Intelligent Machine Space for Interacting with Human in Ubiquitous Virtual Reality

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Abstract. Various computing paradigms such as ubiquitous computing, pervasive computing, ambient intelligence, and ubiquitous virtual reality have appeared. Now we should consider interaction between human and robots in ubiquitous virtual reality known as DigiLog space. In this paper, we propose intelligent machine space for human robot interaction in DigiLog space. For the human robot interaction in DigiLog space, a robot has to recognize the current situation and select proper behavior by itself. It has to receive information and context from DigiLog space and transfer current state of robot itself bidirectional way. Moreover, the robot has to accept user's commands and provide proactive services to users.

Keywords: human robot interaction, ubiquitous virtual reality, intelligent machine space.

1 Introduction

Recently various computing paradigms which are a concept of combining real and virtual world, such as ubiquitous computing, pervasive computing, ambient intelligence, and ubiquitous virtual reality have appeared to improve the quality of human life [1,2]. The paradigms are post-desktop model of human-computer interaction in which information processing has been thoroughly integrated into everyday objects and activities. Especially ubiquitous virtual reality supports expansion of human ability in real environment, like human in virtual environments with various technologies. Various sensors are installed in intelligent space such as smart home, smart office and smart car. The intelligent space acquires data from the sensors to understand situation and context and provides adaptive services or personalized services with human. Moreover ubiAgent and AR agent which have form of computer graphics have been developed [3,4,5]. These types of agents take a role of information guide. However it is lack of reality because it is not physical objects.

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Now we should consider how human and robots interact with each other in DigiLog space. Researches on robotics have a great effort to design and to implement various types of high performance robots [6,7]. Robots applying state-of-the-art technology such as ASIMO, HUBO have been developed [9,10] and robots such as a cleaning robot, AIBO are used in the daily life of human [14,15]. On the other hand some researchers on ubiquitous virtual reality proposed DigiLog space that combines physical world and its mirrored world to realize the 4D+ augmented reality [13]. In the DigiLog space, graphical agents could replace by physical robots and graphical agents and physical robots could exist in the same space. Now two research areas are fused, and it should be handled how to interact robots to coexist with humans in a smart environment.

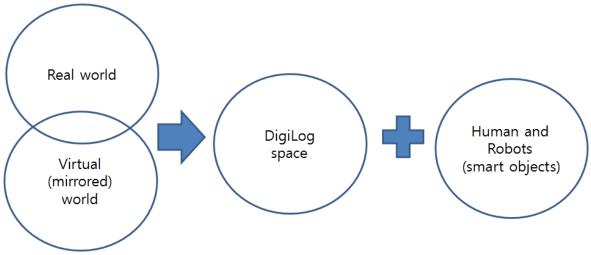

Fig. 1. Intelligent machine space with Digilog Space and Robots

In this paper, we propose intelligent machine space for human robot interaction in DigiLog space. DigiLog space is a place where virtual and real world are merged and where human and robots coexist (fig. 1). For the human robot interaction in DigiLog space, a robot has to recognize current situation and selects proper behavior by itself. It receives information and context from DigiLog space and transfer current state of robot itself bidirectional way. Finally the robot accepts the user's command and provides proactive service to a user.

This paper is organized as follows. In section2, DigiLog space and agent middleware in UVR is introduced. Intelligent machine space is proposed with several scenarios in section 3. We introduce a humanoid robot we are developing in section 4. Finally, the conclusions mentioned in section 5.

2 Related Works

2.1 Ubiquitous Virtual Reality and DigiLog Space

Ubiquitous virtual reality is a computing paradigm combining virtual reality with ubiquitous computing. Currently the ubiquitous virtual reality research aims at the development of novel computing paradigms for "holistic DigiLog life in smart space." 'Ubiquitous Virtual Reality' is called 'U-VR','Ubiquitous VR', or 'UVR', according to emphasizing viewpoint how to combine real and virtual world.

It was defined that "U-VR is a new paradigm combining virtual reality with ubiquitous computing. This can provide user with various applications according to the context of users or environments"[16]. In this definition, 'context' is one of important factor to combine virtual reality and ubiquitous computing. Later U-VR was defined as "A concept of creating ubiquitous VR environments which make VR pervasive into our daily lives and ubiquitous by allowing VR to meet a new infrastructure, i.e. ubiquitous computing". This is similar to the concept of cross reality [17].

Now, researchers on ubiquitous virtual reality began to study DigiLog space. DigiLog space is a result of combining physical world and its mirrored world (virtual world) for building the 4D+ augmented reality with the technology such as real-time dual-space registration and context of interest based information visualization [13]. It has following three properties: a plentiful 3D link between real and virtual space with additional information, an immersive five-sense augmentation in real world, and bidirectional interaction on the fly in linked dual spaces.

2.2 Agent Middleware in Ubiquitous Virtual Reality

UCAM stands for unified context aware application model. Early UCAM was evolution of middleware model ubiquitous computing researchers proposed such as the context toolkit. The UCAM connects sensors and applications by using a unified context in the form of Who (user identity), What (object identity), Where (location), When (time), Why (user intention/emotion) and How (user gesture), called 5W1H [18]. The UCAM applied to the sensors and applications in the ubiHome, a test bed for ubiComp-enabled home.

Later the UCAM has evolved in the three areas: ubi-UCAM, vr-UCAM, wear-UCAM. As ubi-UCAM is for ubiquitous computing environment (real world), vr-UCAM is for virtual environments and wear-UCAM is for human body area, that is wearable computing environments [19,20].

While people's attention has been focused on mobile computing, UCAM changed context-aware mobile augmented reality platform (CAMAR)[21,22]. CAMAR lets users interact with smart objects through a personalized control interface on a mobile AR device. Also, it supports enabling contents to be not only personalized but also shared selectively and interactively among user communities. To realize CAMAR, CAMAR core platform was proposed. The architecture is mainly composed of two parts: context-aware framework for a mobile user (UCAM), and AR application toolkit using OpenScene Graph [23]. The architecture shows context-aware toolkit could help mobile AR application in order to enhance different levels of decision making process.

Initially CAMAR focused on the visualization methods and tracking algorithm for augmented reality, later it developed to AR agents [24]. In the ubiquitous virtual reality environment, AR agents adaptively perceive and attend to objects relevant to their goals. To enable AR agents to perceive their surroundings, the agents have to determine currently visible objects from the scene description of what virtual and physical objects are configured in the camera's viewing area.

To generalize the idea, context-aware cognitive agent architecture was proposed. The proposed agent architecture has a vertically layered two-pass agent architecture with three layers. The three layers are AR (augmented reality) layer, CA (context-aware) layer, and AI layer. This architecture enables ambient smart objects to interact with users in various ways of intelligence by exploiting context and AI techniques.

In summary, the UVR has been developed to provide a platform technology for complete DigiLog space, and agent technology for intelligent services and content. There has been much effort to merge virtual and real world with physical or contextual methods and to provide intelligent services or content in this environments. Now we need to consider not only software services in the form of invisible applications, AR agent but also visible physical objects in the form of embedded systems or robots.

3 Intelligent Machine Space in Ubiquitous Virtual Reality

In this section, we introduce intelligent machine space for human robot interaction in DigiLog space. DigiLog space is a place where merging real world with mirrored world. Here 'merging' means that matching real and mirrored world with 3D coordinates, context of interest (CoI), and bidirectional exchange of information between real and mirrored world. CoI is defined as a user's interesting context about any information that characterized the situation [13]. Mirrored world is a database for saving data and information of the real world. The mirrored world could be built by ubiquitous virtual reality infrastructure such as UCAM, CAMAR, etc. Therefore, the mirrored world is filled with contextual information.

Fig 2 shows robots and human in DigiLog space. Let R^4 and M^4 are real world and mirrored world including time dimension respectively. CoI_R and CoI_M are subsets of R^4 and M^4. R and H are space for representing a robot and human. Fig 3 shows interaction model for human robot in intelligent machine space. While real world and mirrored world can be surjective (not injective), CoIs could be a bijective mapping.

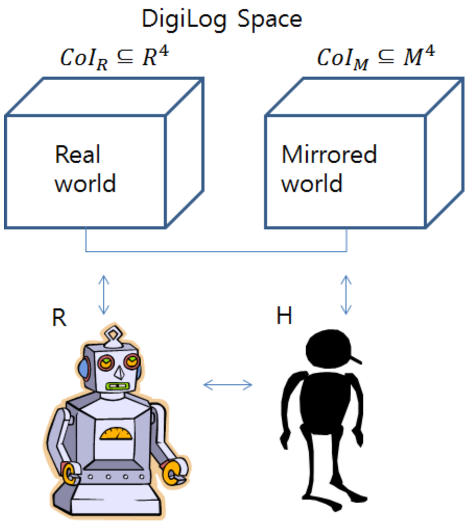

Fig. 2. Robot and human in intelligent machine space

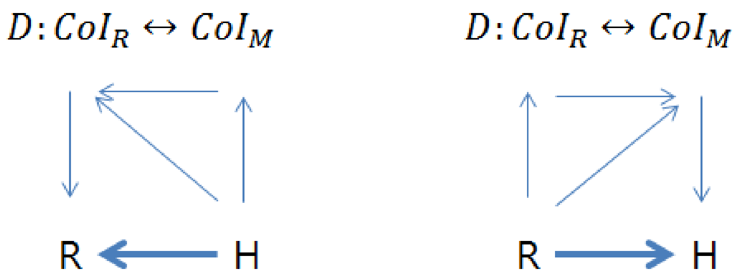

Fig. 3. Interaction model for Human and robot in intelligent machine space

For the human robot interaction in intelligent machine space, a robot has to recognize current situation and selects proper behavior by itself. A robot gathers data from sensors that it has and receives information from mirrored world. For instance, a robot would be able to identify positions in successive frames for object tracking, or to aggregate basic coordinate data and sensor values with clustering techniques into object regions. For the responsiveness, the robot would be able to generate behavior comparable to involuntary response directly from perceptual input, to generate behavior comparable to voluntary response by interpreting a local action, and to interpret the local action with respect to continuously updated information retrieved from perception, such as tracking data.

A robot should receive information and context from DigiLog space and transfer current state of robot bidirectional way. When a robot navigates in a building, it is hard to find current location of robot with only sensors attached itself because large scale indoor location tracking system is still not working perfectly. In this situation, the robot would receive proper clues to find current location from DigiLog space. The clue could be some textures for video tracking, Wi-Fi signal strength, ultra-sonic sound, etc. The robot compares the data from sensors attached itself with the data from DigiLog space to find out current position.

The robot has to accept the user's command and provide proactive service to a user. There are two types of user's command: direct response command and long-term goal command. Direct command means that a command from users which can be followed directly without special consideration or algorithm. For example, if the robot gets an order such as 'move this way' or 'turn around', then it could to it without any special approaches. If the robot gets an order such as 'go room 215 and find a document and bring it back to me', it has to solve many technical problems by itself. First it has to find a way form current position to room 215 and start to move. While it moving, if some obstacles appears (e.g. elevator is not working properly), the robot search the path again. After the robot arrives at the room 215, it has to find where the document is. Then the robot get back to a place where user stays currently (in case, user moves other place). This process is really hard work with only sensors robot has without information from DigiLog space.

4 CHARLES: a Humanoid Robot in Intelligent Machine Space

CHARLES is a humanoid robot developed by Intelligent Space Lab. in Mokpo National University. The robot is a child-size light weight humanoid robot. The CHARLES has about 1m height and 12kg weight. It has 9 motors in upper body and 12 motors in lower body. CHARLES is designed for special purpose that it plays with child in safe way. Because a big and heavy robot could be dangerous, when it fall down on children by accident. Fig. 4 shows pictures of CHARLES.

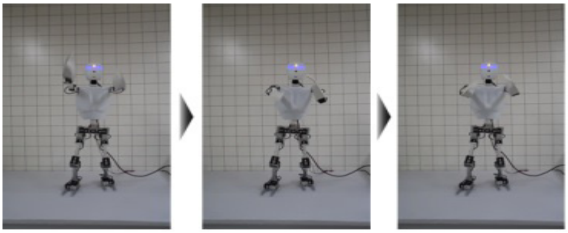

Fig. 4. CHARLES: a humanoid robot in intelligent machine space

5 Conclusion and Future Works

In this paper, we proposed intelligent machine space for human robot interaction in DigiLog space. For the human robot interaction in intelligent machine space, a robot has to recognize the current situation and select proper behavior by itself. A robot should receive information and context from DigiLog space and transfer current state of robot bidirectional way. Finally the robot has to accept user's commands and provide proactive service to users. We are developing CHARLES, a humanoid robot, for human robot interaction in intelligent machine space. We expect that CHARLES will provide users with proactive services.

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