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Utilizing Simultaneous Localization and Mapping (SLAM) in Augmented-Reality Shell Game for iOS

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Abstract:
Augmented Reality (AR) are now integrated for productivity and quality improvements. Hence, this study aims on the improvements of mental training through AR using SLAM algorithm. The authors developed an augmented reality game where the application of skills and user interactions are monitored. This enhances cognitive development and training of users apart from having an immersive feeling that provides exciting, entertaining and engaging experience. A new AR tool was adopted by this study. In an AR implementation, integrating the ARKIT tool would remove the need of creating marker-based application. iOS mobile phone can adapt in the ARKIT tool by simply using visual sensors of the camera. This uncovers innovation of SLAM algorithm in the improvement of user experience on games. Through detailed analysis of the data, we found that 25 gamers and 25 non-gamers students were able to synchronize their actions and engage in both virtual and physical world during the visual evaluation process. Respondents who tested the game, non-gamer and gamers alike, commented mostly about the ARKit game that grant more entertainment as compared with others. In the end, ARKit framework displayed the proficiencies and bounds of SLAM algorithms when implemented in an augmented reality game for iOS; and at the same time, the shell game, incorporated by the power of AR, provided challenge on the memory and spatial skills of the participants.

Keywords: ARKit Framework, Augmented Reality, iOS game, SLAM algorithm.

I. INTRODUCTION

Augmented reality has been a hit in the technology world nowadays. Augmented Reality is used to overlaycomputer-generated images onto photos taken using smart gadgets in real time. According to Patrick Schueffel, Augmented Reality enhances one’s current perception of reality [1].

When developing AR applications, one of the ultimate challenges is how to make the application location aware with enough precision in different environment as stated by JonasHalvarsson in his research. He said that aconceivable solutionis to use Simultaneous Localization and Mapping (SLAM). He defined this algorithm as “when a moving camera or robot is using its sensory data to simultaneously construct a representation of the area it is in and position itself in that representation. This could then be used to create a better experience for the end-user by making a more streamlined experience with less mundane actions for the user to take”[2].

SLAM is a popular and significant autonomous mapping and navigation method used in mobile robotics according to Kozlov. He even added that SLAM development and testing is challenging because of the probabilistic nature and the real-world uncertainties in which the robot or device

November-December 2019
ISSN: 0193-4120 Page No. 4973 - 4979

functions and behave. The struggle occurs because of the lack of constant and cognitive overlap between the robot or device and the human engineer. It is hard to understand and visualize what the robot or device is seeing and processing real-time [3][4].

Broadly, the research deals with applying the technique of AR to visualize SLAM information, for system observation and development. As stated earlier, little work has been done in using visualizations for cognitive overlap in the context of SLAM. Current techniques are purely virtual visualizations (e.g. plots) of basic SLAM information. By using AR, the aim is to offer a significant cognitive overlap between the device and the researcher. By understanding the algorithm and its workings through visualization, the researchers should be able to observe and monitor its operation, and detect any algorithm or implementation related faults. Furthermore, as the AR view shows the real-world environment in which the device operates, the causes of faults which originate in the real environment should be easier to discover.

Since the technology is relatively new and unexplored, the researchers are motivated to device an application of SLAM algorithm in an AR setting in the means of an iOS game. The researchers aim to observe and understand the algorithm behind ARKit framework and test its accuracy, efficiency and overall implementation. The integration of SLAM algorithm in the iOS game is vital, as it is the foundation of every augmented-reality architecture. The researchers designed a simple shell game that uses permutation algorithm for its gameplay. To implement the SLAM algorithm in the iOS game, the researchers used the ARKit to provide an augmented-reality environment where the shells can be placed on a flat surface and simulate and blend it in the real world.

II. RELATED LITERATURE

SLAM algorithm has deviated to many versions, honing its efficiency and utility.

Mapping and localization are the main structure of SLAM. The problem arises on what to do first. This is a paradox that the algorithm needs to address. According to to a research by [5], he indicated in his study that the relocalization problem can be outlined back to robot or device global self-localization in given map. The relocalization turn into a tracing recovery problem with robots progressively applied to real world[6].

In a research of Rainer Kummerle [7], he discussed the Urban Search and Rescue Simulation. He cited that Balaguer et al. [8] employ the USARSim robot simulator. They compared the simulation and the real robot data and observed that the maps that they got was closely similar. The researchers concluded that in benchmarking different SLAM approaches, the engine simulator could be used. This broadens the potentiality of SLAM algorithm on its usage in mapping algorithm.

According to R. Lemus [9], he cited a research of Guivant, E. Nebot [10], The Kalman filter-based algorithm Compressed Extended Kalman Filter-based SLAM (CEKF-SLAM) maps by means of environment landscapes. This rises the algorithm's effectiveness without lessening the accuracy of full SLAM algorithms. Results of the study were promising.

He then introduced Extended Kalman Filter-based Monocular SLAM (EKFM-SLAM), founded on EKF-SLAMalgorithmhaving a camera add on as single sensor [9].In assimilatingdata of camera, the Random Sample Consensus [11] approach was implemented, where the movement of the camera was approximated; this technique also allows to get parameters' estimations.

November-December 2019
ISSN: 0193-4120 Page No. 4973 - 4979

Feder HJS et al. [12] discussed in their study that Loop closure is one more important challenge in SLAM. The robot's movement can affect algorithm's execution. Their system presents the idea of controlling the robot's movement into the relocalization, which seek to set right the shift and ultimately attain higher accurateness.

A solution was introduced by some researchers that was quoted in the study of Dellaert F. [6]. The researchers said that Clemente et al first implemented that solution[13]. These authors cited that they discovered match among landmarks in two submaps, which are very intricate and time-consuming.

Giorgio Grisetti elaborated an algorithm that can help in mapping estimates. He cited in his study that the Frese'sTreeMap algorithm [14] can be used to calculate nonlinear map estimates. This calculation disregards minor entries in the data matrix. Frese can do a reform in O(logn) where n is the number of landmarks. The aim is to calculate a network of constraints given an array of sensor analyses. At each level of the hierarchy, each section keeps a matrix rendering some of the landmarks confined in this section. To retain those matrices little, only those landmarks are characterized that are apparent from outside the section[15].

Mohamed Mustafa Abdalla Mustafa [16] deliberated a study about an interval approach for SLAM. The study proposed an interval SLAM (i-SLAM) algorithm as a new method that discourses the robotic mapping problem in the situation of interval methods. The authors indicated the noise of the robot sensor is assumed confined, and without any previous knowledge of its distribution, the author specified soft conditions that assure the conjunction of robotic mapping for the case of nonlinear models with non-Gaussian noise[17].

In applying the SLAM algorithm to augmented-reality, Dr. Joseph J. LaViola Jr. discussed in his study the framework used to try out a set of SLAM algorithms and evaluate their proficiencies of tracking a human subject carrying out a set of movements. They detailed the SLAM algorithms evaluated and explicate their potential practice given equipment combinations that may be established in a lab setting. They also go through each movement set, describing the hardware used in the recording procedure and how the user's actions are premeditated to test the limits of a SLAM algorithm. By developing a networked framework, they presented how the structure is simply improved to evaluate an algorithm with minor alterations to its code and how it may be utilized to device future SLAM study. The author concluded that their framework demonstrates the proficiencies and bounds of SLAM algorithms when tracking a user in an augmented reality environment [18]. Another study of Georg Klein [19] which focuses in Parallel Tracking and Mapping for Small AR Workspaces. He discussed way of approximating camera pose in an unknown environment. The authorssuggested a structureexplicitlyintended to trace a hand-held camera in an AR environment. The authorsrecommended to divide tracking and mapping into two isolated tasks, calculated in nonsequential threads, one thread assigned with the job of vigorouslytracingirregular hand-held movement, while the other construct a 3D map of point landmarks from formerlydetected video frames. The outcome is a structure that constructscomprehensive maps having thousands of landmarks which can be traced at frame-rate, havingaprecisionresembling that of advance model-based systems [20].

Additionally, Georg Klein also used SLAM on his study for augmented-reality using visual tracking. The author explained the steps on how he achieved his results. He stated that the studydisplays that visual tracking with low-cost

November-December 2019
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cameras can be adequatelysolid and precise for AR applications. Early visual tracking has been implemented to AR, thoughit needed artificial markers placed in the area; it proved to be unnecessary by the author. The studypresented that not only can tracking be made robust to motion blur, it can alsotake advantage from it. The effectiveness of the suggestedtechnique makes it a feasiblesubstitute for inertial sensors [21].

III.METHODOLOGY

This chapter will explain the steps and framework development taken to analyze the Augmented Reality Shell Game for iOS. The development of the game is discussed below.This game was used for the observation and evaluation of utilization of SLAM algorithm, its process and development. The following components give more detailed explanation for the steps and framework of the algorithm.

In developing the game utilizing the SLAM algorithm, ARKit Framework was used to implement the hardware and software requirements of the game. ARKit framework was announced with the release of iOS 11 and it is accessible for development with XCode 9.

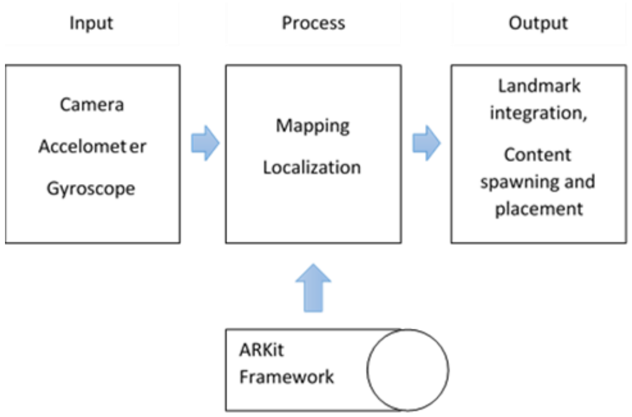

Figure 1. Conceptual Framework of ARKit utilizing SLAM algorithm in Game Design

Figure 1 shows the conceptual framework behind the development of the game. By implementing the ARKit that iOS and XCODE provide, the researchers modelled the flow of how SLAM algorithm coincides with the device's hardware and software. The device's hardware sensors like the camera, accelometer, and gyroscopes get the necessary data and the framework process that data to simulate the mapping and localization that the SLAM algorithm is designed for.

With the principles by Cadena et. al [22] in their paper, the standard architecture of SLAM is something like in figure 1. The figure shows three segments: (1) Input: On smartphones, this is mainly Camera, augmented by accelerometer, gyroscope and depending on the device light sensor. These sensors will collect the data for visualization and mapping; (2) Process: The feature extraction and data association perform error correction to compensate for the drift and takes care of localizing landmarks and overall geometric reform; (3) Output: This is the outcomeencompassing the tracked landmarks and locations. By pinpointing the change in position of the device relative to the landmarks, content is then adjusted.

Laviola J. cited that, the SLAM algorithm is then to compute an approximation of the device's location and environment's map. He added that the solutions to inferring the two variables together can be foundbyalternating updates of the two beliefs in a form of Expectation–maximization (EM) algorithm[23] [24].

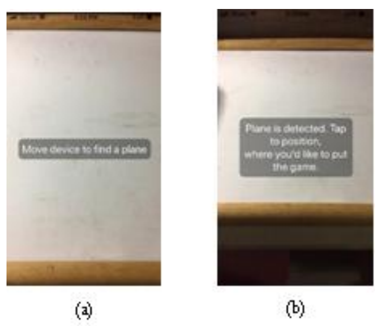

Figure 2. Example frames from initial screen of the game. (a) the device search for a plane. (b) plane detected and saved as landmarks.

TEST Engineering & Management

November-December 2019
ISSN: 0193-4120 Page No. 4973 - 4979

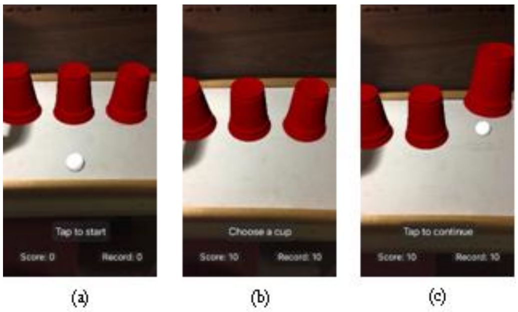

Figure 3. Example frames from gameplay. (a) 3D objects are spawned and placed after landmark. (b) gameplay proper. (c) game result.

Figure 2illustrates the initial screen of the game. The user is prompted to search for a plane for the landmarks to be registered. Once the landmark is established, the 3D game objects are then spawned and placed on the plane, as shown in figure 3. The game mechanics is a simple guessing game where the user needs to choose what cup contains the ball.

IV. RESULTS AND DISCUSSION

Analysis and interpretation of data gathered are presented for the evaluation of the effectiveness of the developed mobile game application Augmented-Reality Shell Game for iOS.

A scale of 1 to 5 is used for the interpretation of the mean of the evaluation. Lowest scale is scale 1 with an interpretation of Strongly Disagree and 5 for Strongly Agree.

The game was tested by a total of 50 individuals which consisted of gamers and non-gamers. The proponents surveyed 25 non-gamers and 25 gamers tested and critiqued the game. Non-gamers were included to ensure that the game could be played and easily understood by the majority and not only those who have prior knowledge in gaming.

The participants were also given a survey after playing the game for data gathering. The data gathered from the survey serves as input from the respondents on the game's functionality, reliability, user interface / user experience, and efficiency. Input from the respondents will also help in further improvements. The game was evaluated from 1 as the lowest and 5 as the highest to get its average.

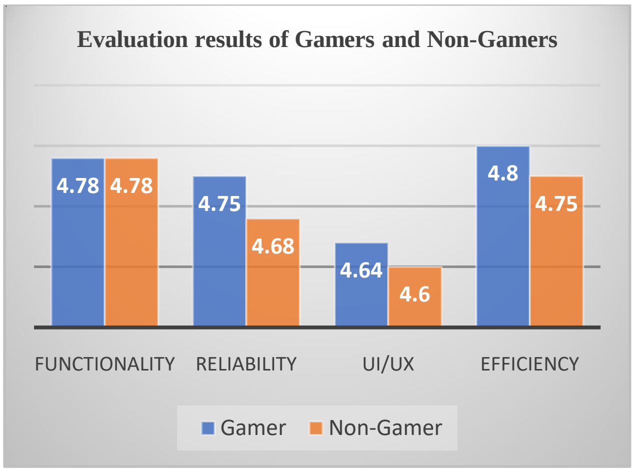

Figure 4. Evaluation results of Respondents.

Respondents mostly remarked the game's functionality as user-friendly and the tapping controls help them to navigate shown in the illustration above. Gamers respondents evaluated the game's reliability and predominantly get the highest average of 4.75 mostly because of the accuracy of the ARKit's detection on flat surface and did not cause any physical harm while playing the game. The UI/UX of the game gain an average of 4.64 and 4.6 by gamers and non-gamers mostly because of its appealing display and realistic 3D virtual objects. Lastly the efficiency of the game was rated 4.8 and 4.75 by gamers and non-gamers mostly because the 3D virtual objects are well rendered and are easy to familiarize.

Respondents who tested the game, non-gamer and gamers alike, commented mostly about the ARKit game that grant more entertainment as compared with others. The Augmented-Reality accords the game realistically and helped the respondents to have an ease in playing the game as a whole.

V. CONCLUSION

In this paper, the researchers created a game to test and simulate the SLAM algorithm that is the

November-December 2019
ISSN: 0193-4120 Page No. 4973 - 4979

baseline and backbone of Apple's ARKit framework. The researchers observed how the algorithm was implemented inside the framework. The two main step of SLAM, mapping and localization was replicated, observed, demonstrated and verified. Thru user evaluation, the study proved the SLAM algorithm, in theory and application, to be coherent and plausible.

Smartphone-based AR applications solve challenges that past Augmented Reality applications had. Marker based AR gave inconvenience of identifying visual markers that are embedded in the system.

The game was tested by a total of 50 individuals which consisted of gamers and non-gamers. The proponents surveyed 25 non-gamers and 25 gamers tested and critiqued the game. Non-gamers were included to ensure that the game could be played and easily understood by the majority and not only those who have prior knowledge in gaming. The participants were also given a survey after playing the game for data gathering. The data gathered from the survey will serve as input from respondents on the game's functionality, reliability, user interface / user experience, and efficiency. Input from the respondents will also help in further improvements.

The shell game, incorporated by the power of AR, provided challenge on the memory and spatial skills of the participants. Incorporating AR technology in games gave insight on other possibilities this technology could give in other aspects of life.

For the ARKit Framework of iOS, with the foundation of SLAM algorithm, we understood that there is still a long way to go to have precise tracking in a marker-less augmented-reality environment. Many solutions are done and implemented for the advancement of SLAM algorithm. Although there is room for improvement, implementation of ARKit framework in developing an AR application prove to have stability, precision, and robustness.

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