Overlay what Humanoid Robot Perceives and Thinks to the Real-world by Mixed Reality System

Kazuhiko Kobayashi* Koichi Nishiwaki† Shinji Uchiyama* Hiroyuki Yamamoto* Satoshi Kagami† Takeo Kanade†

* Human Machine Perception Lab, Canon Inc., Japan
† Digital Human Research Center, AIST, Japan

ABSTRACT

One of the problems in developing a humanoid robot is caused by the fact that intermediate results, such as what the robot perceives the environment, and how it plans its moving path are hard to be observed online in the physical environment. What developers can see is only the behavior. Therefore, they usually investigate logged data afterwards, to analyze how well each component worked, or which component was wrong in the total system. In this paper, we present a novel environment for robot development, in which intermediate results of the system are overlaid on physical space using Mixed Reality technology. Real-time observation enables the developers to see intuitively, in what situation the specific intermediate results are generated, and to understand how results of a component affected the total system. This feature makes the development efficient and precise. This environment also gives a human-robot interface that shows the robot internal state intuitively, not only in development, but also in operation.

CR Categories and Subject Descriptors: Index Terms: I.2.9 [Artificial intelligence]: Robotics—Operator interfaces; H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—Evaluation;

Additional Keywords: Humanoid robot

1 INTRODUCTION

Robotics aims to realize an intelligent system that requires wide range of functions, such as perception and action. Among various types of robots, an autonomous humanoid robot, or humanoid in short, has a human-like shape with two legs and two arms. This type of robot is designed to coexist and collaborate with humans in our daily life. The autonomous humanoid robot requires the following functions [1]: 1) Sensing the physical environment. 2) Combine the sensory data to reconstruct the environment. 3) Planning its task and movement based on the given task. 4) Execution of the planned behavior with an adaptive motion control.

In order to develop such a complicated system, a development platform for humanoids was recently made available [1]. This platform enables developers to implement and test each component, such as sensing, perception, planning, and action, independently and to integrate them into a humanoid system. Furthermore, we can analyze them in the physical environment. Although the platform is useful, it is difficult to debug a humanoid in real space, since the system is not only complicated, but also dangerous to developers. The robot may harm itself, or people around it once it makes unexpected actions. Debugging the system, not in the real environment, but in virtual space could reduce these problems. For the purpose, a dynamics simulator in virtual space, without using a real humanoid, is used [2]. However, it is impossible to simulate the real humanoid and real environment with the virtual simulator, because it is too expensive to make virtual models of the real world.

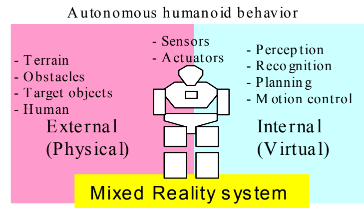


Figure1: MR integrates internal and external state of the Humanoid Robot.

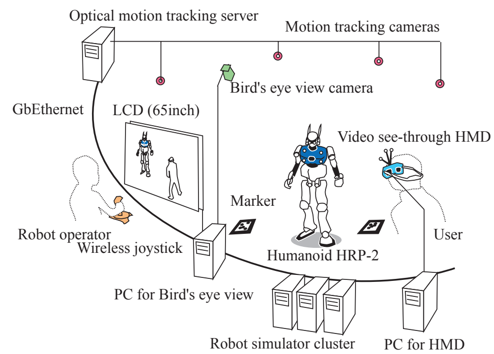
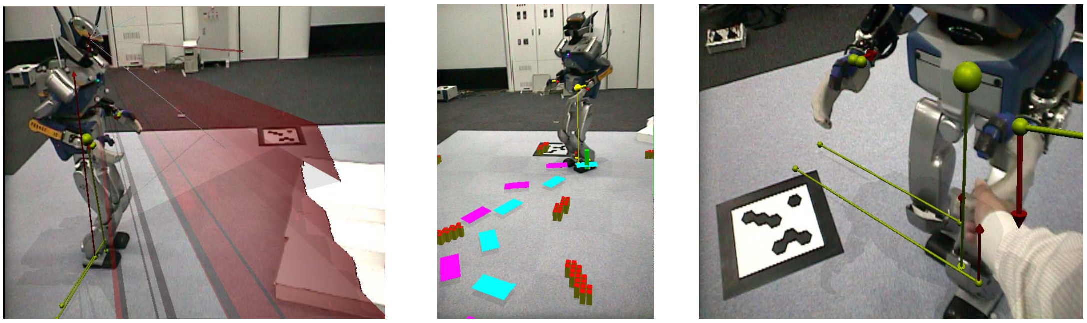


Figure 2: Deployment diagram for our MR development environment.

Figure 1 shows the concept that a humanoid exists on the boundary of the external and internal space. The external space is the physical environment and humanoid's body, in which the humanoid senses, perceives, and acts. The internal space is the virtual one, in which the humanoid stores the perceived data and makes planning. Until now, there is no way for developers, who exist in the external space, to see and understand efficiently the internal status that corresponds to the external one. The lack of this correspondence causes the frustration described above.

Mixed Reality technology can give us a solution for the described problem. Using MR technology, it is possible to overly what humanoid robot perceives, plans, and controls to the real environment, as the SenseShapes [3] shows the view of sensors or other things of interest using AR technology. We expect that this feature improves the humanoid development process significantly. In this paper, based on the discussion above, we introduce a novel environment for humanoid development in which the internal status of the system is overlaid on external space using MR technology. Although previous work exists in using an MR display to operate a remote robot [4] and diagnosing multi

e-mail: kobayashi.kazuhiko@canon.co.jp
k.nishiwaki@aist.go.jp
uchiyama.shinji@canon.co.jp
yamamoto.hiroyuki125@canon.co.jp
s.kagami@aist.go.jp
t.kanade@aist.go.jp



(a) (b) (c)

Figure 3: (a) Sensory information of humanoid is overlaid in real-time (triangle shapes represents measurements of the laser range sensor on the head). (b) Interactive planning of humanoid (footstep avoiding obstacles). (c) Properties of motion control of humanoid (when the developer push the left hand, representations of the force sensor measurements are changed immediately).

functions of a simple robot [5], this is the first application that applies MR to development of a complicated autonomous robot such as a humanoid.

2 System Configuration

Figure 2 shows the configuration of the proposed system. The system mainly consists of three parts: a target humanoid with its controller, an MR visualization module, and a tracking module.

We use a modified version of HRP-2 [6] as a target humanoid. The humanoid has 38 joints, its weight is 58kg, and the height is 154cm. The Zero Moment Point (ZMP) theory is employed as the biped motion control. A short periodic walking pattern generator [7] realizes autonomous and sequential behavior based on perception and planning. These processes are executed by CPUs installed in the humanoid body. The internal status such as sensory data, planned motion, and motion control data are available to external PCs via wireless LAN.

Two types of display devices are utilized for MR visualization. One is a COASTAR type video see-through HMD: VH-2002 [8]. It allows developers to observe the internal status from arbitrary viewpoints in the real environment. The other is a 65inch flat panel display. The bird's eye view of MR visualization is displayed on this monitor for promotion of discussion among multiple developers. For this purpose, a bird's eye camera is set on the ceiling. Each PC attached to a display receives internal state of the humanoid, converts it into 3D computer graphics representations, and overlays the rendered image on the image captured by a camera installed in the HMD, or on the ceiling. The rendering process is synchronized with the actual humanoid behavior.

An optical motion tracking system, MotionAnalysis Eagle, measures poses of the HMD and the humanoid. The tracking system covers 5m x 5m space. Square markers are located on the floor, and they are used to compensate the error of the HMD pose obtained by the tracker. We use a modified version of the registration method proposed by Satoh et al. [9].

3 Visualization

Figure 3 (a) shows an example: sensory information, measured by the humanoid, is directly overlaid onto the physical space. Figure 3 (b) represents the footsteps [10] as an example for externalizing what the robot plans. In Fig.3 (c), the properties of humanoid motion control are shown for analyzing its dynamics. A developer can arbitrarily move around the humanoid and see these data as they wish. Moreover, the developer can touch and push the humanoid interactively and get the changes in internal status that corresponds to the external space. Thus, this system provides a powerful tool for developers.

4 Conclusion

In this paper, we presented a novel environment for humanoid development in which the humanoid perceived information and thought were overlaid to the physical environment using Mixed Reality technology. Real-time observation enables the developers to see in what situation the specific intermediate results are generated. It is also useful for understanding intuitively how results of a component affected the total system. This environment also shows the robot internal state intuitively, not only during development, but also in operation. We will examine the effectiveness of the system in practical humanoid development environments.

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