Real and Virtual Worlds Linkage through Cloud-Mobile Convergence

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***Abstract*—In this paper, we introduce real and virtual worlds linkage through Cloud-Mobile Convergence for Virtual Reality (CMCVR). First of all, we consider opportunities and requirements for dual (i.e., real and virtual) worlds linkage through CMCVR. Then, we present an implementation of an object-based linkage module prototype on a mobile phone, evaluation results of obtained 3D points normalization, and applications. Through the prototype, we derive and discuss what is necessary for releasing the initial point assumption. Following to these steps, we have confirmed possibilities of such dual worlds linkage to play a vital role in bridging objects and content in CMCVR.**

I. INTRODUCTION

Recent developments in Ubiquitous Virtual Reality (U-VR or ubiquitous VR) [1] and Cross-Reality (X-reality) [2] enable seamless information exchange and synchronization between the real world and a virtual world system. The two worlds are blended by linking the real world to the virtual world and vice versa. In this setting, resources such as objects and content that have existed in only one side of the world become ubiquitous in both worlds. Therefore, users need a novel linking method to create an interest point on an object with associated digital content for sharing and managing them in both worlds consistently as proposed in previous work [3].

Previous works on integrating the physical world and the virtual world have focused on bi-directional information exchange between the both worlds. Yoosoo Oh and his colleagues introduced the U-VR Simulator that connects entities in both worlds for simultaneous monitoring and simulation [4]. Beth Coleman introduced sensor-based projects that create sensory information flows from the real world to the virtual world or real-virtual-real with feedback loops [5]. Michael Rohs proposed visible entry points that allow for a quick transition between the real world and the web as an example of the virtual world [6].

On the other hand, the goal of "Cloud-Mobile Convergence for Virtual Reality (CMCVR)"[7] is to effectively integrate

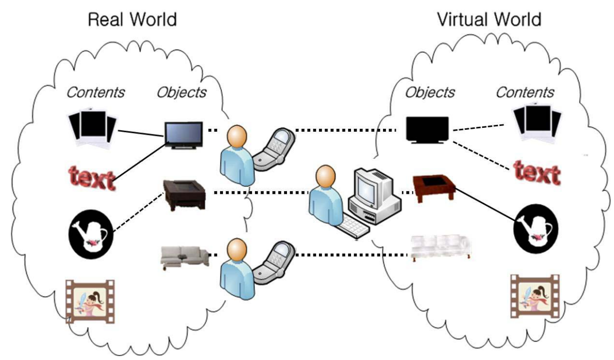

Figure 1. A Model of Real and Virtual Worlds Linkage through CMCVR

mobile device and cloud-based resources such as content and computing power. In this viewpoint, objects (e.g., TV, table and couch) and content (e.g., digital multimedia resources such as photo, text, 3D model and video) in real and virtual worlds are cloud-contents, and mobile phone and desktop are cloud computing resources as shown in Figure 1. In this paper, we introduce real and virtual worlds linkage through CMCVR. For realizing such a linkage, we examine some requirements and implement an object-based linkage module prototype on a mobile phone. During a process of experiments, we have confirmed the need to release the initial point assumption and proposed future direction of our work.

II. OPPORTUNITIES FOR DUAL WORLDS LINKAGE THROUGH CMCVR

While three major parts (i.e., scene, rendering and interaction) of VR/AR applications could be enhanced through CMCVR in [7], dual (i.e., real and virtual) worlds linkage through CMCVR improves scene and interaction as follows. Up to now, though we didn't improve rendering part, we can exploit pervasive processing power to complement the limited resource of a single mobile device.

- **Scene:** Dual worlds linkage enables a mobile device to add various content from the Internet on user-generated dual locations. Therefore, cloud-based content can be converged through the linkage.
- **Interaction:** For authoring task, mobile device-based interaction such as translating and rotating is difficult in the real world, while desktop-based such interaction is

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TABLE I. DATA FORMAT FOR CONSISTENT MANAGEMENT OF RESOURCES IN DUAL WORLDS

Category	Attribute	Field
Environment	Location	Latitude, Longitude
User	Community	Group ID
Object	Name	Object ID
	Geometry: PointSet	Number, Color, Coordinate
	Geometry: IndexedLineSet	Number, CoordniateIndex
	Geometry: IndexedFaceSet	Number, CoordinateIndex
	Appearance: TextureSet	Number, CoordinateIndex, TextureURL
	Relationship: TagListSet	Number, TagID, Transform
	Descriptor	Number, DescriptorURL
Content	Type: Text	Number, String, Transform, Size
	Type: Photo	Number, PhotoURL, Transform, Width, Height
	Type: 3D Model	Number, 3DModelURL, Transform, Width, Height, Depth
	Type: Video	Number, VideoURL, Transform, Width, Height

simple to control in the virtual world. Therefore, these two types of interactions need to complement each other in dual worlds.

III. CHALLENGES FOR DUAL WORLDS LINKAGE THROUGH CMCVR

In addition to above enhancements, there are requirements for dual worlds linkage through CMCVR as follows.

- **Data Format:** In order to share linkage-related information between different platforms such as a mobile phone and desktop in dual worlds, we should use inter-operable data format. In previous work [3], we proposed a tag data model called CAMAR Tag, which is composed of a model context, an environment context, a user context and a content context. In this paper, we consider the minimum but essential requirements for consistent management of resources in both worlds as follows. 1) It should include attributes to transfer real world objects and content to the virtual world counterpart. 2) It should include attributes to render and visualize virtual content in the real world. 3) It should contain attributes that can be easily indexed and checked for relevancy according to the current context, so that only relevant tags are retrieved from the virtual world server. 4) The relationships of tagged objects should be included in attributes. This enables accessing and displaying an object and content of one tag from accessing another tag transivitively. Table 1 shows tag data format derived from above requirements

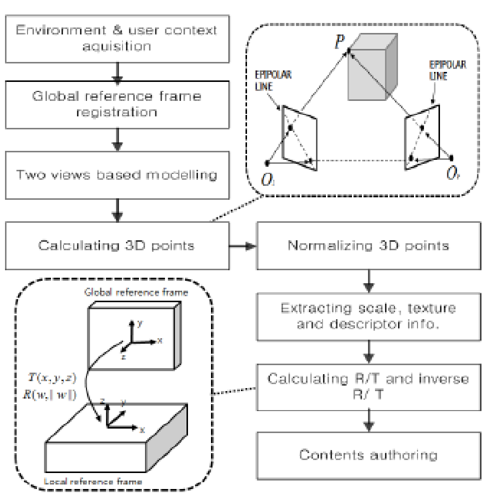

Figure 2. Flowchart of model-based object linkage with an initial point

- **Registration:** As shown in Figure 1, a user on a desktop navigates mainly virtual world and carries out an authoring task. On the other hand, a user on a mobile phone navigates real world and performs an authoring task while expecting the results to be reflected in the corresponding virtual world. Therefore, mobile phone-based authoring task needs a linkage task, which consists of global registration and local registration for setting up a reference point visually. Another term for the global registration is initial registration, which is a required process for making arbitrary local registration-based reference point.

IV. PRELIMINARY RESULT

A. *Model-based object linkage with an Initial Point*

This section describes dual worlds linkage method accomplishing global registration as an initial point and local registration as a model-based object. We assume that the initial point is already known, and exploit it for global registration.

Then, we conduct two-views based modeling interaction for calculating 3D points. In this step, we obtain rough points by clicking on touch screen, and get precise points by dragging and adjusting them to model-based object. After that, we obtain model-based object attributes such as lines, faces, textures, and descriptors. Figure 2 shows this processes.

B. *Evaluation Results*

We used the ubiHome, which is a smart home test bed to represent a real world and the virtual 3D ubiHome as the corresponding virtual world [8, 9]. We used a mobile phone with a 624-MHz CPU and 80MB memory and a desktop with 2.8GHz CPU and 1GB memory. As shown in Figure 3, real and virtual TV objects are common in both worlds by using pattern marker for global registration. Therefore, we can calibrate two camera views extrinsically from extrinsic parameter results of the pattern marker. Figure 3 shows processes of table and box model-based object linkage,

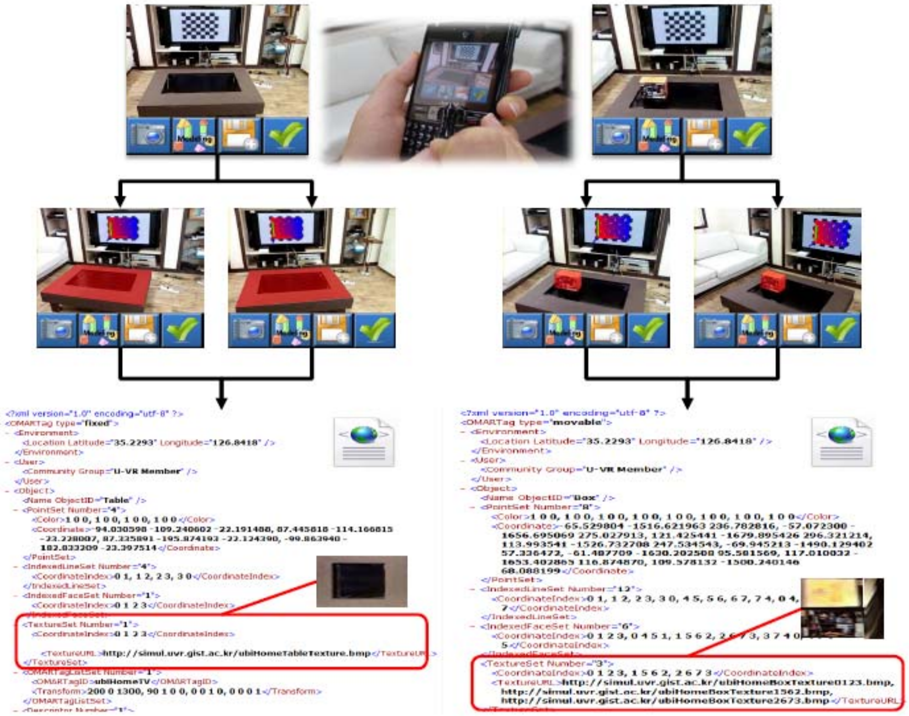

Figure 3. Implementation of model-based object(e.g., table and box) linkage with an initial point(i.e., pattern marker)

respectively. XML is used to represent tag information. Figure 4 shows before and after normalization of the obtained 3D points of a table when carrying out modeling interaction. As shown in the Figure 4(1), we acquired correspondences based on two-views, where yellow lines denote epipolar lines. However, the obtained 3D points were not stable, and the Figure 4(3) shows the points as original xy and yz points. To make the points more stable for rendering, we applied points normalization by considering a primitive model's geometry structure. The Figure 4(4) shows the results maintain object's geometry structure. Then, the resulting 3D points can be rendered with a texture in the virtual 3D ubiHome as shown in the Figure 4(2).

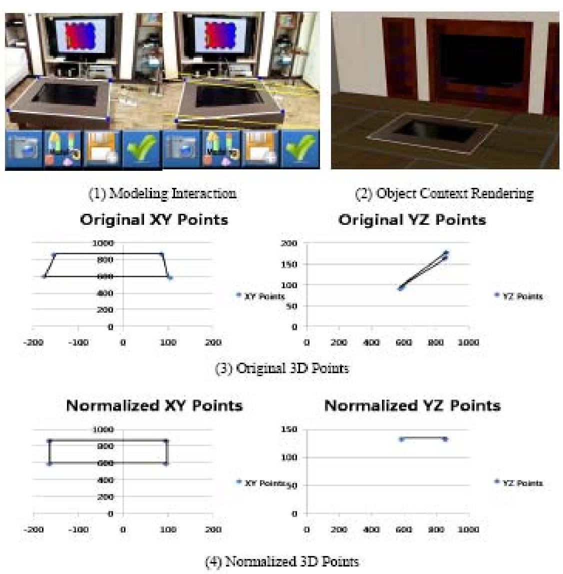

Figure 4. Before and after normalizaing obtained 3D points of a table when carrying out modeling interaction

C. *Applications*

Figure 5 and 6 show content authoring from real world to virtual world and vice versa. In the former case, a user using a mobile phone generates tag information including a box object

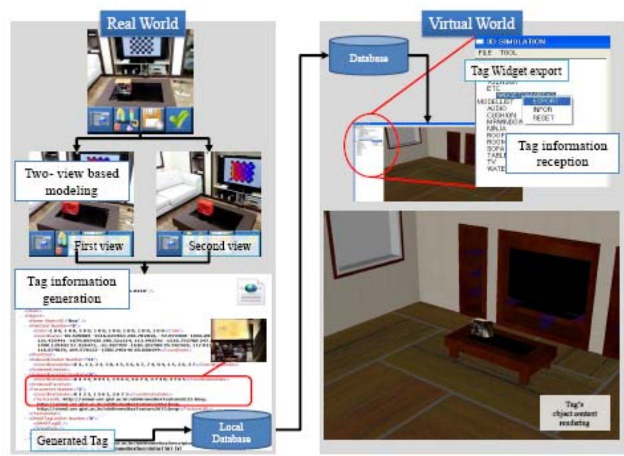

Figure 5. From real world to virtual world

from two-views based modeling in real world. Then, another user on a desktop receives the tag information and renders the box object in the virtual world. In the latter case, a user on a desktop performs 3D content (e.g., watering pot) authoring task. As a result, another user on a mobile phone receives the updated tag information including watering pot authored, and augment watering pot 3D model onto real world's object such as table.

Figure 7 shows poster linkage processes from real world to virtual world. In this case, we also assume that first poster's width and height values are already known, and exploit it for global registration. After the initial registration, we can obtain 3D points of posters in the neighborhood of the initial one. Finally, we can extend to other posters in the virtual world according to the real world's geometry.

V. NEXT DIRECTION OF OUR WORK

Currently we only worked on tagging and registration of other new objects on the assumption that we already know a object for initial registration. As an attempt to solve the limitation of this assumption, we are planning to use 3D model of space for global registration. Figure 8 shows real gallery space and virtual gallery 3D model. When a user enter the gallery space, a location information can be obtained by using location sensor or semi-auto interaction, and a direction information can be obtained by using compass sensor on mobile phone. Then, 3D gallery model according to the location and direction is loaded and rendered transparently onto camera image like Figure 8. Now, global registration is accomplished by using semi-automatic interaction of the user to make arbitrary local registration-based reference point through obtaining 3D points.

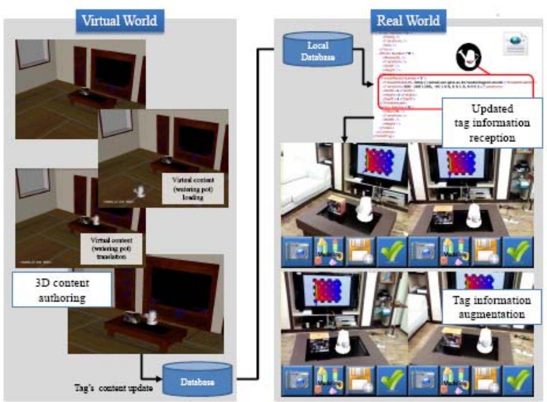

Figure 6. From virtual world to real world

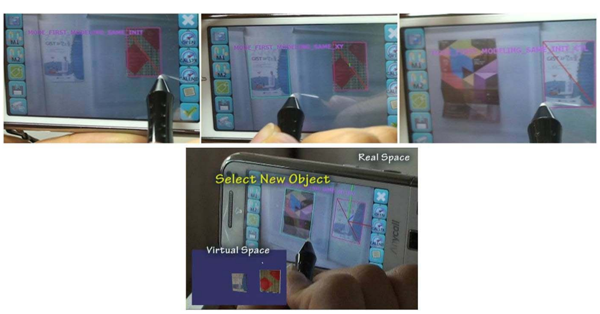

Figure 7. Poster linkage in dual worlds

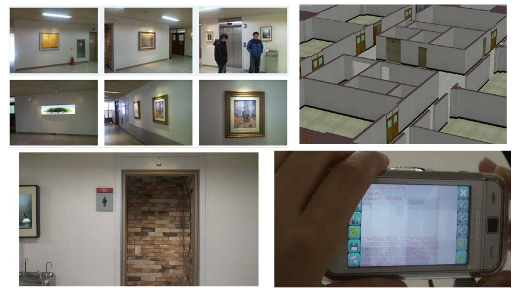

Figure 8. Next direction using 3D model space registration

VI. CONCLUSION

We introduced an on-going work on a real and virtual worlds linkage through CMCVR. First of all, we examined opportunities for dual worlds linkage through CMCVR from scene and interaction aspects. Second, we considered and discussed requirements for the linkage and implemented an object-based linkage module prototype on a mobile phone. Through the experiments, we discovered the need for releasing the initial point assumption and the future direction of our work. According to these steps, we have confirmed possibilities of such dual worlds linkage to play a vital role in bridging objects and content in CMCVR.

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