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Techniques in Augmented Reality

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Abstract: ***This paper is a result of the literature survey in the field of Augmented Reality and helps in understanding the concept behind Augmented Reality. It includes the methodologies involved in the implementation of Augmented Reality. Marker-less and Digital Markerbased AR, being the two ways through which AR can be implemented, have been explained in detail in this paper. The detailed steps involved in the implementation of***
Marker-less AR – Edge Vectorization of Objects using CVSDF graphs, Detection of objects, Recognition of Variation of Objects, Calibration have been covered in detail. An image processing algorithm is used to detect visual code markers. Features of these fiducial markers and the process involved in detecting them have been explained in detail.
Keywords: Augmented Reality, Edge Vectorization, Object recognition, Fudicial markers.

I.INTRODUCTION

Augmented Reality (AR) is a general term for a collection of technologies used to blend computer generated information with the viewer's natural senses [1]. It is a technology that works on computer vision based recognition algorithms to augment sound, video, graphics and other sensor-based inputs on real-world objects using the device camera [2]. It is a good way to render real-world information and present it in an interactive way so that virtual elements become part of the real world. Hence, the user is aware and can still interact with his environment.

AR plays a huge role in enriching the content, increasing sales, improving notoriety, saving costs, reducing risks, etc. There are some factors which could slow down the mass adoption of augmented reality. Public Awareness and reach of Mobile AR [2], Technological Limitations, Addressing Privacy Issues, Mobile Internet Connectivity in Emerging Markets are few factors that will have to be overcome for AR to have a huge potential market.

Augmented Reality technology can be applied to all kind of fields and levels of knowledge [3]. Military and Law Enforcement, Vehicles, Medical, Trial Rooms, Tourism, Architecture, Assembly lines, Cinema
/Performance, Entertainment, Education, Art, Translation, Weather Forecasting, Television, Astronomy are some of the fields in which AR is splendidly used. Fig.1 represents the statistical data of a few fields in which AR application are commonly used [4].

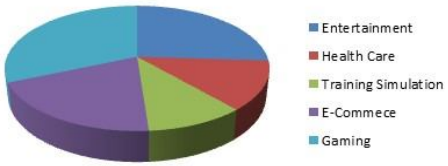


Fig.1 Applications of Augmented Reality [4]

The inputs of AR applications may range from sound to video, to graphics to GPS overlays like GPS, gyroscopes, accelerometers, compasses, RFID, wireless sensors, touch recognition, speech recognition, eye tracking, and peripherals. The output display of AR application may be a simple Monitor or systems such as optical projection systems, head-mounted displays, eyeglasses, contact lenses, the HUD (heads up display), virtual retinal displays, Eye-Tap (a device which changes the rays of light captured from the environment and substitutes them with computer generated ones), Spatial Augmented Reality (SAR – which uses ordinary projection techniques as a substitute for a display of any kind) and handheld displays.

Augmented Reality can be achieved using two approaches. They are

1) A marker-based [2] AR works on the concept of target recognition. The target can be 3D object, text, image, QR Code or human-face called markers. After detection of the target by AR engine, one can embed the virtual object on it and display it on their camera screen. An object can be recognized by extracting the 2D features from an image captured by a camera. If the shape or the physical structure of the image is known, the process is known as a model-based approach.
2) Marker-less AR, also known as location-based AR, uses GPS of mobile devices to record the device position and displays information relative to that location.

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II. RELATED WORK

[5] has focused on determining the feasibility of using a multi-touch table-top system for applied mathematics learning in primary education for students with special needs. The instructional content designed on the tabletop focuses on Augmented reality. [6] has proposed several augmented reality overlays for visual guidance in training for laparoscopic surgery using a 2D display, with the goal of aiding the user's perception of depth and space in that limiting environment. [7] is a research paper based on how Augmented Reality has been used to stimulate learning in Engineering Education through which it is revealed that introducing this technology has also a visible effect in reducing academic procrastination. Quantum spacetime travel with the implementation of augmented reality and artificial intelligence.[8] explains about four exemplary applications, "Virtual Stratigraphy", "the virtual Cathedral of Siena", "Arche Guide, a personalized AR-Guide" and the "AR-Telescope". This paper enables us to understand the concept behind augmenting information of the recognized objects. [9] aims at the concept of using Augmented Reality as a tool for facilitating the configuration process of a Time-ofFlight camera and evaluate if Augmented Reality enhances the understanding of the process. This paper gives us better clarity about object recognition and helps us in understanding the concept behind the region of interest through polar and Cartesian reduction. [10] focuses on object recognition and tracking approach for the mobile. It helps in the localization of 2D features that are extracted from images and are compared with known 3D models. [11] represents a framework for augmented reality applications that run on smart mobile phones and enables realistic physical behavior of the virtual objects in the real world. It also focuses on the reconstruction of the 3D representation of the real world. [12] helps us in understanding Edge Vectorization in an image and is based on the allocation of edges in the gradient transition using a threshold filter. [13] is based on the use of video see-through head-mounted displays. (VST-HMD) for augmented reality is the presence of latency between real-world images and the images displayed to the HMD. It corrects the registration of a moving object by using a Kalman filter to predict its forward trajectory. [15] presents a digital image processing algorithm which automatically locates the marker on a cell-phone camera captured image. With the exact location of the code marker, detailed bits information of the visual code marker is returned. [16] presents the architecture of an authoring tool for allowing non-experts creating realistic and interactive augmented reality (AR) experiences. The tool implements an approach for designing AR scenes that combine the use of AR model-based techniques with few possibilities that current game engines offer for the design and management of 3D virtual environments. [17] presents the design and implementation of a handheld Augmented Reality (AR) system called Mobile Augmented Reality Touring System. This experiment aims at studying how such a tool can transform the visitor's learning experience by comparing it to two widely used museum systems. [18] enhances the understanding of AR and conceptual uses & gratification framework on the uses of Augmented Reality Smart Glasses by proposing the role of existing and novel constructs to the stream of U&GT and AR research.

III. TECHNIQUES

A. Markerless Vision based Augmented Reality

In the marker-less object recognition [10], the captured images can be considered as the reference component of the tracker. At a given viewpoint, a set of reference images is selected. The user view, i.e., the current live video image is compared to all reference images and a correlation score is computed. The best score is retained and the 2D transformation between the video image and the reference image is evaluated. Considering that the reference images are calibrated, the current camera position and orientation are deducted. The object recognition process consists of two parts: 2D Vision [10] and 3D Vision [10]

1) *2D Vision:* It extracts 2D features of the objects to be searched [10]. The extracted and vectorized edges are matched with 2D views of the 3D object models. The pixel images are preprocessed using a Sobel Filter and a Non-Maxima Elimination and finally vectorized using an Edge detection algorithm.

[10] The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically, it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image

[10] Non-max suppression is a way to eliminate points that do not lie in important edges. If the gradient is close to zero degrees at a given point, that means the edge is to the north or to the south, and that point will be on the edge if the magnitude of the point is greater than both magnitudes of the points to its left and right.

The vectorized edges are virtually elongated and the intersections of the elongated edges are used as vertices of a 2D graph describing the edge structure of the input image called the 2D image graph. 2D views of the 3D model are used to identify

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potential locations of the objects to be searched. These 2D views consist of two types of edges they are Essential edges [11] and Optional edges [11].

Using graph-matching algorithms, potential locations of the 2D views inside the 2D image graph are evaluated. The constraints for the matching algorithm are the aspect ratios between the length of the edges and the angles between the edges. Fig.2 shows the four steps of 2D vision.

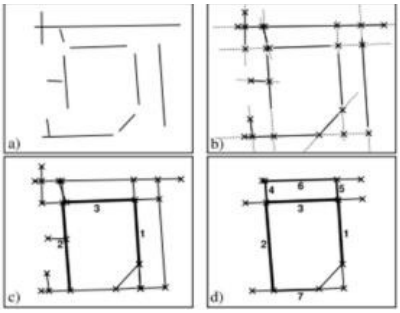


Fig.2 - Generation of 2D Graph [11]

Four steps of the 2D vision:

a) The vectorized edges

b) The virtually elongated edges

c) One match of the essential edges

d) One match of the 2D view including neighboring edges.

2) 3D Vision: In the 3D vision part, the 2D features are compared with CAD data, containing highly visible edges, faces and texture information [11]. With correspondences of image features and 3D-model features, hypotheses for the orientation of the model relative to the camera are generated. Each generated hypothesis will be verified by projecting the model into the image plane. This projection is compared with the extracted edge graph of the input image and the matching of both graphs is evaluated. The best matching hypothesis is taken to determine the recognized object, its Location, and orientation relative to the camera coordinate system. The main objective is the recognition of technical objects with many straight edges, edge correspondences are used to compute the orientation of these objects.

Fig.3 represents Edge parameters of the given 3D object. With three 3D–2D–edge-pairs it is possible to compute the relative orientation of the camera to the object, therefore, hypotheses consisting of three edge-pairs are used.

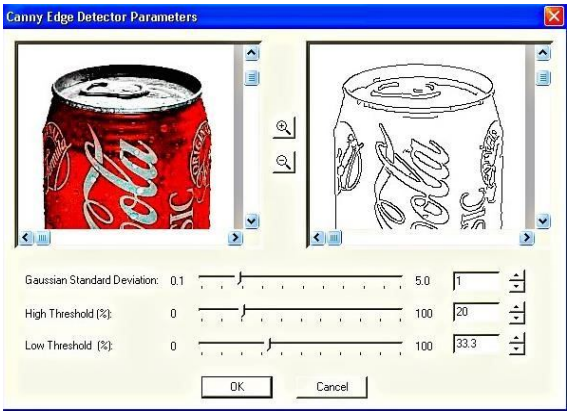


Fig.3 Edge Parameters of given object [11]

In object recognition systems, depth data provides otherwise absent geometric data, a potentially powerful tool for discrimination between objects [3]. Depth images contain local information about object geometry but also provide information on global geometry, object position, and object shape. Depth maps are also used for automatic object placement, based on detecting collisions between real and virtual objects.

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3) *Edge Vectorization of Objects:* The principle of object recognition in an image is based on the allocation of edges in the gradient transition using a threshold filter [12]. The edge vectorization is designed using CV-SDF model, computer vision extension to SDF (Synchronous Data Flow graph). They are also widely used in RTS applications with streaming data like audio compression and decompression.

a) SDF Graphs consists of nodes which contain the program code and edges between the nodes. Each edge is annotated with a number of tokens.

b) The CV-SDF model partitions image frames into slices of identical size. A slice may be one image line, 8x8 image blocks. These slices are the tokens (the data instances) which are transferred over the edges of the graph.

c) The nodes of CV-SDF graph contain computer vision operations in the form of functions.

If two modules, M0 and M1 represent input and output respectively Fig.4, the output edge of the module is annotated with the number of slices with each activation.



Fig.4 Representation of input and output of CV-SDF graph [12]

The input edge of the module is annotated with a triplet {consumed, slice interval, previous frame}. Fig.5 represents the CV-SDF Graph.[12]

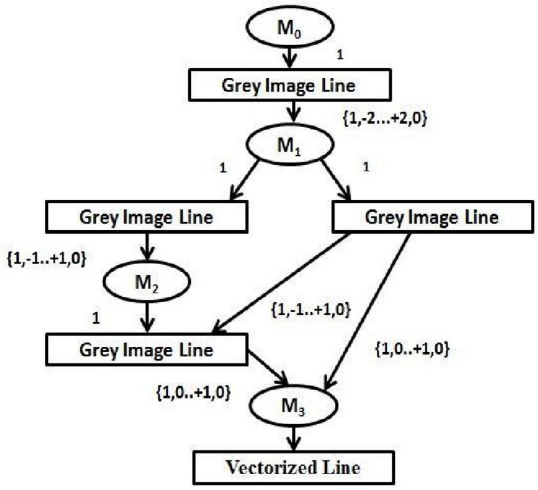


Fig.5 CV-SDF Graph [12]

All slice data types are line-based. That means each module consumes and produces slices which correspond to one line input image. There are three different slice data type:

i) *Grey Image Line:* This data type stores the lightness of the pixels of exactly one line of the image.

ii) *Gradient Line:* This data type stores the gradients of the pixel as a result of the Sobel filter [11]. It also stores the data for one image line.

iii) *Straight Edges Line:* The data type stores the number of StraightEdge Buffer-slots the pixels of exactly one line belong to.

Straight Edge can be represented in two possible ways:

a. Using Start and end points

b. Using Moments (representation of regions)

Since the algorithm works top-down and from left to right, the neighbor pixels which are not yet been processed have to be compared with the actual pixel.

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4) *Detection:* The original pixel matches with one or more of its neighbors if the orientation of the original pixel and the orientation of the neighbor pixel differs one step (Fig.6&7) [12] (in reference to quantization value 8).

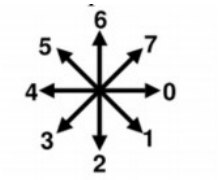


Fig.6 Quantization of Gradients [12]

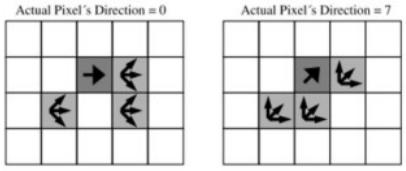


Fig.7 Example of a pixel neighborhood [12]

If two or more neighbors match the actual pixel, one of the following actions is performed.

a) If all pixels are not yet assigned, a StraightEdge is initialized with matching pixels.

b) If exactly one of the pixels has been assigned to a StraightEdge, all non-assigned pixels are added to that StraightEdge.

c) If two pixels are assigned to different StraightEdge, these StraightEdges are merged and all non-assigned matching pixels are added to that merged StraightEdge.

d) If two pixels are assigned to the same StraightEdge, all additional non-assigned matching pixels are added to the merged StraightEdge.

5) *Recognition of Variations of Objects:* For different objects with identical or similar geometry, it is difficult to recognize these objects only by using geometry features such as edges [13]. For recognition of variations of objects (e.g. models of the same brand), texture matching of regions of interest is used.

a) These regions of interest have to be separated and normalized first. Since the base model and its orientation in the image are known from the previous processing step of hypotheses generation, the location of the region of interest can be determined.

b) These regions are distorted by perspective projection in the image. So with the known extrinsic camera parameters, the regions are deskewed and normalized.

c) On the normalized regions, filter operations for comparing these regions with known models are applied. The histograms of all models are saved beforehand in a grayscale image.

d) The extracted histogram is compared by crosscorrelation with the reference histograms and the best matching correspondence identifies the model.

e) For measuring similarities between any two images, videos or any two temporal sequences, which may vary in speed, Dynamic Time Warping Algorithm [13] can be used.

f) It aims at aligning two sequences of feature vectors by warping the time axis iteratively until an optimal match (according to suitable metrics) between the two sequences is found. Fig.8 represents recognition and segmentation of objects.

g) The algorithm is head motion-independent, pixel-based, and can be run on any two consumer cameras.

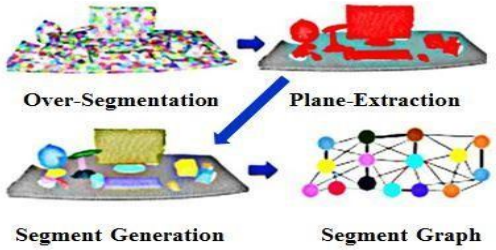


Fig.8 Recognition and Segmentation of variation of objects [12]

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6) *Calibration:* The calibration of devices and objects is an essential component of augmented reality. By utilizing computer vision algorithms [14], a user manually identifies known landmarks in a digital image of the object that has been grabbed through a calibrated camera. These point correspondences are used to calculate the rigid transformation that aligns the object and the model. But, this technique suffers from an excessive error in the direction perpendicular to the focal plane of the camera. Hence, an alternate technique is used in which a calibrated pointing device is used to locate the object landmarks in the world coordinate space. Correlating the two sets of points produces accurate transformations. An accurate calibration can be used to produce a variety of powerful visual effects.

B. Digital Marker Based Augmented Reality

Fiducial markers are visible objects placed in an imaging system (camera) as reference points or measuring units [15]. In AR, fiducial markers are used for positional tracking of HMDs and Input Devices. They can be utilized in both inside-out tracking and outside-in tracking. An image processing algorithm is used to detect visual code markers [15] and extract the embedded data. The algorithm uses an adaptive thresholding technique to produce a binary image with an accurate representation of each visual code marker from an input RGB image. It is highly reliable for 2D objects. Considering a visual code marker of a 2dimensional array, the array consists of 11x11 elements and each element is either black or white. As shown in the figure, the feature of the code marker is fixed with three of the cornerstones in black, one vertical guide bar (7 elements long) and one horizontal guide bar (5 elements long). The immediate neighbors of the corner elements and the guide bar elements are fixed to be white. This leaves us with 83 elements which can be either black or white. Fig.9 is an example of a code marker.

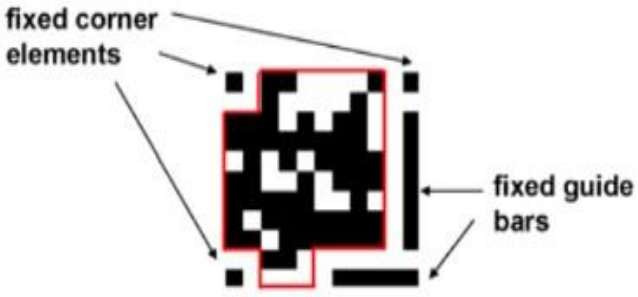


Fig.9 Sample visual code marker [15]

At first, the location of the code marker is found, and then the embedded bits information is extracted. Due to the limitations on the luminance and color from the camera phone, these images are of low resolution and subject to sometimes severe color distortions which result in difficulties in locating the visual marker on the image and extracting its embedded information.

Features of Digital Marker

1) *Maximum Contrast Level:* The marker is designed in black and white color so as to achieve the maximum contrast level between the background and the fixed elements, as well as the embedded bits.
2) *Two Orthogonal Guide Bars:* The two guide bars which are very noticeable in the images are utilized to look for the position of the code marker in the image. The relative angle between the two bars should be investigated to eliminate false positive findings. Under the condition of the tilting, the two bars might not be perpendicular to each other, but they will certainly lie in a range near ninety degrees.
3) *Three Cornerstones:* In addition to the guide bars, there are three fixed elements on the three corners of the marker respectively. These cornerstones mark the boundary of the marker and thus can be used to ensure a visual code marker has been found, and eliminate false positives.
4) *Structural Information:* The position of the guide bars and cornerstones provides important structural information for us to derive a transform between image coordinates and standard marker plane.
5) *Detection of the Code Marker:* Given the set of features described above for the code marker, the detection algorithm is as depicted in the flow chart as shown in Fig.10

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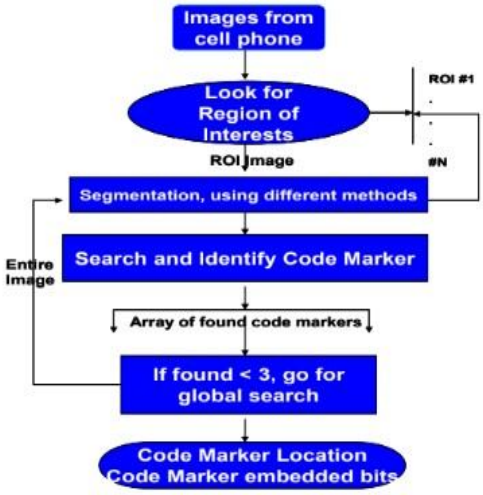


Fig.10 Code Marker Detection Algorithm

The following steps take place in the detection of a code marker

a) Extract Regions of Interest

b) Segmentation

c) Detection and Identification

d) Global search for visual code markers

e) The mapping between image coordinate with code marker coordinates

IV.USER STUDY

This literature survey has been prepared by referring to research papers on Augmented Reality that has been implemented using various methods and techniques. These techniques can be used in AR applications in various fields such as medical, military, education, etc. The discussed techniques are described in tabulated form for convenience.

Survey papers	Algorithm used	Advantages	Disadvantages	Comparison
[19]	• Creating 3D models • Fiducial markers	• Audio-visual information	• Complex	• More usability • Highly reliable • complex
[13]	DotWarp	• Improvement in error	• Can only be compensated in RGB tracking	• More sensitive • Less latency
[10]	AR-PDA	• No need to create markers	• less accurate	• less hardware involved
[15]	Marker detection	• 2-D array creation is easier than 3-D	• High distortion • Low resolution	• Less complex • Highly reliable

In this paper, we have briefed about the processes involved in Markerless AR and AR based on digital markers. This paper explains about 2D and 3D object recognition, Edge Vectorization, Detection and Calibration of recognized objects. The paper also summarizes about depth sensing and recognition of variations in the identified objects. The paper gives details about the digital marker that is used in markerbased Augmented Reality with features and fundamental steps that are involved in the detection of a digital marker.

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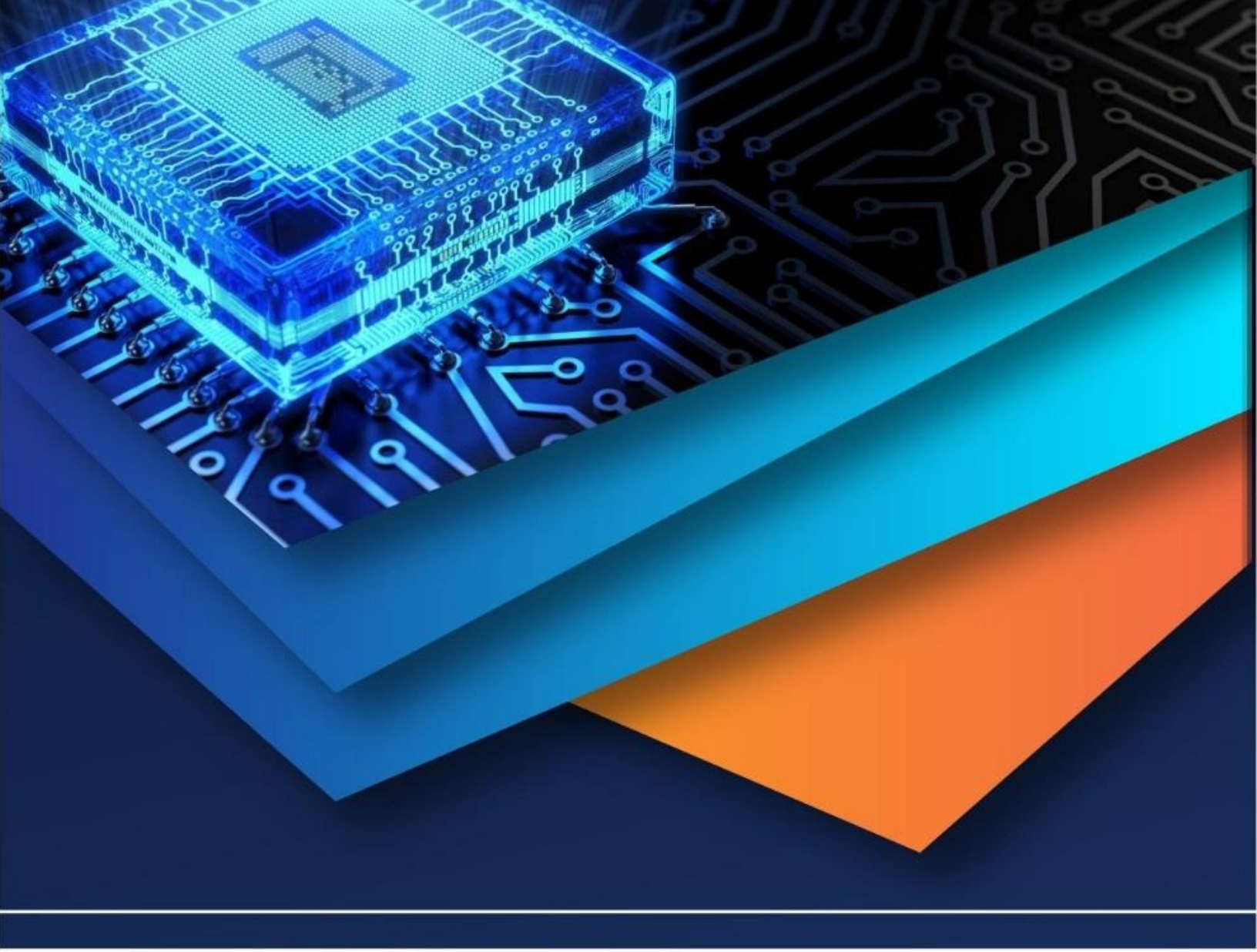
V. CONCLUSION

With the help of this survey, the importance of Augmented Reality and its role in shaping our future was brought to light. Implementation of Augmented Reality in the field of Education will bring tremendous change in both, a way of teaching and learning. Hence, our further work will be based on the development of Augmented Reality application for students that will help them in the detection of various electronic components.

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