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Abstract

Purpose – The purpose of this paper is to investigate the related issues of physical annotation systems and also to study their historical development. Moreover, the paper provides a taxonomy of physical annotation systems, including augmented reality systems and concludes with future challenges concerning such systems.

Design/methodology/approach – The authors first provide a review and a comparison of existing physical annotation systems. The authors' classification of the physical annotation systems is based on the capabilities they provide.

Findings – Physical annotation systems evolve as technology progresses. However, there are issues such as cognitive overload, trust, transient associations, and integrating of social networking with physical annotations.

Research limitations/implications – As technology develops, physical annotations will become increasingly important in daily life. Hence, there are important research issues to address with regards to physical annotation systems.

Practical implications – New better physical annotation systems are needed, which will change the way we do things in life, including personal memory, tourism, commerce, security, games, traffic management, entertainment and health.

Social implications – Physical annotation systems will affect the relationships between people, between people and places and between people and things. There is a potential shift in the way people view the physical world, not only as what we see but as what we see through the devices we carry.

Originality/value – The paper is an original review of physical annotation systems; there does not seem to be many such reviews on this area. The paper presents a set of future challenges regarding such systems.

Keywords Internet, Pervasive computing, Mobile applications, Labeling the world, Physical annotations, Physical annotation systems, Ubiquitous computing, Internet applications

Paper type Literature review

1. Introduction

Physical annotation (PA) systems are a type of information system which allows a user to label or annotate a geographical spot or an object in the physical world, and share that information with others. In other words, these systems add virtual information to a physical object (Wither *et al.*, 2009; Weigelt *et al.*, 2010).

This label or information could be used for public purposes such as commercial advertising, or for private purposes like memories recording, e.g. to remember a particular spot. PA is not a new concept. In fact it has been around since prehistoric times for thousands of years like paintings and drawings on caves walls which have become art or graffiti today (Tanabe, 2009). Mankind uses such situated inscriptions in order to tell a story of places' history and culture at particular time. Recently, PA has been developed in many new technological forms and different techniques. For instance, users can use new technologies such as global positioning system (GPS) which helps

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users to situate or get access to such PAs or labels. The purposes of PA systems recently have changed slightly. Today, PAs are still used to record and share memories, stories, but can also be used for commercial purposes or even for security purposes. PAs have been called many names in the literature such as (rather broadly) location-based information systems, labels for the physical world, geo-located or geotagged information, and spatial annotations. Some research such as (Hansen *et al.*, 2006) have discussed PA challenges such as PA structure, the way of accessing PAs, presenting and editing PAs. Therefore, this type of annotation has grown rapidly in the last few years. The demand for getting richer and more comprehensive structure in PAs and better approaches to represent and access the annotation have brought more attention from developers and researchers. Augmented reality (AR) systems are a popular subset of PA systems.

The aim of this paper is to review PA systems, and to note future trends and research directions in this emerging category of internet-enabled applications. We aim to highlight applications of PA systems and their architectures, which we see as an important emerging technology for the future. We investigate current PA systems and compare their functionality and enabling technologies, providing a taxonomy for all PA systems.

In the rest of this paper, in this section, we outline potential applications of PA systems and provide a brief background on the concept. Section 2 then analyses trends in the development of PA systems, outlining primitive PA systems and the advanced PA systems. Section 3 compares the systems and discusses the PA systems, and Section 4 reviews specification languages for PAs. In Section 5, we highlight the research challenges of PA systems and future work.

1.1 Why PAs are important

PAs are one of the most important methods for providing information efficiently, quickly, and interactively about physical entities. PA makes the physical entities more "alive" and "friendly" to the users in the way that entities can provide information about themselves. Therefore, PA provides many benefits and the demand of expanding it is growing rapidly. The following points provide some of the important uses and benefits of PA.

1.1.1 Personal memory. When a person visits a place, or has a special moment, s/he may want to record this moment to remember later, or share it with friends. This concept is used by many systems in recent years. Flickr (2009) for example, allows the user to remember exactly where that picture was taken. And the user also could share that annotation with his/her friends and add comments to it. ZoneTag (Ames and Naaman, 2007) is a camera phone program which allows the user to capture a picture with his/her mobile and associate it with GPS coordinates and other comments and upload it to the internet, to be recalled or shared later. In addition, this annotation may be used in social network systems as in GeoNote.Net (Nakayama *et al.*, 2006).

1.1.2 Tourist information. A new tourist may want to know more information about tourist attractions like the historical information of an old museum, or perhaps s/he would like advice about the best place to visit. So, instead of asking people in that city, PAs could be of assistance. There are some systems for this purpose, such as Murmur (Todras-Whitehill, 2005), R-click (NTT DoCoMo, 2009; Tallgren *et al.*, 2007), Hyconexplorer (Bouvin *et al.*, 2005) and Yellow arrow (Counts Media, Inc., 2004).

1.1.3 Commercial uses such as shopping or advertising. PA systems provide many benefits for retailers. With this technology retailers are able to spread advertising around their shops. For instance, certain products are labeled, so a customer can get annotations on products on discount or simply more product information (Choi *et al.*, 2008). An example is My-shoppingGuide (Merrill and Maes, 2007) which uses a Bluetooth earpiece or a Finger-Worn ring with a RFID reader and tag to get more information about a product; and also, to help the user to pick up his/her shopping list items (Schwerdtfeger and Klinker, 2008). Customers can get benefits from labels. For example, if a user went to a restaurant, s/he may leave an annotation for his/her friends, so that if one of them is nearby, s/he will get an annotation about that restaurant, whether it is recommended or not, and an idea of the prices. There are many systems that could be used for that such as GeoNotes (Espinoza *et al.*, 2001). Another example of PA for commercial use is if a user was riding on a bike trail, s/he may annotate his/her car or bike to sell it to others, replacing the often seen "for sale" paper note on the back window of a car or on a bike.

1.1.4 Warning notices or security applications. Some areas in certain times can become more dangerous. So, a PA may be used to warn people there to be more careful when they come to that area at that time.

1.1.5 Games and entertainment. PA system could help relieve stress by allowing people to leave jokes strategically at certain times and locations, or allow suitable music or even video to be played, as associated with certain objects and places at certain times. Gaming is a good example of using geographical information and PAs. There are many games that have arisen recently which use GPS or RFID technology such as Geocaching (2009) and Sharon (2006) which is a treasure hunt game using GPS. Also, it can be used for educational games, for example, to learn children's healthy eating habits (Pollak *et al.*, 2010) or generally, for knowing how to call objects and spaces.

1.1.6 Lost and found. People may annotate a geographical position when they lose or find something, so that when someone comes back later, s/he may know where to go or who to ask. For example, John found an iPod at a particular location, and takes it with him, but leaves a note at that location, so that when the owner comes back to that location, s/he can contact John.

1.1.7 Traffic warnings. The police may use PAs to help motorists to be safer or better drivers. For example, digital notes (associated with road segments) can be dropped by police at different points of a road in order to warn motorists to avoid certain roads ahead, or when traffic jams are expected, or an accident has occurred.

1.1.8 Health indicators. A person with health issues could be annotated (or annotations triggered/generated at emergency situations) so that when s/he gets sick (e.g. a heart attack or stroke), the people around him/her can be better aware of the situation and provide suitable help more quickly (Orwat *et al.*, 2010).

In conclusion, PA is a useful pervasive computing concept that can provide many benefits for individuals or for society as a whole. It can be used for serious issues such as police warnings, and disaster warnings (of danger zones of floods or bushfires), or for entertainment matters like movies' advertising.

1.2 What can you associate annotations with?

PAs can be used to annotate different entities in the real world, whether indoor or outdoor, these entities can be categorised into two major types, the first one is annotating an object but its location can be changed so its position is not static, and the second one is annotating a geographical area which often is static. The following are descriptions of each type:

(1) *Associating annotations with physical things/objects*. These objects are often small and can have different locations, this type is further subdivided into three types:
   - *Single object*. Such as a cup, a piece of furniture, or a pen.
   - *Collection of objects*. This type could have more than one object, a user can annotate three objects together, for example, which have similar features like these three objects belong to Ali.
   - *People*. A user need not annotate inanimate objects only, but s/he should be able to annotate a person, such as annotating a person with more details about his/her position or job. This person can have an RFID tag on him/her, which could be very small, say the size of a grain of rice as in the VeriChip (Halamka *et al.*, 2006) that is placed under the skin. Or, this person can be tagged by using advanced face recognition without attaching any tag to him/her; an example of this is a program called TAT augmented ID (Larsen, 2010) which uses the Polar Rose platform and allows facial detection.

(2) *Associating annotations with geographical spots.* Geographical spots often have static location so cannot be moved; they can be further divided into two categories:
   - Single point in geographical space – roads intersection or a building location; the scale or accuracy of the point depends on the technology used.
   - Collection of geo-points which has more than one coordinates and can be:
   – A geographical line, such as a bicycle trail, so when the user rides his/her bike, s/he will get the relative annotations associated with this line.
   – An area, such as a block in the city, where the user can get a specific annotation when s/he enters this block. This type could be a two-dimensional or three-dimensional space.

Figure 1 shows all three types of geographical entities, with which annotations may be associated.

2. Trends in PA systems

This section will summaries the trends in PA systems over the past, and analyze the advantages and disadvantages of a categorization of PA systems. The PA systems over the past can be classified into two major groups: primitive PA systems, and advanced PA systems.

2.1 Primitive PA systems

There are some similarities and differences between primitive and advanced annotation systems, However, based on many different systems we have reviewed, whether it is a primitive system or advanced is based on the way that users can access and retrieve the corresponding annotations. In primitive systems, the user's role is just using traditional methods of getting information which include the direct reading from

Figure 1.
Types of geographical entities

the object itself like the street signs or wall painting (or by simply dialing particular numbers on the phone to hear related information – we include this in the primitive category since such annotations are mainly read-only and the technology used is relatively simple and old). Non-interactive primitive systems often use human readable non-technological annotations and are always visible by normal human eyes, and there is no need to use special devices, rather than the phone, to read the annotation.

2.1.1 Rock carving or rock art. PA is a feature of human activity which has been used for thousands of years (Sharpe *et al.*, 2008). Humans used it to express their identity and culture to other nations. Rock art depicts hunting, animals, plants and lifestyles in pre-historic times. In addition, the meaning of those paintings depends on their location, age, and the type of image. Since prehistoric times, the ideas of PAs have been changed and given a reinterpretation in terms of modern technologies as we will see in subsequent sections.

2.1.2 Sticker annotations. The idea here is to place a sticker in an interesting spatial position with a unique number in order to grab people's attention. A user can see the sticker in order to know more about it by dialing a particular phone number and entering the unique number to hear a voice message about that position. This type of annotation is read only. That means that the user just listens to the information, but cannot contribute by adding a review or details (Coenen and Steinmetz, 2008). There are many systems which work with this idea. A well known example is a project called Yellow Arrow (mentioned earlier) which has a sticker shaped as an arrow in yellow. This arrow points to a physical spot and has a general phone number with a unique code. The user has two options to get more information about this spot. One is by dialing the phone number and entering the unique code to hear a voice message; the other option is by logging onto the web site of Yellow Arrow and getting the information. Yellow Arrow was first introduced in New York City in 2004. This project still has a lot of success and has been used in recent years despite new technologies which have emerged. There are 7,537 arrows spread throughout 467 cities around the entire world. Another related project is Murmur (mentioned earlier) which was introduced in Kensington Market in Toronto in July 2003. Basically, Murmur was a voice documentary library about points of interest in Toronto. It was also adopted by many cities around the world.

2.2 Advanced systems (interactive)

Advanced systems often include some new technologies which help to get or access the annotations, even if the user reads only that annotation without any contribution. The way to access the annotation includes bluetooth, RFID, GPS, electronic compass and more. Thus, the user here must use a device to discover and retrieve the annotation, and often use the internet to access it. Advanced systems could use physically visible marks such as QR codes so the user will know there could be more information in that mark. Also, advanced systems could be invisible such as wireless annotations or GPS annotations, and the user needs a special device to first detect if there is an annotation at a spot, and then he/she needs a further step to gain access to the annotation itself.

2.2.1 RFID for interactions between user and physical objects. An enhancement to PA systems, in general, is by making the user interact with the physical world. Instead of the manual approach that was used in previous technology when the user has to enter the phone number and the unique code to get the relevant annotation, the user can now use more advanced technologies such as RFID tags, and wireless connections to get more information about the annotated spot (whether that is a place or an object). For example, the user can use a RFID reader to get more information from an object tag, which was previously configured.

An example of this technology is the Cooltown project (Kindberg *et al.*, 2002) which allows the user to identify physical objects by using a wireless networked device equipped with an RFID reader or bluetooth. One example implementation scenario of this project is in a museum. As the user moves around the exhibition, his/her PDA receives a web URL from a wireless beacon such as IR, bluetooth or RFID tags so the URL is linked to more information on the web about that artwork. Another example of this kind of technology is the R-click system (mentioned earlier) which was implemented in Tokyo 2003, the idea was to distribute 4,500 RFID tags around a shopping complex and restaurants, so the user can move around and get more information about a product by swapping his RFID reader such as Nokia 5140 (Nokia, 2009) over that product. RFID technology is widely used, and can now be implanted in the human body such as VeriChip which may be used to annotate sick people, so when they arrive in an emergency room, the doctors can quickly get information about the person from that chip.

Recently there is another technology which is used to annotate the physical world in the same way. It is a two-dimensional code such as the QR code (Kato and Tan, 2005). This is a printed picture containing specific data which a user can access with a mobile camera, to read that information and using an application to decode the QR image. The authoring of this annotation (converting data into QR codes) can be done using particular software or web pages (QRCode, 2009).

2.2.2 Location-based annotation by GPS only. With the new technologies of mobile and communication systems, there have been significant improvements and changes in the concept of PA. Location information awareness systems allow users to discover persons, places and objects in the physical world. Now, since positioning capability is available in more mobile devices in the market today, as a result, PAs become even more advanced. GPS, which allows the user to get his/her position coordinates (e.g. longitude and latitude), is the main element in the location-based information services (LBIS). Therefore, the combination of mobile devices with GPS, 3G mobile network and web 2.0 services has driven PA to an advanced level (Bellavista *et al.*, 2008). A user can now create a small mobile application to record his/her location coordinates and associate more information with it and upload it via web services to enable processing with the uploaded annotations associated with physical locations or GPS coordinates. This simplicity of this type of applications has helped commercial use and individual users. Businessmen now can easily annotate their location and their services. Users can as well annotate their location and share them with others, or even search for nearby services that s/he is interested in using such annotations. There are many applications and systems which provide that type of services such as Pinpoint Search (Hariharan *et al.*, 2005) or Google map-based applications.

Another good example of LBIS annotation is the mobile social network system in (Bleecker, 2006). Users can share geographical information in these systems. In addition, the user can know the current position of a friend. There are many such systems such as Rummble (2011) which you can share your location with your friends in your social network.

Photo social network systems as well are using PAs. For example, in Flickr, the ZoneTag application (Ames and Naaman, 2007) allows a user to take a picture using his/her phone camera and to annotate that picture by adding GPS coordinates and other descriptions, and uploading it to the Flickr server. PhotoMap (Viana *et al.*, 2007) is another multimedia annotation system that allows users to annotate a picture that was captured by a mobile camera, and annotating it by adding more information such as location coordinates, time, weather conditions and a user's friends nearby. Moreover, Historypin (2011) is another annotation system, which was established in mid-2010 in UK, that allows users to annotate an outdoor location by adding an old picture of that location and telling a story about it. Elderly people can share their memories and knowledge with the younger generation using Historypin. Hence, the annotations themselves are not confined to merely text but can be multimedia (images or video) or combinations thereof.

2.2.3 Location-based annotation by GPS and AR systems. AR is technology that seamlessly mixes the physical world with the virtual world (Takacs *et al.*, 2008; Malik, 2002; Tokusho and Feiner, 2009). It is combining-the location-based information with the current user's real-time view. The concept of AR is not new, it has been used in Hollywood movies (Malik, 2002), but it required multiple technologies to be properly integrated, and it was costly. As far back as a decade ago, there was work on some systems that use AR for navigation and PAs; nevertheless they required using certain equipment such as a notebook computer which the user has to carry on his/her backpack, a wireless LAN device, and a head-mounted display such as Sony Glasstron headset which allows the user to see and hear through it. An example of such a system is in (Reitmayr and Schmalstieg, 2004).

In recent years, AR has been developed by many developers. And it may be divided into two categories. The first one is AR for indoor purposes, often used for interactive gaming such as Eyepet (2010).This category uses the computer camera (open video stream) to track a particular black square mark or by using image recognition algorithms to interact with the user and perform the AR. Another example of this is the medical training purposes, AR could help a novice doctor by remind him of the required step in the surgical room without need to going back to the manual (Kancherla *et al.*, 1995).

The other category for AR is for outdoor purposes such as navigation and outdoor feature annotation. Outdoor AR often requires a camera, GPS and compass functionality. The GPS is used to determine the current user's location and the compass to determine which direction the user is looking.

By using GPS and compass, the application could perform AR annotations. The camera is used only as an interface for the user – the user sees the annotations superimposed on the physical world objects through the camera. Outdoor AR nowadays with high technology mobile phones, and high speed mobile connections like 3G, the technology to combine the virtual world and the physical world has become easier and available for many users. The idea of PAs by using AR in mobile devices is to point a camera (in a mobile) towards a building and the relevant annotation for the building will show up on the mobile. Figure 2 shows that a user is choosing a direction (relative to the current orientation) to retrieve information about, or adding some PA.

The mobile phone application will use an internet connection to retrieve ora PA and then combine this information with the camera video stream of the real word and present that to the user. The camera here is just used as an interface and the system could work without it. There are many systems doing this type of annotation such as GeoNote.net (Nakayama *et al.*, 2006), Layar (2010), Wikitude World Browser (2010), SURF (Takacs *et al.*, 2008), AR Street View (Tokusho and Feiner, 2009) and Junaio (2011):

GeoNote.net, which was introduced in 2006, is a social network mobile aimed to integrated the social network with the web GIS by using the AR. It also includes real time navigation and PA services and can also be shared. It was introduced in

The Layar project and the Wikitude project are the two first free applications available for the public. It displays a virtual layer of digital information on the top of the physical world through the phone camera view. They use GPS, compass and 3D graphics in order to determine user's location and the direction of the mobile, high internet connection will help to retrieve corresponding annotation at the real-time. The both projects contain layers of geotagged of point-of-interest (POI)

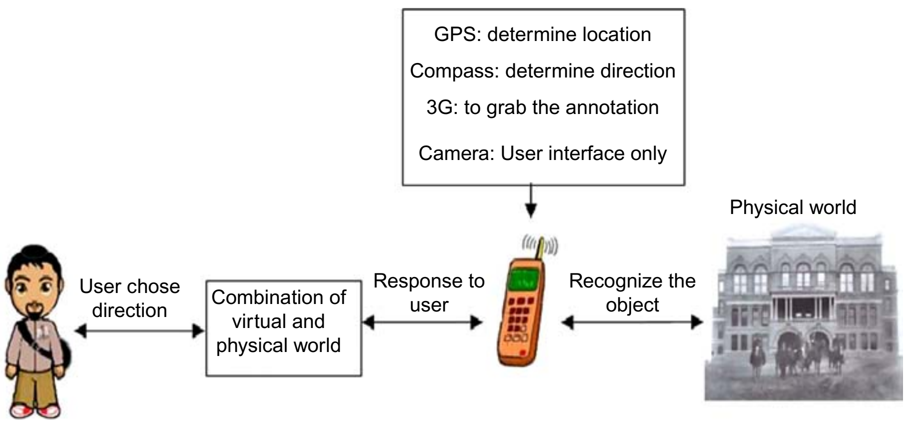

Figure 2.
The outdoor AR

(Eishita and Stanley, 2010), which allows the user to choose different layers of AR contents as s/he prefers. These layers help to reduce the overload of the annotations. However, they still have many limitations in term of managing the huge number of annotations. Also, the annotations there are still more static.

Junaio, created by metaio GmbH, is another AR browser where users can create channels of content, similar to the concept of the layer in the Layar application, and the world in the Wikitude browser. The advantage of Junaio is that it can work indoor as well by using 2D barcodes which are called LLA markers, which encode latitude, longitude and altitude coordinates thereby providing highly accurate location coordinates.

3. Comparison and discussion

Table I is a comparison of a representative set of previous projects on PA. The table shows the different types of technologies used, whether it is interactive or not, how tagging is done, what is tagged, and what happens after a tag is detected.

Table I shows how the idea and concept of PA has changed dramatically in the last few years. The early editions of PA systems were simple and use basic and very limited technology such as a sticker and the user needs to dial a particular phone number to hear the related information. Then, PA systems improved by using context-awareness technologies such as RFID which provided interactive sensing to it. However, the interactive PA systems were very limited because there was no internet connection and the contents of the PA were small. The next stage of the improvement of PA was the location-based annotation which used the geographical coordinates to associate annotations with a physical object. At that stage also, internet connections became faster and more reliable. Therefore, the PA at this stage used the internet mainly to grab the corresponding annotation which provides rich information and more interactivity. Moreover, LBA has presented more services to social network websites by allowing the members to share their locations and their interest spots. In addition, with the popularization of cameras in mobile phones, the augmented reality technique has become an important service to the PA. AR provides a combination of physical world and virtual world layering, which leads to a new concept of PA systems. As we can notice from the development of PA systems, the PA always is impacted by the development of other related factors such as internet connectivity; in the past, it was almost impossible to use the internet on the mobile, but with a high speed internet connection such as 3G, the majority, if not all, of PA systems use the internet connectivity to get more and rich interactive information. Other factors that impact the development of PA is the mobile device resources such as the processor and memory, the first mobile generation had a lot of constraints in CPU speed and memory. However, third generation phones have more resources and easily can be programmed. In addition, mobile devices have now more features such as GPS and a high resolution camera; as a result the PA systems have improved significantly due to these factors and as these factors will be improved in the future, the PA will be impacted and will further improve.

However, despite the fact that interactive systems have more services and richer information than the non-interactive systems, the interactive system is not always the better choice for the PA and there are some advantages and disadvantages for each system. Table II elaborates on that point.

Based on the previous systems, we defined a PA taxonomy based on approaches that users can use to access the annotation (there could be many different taxonomies,

Table I.
Summary of PA systems and their properties

Project name	In or out-door PA	What is tagged	Form of tags	What is included in a tag	What happens after a tag is detected	Year	Interactive
Yellow Arrow	Both	location	Sticker	General phone number + unique number	Hear voice annotation	2004	No
Murmur	Both	Tourism places	Sticker			2003	
Cooltown	Both	Museum artwork, conference room	RFID	URL	Web services	2000	Yes
R-click	Both	Object, shops	RFID	URL	More info	2003	
Pinpoint	Out	Street address	GPS	URL	Web page about nearby interest	2005	
Rummble	In/out	Location	Wi-fi, *Skyhook* wireless (hybrid positioning system XPS)	Comment, photo	Social network, comment, rate	2007	
Zone tag	Out	Photo	GPS	GPS coordinates	Upload to Flickr	2007	
PhotoMap	Out	Photo	GPS	GPS co-ordinates + weather condition + nearby friends	Social network	2007	
Historypin	Out	Location	GPS	GPS co-ordinates	Historical information	JUNE 2010 NOT I N MOBILE YET	
Geonote.net	Out	Location, object	AR + camera + GPS + compass	GPS co-ordinates	Social network	2006	
Layar	Out	Any outdoor location		Photo, more info, address	Web services	2009	
Wikitude						2009	
AR Street View	Out	Locations at google street view		label	Navigation + explorer	2009	
Junaio	Both	Outdoor/ indoor entity	AR + camera + GPS + compass + image re-cognition	GPS / LLA marker	Web services	2009	
SURF	Out	Location, object	AR + GPS + camera + image retrieval	GPS coordinates + image recognition	Photo, more info	2008	

Factor	Advanced system	Primitive system
Cost	Cost more money, time (e.g. to retrieve annotations as oppose to reading a physical sticker), energy and internet usage	Cost less
Internet connectivity	Often need high internet connection or server	Not necessary
Technology experience	Need more skills, suit some people	Normal skills, suit all people
Visibility	Often invisible, you find it when you need it	Visible /noticeable, always see it even you do not need it
Required technology	Need more and complex technologies. RFID,GPS	Basic technology, e.g. phone
Information content	Gives rich and significant information, more services	Gives limited and basic information
Required maintenance	May often have a technical problem and need regular maintenance	Need less maintenance
Speed	May need more time to access the information	Faster
Appearance	Looks better	May look unattractive

Table II. The differences between primitive and advanced systems

e.g. based on the information relevant to the object). The tree structure in Figure 3 shows our taxonomy and Table III shows the changes in the PA systems over the last ten years.

We have seen how PA systems are improving rapidly in the last few years. From non-interactive systems to augmented reality, there are more technologies involved. Often, PA systems are about labeling geographical locations, which do not change their GPS coordinates. Therefore, it is still not available to annotate non-stationary objects, which often change their locations such as people. However, with the improvement of facial recognition such as PolarRose (2009), it might be easy to annotate them. Recently, many social websites such as Flickr and Facebook are using this facial recognition application in their systems. Applications like TAT augmented ID (Larsen, 2010), which is still under development, combine the facial recognition with augmented reality. So, if a user was in a conference, s/he may like to know more about the speaker. By this program s/he can point the mobile camera at a speaker and the application will bring more information from the speaker's social network. So, the next step of PA is to annotate people by using facial recognition systems. This improvement will provide a lot of benefits. On the other hand, there might be some privacy issues for annotating people if it is done without any restriction. Others use laser-based scanning techniques to build 3D models of the world (Harrap and Daniel, 2009). We discuss further directions for future work later in this paper.

4. Specification languages for the PA

For representing PAs and the entities being annotated, there is a need for some language.

There are many common markup languages which aim to describe the physical word alongside with the digital world. One of the earliest languages was the Physical Markup Language which was introduced by David L. Brock in 2001 (Brock and Lewis, 2001).

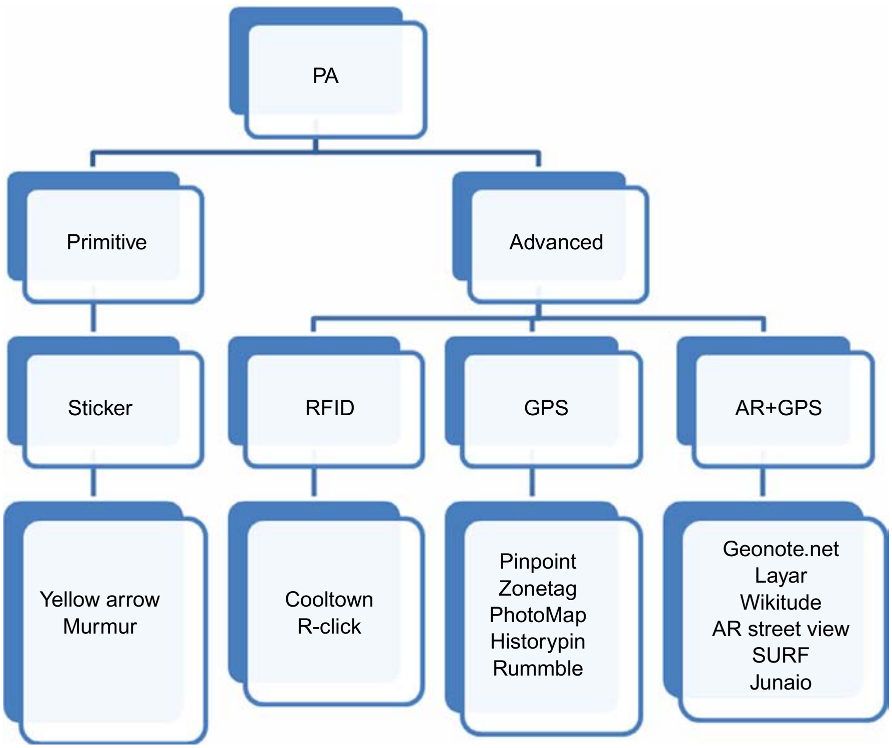

Figure 3.
Types of PA systems

It aimed to provide a common language to describe physical objects, processes and the environment. With the growth of PAs combined with the digital world such as augmented reality browsers, there is a need to develop a markup language to contain and present the new features of the new technology's requirements.

Many markup languages appeared to deal with the mixed reality information. One of them is Google's Keyhole Markup Language (KML, 2011), which is a file format to describe the geographical annotation and visualization features such as placemarks, images, polygons, 3D models, and textual descriptions, for presentation on the Google earth system; Google map's users can use the format also to share geographical places with others.

The following is a snapshot of the KML description of a house and its location and related information, just to give an idea what it looks like:

```
<?xml version = "1.0" encoding = "UTF-8"?>
<kml xmlns = "www.opengis.net/kml/2.2">
<Placemark>
        <name> my house in Preston, VIC </name>
        <description>
                I live in this area for 5years now
        </description>
        <LookAt>
```

AR + GPS							Geonote.net		SURF	Layar, Wikitude, AR street view, Junaio	Historypin
GPS only						Pinpoint		Zone tag, PhotoMap, Rummble			
RFID paper signage	Cooltown			R-click Murmur	Yello Arrow						
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010

Table III.
PA trends over the last ten years

```
        <longitude>144.9926490658861</longitude>
        <latitude>-37.72342590506222</latitude>
        <altitude>0</altitude>
        <heading>0.009007330927132991</heading>
        <tilt>0</tilt>
        <range>331.943301734499</range>
        <altitudeMode>relativeToGround</altitudeMode>
        <gx:altitudeMode> relativeToSeaFloor</gx:altitudeMode>
        </LookAt>
        <styleUrl>#msn_ylw-pushpin</styleUrl>
        <Point>
        <altitudeMode>clampToGround</altitudeMode>
        <gx:altitudeMode>clampToSeaFloor</gx:altitudeMode>
        <coordinates>144.9926490658862,
                − 37.72342590506222,0</coordinates>
        </Point>
        </Placemark>
</kml>
```

However, GML does not fully support the conceptual features of PA, and so, there is a need for a language that does support and adopt the PA and the mixed reality concepts. One of the current markup languages is the Augmented Reality Markup Language (ARML), which was proposed in 2009 by Mobilizy, the company behind the Wikitude world browser (Lechner and Tripp, 2010; ARML, 2010). ARML is based on KML described earlier. According to ARML's author, KML tags are needed in the AR applications. An example of this is the ar:provider which identifies the creator or the provider of the annotation. Another example of ARML specifications is the POI description which describes the annotated entity. However, some necessary features in KML are not adopted in ARML such as 3D models.

ARML contains two sections. The first section is to describe the POI itself, and the other section is to define the content associated with that POI. The following is a snapshot of ARML describing the POI information which contains basic information such as name of the content provider, description, phone, URL, e-mail, address, and the point being annotation, identified by the location coordinates (i.e. latitude, longitude, and altitude):

```
<Placemark id = "123456">
<ar:provider>myCpId</ar:provider>
<name>Title of my POI</name>
<description>My POI description</description>
<wikitude:info>
<wikitude:thumbnail>
   http://thumbnailUrl.com
</wikitude:thumbnail>
<wikitude:phone>123-456-789</wikitude:phone>
<wikitude:url>/wikitude:url">http://poiUrl.com</wikitude:url>
<wikitude:email>inf@myPoi.com</wikitude:email>
<wikitude:address>
```

```
    My POI Street 5, 5020 POI, Austria
  </wikitude:address>
  <wikitude:attachment>
    http://myAttachmentLink.com
  </wikitude:attachment>
  </wikitude:info>
  <Point>
  <coordinates>
    13.048056,47.797222,432.0
  </coordinates>
  </Point>
  </Placemark>
```

Kim *et al.* (2011) have introduced a markup language to present the mixed reality contents. They consider five scenarios of mixed reality:

(1) fixed object with virtual information;

(2) movable object with virtual information;

(3) fixed object and movable object with virtual information;

(4) augmented object belonging to others with your own virtual information; and

(5) displaying virtual information associated with objects to other people.

The markup language they suggest contains three sections; the first one is to describe the real content presentation, the second is to present the virtual contents representations, and the last one is to describe the real-virtual contents representation. They present the three sections in the form of 4w1h (who, when, where, what, how). The following snapshot illustrates Kim's markup language for mixed reality content:

```
<realcontent id = "{4CDCF772-DAB2-4C7D-A1EB-7B781DF4DFB7}">
  <who>
        <owner id = "{7DD22961-78EE-4B66-8766-F6B388F6B9DD}"/>
        <author id="{7DD22961-78EE-4B66-8766-F6B388F6B9DD}"/>
  </who>
  <when>2010-09-24T09:34:00 </when>
  <where>
        <latitude>37.551425</latitude>
        <longitude>126.988</longitude>
  </where>
  <what>
        <description>
                  <tag><![CDATA[User A]]></tag>
  <img>http://uvr.gist.ac.kr/imgs/usera1.jpg</img>
       http://uvr.gist.ac.kr/imgs/usera2.jpg</img>
       http://uvr.gist.ac.kr/imgs/usera3.jpg</img>
     </description>
  </what>
  <how>
       <movable>dynamic</movable>
```

```
            <access>public</access>
        </how>
    </realcontent>
    <virtualcontent id="{3EA3D510-4673-486E-83BD-2C578302DCCB}">
        <who>
            <owner id = "{BC920170-B300-4449-A047-6FD496B79D88}"/>
            <author id="{7DD22961-78EE-4B66-8766-F6B388F6B9DD}"/>
        </who>
        <when>2010-09-24T09:40:00</when>
        <where url="http://uvr.gist.ac.kr/userahousedirection.collada"/>
        <what>
            <description>
                <tag><![CDATA[arrow from user A to user A's
home]]></tag>
                <type><![CDATA[collada]]></type>
            </description>
        </what>
        <how>
            <movable>dynamic</movable>
            <access>public</access>
        </how>
    </virtualcontent>
    <link id="{CE5BA114-04F6-47DB-B955-E34B228B0EA9}">
                                                        <who><author
id = "{7DD22961-78EE-4B66-8766-F6B388F6B9DD}"/></who>
        <when>2010-09-24T09:41:00</when>
        <where relation="absolute">
            <latitude>37.551425</latitude>
            <longitude>126.988</longitude>
        </where>
        <what>
            <rid>4CDCF772-DAB2-4C7D-A1EB-7B781DF4DFB7</rid>
            <vid>3EA3D510-4673-486E-83BD-2C578302DCCB </vid>
        </what>
        <how><access>public</access></how>
        </link>
```

Junaio, as we discussed before, is another AR browser which is used as a mixed content application. Junaio presents the data in its own markup language which is called Junaio XML. Besides the outdoor coordinates, they also present the indoor coordinates in the format of LLA markers. It also presents the 3D model. The following is a snapshot of how Junaio is presenting contents associated with a POI in a 3D model:

```
<?xml version = \"1.0\" encoding = \"UTF-8\"?>
  <results>
    <poi id = \"poi1\" interactionfeedback = \"none\">
      <name><![CDATA[Hello 3D World]]></name>
      <description><![CDATA[This is my first 3D POI.]]>
```

```
            </description>
          <author>YOU</author>
          <date/>
          <l>48.161036,11.55107,0</l>
          <o>0,0,0</o>
          <minaccuracy/>
          <maxdistance/>
          <mime-type>model/md2</mime-type>
    <mainresource>http://www.junaio.com/../mymodel.md2_enc</mainresource>
       <force3d>true</force3d>
       <s>1</s>
       <behaviours>
          <behaviour type=\"idle\">
            <length>0</length>
            <node_id>frame</node_id>
          </behaviour>
       </behaviours>
       <resources>
    <resource>http://www.junaio.com/../mymodelstexture.png</resource>
       </resources>
    <thumbnail>http://www.junaio.com/../icon.jpg</thumbnail>
    <icon>http://www.junaio.com/publisherDownload/tutorial/icon.jpg</icon>
       <homepage>www.metaio.com/</homepage>
       </poi>
    </results>
```

Another markup language is called KARMA which is part of the KHARMA architecture (Hill *et al.*, 2010). It aims also to provide a common and advanced markup language for the mixed reality and PA. Similar to previous systems, KARMA is based on the KML, extending KML to adopt the conceptual features of AR, such as the KMLBalloon and KMLLable which are used to present the content of the annotation for a particular entity. The difference between the ARML and KARMA is that ARML just adopted what was necessary for AR, whereas, KARMA adopted the complete specification of KML which gives KARMA an advantage to present some important features such as 3D models. However, complete KML specification may be too much for the concept of AR and many tags may not be necessary or relevant. KHARMA proposed a combined KML/HTML augmented reality mobile architecture. KARMA also fully supports HTML, panoramic photo overlays, sound, and standard KML network updates. KARMA added also many features to KML such as undecorated displayMode, Balloon element and relative locationMode. The following snapshot shows an example of a POI in KARMA:

```
     <Placemark>
       <name>MyPlacemark</name>
       <description>My example placemark relative to user</description>
       <Balloon>
         <locationMode
  targetHRef = ”#user” >relative</locationMode><!– fixed (default), relative –>
```

```
        <location>
          <latitude units="meters">2.0</latitude>
          <longitude>0.0</longitude>
          <altitude>0.0</altitude>
        </location>
        <orientationMode>billboard</orientationMode>
<!– fixed (default), relative, billboard –>
        <scaleMode>relative</scaleMode><!– fixed (default), relative –>
      </Balloon>
    </Placemark>
```

As noted earlier, there are significant works aiming to provide advanced markup languages for the PA and mixed reality. However, these markup languages still have some drawbacks, as they do not cover all the features of the PA: first of all, there is a need for clear definition and formalization for the PA and mixed reality concepts which include the features and properties of the annotation. Second, supporting dynamic annotations more than static annotations are definitely required, especially when we are dealing with dynamic context that may change frequently. We also need a common standard markup language to be shared between the AR mixed reality and PA systems, so that annotations can be shared and accessed via different AR browsers.

5. Challenges and future directions

We have seen how PA systems have developed over the last decade. We conclude by outlining here a number of emerging issues and future directions for explorations.

5.1 PA overload

As the use of PA systems grows, there will be an anticipated information overload. Figure 4 shows a plethora of annotations for objects within an office. Inset is a diagram depicting an annotation shown on a mobile device as it is brought near a book. The annotation for the book states that the book was "borrowed from Tom, to return next week" and states that the book is "main text on Web services".

In a shopping center, there could be annotations for every floor, every shop on every floor, every shelf in a shop, every item on a shelf in a shop, and every person might have a different annotation for every item on every shelf in every shop on every floor, and every person has a different annotation at a different time for every item on every shelf in every shop on every floor. Hence, a cognitive overload of annotations can arise for a person trying to view annotations at a location. Systems such as Layar as mentioned earlier employ a layering model to tackle this annotation explosion and clutter, by classifying the annotations into categories viewed as separate overlays over the same physical environment, and a user can view only a few layers at a time. However, we would expect a myriad of such overlays and likely, different context attributes are needed to provide a much finer-grained classification of annotations. Indeed, there are various dimensions in which such annotations can be classified that can be used to filter annotations, including "purpose" and "intent" of the annotation, which requires further exploration. Another possible solution is automatic summarization, but that depends on the purposes of the annotation. There is emerging work that attempts to support grouping of tags or annotations, either manually or automatically using the nearest

Figure 4.
Indoor annotations
within an office

neighbour algorithm (using the distance between the location of tags/annotations and the location itself) (Choi *et al.*, 2011).

5.2 Trust and annotation reliability

When several annotations are applied to the same object, and where there is possible impact on users, e.g. commercial impact due to misguided annotations about products, then the trustworthiness and reliability of annotations become important. Annotation provenance (akin to data provenance) can provide a degree of traceability, and similar issues are faced with the open web environment.

5.3 Transient associations

Some annotations only have validity for a certain period of time, and some are associated with location and objects only for a certain time, there is an issue of managing transient associations. While current annotation systems tend to have the user manually create that association between objects and annotations, there could be automated support for creating annotations of objects automatically (as specified in a some language) – for example, a predicate can be defined to associate a label with "all objects belonging to Ahmad". Thereafter, all such objects will have an annotation generated for it. A collection of objects (e.g. pens in a box) might temporarily have a label (e.g. a box of pens) which provides meaningful information for such a collection. The work in Loke (2010) begins such work, on generating labels based on spatial relationships among objects. Since such annotations are automatically mapped to objects according to a predicate, the associations of an annotation with an object can be broken as soon as the predicate becomes invalid for that object.

5.4 New modes of access, and new kinds of associations

As sensor technology improves and the range of sensors increases, there is an increasing number of ways to access annotations (including multimodal forms of inputs such as recognizing human body movements, relative positions among objects, and gesture recognition). All these forms of inputs provide interesting triggers for annotations and novel means of accessing annotations. For example, a set of dance steps over a block of concrete paving is sensed and detected and results in new annotation being added or retrieved. Putting a shirt next to a matching pair of trousers triggers a "clothes matching" annotation to be created. Also, relating to the idea of automatically generating annotations, the arrival of a car in a new city (say for the first time) could result in an annotation generated to record this first time arrival. Facial or object recognition technologies can be further used for associating annotations with objects or people.

5.5 New forms of annotations

We have seen text as a main media type for annotations, and images are increasingly be used as a tag or label. The future could see the use of other media forms (e.g. 3D holograms) or combinations of media types as annotations.

5.6 New application areas

We describe a number of application areas of such PAs. Extensive use in shopping and commerce, tourism and health (including in-hospital) scenarios remains to be seen.

5.7 Social networking and PAs

With the advent of social networking, the combination of PAs with social networking services become feasible. A group of users might leave annotations collaboratively or annotations might be automatically propagated to friends or only friends (or friends of friends, etc.) might have access to annotations. An annotation for a location might only be accessible with the co-location of a group of users. Also, there is the use of information in social network websites as annotations for physical world entities –, e.g. information about a person on facebook can be used as an annotation for a person, or a posting or comment about an object becomes associated with that object as the object's annotation via an application.

5.8 Standards for PAs

With the advent of numerous AR and PA systems, the ability to share or support interoperability of user annotations become increasingly important.

References

Ames, M. and Naaman, M. (2007), "Why we tag: motivations for annotation in mobile and online media", *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, San Jose, California, USA*, pp. 971-80.

ARML (2010), ARML Specification for Wikitude 4, available at: www.openarml.org/wikitude4.html (accessed June 2010).

Bellavista, P., Küpper, A. and Helal, S. (2008), "Location-based services: back to the future", *IEEE Pervasive Computing*, Vol. 7 No. 2, pp. 85-9.

Bleecker, J. (2006), "What's your social doing in my mobile? Design patterns for mobile social software", paper presented at WWW2006 Workshop MobEA IV-Empowering the Mobile Web, Edinburgh.

Bouvin, N.O., Brodersen, C., Hansen, F.A., Iversen, O.S. and Norregaard, P. (2005), "Tools of contextualization: extending the classroom to the field", *Proceedings of the 2005 Conference on Interaction Design and Children, ACM, Boulder, CO, USA*, pp. 24-31.

Brock, D.L. and Lewis, T. (2001), "The physical markup language core components: time and place", MIT Auto-ID Center White Paper.

Choi, J., Jang, B. and Kim, G.J. (2011), "Organizing and presenting geospatial tags in location-based augmented reality", *Personal and Ubiquitous Computing*, Vol. 15 No. 6, pp. 641-7.

Choi, J., Seol, H., Lee, S., Cho, H. and Park, Y. (2008), "Customer satisfaction factors of mobile commerce in Korea", *Internet Research*, Vol. 18 No. 3, pp. 313-35.

Coenen, C. and Steinmetz, A. (2008), "Pock-it: annotate the world", *Proceedings of the 12th International Conference on Entertainment and Media in the Ubiquitous Era*, ACM Press, Tampere, pp. 105-8.

Counts Media, Inc. (2004), "Yellow Arrow", available at: http://yellowarrow.net/v3/index.php (accessed 8 June 2009).

Eishita, F.Z. and Stanley, K.G. (2010), "THEEMPA: simple AR games using Layar", *Proceedings of the International Academic Conference on the Future of Game Design and Technology*, ACM Press, Vancouver, pp. 219-22.

Espinoza, F., Persson, P., Sandin, A., Nystrom, H., Cacciatore, E. and Bylund, M. (2001), "Geonotes: social and navigational aspects of location-based information systems", *UbiComp '01 Proceedings of the 3rd International Conference on Ubiquitous Computing*, Springer, London, pp. 2-17.

Eyepet (2010), available at: www.eyepet.com (accessed 12 February 2010).

Flickr (2009), available at: www.flickr.com (accessed 19 April 2009).

Geocaching (2009), available at: www.geocaching.com (accessed 14 May 2009).

Halamka, J., Juels, A., Stubblefield, A. and Westhues, J. (2006), "The security implications of VeriChip cloning", *Journal of the American Medical Informatics Association*, Vol. 13 No. 6, p. 601.

Hansen, F.A. (2006), "Ubiquitous annotation systems: technologies and challenges", *HYPERTEXT '06: Proceedings of the 17th Conference on Hypertext and Hypermedia*, ACM Press, New York, NY.

Hariharan, R., Krumm, J. and Horvitz, E. (2005), "Web-enhanced GPS", *1st International Workshop on Location- and Context-Awareness* (*LoCA*), Springer, Oberpfaffehofen, pp. 95-104.

Harrap, R. and Daniel, S. (2009), "Mobile Lidar mapping: building the next generation of outdoor environment models for AR", paper presented at IEEE Internatiomal Symposium on Mixed and Augmented Reality ISMAR 2009, Let's Go Out Workshop, Orlando, FL.

Hill, A., MacIntyre, B., Gandy, M., Davidson, B. and Rouzati, H. (2010), "KHARMA: an open KML/HTML architecture for mobile augmented reality applications", paper presented at 9th IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Seoul.

Historypin (2011), available at: www.historypin.com (accessed 12 January 2011).

Junaio (2011), available at: www.junaio.com/publisher/gettingstarted

Kancherla, A.R., Rolland, J.P., Wright, D.L. and Burdea, G. (1995), "A novel virtual reality tool for teaching dynamic 3D anatomy", *Proceedings of the 1st International Conference on Computer Vision, Virtual Reality and Robotics in Medicine*, Springer, Berlin, pp. 163-9.

Kato, H. and Tan, K.T. (2005), “2D barcodes for mobile phones”, paper presented at Mobile Technology, Applications and Systems, paper presented at: 2nd International Conference, Guangzhou.

Kim, H., Yoon, H., Choi, A., Baek, W., Lee, I., Kim, D. and Woo, W. (2011), “Data markup representation for mixed reality contents”, paper presented at the International AR Standards Meeting, Barcelona Via Augusta, 17-19 February.

Kindberg, T., Barton, J., Morgan, J., Becker, G., Caswell, D., Debaty, P., Gopal, G., Frid, M., Krishnan, V. and Morris, H. (2002), “People, places, things: web presence for the real world”, *Mobile Networks and Applications*, Vol. 7 No. 5, pp. 365-76.

Larsén, O. (2010), “Recognizr covered by *FOX News* and *SC Magazine*”, available at: www.tat.se/blog/recognizr-covered-by-fox-news-and-sc-magazine/ (accessed 15 March 2010).

Layar (2010), available at: http://layar.com/ (accessed 1 September 2010).

Lechner, M. and Tripp, M. (2010), “ARML – an augmented reality standard”, paper presented at Mobile AR Summit MWC 2010, Barcelona, Spain.

Loke, S.W. (2010), “Context-aware labels generation and verification”, *Proceedings of the International Conference on Pervasive Computing and Communications* (*Percom 2010*), *Mannheim*.

Malik, S. (2002), “Robust registration of virtual objects for real-time augmented reality”, MSc thesis, School of Computer Science, Carleton University, Ottawa.

Merrill, D. and Maes, P. (2007), “Augmenting looking, pointing and reaching gestures to enhance the searching and browsing of physical objects”, *Proceedings of the 5th International Conference on Pervasive Computing*, Springer, Toronto, pp. 1-18.

NTT DoCoMo (2009), “DoCoMo-developed area information service to be tested in Roppongi Hills”, available at: www.nttdocomo.com/pr/2003/001106.html (accessed 15 July 2009).

Nakayama, K., Maekawa, T., Tomiyasu, H., Hara, T. and Nishio, S. (2006), “GeoNote.net: a social network system for geographic information”, *Proceedings of the 7th International Conference on Mobile Data Management* (*MDM’06*), IEEE Computer Society Press, New York, NY, p. 144.

Nokia (2009), “Nokia, 5140 features”, available at: http://europe.nokia.com/find-products/devices/nokia-5140 (accessed 9 August 2009).

Orwat, C., Rashid, A., Holtmann, C., Wolk, M., Scheermesser, M., Kosow, H. and Graefe, A. (2010), “Adopting pervasive computing for routine use in healthcare”, *IEEE Pervasive Computing*, Vol. 9 No. 2, pp. 64-71.

PolarRose (2009), available at: www.polarrose.com/ (accessed 15 June 2009).

Pollak, J., Gay, G., Byrne, S., Wagner, E., Retelny, D. and Humphreys, L. (2010), “It’s time to eat! Using mobile games to promote healthy eating”, *IEEE Pervasive Computing*, Vol. 9 No. 3, pp. 21-7.

QRCode (2009), available at: http://qrcode.kaywa.com/ (accessed 9 August 2009).

Reitmayr, G. and Schmalstieg, D. (2004), “Collaborative augmented reality for outdoor navigation and information browsing”, *Proceedings of Symposium Location based Services and Telecartography, Vienna*.

Rummble (2011), available at: www.rummble.com/

Schwerdtfeger, B. and Klinker, G. (2008), “Supporting order picking with augmented reality”, *Mixed and Augmented Reality, ISMAR 2008, 7th IEEE/ACM International Symposium*, IEEE Computer Society Press, New York, NY, pp. 91-4.

Sharon, M. (2006), “Mobile Mappa Mundi-using cell phones as associative mapping tools”, Socialight White Paper.

Sharpe, K., Barnett, T. and Rushton, S. (2008), *The Prehistoric Rock Art of England: Recording, Managing and Enjoying Our Carved Heritage*, BPR Publishers, Cresswell.

Takacs, G., Chandrasekhar, V., Gelfand, N., Xiong, Y., Chen, W.C., Bismpigiannis, T., Grzeszczuk, R. and Pulli, K. (2008), "Outdoors augmented reality on mobile phone using loxel-based visual feature organization", *Proceedings of the 1st ACM International Conference on Multimedia Information Retrieval*, ACM Press, Vancouver, pp. 427-34.

Tallgren, M., Pihlajamaa, O. and Törönen, J. (2007), *Ubiquitous Customer Loyalty Services: Technology and Market Outlook*, Technical Research Centre of Finland (VTT), Otaniemi.

Tanabe, J.P. (2009), "Prehistoric cave paintings", available at: www.squidoo.com/cavepaintings (accessed 6 July 2009).

Todras-Whitehill, E. (2005), "The web behind the Scrawl", available at: www.nytimes.com/2005/05/04/technology/techspecial/04ethan.html?_r=1 (accessed 11 June 2009).

Tokusho, Y. and Feiner, S. (2009), "Prototyping an outdoor mobile augmented reality street view application", paper presented at ISMAR 2009 – Let's Go Out: Workshop on Outdoor Mixed and Augmented Reality. Orlando, FL.

Viana, W., Filho, J.B., Gensel, J., Oliver, M.V. and Martin, H. (2007), "PhotoMap – automatic spatiotemporal annotation for mobile photos", *Proceedings of the 7th International Conference on Web and Wireless Geographical Information Systems*, Springer, Cardiff.

Weigelt, K., Hambsch, M., Karacs, G., Zillger, T. and Hubler, A.C. (2010), "Labeling the world: tagging mass products with printing processes", *IEEE Pervasive Computing*, Vol. 9 No. 2, pp. 59-63.

Wikitude World Browser (2010), available at: www.wikitude.org/ (accessed 1 September 2010).

Wither, J., DiVerdi, S. and Höllerer, T. (2009), "Annotation in outdoor augmented reality", *Computers & Graphics*, Vol. 33 No. 6, pp. 679-89.

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