

Rebirth of Augmented Reality – Enhancing Reality via Smartphones

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Abstract—Mobile augmented reality sensitizes a new dimension of perception to see, hear and immerse in real world via interactive and enriched look and feel on physical world objects/places. This potential blend open new vistas for overlaying information on physical infrastructure, places and object of interests. No doubt, smartphone arena has boasted this technology to a wide spread domains, potentially gained an industrial support in revenue generation and commercialization. Recent advancements in smartphone computational capabilities, sensors support, and application portability has pitched new grounds in achieving perception of reality. A typical smartphone with camera and sensor capability can unfold the majestic potential of mobile augmented reality. This paper aims to present a survey on augmented reality applications, systems and trends, review on platforms, browsing and development environments for exploration of augmented spaces on smartphone. This review will enlighten researchers, industrial scientists, who are planning to build solutions for real world problem in the area of mobile-based augmented reality

Index Terms — Augmented reality, Augmented Virtuality, AR Technologies/Applications, Mobile Augmented Reality (MAR), AR Browsers.

I. INTRODUCTION

Perception is the organization, identification and interpretation of sensory information to represent and understand an environment. This visual perception is the transformation of historic shift of percept, where a user can visualize through its vision, bringing perceptual context into reality view. Virtual reality aims to provide augmentation and perception in close environment operated under fixed and bound set of parameters, whereas user can perceive reality in the same place as of the place of object registration. Achieving perception of reality in open space is the vision of augmented reality. Azuma [1] [2] described an augmented reality system as a combination of real and virtual objects, registration of virtual and physical objects and its alignment whereas, these components work interactively in three dimension space in real time. Three aspects of the above definition are important to mention, firstly it is not limited to any particular sense, AR can be apply to all senses including hearing, to touch and smell, Second dimension has mainly covering object registration and tracking in open space, and finally it is not restricted to particular display and tracking technologies. More preciously augmented reality is an

enriched and annotated view of physical environment, overlaid by computer-generated contents. Azuma definition of augmented reality is consider as a validated definition in the AR literature. No doubt augmented reality technology is a way forward for creating next generation reality based interfaces, providing freedom, liberty and openness of physical world and would be considered as new era of human computer interactions[3]. Emergence of smartphones have forecasted a potential market for augmented reality applications. A typical smartphone with camera and support of sensors capabilities like GPS, accelerometer and gyroscope can unleash a full potential of augmented reality. Augmented world of things is the future of reality world, these enriched presentations are not specifically for advertisement or tourist attractions but rather its universal impact will echo across different sector of life ranging from industrial manufacturing to e-business, medical surgeries to e-learning, strategic war planning to effective surveillance etc. AR services are supposed to envision as future of mobile services delivery for consumers for business development and economic uplift of business and economy. Electronic marketing and citizen services can be deliver in more interactive manner with this technology.

The organization of the paper is as follow: Section II presented introduction and historical development in field of augmented reality. Section III illustrates mobile augmented reality systems, section IV describes state of the art on mobile augmented reality system, AR Browsers, AR Toolkits, development environments, Challenges of mobile AR are described in section V. Section VII having brief outlook on recommendations and conclusion. The paper outlines the following objectives:

- The analytical review of current augmented reality systems, historical development, techniques and its state-of-the-art is the vital contribution of the study
- A detail coverage on smartphone emergence in area of augmented reality, analytical review on mobile operating systems with current industrial forecast in markets are focused
- Novel contribution is to review cross platform mobile development tools, augmented reality application development SDKs and toolkits
- Recommendation highlighted, will open new vistas for researcher in this domain for addressing real world issues and challenges

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II. AUGMENTED REALITY – BEGINING OF REAL WORLD REALITY

A. Background

Virtual reality systems were developed to stimulate reality in close environment to produce natural feelings to the user in order to see, feel, touch and explore interactively via computer system[4]. Building blocks of virtual reality system includes displays for delivering simulations, sensors to detect user actions and computer system to process user's action and generate display output annotated by computer generated information. Virtual reality operations performs in controlled and restricted environment, reality experience can be feel only in the premise or area of simulation or experimentation. Moving away from the area will result in reducing the visibility of realism; this leads a major disadvantage to VR technology in open spaces. Transforming realism from close environments to real world is the vision of augmented reality system. Augmented reality has enhanced the realism in the real world environments by capturing user scene from real world and annotating information on object of interests. Augmented reality [1] mechanics depends on object registration in real and virtual environment in three dimension spaces, providing freedom of augmenting any type of information on real environment. Another perceptive of realism is defined by Milgram's Reality-virtuality continuum [5] in this organization augmented reality lies in between continuum of virtual environment and the real environment, gaining reality potential of both of the environments as illustrated in Fig 1.

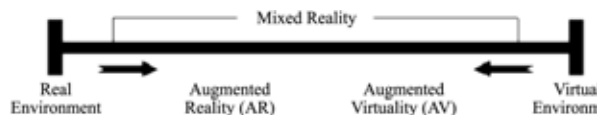


Fig. 1. Reality-virtuality continuum [5]

Reality-virtuality continuum outlooks placement of augmented reality with real environment and virtual reality with virtual environment. The continuum focuses on extreme endpoints of reality view whereas; all relative interfaces have registered to real or virtual environment. On the other hand Metaverse Model of Reality [6] presents merging of reality augmentation on physical point of interest on virtual space for enriched reality interfaces.



Fig.2 . Metaverse Roadmap [6]

The Metaverse model providing coverage into four areas i.e. life logging, virtual worlds, mirror worlds, augmented reality and virtual worlds covering four

scenario including augmentation, External, Intimate and Simulation. Strategically, the spectrums illustrates emergence of augmented reality in real environment with enhanced content modeling as illustrated in Fig 2. Although, both theories and roadmaps pinpoint augmented reality in different perceptive, however, the development of augmented reality system has been started before the interventions of these models, details historical outlook has been devoted from origin up to date in augmented reality in the next section of development history

B. Augmented Reality Development History

Technology world had witness first augmented reality system in 1950, Morton Helig a cinematographer designed a simulator called Sensorama, aims to turns cinema to an interactive activity[7]. Sutherland[8] introduced first HMD system in 1966, composed of an optical see-head-mounted display tracked by one-to-two different 6 degree of freedom trackers. In 1960 - 70's decade, US Air Force had introduced helmet-mounted display aims to provide a simulated experience to air force pilots. Knowledge-based AR Maintenance Assistant [9] was an AR systems introduced in 1980, called virtual fixtures[10]. Loomis, Gollidge, et al [11] proposed an outdoor navigation system for visually impaired in 1993, the solution was composed of notebook, head-worn electronic compass inbuilt with differential GPS receiver. Other than commercial and academic solutions, researcher proposed diversity of theories and models for example Virtuality Continuum[5] was introduced in 1994 covering models of real environment, virtual environment and mixed reality models, the most accepted definition for augmented reality was written by Ronald Azuma in 1997[1]. Rekimoto[12] introduced concept of fluidal, a 2D matrix markers. One marker system had used for camera tracking in 6DOF.

Touring Machine[13] was considered as first mobile augmented reality system composed of see-through head-worn display, orientation tracker; a backpack holding a computer, differential GPS, digital radio for wireless web access and a hand-held computer with stylus and touchpad interface. Touring machine laid down foundation for backpack based augmented reality systems, in the same direction Thomas, Demczuk, et al presented [14] "Map in the hat" was an extension of wearable computer composed of GPS, compass, HMD and backpack computer system used for navigational guidance and way finding. Kato, H. and M. Billinghurst [15] introduced ARToolKit, a tracking library used for recognition of square fiducially, template based objects and pose tracking of visual objects. Hollerer, Feiner, et al[16] had developed mobile AR system for exploring multimedia news contents located in different geography sites. Thomas et al [17] presented ARQuake, was single user perception application powered by GPS, digital compass and vision-based tracking of fiducially markers. Julier, Baillet, et al presented BARS[18] battlefield augmented reality system. BARS was composed of wearable computer, wireless network system and see-through HMD, used in reality-based augmentation of a

battlefield scene annotated with digital information about battlefield positioning and situation analysis.

The next decade can be term as revolutionary chapter in the history of augmented reality development, Newman, Ingram, et al. [19] developed BatPortal in 2001, users worn specific devices called Bats fixed on receivers which are installed on the floors, ceilings and building-wide infrastructure. Localization can be measure on basis of travel time of ultra-sonic pulses between bats and floor ceilings. Fuend, Geiger et al. [20] presented AR-PDA, a wireless augmented reality system for indoor navigation. The prototype composed of palm-sized hardware materializing unleashed the true spirt of augmented reality through live camera images. Reitmayr and Schmalstieg [21] had developed first mobile multi-user collaborative AR System. Vlahakis, Karigiannis et al. [22] presented a mobile based augmented reality system for augmenting cultural heritage and museums with name of “Archeoguid”, while Bell, Feiner, et al. [23] presented touring machine based augmented reality restaurant guide. The guide overlay bubble information round about restaurants, menus, photos and web address. Kooper, R. and B. MacIntyre [24] designed Real World Wide Web Browser which can be truly term as first browser of its kind. Kalkusc, Lidy, et al [25] presented AR system for indoor navigation. The solution has based on wireframe model of already labeled and registered point of interest. Annotations can viewed through head display whereas pad device has been use as input device. Raskar, van Baar, et al. [26] presented iLamps, an object augmentation system operated via camera and projector-camera system. Wagner and Schmalstieg [27] presented an indoor AR guidance system. This PDA based application facilitate user in viewing the information in 3D view. The Siemens SX1 [28] had released first commercial mobile AR camera game called Mozzies (also known as Mosquito Hunt). The mosquitoes has superimpose on the live video feed from the camera. Güven and Feiner [29] presented system for creating/editing 3D content for hypermedia contents. Mohring, Lessig, et al [30] presented a mobile based system for tracking 3D markers. This was first commercial AR system for cell phone consumers. Henrysson, Billingham, et al. [31] designed ARToolKit for Symbian mobile operating system, they have presented AR collaborative Tennis game for mobile phones as well. Reitmayr and Drummond [32] presented an outdoor navigation system for urban places, a hybrid tracking system on handheld devices in real time. Nokia [33] presented MARA, a mobile augmented reality guidance application utilizing sensors for context guidance. HIT Lab NZ and Saatchi demonstrated advertising application for Wellington Zoo [34] promoting various Zoo aspects. METAIO [35] promoted Islamic art with introduction of a commercial mobile augmented reality application for museum guide. Mobilizy [36] launched Wikitude, an augmented reality browser which consolidates GPS and digital compass integrated with Wikipedia, YouTube, flicker etc. Wikitude World Browser augment digital contents on camera view in real time. Morrison, Oulasvirta,

et al [37] presented “MapLens” is an extended map created over mobile augmented reality application. White and Feiner [38] Sean White demonstrated “SiteLens”, a mobile augmented reality application for urban design and planning. SPRXmobile introduced Layar [38] an advanced version of Wikitude AR browser using the same registration mechanism (GPS & compass) used in Layar as in Wikitude. ARhrrrr! [39] was augmented reality based game supported with high quality content.

Recent advancements in technical capabilities of smartphones and mobile operating systems, a huge growth in the area has forecasted. Seamless adoptive interfaces would be a part of large-scale industrial development for expending business vertices and consumer horizon.

III. MOBILE AUGMENTED REALITY – REBIRTH OF REALITY

A number of driving forces are behind the rebirth of augmented reality, mainly, moving with cumbersome hardware, heavy weight backpack, GPS sensors was not an effective scenario for achieving reality experience. Emergence of smartphone severed as charming blend for augmented reality system due to low cost, highly functional specification, powerful computational capabilities, advance user interaction, camera, sensors and display features made it feasible to provide all solutions in one place. Next generation of mobile device having greater processing cores, well supported by modern network technologies i.e. 4G and Wi-Fi, build-in integrated camera, GPS, accelerometer, gyroscopes and other sensors make it convenient to gather all required component in one device. Process of registration, tracking, overlaying and annotation are much speedy and accurate never before in traditional setup of augmented reality. Another edge, which has boosted this area, property of self-learning and high acceptance rate of adopting smartphone applications, a typical smartphone with camera and build-in sensors can utilize the power of augmented reality. Portability, self-learning and acceptance rate of adopting applications, provision of high quality graphics responsive user interfaces and interaction are the major driving force making smartphone as enabler of augmented reality solutions. MIT sixth sense project [40] is excellent illustration of using phone enabled devices for projective display on normal surfaces, anyone can dial, take pictures on ordinary interfaces. Mataio printer service [41] in the form of mobile phone application support their customer on procedure of change of cartridge. Mobile phone camera scan the structure of the printer and recognized the accurate model and present annotated view of object on view point of camera to show how to change the cartridge of the printer visually. Many other global trends also contribute in emerging of augmented reality on smart phones devices.

A. Recants Trends of Mobile Augmented Reality

1) Hype cycle for emergencing technologies

Hype Cycle is the projection of strategic and innovative planning of emerging technologies, highlighting by a set of

technologies and innovation having wide impression across the business and technologies in upcoming years. This cycle set future trends for upcoming technologies for specific span of time. Gartner [42] reflected these technologies in four themes including connected world, interface trends, analytical advances and new digital frontiers. Augmented reality lies in the area of connected world, bringing potential of digital world to the point of interests in the physical world. Moving along hype, augmented reality would take another decades to unfold its full potential; a number interesting and commercial opportunities will arise along the way of this hype. Fig 3 depicted the hype cycle showing augmented reality as potential technology

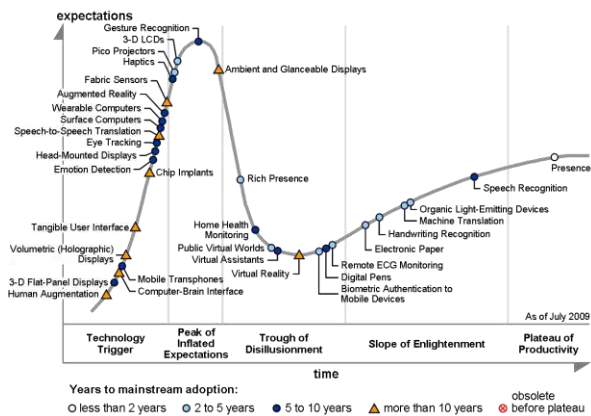


Fig. 3. Augmented Reality Hype Cycle

2) Top 10 Strategic Technologies

Gartner’s [43] top 10 strategies technologies covering social networking technologies, web mash-ups, in-memory computing, big data, cloud computation and mobile centric applications, augmented reality lies in second top category of mobile application and interfaces.

3) Google Search Results

Global trends had seen for future of mobile augmented reality in research and industry. Google Search provides an outlook on depicting searching trends. Figure 4 depicts Google search[44] requests for augmented reality between years 2004 and 2012-2013. The y-axis shows search requests normalize to the range from zero to 100. This number represents a fraction of highest search activity in from 2009 onward in up direction [98].



Fig. 4. Google Search Results for AR

4) Camera Phone as Starter for MAR

Camera captures live streams and context of users and thus act as driver for augmented reality applications. Camera phones are the basic phone for utilizing any type AR services. Proportional growth in camera enabled

mobile phones facilitates users for getting perceptive in mobile based augmented reality, and thus becoming a winning trend in success of mobile augmented reality.

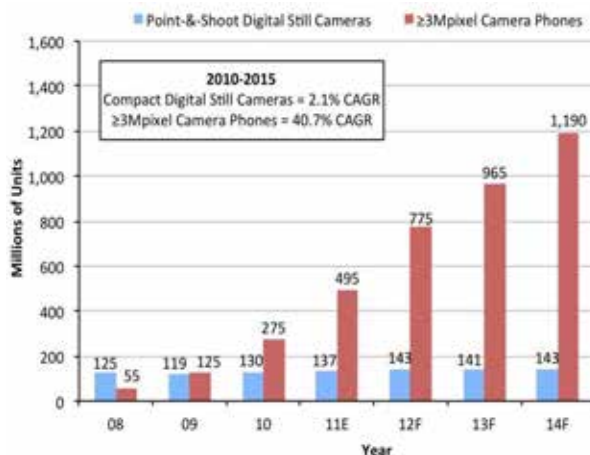


Fig. 5. Camera Phone vs Digital Camera

Figure 5 illustrates boosting ratio of camera-enabled mobile phone as compare to digital still camera. This trend of mobile phone serves as direct opportunity for mobile augmented reality to boost in upcoming years.

5) Market dynamics and Revenue Shares

Direct revenue associated with Augmented Reality[45] is expected to grow from about \$2 million to more than \$732 million in 2014. Fig 6 depicted revenue generated from AR services through incremental, promotional and point of sale applications in 2010 with projected estimates of 2014. Juniper forecasted AR revenue would be generated through point-of-sale purchases, incremental revenue and advertisement applications.

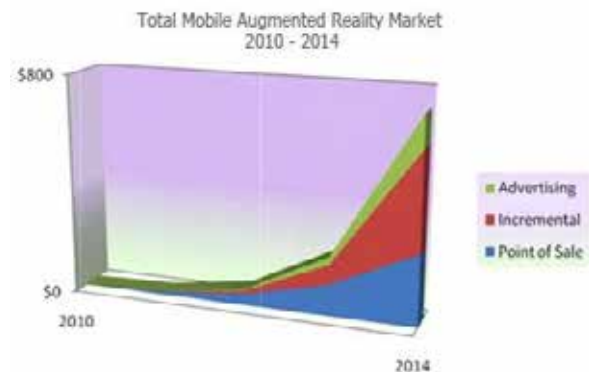


Fig. 6. Juniper AR Forecast [45]

Mobile world has enriched the augmented reality industry and due to the same reason, MIT forecast the impact of augmented reality base technology would alter research and industry in number of ways. Though Mobile Augmented reality is an infancy stage, technological advancement gap, GPS location accuracy and other reliability issues are still open issues in the area. Development of cost effective and efficient software/applications and designing of high performance

and energy saving hardware platform will make a difference in achieving augmented reality a success story.

B. Augmented reality tasks

H. López, A. Navarro, and J. Relaño [46] presented four basic operations required for achieving augmented reality experience. These are (I) Scene capturing (II) Scene identification based on registration (III) Scene processing for information overlaying and (IV) Augmented scene visualization.

1) Scene capturing and augmented scene visualization,

Scene capture is basic operation for capturing images or scene in focus by either camera or video-through, see-through devices or any capturing devices. Majority of augmented reality system captures image of reality for augmentation purpose and thus considered as starter of the augmented reality process. Camera in mobile devices has used for capturing live streams and context.

2) Scene identification

Identification of scene is vital process of augmentation, scene can be captured either using marker based approach or marker less approach depending on nature of scene. Marker based utilizes specialized visual tags; these tags determine the orientation, center and coordinate system most commonly used in indoor environments. Such capturing has considered as precise identification technique due to close nature of environment. On the other hand, marker-less technique uses coordinates and sensors for scene identification and object recognition. In nutshell scene can be identified either using image recognition, computer vision techniques or Geo-positioning techniques using GPS (Global Positioning System).

3) Scene processing or augmentation

This involves overlaying information on object/places etc in physical world. Rendering and mixing libraries are available for augmentation purpose. Open GL[47] an open source software library available for such purpose. Figure 7 illustrates process of capturing, processing and augmentation. In first instance scene is capture using camera, the same captured image are match with existing images in the data store. The scene are then processed using augmentation techniques, more digital information are overlaid on the scene and visualized to user on mobile device in highly enriched and interactive presentation.

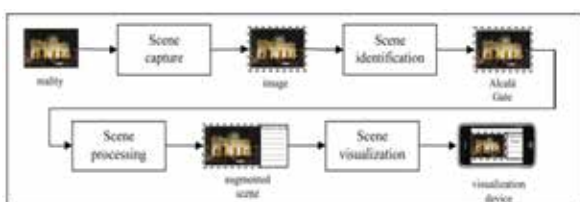


Fig. 7. Tasks in Augmented Reality [40]

C. Requirinements for achiveing mobile augmented reality experience

The following main components are necessary to delivery rich augmented reality experience on mobile phone these includes:

Mobile Processor:

Processing user input, video/image, scence processing and augmentation required powerful processing capabilities of smartphone to render and augment/annoate digital information. Quad-core and dual core processor are now available in recent smartphone for processing purpose e.g. LG Optimiums 4X HD P880 and HTC One X having 1.5 GHz Quad-core Processor.

Graphics Hardware:

Graphics rendering are the crucial part of augmented reality system. Graphical Processing Unit are used for generating virtual objects, transformation and rendering. Dedicated graphics processor enhances the capabilities of general purpose CPU resulting optimal performance and reduction in power usage of battery. Different rendering standards are available for such purpose. OpenGL ES is an extension of popular OpenGL[47] graphics standard similarly, ShaderX7 is the advance rendering techniques for graphics rendering in mobile phones.

Camera:

Camera hardware serve as starting point for augmented reality oprations. Capturing live stream are used for tracking and/or overlaying virtual imagery onto physical world objects. Good Resolution of camera enhance enriched presentation but resolution does not impact the overlaying mechanism as such. Auto image optimization in case of lighting and other weather/technical conditions can effect the identification process.

Display:

AR scene visulization can be viewed with disply output. Traditionally, the display are in the form of handheld, head mounted or projected display used to combine virtual images with images of the real world for scene visulaziation. Smartphone display supports TFT base LCD, Super LCD,NOVA, AMOLED, Super AMOLED depending on the colors, viewing angles, visibility etc. Recently available smartphone offering vibrant images, blur-free video, crisp text and auto brightness to see outdoors environment and thus ensuing best display for augmented reality applications.

Networking:

Wireless or cellular networking allowing mobile device to connect to establish data linkage across application and data source. Usage of Wi-Fi and high data network like 4G make it efficient for retrieval augmented reality objects from remote locations and remote webservices/databases.

Sensors:

Sensors are the additional components used for enhancing reality view by integerting supplementary

information related to point of interests. GPS, accelerometer, compass or gyroscopic sensors are used to specify the user's position or orientation. Sensor determine position and orientation of user's viewpoint, as users change their viewpoint, augmented reality system update coordination system and overlaying mechanism also update user viewpoint accordingly.

For experiencing mobile augmented reality, the following steps are required to perform, these are ;

1. Designing an identical coordinate system as like real environment for building augmented environment
2. Identify user's viewpoint through position and orientation by using sensors and camera.
3. Overlay digital information on top of camera as like in the position and orientation of user viewpoint.
4. Annotation of digital information over physical world on the user's display
5. Consolidation of physical and virtual objects over point of interests

D. Types of Mobile Augmented Reality

a) Marker-based AR

This reality type uses visual marker known as fiducial or AR card to determine center, orientation and range of coordinate system. In marker-based technique, the system detect marker, identify and calculate pose of the object with help of computer vision techniques. Computer vision system can robustly detect and identify good quality markers in timely manner. Black and white markers are most feasible for detecting objects under varying lighting conditions. Template and 2D barcode markers are the two type of markers used in this technique. Template marker is black and white markers having single image inside a block border, on the other hand 2D Marker consisting of black and white data cell holding information about object of interest or landmarks, 2D marker is also known as data marker or ID marker. 2D markers following standards of Datamatrix[48], QR Code[49] and PDF417[50]. These markers normally placed at the location of object or location such as book, stores, products and landmarks. This approach is widely used in indoor environment for tracking objects. AR Toolkit [51] help to identify, detect and process markers. OpenCV[52] is computer vision library using computer vision technique for identifying and recognizing images of real world with overlaid graphics.

b) Marker-less/ Gravimetric AR

Marker-less augmented reality utilizes GPS (geopositioning), compass and other related sensors, this type of approach is widely used in outdoor environments/open environments. Augmented reality browsers help users to navigate between POIs (Point of Interests) appear on camera view for exploring AR contents based on location and context.

IV. STATE OF THE ART TECHNOLOGIES, PLATFORMS, BROWSERS AND DEVELOPMENT TOOLKITS

AR is not standalone technology but indeed combination of diverse technologies supported by number of platform enabling consistent and cross platform seamless reality experience. Numerous aspects of AR technologies have outlined below including emergence of smartphones, mobile platforms, development of hardware sensors; AR development toolkits, AR software's and frameworks have been discussed briefly

A. Platforms

The mobile devices (smartphone, tablets etc.) operated with the help of dedicated software controlling phone functions, security, hardware, driver supports, power management and multimedia functions. Application installed are known as Apps, developed for specific operating system. Gartner [53] analyzed market share (in percentage) segmented by Mobile Operating Systems, Android OS hold 79% market share in fourth quarter of 2013. However, aggressive competition of Android and iOS seems clearly as result of selling of large number of units of Apple iPhone.

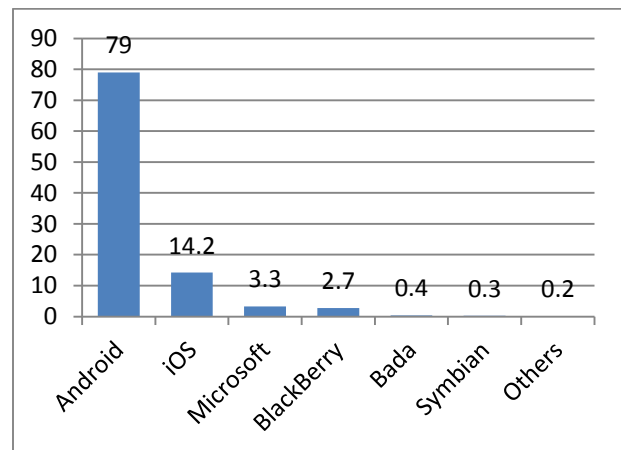


Fig. 8. Operating System wise Smartphone Sales in 2013 [53]

Examples of currently marketed operating system are

1) Android

Android[54] is an open source operating system for smartphone and tablets developed by Google in collaboration mobile manufacturing companies in 2007. TT-Mobile G1 having formal software development kit (SDK) in 2008 was first commercial product. As for as architecture is concern, Android has developed on top of Linux kernel. The architecture providing access to other low-level hardware access through specific interfaces to gain upper level to access low-level hardware functionalities. Android application has developed in Java language. The program run as a single process on Linux own instance called Dalvik Virtual Machines (DVM), which is an optimized java virtual machine for mobile device. Android supports Open GL 3D graphics engine, SQLite for data storage. Android currently holds 79% of

the global market share [53]. The Android Market/Google Play[55] publish wide variety of android and 3rd party apps. Current Android OS version is 4.3 Jelly Bean.

2) iOS

iOS[56] is an operating system for iPhone, an adoption of Darwin POSIX compliant open source operating system developed by Apple Inc. Currently holding 14% of market share [53]. iOS has boosted recently in the market due to innovations in their touch based user interfaces. iTunes app store published wide array of iOS applications in different categories. iPhone hardware has designed specifically in close support and integration of iPhone OS. Most famous feature of iOS is the multi-touch, support of accelerometer, camera to provide sophisticated input to mobile. Xcode is the development environment for iOS SDK written in Object C, current iOS version is 6.0 for iPhone, iPad and apple TV.

3) Symbian

Symbian[57] is backed by Nokia, designed especially for mobile devices. Symbian is an open OS supporting third party application developer to write device independent applications. Symbian has developed in C++ asynchronous in nature, having pre-emptive feature and multitasking operating system. Symbian is now in joint venture with Window OS announced his first Nokia window phone. Currently holding 0.3 % of market share.

4) Blackberry OS

Blackberry OS[58] is a platform developed by Research in Motion released in 2002. Integrated push email system is of one of innovative feature. It can act as wireless agent to have user's mailboxes featuring "Always on". BlackBerry have separate OS for Tablets called Black beery tablet OS, providing Java SDK and API for development of applications however, some classes are digitally signed and can't be used openly. Currently hold 2.7 % of market share.

5) Window Mobile

Window Mobile[59] was platform for pocket PC developed by Microsoft based on window CE. It was design to support 256-priority level of threads, mutual exclusion and synchronization methods. Currently hold 3.3 % of market share globally in smart phone market

6) Others

Small portion of other operating systems from open source and closed source are also available for smartphones including Palm OS, Samsung Bada, and Nokia/Intel MeeGo.

B. Augmented Reality Software

Marker and marker-less techniques required specialized augmented reality software. This may include toolkits, SDKs, Browsers for capturing and rendering. ARToolkit[51] popular toolkit for rendering marker base augmented reality solutions Layer, Wikitude etc are mainly

used in marker-less. Such application run across number of popular smartphone platforms.

C. AR Toolkit

AR toolkit[51] is a software library for building augmented reality applications were developed in 1999. Based on continues improvement in tracking algorithm, the toolkit is improved in wide spectrum of features. One of the key issue in development AR application is tracking of user view point in real time, AR toolkit utilize computer vision algorithm to solve the problem of dynamic user viewpoints, calculating real camera position and orientation thus ensuring fast and precious tracking. AR toolkit designed by Dr. Hirokazu Kato in C language, runs on SGI IRIX, PC, Linux, Windows platforms. Fig 9 illustrates different operations of AR toolkits processing mechanism, enabling camera tracking with help of black squares including fast and cheap 6D marker tracker. AR toolkit supports a number graphics formats including RGB/YUV 420 P, YUV.

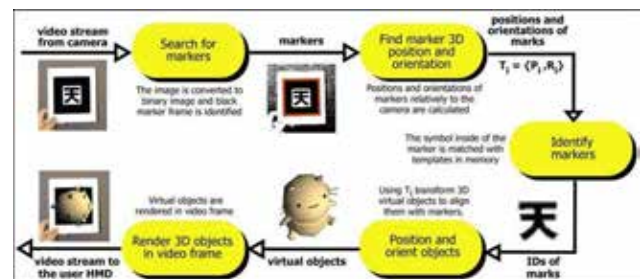


Fig. 9. Diagram shows image processing using AR Toolkits[51]

D. AR Development Kits

1) Qualcomm AR SDK – Vuforia

Vuforia enables AR developer to create powerful, high performance and interactive AR applications supported by Qualcomm AR platform. Vuforia computer vision system precisely recognize a number of 2D/3D visual targets/objects. This SDK can run on Android, iOS and Unity 3D platforms furthermore, it also allow native app development for smartphone and tablets. API for android and iOS is also part of Qualcomm platform. Technically, Vuforia SDK is based on application composed of the following core components, i.e. camera, video renderer, image converter, tracker, application code and target resources thus providing an extensive solution for marker based augmented reality systems.

2) Metraio SDK

Metraio Mobile[61] SDK is famous for its patented gravity-awareness visual tracking technology for 2D/3D objects. Android, iOS, symbian and window Mobile are supported platforms. Optimized tracking and NS rendering pipeline for major mobile chipsets is one of the winning feature. Beauty of this SDK extends to Barcode scanning, QRcode, and location-based POI visualization engine for creating custom AR interfaces. World advance AR Browser Junaio has based on this SDK.

4) *D'Fusion - Total Immersion*

D' Fusion[62] is a patent technology of Total Immersion to design and deploy augmented reality applications, supports multiple platforms including Android, iOS. It has considered as best SDK for fast recognition on live video streams. Being favorite in large angle recognition, it is majorly supporting 2D/3D tracking, Finger Pointing, Multi Camera support features. Ogre 3D engine is use for rendering purpose. Lua Scripting and computer vision modules are the primary components of this SDK.

5) *Wikitude AR SDK*

Wikitude[63] AR SDK allows development of truly enriched augmented reality experience. It is based on an ARchitect Engine encompasses wide array of developer standards including HTML5, CSS, and JavaScript. Developers have the magic of quickly and easily creating Geo-Objects for defining or triggered by specific geographical locations, infinitely configurable drawables supports. This SDK has supported by Android and iOS platforms

6) *Spring AR SDK*

Spring[64] is high performance SDK for iOS platform; enabling developer to add 3D objects in the form of markers. It is a commercial SDK available under pro and campaign licensing. Frame rate of Camera hardware is restricted to run at ~70FPS on 3G networks while track up to 10 images simultaneous.

E. *Platform Independent Mobile Development Tools*

Platform independent application development tools deliver native application code, used to deploy on all mobile supported operating systems. Cross platform development tools gaining popularity all over the world due to numerous advantages of cost and time effectiveness across platform development. Application development in these tools are easy and time saving unlike developing application for different platforms. Native applications have full access to device specific functions like camera, sensors etc. Some of major available market tools include Rhomobile, Mosych, PhoneGab and DragonRad.

1) *Rhomobile*

Rhodes[65] is Ruby-based framework for building native apps supported by iPhone, Android, RIM, Windows Mobile and Windows Phone 7 aims to manage enterprise application and data. Native applications having improved end-user experience, supporting users to synchronized local data with device and other capabilities like Barcode, Bluetooth, calendar, camera, GPS, screen rotation etc. This framework is based on Model View Controller (MVC) pattern, a popular design pattern. These applications are compiles in byte code for blackberry platform while on other platforms Ruby1.9 byte code is used.

2) *PhoneGap*

PhoneGap[66] is a mobile development framework under MIT license. Application developers having the liberty to create free/commercial and open source applications. This development environment is cross-platform supported and allows developer to create application for iOS, Android, WebOS, Window Mobile, Symbian and Blackberry. PhoneGap does not provide any specific IDE to develop application for all mobile platforms; however, developers can execute source code in available IDEs like ellipse. Phone Gap have specialized API for sensor and data.

3) *Dragonrad*

DragonRad[67] is platform independent mobile development tool allowing developer to develop, manage and deploy native applications across. DragonRad support in database system intern of integration and synchronization also facilitate in native function of above defined mobile operating system like contacts, calendar, and location-based services, map and camera. Core architecture is mainly composed of DragonRed designer, host and client.

4) *Mosync*

Mosync[68] is an open source SDK facilitate developers to develop and package for all type of applications. Mosync SDK is providing powerful tool with many companies tightly couple together. Singh, I. and M. Palmieri [69] made comparison of cross mobile development tools on the basis of architecture, design patterns, licensing, supported mobile operating system, development languages and output app format. Table I analyzes comparison of above discussed tools. A major driving force in overall analysis illustrates output format, usage of existing technologies and support of MVC design patter for achieving code standardization. PhoneGap has gaining popularity due to utilization of existing web technologies like HTML, Java Script etc. in development.

F. *Augmented reality Browsers*

Augmented reality browsers [70] are generic applications for retrieving, presenting and traversing resource through augmented realty interface. A mobile AR browser is responsible for i) managing (pulling and management) data from app source and third party data set ii) Rendering 2D and 3D objects iii) Camera interfacing for display output and browsing information space that ties sensors data with digital contents. These browsers serve as interface for perceiving reality vision of the physical world. Most popular AR browsers had surveyed below

Description of Existing AR Browsers

AR browser facilitate users to navigate across different Point of Interests (POIs), through GPS and camera tracking. The following are most commonly available AR browsers.

TABLE I. Comparisons of Cross Application Development

Tool Name	Mobile OS Support	License	Architecture	MVC	Language	IDE	Output App
RhoMobile	iPhone,windows Mobile, BlackBerry, Android	MIT	Local, web	Yes	Ruby, HTML, Java Script, CSS	RhoStudio	Web
PhoneGap	iPhone, Windows Mobile, BlackBerry, Android, Symbian, WebOS	MIT	Local, web	No	HTML, Java Script ,CSS	IDE of Native Mobile OS Eclipse, xcode	Web
DragonRad	iPhone, Windows Mobile, Blackberry, Android	GPL/ Commercial	Translate	No	D & D	DragonRed Designer	Native
MoSync	iPhone, Windows Mobile, BlackBerry ,Android JavaME, Symbian	Commercial	Local, Web	No	C & C++	Eclipse	Native

1) Layar

Layar[71] was launched in 2009 introduced SPRXmobile is a Marker-less system, identify user location and point of interest, retrieves content based on POI and overlays data over camera view by using mobile phone camera, GPS and compass. Layar provide information on top of camera view in various categories including eating and drinking, entertainment, health care, directory services etc. Layar also help to publishers in order to create own content and publish channels called Layars. Typical Layar consisting of three parts i) Layar definition ii) POIs list iii) and POI. Layar definition is use for creation of Layar, developer have to define look and feel of each Layar with help of customized parameters such as branding, color scheme, titles and POI indicators. POI list is list of POI for particular Layar along with location is loaded from third party datasets and POI, each POI contain information that is to be displayed on the screen as soon as POI come into focus. All Layars are register on Layar Server with different branding options, classified as features Layar are managed category wise. Layar is supported by multiple by operating system i.e. Android, iOS with 20 million installs and 3 million active user per month.

2) Junaio

Junaio[72] was developed by Munich based on Mateio GmbH is the only AR browser having built-in optical tracking capabilities, providing advantage over limitation of location base tracking. Junaio browser make use of LLA marker (Latitude, longitude, altitude markers) which mainly overcomes limitation of GPS navigational accuracy; this is especially useful for inside buildings and indoor navigation. Junaio uses “Target less Augmented Reality” approach, which does not require any 2D markers for tracking and mapping. Contents have managed in the form of channel. It has supported by Android and iOS platform. Junaio API called Junaio Glue API is also available for creating interactive AR experience.

3) Wikitude

Wikitude[73] is a general purpose AR browser introduced Mobilizy, featuring location based tracking and support for 2D images. Users can navigate across 100

million places annotated by interactive content from more than 3,500 content providers or “Worlds”. Wikitude has supported by android, iOS, blackberry, symbian and window 7. Wikitude can search in between existing points of interest like YouTube, tweeter, Wikipedia and Flickr etc. Wikitude is based on ARML (augmented reality markup language), popular language for developing augmented reality applications.

Table II aims to analyzed an overview of major AR browsers available along with their advance features. Junaio having an extra edge as compare to other browser due to its support of both marker and marker-less techniques of augmentation and LLA markers support. On the other side, Layar and Wikitude are using mainly Marker-less approach, data retrieved based on geographical location using GPS and allied sensors. POI actions are display out for users perceiving augmented reality experience in the form of information, audio, video, SMS and Map event. Future browsers has predicted to be highly interactive enriched via faceted browsing, solve design constrains of continuous data usage, safety and spamming, and establish common standards for cross browser content sharing.

V. CHALLENGES OF MOBILE AUGMENTED REALITY

Recent advancement in augmented reality technologies has considered as uplifting factor for smartphone industry. Potentially wide spectrum of range are still need to be explore and commercialize for larger interest of government and public. As this area is still at infancy stage, design constraints, context registration, efficiency of computer vision tools and techniques, augmented reality browsers capabilities of managing information overload and platform independent user interface design are still challenging issues. Other than above mentioned, some of the key challenges of mobile augmented realty are:

Image Capturing Capability

Image capturing capabilities of smartphones camera are dependent on lighting conditions. Mainly they are supposed to produce poor results in case of bed lighting conditions.

TABLE II. Comparisons of Augmented Reality Browsers

Features	AR Toolkit	Wikitude	Layar	Junaio
Mobile OS Platform/s	Symbian / iOS/ Android	iOS/ Android / Symbian / Bada	iOS / Android / Bada	iOS / Android
Development stage	Alpha	Release	Release	Release
First Launched	2003	2008	2009	2009
Augmented Reality Type	Marker-based	Marker-less	Marker-less	Both
Zones as POI	-	-	Partial	Partial
Standards used	Proprietary	KML / ARML	Proprietary	Proprietary
Technical ease	Advanced	Basic Knowledge	Technical competence required	Basic knowledge
Input Method	Varied	Web / API	API	API / XML
AR Content View	-	2D	3D , 3D Animation , 2D	3D , 3D Animation , 2D
POI Actions	-	Information, Map, Email, Call, Event	Information, Audio , Music, Video, Email, SMS , Map , Event	Information, Audio, Video, Map , Event

Blur quality images resulting problem in recognition and thus producing misleading information annotation. The use of API for handling camera sensors allow specific high-level to access, for example rendering control of exposure, aperture etc. optimization of poor quality imaginary captured from smartphone camera should managed for achieving high degree realism via reality interfaces.

Energy Consumption

Energy consumption remained an open challenge for smartphones. Camera, GPS and sensor consume gigantic amount of energy as compare to phone calls and messaging applications. For example, camera sensor requires a lot of energy while capturing continues images at higher frame rate, beside camera; computer vision techniques also produce battery drainage quickly

Data availability on Networks

Augmented reality applications access a large amount of data or third party dataset over networks for locating/navigating point of interests, any downtime of network access may harm instant response to users. Network converge from different telecommunication vendors are still insufficient in certain geographical areas. Available data plan for accessing network coverage is either unavailable or expensive to utilize for experiencing normal augmented reality applications.

Sensor information accuracy

Accuracy of sensor information is a vital component for indoor and outdoor navigation. GPS and compass provides information about position and orientation. GPS provide information in narrow urban canyon can be up to 100 meters. Similarly, compass reading has also affected by magnetic disturbance in the field. Accuracy of these

sensors has provided a basis for accurate overlying of digital information on point of interest

Lighting Conditions

Smartphone typically use LCD screens and light emitting diode to display output, both technologies are struggling to remain readable in bright outdoor conditions, increasing screen brightness solved this issue up to some extend however, high brightness derange battery life majorly. An intermediate approach between full lighting and battery consumptions is still area needs further exploration

Technology Adoption Life Cycle

Any new technology like the one AR goes through "Technology adoption life cycle" people resists change to adopt new operating mechanism for handling devices and learning new methods of interactivity and realism.

VI. RECOMMENDATIONS/CONCLUSION

Augmented reality enriched the real world by annotating computer-generated information to the user. As the utility of smartphones is very popular among general masses. Mobile augmented reality has perceived as technology of the future bridging digital world and real world. Although, AR is still in infancy stage, it will take almost five to ten years to unfold its full potential. MIT sixth sense project [40] has an excellent example for AR researcher for development of low cost reality interfaces, whereas, making call, capturing photos etc, these common activities can be projection via ordinary surfaces. CISCO has imaged AR world could be used for replacing interactive try rooms for traditional fitting room; it will not only save time but also extends achieving new horizon on industrial market. Similarly, AR brings possibilities for enhancing missing senses for hearing impaired users and visual impaired users, easily facilitated through voice,

visual clues and hepatic responses. Amazing apps will change over the world of augmented reality into interactive activity for different sectors. After an extensive review we come up with number of recommendations require attention from research communities and industry to build up infrastructure for underlying reality interfaces

- Development of augmented reality systems on smartphone need improvement in currently available hardware devices and sensors backed by economic power consumption patterns for serving efficiently in livelong energy consuming applications. Future of smartphone will be serve as visual computing device that will aims to unleash every possible interactivity on smartphone addressing common and specific needs of the diversified users.
- Minimizing cognitive overload can be achieve while bringing structured enhancements in the information space and organization of datasets by embedding richer semantics. Linked open data is still an open area for utilizing information space to be integrated and promoting visualized point of interests (VPOIs). The potential of semantic web

technologies can be integrated with augmented space for better understanding of visualization and reusing dataset and ontologies

- Pervasive computing can be easily transform to augmented computing, as AR have full potential of capturing, manipulating, pattern matching of sensors and allied devices. This area may have potential for augmented reality.
- Extended augmented reality browsers are the need of the day, AR application must be designed in such a way either it should serve as pluggable component in existing mobile/web browsers or existing mobile clients may be as augmented reality client without the need of installing any specific component for indoor or outdoor AR experience.

Augmented reality is all about augmenting digital information over the real environment, it is all about augmented people skills and mindset of how they want see and feel around. We believe this study will help and provide a guideline to researchers that are looking for next generation of perception of reality on their smartphones

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