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Fast track article

Creating human digital memories with the aid of pervasive mobile devices

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ABSTRACT

The abundance of mobile and sensing devices, within our environment, has led to a society in which any object, embedded with sensors, is capable of providing us with information. A human digital memory, created with the data from these pervasive devices, produces a more dynamic and data rich memory. Information such as how you felt, where you were and the context of the environment can be established. This paper presents the DigMem system, which utilizes distributed mobile services, linked data and machine learning to create such memories. Along with the design of the system, a prototype has also been developed, and two case studies have been undertaken, which successfully create memories. As well as demonstrating how memories are created, a key concern in human digital memory research relates to the amount of data that is generated and stored. In particular, searching this set of big data is a key challenge. In response to this, the paper evaluates the use of machine learning algorithms, as an alternative to SPARQL, and treats searching as a classification problem. In particular, supervised machine learning algorithms are used to find information in semantic annotations, based on probabilistic reasoning. Our approach produces good results with 100% sensitivity, 93% specificity, 93% positive predicted value, 100% negative predicted value, and an overall accuracy of 97%.

1. Introduction

Memory influences every aspect of our lives. It is considered to be the most basic and important operation of the brain, with very few cognitive processes (recognition, language, planning, etc.) being able to operate effectively without a contribution from it [1]. Memories are a significant part of our existence that can be shared anywhere and at any time. Reminiscing, over past experiences, is a substantial part of our lives. It is a practice that has been performed over thousands of years and is what makes us who we are. However, losing the ability to recollect memories is not only disadvantageous, but can prove quite detrimental, particularly to many older people [2]. Nevertheless, recent advances in technology can alleviate this problem, to a certain extent. As technology advances, computing devices have now taken a more central role in our lives. They have shifted in reliance from just being seen as "glorified calculators" [3], to devices that are capable of capturing and storing our entire lives. As such, this shift has resulted in the area of creating and managing human digital memories being declared a grand challenge in computing research [4].

In today's society, the proliferation of "smart" mobile devices is becoming more abundant. Currently, 81.6 million mobile subscriptions are held in the UK [5]. By 2016, Cisco predicts that there will be more than 10 billion mobile Internet-connected devices, which exceeds the worlds projected population, at that time, of 7.3 billion [6]. Devices are now smarter, smaller, easier to transport and able to capture a variety of data, such as photos, location and videos. Body sensors are

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also becoming more widespread, as people develop an interest in monitoring their health. These devices are capable of capturing physiological data, such as sweat rates, body temperature and heart rate, whilst environmental sensors can gather temperature, humidity and atmospheric readings. As these devices become more prevalent, within our environment, a vast array of information about us and our surroundings can be captured and utilized. Storage capacities are also increasing, and a lifetime of data can be saved, resulting in an increasing amount of content being captured, stored and shared. The explosion of mobile computing and ubiquitous content sharing has enabled users to create and distribute data instantly.

As mobile devices become more widespread, and sophisticated, this has led to a generation of users who capture more content, ubiquitously, than previously seen. For example, in relation to YouTube, traffic from mobile devices tripled in 2011 and over 4 billion hours of video are watched each month, with more than 20% of global views coming from such devices [7]. This shift in ubiquitously capturing and sharing content has led to people creating extensive digital collections and reflection of those items has become an active part of people's lives [8]. Taking the concept of capturing personal content one step further, the practise of "lifelogging" refers to the process of automatically recording aspects of one's life in digital form [9]. As described by Dodge and Kitchin [10], "*A life-log is conceived as a form of pervasive computing consisting of a unified digital record of the totality of an individual's experiences, captured multimodally through digital sensors and stored permanently as a personal multimedia archive*". Whilst the process of recording this information is known as lifelogging, the outcome is often referred to as a human digital memory (HDM). As defined by Kelly [11], "*A HDM is typically a combination of many types of media, audio, video, images, and many texts of textual content*". These personal archives are constructed from a wide range of data sources, across various media types [12]. As technology advances and sensors become more prevalent within our environment, the range of data that we have access to is increasing. Therefore, a greater level of detail can be incorporated into the creation of a HDM. New possibilities will allow content about us, and family and friends to be clustered and linked together, based upon a multitude of factors. This will include information from mobile and physiological computing. This data provides a richer understanding about aspects of our health, level of activity and physical wellbeing, even providing information on how we made others feel at that time. However, whilst we have access to many data sources, capturing and collating all of this information is a challenge. The vision, and one of the challenges, of memories for life is to help people manage and use their digital memories across their entire lifetime [4]. This work illustrates how data, from pervasive devices, can be used to create a more vivid HDM and how this data can be captured and utilized for an extensive amount of time.

This paper explores how HDMs can be created, using pervasive devices, and is an extension of previous work [13]. In this work, the DigMem system is presented, which creates rich and interactive HDMs, utilizing devices in the user's present environment. In order to create these dynamic memories, a new method is being proposed. The approach creates an ad-hoc peer-to-peer (P2P) network and obtains data from ubiquitous devices. Utilizing linked data and machine learning, these various pieces of information are brought together to form a HDM. Whilst each device generates many specific pieces of data, these individual datasets are not suitable, on their own, for representing a HDM, as the level of detail is very low. In order to overcome this, memory boxes are created by semantically linking all the related data and turning it into visual items of events. Previous work [13] focused on creating the P2P network that is used to obtain information, from a number of device-specific services. In this paper, the idea is extended into a fully functional system that takes the gathered information and constructs it into a HDM. This is achieved using machine learning and semantic web technologies. In this sense, the system is capable of creating HDMs that take advantage of the user's current environment. This is beneficial as DigMem provides a standardized method that enables the user to create an ad-hoc P2P network and obtain information from devices prevalent within their environment. This approach eliminates the need to purchase specialist equipment and allows a more dynamic memory to be created, as a number of different services can be brought together to produce a richer HDM. The approach also benefits from being flexible enough to collect and use HDM data over an extensive period.

In order to demonstrate the applicability of the design, a prototype has been developed. To validate the implementation, two case studies have also been undertaken. A key concern in human digital memory research relates to the amount of data that is generated and stored. In particular, searching this set of big data is a key challenge. In response to this, the paper evaluates the use of machine learning algorithms, as an alternative to SPARQL, and treats searching as a classification problem. Based on probabilistic reasoning, supervised machine learning algorithms are evaluated to find information, in semantic annotations.

2. Related works

Capturing memories is an activity that all of us do regularly. From taking photos and videos to inadvertently saving emails and texts, our lives can be reconstructed from our digital artefacts. Nowadays, these moments are less likely to be captured on "traditional" cameras and camcorders but increasingly on mobile devices and sensor equipment. This shift has resulted in the effortful selective capturing of moments being replaced by digital lifelogging, which seeks to be effortless and all-encompassing, in terms of data capture [14]. Content is being captured constantly and with minimal user involvement (i.e. with the use of automatic, wearable devices). Mobile devices and sensor equipment are now able to capture a more comprehensive record of everyday life, more or less as and when it happens [14]. These devices offer an innovative and less obtrusive method for capturing content ubiquitously and are able to document our entire lives. A vast collection of information can be recorded about ourselves at any time. Automatically recording this data, and quantifying how a given aspect of our body changes over time, provides an insight into our underlying behaviours [9,15]. This increasing trend is one that will only strengthen over time, presenting us with new and novel ways in which the data can be obtained.