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Mixed Reality Environment for Autonomous Robot Development

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I. INTRODUCTION

This video demonstrates a Mixed Reality (MR) environment which is constructed for development of autonomous behaviors of robots. Many kinds of functions are required to be integrated for realizing an autonomous behavior. For example, autonomous navigation of humanoid robots needs functions, such as, recognition of environment, localization and mapping, path planning, gait planning, dynamically stable biped walking pattern generation, and sensor feedback stabilization of walking. Technologies to realize each function are well investigated by many research works. However, another effort is required for constructing an autonomous behavior by integrating those functions. We will demonstrate a MR environment in which internal status of a robot, such as, sensor status, recognition results, planning results, and motion control parameters, can be projected to the environment and its body. We can understand intuitively how each function works as a part of total system in the real environment by using the proposed system, and it helps solving the integration problems. The overview of the system, projection of each internal status, and the application to an autonomous locomotion experiment are presented in the video clip.

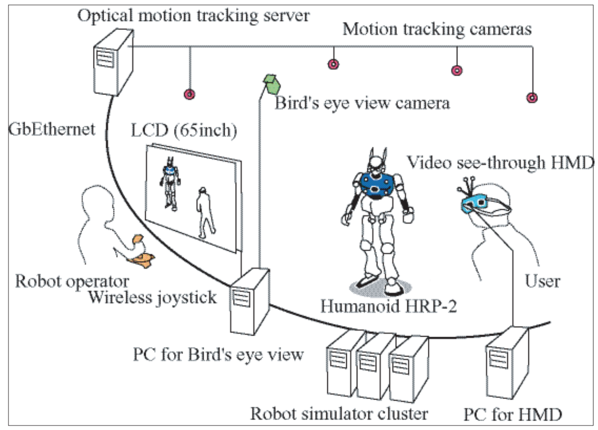

Fig. 1. Overview of the MR System

Fig. 2. Video See-Through HMD: VH2002 with Marker Balls

II. RELATED WORKS

There are several robot behavior development environments that include simulation and visualization, such as OpenHRP[1] and Microsoft Robotics Studio[2]. Onishi et al. also developed an immersion-type Virtual Reality dynamics simulation environment for simulating robot human interaction[3], [4]. They are powerful development tools for accelerating the development of autonomous behaviors or human robot interaction behaviors. However it is hard to implement every uncertainty of real environments and sensor characteristics (including noises) to the simulators. We finally have to carry out adjustments and debugging in the real environments even when those tools are adopted. The proposed MR system targets the adjustments and the debugging in the real environment.

We previously developed a system that overlay the footstep planning results to the captured video image [5]. We confirmed the system is useful for tuning the behavior of the planner in the real world before carrying out the real experiments. In this video, we introduced Head Mounted Display (HMD) that allows online observation from an arbitrary view point and developed a system for viewing internal statuses of the robot for the whole process of autonomous behavior development.

III. PROPOSED SYSTEM

The configuration of the proposed system is shown in Fig. 1. Our current target robot is the humanoid, HRP-2[6].

COASTAR type Video See-Through HMD, VH2002[7], is adopted for the MR environment (Fig. 2). It has two cameras and two LCD displays. Camera images are captured by a PC and internal statuses of the robot are overlaid to the images by using the robot position and the HMD position.

We used an optical motion capture system (Eagle Digital System, Motion Analysis Corp.) for measuring the position of the robot and the HMD. Positions of optical markers attached on the robot and the HMD is measured by the system online by using 10 surrounding cameras at 120[Hz]. Measured marker positions are sent to a rendering PC with around 20[ms] delay from the measurement.

As another display of MR, we used a bird's-eye view camera attached on the ceiling. The camera image is captured by another PC and the robot statuses are overlaid by the same

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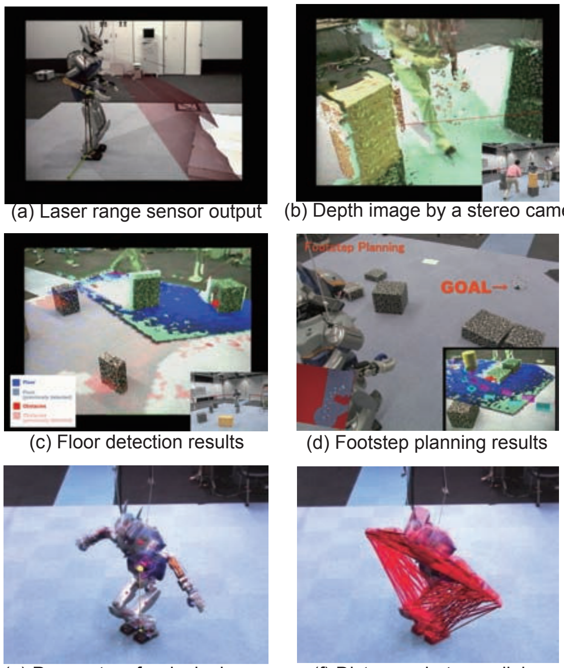

(a) Laser range sensor output (b) Depth image by a stereo camera

(c) Floor detection results (d) Footstep planning results

(e) Parameters for designing whole body motion (f) Distances between links

Fig. 3. Overlaid Statuses

manner. The overlaid image is shown in large LCD monitor (65 inch). Though the view point can not be moved in this case, the advantages to the HMD are easiness of getting the overview and sharing the same view among multiple developers.

IV. Overlaid Statuses

Currently implemented functions that project the internal statuses of the robot to the real world are explained in this section.

a) Output of a Laser Range Sensor: We can verify to what points the sensor is projecting the light, and the accuracy of measurement. (Fig. 3 (a))

b) Depth Image obtained by a Stereo Camera: We can understand environment shape recognition results by comparing the overlaid view with the real objects.

c) Floor Detection Results: Floor region are detected by using the depth image and camera position and orientation. The region currently detected as floor, and the region currently detected as occupied by obstacles are overlaid to the environment to show the result. The regions which are out of view but previously detected as floor region and as obstacle region are also shown. (Fig. 3 (c))

d) Footstep Planning Results: Footstep planner generates sequence of stepping positions from the current position to the goal[8]. The result of planning by using the floor detection result is shown Fig. 3 (d). We can verify how the planner works in the real world by moving the goal and obstacles, and we can tune the heuristics and the foot transition set that are used in the search process.

e) Parameters for designing whole body motion and walking control: The following parameters can be drawn on the robot body for designing whole body motion and walking control (Fig. 3 (e),(f)):

- Center of mass position of the robot,
- Center of mass of each link,
- Ground projection of center of mass,
- Measured center of pressure of each foot,
- Attitude sensor output,
- Motor current sensor output,
- Distances between links,
- ZMP (designed position),
- External forces and torques measured at the wrists and the ankles.

Fig. 4. Application to an Autonomous Locomotion Experiment

V. Applying the System to an Autonomous Locomotion Experiment

We applied the developed system to an autonomous locomotion experiment. Depth image, floor detection results, planned footprints are projected to the environment at the same time (Fig. 4). We were able to see easily how the recognition results affect the planning or how accurately planning results were realized by actual walking.

VI. Conclusion

We developed a MR environment which can overlay internal statuses of a robot, such as, recognition results and planning results. We confirmed the environment is useful by applying it to an autonomous locomotion experiment. We will use the system for constructing highly integrated autonomous behaviors for robots.

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