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Collision Avoidance in Virtual Worlds Using Repulsive Field Methods and Augmented Reality Applications

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ABSTRACT
Augmented Reality (AR) is a merger of the virtual world with the real world in real time. This paper presents a simulation that is able to detect collisions between 3D objects and display collision avoidance movements naturally using AR technology. The methods used are Sphere-Plane Detec-tion (SPD) and Sphere-Sphere Detection (SSD) to detect collisions with reference distance and re-pulsive type potential field methods for collision avoidance. To display the simulation results of collision avoidance between 3D objects, the ARToolkit engine is used. The test was carried out on a web browser with a number of dynamic ± 5 objects and several static and dynamic obstacle objects. Based on the tests carried out using the SPD method, the detection distance is d 1m, while using the SSD method the detection distance is d 2m, collision avoidance using a repulsive field is obtained the vector value |V| from the initial position to the destination for object A1 is 60.9063, object B1 is worth 68, object C1 is worth 26.6 and object D1 is 27,155. Changes in repulsive values can affect object movement and object distance with dynamic obstacles and static obstacles.

Keywords-Collision detection,collision avoidance,repulsive field,augmented reality,web browser.

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I. INTRODUCTION

As technology advances from time to time, technology is able to meet human needs in various ways. One of them is a technology that is able to detect the presence of other objects by providing an avoidance response when a collision will occur with a certain distance reference.

With technology, humans can easily issue imaginations that are able to combine the virtual world with the real world which is called augmented reality [1]. Augment-ed reality is a merger between the real world and the virtual world with an intermedi-ary camera to take pictures from markers so as to produce virtual interactions that appear on the real world display both on the screen and head mouted display (HMD). The use of augmented reality itself is as a support tool in real life. For example, using 3D objects as information and so on. 3D objects on the web are created using a Virtual Reality Modeling languagecalled VRML is the first step towards the 3D Web. Conven-tionally, a VRML world is created by adding one or more 3D/2D objects or a combina-tion of these objects together [18].

From these two technologies, in this paper, simulations are made between 3D ob-jects in cyberspace made with VRML which is an international standard to describe 3D shapes. VRML uses the basic concepts of computer science as the creation of 3D graphic objects [2]. The VRML model builder module is responsible for writing out the .wrl file for the model which is later visualized using a VRML enabled browser. The generated .wrl file can be viewed using Cortona 3D viewer 6.0 on the Internet Explorer [16]. The artificial intelligence of virtual reality technology can create a more real environment for people, and the three-dimensional sense of human vision is also stronger [17]. VRML, as an international standard of virtual reality, has developed rapidly [19]. The 3D shape is displayed in real time using ARToolkit which is able to detect collisions by providing an avoidance response using a marker that is read by the camera on the PC [3]. The marker will be executed by the user using a PC camera by first installing the software to execute the marker. 3D animation object designed to detect an object whether there is a collision with another object or not based on a distance reference using the Sphere-Plane Detection (SPD) method [4], Sphere-

Sphere Detection (SSD) and avoidance detection so that there is no collision between objects which refers to the method potential field, especially the type of repulsive field [5] which is applied in augmented reality.

The establishment of the physical model requires the Script of VRML, the TimeSensor node, the space location node and the space sensor, and the TimeSensor sends out the clock information in a specific period. The Script automatically calcu-lates the new physical properties of the object according to the values of the moving features of the objects at that time [21]. For example, speed, acceleration, displacement, deformation, etc. In its application, making animated objects is equipped with sensors, one of which is a sphere shape with a certain radius, so that it can informwhether other objects are within the range of the sensor or not, if the distance is the same as the sensor range, the object will avoid collisions by moving in another direction. Thus, re-sponding to collisions and discovering if a collision has occurred is the basis of this problem.

Using VRLM language programming, run on the basis of the established system so as to get the visual results [20]. The results of the research can be implemented on the augmented reality web in the form of a simulation of controlling more than one object that moves to the same destination by going through several obstacles, both static and dynamic, without having to collide with existing obstacles or with other objects.

II. SYSTEM OVERVIEW

A. System Planning

Figure 1 is the stage that will be carried out in the research.

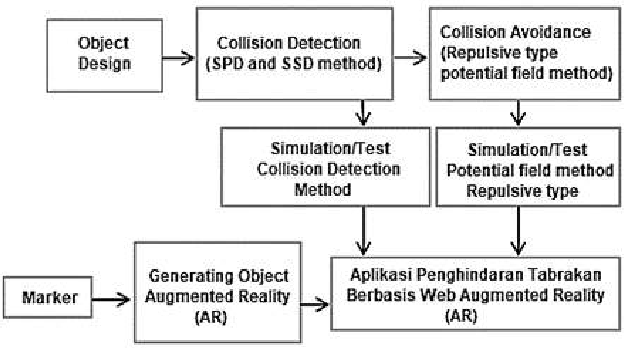


Fig. 1. System block diagram

Starting from the creation of dynamic objects and static and dynamic obstacles, using collision detection and collision avoidance methods, to simulating on the augmented reality web.

B. 3D Object Design

VRML defines a file format that integrates 3D graphics and multimedia. Concep-tually, each VRML file is a 3D time-based space that contains graphic and aural objects that can be dynamically modified through a variety of mechanisms [22]. In this paper, objects are in a virtual world created with VRML to describe 3D shapes. The basic objects that have been created include the geometry of the sphere, box and cylinder.

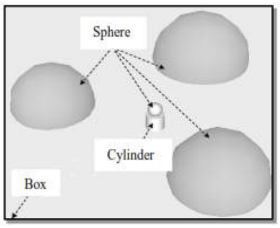


Fig. 2. Basic geometric objects

Figure 2 sphere objects and small cylinders as dynamic objects that will reach the destination and will avoid collisions with the sphere large size which is a static and dynamic obstacle. While the box geometry is a plane. In order for a dynamic object to recognizeits environment, it is necessary to provide a sensor to be able to receive information around it. Spherical objects and small cylindrical objects which are dynamic objects are equipped with a sensor sphere.

C. Collision Detection

Collision detection is a central task in the simulation of multibody systems [23]. The two main parts of collision detection are detecting whether a collision has occurred or not. Thus, detecting a collision and discovering if a collision has occurred is the basis of this problem. Examples of design objects that have been created include the geometry box and geometry sphere objects which are illustrated in Figure 3.

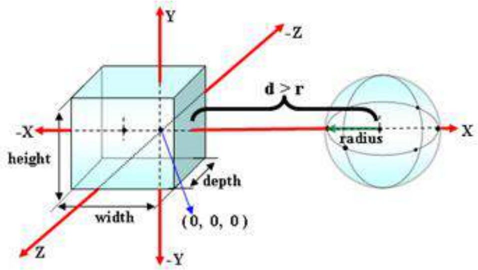


Fig. 3.Sphere and box geometry

It should be noted when detecting a collision that the distance between the sphere and the plane does not have to be zero (translucent plane) or the same as the plane so that there is no collision and the sphere will move in another direction avoiding the plane.

From the geometry of the sphere and box in Figure 3, it becomes the basis for collision detection using the sphere-plane detection (SPD) method. SPD method to determine whether a plane object has an intersect with a spherical object. If the distance from the center of the sphere to an object plane (d) is less than or equal to the radius of the sphere (r), then a collision has occurred [4].

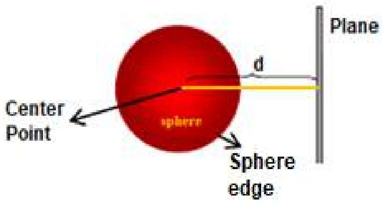


Fig. 4.Sphere-plane detection method

The main point is not to let the sphere get too close to the plane. Before doing so, each plane must have its own normal vector n and a value of D. The radius of the sphere (r) is seen from the center of the sphere to the edge of the sphere. Before performing the SPD method, each plane must have its own unit normal vector n and a value of D [4,5].

$$d = (C - P_0).n \quad (1)$$

$$D = -P_0.n \quad (2)$$

So: $$d = n.C + D \quad (3)$$

Where: C = Center point of sphere
P0 = Every point on the plane.
n = Normal unit on plane

In Figure 5, another way to detect collisions between objects is with Sphere-Sphere Detection (SSD) [5], namely if the distance from the center of the sphere to the center of another sphere object (d) is less than the sum of the radius of the two sphere (r1 + r2), it will a collision occurred.

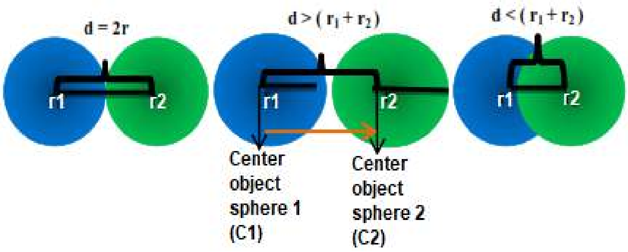


Fig. 5. Sphere-sphere detection method

The equation to determine the distance between the above objects is:

$$D = (C_2 - C_1) \quad (4)$$

$$d = \sqrt{(D.x)^2 + (D.y)^2 + (D.z)^2} \quad (5)$$

If the value of d = 2 r collision occurs, if the value of d < (r1+r2) a crash occurs and if d > (r1+r2) there is no collision.

Detecting collisions with the SSD method, a sphere shape sensor with radius (r2) interacts with other spheres with a radius (r1). By knowing the coordinate position of the center point of each sphere object, the value of (r1+r2) and the distance d of the two objects can be calculated. If the distance is less than the sum of the two radii of the sphere, a collision between the two objects is detected. If a collision is detected between the two objects, it will result in a response from a sphere object with a radius (r2) that will avoid another sphere object with a radius (r1).

D. Collision Avoidance

There are two models of potential fields, namely attractive and repulsive. The potential field algorithm where the attractive and repulsive forces have been modified by using virtual potentials which when applied in planning a path, will be able to quickly avoid static and dynamic obstacles [15]. Figure 6, is an illustration of giving relpulsion to a 3D object.

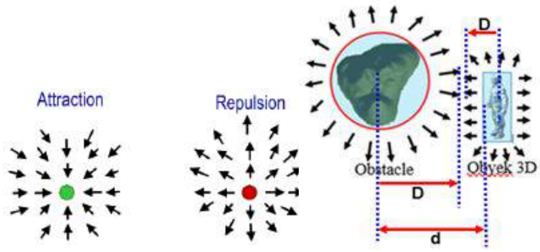


Fig. 6.Attractive and repulsive fields forces

Its target location exerts a force that attracts the particle while obstacles exert repulsive forces [12]. Thepotential field method can produce low impulsive fuel and can be implemented online with a low computational effort. At each time step, the artificial potential field algorithm generates the desired velocity and orientation required for reaching the target. [7]. Collision free path planning is a pre-imperative [10]. How to find a safe and collision-free path in the environment with obstacles is always an important issue [13].

The collision avoidance process between objects is designed using the repulsion method. Then there is a repulsion from each agent/object which results in mutual repulsion or no collision because the repulsive field function is active [6].Equation 6, shows the value of repulsive field repulsion on an object.

$$V_{direction} = 180°$$

$$V_{magnitude} = \begin{cases} \frac{(D-d)}{D} & for\ d \le D \\ 0 & for\ d > D \end{cases} \qquad (6)$$

Where :
D is the maximum range of field effects
d is the distance of the object to the center point

Establishing the repulsive field between the nearest points on every joint and obstacles with the closest distance was sufficient for achieving obstacle avoidance [14].

E. ARToolkit

A variation of virtual reality (VR) is Augmented Reality (AR), which combines the digital and physical worlds of users by superimposing computer-generated infor-mation (for example texts, 3D graphics, or animations) onto the physical world [24]. Augmented Reality (AR) can use Google ARCore, where ARCore works to display 3D models [8]. In this paper using AR with ARToolkit, the process of how the ARToolkit works is as shown in Figure 7. Based on the diagram block above, the webcam takes the image input around it repeatedly (video stream). Before the camera is used, the camera must be calibrated first. Camera calibration is a very important part of the video input process. This is caused by distortion on the camera lens which each camera is different from its characteristics [9].

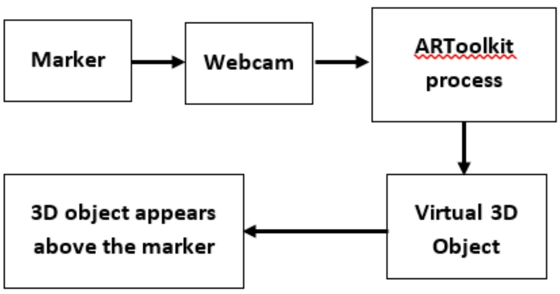


Fig. 7. Artoolkit diagram block

Webcam is looking for where the marker is in accordance with the one on the PC server to then be occupied by 3D objects.

After the marker is detected, the 3D object will appear above the marker on the PC.

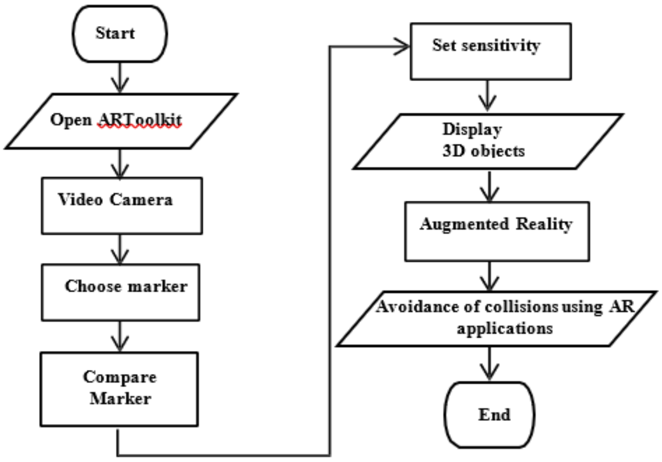


Fig. 8. Flowchart augmented reality application scheme

Figure 8, shows an AR scheme with ARToolkit that begins with the user opening AR and activates the camera. The marker has been printed on the show in front of the camera, then the camera will read the marker and processed the ARToolkit library. When the marker detected by the camera is in accordance with the marker that has become a previous reference, it will be displayed 3D animation by simulating a collision detection but if the marker read by the camera is not the same as the marker which is a reference, the image of the image input will be carried out. Types of markers such as Figure 9, from left to right, SPD, SSD, repulsive and ARrepulsive markers.

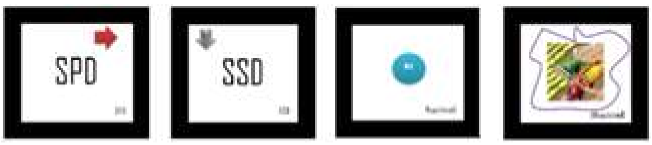


Fig. 9. Marker's reference

III. RESULT

The results in this research were tested by testing collision detection and collision avoidance tested with ARToolkit and a web browser.

A. Collision Detection Testing

The first test displays the results of 3D object collision detection based on augmented reality based on the sphere plane detection (SPD) method in the form of a spherical object with a sensor distance of 0.6m which is run on ARToolkit. The results are shown in Table 1.

TABLE I. COLLISION DETECTION RESULT USING SPD ON ARTOOLKIT

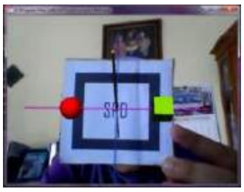
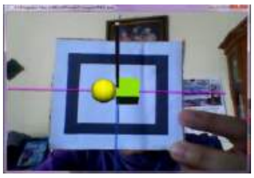
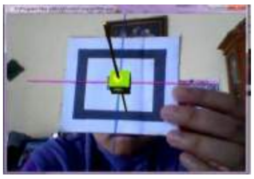
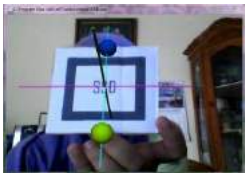
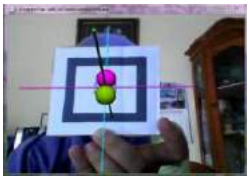
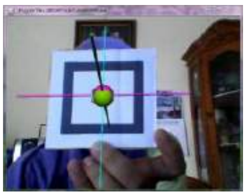
Scene	Display	Description
1		Sphere has not detected a collision with the box because the sphere has not yet intersected with the box, so the sphere has not collided or (d > r).
2		Sphere collision has been detected when the distance between the sphere and the box is d = r, because the sphere is already coincident with the box, the sphere responds to a color change to yellow.
3		Sphere has been a collision until it penetrates the box with both objects in one position, then d<r so that the response turns yellow.

TABLE II. COLLISION DETECTION RESULT USING SSD ON ARTOOLKIT

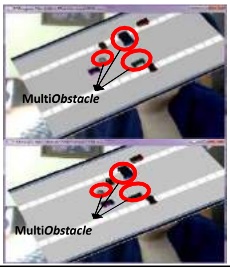
Scene	Display	Description
1		The blue sphere has not detected a collision with the green sphere because the blue sphere has not yet intersected with the green sphere, so there has not been a collision or (d > r1 + r2).
2		The blue sphere collision has been detected when the distance between the two spheres is d = r1 + r2, then the blue sphere responds to a color change to purple.
3		The blue sphere has collided until it penetrates the green sphere with both spheres in one position, so d< r1+ r2, thus giving a purple response.

In the second test, it displays 3D objects based on augmented reality based on the sphere sphere detection (SSD) method in the form of a blue sphere object as a sensor with a sensor distance of 1.2m which is run on ARToolkit. The results are shown in Table 2.

B. Collision Avoidance Testing on ARToolkit

Collision Avoidance (CA) systems have been used in wide range of different robotics areas and had extraordinary success in minimizing the risk of collisions [11]. In this research, Collision Avoidance is applied to 3D objects in the virtual world and tested using ARToolkit. This test displays the results of 3D objects based on augmented reality with repulsive field and SSD methods that are integrated on dynamic and static obstacle objects by providing a repulsion force on dynamic objects so that they move to avoid these obstacles. The dynamic object can move away when there is a potential for a collision with an obstacle, where the dynamic object is equipped with a sensor sphere with a sensor distance of 2m.

TABLE III. COLLISION AVOIDANCE RESULTS USING REPULSIVE FIELD ON ARTOOLKIT

Scene	Display	Description
1		Static objects in the form of buildings on the side of the road and dynamic objects in the form of vehicles. The two dynamic objects have not detected a collision or (d> r1+ r2).
2		Dynamic objects have been detected according to the distance between the sensor and the obstacle (d=r). Then the dynamic object will respond by moving to avoid obstacles.
3		The dynamic object has detected a collision with an obstacle (d=r). Then the dynamic object moves away from the obstacle or away from the obstacle.
4		The results of the multi obstacle consist of dynamic objects and 3 static and dynamic obstacles. With the repulsive field method dynamic objects will pass through the obstacle without colliding.

C. Collision Avoidance Testing on the Web

VRML is an international standard for describing 3D shapes and scenery on the World Wide Web. VRML's technology has very broad applicability, including web-based entertainment, distributed visualization, 3-D user interfaces to remote web resources, 3-D collaborative environments, interactive simulations for education, vir-tual museums, virtual retail spaces, and more. VRML is a key technology shaping the future of the web [26]. By using VRML, a virtual 3D scene can be created, which pro-vides an effect of 3D animation and more interaction with users based on 3D objects on the web page [25]. Collision avoidance between 3D objects created with VRML in this paper is tested on a web browser to analyze the distance between objects by displaying the coordinates of each object so that a graphic display can be made.

TABLE IV. COLLISION AVOIDANCE RESULTS USING REPULSIVE FIELD ON THE WEB

No	Display	Description
1		The initial position of the dynamic object that is still far from the obstacle range so that the dynamic object's distance from the obstacle (d>r).
2		Dynamic objects have been detected according to the distance between the sensor and the obstacle (d=r). Then the dynamic object will respond by moving to avoid obstacles.
3		The dynamic object has detected a collision with an obstacle. Then the dynamic object moves in another direction and away from the obstacle so that the dynamic object's distance from the obstacle (d>r).

The value of the distance (d) of dynamic objects with obstacles in table 4 can be calculated using equation (5). The collision detection method used is Sphere-Sphere Detection (SSD). The results of the distance values are shown in table 5.

TABLE V. DISTANCE VALUE DYNAMIC OBJECT WITH OBSTACLE

No.	Dynamic Object Position			Obstacle Position			Distance Value (d)
	X	*Y*	*Z*	*X*	*Y*	*Z*	
1	4.79	-0.5	0.3	-9.29	-0.5	0.3	67
2	-1	-0.5	0.3	-3	-0.5	0.3	2
3	-1.6	-0.5	-1.8	-3	-0.5	0.3	4.4

While the results of the collision avoidance test with multi obstacles on the web browser are shown in Figure 10.

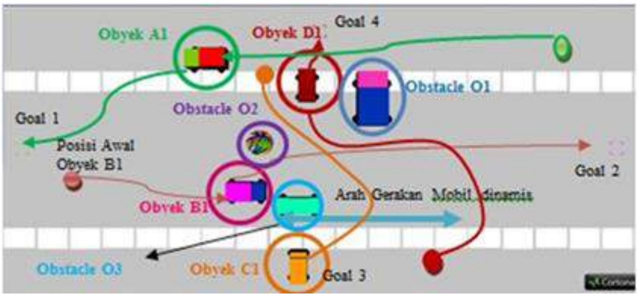


Fig. 10.The movement of each object is dynamic on multi obstacles.

In Figure 10, the movement for object A1 departs from the +x axis to the -x axis (goal 1). Object B1 departs from the -x coordinate axis to the +x axis (goal 2), Object C1 moves from the top/+y axis towards the bottom or the -y axis, which is goal 3. While D1 Object moves from the bottom or -y axis going up / +y axis (goal 4). Form Fig.10 shows the motion graph for objects A1, B1. C1 and D1 as in Figure 11. The calculation of the vector object A1 from the initial position Pa = (25,0,-12) to the final position Pb = (-34.77, 0, -0.29) using the 3D vector equation [4] as follows :

$$V = (X2 - X1).(Y2 - Y1).(Z2 - Z1)$$
$$V = (-34.77 - 25).(0).(-0.29 - (-12))$$
$$V = (Vx, Vy, Vz) = (-59.77, 0, 11.71)$$
$$|V| = \sqrt{(Vx)^2 + (Vy)^2 + (Vz)^2}$$
$$|V| = \sqrt{(-59.77)^2 + (0)^2 + (11.71)^2} = 60.9063$$
$$Vx = \frac{Vx}{|V|} = \frac{-59.77}{|60.9063|} = 0.98134 \; ; \; Vy = 0$$
$$Vz = \frac{Vz}{|V|} = \frac{11.71}{|60.9063|} = 0.19226$$

When all components of the vector are added it will equal 1.

$$Vx + Vy + Vz = 0.98134 + 0 + 0.19226 = 1.1736$$

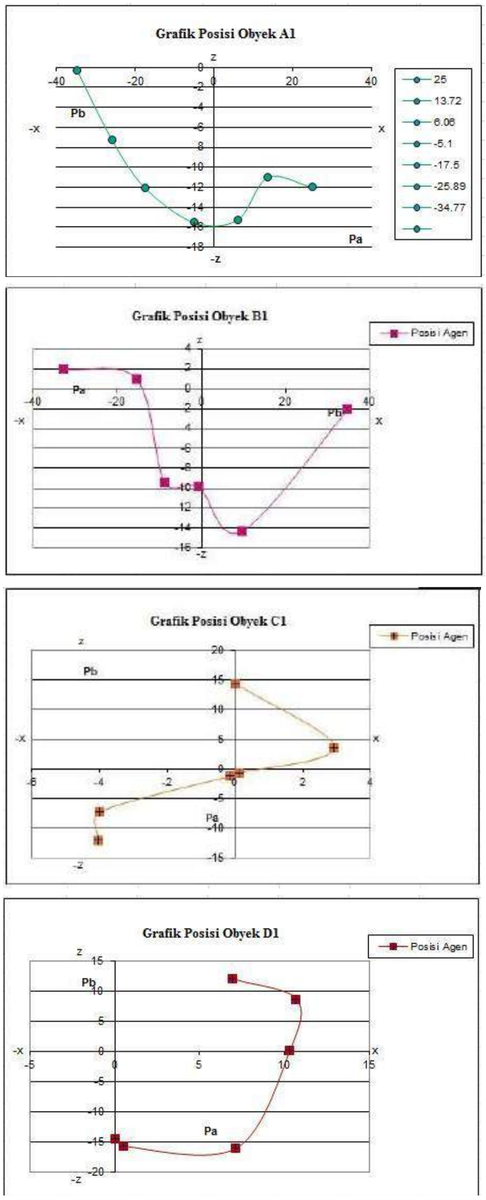


Fig. 11. Graph of movement path of each object on each coordinate axis.

The calculation of the vector object B1 from the initial position Pa=(-33, 0, 2) to the final position Pb=(34.88, 0, -2.08) in the same way the results are as follows:

$$V = (Vx, Vy, Vz) = (67.88, 0, -4.08)$$
$$|V| = \sqrt{(67.88)^2 + (0)^2 + (-4.08)^2} = 68$$
$$Vx = \frac{Vx}{|V|} = \frac{67.88}{|68|} = 0.9982; \quad Vy = 0;$$
$$Vz = \frac{Vz}{|V|} = \frac{-4.08}{|68|} = 0.06$$

When all components of the vector are added it will equal 1.

$$Vx + Vy + Vz = 0.9982 + 0 + 0.06 = 1.0582$$

The calculation of the object vector C1 from the initial position Pa=(-4, 0, -12) to the final position Pb=(0.05, 0, 14.29) is as follows:

$$V = (Vx, Vy, Vz) = (4.05, 0, 26.29)$$
$$|V| = \sqrt{(4.05)^2 + (0)^2 + (26.29)^2} = 26.6$$
$$Vx = \frac{Vx}{|V|} = \frac{4.05}{|26.6|} = 0.15225; \quad Vy = 0$$
$$Vz = \frac{Vz}{|V|} = \frac{26.29}{|26.6|} = 0.98834$$

When all components of the vector are added it will equal 1.

$$Vx + Vy + Vz = 0.15225 + 0 + 0.98834 = 1.14059$$

The calculation of the vector object D1 from the initial position Pa=(7, 0, 12) to the final position Pb=(0.08, 0, -14.43) is as follows:

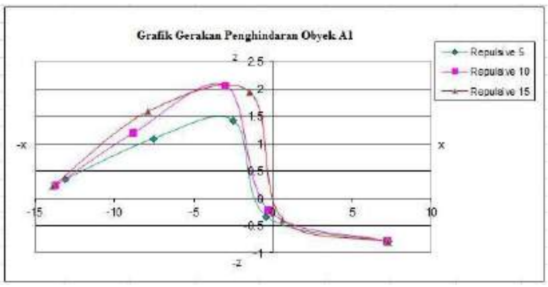
$$V = (Vx, Vy, Vz) = (-6.92, 0, -26.43)$$
$$|V| = \sqrt{(-6.92)^2 + (0)^2 + (-26.43)^2} = 27.155$$
$$Vx = \frac{Vx}{|V|} = \frac{-6.92}{|27.155|} = 0.2548$$
$$Vy = 0$$
$$Vz = \frac{Vz}{|V|} = \frac{-26.43}{|27.155|} = 0.9733$$

When all components of the vector are added it will equal 1.

$$Vx + Vy + Vz = 0.2548 + 0 + 0.9733 = 1.2281$$

D. Testing the Effect of Changes in Repulsive Field Values

Changes in the repulsive field value of the obstacle can affect the direction of the object's movement to get further away from the goal. Changes in repulsive values 5, 10 and 15 are shown in Figure 12.



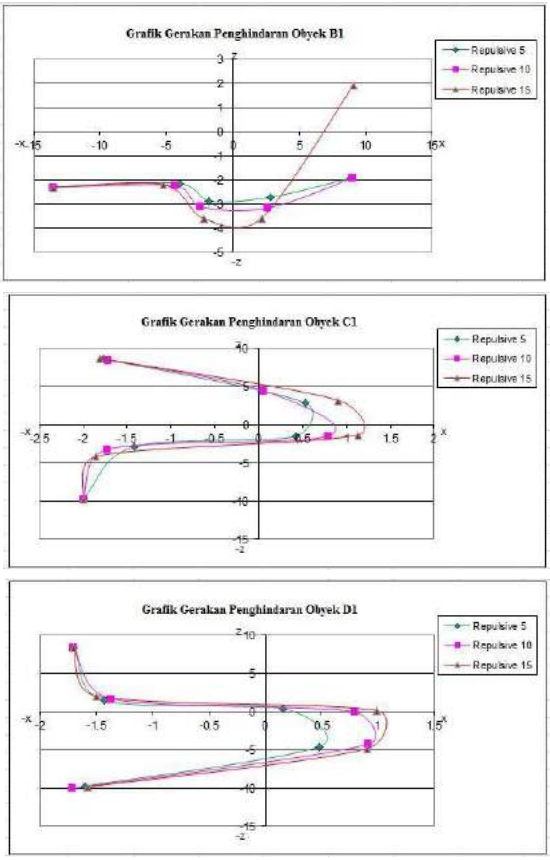
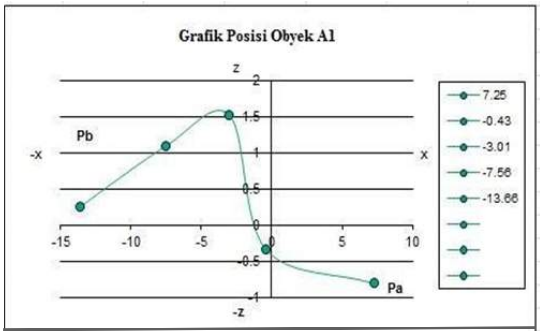


Fig. 12. Changes in repulsive values for the movement of objects A1, B1, C1 and D1.

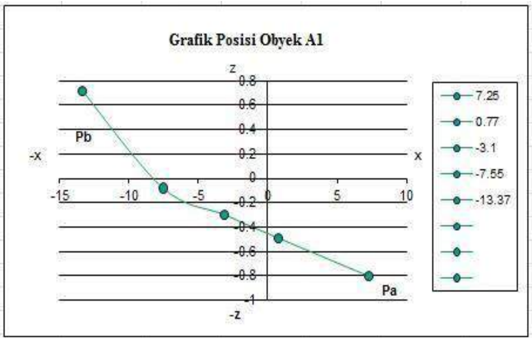
From all the graphic images above, the dynamic object movement as a result of changes in the larger repulsive value causes the dynamic object to move further away from obstacles due to the repulsive field so that the path traversed by dynamic objects to get to the goal is getting farther away.

E. Testing Object Movement Using Repulsive Field and Without Repulsive Field

The results of the movement of the A1 object using a repulsive field and without a repulsive field are shown in Figure 13. The movement of object A1 is from the positive x axis to the negative x or from right to left. Figure 13 (a) is a graph of the movement of object A1 when the obstacle is repulsive, while graph of Figure 13 (b) is shown that if the obstacle that is passed by object A1 is not repulsive, then the movement of object A1 tends to be linear because this path is considered a path closest.



(a) A1 object movement graph using a repulsive field



(b) A1 object movement graph without using a repulsive field

Fig. 13. A1 object movement graph with repulsive and without repulsive

This repulsive potential is stronger when closer to the obstacle and has a decreasing influence when is far away to the obstacle.

IV. CONCLUSION

Without the repusive field method on the obstacle graph, the dynamic object movement tends to be nearly linear as the path to reach the goal. Giving a repulsive field to obstacles, provides a path model for dynamic objects to get to the goal. Changes in the repulsive field value affect the direction of movement and distance of dynamic objects, the greater the repulsive value, the farther the dynamic object is from the obstacle.In this research, the number of objects that can avoid collisions is still limited according to road capacity. To get a good movement, it is necessary to have an accurate level of obstacle position and the right repulsive value where the objects displayed on ARToolkit are still using markers. For this reason, further research is needed to achieve this by using the markerless concept so that the marker does not have to be in the form of a black

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