal live archives will very soon be a phenomenon available to everyone and exploiting the personal life archives will positively impact on everyone who uses the technology. Through integration with other wearable sensors (for example Bluetooth on cell phones) new opportunities are presented, namely:

- **Easy sharing of natural life experiences:** There has been an increased prevalence of photo sharing on social networking sites such as Facebook, Instagram or Flickr. In particular uploads from mobile devices are becoming ever more common, e.g., the Instagram website has 700 million users at the time of writing who produce images and videos plus additional metadata. However until now the user has had to make a conscious decision to capture every image or photo. This has meant that any experience a user wants to capture had to be interrupted to take a photograph. The lifelogging platform of passive life experience capture now allows users to enjoy their experiences, safe in the knowledge that the media rich experience can easily be reviewed and shared after the experience has ended.

- **Prospective memory feedback to enhance productivity:** Most memory research exploiting visual lifelogging has focused on retrospective episodic memory tasks [11]. However as real-time upload of the visual field-of-view becomes feasible, we can now begin to support human prospective memory [2]. Given a user's prior set of experiences and preferences (historical lifelog data), and their current situation (gathered via on-board mobile device and wearable sensors), prospective memory prompts can be provided.
- **Personalised wellness feedback:** Poor diet and physical activity lifestyle choices are strongly associated with the early death of millions of people [45]. Passive capture lifelogging devices offer the potential to automatically identify episodes of physical activity [32] and diet [40]. Through learning the extent of the user's current physical activity and diet levels, in addition to setting some targets, an individual can be automatically relayed prompts to help them make the healthy lifestyle choice.
- **A greater knowledge of self:** Coupled with the concept of personal wellness, the era of personal life archives will provide information to the individual about their own life activities and performance; information that otherwise would go unnoticed. One can identify trends and pattern in lifestyle and wellness over an extended period of time.
- **A memory assistant:** Neurodegerative disease affects a large proportion of an aging population and maintaining a personal life archive has been shown in initial small-scale studies to help offset some of the debilitating effects of memory impairment [28]. Even for individuals with fully functional memories, the ability to refer back to the personal life archive will allow for disambiguation of faded memories and more accurate recall of the past, when such accuracy is needed.
- **An opportunity to better understand the functioning of the human memory system:** Given that self-reporting is notoriously prone to error [32], visual lifelogs offer the opportunity to verify the contextual details of episodic memories recalled by individuals and can play an important part of modern studies into human memory.
- **An opportunity to better understand the associations between lifestyle, environmental context and mortality:** Understanding the determinants and barriers to physical activity behaviours is important in designing interventions to positively change these behaviours [41]. Accurate measurement of the type and context of physical activity episodes is therefore important [6]. Examples of important context attributes of an episode of physical activity include: whether it occurs indoors or outdoors; the time of day it occurs; if it is alone or in companionship; and its domain (home, occupational, etc.). Currently, some of these attributes are subjectively measured via self-reporting, but for interventions to be successful, accurate measurement of existing behaviour on what people are doing and when, as well as under what conditions, is critical. Automatic lifelogging on a cell phone offers an opportunity to more accurately measure associations between lifestyle, environmental context, and mortality.

The potential for personal life archives is enormous. We do acknowledge that there are challenges to be overcome, such as privacy concerns, data storage, security of data, and the development of a new generation of search and organisation tools, but we believe that these will be overcome and that we are on the cusp of a positive turning point for society; the era of the quantified individual who knows more about the self than ever before, has more knowledge to improve the quality of their own life and can share life events and experiences in rich detail with friends and contacts.

5 INITIAL IMPLEMENTATION

This section presents our first implementations to tackle the challenges mentioned earlier as well as to inspire and motivate researchers in the multimedia community to use their know-how in this new emerging and societal important area.

5.1 Building Personal Archive Datasets

Researchers usually need data to evaluate their methods, and there is no exception for researchers in personal life archive organisation and retrieval. To support such research efforts, we gathered large volumes of lifelog data from several volunteer lifeloggers and organized, annotated and published them for researchers as the two lifelogging tasks in NTCIR 12 - Lifelog [25, 26] and NTCIR 13 - Lifelog 2[2]. To the best of our knowledge, our collections are the largest (in terms of number of days and the size of the collection) and richest (in terms of types of information) datasets on personal life archives. These datasets are summarised in Table 1.

Moreover, over the last decade, we pointed out the challenges for building a shared personal life archive dataset [23], proposed principles, built and described the whole processes from data gathering to determining the roles for the people who are building, sharing and exploiting such kind of data [14]. These principles can be considered as references for systems that collect personal life archive.

Table 1: Statistics of the Datasets.

	NTCIR-12	NTCIR-13
Number of Lifeloggers	**3**	**2**
Number of days	**87**	**90**
Size of the Collection (GB)	**18.18**	**26.6**
Size of the Collection (Images)	**88,124**	**114,547**
Size of the Collection (Locations)	**130**	**138**

[2]http://ntcir-lifelog.computing.dcu.ie/

5.2 Benchmarking Initiatives and Workshops on Life Archive Analytics

As the first step of building the community working on personal life archives, we increasingly organize related workshops and panels: iConf 2016[3], Lifelogging Tools and Applications in ACM MM 2016 [24] and ACM MM 2017[4].

Together with these, we organize rigorous comparative benchmarking initiatives: NTCIR 12 - Lifelog [25, 26], NTCIR 13 - Lifelog 2, and the LifeLog task [13] at ImageCLEF 2017 [29], which aim to bring the attention of personal live archive analytics to a wide audience and to motivate research into some of the key challenges of the field.

Table 2: Statistics of the Benchmarking Campaigns.

	NTCIR-12 (2016)	NTCIR-13 (2017)	ImageCLEF (2017)
Number of Tasks	**2**	**4**	**2**
Number of Topics	**58**	**59**	**51**
Number of Submissions	**14**	**21**	**18**

Typically, for each benchmarking initiative, together with the dataset, we introduced several tasks which aims at advancing the state-of-the-art research in lifelogging as an application of information retrieval. For example, in ImageCLEFlifelog 2017 edition[13], we introduce two tasks: Lifelog Retrieval Task (LRT) and Lifelog Summarisation Task (LS). In LRT, the participants had to analyse the lifelog data and for several specific queries, return the correct answers, for example *"In a Meeting: Find the moment(s) in which the user was in a meeting at work with 2 or more people"*. In LST, the participants had to analyse all the images and summarize them according to specific requirements. For instance: *"Shopping: Summarize the moment(s) in which user doing shopping. To be relevant, the user must clearly be inside a supermarket or shopping stores (includes book store, convenient store, pharmacy, etc). Passing by or otherwise seeing a supermarket are not considered relevant if the user does not enter the shop to go shopping. Blurred or out of focus images are not relevant. Images that are covered (mostly by the lifelogger's arm) are not relevant."*

Table 2 summarises our evaluation benchmarking campaigns. According to the results, we can confirm that the proposed dataset is enough for the proposed topics, in which the answers can be achieved by exploiting the provided multimodal data. For more details of these campaigns, please see in [13, 25, 26].

5.3 A Base-line Search Engine for Life Archives

Another means of supporting the research community, besides constructing datasets, organizing benchmarking initiatives and workshops, is building a baseline search engine for personal life archives. This baseline engine serves as a basic retrieval system where the query is made up from basic information needs, where each of them is asking for a single piece of information, which are already extracted and indexed. Queries were submitted that generate ranked lists based on faceted queries, by userID, location visual concept and/or physical activity. A preliminary version of this search engine can be obtained via: `http://search-lifelog.computing.dcu.ie/`, which provides a basic retrieval model for the lifelog datasets (other details of the data used in this baseline search engine are summarised in Table 3).

[3]http://irlld2016.computing.dcu.ie/index.html
[4]http://lta2017.computing.dcu.ie

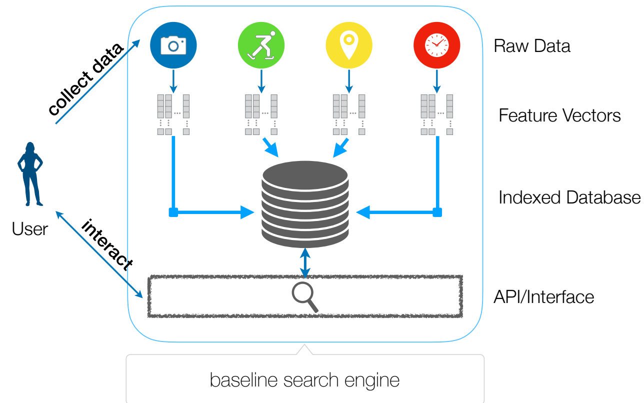

Figure 1: The baseline search engine architecture

Table 3: Statistics of the Data Used in the Baseline Search Engine.

Number of Lifeloggers	**1**
Number of Days	**90** days
Size of the Collection	**12.2** GB
Number of Images	**51,209** images
Number of Locations	**24** locations

Figure 1 summarises how we designed the baseline search engine system [48], as follows: from the raw lifelog data, we extract locations, visual concepts, time, and activities and transformed this raw data into indexable feature vectors. These feature vectors are then indexed and hierarchically organized. Finally, a user or other system can define a faceted query and retrieve ranked moments via the interface.

5.3.1 Data Organisation and Retrieval Process. To organise and index the data, we arrange features as chronological order, and use the minute as the basic unit of indexing and retrieval. Building up from these minutes, we organize the data at higher level which can be turned into more useful information, the minutes are hierarchically grouped into event nodes (typically, in a full day, a person encounters anything upwards of 20 individual events, with each lasting (on average) 30 minutes [18, 31]), then ultimately leading to larger units such as days and multi-day events (e.g. holidays).

In order to turn a query into specific criteria, i.e., to make the baseline search engine able to get insights from the personal life archive, we apply two approaches: firstly, automatic query generation by considering the terms in the query as identifiers of concepts and then searching for all images that contain those concepts, and secondly, a fine-tunning method by manually generating a query string i.e., the researcher (we) will read the topic and "translate" it into the search criteria. For example, with the query:

(a) 20160818_Taking a train (b) 20160827_Taking an airplane (c) 20160829_Taking a bus

(d) 20160830_Taking a taxi (e) 20160906_Taking a coach (e) 20160906_Taking a bus

Figure 2: Examples of the results retrieved by the proposed baseline search engine for the query "Find the moment when I was taking public transportation or taxi at sunset."

`"Find the moments when user u1 was using public transportation or taxi at sunset."`

We follow the study methodology proposed in [49] and "translate" that query into specific required pieces of information, as follows:

- `User = {u1}`,
- `Concepts = {sunset}`,
- `Activity = {transport, airplane}`,
- `time = {16:00-21:00}`
- `Location = {n/A}`

5.3.2 Ranking. To refine the results, i.e., to increase the precision of the top retrieved images, we use a hierarchical agglomerative clustering algorithm (see [12]) to group similar images into the same cluster based on all of their features. The clusters are then sorted based on the number of images, in decreasing rank order. Finally, we produce the ranked list by selecting representative images from the clusters by choosing the images closest to the center of each cluster.

5.3.3 Results. We applied the baseline search engine to the benchmarking campaigns mentioned in Section 5.2, serving as a baseline for the comparison. For some topics, the scores were 1.00 and 0.92 for precision and recall, which shows the potential of this baseline search engine. Consequently, this engine was added as a part of the campaigns, allowing participant to obtain baseline results and develop more complex retrieval systems on-top of this baseline search engine. Some other examples can be seen in Figure 2.

6 CONCLUSIONS

In this paper we presented a set of possible challenges and opportunities from personal life archives. We identified methods and technologies that can aid users to get insights in their data, from public resources to their social connections and closer intimacy, and moreover, from their personal life archive, including different granularities of information from their past experiences. We presented the current state of the field and provided a number of potential benefits. Furthermore, we identified and proposed solutions to the challenges that arise with such data. This will be increasingly important over the coming years as we learn more about ourselves and have access to technologies that will help us in many aspects of everyday life. We also showed that there are several research challenges to address in the fields of Artificial Intelligence, Cognitive Science and Information Retrieval. Starting with security and privacy, human computer interaction, and memory science, valuable insights into how to address these challenges can be obtained. Finally we presented a baseline search enginge that achieves reasonable results that can be useful for other researchers interested in the field.

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