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THE RISE OF AUGMENTED REALITY BROWSERS: TRENDS, CHALLENGES AND OPPORTUNITIES (Review Paper)

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ABSTRACT: An augmented reality browser is an alternative of a web browser in augmented spaces, which aimed at navigating and publishing overlaid interactive contents. This enabled end users to explore digital information on existing points of interests (POIs) and the application developers to publish overlaid information in the form of layers and channels, etc. These browsing interfaces were vital for publishing and locating contents to unfold the potential of augmented spaces. This paper contributed an analytical review on the recent emergence of mobile augmented reality browsers from the perspective of technological information publishing and usage scenarios. This comparative analysis of the augmented reality browsers would help researchers and industrial scientists to identify the most relevant augmented reality browser for specific applications like object tracking, content overlaying, and ensuring realism up to major extent. This study would also provide guidelines for next generation enriched, seamless and adaptive augmented reality browsers.

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Mobile Augmented Reality – A Perception Or Reality: Reality is the preview of the perception articulated through sensory mind maps. Achieving perception in fixed environment under predefined operating setup is termed as virtual reality (VR). Virtual Reality aims to provide an augmentation and perception in close environments followed by definite and bounded-set of object registration, whereas, user can perceive in the premises as of augmentation/registration (Burdea and Coiffet, 2003). Experiencing superimposed reality in open environments is the vision of augmented reality – a new era for next generation reality interfaces. Augmented reality is an enriched view of physical world empowering users to see, hear and immerse in reality world, presenting highly enriched and interactive superimposed multimedia contents (Hollerer and Feiner, 2004; Van and Poelman, 2010). Augmented reality system is a combination of real and virtual objects, registration of virtual and physical objects and interactively working of these objects in three dimensions in real time (Azuma, 1997; Azuma *et al*., 2001 and Kato and Billinghurst, 1999). Since 1950 augmented reality showed tremendous development in different sectors i.e. medical, engineering, learning etc as reported by (Van and Poelman, 2010). Traditionally to experience AR in real world requires bulky and heavy weight hardware equipment to carry along (Feiner *et al*., 1997). Emergences of Smartphones have forecasted a potential market for augmented reality applications. A typical Smartphone with camera and sensors like GPS, accelerometer and gyroscopes can unleash full potential of augmented reality. Currently, Augmented Reality is a leading technology in medical surgeries, interactive newspapers, gaming in virtual environments, shopping and interactive learning solutions as reported by (Van and Poelman, 2010). A wide range of augmented reality applications are now available for Smartphones, yet the most common applications for browsing augmented contents are the substitute of web browsers in augmented spaces. Exploring augmented spaces and publishing information on particular point of interests requires specialized interfaces know as augmented reality browsers. AR browsers are specialized augmented reality interfaces to display geo-located multi-media contents using virtual representation on real world (Grubert *et al*., 2011). This direct overlaying reduces cognitive overload on the user and provide an advantage over location aware interfaces such as tactical maps and digital overlays. The core function of AR browser is to display annotated contents i.e. plain and multimedia on places and object of interests registered in the real world (Grubert *et al*., 2011). AR services have envisioned as future of mobile services delivery for consumers and business. Within, this review, the issues and challenges of the commercially available AR browsers have been highlighted and further elaborated as to how we can make AR browsers more enriched, simplified, usable, and scalable on Smartphones.

The contributions of this paper include:

- The review of mobile augmented reality browsers and its state-of-the-art
- A viewpoint on AR browsing with respect to leading trends in industrial market
- A number of recommendations have highlighted to serve as new dimensions for the researchers in this domain.

Augmented reality browsing trends: The virtual reality systems carried out by (Steuer, 1992; Pimentel, 2000; and Burdea and Coiffet, 2003) were aimed to provide a realistic reality experience to the users to immerse in virtual environment. (Fisher *et al*., 1987) also supported by computer system in a close vicinity. The building blocks of virtual reality systems include display 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 systems are operated in restricted environments only, effect of realism are felt only in the region of simulation, moving away from the augmentation area will reduce the effect of reality-based experience. Transforming reality from close environments to real world is a vision of augmented reality system. Augmented reality has enhanced reality in the real world environments, whereas, user captured scene from real world and overlay enriched digital information on the same place in highly interactive manner (Azuma *et al*., 2001; Hollerer and Feiner, 2004). Augmented reality combines real and virtual objects in real environments, registered real and virtual objects and could work interactive in three dimensions providing freedom of augmenting information in real world (Caudell and Mizell, 1992; Azuma, 1993 and Azuma *et al*., 2001). Milgram's Reality-Virtuality continuum reported by (Milgram and Kishino, 1994; Milgram *et al*., 1995) introduced a new aspect of mixed reality system, whereas, augmented reality be positioned in continuum of virtual environment and real environment gaining the beauty of real and virtual environments.

Fig-1. Reality-virtuality continuum

Figure-1 illustrates reality-virtuality continuum depicting placement of augmented reality in real environment while virtual reality in virtual environment. The continuum has focused on extreme ends of reality viewpoints, moving along with the continuum from one edge to another edge exposing reality from open environment to close environments. A number of driving forces are behind the forth uplift of augmented reality system, mainly portability, moving with cumbersome hardware, heavy weight backpack, GPS sensors (Ohkubo *et al*., 2005) was not an effective scenario for achieving reality experience in many cases as reported by (Arango *et al*.,1993; Feiner *et al*., 1993). Emergence of Smartphones serving as appealing blend for augmented reality system due to cost effective functional specifications, powerful computational capabilities, advance user interfaces, camera, sensors and display features made it possible to provide many features in one place (Kock, 2010). Currently available and upcoming generations of Smartphones will be having higher processing cores, supported by modern network technologies like 3G, 4G and Wi-Fi, having built-in integrated camera, GPS receivers, accelerometer, gyroscopes and other sensors (Ohkubo *et al*., 2005). With advent of Smartphones the process of registration (Azuma, 1993), tracking, overlaying and annotation (Rose *et al*., 1995) are now more speedy and accurate. Furthermore, camera in the Smartphone enables users to see who is in the surroundings also capturing live streams of environment and context via picture, videos and sensors collaboration (Piekarski and Thomas, 2001, Thomas *et al*., 2000). Portability, self-learning and high acceptance rate of adopting mobile applications, provision of high quality graphics, responsive and intuitive user interfaces and interactions are the major driving force for making Smartphone as enabler of mobile augmented reality solutions are reported by (Khan *et al*., 2015). The following sub-sections have devoted to cover global trends and analysis of augmented reality browsing.

Mobile Augmented Reality Trends: Gartner hype cycle forecasted maturity of technologies over next decades for upcoming innovations and technologies (Gartner, 2012). These innovations and technologies have classified into four themes i.e. connected world, user interface trends, analytical advancements and new digital frontiers. Augmented reality has represented in connected world, bridging influence of digital world into the objects and places of interest for archiving realism (Yeh and Wickens, 2001). Augmented reality would take other decades to unfold his full potential; many interesting and commercial opportunities will arise along with the hype. Figure-2 illustrates hype interventions for upcoming augmented reality technologies and its impact on technology paradigm.

Augmented Reality is at the peak of this hype and will remain persistent for next five to ten years. Camera equipped mobile phones have also extended another possibility for unleashing horizons of augmented reality in diversified industries. Proportional growth in camera equipped mobile phones made it more convenient to the end users to avail different services at one place. Figure-3 shows comparison of compact vs. camera phones in term of number of units sold over the years. Camera equipped mobile phones are serving as a leading indicator for achieving augmented reality experience.

The Smartphone having advance capabilities of handling all functional operations of augmented reality in one place, such as scene identification, processing, annotation of scene and overlaying digital information are reported by (Kock, 2010). Juniper (2012) has forecasted trends of mobile phones as direct opportunity for mobile augmented reality to boost in upcoming years, he further added that the revenue associated with augmented reality will continued grow-up from about $2 million in 2010 to more than $732 million in 2014. Though mobile augmented reality is at foundation stage, technology advancement gap is still there to understand and accept new technological issues; GPS location accuracy is still inadequate for many indoor navigation situations. However, advances in mobile application development, hardware and sensors would make a difference in achieving augmented realty a success story in the years to come.

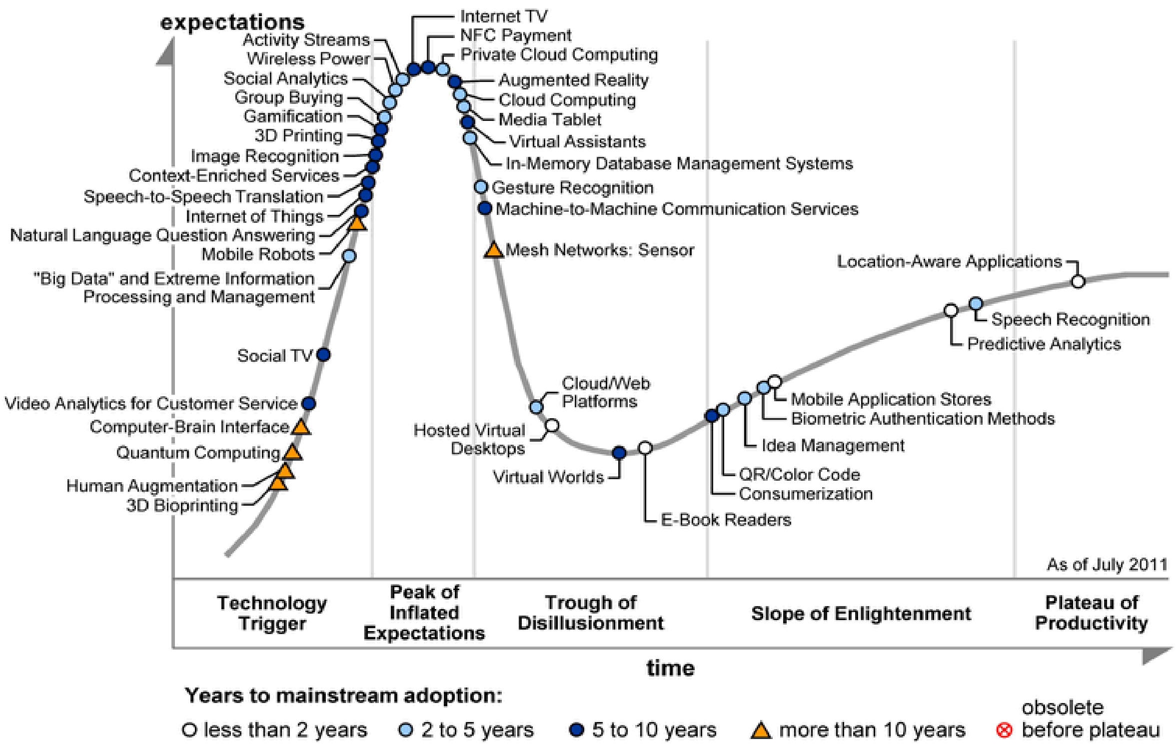

Fig. 2-Augmented Reality Hype Cycle

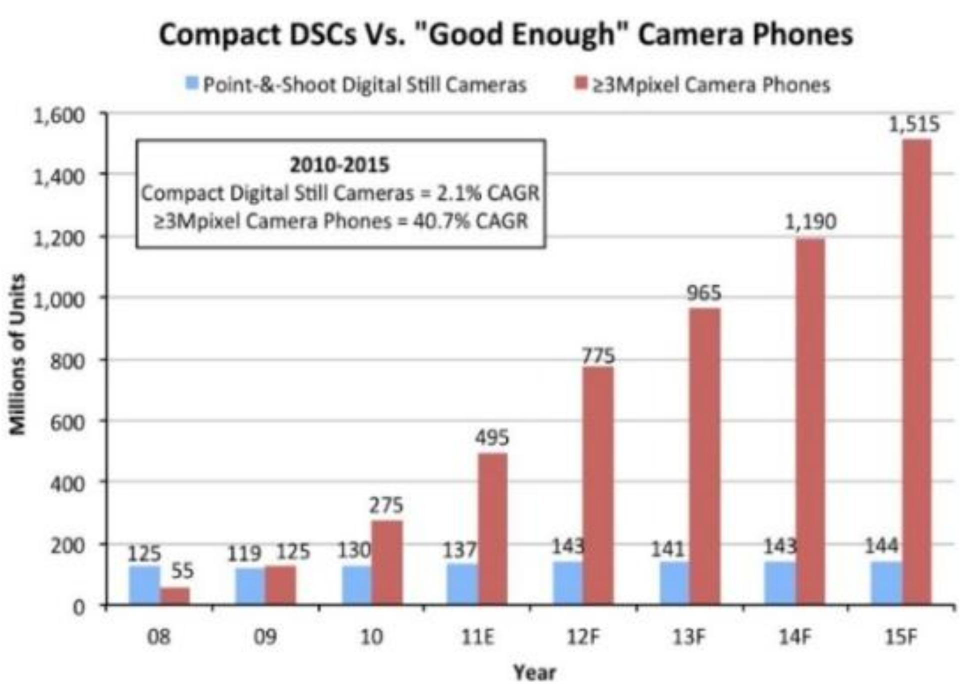

Fig-3 Camera Phone vs. Digital Cameraa

Emergence of Smartphone: Enhancement in Smartphone features like processing capabilities, power saving and portability offered by Smartphones is acting as a driving factor in the rise of Smartphones market over the last few years (Van and Poelman, 2012; Kock, 2010). A Smartphone presenting large touch screen, provision of sensors, geo-location awareness and context awareness etc. can equally compete the requirements for augmented reality systems. Egham (2012) had estimated 426 million sales of Smartphones worldwide in first quarter of 2013; an approximant 226 million mobile phone were sold to end-users in Asia/Pacific. Similarly, International Data Corportaion (IDC) (2012) has forecasted that the average sales for Smartphones in 2015 would be nearly 982 millions. Fast growing market of Smartphones has fuelled by enhanced Smartphone functionality and cost effective data plans etc. have made these devices accessible and affordable for public. A similar expansion has expected in the market of touch screen tablets as well. Allied Business Intelligence (ABI) research argued that the tablet devices would become a significant consumer market with sale rate of 57 million units in 2015 (ABI, 2015). Tablets have potential of offering useable services for AR applications due to large size display involving users with intuitive presentations. The total value of mobile AR applications will approach to $1.5 billion in 2015 supported by (Juniper, 2012) indicating average annual growth of mobile AR app value during the forecast period of 295%. Location based/awareness services are the most predicted applications for travel and outdoor services in upcoming years. Augmented reality browsers are serving as a best utility in exploring augmented reality spaces.

Browsing augmented spaces - an overview: Exploring information spaces in real world requires specialized interfaces to view, publish, annotate and navigate among sets of point of interest, these interfaces are facilitating end-users to find information of their interests in an intuitive and presentable way. There is a need for specialized browsers, which are the substitute of web browsers in augmented spaces that could facilitate end-users to customize their realism experience and help developer to publish technical details on augmented reality cloud. This section has devoted to identify needs for mobile browsers, exploring their functionalities, publishing and consuming contents and exploring associated parameters related to navigation and browsing. Major emphasise has made to explore the utility of augmented reality browsers for experiencing reality in physical world.

Mobile Browser: Mobile browser is a compact browser designed specifically for mobile devices in order to render web contents on mobile phone's (Hernandez, 2009). Mobile browser connects via cellular network or wireless Local Area Network (LAN) using standard internet protocols. Mobile browsers are of two type's i.e. compact browser and full browser (Ye, 2010). Full browser have almost the same functionality as of the web browser i.e. rendering same type of contents as on web browser in PC, whereas compact browser framework needs to transfer or intermediate server to connect to internet web server. Contents are retrieved from web server; web contents are converted into mobile compatible format and elements of the web pages ensuring good performance to the mobile end-users due to optimization of pictures and contents. Hernandez (2009) has analysed mobile browser on the basis of the features like rendering engine, zoom in/out, touch support, multimedia, widgets, platforms supported by browser, narrow band and broadband features. He has analysed and presented the summary of popular open source and commercially available mobile browsers. Wireless Application Protocol (WAP) browsers are still most popularly deployed whereas, graphical browsers are used in J2ME enabled phones. These phones are serving as a good utility for performing common activities on mobile devices. However, while addressing complex kind of activities like navigation and path finding, mobile browsers do not offer any specific utility for end users in usability and content integration.

Real World Wide Web Browser (RWWW): Real World Wide Web (RWWW) is the information space based on enriched World Wide Web. The objects in RWWW having contextual meta-data associated with it (Kooper and Macintyre, 2003). They further reported that the objects in RWWW were the web pages annotated with 2D and 3D visual and auditory information. Annotated metadata is used to assist decision regarding when/and where to present visual information to the users registered for specific objects, places or landmarks. RWWW browsers are interfaces for interacting with RWWW objects for rendering information on smart devices. The RWWW would be the future of context-aware mobile technologies. Augmented reality took the idea ahead further to the location-aware techniques for overlaying textual and graphical information onto the real world (Hollerer and Feiner, 2004). One of the most common applications for augmented reality browsers is to find point of interest in the real world while overlaying digital contents on it for enriched visualization.

Augmented Reality Browsers: Augmented reality browsers reported by (Grubert *et al*., 2011; Jonghong**,** 2014; and Langlotz *et al*., 2014) are specialized augmented reality applications for rendering geo-located multimedia contents augmented on point of interest of the real world. AR contents are the information that are relevant to certain places or objects called Point of Interests (POIs) comprising of description of place or object, context details, images and audio video annotation (Feiner *et al*., 1993; Ahn *et al*., 2014). These contents are displayed on specific place or object of interests having prior registration with related POI. Generally, the browsers gain access through remote resource via web standard protocols and services i.e. HTTP, Methods, and REST, indexed contents through media streams like channel, layers and worlds; and supports a variety of MIME formats (html, image, audio, video or 3D). A typical mobile augmented reality browser having the following features i.e. capturing camera view point for registration and displaying output, rendering 2D and 3D objects have been reported by (Tatzgern *et al*.,2014), fusion of sensor data with digital contents have been reported by (Ali *et al*., 2014; Arth *et al*., 2012) and managing data from app sources and third party datasets.

The following constraints have confronted in exploring augmented spaces. These issues have faced in case of searching particular point of interests and nature of information overlaying. Some of the constraints have been analysed by (Kooper and Macintyre, 2001; Kooper and Macintyre, 2003) for browsing augmented spaces as listed below;

i. **Continuously changing data (continuous use of devices):** Outdoor AR applications reported by (Van and Poelman, 2010) mainly rely on capturing and manipulating context of the users, ordinary change in context like user's location and time could resulting a significant change to the information overlaid on particular object or place of interest (Chon and Cha, 2011). Rapid changes in point of interests related to GPS positioning resulting frequent updating of point of interests have been reported by (Zandbergen *et al*., 2011). Thus, continuous data usage resulted in a drastic effect on Smartphone battery and performance of Smartphone

ii. **Safety and Spamming:** Augmented Reality view is mainly dependent on the AR contents generated from heterogeneous source (Ahn *et al*., 2014). Trustworthy and untrustworthy data have mixed in the AR view. This issue lead to unauthentic information and spamming. Thus, a proper mechanism needs to be developed while, publishing and maintaining data security, accuracy and integrity to avoid spamming of data. Misinformation or spamming contents overlaid on POIs would results in confronting risky situations for the AR user's in real time activities pertaining to emergency and disaster.

iii. **Heterogamous data:** The AR views should be enriched only if tagged, untagged and contextual information could be mixed together for future display of AR Space (Kooper and Macintyre, 2000; Olsson *et al*., 2012; and Leigh and Maes, 2015)

iv. **Non-interference:** Augmented Reality interface should support continuous awareness of virtual space without interfacing with other application tasks. Information being displayed should not overlay or clutter the AR View.

v. **Quality of AR Contents:** Augmented Reality browsers are dependent on the information related context-aware details. Integration of other media types are also lacking feature in currently available augmented reality interfaces. Content density is another factor effecting realism experience. City centres may be intermixed with different POIs and could result inaccurate information in currently aware context solutions. Without intelligent automation of filtering and selection tools, the available browsing solutions would always lead to disinformation.These issues could be addressed by optimizing the existing components like GPS accuracy proposed by (Olsson *et al*., 2012), battery life improvement etc. and other constraints may need adoptive and development of persistent modules for addressing issues like quality of content, usability and integrated interfaces.

Description of Existing AR Browsers: A number of Augmented Reality browsers are available enabling users to navigate between different point of interests via GPS or camera tracking techniques. The most marketed Augmented Reality browsers, currently available have been organized by vendor, URL, plateform supported and head office of respective augmented reality browser organizations (Jonghong, 2014). The following are description of commerically available augmented reality browsers;

Layar: Layar is based on marker-less system which mechanizes the identification of user location, retrieve data based on geographical coordinates, overlays content over camera view, GPS and compass, was introduced in 2009 by SPRX Mobile Company (Layar, 2014). Layar provided information on top of camera display view in various categories including eating, drinking, entertainment, health care, directory services etc. Publishers having liberty over creation of own contents and publishing channels known as Layar. Sponsored Layar appears higher in the list of suggested or popular layers while other layers may appear subsequently. Layar Store aims at providing users to buy access to Layar with classified information. A typical Layar consisting of three parts i.e. Layar definition, POI list and the POI. Layar definition comprising of information about creation of Layar developer, having privilege to define look and feel of each Layar based on customized parameters such as branding, colour scheme, titles etc. POI list represents location of Layar to be loaded from third party datasets and POIs. Layar are stored in Layar Server in categorized manner and can be searched via keywords. POIs are refreshed at interval of 100 m or 5 min. Layar has supported by android, iOS. Technically, Layar is composed of two parts, a browser application for mobile devices and an online platform to manage information about the services related to pubic interests. It also allows developers to use different icons to represent points of interest on screen; 3D graphics is new valued added feature. However, it will take time to utilize its full potential in enabling 3D immersive environments. The only downside of Layar is the extraction of huge dataset on Smartphone. To visualized realism, Smartphone may require to download large amount of data, thus, requiring a high and stable data connection for application to react instantly. Figure-4 illustrated architecture for Layar browser representing different components of architecture.

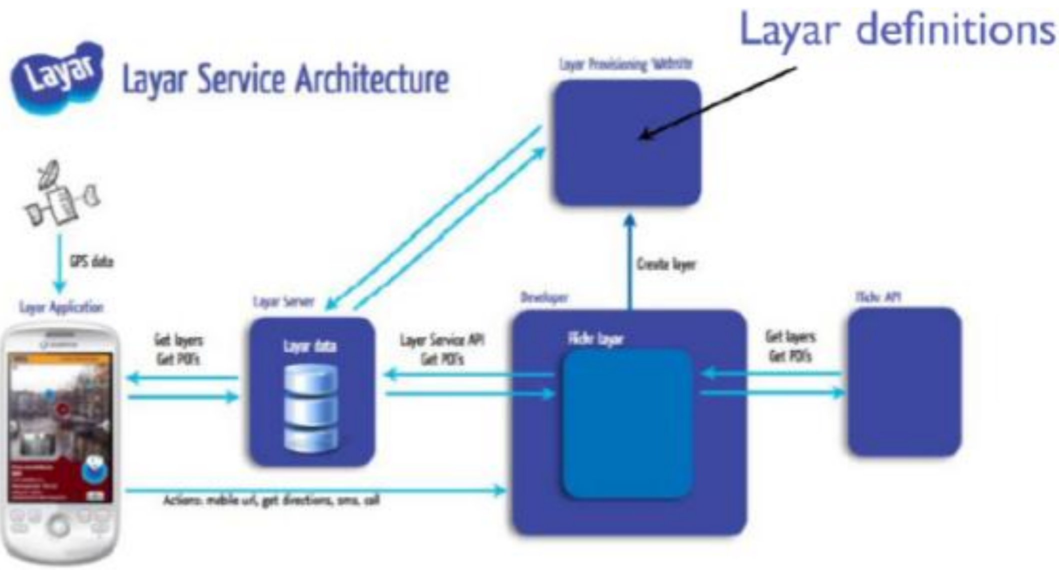

Fig- 4 Layar Architecture

Junaio: Junaio is an augmented reality browser having built-in optical tracking capabilities introduced by Munich based on Mateio Gmbh (Junaio, 2014). Junaio browser have introduced LLA marker (Latitude, Longitude, Altitude markers) which overcomes limitation of GPS navigation accuracy in an indoor navigation. Target less augmented reality approach has been adopted resulting advantages of not using 2D markers or template based mapping. Contents are managed in form of Channels. Android and iOS are supported platform. API for interacting with other applications namely Junaio Glue API is also available. Figure-5 illustrates architecture of Junaio.

Fig-5 Junaio Architecture

Wikitude: Wikitude is a general purpose augmented reality browser introduced by Mobilizy, featuring location based tracking and support for 2D images (Wikitude, 2014). Users can browse more than 100 million places within interactive contents from more than 3,500 content providers or *"*Worlds*"*. Wikitude support variety of mobile operating systems and platforms including Android, iOS, blackberry, Symbian and window 7. Wikitude searches in an existing point of interests like YouTube, Tweeter, Wikipedia, Flicker etc. Technically, build upon ARML (Augmented reality mark-up language) aimed for crowd sourcing resulting sharing of point of interest with each other. Crowd sourcing provides valuable information about product and services thus contributing a collaborative information space. Wikitude is a specific web application to encourage users to add their point of interests to the application, user can sign-in with social networking website for content sharing. However, lack of moderation mechanism leads to spamming of content to augmented spaces. Secondly, limited categories for content contribution are available for end users

Sekai Camera AR Browsers: Sekai camera has been based on social network location based service, which is composed of client-side and web services, enabled with camera-equipped mobile phone to access information by creating clickable world called AR-hyper-tags (Sekai, 2014). It utilizes location base tracking and offers an API for developer and content publisher under commercial license. Sekai Camera having the features of Air Tag, Air filters, Air Pocket, Sekai Life, Air profile and Air Tweets. Sakai aimed to make world full of tagging as a result of the user contribution in the form of text, images and social media posts.

Argon AR Browser: Argon is a Real World Wide Web (RWWW) browser aimed to bring Augmented Reality into masses through web centric model (Macintyre, 2014; Sekai, 2014). Argon provides flexibility for delivering contents by the use of latest web technologies e.g. HTML5, CSS3, Java Script and KML. Argon utilizes KML/HTML based augmented reality mobile architecture (KHARMA) which addresses several problems related to mobile AR development and delivery of contents. KHARMA framework has built various layers including channel servers, infrastructure servers, geo-spot servers and an open source standards-based mobile client. Figure-6 illustrates KHARMA framework for Argon AR Browser.

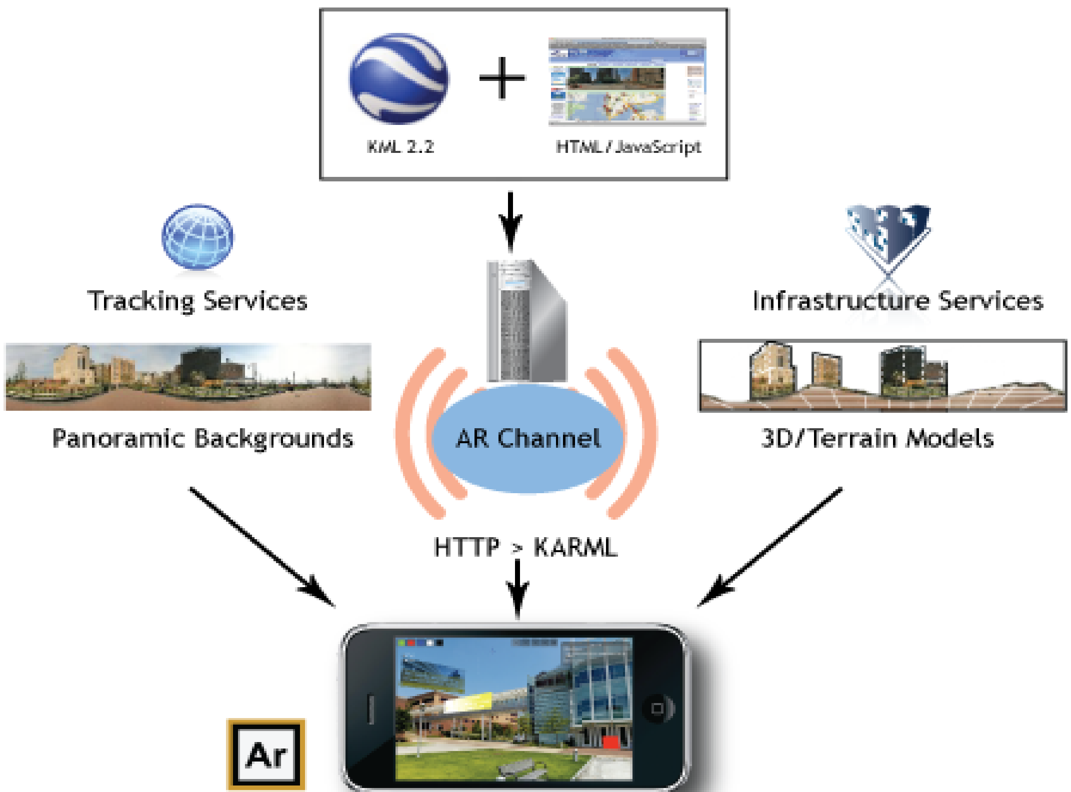

Fig-6 KHARMA framework

Framework for Evaluation of Augmented Reality Browser: Augmented reality browsers are serving as unified interface for presenting point of interests from heterogeneous sources, providing an interactive and enriched reality experience to the users. General evaluation indicators have been adopted by (Kock, 2010; Butchart, 2011; and Jonghong, 2014) for comparing AR browsers. The following parameters are opted for evaluation of commercially available augmented reality browsers.

Augmentation and Registration: Registration and augmentation of reality are the fundamental components for achieving realism in augmented reality system (Zandbergen *et al*., 2011; Jain *et al*., 2015). Objects or places of interests are registered into augmented reality system; later on, the same registered points are used for augmentation purposes. GPS, Marker-based and computer vision approaches are used for the purpose of registration and tracking in 6DOFs. In Smartphones, sensors like GPS, digital compass and accelerometer are used for tracking purposes. Marker-based approach providing support to optical character using marker is called fiducials, these markers utilize schemes or patterns for optical tracking like QRcode, Barcode etc. Optical tracking has been achieved by computer vision algorithms using natural features detection or image recognition technique. Adding 3D object registration feature may be included in the future evaluating AR browsers.

User Actions: User actions are set of operations performed by users in AR browsers. The basic actions to perform in this context is to search particular point of interest and visualize search results. Most of the user actions are processed on information overlay layer. The user can post text with 2D icons or 3D icons to represent information in the reality browser. User can also post images already in mobile device or by capturing through real time camera streams. 3D model is an option at user's side for posting complete 3D models like indoor plan of building and floor plan etc. Users having access to common features of social networks like posting, invitation, and comments have another facility as part of user's actions.

Application Programmable interfaces (API)

Publishing API: Augmented Reality browsers offer various techniques for developers to publish their own point of interest, search and interact with contents. A number of publishing techniques are available including Open Key, Crowed Source, Restricted, and Bundled. Open Key API allows developers to publish their own data in augmented spaces. There is no registration fee for developer, having restriction on user limit. Users crowd sourced contents are published by regular user through browser specific features of uploaded contents, images, 3D models etc. providing ease to non-technical users to contribute content. Restricted key API requires fee on particular providers. Bundled is a self-contained content embedded in into the app itself, knowledge of augmented reality browser source code is required for working with publishing API

Application API: Unlike publishing API, this API deals with appearance or capabilities of browser i.e. functionality or customization of appearance with local brand of the business. This API came under Open key, Restricted Key, Commercial key and Customized key licenses. Open key API reuse browser code by combing related APIs to create their own version of browsers resulting application independent of particular platforms. On the other hand, restricted key developers can create their own version but standard license may apply. While commercial key as name shows has commercial fee or license which is required to develop application using API/ frameworks. In Customized API, developers do not have control over internal manipulation of code but can change the appearance and functionality

AR Contents: Contents play a vital role in enriching information space; rich contents enhance the beauty of augmented spaces (Ahn *et al*., 2014). AR Contents are the information overlay which superimpose on reality view of the users (Belimpasakis *et al*., 2010). 2D icons can display content on particular point of interest. Diversity in shapes and size of icon represents content importance and frequency of its usage. 2D markers, icon, text, bubbles, can represent POI and 3D objects are used to represent information on augmented spaces (Langlotz *et al*., 2012).

Point of Interest Actions: Point of Interest (POI) represents an individual data item associated with geographic location or visual pattern rendered by AR application. Data type of POI describes location information or reference image used in tracking. POI actions describes various action related to POI like searching and visualization etc. Users normally see POI in the form of icons, text bubble, images, and summary of text block. Pressing the POI icons or links the users have presented with different actions. The actions mainly depend on nature of POI. "Info" which is used for linking objects with web page. Playing audio, video, music, rendering map, making a call, sending an email and SMS, publishing social and event are common actions provided by POI

Interface and Accessibility: Augmented reality applications have been designed to cater the issues of continues usage of mobile network for downloading data for loading POIs (Julier *et al*., 2003). Various applications allow users to cache or bundled the data, thus POI can be loaded even if the network data is not available. Online only applications requires network connectivity, all the time to work properly, offline application data synchronizes once the application gets online. Cacheable mechanism is also an option for layers, cached online for speedy use

Sensors Device Capabilities: Context awareness is the key technique for augmented reality applications, use of sensors is a potential source for mobile device. Smartphones normally support various types of sensors like GPS, WPS (WiFi Positioning sensor), NFC, Accelerometer, Gyroscope (motion sensor), Magnetometer (digital compass) and Bluetooth interface as reported by (Schall *et al*., 2009). However, continuous usage of battery hungry sensors like GPS reduces the time of experiencing reality view.

Analytical review of augmented reality browsers: Augmented reality browsers have been analysed based on different parameters including Augmentation and Registration, User Actions, API, AR Contents, POI Actions, Interface, accessibility, and Sensors device **c**apabilities**.** Table-1 shows an analytical review of augmented reality browsers in the evolution of framework based parameters for analysing browsers in the perspective of users and developer, publishing and using of contents, actions of users and developers, liberty of code reusability and customization of appearance and backend processes. Augmented reality browsers render geo-located multimedia contents on real world objects and places of interests (Madden, 2011). Managing (pulling and management) data from app sources and third party datasets, render 2D and 3D objects, camera interfacing for display output and browsing information space ties sensors data with digital

Table 1 . Comparisons of Augmented Reality Browsers

Browsers	**Layar (Layar 2014)**	**Wikitude (Wikitude 2014)**	**Junaio (Junaio 2014)**	**Sekai Camera (Sekai 2014)**	**Libre Geo Social (Social 2014)**	**Macintyre (2014)**
Registration and Tracking						
GPS	Yes	Yes	Yes	Yes	Yes	Yes
Marker Based	No	No	Yes	No	Yes	Yes
Marker less	Yes	Yes	No	No	No	No
Built-in User Action						
User Actions	Web View	[redacted]	Post Text, Images, Photos, 3D, Social	Post Text, Sound, Images, Social	Post text, Picture, Sound, Social	Post Text, Pictures
API						
Publish API	Open Key	Open Key	Open key + Crowd	Restricted, Commercial, Crowed	Crowed, Open Source	Open
Application API	Custom	Custom	Custom	Custom	Open	Custom
AR Content View						
Contents	3D, 3D Animation ,2D	2D	3D , 3D Animation , 2D	2D	2D	3D, 2D
POI Actions						
Actions	Information, Audio, Music, Video	Information, Map, Email,Call, Event	Information, Audio, Video, Map, Event	Information, Audio, Map, Social	Information, Audio, Map, Social	Information, Video, Audio, Map
Interface and Accessibility						
Offline Mode	Online Only	Cacheable	Online Only	Online Only	Online Only	Online Only
Platforms						
Availability on Platforms	iPhone, Android, Symbian	iPhone, Android, Symbian	iPhone, Android, Nokia	iPhone, Android, iPad	Android	iPhone
Sensors Device Capabilities						
Camera	Yes	Yes	Yes	Yes	Yes	Yes
Compass	Yes	Yes	Yes	Yes	Yes	Yes
Accelerometer	Yes	Yes	Yes	Yes	Yes	Yes
Push Data	No	No	No	Yes	No	Yes
Markers	No	Yes	No	Yes	No	Yes
OCR	No	No	No	No	No	No
Gyroscope	No	No	No	No	No	No
Microphone	No	No	No	No	Yes	No
Technical Ease						
Ease of Use	Technical	Basic Knowledge	Basic Knowledge	Basic Knowledge	Basic Knowledge	-

contents are salient features of a generic AR browser. Junaio browser use marker-based approach that utilizes built-in optical tracking with the help of LLA markers. Especially, they overcome accuracy and limitation of GPS navigation through LLA markers making it favourite for indoor navigation. However, due to non-availability of cached layer, continuous battery consumption is a big disadvantage. On the other hand, Layar and

Wikitude are mainly utilizing marker-less approaches, from the data retrieved from different geographical locations using GPS. Both browsers have the benefit of using Open Key license providing extensibility in customization of appearance and its functionality. Similarly, Argon is an emerging browser integrating existing web technologies using KHARMA architecture in augmented reality environments, KHARMA using KML/HTML and already developed web technologies for porting into augmented reality system (Hill *et al*., 2010). The future browsers have been envisaged, being highly interactive supporting faceted browsing, which will resolve the design constrains of continuous data usage, safety, spamming and integrating common standards for cross browsers contents sharing and integration. Powerful augmented reality browsers need to develop for exploration of augmented space contributed by diversified users. Aspect of data privacy, security and pluggable architectures should be kept in mind while designing new browsers or plugging with existing mobile browsers. Primary features of presentation, navigation, content postings, searching POIs, manipulating POIs; publishing through APIs, POI actions, offline modes, sensors and device capabilities are the standard features offered in most of the available browsers.

Issues in AR browsers: Drawbacks of current AR browsers include insufficient tracking techniques, static nature of contents and inadequate users interfaces support etc. Mobile augmented reality browsers combine the augmented reality technology using Smartphone assisted by sensors like GPS, camera and compass. However, this technology is still at an infancy stage and has to face a number of issues and challenges. Some of the key challenges in the area of mobile augmented realty browsing are;

- Augmented reality is under an intensive development stage there will be technical bugs and glitches, observed by tech users and may have worst effect on its potential use for their common goals and interests.
- Cross-platform support is still an open challenge so there is a need of communication protocols that could communicate among different AR browsers, resulting usable and a similar experience across different platforms and mobile devices. Currently different versions of the same AR browser have experienced different realism for a same POI;
- Image capturing capabilities of Smartphones are dependent on picture quality. Augmented reality output may produce poor results in case of bad lighting conditions or in case of blur images which may result in recognition and registration issues. Capturing of scene is also dependent on tracking in marker based approach, AR browsers may produce invalid result due to poor capture quality in such conditions.
- Continuous use of mobile internet data, camera live stream, GPS and sensing sensors data consumes huge amount of energy as compared to common activities like phone calls and messaging. For long energy conservation AR browsers should be capable of handling offline to online data mode synchronization.
- Any new technology like the one AR goes through “Technology adoption life cycle” people resist change to adopt new operating mechanisms for handling devices and exploring information.
- Inadequate standardization for interoperability between AR browsers may results in contents sharing between different browsers for aggregated results across multiple AR browsers.

Conclusion and Recommendations: Mobile Augmented Reality browsers are specialized interfaces for exploring augmented spaces. Indoor and outdoor realism has achieved an enriched way either by using Maker or Marker-less approaches. Point of interest acts as a container for holding augmented annotation in the form of text, images, audio, video and 3D models. This information has overlaid on places of interests or objects. Currently, commercially available AR browsers have organized information in the form of Layar, World and Channel. Argon AR browser taking an edge over others due to the use of existing web technologies like HTML5, CSS3 and java script. The web enabled interfaces for AR spaces need to be integrated with existing web and mobile browsers. After a comprehensive review the following recommendations are highlighted which need an immediate attention of the research community and industry people.

i. Major driving force for development AR browsers should support cross platform and operating system compatibility, AR browsers should behave the same experience across number of operating system and platforms.
ii. Point of interest could be made more enriched with embedding semantic web techniques to reduce the cognitive overload on the AR users.
iii. AR browsers should utilize the potential of Linked Open Data for integrating LOD entry points to augmented reality objects. Potential of 3D world dataset like Open Street Map and Google Earth could be utilized for enriched 3D presentation on Smartphones.
iv. Seamless integration of textual, audio, video and 3D contents would be an essential development in future browsers. Supporting faceted search in points of interest and responsive visualization will be an added feature.

v. Extended augmented browsers plug-ins should be design based on rich, seamless and adoptive manner, which would communicate in seamless fashion with existing mobile and web browsers. Existing mobile clients may act as augmented client without the use of specific browser for in-door or outdoor AR realism.

vi. Augmented tag cloud may serve as a new dimension in augmented realty system. The concept of reality cloud for POI can be introduced in centralized Augmented Reality cloud, that would facilitates users in accessing objects and point of interests from centralized repository, thus resulting minimal cognitive overload on the end users.

vii. Semantically enriched AR architecture should be designed for effective research, and reasoning augmented contents. Potential of semantic web technology could be utilized for information inferring and association of metadata with point of interests.

viii. Extensive standards/protocols should be developed for interoperability of data sharing across various AR browsers. Interoperability between devices and contents are the future dream, communicating with autonomous agents and browsing information integration which would be beneficial for consolidating POIs via unified interface.

ix. Protection mechanism for user's personal information and private data should be developed; privacy be enhanced for AR users

x. All AR browsers should provide a uniform format for content sharing and reuse. There is a need for establishing a common data structure/format for uniform content sharing and reuse.

Augmented reality is all about augmenting the real environments with visual contents, it is all about the augmented peoples skills of how they want to see and feel it. This study will provide help and guidelines to the researchers who are looking for next generations of perception of reality on their handheld devices.

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