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Intuitiveness 3D objects Interaction in Augmented Reality Using S-PI Algorithm

Ajune Wanis Ismail*, Mohd Shahrizal Sunar
UTMVicube Lab, Faculty of Computer Science and Information System,
Universiti Teknologi Malaysia, 81310 Skudai Johor, Malaysia
Corresponding author, e-mail: ajune@utm.my, shah@cs.utm.my

Abstract

Numbers of researchers have developed interaction techniques in Augmented Reality (AR) application. Some of them proposed new technique for user interaction with different types of interfaces which could bring great promise for intuitive user interaction with 3D data naturally. This paper will explore the 3D object manipulation performs in single-point interaction (S-PI) technique in AR environment. The new interaction algorithm, S-PI technique, is point-based intersection designed to detect the interaction's behaviors such as translate, rotate, clone and for intuitive 3D object handling. The S-PI technique is proposed with marker-based tracking in order to improve the trade-off between the accuracy and speed in manipulating 3D object in real-time. The method is robust required to ensure both elements of real and virtual can be combined relative to the user's viewpoints and reduce system lag.

Keywords: *augmented reality, real-time vision-based tracking, interaction technique, 3D object manipulation.*

1. Introduction

AR is a single domain that merges real and virtual objects in real-time representation. Azuma [1] defined AR is the combination of both virtual entities and real world entities in single viewing. The goal of AR system is to overlay virtual information in real world to improve the user's view and interaction [2]. In order to develop AR application, there are needs should be prepared for general perspectives of view and considered as their common requirements. There are a few important requirements are highlighted develop AR environment such as AR interfaces, display technologies, tracking and interaction techniques.

The two common divisions for AR display technologies as defined by Fiala [3], there are magic lens and magic mirror. The display technologies that bring 3D objects into the real environment called magic lens. It was forcing humans to go into the virtual world. When it was moving a camera, object, or tablet PDA around, it would be more intuitive compared to input devices like keyboard keys and mouse actions to move around virtual environment. In contrast for second paradigm is magic mirror display that provides the setting with the projection screen such as the mirror or video camera. Web camera with personal computer screen also considered as Magic Mirror types besides Monitor-based or Projector-based.

The AR interfaces categorized as transitional, collaborative, tangible and hybrid [4]. Application such as MagicBook [5] is transitional interfaces. Kato et al [6] define Tangible AR interface as a fusion of AR display technologies with intuitive tangible user interfaces (TUI) which is conventional interface for 3D object manipulations. Collaborative AR interfaces have been defined [7] the ability to support group interaction and multi-user collaboration [8]. Hybrid AR Interfaces has been described when AR technology was being merged with other technologies of collaborative [8].

Tracking system is important since it was fundamental issue that necessary to be solved in order to enable AR technologies. In many AR applications, tracking is also one of the problematic factors that contribute to the ineffective AR presentation [9]. For AR system to be able to provide the user with the correct information of real and virtual images, it needs to know the user location virtually. Tracking is used for providing the input such as specific pattern of marker defined in calibration process, is needed for the correct registration between virtual objects and real world relative to single alignment. AR tracking recently can be divided into

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sensor-based [10], vision-based [10, 11], and hybrid tracking techniques [12]. In this paper, S-PI interaction involves with marker-based interaction, that purposely the vision-based tracking is chosen.

This paper will discuss the intuitiveness of S-PI algorithm in order to provide robust tracking in AR for 3D object handling in real-time. The algorithm designed in S-PI interaction technique attempts to detect the interaction behaviors. This method is robust that has been proposed due to the limitation in vision-based tracking since it was most important issue to deal with marker-based interaction technique. In this case, accurate user interaction is required to ensure both elements of real and virtual can be combined relative to the user's viewpoints. As a result it may reduce system lag and increase the speed in real-time 3D object manipulation that keep updating drawn on the marker ground without delay.

2. Augmented Reality Environment

The tracking system in this project uses the vision-based tracking that involves image processing in order to calculate pose of camera to be aligned to real world objects correctly. In tracking there are static and dynamic registration errors but many researchers have found the ways to solve [13]. The ARToolKit [5] library has developed for vision-based tracking very famous in AR area, while other researches described efficient approaches minimizing the registration errors in tracking [10]. Marker-based was original tracking for vision-based traditionally tracking by using ARToolkit like tracking multiple distinct markers works best when the marker attached another marker. However, model-based is usually useful for correspondence between 2D entities and their 3D world coordinate. Model-based is the technique that renders 3D objects when world coordinate of marker track the world coordinate. Markerless also current trends improvement for vision-based tracking which is detecting the user hand [14].

Vision-based tracking use camera to capture real ob-ject to display the virtual object on the real object went through a few process. Marker detection occurs when tracking process has done that tracks the 3D object to available on the marker in real world, the viewpoint of the virtual object has calculated and the rendering process complete to draw the object.

2.1. Unique Markers Detection

In this process markers went through image processing for their thresholding in the constant value. Contouring process bring the regions for outline that has fitted by extracting the four line segments. This set of lines pro-duce four vertices the the coordinates. The vertices of the regions are useful for intersections. They collided and the line segments are calculated to be stored in the sys-tem.

Fiala [3] has improved standard tracking with digital processing by storing the values in array and represents the IDs. All markers pattern store defines by IDs, known as user-defined markers, has improved the accuracy of tracking, use them on many objects without needs of running out. If single marker is detected, ID of marker is being passed as an integer to the first parameter of marker configuration and the optional marker considered as double to the second parameter. The tracking involves orientation and position tracking which sometimes tracking only involves the orientation tracking

2.2. Calculating and Estimating the Viewpoints

The aim in this process is to obtain the Tcm as shown in figure 1 is the transformation matrix has found from markers detection produce both of coordinates marker and camera. By using the perspective transformation matrix, matrices values from rotation and translation matrix are found.

The perspective viewpoints for transformation matrix have transformed the camera viewpoints as shown in Figure 1. This perspective transformation matrix is being found from the default initialization of calibration process. The calibration process was necessary to define the matrix of world coordinate for camera calibration. Camera calibration is a camera position and orientation in the world is recognized as extrinsic parameters.

All involves viewpoint calculation and their estimation process. When two markers detected in parallel on the screen, the equations of points drawn on the tool marker and fiducial marker tracked in the ideal screen coordinates.

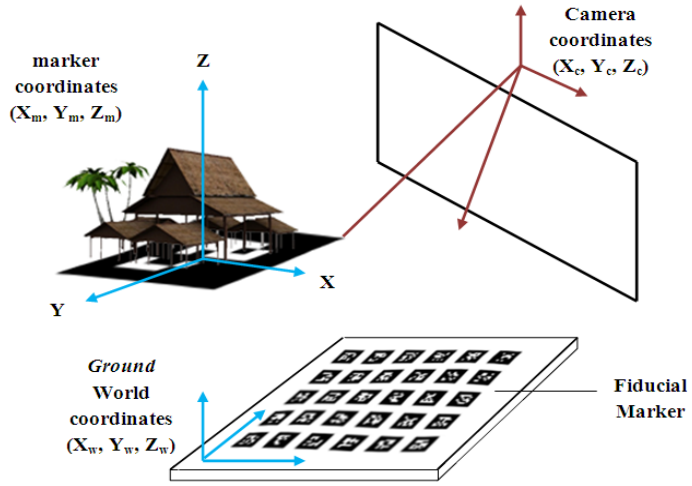

Figure 1. Calculate viewpoints in coordinates system

When computer is running the program, the IDs that defines the markers has assigned to array list since it gains the parameters values. The use of marker represented in list of array has unique characteristic that 3D position can be counted from a single marker. The same results can have by using multi markers' arrays. The variable declared the near sources position and far sources position, both position are detected relatively. User freely moves around spreadly over a wider area since we have defined how far they can spread as well as how near can be viewed. Therefore this tracking method proposed in this paper uses the system-defined IDs of marker arrays. Pattern for marker arrays defined in Marker node in scene graph. Computer captured and recognized the relationships of all markers. This will describe in world coordinates

3. 3D Objects Interaction Technique

S-PI is the point-based intersection producing an intuitive interaction technique. The AR system provides user with the opportunity to interact with virtual elements in many ways [15]. However numbers of issues has been encountered. In a technical aspect, tracking and registration issues for accuracy, the robustness and system configurations itself. In contrast from the usability aspect, the AR interaction should be in natural manner and intuitive interfaces. The occlusion issue is one of the usability when we need to solve the boundaries for real elements to occlude virtual elements.

Many researchers have explored interaction techniques applied in AR. In AR interaction techniques like-Go-Go Interaction [16] has encouraged other researchers to continue studies in interaction issues. VOMAR [17] application developed for 3D object handling method by using a marker represented as paddle in tangible setting. The FingAR [15], the MagicCup [18] are example of multimodal interaction use gestures and speech. Mobile phone or wearable technologies explored acts as an interaction device for object manipulation in AR [19]

With marker-based tracking, the single marker represents as a tool to allow user interacts and manipulates the desired object. In global define, this single marker contains with points as shown in Figure 2, points that connects with geometry node for every 3D object to be picked and release.

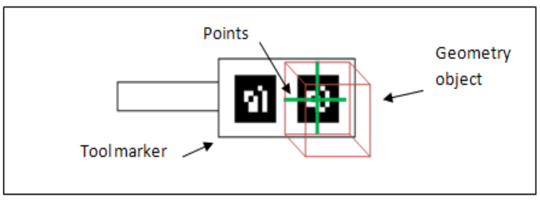

Figure 2. Tool marker use for S-PI interaction

The single marker contains with points must relative to the ground fiducial markers to approve the collision detection in order to place and remove the object on ground. By updating the transformation matrix for each function called by single marker node and ground marker node.

```
Pseudo code :
1.0    Start
2.0    Set List<PickedObject>, nearPoint, farPoint
3.0    Start for loop
       3.1    Condition : PickedObject < ObjectLimit
       3.2    Start Single-if
              3.2.1  Condition : markerGround.Found && Tool.found
              3.2.2  Compute : intersectPoint = nearPoint *
                     1 - pickedObjects[i].IntersectParam) +
                     pickedObjects[i].IntersectParam * farPoint;
              3.2.3  Perform Behaviour : Translate
       3.3    End if statement
4.0    End for loop
5.0    Store : markerNode.AddChild(objectTransNode);
6.0    Store : objectTransNode.AddChild(objectNode);
7.0    Update : List<objects>
8.0    Store : selectedObjects.Add(objectNode);
```

Figure 3. S-PI interaction Algorithm

The flow of S-PI interaction algorithm as described in figure 3. When the multiple marker belongs to the container has detected, the list of 3D objects being are called by the draw function. This condition is similar to the tool marker detection. When both of markers successful detected, then system checks for collision detection between tool marker and the desired 3D object has touched and it will decide either the 3D object is picked or released. S-PI interaction proposed will allow user freely moves around with maintain in his own viewpoint through the ground to copy the 3D object on the tool marker. The system runs need to detect both of the markers. The intersection between near point and desired object allow user to manipulate the picked object by changing the position.

3.1. S-PI Detection for 3D Objects Handling

In S-PI interaction, detecting the 3D manipulation behavior such as translation, rotation and clone, the collisions between the points on the tool marker with the 3D objects are calculated and the geometrical relationship between 3D object are defined. This section discuss the S-PI interaction performs the intersection between the points to detect clues for spatial manipulation by updating the matrices.

The implementation of touch behavior for S-PI interaction has proposed, the 3D object is overlaid on the container fiducial marker intersection with the geometry points contains on tool marker make the object appear overlay on the tool marker. When collision detection is true, then need to offset the container marker transformation.

Thus, multiply the tool marker transformation with the inverse of the container marker transformation, which becomes

$$T*G(inv)*G = T*I = T$$

Where T is the transformation of the tool marker array, G is the transformation of the ground marker of the container, and I is the identity matrix. This viewpoint calculation display the result as captured in Figure 4.

There is a difference in task with difference completion times in second (s) are recorded to evaluate the accuracy and performance. The users use marker to perform interaction. Times recorded by identify a few questions in general.

The testing result shows that the users thought that when the object was handling in AR using marker-based was very interesting. It was easier to pick the object correctly on the tool marker (Case 1) but if they could position the object more accurately (Case 2). Single-marker interaction work through marker-based for picking more accurate due to angle tracking between tool marker coordinate to camera coordinate was easily touched only with any single point.

(a) (b)

Figure 4. (a) Object is being picked (b) Object allocates on the ground markers

However to drop the object on the ground a bit delay compare to picking. Due to the placement object on the ground marker was involves tracking multiple marker which require accurate angle and pose to track from single marker to multiple marker while the viewpoint of camera is still running.

3.2. 3D Objects Manipulation

Detecting the 3D manipulation behavior such as translation, rotation and clone, the camera position estimation every single frame when marker detected and it will provide extrinsic parameters. The collisions between the points on the tool marker with the 3D objects are calculated based on the desired coordinate relatively. The geometrical relationship between 3D object are defined in order to detect the behavior for translate, rotation and also copy the same object that being selected for the current pose for intersections.

For usability evaluation on robust tracking and on clues detection of object manipulation for user to naturally interact with the objects, the number of respondents recruited into categories of novices and non-novices. Total of 10 users for novices and, only five of who were non-novices. They are for total 15, are all between 18 and 40 years old. Users selected among undergraduate and postgraduate students, also involving lecturers in the faculty. For non-novice, subjects are in the area of computer science and got the knowledge in AR. For novice, they are not in area of computer science neither in AR.

Using a rate of 1 stands for not very easy and 6 highly stand for very easy. Graph in Figure 5 shows the result from user experience based on ranking. Result shows that users rating the effectiveness performances for overall are positive. In contrast, for pick behavior, both of user novices and non-novices satisfied for the effectiveness of allocating the objects on the ground. However novices did not prefer much on rotation but they prefer clone task for more easily conducted compared to rotation.

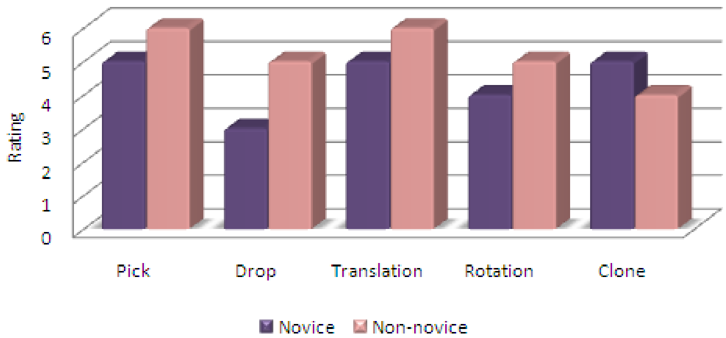

Figure 5. Result of robust 3D objects handling

Translate behavior assigned for enabling function to change the position of the selected object and update the coordinates of selected object. The conditions when the selected object in geometry node response to the tool marker by connecting the selected object relative to virtual string. Then object will corresponds for positioning. The S-PI interaction performs the intersection between the points by both so that correspond with each other to perform translate by updating the matrices.

Rotate behavior assigned with the proposed S-PI interaction for enabling function to rotate the selected object and update the angle of selected object. The condition when the selected object in geometry node response to the tool marker rotation. By rotating the marker, the object will correspond to rotate as well. Touch the selected object to the tool marker for intersection then the points by both will correspond with each other to perform rotation.

We also recruited the number of respondents into categories of novices and non-novices. Total of 10 users for novices and, only five of who were non-novices. They are for total 15, are all between 18 and 40 years old. Users selected among undergraduate and postgraduate students, also involving lecturers in the faculty. For non-novice, subjects are in the area of computer science and got the knowledge in AR. For novice, they are not in area of computer science neither in AR.

Using a rate of 1 stands for not very easy and 7 highly stand for very easy. Graph in Figure 6 shows the result from user experience based on ranking. Result shows that users rating the effectiveness performances for overall are positive. In contrast, for drop behavior, both of user novices and non-novices satisfied for the intuitiveness of allocating the objects on the ground. However for the rotation task, non-novices did not prefer much.

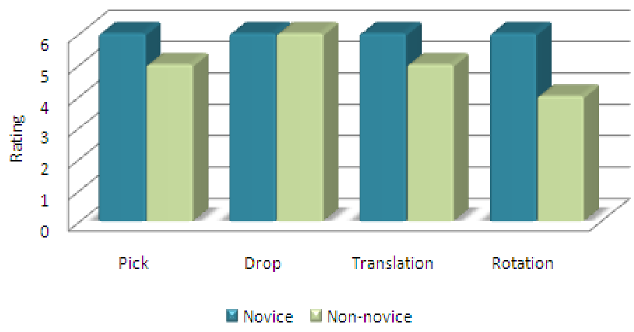

Figure 6. Result of intuitiveness 3D objects Manipulation using S-PI interaction

4. Conclusion

As conclusion, this paper contributes to the design of interaction technique, S-PI, in AR environment. The issues in user tracking in AR for 3D object handling is investigated. In order to develop interaction technique in AR, robustness of tracking system and providing user an intuitive metaphor for 3D object handling.

In this paper describes about the new interaction technique by using marker-based tracking for interaction called S-PI interaction. In S-PI interaction design had assigned each points with coordinate axes belongs to tool marker intersect with geometrical model coordinates for collision detection. This method is for speed up the tracking process and with the S-PI interaction technique helps the accuracy and robust in dealing with virtual object when camera viewpoint is keep calculating in real-time.

In this paper we also explain on user tracking in S-PI interaction using marker-based tracking proposed to offer intuitive user interaction in AR environment where marker considered as a device to interact with 3D objects. The 3D object manipulation such as translation, rotation and clone the selected object has been proposed in S-PI. The S-PI technique with vision-based tracking technique is robust that has improved the trade-off between the tracking accuracy and the speed in tracking system. The robustness in tracking is required to ensure both elements of real and virtual can be combined relative to the user's viewpoints and reduce system lag.

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