MARKER BASED TRACKING IN AUGMENTED REALITY APPLICATIONS USING ARTOOLKIT: A CASE STUDY

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ABSTRACT

TIn Augmented Reality applications, registration between a virtual and a real world object is necessary. The registration is needed for tracking video camera pose (position and orientation) with respect to the real world objects. In existing vision-based augmented reality systems, marker-based technique is widely used approach to track the video camera pose. In this paper, we present an analysis of marker-based tracking using ARToolKit. We investigate the effect of marker size, distance between markers and camera, the speed of marker with respect to camera, relationship between marker size and distance, the brightness and contrast level of a camera on tracking a single marker. Experiments were conducted to produce the analysis of these factors.

Keywords: *Augmented Reality, Maker-based Tracking, ARToolKit Analysis*

INTRODUCTION

In Augmented Reality (AR), the view of real world environment is augmented by computer generated objects/elements. Tracking, interaction, display and sensing are basic requirements to design a typical AR application (Figure 1)[1]

Tracking and registration are the main challenges faced during the development of AR applications. These challenges deal with the proper alignment of objects in real world and virtual one. When a user changes his/her position, the virtual information must remain properly associated with the position and orientation of the objects in real world. This proper association of virtual contents to the objects of real-world is called registration[2,3].

Vision-based tracking technique is currently more active research technique of AR[4]. Vision-based tracking uses computer vision approaches to estimate the camera pose relative to the objects in real-world environment[5]. Fiducial markers are most widely used in vision based tracking for prepared environments[6, 7]. Markerless tracking may use model based or feature based approaches to calculate the camera pose[8-11], but they are computationally costly and require more resources than marker-based tracking. It is, therefore, needed to develop such a system that provides accurate and fast tracking with lowest costs and less efforts to prepare the environment[12]. Augmented Reality ToolKit (ARToolKit) is a library for developing AR applications using marker-based approach[13]. It contains different patterns of markers as shown in Figure 2 and software that has the capability to track these patterns[14,15].

These patterns consist of square black borders having a specific encoding on each pattern. These patterns are then compared against several stored patterns. ARToolKit is open source and is, therefore, widely used by designers and researchers to develop AR applications[16].

MARKER-BASED TRACKING

In marker-based tracking, fiducial markers (artificial

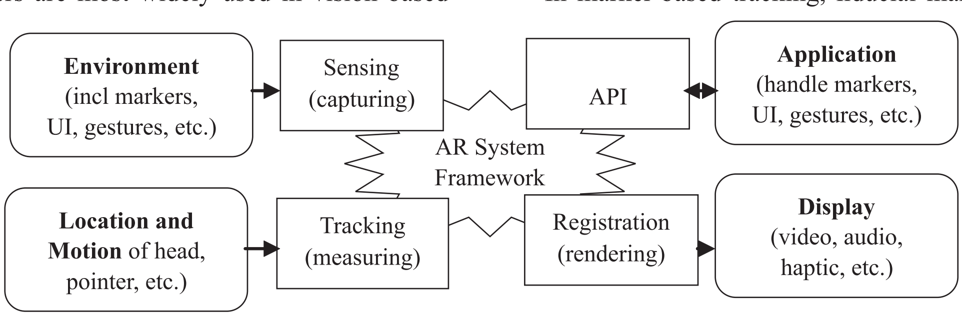

Figure 1: Typical Augmented Reality System Framework Tasks[1]

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Figure 2: Sample Markers of ARToolKit[15]

markers) are positioned in the environment to develop augmented reality systems. These markers having specific pattern which make them easy to identify their pose relative to the objects in real-world environment. Depending on different patterns inside a marker, it allows the design of many different markers to enable continuous tracking inside a large building[17].

A real-time marker-based AR tracking[18] was developed to recognize and track unknown markers using corners information to estimate the camera position and orientation. These corners information increase tracking robustness upto large distance and provide more reliable tracking system under severe orientations. A mobile phone tracking solution was presented that used color-coded markers[19]. Steinbis et al.[20] developed fiducial markers from set of 3D cones that are more scalable in both indoor and outdoor tracking environments as these markers can be easily segmented into regions. Maidi et al.[21] presented an approach by merging extended Kalman filter[22] with analytical method[23] to achieve direct resolution of pose parameters computation. It enhanced accuracy, stability and convergence of the pose parameters.

Recently, a real-time tracking method[21] was introduced that estimates 3D pose and track weakly textured planar objects simultaneously. This method track each frame independently and used "tracking-by-detection" approach for tracking non-textured objects[24]. Tracking is failed by viewing the plane using a significantly oblique angle. Modeling the sampling and reconstruction process of an image is used to solve this tracking problem. Linear filter approach is used to correct the template that is calculated by using the tracked pose of the plane[25].

Lieberknecht et al.[26] developed a real-time tracking approach having the capability to track the camera pose in unknown environment that is based on a consumer RGB-D camera. In this system, it reconstructs a dense textured mesh. Seo et al.[27] presented an approach that handles the problem of occlusion and jitter in marker-based augmented reality applications.

This paper presents the analysis of different attributes such as size, distance (between marker and camera), speed (marker speed with respect to camera), and the level of brightness and contrast of camera for tracking a single marker using a single camera. A number of experiments were conducted and data was analyzed.

RELATED WORK

Different researchers analyzed the functionality of ARToolKit for the parameters of their interest. Malbezin et al.[28] performed test on the accuracy of ARToolKit tracking over large distance. Their results showed that tracking error increases with the increase of distance. Zhang et al.[29] compared different marker systems that were based on square coded fiducial markers. They evaluated their results based on usability, reliability, efficiency, and accuracy of each tracking system. An extensive accuracy experiments with single marker were conducted by Abawi et al.[30] and they discovered that the accuracy of marker tracking dependents on the distance between marker and camera along with angle between them.

A simulated approach was developed by Meier and Klinker[31] to get tracking precision information from ground truth data. Their results showed that accuracy of tracking and estimating pose considerably vary for different values of input parameters (size, distance and rotation angle).

The aim of this study is to analyze the effect of different attributes such as marker size, marker distance from camera, marker speed along different axis, the level of brightness and contrast of camera on single marker tracking via single camera using ARToolKit. The results and conclusions were produced on each attribute separately.

EXPERIMENTS

The experiments use ARToolKit library to track a single marker with a single camera. A number of experiments were conducted that considered different size of markers, distance between the camera and marker, speed of a marker with respect to camera, different size and distance effect, the level of brightness and contrast of the camera as shown in Table 1.

Experimental Setup

We developed a different experimental setup for each experiment (size, distance, size vs. distance, speed, brightness and contrast) (Table 1). The experiments were carried out on Sony VAIO core i5 laptop with a webcam of "ArcSoft Companion 4" having a resolution of 640×480 pixels. The laptop has the specification of 2.4GHZ processor with 4GB RAM and NVIDA graphics card.

The experimental setup used by all above mentioned experiments is shown in the Figure 3.

In each experiment, we performed 4 experimental trials to get best results. The data obtained from each

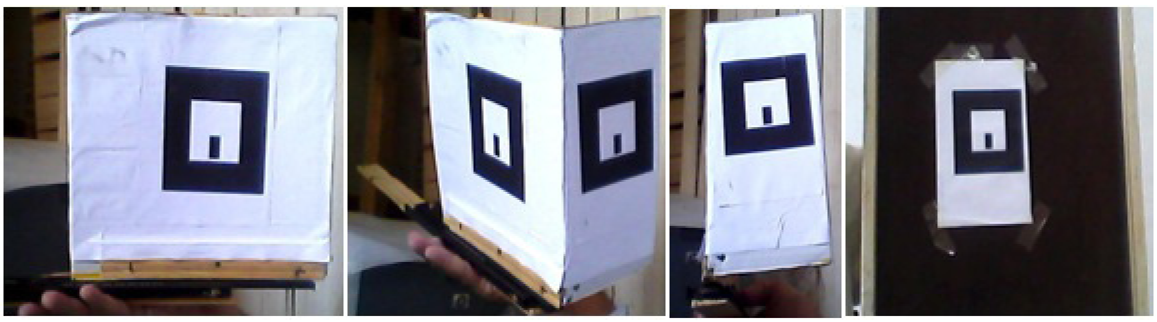

Figure 3: Experimental Setup

Table 1: Experimental Setup

Experiment No	Attributes		Setup Requirements	Setup Design
1	Marker Size		Markers with different size ranging from 0.5 × 0.5 cm to 20 × 20 cm of “sample1” and a hardboard	Attached each marker on hardboard at constant distance of 60 cm from the camera
2	Marker Distance		“sample1” marker of size 10 × 10 cm and hardboard fixed with channel	Fixed the maker on hardboard. The movement of channel displace the marker at different distances
	Marker Speed	Along x-axis	Constant marker size and hardboard attached with channel	Fixed marker on hardboard and move the channel along x-axis.
		Along y-axis		Fixed marker on hardboard and move the channel along y-axis.
		Along z-axis		Fixed marker on hardboard and move the channel along z-axis.
4	Brightness Level		Constant size marker and hardboard	Fixed marker on hardboard at some constant distance
5	Contrast Level		Constant size marker and hardboard	Fixed marker on hardboard at some constant distance
6	Size and Distance		“sample1” marker of size ranging from 0.5 × 0.5 cm to 20 × 20 cm and hardboard fixed with channel	Each marker is attached one by one on hardboard that can move at different distance.

trial was saved in a different text file which is analyzed using SPSS16. To perform these experimental tests we developed testing program for each parameter using ARToolKit library. These programs extract the data of our interest during each experiment.

Experiment Data and Analysis

The data extracted from each experiment is saved in different files which are analyzed. The experimental data analysis and results of different parameters are discussed in the following sections.

- Experiment 1 (Marker Size)

In this experiment, we analyzed the effect of marker size on tracking process using ARToolKit. Fourty markers of different size ranging from 0.5 × 0.5 cm to 20 × 20 cm were taken for this purpose. Each marker was fixed on hardboard one by one and placed in front of the camera for tracking. The data produced from this experiment was saved in a text file. The data contained marker size with marker recognition errors produced during tracking that marker. The distance from the camera was same for all markers. This data is then analyzed. The graph of tracking different marker size is shown in Figure 4.

In Figure 4 the marker size is indicated horizontally where as the recognition errors are shown vertically. The marker tracking errors range from 0 to 1. Zero indicates complete marker tracking while 1 indicate no marker tracking. The threshold value for marker tracking is set to 0.5. We concluded that the marker tracking errors are increased with very small marker size at distance of 60 centimeters. As the marker size approaches to 4 × 4 cm or above, its recognition by ARToolKit is increased. We concluded that when the size of the marker increases the marker recognition errors decreases.

- Experiment 2 (Marker Distance from Camera)

The second experiment was developed to analyze the tracking errors for different distances. A program was designed in ARToolKit that produced the distance of marker with respect to camera position along with the marker recognition errors. For this experiment a constant size of marker was fixed on hardboard that can move away from camera at different distances. The program was executed and board with marker attached was moved to different distances and the data was saved in a text file for analysis. Figure 5 shows the relationship of tracking errors and marker distance from camera.

The graph indicates that a constant marker size has its minimum and maximum tracking distance limits. The distance beyond these limits will provide more tracking errors. The 10 × 10 cm marker minimum and maximum tracking distances are 20 and 250 respectively.

- Experiment 3 (Marker Speed)

The third experiment was conducted to investigate the effect of marker speed along different axes on marker recognition errors. We analyzed the marker speed with the errors produced during tracking a moving marker along with some specific direction (x-axis or y-axis or z-axis).

Speed along x-axis

To calculate the speed along x-axis with marker recognition errors, we fixed a marker on hardboard attached to a channel. The channel can move along x-axis at different speed. After executing the program the channel is moved at different speed and data is saved in a text file. The data contained the speed of marker along x-axis and the marker recognition errors. Figure 6 shows the analysis results.

It shows that the marker recognition error increases with an increase of marker speed along x-axis. As the marker speed approaches to 3.4 meter/second, the tracking error increases and marker tracking failure occurs at speed of 4 m/s and above.

Speed along y-axis

Similarly, the speed along y-axis is calculated by fixing a marker on hardboard attached to a channel that moves along y-axis. When the program is executed it will record the marker speed along y-axis as the marker moves along y-axis at a different speed. The data is saved in text file. The data contain speed of marker with marker recognition errors. The analysis of the data is shown in Figure 7.

It indicates that speed along y-axis produces more errors than x-axis. Marker recognition errors increase with an increase of speed along y-axis.

Speed along z-axis

For the speed calculation along z-axis, a marker is fixed on hardboard that is attached to a channel that can move along z-axis. The program that stores the marker speed along z-axis is executed and the marker is moved along z-axis at different speed. The data contain the speed of marker along z-axis and the marker recognition errors. The analysis is shown in Figure 8.

The speed along z-axis is shown horizontally whereas the marker recognition errors are provided vertically as shown in Figure 8. It indicates that the marker speed along z-axis produced smaller number of marker recognition errors as compared to speed along any other axis. The increase of marker recognition errors slowly increase with the speed along z-axis.

- Discussion on Marker Speed

The speed of markers along x-axis, y-axis and z-axis were analyzed above which showed that the speed along z-axis produced smaller marker recognition errors as

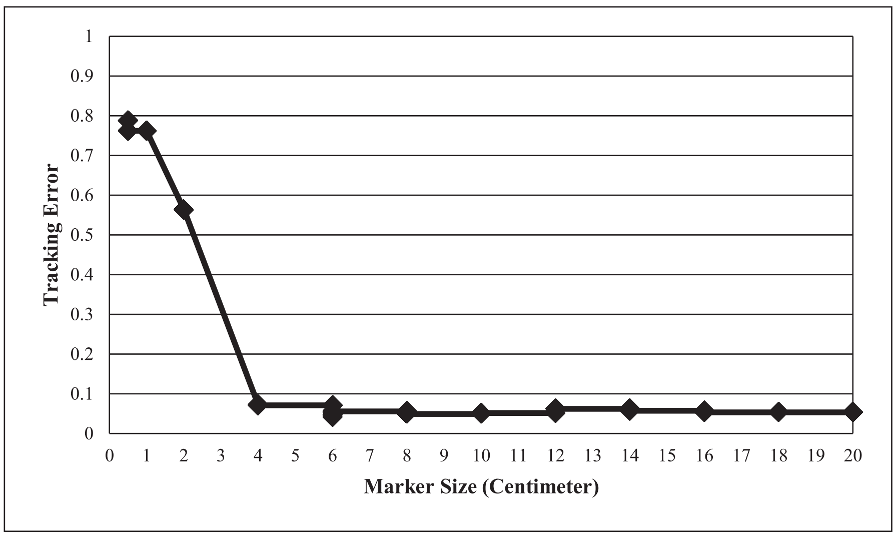

Figure 4: Corresponding Errors for Increasing Marker Size

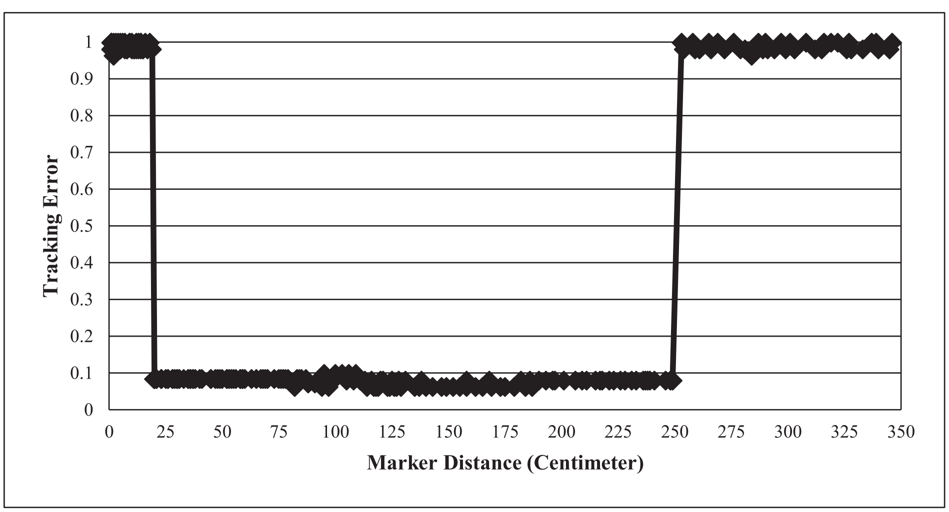

Figure 5: Corresponding Tracking Errors of Marker Distance from Camera

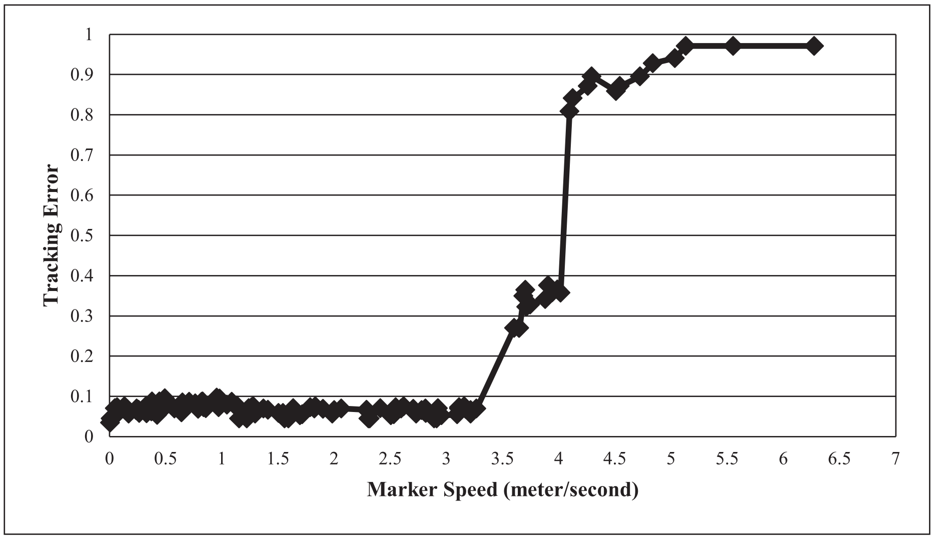

Figure 6: Errors of Marker Speed along x-axis

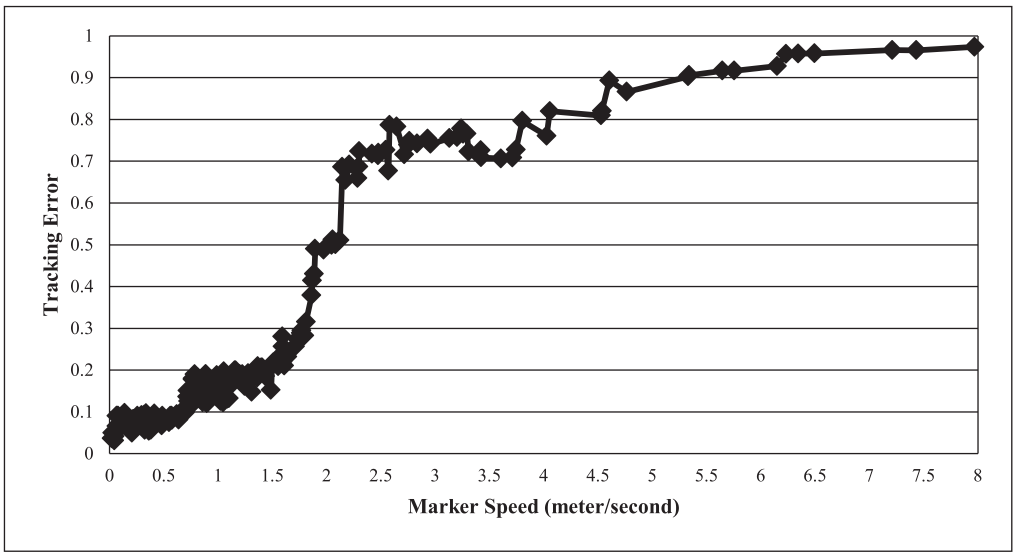

Figure 7: Errors of Marker Speed along y-axis

compared with x-axis and y-axis. This mean that when a marker is zoom in or zoom out in front of camera at different speed will produce minimum marker recognition errors. The speed along y-axis produced more recognition errors as compared with x-axis and z-axis. The vertical movement of a marker in front of camera produced maximum marker recognition error. It is difficult for ARToolKit to recognize a marker movement along y-axis. We concluded that the marker recognition errors increase with the increase of maker speed.

- Experiment 4 (Brightness Level of Camera)

The camera used to perform the experiments having brightness level ranges from -64 to +64. The default value of brightness is 0. A program was designed using ARToolKit that stored the value of brightness level and marker recognition errors in a text file. For this experiment a constant size marker was fixed on hardboard at some constant distance. The data analysis is shown in Figure 9.

It indicates that as the camera brightness value raise from the default value of Zero, the marker is easily recognized. It produces better marker tracking results at the level of 8. But when its value is increased further then

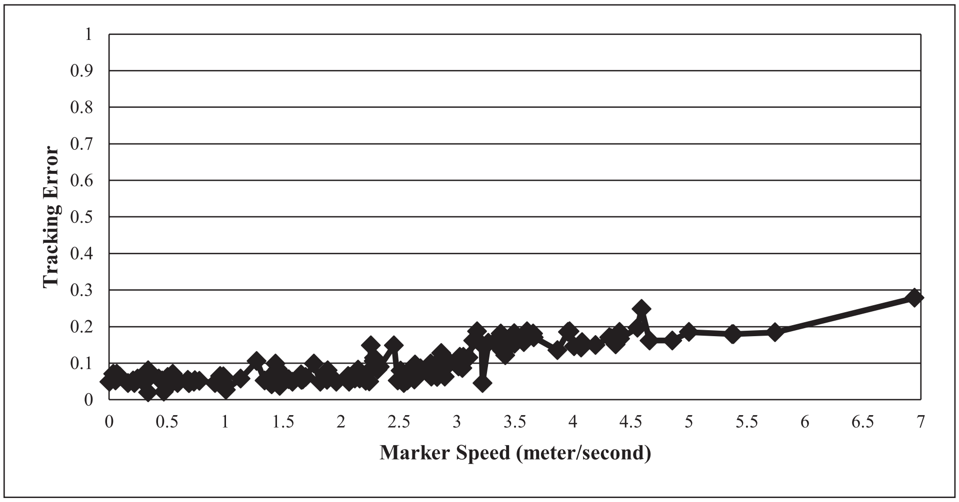

Figure 8: Errors of Marker Speed along z-axis

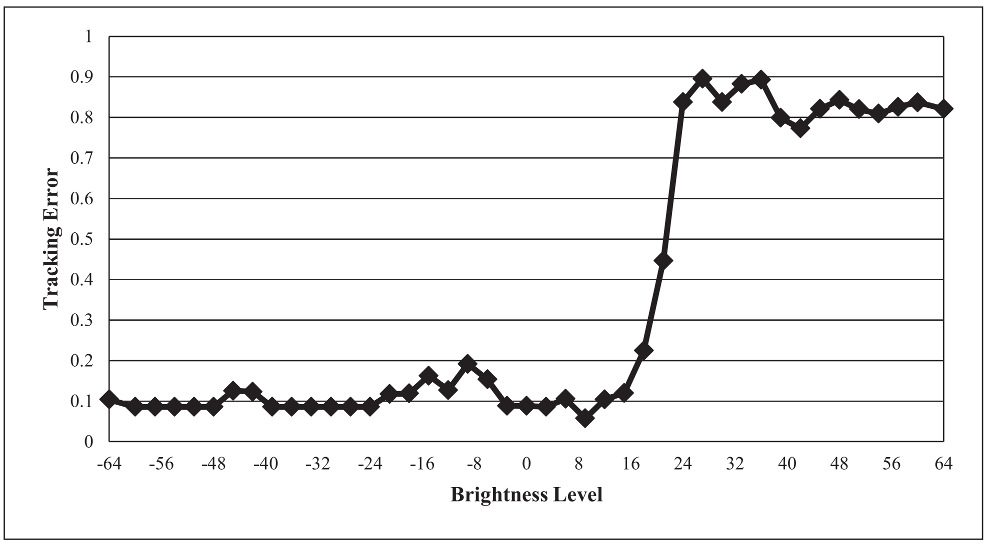

Figure 9: Error Analysis against Brightness Level

the maximum errors were reported. It also indicates that the decrease in brightness value produces no significant changes in the tracking errors.

- Experiment 5 (Contrast Level of Camera)

The effect of camera contrast behavior against marker recognition was examined in this experiment. In this experiment, the camera contrast level ranges from 0 to +64 having 32 as a default value. To get the result of contrast level and marker recognition level, a constant size marker was fixed on hardboard at some constant distance. Using ARToolKit a program was designed that stored the value of contrast level and marker recognition errors in a text file and analyzed. Figure 10 shows the analysis graph of contrast level and marker recognition errors.

It indicates that as the contrast value slightly increasing from its default value of 32, the marker recognition is increased. The marker recognition errors reached to its lowest level at the value of 40. After this level, the marker recognition errors are increased rapidly. We also noted that with a decrease of contrast value from its default value, no significant changes in the marker recognition error were recorded.

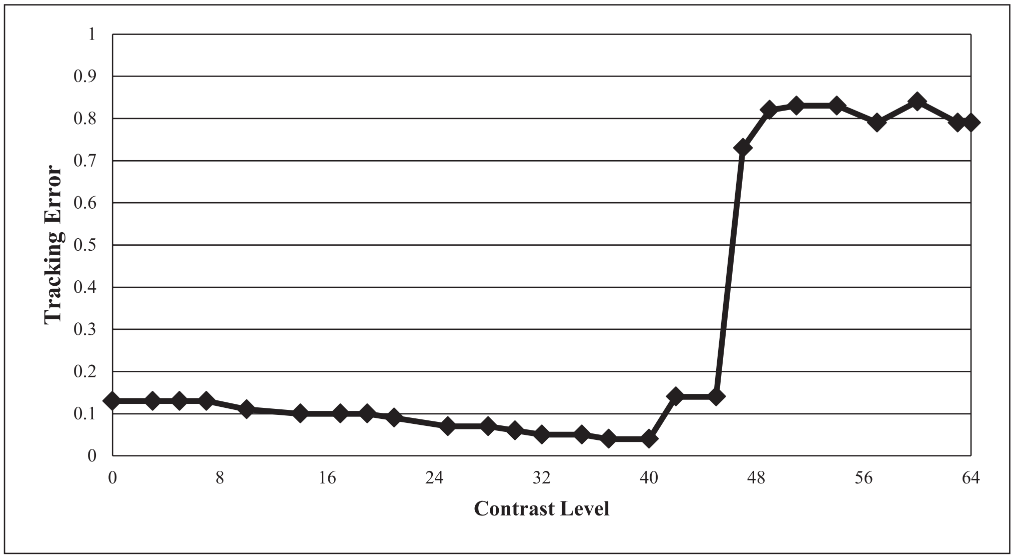

Figure 10: Error Analysis against Contrast Level

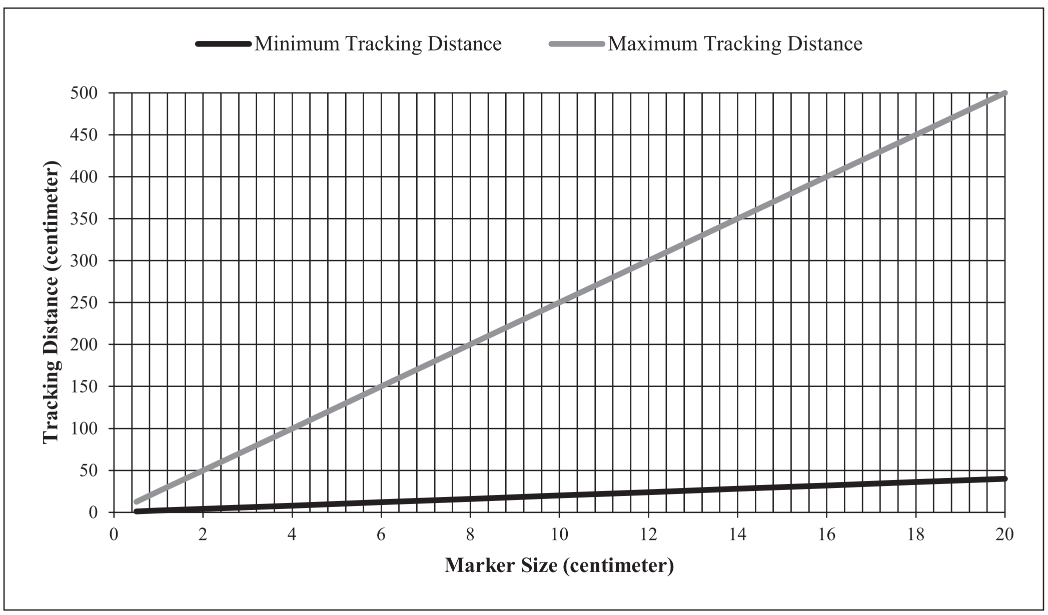

Figure 11: Marker Tracking Errors for Different Size and Distance

- Experiment 6 (Size and Distance)

The last experiment was carried out to study the relationship between marker size and its distance from camera. A program was designed in ARToolKit that gets the size of marker from user, calculates the distance of marker with respect to camera position along with the marker recognition errors. This experiment is carried out using different size of markers ranging from 0.5 × 0.5 cm to 20 × 20 cm and is fixed on hardboard one by one. The board is attached with a channel that can move away from the camera. When the program is executed it reports the marker size, the distance between marker and camera and the marker recognition errors. Figure 11 shows the graph of marker tracking rang for different marker size.

It shows the minimum and maximum tracking distance of different marker size. It indicates that each marker size has it tracking range. Beyond the tracking range a marker is not recognizable. The tracking range of marker is increased with the increase of its size.

CONCLUSION AND FUTURE WORK

This paper discussed the tracking of marker using ARToolKit based on different parameters. The parameters include marker size, marker distance from camera, the marker speed with respect to camera position, the level of camera brightness, camera contrast level and marker distance and size. For the analysis of these parameters we designed different programs that extracted the data of our interest. The extracted data is then analyzed using SPSS 16.

From the analysis of data, we concluded that the marker recognition errors are affected with the change of different parameters. The conclusion is summarized in the Table 2.

During these experiments we concluded and other researcher[14] mentioned in their research work that ARToolKit produces the false detection rate i.e. false negative rate and false positive rate and inter-marker confusion rate. Our future work includes the design of an algorithm that provides accurate and robust tracking solution for inter-marker confusion rate.

Table 2: Conclusions from Experiments

Experiment No	Experiment Name		Conclusion
1	Marker Size		The marker recognition error is greater when the marker size decreased to very small size.
2	Marker Distance		Marker tracking is successful within the limits. Increase marker distance or decrease causes tracking errors.
3	Marker Speed	Along x-axis	Marker speed with respect to camera position causes marker recognition errors.
		Along y-axis	The speed along y-axis produced higher marker recognition errors as compared to x-axis and z-axis.
		Along z-axis	The speed along z-axis produced smaller marker recognition errors than any other axes.
4	Brightness Level		The increase of camera brightness level from its default value (Zero) produced more tracking errors whereas decreasing the camera brightness level from default value has no greater affect.
5	Contrast Level		The increase in camera contrast level from its default value gave less marker tracking and decrease causes no greater affect.
6	Size and Distance		Each marker size has its minimum and maximum tracking distance.

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