Single Access Point based Indoor Localization Technique for Augmented Reality Gaming For Children

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Abstract— **In this paper we discuss our attempt to solve the problem of Indoor Localization for a game intended to enhance learning among children by involving them in 'learning' along with 'play'. The first part of the paper describes our methodology towards the construction of the Augmented Reality Game for enhancing astronomy learning in children, emphasizing the experiential nature of tangible interactions and the remote dimension which the game can take, due to the available social media tools, by bringing people into a virtual 3D space to interact with each other. To keep the game simple and less complicated, we employ Single Access Point based Indoor Localization technique for tracking players. In the latter part of the paper we discuss the Indoor Localization system being implemented to track real time location of the player in his/her physical environment and the same being mapped on a virtual game arena for facilitating remote play dimension.**

Technologies used for early prototype:- basic optics for creating a device that gives 3D illusion of celestial objects appearing on 2D screen, a Kinect-sensor environment, and potentiometer for interactions.

Technologies for the game being currently developed: augmented and virtual reality elements, indoor position tracking using Kalman filter implemented inertial navigation system, with Wi-Fi RSSI data, onboard sensory data, geo-tagging.

Keywords: Tangible, Gestural, Intuitive, Interactions, Augmented reality, Virtual reality, Space coordinates, Depth perception, Experiential, Play and Learn

I. Introduction

Interactive, visual-based environments are known to facilitate learning in children, as well as pushing their ability to learn intuitively by using inputs from observation of their immediate environments. Given that increasingly children are being moved into non-activity based situations, often indoors, thus limiting their propensity for physical actions or their yearning for observation of their surroundings, can we leverage new available forms of tangible and spatially oriented computer-driven interactions with location-supported technologies to design experiences that feed naturally into ways in which children learn intuitively. Further, when this learning is masked by play (gaming being only one of several forms of play), such systems can be utilized to effectively support children's early cognitive development, in this case, for children under the age of twelve.

As stated in [1], ―with games being an original educational vehicle it is only natural to use them to teach children new information when children are unaware or uninterested in learning, thus stealth learning. The benefits of gaming include increased memory, class performance, social benefits, and improving the transfer of learning. Created with collaborative and cooperative learning built into the overall experience, games offer an engaging environment for information assimilation. Through games, players learn that rules are a part of our daily lives. When children are learning to play games, they are in fact learning a new literacy or language that is defined above and beyond traditional reading and writing, but through multiple interactions including images, text, diagrams, symbols and movement.‖ With current advancements in social media technologies, remote play can be made possible to enable the child to interact with those located away from the child's physical location.

For remote play to be possible, players though in different physical locations must share same virtual space and this demands real time position tracking of players and mapping the same in the virtual space shared. Since the game is typically indoors, it requires indoor localization of players. For GPS does not work indoors, many possible technologies were looked at. In subsequent sections we discuss how, depending on the constraints of game play, we used a single Wi-Fi router and the sensors available in mobile phone to approximately locate the player.

II. Early Prototype

The subject of Astronomy in itself is a cocktail of stories from different mythologies, intriguing science and fantasies of aliens and world beyond what is seen. Observing a lot of curiosity in understanding what lies ‗out there' among children, the subject of Astronomy was chosen to form the game around it.

With the intention of introducing the child with the nine planets of our solar system, their relative positions and their relative sizes, our initial attempt was to develop a multi-player

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Fig. 1: Early prototype – stack able device on a 2D screen to give a 3D perception of celestial bodies.

game with an intuitive and interactive interface. Realizing the competitive nature among children, a game where one player would pop different planets to trap the rocket being controlled by the second player while the second tries to escape was developed using the Processing software. To give a 3 Dimensional perception of the planets, a stackable device which would give a 3D illusion of any celestial body being shown on the 2D screen was developed.

The motivation for the development of this hardware was drawn from the famous Pepper's Ghost projection magic technique. Pepper's Ghost projection is an illusionary technique in which plate glass is normally used to make objects appear, disappear, to make objects transparent or to make one object morph into another. The hardware consisted of three such plate glass panes arranged at an angle of 45 degrees with the screen, at specific distances so as to avoid multiple reflections. This contraption ensures that the projection of objects on the screen falls exactly on the vertical plane of the virtual screen behind the glass panes. Due to the limited size of the tablet screen we used and in order to avoid multiple reflections three such panes were used.

The interface for the game was designed to be tangibly driven. Kinect sensor environment was made use of for gestures controlling the motion of the rocket while a microcontroller driven circuit was designed for facilitating the player with popping planets of his choice to trap the opponent's rocket and win the game.

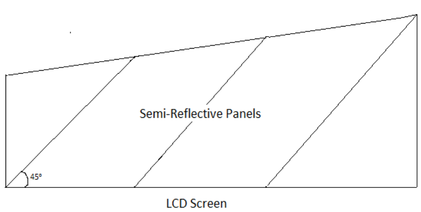

Fig. 2: Hardware setup used in the early prototype.

III. SECOND PROTOTYPE

Realizing that every child often has two friend circles – one that they interact at school and one at the place of residence and that maximum learning happens with the peer group at school, it was necessary that the game has a remote play dimension. With current social media technologies available, remote play can be realized to not only interact and involve with the concerned peer group, but also to involve in a game with any known people in known environment. Tangible interfaces go very close to how a human would react to any real object in day to day life; hence they are more intuitive in nature. For the child to play and learn in his very own physical environment, it is necessary that the interactions remain largely tangible and the intangible objects be augmented into the real world.

Tangibility, Remote, Social Media, Game were the keywords that had to be connected to make meaningful concept. For the game should be something easy to start, play with known friends in known environment (hence safe), has dynamic nature and not sitting in front of a screen incorporating tangibility and to bring together children not at one location to play together in the play environment. Game augments a virtual galaxy on physical space and the game-play happens through physical play and the virtual layer be shared in remote situations.

This requires real time location indicators to facilitate social interaction through physical play among children. And a device which would create a virtual gaming environment mapped onto the physical space defined by the user, and an augmented reality game which runs on the phone.

A. *Interface*

The players would walk into the space they want to convert into game environment and mark the centre of the game arena by placing the tangible toy on the ground and pressing the button. Once the game arena is set, the players share the same virtual layer still being in their respective physical locations thus facilitating remote play. Through Augmented Reality and facilitating geo-tagging, players can use their very own physical environment to interact with.

IV. INDOOR LOCALIZATION

The game demands real time localization of players in their respective physical environments and the same mapped on a virtual layer shared by all the players. As GPS does not work indoors, other alternative possible technologies were looked into to attempt solve this problem of localization of players.

WLAN-based systems, such as RADAR, are used to calculate positions by measuring the received signal strength of a radio frequency. On the other hand, the infrared-based methods, such as "Active badge system", finds positions using sensors that recognize the unique ID codes of IR devices. Although the system is simple and cost effective, it has a limited visibility range and line-of-sight obstructions. Ultrasonic-based systems like The Cricket system and the Active bat system uses the difference in the transfer speed between RF and ultrasonic signals. An RFID system which utilizes a tag-and-reader scheme transmits an activation signal to a tag and the tag replies to the reader, sending its unique ID.

Evaluating the available systems, the WLAN-based system has many advantages in terms of signal range, cost, availability and feasibility with the game. With an android powered device

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equipped with WLAN capability, it is easy to implement a positioning system compared to the other systems. NFC and RFID have very low range and BLE tags and Wi-Fi differ only in the range of coverage of its signals. Since Wi-Fi has a larger range compared to BLE tags, Wi-Fi was chosen to determine player's distance from the router. Moreover, the tangible toy which would be used in the game to mark the game arena would be the Wi-Fi router itself.

A. *Methodology*

Initially the approach for approximately determining distance of the player from the Access Point was chosen drawing analogy from an atom. If the Wi-Fi router is imagined to be the nucleus of an atom, and the players be the electrons in the electron cloud (here game arena), can we locate the players as electrons are approximately located around the nucleus – fully aware of the fact that the physical environments in either case are completely different [3]. If the maximum coverage area of the router and the percentage of signal strength at a point is known, can distance from the Wi-Fi router be calculated as

$$\text{Distance, } d = m*(1 - p)$$

where p is the percentage of signal strength and m is the maximum coverage area.

Since the RSSI and distance are not linearly proportional, of all available techniques, the best approach we thought was to use the Wi-Fi fingerprinting method. People could get really close to nearly accurate positioning by using Access Point triangulation methods. But since the game demands remote play, the best symmetric position of Wi-Fi router which all the players (typically children under age 12) could use is the centre of game arena – also one Wi-Fi router is something which is normally expected in homes these days.

But with a single Wi-Fi router only the distance of the player from the router can be determined. That means, the player can only be located on a circular region anywhere around the Wi-Fi router. So to determine the orientation of player with respect to the router, the available sensors on the android phone can be made use of.

A Navigation System was implemented using the available sensors on the phone and generating virtual sensors using the concept of Sensor Fusion. Displacement can be calculated by double integrating the acceleration data obtained from the accelerometer. But as the drift in the displacement values obtained from the system is very huge a Kalman Filter was implemented in the system to take care of the errors creeping in due to double integration [4],[5]. The navigation system would approximately give displacement value from the router and thus the orientation with respect to the router. Thus the radial distance of the player from the router and the orientation relative to router (along with distance from router, increasing the precision) can be determined using the Wi-Fi signal strength values and the sensors on the phone.

B. *Algorithm Model*

To determine distance of the player from the center of the WiFi router, an RSSI fingerprinting technique was adopted. Fingerprint technique consists of a two-phase process. In the

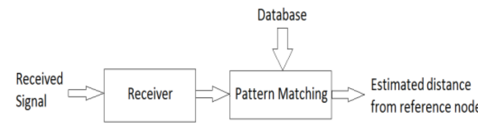

Fig. 3: Fingerprinting technique for indoor localization.

first phase, called the offline phase, the fingerprint information will be recorded as database and the corresponding distance vs RSSI curves will be drawn. These curves would look similar to Latapy curves used for mobile localization by cell phone towers, i.e. concentric circular regions with each region comprising of a range of signal strength values. In the second phase, called the online phase, the current measured signal information will be compared with those in the database by using the pattern matching algorithm and the region in which this particular signal strength would fall will be recognized.

As in Figure 4, let R denote the signal strength value and D denote the distance from the WiFi router (reference node). Let us suppose within the distance D_1 signal strength takes values from R_1 to R_2. Similarly R_2 to R_3 within the distance D_1 and D_1+D_2 from the node, R_3 to R_4 within the distance D_1+D_2 and D_1+D_2+D_3 from the node and so on.

Now if the measured signal strength value during the online phase, say R_{m1}, falls within R_2 and R_3 that means that the player may be located within the distance D_1 and D_1+D_2 from the reference node. In this way distance of the player from the reference node can be determined.

By making use of the onboard sensors in an android powered device, a navigation system can be implemented. Taking into account that the distance estimated by the navigation system is erroneous compared to that estimated by WiFi finger printing, the navigation system is used to estimate the orientation of the player with respect to the reference node.

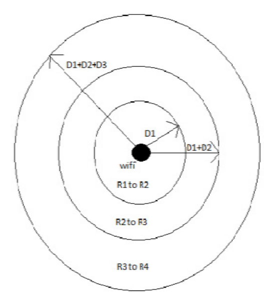

Fig. 4: Model showing RSSI vs Distance curves.

C. *Experimental Findings*

The experiment was performed in the first floor lobby of Humanities and Social Sciences Department, Nanyang Technological University, Singapore. A simple experiment was carried out where a single Wi-Fi router and an android powered device was used to map linear distance data with RSSI values in ASU metric for ASU metric had a lesser error range compared to other metrics. The measurements were performed using a specifically-designed Java API implemented on an Android device.

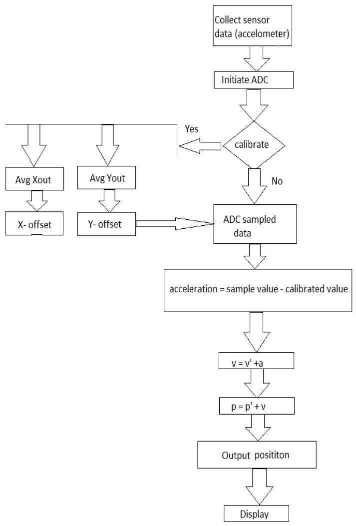

Fig. 5: Algorithm for implementing navigation system using sensors.

It can be clearly observed from Fig. 6 that the RSSI values followed similar pattern with distance in different directions as expected. Interestingly the signal strength values showed nearly constant drop in values over a specific distance range as observed in Fig. 7. Annular regions were located around the router based on the drop in RSSI values. Now the signal strength of the Wi-Fi signal which the phone receives will be monitored and based on the drop in values seen, the player can be localized in one of the regions. The orientation can be determined by using the mobile phone sensors through the navigation system. An accuracy of around 3.5 meters was achieved as far as linear distance data obtained from Wi-Fi was concerned and any inaccuracy would become part of the game.

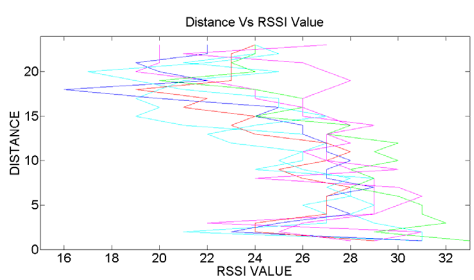

Fig. 6: Distance (foot) vs Signal strength (ASU) plot for measurements taken in different directions.

V. CONCLUSION AND FUTURE WORK

The early prototype described in this paper has proved to be suitable in enhancing the child‘s yearning towards learning our Solar system. With the assumption that the augmented reality game we are developing will help create within the child the

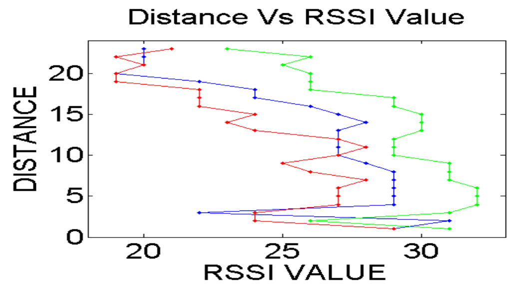

Fig. 7: Plot showing Distance vs Signal strength. It can be observed that though absolute values are different, drop in RSSI value is nearly same.

intended interest for space and the night sky an interface for locating players indoors has been developed. The positioning system is based on the existing Wi-Fi infrastructure and the phone sensors, and can be implemented on android powered devices. The main contribution is the proposal of blending Wi-Fi and the MEMS sensors of mobile phones for real time positioning of the player and mapping that on a virtual layer to facilitate remote play

Future work includes looking into the distance estimation techniques using the concepts of Time of Arrival, Angle of Arrival for LOS (Line-of-Sight) communications and to increase the accuracy in positioning by refining the filter implemented for dead-reckoning and thus increasing the accuracy of positioning. To increase the accuracy of localization in Line-of-Sight environments, techniques based on Optical Frequency-Domain Reflectometry are currently being tried out.

ACKNOWLEDGMENT

This research is partly supported by the Singapore National Foundation under its International Research Centre @ Singapore Funding Initiative and administered by the IDM Programme Office.

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