A Useful Visualization Technique: A Literature Review for Augmented Reality and its Application, limitation & future direction

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Abstract. Augmented reality (AR), a useful visualization technique, is reviewed based literatures. The AR research methods and applications are surveyed since AR was first developed over forty years ago. Recent and future AR researches are proposed which could help researchers of decide which topics should be developed when they are beginning their own researches in the field.

1 Introduction

Augmented reality (AR), a useful visualization technique, is a field of computer research which deal with the combination of real-world and computer-generated data (virtual reality) [129]. Basically AR is that the virtual images made by computer are merged with the real view to create the augmented display [171]. The basic idea of AR is to mix reality with virtual reality. In general not only virtual reality but also more information data such as graphics, audio, senses, touch, smell and taste which are superimposed over a real world environment to produce an AR environment. AR can make the user to interact with the virtual images. Typically computer generated graphics are overlaid into the user's field-of-view to provide extra information about their surroundings, or to provide visual guidance for the completion of a task [170]. AR is an advanced visualization technology. Therefore, as a useful visualization technique it is possible that AR technology can be used in many domains such as engineering, medical, robot, military, mobile, traveling, education, entertainment and so on. The AR technology was developed in [130]. The first Videoplace allows users to interact with virtual objects [131]. Since then AR has become an important research direction which combine computer vision, computer graphics and image processing. More and more research papers are published in some international conferences and journals. The first International Workshop on AR (IWAR'98) in San Francisco, October 1998. The first International Symposium on Mixed Reality (ISMR'99), Yokohama, Japan, March 1999. The first International Symposium on AR (ISAR 2000), Munich, Oct. 2000. The first International Symposium on Mixed

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and AR (ISMAR 2002), Darmstadt, Oct. 2002. The AR world is coming closer and industry will increase awareness. The first Workshop on Computer Aided Medical Procedures & AR (AMIARCS 2004), held in Rennes, France, Sept. 2004. AR was introduced in [177-181]. Some related AR surveys and reviews can be found in [182, 5, 114, 25, 86, 128].

2008 was a great year for AR. This emerging technology is on a 15-plus-year-long journey from the lab and into the mainstream. With too many events to list, 2008 marks an important year in that quest.

Some important AR research results have been developed in 2008 [132]: the year started with the largest consumer electronics show (CES); video game gurus recognize AR as the future of gaming; high end mobile AR devices hit the market; native mobile tracking engines released; the AR market picked up steam in 2008 with high visibility deals such as Total Immersions products.

Approaches and applications of AR are described in Section 2. The limitation and future research of AR is discussed in Section 3. Finally a conclusion is given in Section 4.

2 Approach and method of AR

AR is the research field in which the computer-generated data are overlay on the real world. Basically, the virtual objects is involved in a real environment. Typically the graphics made by computer are overlaid on into the users field-of-view to provide extra information about their surroundings, or to provide visual guidance for the completion of a task [170]. Therefore, the computer graphics, computer vision and image processing with regard to AR need to be approached. AR has been used on robotic navigation, mobile, computer assisted surgery, education, entertainment, gaming, advertisement, market shopping, tourism, military device, manufacturing, product assembly and repair, architecture etc. Many subject researches with regard to AR have been developed. It is clear that these subjects concern of many researches such as computer graphics, computer vision, image processing, multiple view geometry and hardware and software development (interface, display and view device).

2.1 Visualization and AR

AR is a useful visualization technique to overlay computer graphics on the real world. AR can combine visualization method to apply to many applications [183]. A vision-based AR system was presented for visualization interaction in [200]. A device, GeoScope, was developed to support some applications such as city, landscape and architectural visualization in [201]. AR visualization for laparoscopic surgery was approached in [24, 27]. An integrated visualization system based AR was developed for surgical planning and guidance [33]. Robot visualising was described in [126]. Two examples of education AR visualization can be found in [282, 187].

Sales, advisement based AR

AR technique can be used in sales, advisement of market where customer could get a lot of product information and services. In 1996, an approach, agent AR, was proposed to support shopping and walking with navigational aids and information [189]. In 1999, augmented commerce based AR was described for shopping in a physical retail store [190]. E-commerce based AR was developed to provide shopping assistance and personalized advertising [191]. The design of an automated AR shopping assistance was approached in [192]. Another AR e-commerce assistance system was developed based on user-centered design principles to provide more direct information about products, and the study (called the future of shopping) found out that tomorrow's customer expects a lot of product information and numerous services at the point of sale based AR in [193]. MINI AR advisements were created by Germany agencies Buzzin Monkey and Die Agentour GmbH in 2008 [195]. Fantas virtual tennis was one of the first real examples to advertise their products based on MAR to give consumers some thing fun that they can play with [64] in 2009. World's first MAR Ad was made in 2009 [67]. The first instance of using AR technique in a consumer communication situation for car sale was shown in [194] in 2009.

Geovisualization based AR

Hardware and software were described for collaborative geographic data visualization using two interfaces based AR [197]. AR can be used for planning of military training in urban terrain [196]. How to demonstrate ecological barrier and show their locations in the landscape was discussed based on AR technology in [203]. An approach was proposed for realistic landscape visualisation based on integration of AR and GIS [204] where using AR to represent GIS-model-based landscape changes in an immersive environment. AR interface paradigms were addressed to provide enhanced location based services for urban navigation and way finding in [202]. A tangible augmented street map (TASM) based AR was developed in [198]. One system based MAR techniques was developed for building and presenting geographical information in [199]. An approach, smart point clouds in virtual globes, was proposed in 3D city modeling in 2009 [205].

Architecture and construction based AR

AR is a decision support way of in architecture and interior design. A system was presented for constructing collaborative design applications based on distributed AR in [210]. AR technique was developed to explore relationships between perceived architectural space and the structural systems in [211]. It was developed for using AR systems to improve methods for the construction, inspection, and renovation of architectural structures in [212]. An approach is using AR to visualize architecture designs in an outdoor environment in [213]. A prototype system was developed to use AR for an architectural application in facility management and maintenance [214]. In [215] calibration-free AR based affine representation was described for urban planning. It was approached for using a tangible interface and a projection-based AR tabletop interface to research urban simulation and the luminous planning table [216, 218]. A System based on AR with a tangible interface was demonstrated for city planning in [11]. AR user interaction techniques were developed to support the capture and creation of 3D geometry of large outdoor construction structures in [219]. A co-operative AR design system, A4D, for AEC (architectural, engineering and construction) was approached in [220]. It was presented that a system with human computer interaction, AR visualization and building simulation can interact with buildings [230, 221]. AR as tool was approached to be used in architecture, building performance visualization, retrieving information of building equipment and construction management in [229--232,228] respectively. In [222], one system based AR was designed to support complex design and planning decisions for architects. 3D animation of simulated construction operations based AR was investigated in [223]. The research spatially AR design environment can be used in urban design [224]. How to use AR technique to aid construction management was described in [225]. Using AR and GIS in architecture was discussed in [226]. Technologies and theories of using AR in architecture were described in [227].

Military training based AR
AR can be used to display the real battlefield scene and augment it with annotation information [206]. Some HMD's were researched and built by company Liteye for military usage [208]. In [173] hybrid optical and inertial tracker that used miniature MEMS (micro electro-mechanical systems) sensors was developed for cockpit helmet tracking. In [196] it was described how to use AR technique for planning of military training in urban terrain. Using AR technique to display an animated terrain, which could be used for military intervention planning, was developed by company Arcane [207]. The helicopter night vision system was developed by Canada's Institute for Aerospace Research (NRC-IAR) using AR to expand the operational envelope of rotor craft and enhance pilots' ability to navigate in degraded visual conditions [209]. HMD was developed to a display that can be coupled with a portable information system in military [185].

2.2 Mobile and AR

Development of mobile hardware and software have made mobile augmented reality (MAR) possible [5, 113, 114].

More MAR research is outdoor tracking with GPS (Global Positioning System), GSM (global system for mobile communications) and UMTS (universal mobile telecommunications system) [97, 77, 98, 100, 78, 84, 152, 82, 91, 115]. An ubiquitous tracking system was described where the gyroscope worn by a mobile user is automatically fused with an insideout marker tracking in [116]. Other mark tracking research and development for MAR were approached [90, 88, 85, 72, 119].

It was designed that MAR mark tracking was used in cultural heritage onsite guide [79, 96]. Optical tracking based mark with ARToolkit and video see through for MAR was approached in [111, 107] respectively. Human Pacman, a mobile entertainment system, was developed for MAR respectively in [117, 93].

Two approaches on MAR game were described in [95, 94]. It is potential that MAR systems can integrate virtual information with the real world to provide it to users for collaborative work. Some researches of collaborative interface and system of MAR were described in [99, 103, 89, 83, 275]. A design review of collaborative MAR can be found in [86].

A MAR system, the SitePack, based feature tracking techniques can help architects making decisions on site concerning visual impact assessment in [62]. Many MAR systems are developed with related to information filtering, industrial environments, writing complex AR applications maintenance of power-plants, geometrical model, virtual reality service, PDA (personal digital assistance), teleoperation system in unstructured environment, construction sentor, pervasive computing environments and industrial maintenance applications [101, 104, 109, 102, 76, 92, 108, 70, 68, 71, 110, 120, 121].

Some MAR research and development are further made. An MAR, Zenitum, was developed not only to detect certain features in incoming video but also to build 3D maps based on a depth perception algorithm engine [69].

Simplified Spatial Target Tracker (SSTT) is a computer vision based tracking library for AMR applications which runs at approx. 1-5fps with tracking and 15fps without on this Samsung Omnia phone [65]. A MAR game, Kweekies, by Int13 can be used in iPhone, Windows Mobile and Smartphones [66].

3D model is overlaid in the mobile phone's display, and user can interactively change the perspective to see them from different angles. The 2D tracking allows the mobile to display photographs from different rooms [72].

Some techniques of MAR were developed in company Zenitum [63]. The first true AR application running on the iPhone was reported based ARToolKit v4.4 in [106].

2.3 Medical applications and AR

AR method can be used in wind range of the medical applications deal with image guided surgery, pre-operative imaging training and education because AR can provide the surgeon with the necessary view of the internal anatomy. Video see-through systems, head-mounted display or Helmet mounted display (HMD) can make precise and reliable augmentation of video.

Surgeries are a prime example of using AR. For example, surgeries can be performed based on pre-gathered information, volume rendered images of physical implants, tumors, the procedure and state of the patient, which is imposed over the view of the subject. The surgeon can take full advantage of x-rays and other knowledge about the patient on the spot in this way. AR application in the operating room was described in [163]. Automated registration methods for frameless stereotaxy, image guided surgery, and AR visualization are approached in [164]. AR visualization in a surgical environment was described in [165]. Evaluating and validating an automated registration system in surgery was discussed in [166]. AR was used in some medical surgeries such as radio frequency ablation [36, 21], laparoscopic liver resection [32, 13, 38, 9, 23], cardiac surgery and needle biopsy [39, 12, 37]. Research in these areas focuses primarily on tracking and registration quality as well as specific visualizations in support of the medical procedure. An AR application for minimally invasive surgery is described in [52].

Rendering, registration and occlusion of AR are important in medical application. A volumetric rendered ultrasound image of the fetus overlaid on the abdomen of the pregnant woman can be viewed with an optical see-through display [167]. Object registration can be used to superimpose registered images onto a video image of a patient's body [168]. A framework for fusing stereo images with volumetric medical images was developed in [169]. A method to perform registration in markerless AR systems was approached using MRI data sets to build up the 3D model for the medical case [40]. In [41] occlusion handling for medical AR was researched using volumetric phantom model. An AR environment was developed which consists of hardware and software system to provide 3D visualization and support direct 3D user intervention for medical application [28].

Tracking methods for medical AR are critical research topics. Three tracking methods were discussed for medical AR with using infrared camera, precise robot arm and camera calibration processing based pattern recognition [42]. Deformation of 3D lung models was described for AR based medical visualization [57, 58]. A hybrid tracking scheme is developed for medical AR based on a certified medical tracking system [43]. In [60] AR was used for minimally invasive therapy. Realtime organ tracking was approached for endoscopic AR visualization using miniature wireless magnetic tracker [44].

AR method provided a useful tool for medical guidance, training, education, procedure and workflow. AR was approached in computer aided liver surgery planning [31]. It was introduced that the results of a randomized, controlled trial to compare the accuracy of standard ultrasound-guided needle biopsy to biopsies performed using a 3D AR guidance system [45]. An interface based AR was developed for a puncture guidance system on an abdominal phantom [48]. An AR system of guiding radio-frequency tumor ablation is described in [36]. In [59] an AR system was approached for therapy guidance. A system for microscope assisted guided interventions was developed to provide stereo AR navigation for ENT (ear, nose and throat) and neurosurgery [47]. Some computer aided surgery planning based AR was approached in [31, 34]. AR for computer-aided medical procedures was researched in [56]. AR in surgical procedures is presented in [51]. Integrated medical workflow based AR was discussed in [49, 50]. AR was used in a laparoscopic simulation system for laparoscopic skills training [55]. AR delivery simulator for medical training was presented in [46]. An AR training kit was developed to offer novel teaching solution for future cardiac surgery and other medical professionals [53]. AR was used to improve training for keyhole surgery [54].

AR was used in modeling 3-D lung dynamics as a planning tool in [268]. AR is described how to understand anatomical relationships to a patient or coworker and learn the interior of the Human Body in [299, 30] respectively.

2.4 Industry and AR

Many researches with AR are approached in industries. Industry and medical AR based real-time was described in [26]. Robot AR approach in design was reviewed in [184]. One AR application was presented for tracking of industrial objects in [269].

One method was addressed to use AR technique for perform real-time flexible augmentation on cloth in [276].

Robotics based AR

AR is an ideal platform for human-robot collaboration [184]. Medical robotics and image guided surgery based AR was discussed in [29, 236, 241]. Predictive displays for telerobotics were designed based on AR [123]. Remote manipulation of using AR for robot was researched in [124, 125]. Robots can present complex information by using AR technique for communicating information to humans [233]. AR technique was described for robot development and experimentation in [234]. In [235] it was researched to combine AR technique with surgical robot system for head-surgery. An AR approach was proposed to visualizing robot input, output and state information [126]. Using AR tools for the teleoperation of robotic systems was described in [239]. It was developed how to improve robotic operator performance using AR in [240]. It was explored for AR technique to improve immersive robot programming in unknown environments in [238]. Robot gaming and learning based AR were approached in [237].

3D AR display during robot assisted laparoscopic partial nephrectomy (LPN) was studied in [246]. It was researched to use markerless AR techniques in the visualization of robotic helicopter related tasks [244] and robots in unprepared environments [243] respectively. AR technique can be used in the operation of robot, which was developed in the company, KUKA Roboter GmbH [245]. A vision system with AR was proposed to used in network based mobile robot [242].

An interface with AR support was designed for the simulation and teleoperation of a robotic arm in [247]. Using AR environment to improve intuitive robot programming was discussed in [248]. The Matrix method (also known as "CyberCode") is a new technique for AR that identifies real world objects and estimates their coordinate systems simultaneously [186].

Design, maintenance and training based AR

AR can be used for design, maintenance and training in some areas such as industries. It was presented to use AR techniques for guiding maintenance of complex mechanical elements in [251]. It was reported that a mobile device offers a multimodal user interface which can synchronize a 3D AR view with a location-sensitive 3D speech-driven interface for industrial maintenance [254]. Nuclear power plant maintenance work based AR was studied in [270, 272]. Aviation maintenance and construction training was approached based on AR support in [264, 266] respectively.

Industry task analysis, planning and training based AR was discussed in [122]. Using AR system for training and assisting in maintaining equipment was presented in [252]. Using an AR system to make additional information into the view of a user for training and assisting in maintaining equipment was presented in [253, 256, 261]. A distributed medical training prototype with AR system was designed to train medical practitioners' hand-eye coordination when performing endotracheal intubations (ETI) in [255].

Interactive tools were approached for evaluating assembly sequences and guidance based AR technique in [249, 263, 274] respectively. Product design, design process tool, assembly feature and architectural design with related to AR were approached in [10, 265, 262, 267, 273] respectively. 3D reconstruction system for modeling urban scenes was presented in [271]. Using AR for improving the efficiency of mechanical design was explored in [257]. VR/AR-supported simulation of manufacturing system was approached in [259]. AR interfaces were developed in waste water treatment work with personal digital assistant (PDA) in [250]. Ten AR projects from automotive and aerospace industry (space station filter change, engine maintenance, tram diagnosis, airplane cabin design, collaborative design review, cockpit layout, fuse placement, picking, wiring and driver safety training) were introduced in [258]. Boeing used AR for wire harness assembly, space flight, decision support, and technical communication [260].

2.5 Edutainment and AR

Education and training based AR How to use AR in education, training, game and tourism is reviewed in this section. Some medical, industry and military education and training based AR are reviewed in the above related sections respectively. One system AR based was presented to be served as an interactive virtual laboratory in educational processes [283].

Mathematics and geometry education with AR technique was approached in [282, 284-288, 328, 291] respectively. Using AR technique to study in chemistry education was researched in [290, 294, 295, 302] respectively. Physical Experiments and teaching with AR were presented in [297, 298] respectively. Remote Experimentation of using AR technology was designed in [277].

AR technique was developed to help students to study geography in [281]. AR technologies can be applied to higher education such as engineering by using engineering multimedia contents with authoring AR tools[292]. An interactive multimedia AR interface for E-Learning was presented in [280]. A support on the remote interaction was approached for utilization in AR systems based on ARToolkit in [296].

MagicBook, an AR interface, was approached to be used in some areas such as book reading of education [278]. The future classroom was described to enhance education with AR technique in [279]. AR system, a visualization tool, was used for computer-aided design (CAD) classes [187]. In one book [300] mobile educational games was described for mobile learning's design, development, and implementation in recent years based AR technology.

A literature review was presented to investigate for training spatial ability with AR technologies in a wide range of studies [289]. It was discussed for AR technology to influence pupils knowledge about human digestive system in [301].

Game based AR

The computer games with AR technologies are not only used for amusement but also used for various fields such as education, tourism and medical treatment. ARQuake, an AR game, was developed to be used for outdoor/indoor mobile AR application in

[78]. Human Pacman, an interactive role-playing game, was developed using AR techniques in [117]. Neon Racer, a multi-user AR racing game which includes the physical reality as part of the game, was developed in [320].

A mathematical education game was developed using AR technology in [328]. Virtools system (www.virtools.com), a 3D Authoring System, was extended to develop an AR game [322]. A location-aware AR game was designed to help fire emergency response students learn embodied team coordination skills in [323]. Battleship, an interactive AR game, was approached in [324]. Ghost Hunter, a handheld AR game system with dynamic environment, was developed in [325]. An AR racing game was created using an AR infrastructure with a game development platform in [327]. In [326] AR in computer games was introduced: computer games using AR components; a game, ARQuake. The techniques of games and technological challenges of AR games were discussed in [317, 329, 78, 319] respectively. An adaptive approach was introduced for augmenting the players satisfaction of a AR games in real-time in [330, 331]. The feasibility of handheld AR games was demonstrated by using marker-based embodied interaction in [321]. The useful tools, MAR (mobile AR) Toolkit components, were presented for building mobile AR games in [318]. AR was approached to enhance the player's gaming experience in mobile in 2009 [61]. ARf, an AR virtual pet on the iPhone has been developed in 2009 [106].

Tourism based AR

The ARCHEOGUIDE, a project AR based cultural heritage on-site guide, was described to provide cultural-heritage sites with archaeological information to visitors [217]. An interactive visualization system based AR technologies was developed to enhance cultural tourism experiences in [309]. AR technique was investigated for historical tourism on mobile devices in [315].

One design, Augmented City, with information sharing and filtering was proposed for tourist guide based on AR technology in [305]. The design of AR interfaces was approached for guided tours (visiting cultural heritage places) using multimedia sketches in [307]. An accessible and collaborative platform was provided for tourist guide based on AR technology and mobile devices in [313]. AR technologies were used to enhance tourists's knowledge exploration experience, exhibitions, mobile multimedia museum guide and viewing in museum in [303, 306, 311, 312] respectively.

In thesis [308] AR technology was described to be used in museum tour in detail. AR techniques were used for museum wandering by recognizing markers with CCD camera in [310].

A tour system with 3D AR technique and mobile computing was developed in [304]. Augmented museum tour system was approached for museum wandering by using AR techniques in [314].

2.6 The Tracking techniques and AR

The most mature AR research development is focusing on tracking the position and motions of the user in virtual reality systems. The primary AR tracking technologies are sensor-based, vision-based, and hybrid tracking techniques [128]. Position tracking is needed in virtual reality to instruct the graphics system to render a view of the world from the user's new position. The type of display used by the AR system will determine the accuracy needed for registration of the real and virtual images. In addition, measurement delays have been found in the 40 to 100 msec range for typical position sensors [137]. AR researchers are looking at hybrid techniques for tracking [135, 136].

The real-time system was development has developed in [172] and it is marker-less model-based real time 3D visual tracking system. The similar work has done in [138, 139] and improved in [140, 141, 15]. The tracking system has further improved in [142--144]. The visual tracking need emerge visual serving which has approached in [145], and the work applied to AR systems in [146--148]. Camera pose computation and estimation vision-based AR tracking systems were studied in [18, 16, 17, 14, 149]. The model-based tracking was demonstrated in [150-152, 155, 156] where features such as points, lines, edges or textures are used. A hybrid visual tracking system was presented in [133], which is based on a computer-aided design (CAD) model of edge and a serving system. A marker-less camera tracking approach and user interaction methodology for AR on unprepared tabletop environments was done in [21], and in which distinctive image features of the scene are detected and tracked frame-to-frame by computing optical flow. A natural feature-based 3D object tracking method was described in [153] for wearable AR. The pose tracking from natural feature is demonstrated in [118]. Robust 2D tracking for real-time AR is a vision-based corner tracker [20]. A vision and inertial pose estimation system was used for real-time hand-held AR [154]. Fiducial tracking and visual marker based tracking were approached in [19, 2, 3] respectively. Outdoor/Indoor tracking is described in [78, 84, 4]. Some video motion tracking approaches can be found in [157--162]. A marker-less tracking technique with the windows (mobile pocket PC platform) allows the development of standalone AR applications for handheld devices based on natural feature tracking [22].

2.7 Hardware, toolkit and AR

Hardware and toolkit development of AR is important. Some user interfaces were developed in [6--8, 48]. Exploring MARS, indoor and outdoor user interfaces to a MAR was developed in [75]. An autonomous mobile platform was designed based on AR in [127].

AR through wearable computing was described in [74]. One AR device, NaviCam, a magnifying glass was approached in [73]. The fundamental communication and navigation platform based AR was described in [80, 81] respectively. Volumetric medical intervention aiding AR device was designed in [28]. AR testbed, feature and HMD systems were designed and developed at Siemens Corporate Research in [174--176], which can allow the physician to see CT, MR or Ultrasound images overlaid on patient during operation. A review of display hardware with medical AR can be found in [25].

It was described that a platform based on field programmable gate array was to help developers on the construction of embedded AR applications [1]. An open source software toolkit was developed based AR for image-guided surgery [33]. An AR toolkit for designers was developed in [35]. ARToolKit, one useful open source AR toolkit, was introduced in [293]. The distributed wearable AR framework (DWARF) was developed in [105]. Field programmable gate array (FPGA) device based AR was developed for image processing of visually impaired people [188].

3 Limitation and future directions of AR

Despite the considerable advances made in each of these areas, there are still limitations with the technology that needs to be overcome. AR system has to deal with vast amount of information in reality. Therefore the hardware used should be small, light, and easily portable and fast enough to display graphics. Also the battery life used by these complicated AR devices is another limitation for AR's uses. Also, AR tracking needs some system hardware such as GPS to provide accurate marker, ask them to be both accurate and reliable enough. These hardware obstacles need to be resolved for practical AR use.

AR systems usually obtain a lot of information, and need software to filter the information, retain useful information, discard useless data and display it in a convenient way.

Several possible future directions are speculated for further research. Many HMDs created specifically with AR in mind need to be developed. HMDs are still too clumsy and have limited field of vision, contrast and resolution. HMDs and other wearable equipments, such as data-gloves and data-suits, is a limitation for the user. All wearable equipments need be developed to be lighter, smaller and easier to work with the user. Also the AR system researchers need consider other challenges such as response time delays, hardware or software failures from AR systems.

One limitation of AR systems is registration error. Occlusion detection is an active area of study of AR systems. Analyzing various tracking methods, possible tracking research directions are identified that allow researchers to effectively capitalize on knowledge in video frames, or integrate vision-based methods with other sensors in a novel way.

It is important to incorporate a recognition system to acquire a reference representation of the real world. Further research on this direction could provide promising results, but it is mostly a top-down process and hard to deal with object dynamics, and evaluation of different hypotheses. The challenge is to construct a pervasive middle ware to support the AR system.

4 Conclusion

This paper has reviewed the development in AR research which related to tracking, medical, mobile, visualization, edutainment, industry and hardware. Other related research areas such as computer vision, image processing, computer graphics and multiple view geometry are also included in these researches. Currently, to bring AR research from laboratories to industry and widespread use is still challenging, but both academia and industry believe that there is huge potential for AR technology in a wide range of areas. Fortunately, more researchers are paying attention to these areas, and it is becoming easier than ever before to be involved in AR research.

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