

Hybrid Cloud Computing for User Location-aware Augmented Reality Construction

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Abstract— In this paper, the *Hybrid Cloud Computing for User Location-aware Augmented Reality Construction* is proposed including three layers: Estimation Layer, Scenario Layer, and Presentation Layer. Based on “Angle of the Arrival” position method in Estimation Layer, the location-aware information of individual user can be considered. According to Scenario Layer, the various augmented reality contents can be rapidly and dynamically re-established. Three types of virtual machines including scenario virtual machine, material and physical parameter database, and re-direction management are proposed. Based on the proposed system structure, the cost of AR construction can be reduced for the various display devices.

Keywords— Augmented Reality, Cloud Computing, Edge Computing, Location Aware, Game

I. INTRODUCTION

From 2016, the mobile game Pokemon[1,4] is released and popular over the world. Niantic developed the game with the location-based augmented reality. The player can see the “monsters” based on the GPS. Furthermore, according to the designing of the mobile game, players can also locate, capture, or battle with the “Pokemon monsters”. Based on the augmented reality (AR), the computer vision, physical real-world, and the virtual reality make the information of the world become interactive and digitally manipulable [2]. Today, various technologies can be used to render the augmented reality environments such as monitors, handheld or mobile devices, and the wearable devices [5]. Then, the users can interact with the objects or environments in the real-and-virtual world [3].

However, to create the augmented reality world, how to integrate augmentations realistically with the real world is the important issue. By processing the algorithms or software, the camera images of the computer vision will be processed as the tracking index for matching the registered images of the database. If the augmented reality players wear the headset display, it means that these players cannot sense the physical space and the real environment based on their instinct. The sense of sight will be limited by the headset display. In other words, most of the augmented reality game based on the wearable devices especially the headset display will be limited or fixed at the specific location or the flat space for the safety. Since the purpose of the augmented reality is to create the

real-and-virtual world, the augmented reality the intuitive sense of sight with various environments can be more interesting.

In addition to the digital camera, GPS, wireless sensors, Bluetooth[6], or RFID [7,16] can be also used as the tracking technologies for augmented reality. According to the feature detection results [14], the augmented reality system restores the real world coordinate by the corresponding virtual objects in the presentation such as screen or application. Finally, the real-and-virtual world for interaction between users and objects can be created.

To track the users and the environments, the GPS technology is generally used. However, GPS signal is not stable or available when users are inside the buildings. The accuracy of the position and location to the users is also not good enough. Therefore, some of the locations-aware or location-based services try to detect the wireless signal for locating the users[15]. Time Difference of Arrival (TDOA) or Time of Arrival (TOA) [17] was proposed to detect the wireless signal of the user. Based on the distance differences between the user (or mobile host) and the terminals (measure points) with fixed locations, the arrival times of radio or wireless signal to different terminals are different. Then, the TOA algorithm uses the time of flight (TOF) between mobile host and terminal to find distance. Similar to the TOA, the TDOA algorithm calculates the differences from the signal receiving time of different terminals to find the location of the mobile device or user. In addition, the Angle of the Arrival (AOA) was also proposed to estimate the location of the mobile host. Instead of the time, the AOA algorithm uses the angle of the signal received by the terminal to find the mobile host.

However, not only the location estimation but also the augmented reality computing are needed. If there are various and many virtual objects in the augmented reality world, rendering the real-and-virtual world will need huge computing resource. In addition, considering the interaction between users and the augmented reality world, the states or functions of the interactions should be computed and processed. Computing or image processing works done only by the mobile host cannot be fast enough. Therefore, to involve the cloud computing for more computing resource becomes the possible solution [18].

Cloud computing today is popular technology for the high performance of computing. All the information can be managed and transmitted via network. The computing resource can be integrated as the resource pool for rapidly using according to the requirements of users. Based on the remote cloud computing platform, the local computing load can be sent and processed via network. However, considering the traffic load of the network, to reduce the transmission of data or information is needed. Hence, the edge computing is proposed [8]. Edge computing is established next to the data of information source. The similar computing jobs will be managed and processed locally by the edge computing. In other words, the data transmitted to the remote cloud platform via network can be reduced.

The rest of this paper is organized as follows. Section 2 presents the related technologies. Section 3 shows the proposed Hybrid Cloud Computing for User Location-aware Augmented Reality Game Construction. In the section 4, the conclusion is presented.

II. RELATED WORK

In this section, the related technologies such as augmented reality, location estimation based on wireless signal, and the cloud computing will be introduced.

A. Cloud Computing and Edge Computing

Cloud Computing was proposed to provide the huge computing resource for rapidly using [12]. All the physical computing resource will be integrated as the resource pool. All the computing resource, machines will be virtualized for the client users via network. In addition, all the information or data processed based on cloud computing will be delivered by network. According to the on demand given requirements of the client users, the corresponding computing resource and virtual machine can be established or re-established quickly. In other words, based on the on demand configured virtual machine, the client users can obtain the huge computing resource via network quickly and return the computing resource to the resource pool immediately when user disconnects the virtual machine.

However, the traffic load of the network will be increased and heavy if all the information or data should be exchanged between the local physical system and the remote cloud virtual machine. Since the cloud computing should be established with huge computing resource, to create the cloud platform next to the data or information sources will be not easy. Therefore, the edge computing can be used to calculate or process the routine functions or evaluations at the local side. In other words, the edge computing can help system process the raw data locally with less time delay of network transmission.

B. Augmented Reality

Augmented reality based on the computer vision and the digital camera integrates the real (physical) world with the virtual objects. The integration results of the real-and-virtual world can be shown by the mobile device. In other words, how to adapt the virtual objects for the corresponding physical

environments including the mapping, material, or rendering of objects is an important issue.

Currently, many augmented reality games are implemented based on the Vuforia [9] which was proposed by the Qualcomm. The Vuforia supports the SDK for the iOS and Android system of mobile phone. The Unity game engine can also supported for augmented reality applications on PC or mobile devices. By including the Vuforia, the Unity can implement the virtual objects and environments more easily. After including the ARCamera and Image Target functions, the camera of PC or mobile device can be used to find the corresponding virtual objects which are presented by the Data set of the Image Target Behaviour (Script). When the camera identify the on demand defined graphic or specific pattern, the corresponding virtual objects of Image Target will be re-presented or shown by the AR devices.

Hence, to integrate the real (physical) world and the virtual world based on the specific pattern identification, AR players can sense or see the real-and-virtual world.

C. Position Estimation

To track the users and the environments, there were various methods proposed. Based on the wireless technologies such as the Bluetooth [6] Low Energy (BLE), Zigbee, Radio Frequency IDentification (RFID), or the WCDMA / 4G LTE, the distance between the transmitter and the receiver can be evaluated according to the equation as follows:

$$P_R = P_T \frac{G_T G_R \lambda^2}{16\pi^2 D^2 L} \quad (1)$$

P_R is the power received at the receiver. P_T is the power at the transmitter. Suppose that the signal length of the wireless signal is the same, and the power transmitted from the transmitter is fixed. Then, the power received will be square inverse proportion with the distance between the transmitter and the receiver. In addition to the distance, the direction should be considered for estimating the location with higher accuracy.

Time Difference of Arrival (TDOA) or Time of Arrival (TOA) [17] detect the wireless signal and calculate the time differences to find the location of the mobile device or user. Two TDOA values from at least three terminals can be used to formulate the hyperbola functions. The intersection point of these two curves can be defined as the location of the signal source (mobile host).

Angle of Arrival (AOA) was also proposed to find the location of the mobile host [10, 11]. Since the receivers or terminals can be developed at the fixed locations with stable power, the directional antenna can be connected for detecting the time difference from the transmitter to the receiver. In other words, to estimate the direction of the transmitter based on the receiver is possible. By deploying at least two receivers or terminals with on demand defined or known locations, direction and distance between the receivers, the location of the transmitter can be estimated by:

$$\begin{bmatrix} x_m \\ y_m \end{bmatrix} = \begin{bmatrix} x_1 \\ y_1 \end{bmatrix} - \begin{bmatrix} r_1 \cos \alpha_1 \\ r_1 \sin \alpha_1 \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} x_m \\ y_m \end{bmatrix} = \begin{bmatrix} x_2 \\ y_2 \end{bmatrix} - \begin{bmatrix} r_2 \cos \alpha_2 \\ r_2 \sin \alpha_2 \end{bmatrix}$$

where x_1, y_1 is the coordinate position of terminal 1; x_2, y_2 is the coordinate position of terminal 2. r_1 is the distance between the mobile host and terminal 1; r_2 is the distance between the mobile host and terminal 2. α_1 is the angle of the two vectors: vector from terminal 1 to terminal 2, and the vector from terminal 1 to mobile host. α_2 is the angle of the two vectors: vector from terminal 2 to terminal 1, and the vector from terminal 2 to mobile host. Therefore, the location of the mobile host or device can be estimated. The concept can be shown as follows.

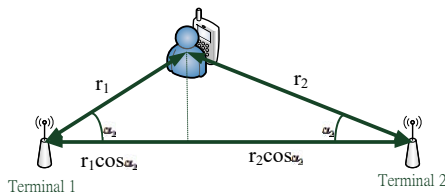


Figure 1. The concept of Angle of Arrival

III. PROPOSED SYSTEM

In this section, the structure of the proposed Hybrid Cloud Computing for User Location-aware Augmented Reality Construction is presented. Corresponding to the dataflow and the location of the devices, there are three layers proposed: Estimation Layer, Scenario Layer, and Presentation Layer. All the information will be exchanged between different layers. The structure can be presented as Figure 2. The components with yellow color are established on the cloud platform for rapidly and repeatedly constructed. The edge computing with the color green can be implemented by the cloud platform or the embedded system at the local side.

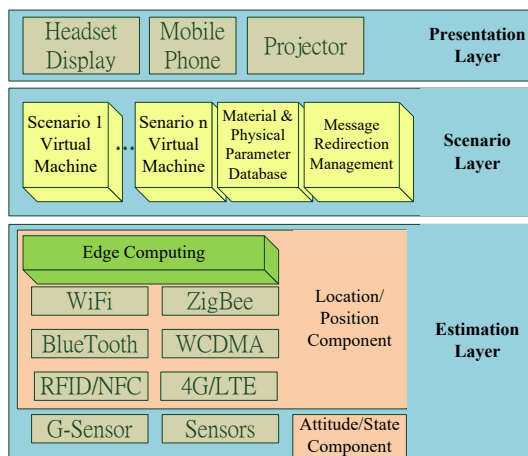


Figure 2. The proposed system structure.

A. Estimation Layer

Today, many mobile devices already equip a lot sensors and communication interfaces such as G-sensor, camera, 4G LTE, Bluetooth, WiFi, Near Field Communication (NFC), etc. To classify these sensors and interfaces, two components of the estimation layer are defined: Attitude/State Component and Location/Position Component.

Based on these sensors embedded in the mobile devices, the angle of depression and elevation, or the direction of the camera can be estimated by the mobile devices. In other words, the state or attitude of the individual mobile device can be estimated and presented as the digital data. Therefore, the sensors or hardware are defined and managed by the Attitude/State Component. In other words, the Attitude/State Component is used to re-present the state or attitude of the mobile device in the digital information way.

In addition, to locate the individual mobile device is needed in the proposed AR environment. Based on the wireless signal including 4G LTE, WiFi, Bluetooth, RFID/NFC, etc., the on demand placed and deployed access points can receive the signal and estimate the position or location of the mobile device. However, considering the implementation in the real (physical) environment, the corresponding location or distance of the access points in different spaces are also different. In other words, the corresponding values or parameters may not be the same when using the same position estimation functions. To exchange all the data between the devices, access points, and remote servers for position estimation will increase the load of the network and the time delay of transmission. Since the position estimation function is the same, and only the values of the parameters may be changed, to estimate the position at the local side based on the edge computing is the possible solution.

In this paper, the Location/Position Component includes not only the wireless signal interfaces of mobile device but also the edge computing at the local side. Due to the on demand placed and located access points, the values of parameters in the estimation function can be on demand given. Hence, the edge computing can only calculate the estimation function when the access points obtain the wireless signal from the mobile device. In other words, the edge computing of each individual space only needs to repeatedly calculate the estimation function even there are many mobile devices. The raw data can be represented as the estimated position data.

Therefore, the proposed estimation layer can be used to represent the raw data from the mobile device as the attitude and position information. The traffic load of the network can be reduced.

B. Scenario Layer

Since the AR environment integrates the real world and the virtual objects, most AR environment should be on demand defined for the AR players. To dynamically change the definition or the presentation corresponding to the Image Target Behaviour (Script) will not be easy. Therefore, in this paper, the scenario layer including the scenario virtual machine, material and physical parameter database, and the

message redirection management based on the cloud computing is proposed.

According to the estimation layer, each space corresponding to the each edge computing will be deployed access points. However, one AR world may consist of several continuous real (physical) spaces. Therefore, all the spaces which are connected for the single AR world should follow the same configuration of the AR scenario. In other words, the estimation results of the edge computing should be sent or exchanged with the corresponding AR server. Hence, the messages from the edge computing should be re-directed to the correct scenario server by the message redirection management. Finally, the information can be exchanged between the edge computing and the corresponding AR server correctly.

Since various physical spaces can be connected for the specific AR scenario, the related physical information or parameters appeared in the virtual world should be the same in these physical spaces. To configure the values of the parameters for each physical space is difficult. In addition, based on the Image Target script, different objects in different physical spaces will be represented by the same virtual objects. In other words, by using the virtual objects based on the Data set of the Image Target, the presentation in different physical spaces can be the same. Hence, in this paper, the material and physical parameter database based on cloud is proposed to record and store the values of material and physical parameter. To describe the virtual objects, the physical parameters such as material, shape, even the reflective should be defined and given. Since the AR scenario can be established dynamically, the corresponding physical parameters of the objects should be also possible for defined dynamically. By using the proposed material and physical parameter database on cloud, every virtual object from the Data set of the Image Target can be defined via accessing the database.

Based on the message redirection management and the material and physical parameter database, the scenario virtual machine can configure the real-and-virtual world environment which based on several physical spaces. In addition, the interaction of the AR players should be also considered and processed. Different AR players may be located at the different physical spaces which are connected as the continuous world in the real-and-virtual world. Therefore, the interaction between the players and the environments should be considered. For example, if the scenario virtual machine creates the AR environment for the shooting emulation training, then the shooting angle, direction, the ratio of the bullets penetration in the real-and-virtual world should be calculated. Since the AR world can be represented by the corresponding to the Data set of the Image Target, the wall, the windows, the doors which appear in the AR world can be represented by another material or virtual objects. According to the on demand configured physical characteristic which from the material and physical parameters database, the wall can be presented as the stone wall, woody wall, etc. Figure 3 shows the AR implementation in this paper. The wall is presented as the gravel wall which consists of the virtual

object presented according to the Data set of the Image Target and the configuration from the material and physical parameters database. Then the scenario virtual machine should compute and evaluate the possible physical situation. Therefore, in the shooting emulation training, the scenario virtual machine will decide that the bullet cannot pass through the wall.



Figure 3. The AR implementation consists of the information from physical parameters database and Data set of the Image Target

Finally, the proposed scenario virtual machine can manage the whole AR environments which consist of physical spaces and the virtual objects for the players.

C. Presentation Layer

Since the AR environments can be established by the scenario virtual machine, only the corresponding information will be sent to the end devices for presentation. In other words, based on the cloud environment, the AR scenario or environment can be re-established dynamically and rapidly. The virtual machine based on cloud computing will process most workload of AR rendering. In addition, according to the presentation conditions, the corresponding AR resolution to the devices such as mobile phone, headset display, projector, etc., will be provided from the virtual machine to the local devices. In other words, the display devices can only used for presentation with less workload.

IV. CONCLUSIONS

Based on the proposed Hybrid Cloud Computing for User Location-aware Augmented Reality Construction, the augmented reality environment can be constructed via connecting several physical spaces with individual edge computing. The user location-aware information can be obtained and computed by the edge computing. Then, the AR players can see the both physical (real) environment and the virtual objects corresponding to the location at the same time. Via using the proposed virtual machine and database, the AR scenario can be dynamically and rapidly re-established. The performance of the AR construction can be higher based on the proposed scenario virtual machine. In addition, the cost of re-construct the AR scenario can be reduced.

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