A REVIEW ON ILLUMINATION TECHNIQUES IN AUGMENTED REALITY

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Abstract : **Augmented reality is a widespread concept having application ranging from medicine to entertainment and education. AR faces many challenges like camera tracking, occlusion handling and inconsistent illumination. Real time illumination of virtual objects in dynamic environment is still a challenging task. Various methods have been proposed for real time rendering of virtual objects in real environment .The illumination techniques range over a number of different methods producing results of varied accuracy. In this paper we will discuss about the various illumination methods in augmented reality, the shortcomings and advantages of different technologies and the classification of different methods. The paper discusses about the problem the current techniques are facing and various scope of improvement in future. The classification suggests the applicability of different techniques in different scenarios and also best utilization of data available with better techniques.**

Keywords
Augmented Reality (AR), Illumination, HDR
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1. INTRODUCTION

Augmented reality effectively combines real and virtual objects. It provides a seamless integration of virtual objects in the real scene. But still there a number of issues that need to be considered for an effective and realistic output of an augmented reality application.
Augmented reality still remains a challenge in the research area [2].In order to achieve seamless rendering in AR, Three different aspects are considered [4].

1. Geometry consistency
2. Illumination consistency
3. Time consistency

Geometry consistency refers to correct positioning of virtual objects in the real scene. This problem has been mainly solved by the use of markers and interest point based approach. Time consistency in turn refers to correct synchronization between real and virtual objects. Illumination consistency refers to correct illumination Correspondence between real and virtual objects. Real time illumination of virtual objects in dynamic environment is still a challenging task. Various methods have been proposed for real time rendering of virtual objects in real environment .In this paper we focus on various illumination techniques to give an overview and classification of various the developments in area of consistent illumination in AR applications.
The rest of the paper is organized as follows. In section 2 we give a brief introduction of augmented reality. In section 3 we describe about illumination in augmented reality. Section 4 gives a review of various illumination techniques in augmented reality and the classification of these various techniques

1.1 CONTRIBUTION TO WORK

Our contribution in this Research field aims in providing a clear view of the importance of illumination in augmented reality applications. The paper presents the classification of various illumination techniques according to different methods followed. The classification gives an overview of different techniques as well as their advantages and disadvantages. The drawbacks of some techniques are also discussed in detail. The detailed analysis of different trends in illumination estimation in present scenario is presented and work also provides an overview of some of the future trends that can be followed in illumination estimation in augmented reality.

2. AUGMENTED REALITY

AR is a concept of superimposing virtual objects in the real scene images. AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world [3]. The computer generated graphical images are integrated along with the real world objects with a realistic view. The 3D virtual objects appear realistic to the user as if they actually coexist in the real environment [1].It is a real time approach and requires a realistic blending of real and virtual objects. In the past years it has gained widespread popularity because of its various applications such as in industrial maintenance, Entertainment, medicine, education and games, Annotation and visualization, Robot path planning, military, aircraft [3].

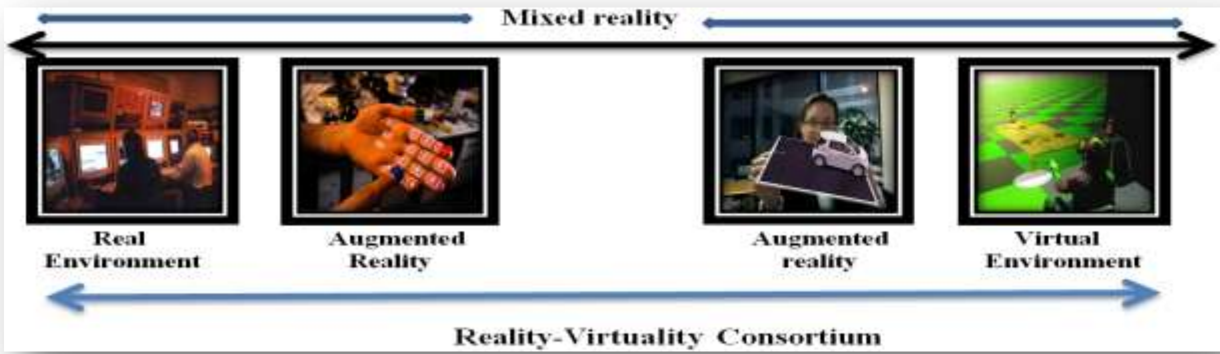

Fig 1. Miligram representation of Reality virtuality consurtuum

3. ILLUMINATION IN AUGMENTED REALITY

Three different illumination methods can be identified [5]:

1. Common illumination: local light incorporated in real and virtual world
2. relighting : changing the illumination
3. inverse illumination: estimating the light from existing images

There are many approaches used for illumination in augmented reality [5]

- omni -directional environment maps
- Use of equipment's like mirror ball/sphere in the scene
- Manually or semi-manually model the entire scene, including the light sources, and perform inverse rendering.

Some of the Challenges faced by illumination in augmented reality are Complex computations, inconsistent geometry of the real scenario, use of complex objects for camera calibration and dynamic changing environment. All these problems leads to inconsistent illumination and thus a challenging task provide seamless illumination in AR.

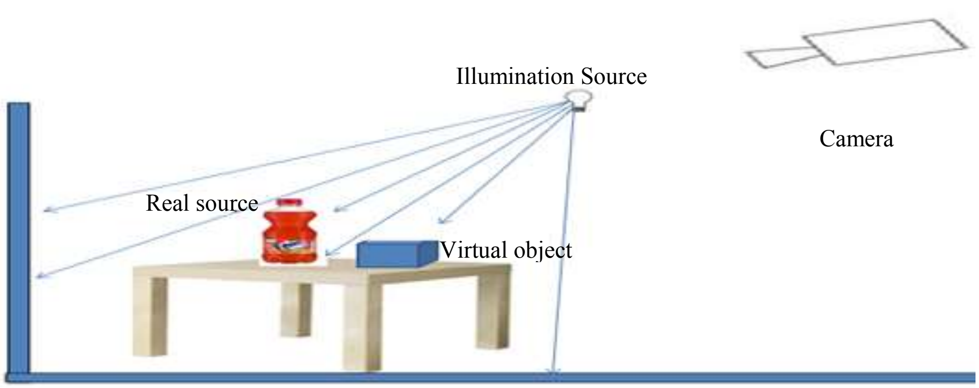

Figure 2. Showing the illumination in augmented reality

4. ILLUMINATION TECHNIQUES IN AUGMENTED REALITY

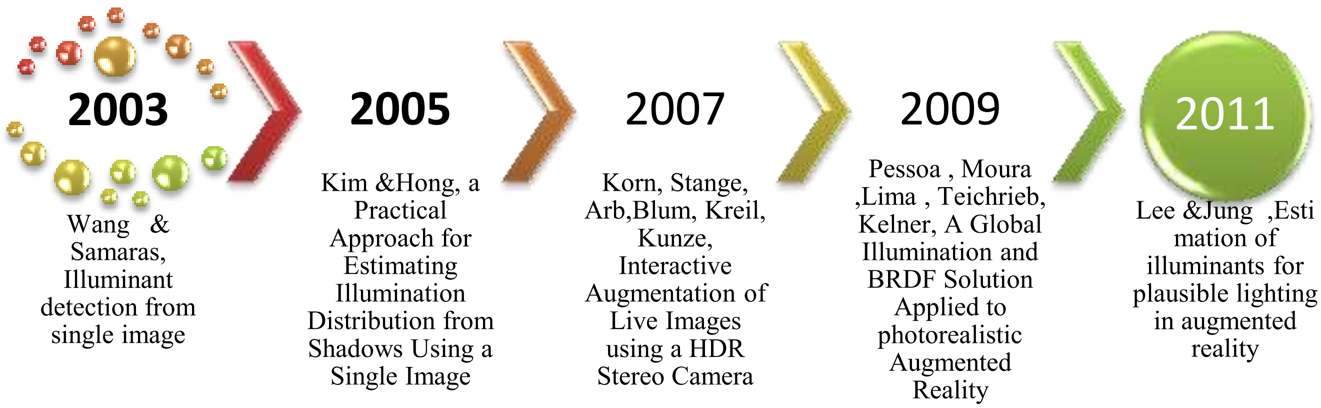

Figure 3: Showing the timeline of various research in illumination techniques in augmented reality

4.1BY USING SINGLE IMAGE WITH KNOWN GEOMETRY

K. Hara et al. [6] presents two methods for the light source position estimation using only a single image and knowledge about the 3D geometry of the scene. The author does not take into consideration the distance illumination assumption .Figure 4 presents the results of their proposed solution .Yang Wang et al. [7] Presents a method that uses critical points for detecting and estimation of multiple directional illuminants by using a single image of any object with known geometry and Lambertian reflectance. The method does not make use of a any pre-calibration object, The results produces a seamless augmented reality scene but has a higher computational complexity and therefore is not suitable for processing in real-time. Alexandros Panagopoulos et al.[8] proposes a similar approach for estimating illumination of real environment and cast shadows in scene with some prior knowledge of 3D geometry ,The paper describes a higher-order Markov Random Field (MRF) illumination model for illumination estimation. . Kenji Hara et al. **[9]** presents a technique removes the idea that light sources are placed at an infinite distance and estimating the illumination distribution of an object from a single view by using the real world image and the geometric model of object. Xue Mei et al. **[10]** present a solution for illumination recovery of an image with cast shadows, by the use sparse set of directional sources. The method proved to be very effective solution for directional light source estimation as compared to previous works. The result of the approach for illumination recovery is shown in Figure 5.

The prior methods require 3D geometry of the scene in advance for illumination estimation from a single image. However this leads to computational complexity. Therefore some methods were introduced for illumination estimation in augmented reality without the 3D geometric knowledge.

Xiaowu Chen et al. **[11]** introduce an approach for illuminating virtual object using a single image is presented. The proposed technique does not require any prior knowledge of the 3D geometry and reflectance. In order to represent illumination of the scene, a sparse radiance map based simple illumination model is used.

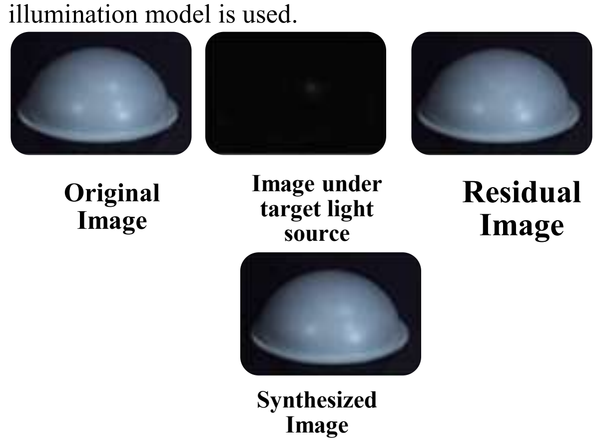

Figure 4: Result by Hara et al. [6] Showing the real and synthesized image after illumination detection.

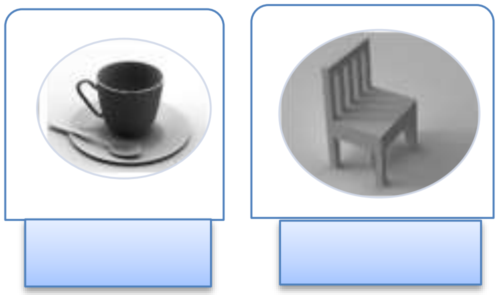

Figure 5: Showing the results of Illumination recovery by Xue Mei et al. [10]

4.2 BY USING HDR IMAGES

Saulo A. Pessoa et al. [12] presents a Technique that produces environment maps with different levels of brightness for every virtual object in the scene. The generated scenes provides satisfactory visual aspects. The method produces seamless illumination of virtual objects with respect to dynamically changing surroundings and also supports functionalities such as shadowing and lens effects. Figure 6 depicts the results of the proposed method. Kusuma Agusanto et al. **[13]** presents an image-based and hardware-based approach to improve photorealism for rendering synthetic objects in augmented reality. The method takes HDR images of a spherical object .It uses image-based lighting, environment illumination maps, and a multi-pass rendering framework for augmented reality, Such a method has high computational complexity and is not suitable for dynamically changing environment. The use of HDR images in order illuminate virtual objects was proposed by Jonas Unger et al. [14].The paper prefers use of HDR images instead of direct lightning to render virtual objects. Gibson S et al [15] makes use of HDR images along with prior geometry knowledge of objects to create an algorithm for rendering virtual objects. Przemys law et al[16] Presents a technique which uses HDR images which is captured by 2-camera system and a third camera is used to capture video of scene. Image based lighting is used for efficient lightning calculation of effective light sources .Figure 7 shows the results of the proposed technique. Peter Supan et al. [17] proposed a technique that uses Image Based Lighting and HDR images in real time for Augmented Reality applications. S. DiVerdi et al. [18] presents an approach which dynamically captures the illumination data of real environment for realistic rendering of virtual objects .use of HDR images improves the realism of the images captured. Giovanni Cagalaban et al. **[19]** In turn proposes an illumination projective technique for outdoor environment that is for dynamically changing environment for various AR applications. The research focuses on providing faster illumination in unprepared environment.

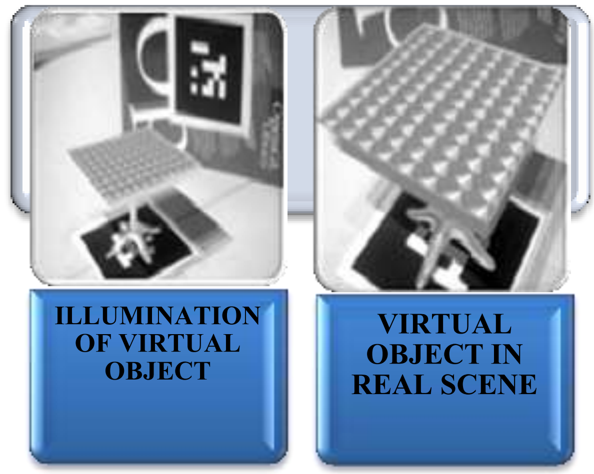

Figure 6: shows the result of [12] Saulo A. Pessoa et al. The result depict the photorealistic rendering of virtual objects into dynamic real scenes

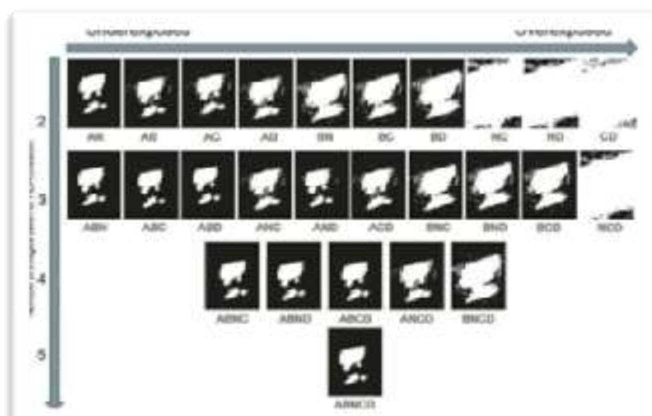

Figure 7: shows the results of experiments by Przemys law et al. [13] showing the HDR images with advanced lightning process conducted using three camera method.

4.3 SHADOW ANALYSIS

Taeone Kim et al. [20] presents a method for illumination estimation using the shadowss for textured surfaces. The geometry of object should be known in advance. The method requires regularization by correlation for illumination..In Yang Wang et al. [21] combines the two different methods to produce better illumination for rendering virtual objects. The methods combine the results obtained from both shadow and shading of an object..Imari Sato et al.**[22]** presents a method for estimating the illumination distribution of the real scenario from image brightness inside the shadows cast by an object. It presents a sampling framework for effective illumination estimation by using a smaller number of sampling directions. However the method does not take into consideration the distances from the occluding object to light sources. Werner Hartmann et al. [23]presents a shadow catcher approach that analysis light source positions estimation by the shadow casts on a sensor geometry. M. Binghamet al. **[24]** introduces a technique for illuminant detection using ***shadow /interest point*** method. Technique does not uses any devices such as mirror ball .Despite uses natural scene geometry which leads to low computational complexity but at the same time require prior knowledge of scene which makes it unsuitable for changing illumination. Yoshie Imai1et al.**[25]** proposed a method for estimating the illumination of scene of multiple light sources under adverse illumination environment. The system estimates the illumination spectrum of light source from high quality image data after detection of specular highlight area .In Ibrahim Arief,et al. [26] presents a new method for dynamically changing environment. The author uses analysis of shadow produced by a reference object that doubles as a 3D augmented reality marker. The technique is suitable for real time illumination direction estimation for mobile augmented reality systems, The method estimated the direction of single light source with good accuracy. The method at the same time does not require any hardware setup like spheres or light probes. There are several weaknesses in the current implementation of the method. The main problem is the need for a uniform surface and consistent shadow. The method also fails in case the light source lies behind the camera making shadow occluded behind camera. Also, the method takes into account a single illumination source. Figure 8 shows the results of light source estimation technique.

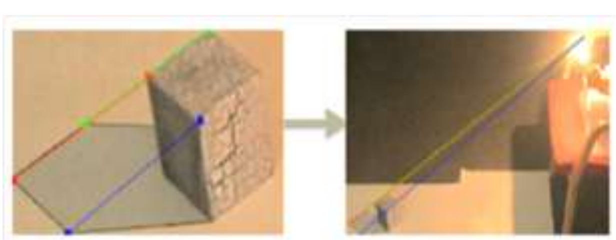

Figure 8: Depicts the results by Ibrahim Arief et al. [26] showing an augmented reality scene with light source estimation

There are few illumination estimation techniques which uses shadows cast on textured surfaces.
Y. Li et al. [27] determines illumination estimation for textured surfaces using information from shading, shadow and specular reflection. Alexandros Panagopoulos et al. **[28]** presents a graphical method for illumination estimation of textured surfaces with a rough 3D estimate. It is a model based on mixture of von Mises-Fisher distributions without requiring any detailed knowledge of geometry unlike in mostly other illumination estimation algorithms. The technique proved to be useful for illumination estimation of complex objects. Figure 9 represents the results of the approach followed.

Figure 9: shows in [28] by Alexandros Panagopoulos et al. result depicting the 3D model along with estimated illumination and shadows in same condition as of the original images

4.4 BY USING DIRECT LIGHTNING APPROACH / ILLUMINATION DETECTION USING FISH EYE CAMERAS AND OTHER VIDEO CAMERAS USING SAMPLING ALGORITHM

Matthias Korn et al. **[29]** presents a system that produces a consistent illumination for virtual objects .The cameras with fisheye lenses are used for recording environmental illuminants ,further a sampling algorithm is used to sample the light sources. The 3D position can then be calculated using epipolar geometry. More advanced sampling algorithm is required which considers complex and stable light sources. In Imari Sato et al.[30] a uses fisheye lens for illumination capturing for real environment .On the other hand, Vlastimil Havran et al.[31] shows real time rendering of illumination of virtual objects in augmented can be done with graphical hardware devices. Simon Gibson et al.[32] Created a framework for illuminating of virtual objects in real time. The system uses an HDR camera along with a fisheye lens for light source illumination estimation using a multipass algorithm. Jae Doug Yoo et al.**[33]** proposes a method for light source estimation in real time using fish eye lenses and ND filters to find out bright regions and use median cut algorithm for light source sampling. Figure 10 depicts the results of proposed technique. Jan-Michael Frahm et al.**[34]** presents a markerless 2-camera system to captures the video and track the light sources . The proposed methods removes the limitations of the systems that need markers for augmentation in the scene or require any additional hardware equipment in the scene to estimate illumination.

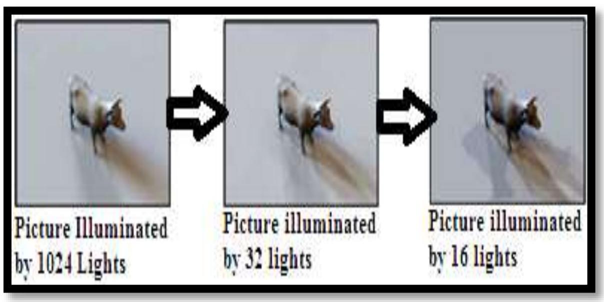

Figure 10 : The picture depicts the shadow quality of image under different light conditions by Jae Doug Yoo et al. [33]

4.5 BY USING A CALIBRATION OBJECT WITHOUT DISTANCE ILLUMINATION ASSUMPTION

Seokjun Lee et al.**[35]** introduces a technique that uses a mirror sphere which is placed on natural marker to estimate the light source position in the real scenario .Multiple images around the sphere is taken in order to find out the principal light direction for each light source which leads to achieve stability. The technique also takes into consideration the changes in moving illuminant and also develops real time shadows. The proposed method produces realistic AR image visualization in real time by estimating the static as well as dynamic illuminant condition without any prior knowledge of lightning conditions. The proposed method is not suitable for outdoor applications. W. Zhou et al.[36] proposes a framework for illumination estimation that can be applied to all types of light sources and uses a sphere as calibration object for scene illumination estimation. The results of the proposed framework are shown in Figure 11. Jin-Tao Ma et al. **[37]** Proposes a diffused spherical model approach to estimate the direction of illuminant regardless it is point light source or directional light source. The key process is finding and extracting the intensity on the sphere. The technique is efficient to accurately obtain light source direction. But at the same time the time complexity increases due to image processing step. The algorithm is also not suitable to detect multiple light sources.

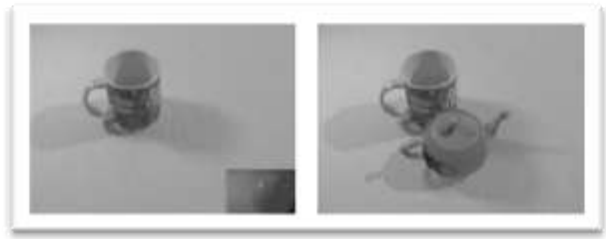

Figure 11: depicts the results showing augmented reality scene with virtual objects rendered in real scene in 2nd image in [36] by W. Zhou et al.

5. CONCLUSION & FUTURE WORK

Illumination in augmented reality is a complex task and faces a lot of challenges due to complex computations required for real time illumination estimation and difficulty in light source representation of dynamically changing real environment. There are few problems that illumination estimation faces in different methods. The problems such as complex light sources, moving objects or dynamically changing environment, unprepared environment, poor geometric information, surface texture. Most of the estimated techniques are independent of the type of light source either directional or point source. Multiple or arbitrary light source estimation for complex scenes was also possible. Estimation in dynamically changing environment without the use of light probes or prior knowledge of the 3D geometry was also possible. Illumination estimation in extreme weather condition was also possible. The estimated model is not so accurate in some cases and occlusion is also not properly handled. Future work can focus on estimating illumination of complex light source scene with arbitrary light sources and geometry with more accuracy. Use of better sampling algorithm for better light source sampling of an image and also complex algorithm for finding large and moving lights removing the assumption of point light sources. More global illumination models can be applied for better scene reconstruction in augmented reality.

	TIME COMPLEXITY	**INPUT REQUIREMENTS SUCH AS GEOMETRIC MODEL OF SCENE**	**NUMBER OF DIFFERENT IMAGES REQUIRED**	**METHOD ADOPTED**	**ADVANTAGES**	**DRAWBACKS**	**SECTION**
[7] Yang Wang et al.	High computational complexity	Requires a 3D model of scene	Uses only a single images	Use of single image for illumination detection	Produces a seamless augmented reality scene	Cannot be used for real Time Processing	4.1
[11] Xiaowu Chen et al.	Can be used for both indoor and outdoor images due to low computational complexity	Does not requires a 3D knowledge of scene	Use only a single image	Use of single image for illumination detection	Produces good results for both indoor and outdoor application having less complex illumination	The model does not produces effective results in case of images having complex	4.1
[13] Kusuma Agusanto et al.	High computational complexity	real lighting information is collected beforehand to improve the photorealistic	Use multiple images around a spherical object	Use of HDR images	The method is very simple and practical to implement for seamless photorealistic	The method is not suitable for dynamically changing environment	4.2
[15] Gibson S et al.	Real time rendering of virtual objects is possible	Requires A-prior knowledge of 3D model of scene	Use of multiple images	Use of HDR images	The method was able to produce realistic augmented reality images for different real	Unable to produce AR affect in case of directional and some other light sources .	4.2
[26] Ibrahim Arief et al.	It has a better computational complexity	Prior knowledge of 3D geometry is required	Single image is required	Shadow analysis	The method estimated the direction of single light source with good accuracy	The method requires a uniform surface along with shadow consistency.	4.3
[28] Alexandros Panagopoulos et al.	Real time AR rendering is possible	No detailed knowledge of geometry is required	Single image is required	Shadow analysis	Illumination estimation for complex objects is possible	Quality of results could be better if some other algorithm could have been used	4.3
[33] Jae Doug Yoo et al.	Real time light source estimation is possible	No prior knowledge is required	U se of multiple hemi-sphere images	light source estimation in real time using fish eye lenses and ND filters	The proposed method can be used for real time light source estimation	As the number of lights increases computation time increases	4.4
[35] Seokjun Lee et al.	Real time Visualization is possible	without any prior knowledge of lightning conditions.	Multiple images	Use of calibration object	The techniques takes into consideration dynamically changing environment	The does not support AR in outdoor applications.	4.5

Table representing the comparison of different techniques based on certain parameters [5]

REFERENCES

[1] Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., MacIntyre, B,"Recent Advances in Augmented Reality". In: IEEE Computer Graphics and Applications, vol. 25 no. 6, 2001, pp. 24-35.

[2] Bimber, O., Grundhoefer, A., Wetzstein, G., Knoedel, S,"Consistent illumination within optical see-through augmented environments". In: IEEE/ACM International Symposium on Mixed and Augmented Reality (ISMAR 2003), IEEE Computer Society (2003) 198–207

[3] Ronald T. Azuma Hughes Research Laboratories .In Presence: Teleoperators and Virtual Environments 6, 4 (August 1997), 355-385. A Survey of Augmented Reality

[4] Sato I, Sato Y and Ikeuchi K, "Acquiring a radiance distribution to superimpose virtual objects onto a real scene," IEEE Transactions on Visualization and Computer Graphics, 5(1), 1999, pp.1–12.

[5] K. Jacobs and C. LoscosClassification of Illumination Methods for Mixed Reality. In Proceedings Computer Graphics Forum, 2006

[6] K. Hara, K. Nishino, and K. Ikeuchi, "Determining reflectance and light position from a single image without distant illumination assumption," in Proc. IEEE Int. Conf. Comput. Vis., 2003, vol. 1, pp. 560–567

[7]Yang Wang and Dimitris Samaras ,"Estimation of Multiple Illuminants from a Single Image of Arbitrary Known Geometry". In ECCV '02 Proceedings of the 7th European Conference on Computer Vision-Part III, Springer-Verlag 2002

[8]Alexandros Panagopoulos, Chaohui Wang, Dimitris Samaras and Nikos Paragios," Illumination Estimation and Cast Shadow Detection through a Higher-order Graphical Model". In Computer Vision and Pattern Recognition (CVPR), 2011 IEEE

[9] Kenji Hara, Ko Nishino and Katsushi Ikeuchi,"Light Source Position and Reflectance Estimation from a Single View without the Distant Illumination Assumption".In IEEE Transactions on pattern analysis and machine Intelligence, Vol. 27, No. 4, April 2005

[10]Xue Mei, Haibin Ling, , and David W. Jacobs, "Illumination Recovery From Image With Cast Shadows Via Sparse Representation" .In IEEE Transactions On Image Processing, Vol. 20, No. 8, August 2011

[11] Xiaowu Chen, Ke Wang and Xin Jin ,"Single image based illumination estimation for lighting virtual object in real scene".In 12th International Conference on Computer-Aided Design and Computer Graphics, 2011.

[12]Saulo A. Pessoa ,Guilherme de S. Moura ,João Paulo S. M. Lima ,Veronica Teichrieb ,Judith Kelner, A Global Illumination and BRDF Solution Applied to photorealistic Augmented Reality In Virtual Reality Conference, 2009. VR 2009. IEEE

[13] Kusuma Agusanto, Li Li, Zhu Chuangui, Ng Wan Sing, "Photorealistic rendering for augmented reality using environment illumination ".In Proceedings of the Second IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR '03)

[14]Jonas Unger, Andreas Wenger, Tim Hawkins, Andrew Gardner, and Paul Debevec,"Capturing and rendering with incident light" . In Eurographics Symposium on Rendering: 14th Eurographics Workshop on Rendering., pages 141.149, June 2003

[15] Gibson S., Cook, J., Howard, T., and Hubbold, R., 2003,"Rapid shadow generation in real-world lighting Environments". In Proceedings: EuroGraphics Symposium on Rendering

[16] Przemys law, Wiktor Pardel and Konrad Wojciechowski."Three Cameras Method of Light Sources Extraction in Augmented Reality".In ICCVG 2010, Springer-Verlag Berlin Heidelberg 2010

[17]Peter Supan,Ines Stuppacher,Interactive Image Based Lighting in Augmented Reality, In: Digital Media. Upper Austria University of Applied Sciences, Hagenberg/Austria(2006)

[18] S. DiVerdi and T. H¨ollerer, "Combining dynamic physical and virtual illumination in augmented reality," Technical Report, University of California at Santa Barbara, Nov.2004.

[19] Giovanni Cagalaban, Seoksoo Kim."Projective Illumination Technique in Unprepared Environments for Augmented Reality Applications". In International Journal of Database Theory and Application Vol. 3, No. 3, September, 2010

[20] Taeone Kim, Ki-Sang Hong ."A Practical Approach for Estimating Illumination Distribution from Shadows Using a Single Image".In Wiley Periodicals, 2005

[21]Yang Wang and Dimitris Samaras ."Estimation of multiple directional light sources for synthesis of augmented reality images". In Elsevier Science , 2003.

[22] Imari Sato, Yoichi Sato and Katsushi Ikeuchi "Illumination from Shadows". In IEEE Transactions On Pattern Analysis and Machine Intelligence, Vol. 25, No. 3, March 2003

[23] Werner Hartmann, Jürgen Zauner, Michael Haller, Thomas Luckeneder, Wolfram Woess ."Shadow Catcher: A Vision Based Illumination Condition Sensor using AR Toolkit".In Augmented Reality Toolkit Workshop. IEEE International, 2003

[24]M. Bingham, D. Taylor, D. Gledhill, Z. Xu. "Illuminant Condition Matching in Augmented Reality: A Multi-Vision, Interest Point Based Approach".In Sixth International Conference on Computer Graphics, Imaging and Visualization, IEEE 2009

[25] Yoshie Imai1,, Yu Kato, Hideki Kadoi, Takahiko Horiuchi,and Shoji Tominaga1."Estimation of Multiple Illuminants Based on Specular Highlight Detection". ,In CCIW © Springer-Verlag Berlin Heidelberg 2011

[26]Ibrahim Arief, Simon McCallum, Jon Yngve Hardeberg.",Realtime Estimation of Illumination Direction for Augmented Reality on Mobile Devices".In 20th Color and Imaging Conference Final Program and Proceedings, Society for Imaging Science and Technology, 2012

[27]Y. Li, S. Lin, H. Lu, and H. Shum, "Multiple-Cue Illumination Estimation in Textured Scenes" .In Proc. IEEE Int'l Conf. Computer Vision, 2003.

[28] Alexandros Panagopoulos, Dimitris Samaras and Nikos Paragios ."Robust Shadow and Illumination Estimation Using a Mixture Model".In IEEE Conference on Computer Vision and Pattern Recognition, 2009.

[29] Matthias Korn, Maik Stange, Andreas von Arb, Lisa Blum, Michael Kreil, Kathrin-Jennifer Kunze."Interactive Augmentation of Live Images using a HDR Stereo Camera" In Journal of Virtual Reality and Broadcasting, Volume 4, 2007

[30] Imari Sato, Yoichi Sato, and Katsushi Ikeuchi, "Acquiring a Radiance Distribution to Superimpose Virtual Objects onto a Real Scene".In IEEE Trans. Vis. Comput. Graph. 5 ,1999.

[31] Vlastimil Havran, Miloslaw Smyk, Grzegorz Krawczyk, Karol Myszkowski, and Hans-Peter Seidel, "Importance Sampling for Video Environment Maps".In Eurographics Symposium on Rendering 2005,ACM Siggraph, 2005

[32] Simon Gibson, Jon Cook, Toby Howard, and Roger Hubbold, "Rapid Shadow Generation in Real-World Lighting Environments".In Proceedings of the 14th Eurographics Workshop on Rendering, Eurographics Association, 2003, ISBN 3905673037, pp. 219–229.

[33] Jae Doug Yoo and Kwan H. Lee, "Real Time Light Source Estimation Using a Fish-Eye Lens with ND Filters".In International Symposium on Ubiquitous Virtual Reality, © 2008 IEEE,ISUVR.2008.

[34] Jan-Michael Frahm, Kevin Kaeser, Daniel Grest and Reinhard Koch, " Markerless Augmented JReality with Light Source lEstimation for Direct llumination".In The 2nd IEE EuropeanConference, Visual Media Production, 2005

[35] Seokjun Lee ; Soon Ki Jung ,"Estimation of illuminants for plausible lighting in augmented reality". In Ubiquitous Virtual Reality (ISUVR), 2011

[36] W. Zhou and C. Kambhamettu. "A unified framework for scene illuminant estimation" . In Image and Vision Computing, 2008.

[37] Jin-Tao Ma, Ya Zhou, Qun Hao, Yang Zhang ,"Marker cube and probe sphere based illuminant detection algorithm".In International Symposium on Photoelectronic Detection and Imaging 2007.