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Survey of Neural Network based Marker and Marker-less Augmented Reality

Dakshita Sharma[1], S. Z. Gawali[2]
[1, 2] Department of information Technology, Bharati Vidyapeeth (Deemed to be) University College of Engineering Pune

***Abstract**: Augmented reality is the means of using a combination of hardware and software to enhance a person's vision of the world for a range of different applications [1]. However, many existing strategies that have been used to develop outdoor environment do not translate well to indoor environment. The reason is either the inability of the global positioning system (GPS) to navigate indoors or lack of input from the imaging device due to low light condition [2]. The vast majority of these implementations have assumed that lighting conditions are static, usually in an indoor or outdoor environment. Unfortunately, many of these implementations have problems adapting to dark lighting conditions. This paper is meant to address this issue directly by implementing a more robust system which takes both positioning and visual data and uses the optimum one. That will also be able to adapt in dark by not relying only on the imaging device.*

The proposed system uses the Bluetooth Low Energy (BLE) beacons for positioning to keep track of user's location as well as their orientation.

***Keywords**: Bluetooth Beacons, Augmented reality, Neural Network, Indoor positioning system, Gyro sensor, Trilateration*

I. INTRODUCTION

Augmented reality (AR) is very similar to Virtual reality (VR) with a difference that in VR user, experiences an entire different scene which may or may not have any relation with the real world, whereas in Augmented reality, scene is taken from the real world where some parts are overlapped or totally replaced. With such a huge potential, AR is already being used in a variety of industry like navigation, education etc. [1]. There are various types of AR technology that we can use that suits our need:

A. Marker Based AR

Generally we need trigger in AR in order to cue system to start displaying the relevant 3D model or image to the user. If the trigger is any image or visual marker then it is known as marker based AR. This type of AR totally depends on the visual information feeded , any obstacle in the visibility of marker will stop the AR from rendering [1].

B. Marker-Less AR

When AR does not depend on visual information but instead uses player's location with the help of GPS, digital compass and accelerometer embedded in the device in order to provide trigger for the system. This type of AR is usually used for navigation purpose. One of the first popular marker-less AR application is Nokia city lens. It was an app for windows mobile which tells you about the nearby restaurants and other places just by pointing your camera in its direction [1].

C. Projection Based AR

This type of AR is more interactive than any other as it can also receive input or interact with user. A light is projected in the real surface and then user's gestures like touch is recorded in order to make relevant action out of it. Laser keyboards can be taken as an effective example build out from projection based Augmented Reality system [1].

D. Superimposed AR

Up till now we have discussed about the AR system which is capable of placing virtual world object into real world without realizing where the object is, but superimposed AR are much more advanced and can basically replace an entire object in the real world with a virtual alternative along with keeping tracks of the plane like whether the object is on floor or on the wall [1]. This type can be observed in Microsoft HoloLens which efficiently uses surrounding information to identify planes.

E. Indoor Positioning System (IPS)

One of the most prevalent ways of locating a person or a mobile device is the use of GPS hardware. According to United States Government claims an accuracy of 4 meters in Global positioning system. This might be acceptable in outdoor environment. However, this might not give the exact position in indoor environment. Moreover, due to obstacles that would hinder the radio signal coming from the satellite. In such scenarios, an indoor positioning system (IPS) is usually deployed. [3]

Indoor Positioning System is based on three elements:

a) Tags - Mounted on objects or persons

b) Anchors – Mounted in the indoor area

c) Access point – Collects tag data in real-time

For indoor positioning there is a wide range of exceptional strategies and technologies [2]. Some of the IPS approaches are:

F. Vision based Positioning

In Vision based approach, there is generally a visual cue such as landmarks or maps in order to determine the location of the captured image. For doing so, the captured image is compared with the stored samples and the one which matches the most is considered. Such type of approach is generally used in robotics navigation [2]. But the issue with this approach is that there is a possibility that more than one image could be mapped with the sample. Also, in the low light condition it won't be able to capture the image in the first place.

G. Radio Frequency

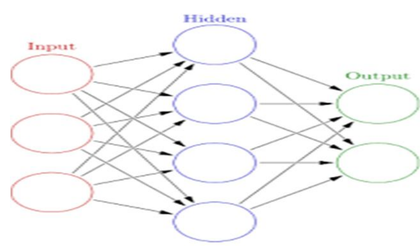
This type of approach uses radio signals through various hardware devices like Wi-Fi router, Bluetooth, UWD (Ultra- Wide band) etc. technologies like Wi-Fi & Bluetooth uses Trilateration i.e. uses data from 3 or more different beacons in order to pinpoint the location of the user. The ranges, power consumption of these devices varies and are used accordingly. However, radio signals can be blocked by obstacles or the person may simply get out of range. Hence, fails to keep track of the location of the user [2].

H. Inertial Navigation System

This approach uses accelerometer and gyroscope used in the smartphones. It is used in conjunction with other technologies to find the initial location of the user and then uses inertial positioning to fine tune the accuracy. In this paper, we are going to use the Bluetooth Beacon Technology for indoor positioning. BLE Beacon Technology has evolved in the past couple of years, as a means of sending position-based information to nearby users. Apple's iBeacon and Google's Eddystone are two types of similar devices that can be connected to almost any surface, which can broadcast a signal which can be picked up by smartphones and other similar devices, BLE gadgets are availed for marketing and informing users of adjacent points of regard [4]. In any case, utilizing RSSI information, an application can evaluate the space to a beacon. Therefore, with the usage of three or extra beacons collectively with a constructive algorithm, the user's location can be pinpointed. This work will assess the performance of few common algorithms for positioning that makes use of BLE Beacon Technology. Beacon Technology has some advantages in being cost-effective, easy to deploy, small in size and consumes low-power. Beacons were essentially built to detect proximity but are also used for localization. Although, there are numerous factors that contrarily affect the precision. Thereby, beacons often find their use case in indoorpositioning as a supplement to different advancements. Bluetooth Beacons can be used as a supplement to Wi-Fi.

I. Neural Networks

A neural network in computer science is replication of neural nets present in human brain in order to provide better reasoning and decision making. There are usually one or more inputs having their own weights which depends upon how much they affect the output.



Before feeding the actual input, the neural networks are to be trained with actual data in order to adjust their weights.

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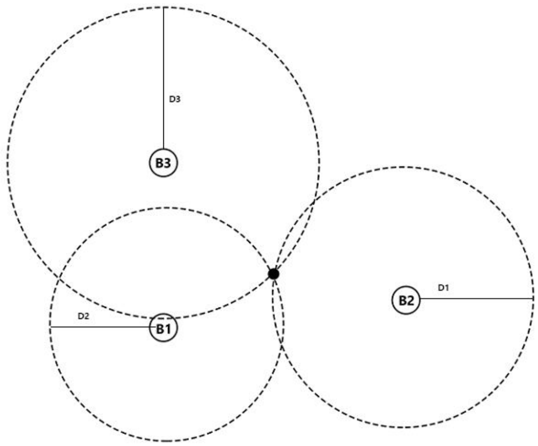
II. BASIC WORK AND ALGORITHM

In this section, the basic algorithms are explained that are used for converting raw data received from the sensors into relevant data that can be used for positioning.

A. Trilateration

Any positioning system do not have a directional information. It can only know how far any signal is coming from with no information of signal's direction. To know from which direction the signal is coming, it is important to have a line-of-sight to three or more reference and compare their RSSI values to each of them. A minimum of three reference are required to deduce the accurate position [5].

Trilateration is the process of determining the absolute position of a point by measuring distances between three or more reference points using the geometry of circles, spheres or triangles.



By measuring the distance of the known anchors, it is possible to know the required point's position. If we measure a certain distance, then we will be in a circle of that radius around the anchor. By measuring the distance with three anchors, it seen that the position is uniquely determined by the intersection of the three circles. This method is known as Trilateration.

The circles do not always intersect at exactly one point. Therefore, we try to find the point closest to all the circles

B. Algorithm

A point *(x, y)* on the Cartesian plane lies on a circle of radius *r* centered at (c_x, c_y) if and only if, it is a solution to this equation:

$$(x-C_x)^2 + (y-C_y)^2 = d_1^2$$

With the same reasoning, we can derive equations for the circles generated by the beacons. Each one has its own position, expressed with latitude and longitudes coordinates, (ϕ_1, λ_1),

(ϕ_2, λ_2) and (ϕ_3, λ_3) respectively.

The problem of trilateration is solved mathematically by finding the point $p = (\phi, \lambda)$ that simultaneously satisfies the equations of these three circles.

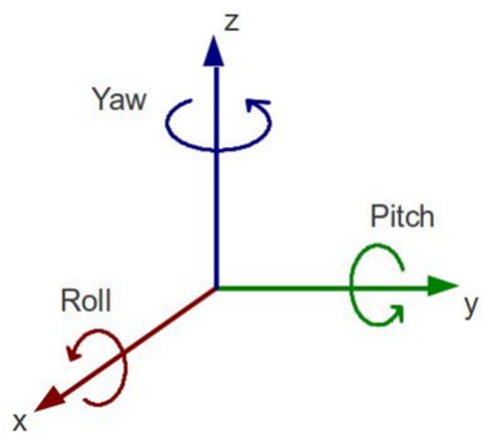
$$(\phi - \phi_1)^2 + (\lambda - \lambda_1)^2 = d_1^2$$
$$(\phi - \phi_2)^2 + (\lambda - \lambda_2)^2 = d_2^2$$
$$(\phi - \phi_3)^2 + (\lambda - \lambda_3)^2 = d_3^2$$

C. Accelerometer & Gyro Sensor

A gyro sensor is a device used to measure the angle and accelerometer, which gives the angular velocity. The above method (Trilateration) gives the position of the point but does not give the orientation in which the device is placed [6].

We can consider Accelerometer as a device which is capable of calculating acceleration of a device towards any axis which ultimately helps us in calculating the orientation of the device.

There are a total of three angles to be calculated in order to define orientation of a device:



Angle of x axis is known as Roll
Angle of y axis is known as Pitch
Angle of z axis is known as Yaw
Suppose the acceleration values towards each axis is provided by the Accelerometer and let them be:

R_x - is the acceleration value of x axis
R_y - is the acceleration value of y axis
R_z - is the acceleration value of z axis

$$Roll = atan2(R_{x,}R_{z,}) * RAD\_2\_DEG$$

$$Pitch = atan2(R_{y,}R_{z,}) * RAD\_2\_DEG$$

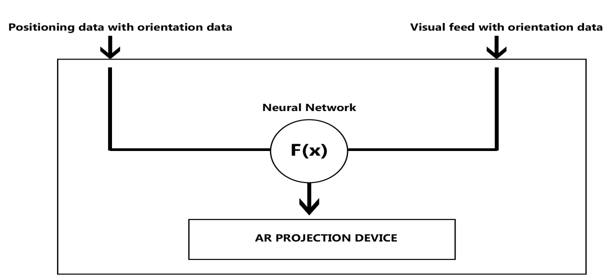
But to get the value of Yaw we need data of gyroscope and magnetometer as the data from accelerometer is prone to noises, even from slight vibrations. So let Ra, Rg and Rm be the respective roll data from the accelerometer, gyro and magnetometer, and w1, w2 and w3 be the weights given to the respective sensors, depending on which is more accurate. Then, the actual roll can be given by:

$$Yaw = (w1*Ra+w2*Rg+w3*Rm)/(w1+w2+w3)$$

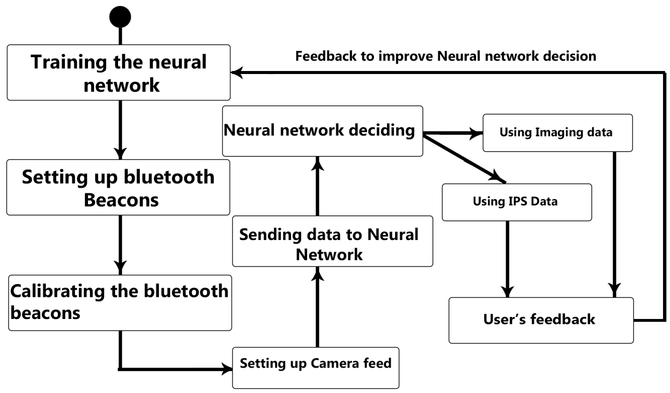
III. SYSTEM OVERVIEW

In our proposed system, basically instead of relying on visual input (as done by Marker based AR) or just relying on position input (as done by Marker less AR), data will be taken from both sides and the one which is more optimum or accurate will be used, or simply both can be used in order to enhance user experience. This would help us in coping with the lighting problems which usually happens in the Marker based AR or problem with the plane detection (detecting walls/floor).

As given in the figure, F(x) is the final output from the neural network which will tell AR projecting device whether to use Positioning data or visual feed or both in order to project best AR scenes.

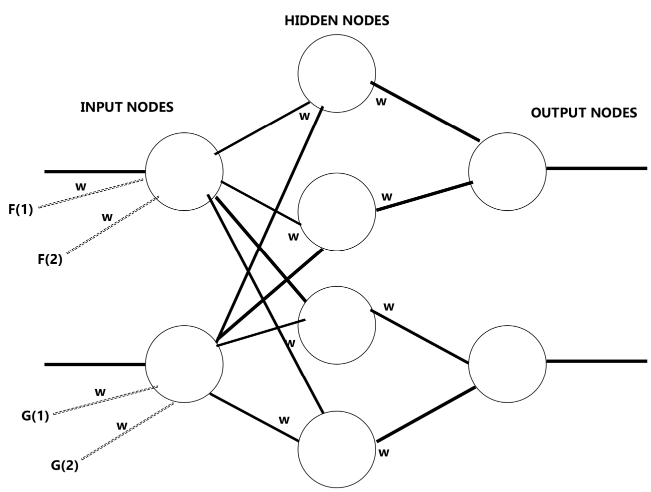


The flowchart shows how system will work initializing from training neural network to using them in order to provide optimum result.



A. Setting-up Neural Network

In this part, we will be deciding the input for the neural network that is to be used in order to make up deciding factor. The weight will be given to each factor of the inputs during training, i.e. imaging and IPS and the one which will be optimum will be chosen by the NN.



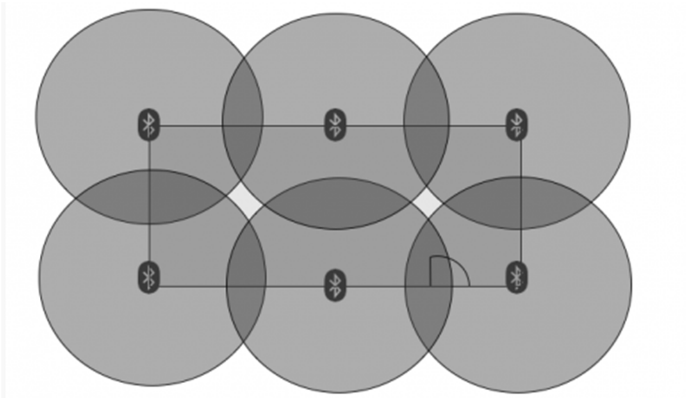
F(1), F(2) and others can be the features from the Imaging input side like light present, whether it's able to detect plane and so on, that may affect the AR scene.

G(1), G(2) and others can be the features from the IPS beacon based on number of beacons sending signals as more number of beacons means more accuracy. Also, whether signals are blocked by any obstacle or not. Or we can add the accuracy of IPS system by getting the average of accurate value from Accelerometer, Gyro sensor and magnetometer, where w1, w2, w3 are the weights given to the respective sensors depending on which is more accurate

$$\text{Average Accuracy} = (w1+w2+w3)/3$$

B. Setting-up Bluetooth Beacons

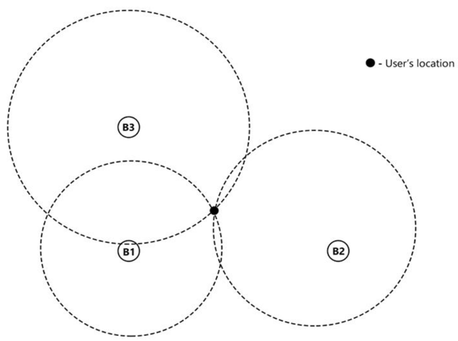
The beacons should be placed on the wall at a height of 2 meters [7]. Find the floor map of the environment and measure the dimensions of the room that would help to know the number of Bluetooth beacons required. Start by placing the beacons at the corner of the room. If the room is larger than the beacon's signal reach, then we would need more beacons in between the corners to provide location accuracy of 1-2 meters. We must make sure the room is large enough as the location accuracy falls between 1 to 2 meters. So, if the room is too small, then the device will not calculate trilateration.



If placing beacons to a shop, then add one to the enrance of the shop. When a customer with a smart device installed on it enters/exits the shop, then the event will be triggered. If aiming for an accurate position in a building with multiple floors, it is recommended to add beacons right after the entering/exiting staircase or lift. The places where you do not want an accurate position, leave it with less number of beacons [8].

Since, the range of Bluetooth is less, therefore, it is important to maintain proper signal in the room and no space in the room should be left uncovered.

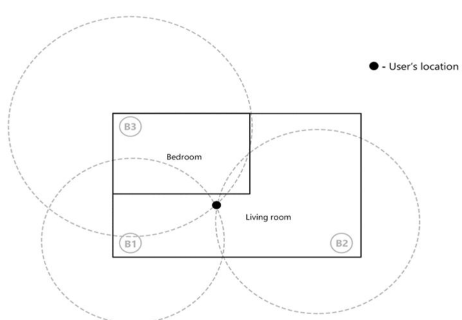
C. Calibrating the system



Initially, the AR device needs to be calibrated in order to determine the initial location from where we can start tracking. As the location data provided by the Bluetooth beacons will just be in respect to them, we need to relate it to the real world in order to start using it in AR scene. Further on, we can use the initial location as a reference in order to pinpoint location of a user. For calibration, the devices use its camera as an input in order to determine user's current location.

D. Updating location and angle

As the device will be used, it will keep a track of its location and orientation from its initial location. Whenever there's a condition of low light or no light, there will be no input



Received from the camera and the AR device will be totally unaware of its position. The data from the Bluetooth beacons and Gyro Sensor will be used to track the user's location and then the AR scene will be loaded up accordingly.

IV. CONCLUSION

In this paper, Neutral network-based marker and marker-less Augmented Reality is proposed which uses both IPS and camera data in order to project AR scene. Using the IPS techniques, it is easy to locate the position of the user in the low/no light condition. Also, we can detect the plane of the user using visual feed.

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