Context-of-Interest Driven Trans-Space Convergence for Spatial Co-presence

Hyeongmook Lee, Taejin Ha, Seungtak Noh, and Woontack Woo

UVR Lab., Graduate School of Culture Technology, KAIST, S.Korea
{hmooklee,taejinha,stnoh,wwoo}@kaist.ac.kr

Abstract. In this paper, we propose a Trans-Space convergence system that exploits realistic 3D remote collaboration with spatial co-presence by using augmented reality technology. To experience it, we define two major enabling technologies: 1) Context-of-Interest (CoI) based Trans-Space registration and selective augmentation and 2) augmented object interaction for realistic collaboration. Through these technologies, a user wearing augmented reality (AR) glasses can naturally experience remote collaboration with spatial co-presence while moving in space. We implemented a prototype of the Trans-Space for a preliminary test experiencing spatial co-presence in an indoor environment. With an assumption that a common physical CoI is in each space, a distant mirror space can be conveniently linked with real user's mirror space and they are merged together as a Trans-Space. Through the proposed convergence system, a human's co-presence experience can be enlarged by selectively context sharing and effectively spatial interaction between remote mirror spaces. We expect this is applicable to AR-based time/space transcended smart applications, such as the next generation of experimental education, training, medical surgery, and entertainment.

Keywords: Context-of-Interest, Trans-Space, augmented reality, spatial co-presence.

1 Introduction

With the development of communications technology, a variety of systems is coming to experience real-time co-presence among people in remote places. The co-presence, which is a similar concept to sense of co-location, is defined as "feeling being together with other people" or "extent of being at the same place with others" in interaction through medium [1]. It can feel in a situation of real-time communication through human sensible elements. As for technically supporting this, the voice telephone is the representative real-time co-presence supporting system focusing communication of auditory sense. The video telephone and tele-conference system provide better immersiveness by delivering both auditory and visual sense on 2D display.

Using Virtual Reality (VR) and Augmented Reality (AR) techniques offers the great possibility of going through more realistic co-presence. It easily supports the enabling of 3D visualization and interaction, compared with the system that only

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enables sitting or staring in front of a 2D display. It means that the spatial characteristic in co-presence is strengthened in remote communications. As state of the art, TeleHuman [2] is a VR system that provides non-verbal communication with a distant user using cylindrical display. It captures multi-view images of the user by using multiple RGB-D cameras for realistic viewing and visualizes a life-size 3D human model on the cylindrical display. Therefore, a user around the display is able to see the figure of the distant user at all viewpoints except up and down. In addition, MirageTable [3] is a projection based AR tabletop system using RGB-D cameras that allows one-to-one remote interaction. In real-time, it brings a small area that is covered by the same tabletop installation, including a remote user, and objects it on the table. For better user visual experience, the system provides rough user-head tracking using the user's glasses in-depth image and correcting 3D perspective views.

However, there are some limitations in existing co-presence supported systems using VR and AR technologies. Specifically, one is that cost and space demands for system construction are considerable, relative to the co-presence experience in implemented tele-communication systems. Furthermore, it is hard to provide realistic collaborative interaction maintaining spatial co-presence. These restrictions were found in the above-mentioned two recent systems. TeleHuman requires five PCs and ten RGB-D cameras for one-to-one video conferencing with 640 x 480-pixel quality on cylindrical display. IN addition, direct interaction between a real user around the display and a distant user on the display is impossible, whereas life-size rendering looks user-friendly. In the case of MirageTable, it enables the construction of the environment for experiencing co-presence with relatively less effort with a few devices, but it takes account of one-to-one user situations sharing objects on a small table. Therefore, it is necessary to cover the spatial co-presence considering the wider space and user movement for more realistic remote collaboration with multiple user support. In this paper, we suggest Context-of-Interest (CoI) driven Trans-Space convergence that coexist a real user and a remote user in each physical indoor space to physical identical space. Here, CoI is defined as an interested context about any information that characterizes a user situation. The situation is tightly coupled with relationships for the interaction between user, application, object, location, and so on [4]. The CoI driven Trans-Space convergence technology provides user-appropriated virtual information selectively to physical 3D space and supports realistic collaboration interaction experiencing spatial co-presence. To achieve this, we first suggest CoI based Trans-Space registration and selective augmentation for reducing the burden in implementation on tele-communication systems and filtering the less relevant information. Furthermore, based on spatial AR technology, we put on augmented object interaction methods for better remote collaboration.

This paper includes the following content: the Trans-Space convergence and phased approach are introduced in Section 2. In Section 3, the technical details of enabling technologies are explained. Section 4 introduces the initial implementation results of the Trans-Space convergence system. Finally, we conclude this paper in Section 5.

2 Trans-Space Convergence

The goal of Trans-Space convergence system is to support remote collaboration with co-presence, including social presence that allows users to overcome time/space restrictions and share information, knowledge, and mood. Conceptually, the Trans-Space, to transcend space, means a newly linked space across the remote spaces. It technically indicates an extended dual-space, which each corresponding mirrored space of each remote user is merged into a single space. Here, the dual-space is a set of real spaces where the user is and mirror space information included corresponding to the real space [5]. In dual-space, based on the referenced CoI (e.g. origin of space), it is necessary to coordinate localization between the CoIs in real space for tracking and the CoIs in mirror space for rendering.

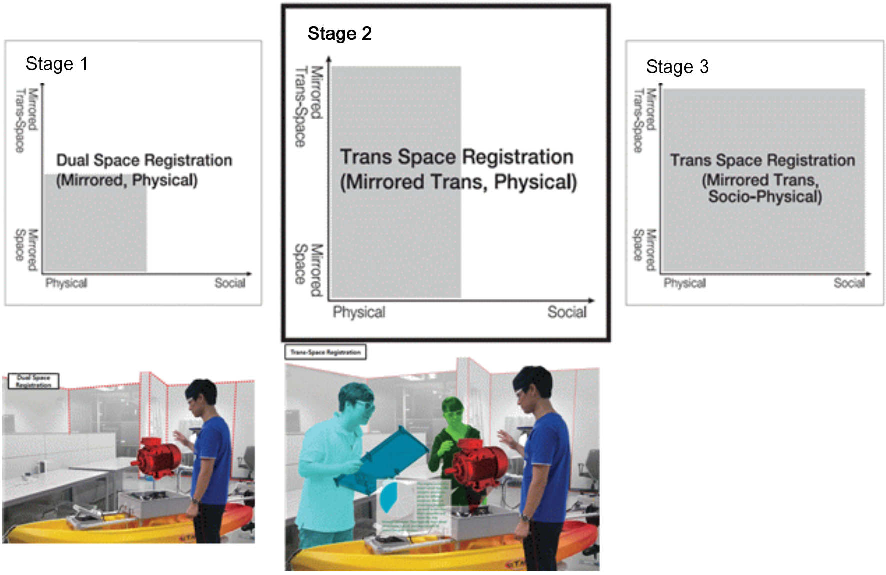


Fig. 1. Phased approach toward Trans-Space convergence

To achieve our Trans-space concept effectively, we planned a phase approach considering the scale of the registration space and manageable target CoI, as shown in Fig. 1. The objective of stage 1 is CoI-based, real-time, dual-space registration to robust under environmental changes. In this step, the main research is to enable robust real-time registration constructing a single space into a dual-space [6][7]. Based on this, the user is able to interact directly or indirectly with trackable and augmented CoIs in the space and visualizes virtual information stably on the space [8][9][10].

At stage 2, the goal is real-time, one-to-multi, semantic space convergence supporting spatial co-presence focused on this paper. From stage 1, we considered how to make a dual-space with a real space and the corresponding mirror space, so we know the agreement of different coordinates and the scale of two spaces. By using the key technology, we focused on realizing the trans-space convergence, in which multiple mirror spaces from remote distances come into single extended dual-space. Through the trans-space, a user in any position of registered real space is able to call remote people naturally and do collaborative interaction with them realistically. Beyond stage 2, CoI-based self-evolutionary Trans-Space convergence supported realistic collaboration among multiple users for stage 3. In this stage, we enlarge the manageable CoI to social factors, including user's sensitivity and emotion. This is the forward key to overcome time/space restriction and make co-presence more sociable.

3 Enabling Technologies

There are two key technologies to achieve CoI-driven Trans-Space convergence for spatial co-presence, as shown in Fig. 2. First is CoI-based Trans-Space registration and selective augmentation that allows users to overcome the restriction between heterogeneous spaces. Second, under the registered Trans-Space environment, augmented object interaction is meaningful and feasible for realistic collaboration.

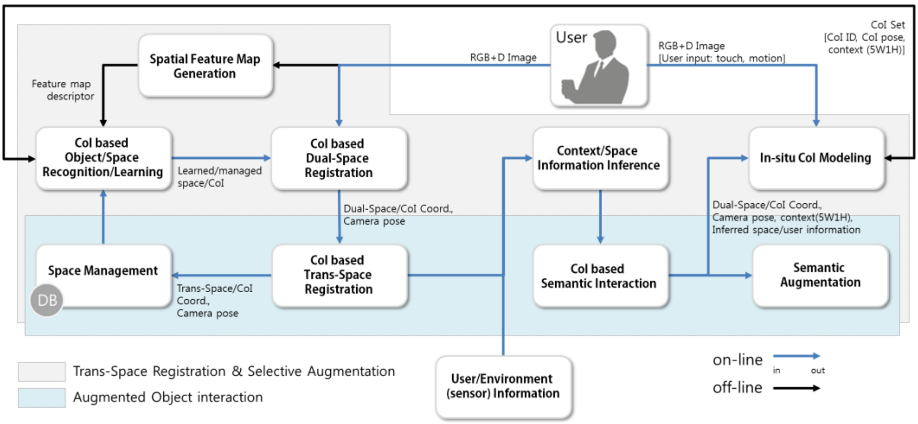


Fig. 2. An overall procedure for Trans-Space convergence (stage 2)

3.1 CoI Based Trans-Space Registration and Selective Augmentation

For real-time and robust Trans-Space registration, we need to figure out a novel spatial feature map that describes strong scene features by systematically exploiting color and depth information. Therefore, it overcomes troublesome vision issues, such as textureless, poor lighting conditions, multiple deformable moving objects, and heterogeneous image devices, in usage of color information only. By capturing and learning various contexts from space, the range of recognition, detection, and tracking is expanded to space domains from object domains. This helps reduce the redundancy for real-time processing so the system might cover wider areas containing lots of CoIs than existing stationary interaction areas (e.g. screen, table, etc.) and elevates users' movement. In addition, this semantic approach enables selective augmentation, focusing user-interested CoIs on all accessible CoIs.

Fig. 3 illustrates an overview of the registration and selective augmentation process for two real spaces with concept drawings. At first, there is a real space 'A' for normal users. The mirror space 'A' can be created by using dual-space registration beforehand and updated on real-time (we called this 'Mirroring'). Then every user who carries a camera and display in space 'A' might interact with tracked physical CoIs and annotated virtual CoIs. Equally, there is a real space 'B' for expert users to distant space. Different from space 'A', the user 'b' and trackable CoIs of the real space 'B' are monitored by the environmental camera system.

In this context, if there is a common physical CoI in both spaces 'A' and 'B', a user 'a' in space 'A' is ready to call the expert 'b' in distant space 'B' and the expert helps him on the spatial co-presence. According to collaborative situations, like teaching, training, or maintaining, Trans-Space is selectively converged with virtual CoIs by contextual requests and filter techniques. Because all of the CoIs do not need to account for visualization at a time, selective sharing of CoIs is required, reflecting user, environment, and event for maintaining real-time performance and effective collaboration.

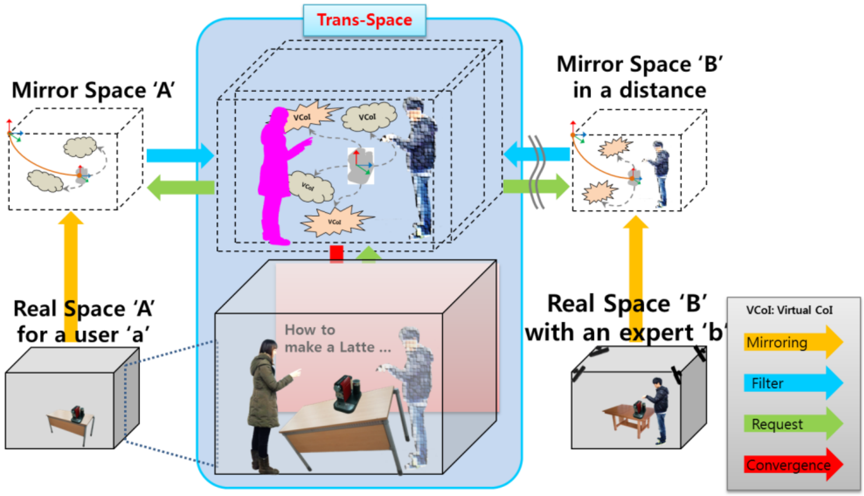


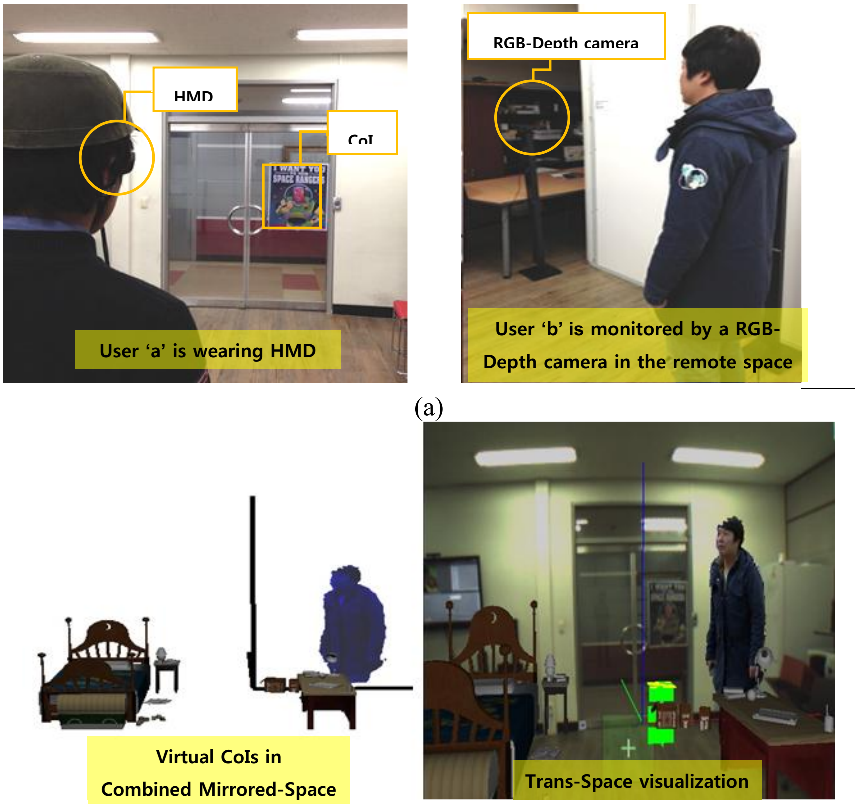
Fig. 3. CoI based Trans-Space registration with relation among real and mirror spaces

3.2 Augmented Object Interaction for Realistic Collaboration

Using Registered Trans-Space, the users between real and remote users enable 3D collaborative interaction. In case of the real users, they experience a seamless interaction with trackable physical CoIs or shared virtual CoIs. For this, we need real-time integrated coordinates management that localizes two independent coordinate systems, physical CoIs and virtual CoIs, to a Trans-Space coordinate system that has the same origin. With similar approaches, it is possible for real-time remote collaboration with distant space. Based on a common physical CoI, we are able to localize and augment distant CoIs, including remote users into real space. Therefore, stably shared CoIs on real-time 3D detection and tracking are easy to manipulate directly and indirectly with the modeled user's hand or sensor-rich mobile devices for realistic collaboration.

4 Implementation

We implemented a prototype of the Trans-Space convergence as a preliminary test in an indoor environment. With the assumption that a common physical CoI is in each space, its mirror world can be conveniently combined together. Specifically, our system captures an environment's images, including CoIs, with an HMD camera and computes image feature-maps for the CoIs in real time [11]. Then, local reference coordinates allocated on the CoI register the corresponding mirrored world and the other mirrored worlds from distant space for the Trans-Space convergence.



(a)

(b)

Fig. 4. Implementation of the trans-Space convergence: (a) our test-bed where two users are apart from each other; (b) virtual CoIs in the mirrored-space are registered in the Trans-Space.

Afterward, mirrored worlds are registered, and some of the virtual content can be shared and shown in an HMD view. In addition, humans in remote environments can be augmented by detecting and segmenting humans with a RGB-D depth camera, and then transmit texture data of the human to the mirrored world [12].

Considering the apparatus, a binocular video see-through HMD was used with 800 × 600 pixel resolution. A camera attached on the HMD captured 30 image frames per second with 640 × 480 pixel resolution. A RGB-Depth camera on the stand was used to detect and segment a remote user. A portable computer in the user's backpack executed CoIs based on mirror world registration, camera pose tracking, and visualization.

As a result, Fig. 4 (a) shows the test-bed. User 'a', who is wearing HMD in space 'A' can see the user 'b' captured from other space 'B'. Fig. 4 (b) shows the shared virtual CoIs, including live 3D models of user 'b' registered in the mirrored world and the HMD view of user 'a'.

5 Conclusion

We introduced a Trans-Space convergence that allows a real user and a remote user in each indoor space to coexist so they feel they are together in the same place. To enable this, a CoI-based Trans-Space registration and selective augmentation was used for reducing the burden in constructing and processing a tele-collaboration system. Toward a semantic AR, a novel feature map is addressed for real-time registration and management in complex environmental changes and massive spatial data. In addition, based on the spatial AR using feature map technology, an augmented object interaction method is introduced for realistic remote collaboration. The enabling technologies can be applicable to many AR collaborative applications. We expect the Trans-Space technology will enhance the spatial co-presence in most remote scenarios so positively substitute the existing solution in remote conference, experimental education, simulation, medical surgery, and entertainment.

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