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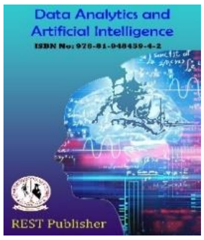

Augumented Reality In IOT

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Abstract: *The Internet of Things allows for the development of hybrid solutions merging physical products with digital services. After the widespread adoption of Internet of Things in supply chains, we are now witnessing a surge of consumer Internet of Things applications. Due to the proliferation of smartphones, Internet of Things applications gain personal, interactive, and behavioral context. Smartphones thus take up a gateway role and mediate between and among people, physical and digital things, and/or the environment. In this article, we discuss why Augmented Reality technologies are essential for evolving this gateway role in the Internet of Things and how alternate form-factors of the smartphone (e.g. glasses, watches, contacts, gloves, etc.) might impact context-aware service interactions. Keywords: Internet of Things, Augmented Reality, smartphones, services, smart objects, digital biomarker, field-of-view interactions, object recognition*

Keywords:
Internet-of-Things (IoT), IoT platforms, IoT applications, sensors, personal health, IoT challenges.

1. INTRODUCTION

The development of Internet of Things (IoT) technology has made it possible to connect various smart devices together through a range of communication protocols. The number of devices connected to the IoT is predicted to grow at an exponential rate, with forecasts predicting that there will be around 26 billion connected devices by 2020 [1]. These devices will lead to a wide variety of services from multiple sources such as monitoring sensors, surveillance cameras and actuators. The management of the services provided by these devices is recognized as one of the most important areas of future technology and has gained wide attention from research institutes and industry in a number of different domains including transportation, healthcare and emergency response [2], [3]. Both service providers and consumers need to be able to engage with IoT applications in a context-aware manner where they sense and react based on the environment and user context. Augmented reality (AR) provides an intuitive interface to IoT as it allows for context as well as superimposing virtual information in the real world such as in cognitive buildings [4]. Service consumers can interact naturally, in a visual manner with suggested nearby services, which are handled by a context-oriented middleware. Service providers can use AR to debug and repair failing IoT devices, by showing key QoS metrics of the services provided by the device such as the response time and throughput. Device-related metrics such as the temperature, CPU and memory usage of the device can also be shown. The internal components of the device can be connected objects, which will allow the field operator to see a specific visualisation to repair the faulty internal component of the IoT device that is not operating correctly [5]. This allows for easy repair and a return to a suitable operating performance. IoT applications can be used in a range of domains that have different QoS requirements based on the sensitivity and criticality of the application. IoT application QoS can typically be categorised as best effort (no QoS), differentiated services (soft QoS) and guaranteed services (hard QoS) [6]. In the hard QoS case, there are strict hard real-time QoS guarantees. This is appropriate for safety critical applications such as monitoring patients in a hospital or collision avoidance in a self-driving car system. Soft QoS does not require hard real-time guarantees but needs to be able to reconfigure and replace services that fail. This could be a routing application, which uses air quality, flooding and pedestrian traffic predictions, to provide the best route through the city. If one of the services is about to fail, the application should be recomposed using suitable replacement services. The final case is best effort, where there are no guarantees when a service fails, such as a simple atomic service that measures the temperature in a house. For hard and soft QoS AR could provide an intuitive way to alert users that a service may be about to fail and that they may need to retake control especially in the self-driving car scenario. Forecasting the failure of IoT service can be accomplished through the use of LSTM networks [7]. The remainder of the paper is organised as follows: Section 2 outlines some of the recent developments in AR that will reduce the barrier to entry and make these applications much more common in an IoT environment. Section

3 demonstrates a service-oriented middleware that can be used to provide context in an IoT environment and a deep edge architecture that provides a scalable solution for AR applications in IoT. Section 4 demonstrates some of the augmented reality applications that we have developed and discusses how they can be used for both service providers and consumers in IoT. We also create some projections of how users may interact with future context-aware applications. Finally in Section 5 we outline the conclusions from this paper and some of the open research questions that need to be explored.

2. AUGMENTED REALITY IN IOT

AR has quickly evolved in recent years and there is a range of commercial software and hardware that can allow for the creation of AR experiences. Today, there are a variety of APIs at the consumer level that makes it possible to create AR experiences with most of them making use of mobile technologies such as smartphones or tablets. Apple has recently launched ARKit [8] that allows building AR environments with little knowledge of the technology behind it. Another example that we use in our demonstration is the Vuforia developer library for Unity, which includes Google’s ARCore allowing AR applications on all modern android devices [9]. This will allow for much more devices to interact with IoT services through an AR interface and will encourage developers to create AR based IoT applications. With the wide penetration of smart phones and the new APIs released by Apple and Google we project there will be an increase in mobile augmented reality in the next few years. The use of mobile phones as augmented reality visors will be a necessary step to allow the development of applications and to evaluate the effectiveness of AR in IoT. The transition after this can be to a number of alternative head-mounted displays such as Google Glass, Microsoft Hololens or Magic Leap Light wear. These head-mounted displays allow for hands free interaction with IoT services and objects, which will be useful for field technicians to interact with devices and view visualizations showing which connected components to replace in order to repair a smart device. Considering the enormous potential of AR and IoT and the large amount of research that has been invested in each technology, the integration of both components is still at an early stage. Most current approaches show characteristics of objects without taking into account additional context such as the user preference, nearby object/locations, time, weather, etc.. Some proposals such as a Sentient Visor infer a high level context of the user using a context interface server to alter the manner in which information is displayed to the user [10]. However, the application of a smart watering plant is simplistic and only needs the local sensor information, also a central server for reasoning don’t take into account the vision of IoT as intelligent objects. In our demonstration we show more advanced examples combining dynamic and heterogeneous services from traditional web services and IoT services and using additional context information to provide intuitive applications. More recent work such as AR IoT provides a scalable AR framework for interacting with IoT devices but focuses on targeting objects rather than derived context through connected objects [11]. Other approaches such as Second Surface, where users are able to create, tag and share data around everyday objects are implemented through a remote server in the cloud [12]. The deep edge architecture that we describe in Section 3 allows all the analysis to take place at the edge of the network reducing response time and jitter and creating a more immersive AR experience.

3. AR DEVICES AS DIGITAL SERVICE GATEWAY

Augmented Reality applications have become popular on smartphones. Big companies are currently experimenting how to further leverage the AR paradigm by putting the smartphone into new form factors. Although AR technologies and smart glasses have been discussed in research for decades, they only recently appeared with support of the big IT companies. The first attempt to (partially) replace smartphones with smart glasses was done by Google in 2013 with their project Glass. The project failed to become a commercial success, not due to technical but mainly due to privacy and social acceptance reasons. Nevertheless, it started a rich experimentation phase especially for business applications with smart glasses. The benefits of having a smart device that leaves the hands free while providing contextual support are extremely versatile. As a further prominent example, Microsoft initiated their project HoloLens for smart glasses in 2016. It is expected that further devices and breakthroughs in this area will follow. Based on the Mixed Reality continuum (Milgram & Kishino, 1994), AR extends IoT experiences from the real environment towards the virtual environment (Figure 2). In addition to enabling novel user experiences for interacting with objects and the environment, AR also reveals new insights about the user. The same sensing technologies required for high-end AR displays can be used to measure the user. This gives new insights into the behavioral, cognitive, and emotional state of the user. With these insights, product-service interactions can be reshaped on a whole new level. Virtual environment Real environment Virtual reality (VR) Augmented virtuality Augmented reality (AR) Tangible user interfaces Mixed Reality (MR) Figure 2. The reality-virtuality continuum (adapted from Milgram & Kishino (1994)) Ilic & Fleisch, 2016 5 The following sections review how AR can be used to accelerate developments and usage of the IoT. The focus will be on the product-service interaction. Identification service: retrieving a digital identifier of a physical object and thereby enabling monitoring and other higher level services. Control services: connecting to a smart object to read or change the state of the object.

Lifecycle services: retrieving related services to an identified object (e.g. ordering of spare parts). See Xu & Ilic (2014) for a comprehensive overview. Several of the ideas and concepts are applicable already to smartphones but likely will unfold their true potential only with smart devices designed for AR such as smart glasses. The following

sections are therefore an extrapolation of observations and lessons learned in order to enable predictions that may guide further developers of AR-enhanced IoT applications.

4. CONTEXT-AWARE MIDDLEWARE

The middleware manages the context of users in the environment in a distributed way across each of the gateways. When a user requests an application the middleware first receives the user request at the request handler, which establishes a request/response communication channel with the user and forwards the request to the context manager. The context manager is responsible for acquiring and maintaining metadata about the services and the environment to support smart service management. The metadata includes service attributes (e.g., location, type, domain, etc.), QoS properties (e.g., response time, energy consumption, etc.), urban-context (e.g., places and their meaning in the city, points of interest, etc), and user preferences (e.g., user feedback, QoS experience, user behaviour, etc.). Service attributes and QoS properties are acquired from providers and the monitoring process. This data is stored as part of the service descriptions. Urban-context is acquired from Open Street Maps (OSM) and formalised using ontologies in OWL format. User preferences are acquired from the discovery and composition process. This data is stored as independent JSON documents in the service registry

5. PHYSICAL WORLD INTERFACE

Object interaction The key element for accessing the digital service component of a physical product is object identification. We distinguish between the following three types of objects: • Smart objects: The functionality of the product is enhanced by fully integrating a computing, communication, sensing, and/or an actuating unit. The digital identifier is unique and part of the product. Smart objects provide a digital communication interface for interaction and control with the product. They also may have a direct communication link to the Internet. The number of smart devices is estimated to exceed 25 billion units1 by 2020 and thereby representing the smallest group of objects in this categorization. • Tagged objects: Products retain their original state and functionality, but a tag is physically attached or integrated with the object. The digital identifier is retrospectively added to the product with the tag and can be read wirelessly or optically. Since the tag is just co-located, there is no control interface for changing or reading the state of the product, which the tag is attached to. Today, the most prominent example for digital identifiers are barcodes or RFID tags used in retailing based on the standard of the Global Trade Identification Number (GTIN). However, these identifiers are predominantly class level identifiers, which means that different instances of the same product share the same identifier.

5.1. Optical codes: A typical approach to assign a digital identity to physical objects is via optical codes. These include 1D barcodes, QR codes, or novel approaches such as digital watermarking, with the code hidden in the pattern of the product4 . These codes typically store either a unique number that can be resolved to an URL of a service point or directly a service point URL. The advantage is that these codes are cheap to deploy and can be read by any device with a camera. A disadvantage is that they require a clear line-of-sight and that the operating range is fairly limited.

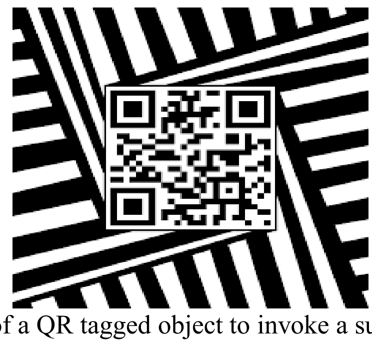

FIGURE 1. Example of a QR tagged object to invoke a supply reordering service.

5.2. ***Wireless transmitters****:* Most smart products come with a built-in wireless communication capability featuring Bluetooth Low Energy (BLE) and/or WiFi integration. These interfaces allow for controlling and managing the devices directly via the user's smartphone. For tagged objects, often BLE beacons are used since RFID and NFC support is limited on today's smartphones. The beacons typically broadcast a unique identifier and/or URL such as used in Google's Physical Web project. We observed a session increase of 35% compared to QR code users due to the fact that BLE broadcasts can be received even if the smartphone is locked. However, 93% of these sessions were triggered accidently by people walking by. To reduce this spam problem, we implemented a physical button on top of the beacon that only broadcasts the service URL when needed by a user (see Figure)

6. CONCLUSION

In this paper we have shown how both users and providers can use AR to interact with IoT devices and services. AR can be used to quickly debug devices as well as providing an easy way to interact with services in a local

environment. In our demonstration of some possible future AR experiences we have shown the importance of context and having accurate information about the surrounding environment from nearby IoT devices. Additional information about the user is also beneficial, for example whether they are a student or a tourist to further personalise the experience. These figures demonstrated the possibilities when combing AR and IoT and we hope will encourage further research.

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