A Toolkit for Easy Development of Mobile Robot Applications with Visual Markers and a Ceiling Camera

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ABSTRACT

We created a toolkit for software engineers to rapidly develop various robot applications. We distributed the prototype system to students in a Human Computer Interaction (HCI) course and observed that students without any prior experience in robot application development successfully developed interesting applications.

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General terms: Design, Human Factors.

Keywords: toolkit, prototyping, robot application, mobile robot, home robot

INTRODUCTION

Small mobile robots are now consumer products. Various cheap and reliable commercial products such as iRobot Rooomba [1], NetTansor [2], and Lego Mindstorm Robots [3] are available. Furthermore, most of these robots support remote controlling APIs. However, the development of robot controlling software is difficult. Basic tasks such as processing of sensor input, recognition, localization (knowing the location of objects and robots), and navigation (moving the robot to a specific location) require a lot of work. What's worse, the difficulties of these tasks vary between hardware platforms, target task or goal, physical environment and context, etc.

On the other hand, computers are useless without applications. Various applications are now available for a given computer platform to satisfy individual user needs. However, this is not yet true for robots. Most robots come with proprietary software and their development is limited to robotics experts. This situation is unfortunate. We envision that various useful and interesting applications will emerge if a variety of people such as HCI researchers and interaction designers can develop applications by themselves.

To ease this problem, we developed a toolkit to make it easy to write an application that remotely controls mobile robots in a given environment. To achieve our goal, we designed a system to be as simple as possible to make it accessible to novices and distributed it as open source to encourage active participation.

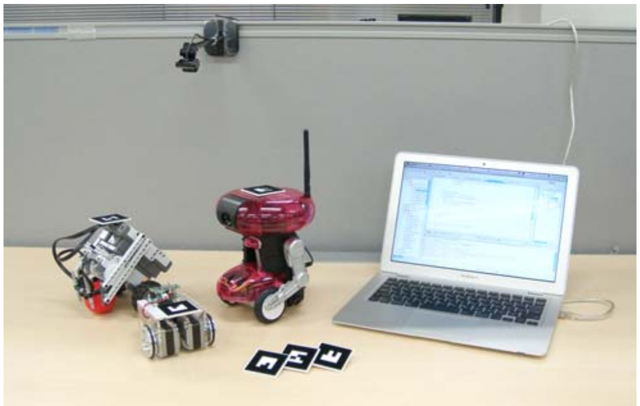

Figure 1 Our toolkit only requires a computer, a web-camera, visual markers, and robots.

IMPLEMENTATION

The toolkit consists of robots and objects on the floor, a ceiling mounted camera, and a control computer. The camera is wire-connected to the control computer and the robots are connected wirelessly via Bluetooth or TCP/IP network. Figure 2 shows a snapshot of the setup.

Mobile Robots and Drivers

Our toolkit currently supports three commercially available robots: iRobot Roomba, Lego mindstorms NXT, and Bandai NetTansor. These robots are small, easy to buy and use, and have the ability to move around the home environment (Figure 2). Our toolkit includes drivers for all supported robots, and the programmer can control the various robots with a unified API. A robot driver is managed as a Java class, and each robot is associated with a corresponding driver in the configuration file. This makes it possible to use various robots at the same time. We also designed the drivers' API in a way that makes it easy to add a driver for a new robot by writing the robot specific code (e.g. communication protocol, low-level control command, etc.) in each deriver class.

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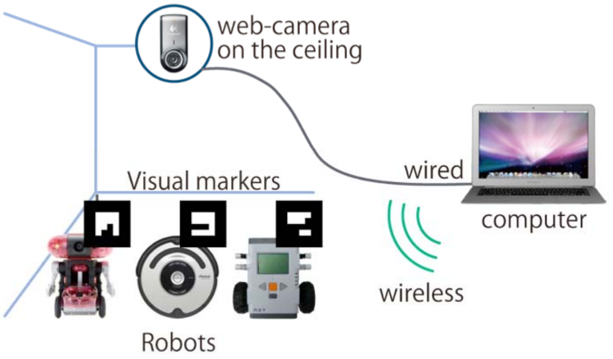

Figure 2 Example setup of the toolkit

Vision sensor with visual markers

The toolkit uses and includes NyARToolkit for Java [4] (wrapper of ARToolkit [5]) to detect the locations of robots and objects. It detects the robots' and objects' IDs and their locations by using visual markers in a given image. The visual marker is a square image like a 2D barcode (Figure 2). When the toolkit detects visual markers, it returns their location (where the marker is in the captured image), orientation, and the ID of the robot and/or objects in the world.

Configuration

The user needs to set the following elements in the configuration XML file:

1. Camera connection
2. Robots / objects and world coupling

The toolkit needs to know which visual marker corresponds to which robot. For each robot, the user specifies the name (1), driver type (2), connection type (TCP/IP, Bluetooth, etc) (3), and visual marker name (4) in the configuration file. For the object configuration, just the object's name and visual marker name are required.

USER STUDY

The goal of our toolkit is to support the development of robot applications for all levels of robot programming. To see if our goal can be achieved, we performed a user study in a course. This section describes the procedure and results of the study.

Procedure

We provided our toolkit and "robot kits" to computer science graduate students in a Human Computer Interaction (HCI) course. Fifteen university students enrolled in the course and formed eleven groups. We provided our toolkit through a web site that included an installation guide and programming guide. The documents were provided as wiki pages, and it had the capability of receiving questions from the students.

Results

We confirmed that the toolkit helped students to develop their robot applications. All students completed their projects and successfully developed robot applications. It was also possible to develop an application that used multiple robots. We were surprised to see that some students developed applications we had never expected. Figure 3 shows some of the robot application that the students created.

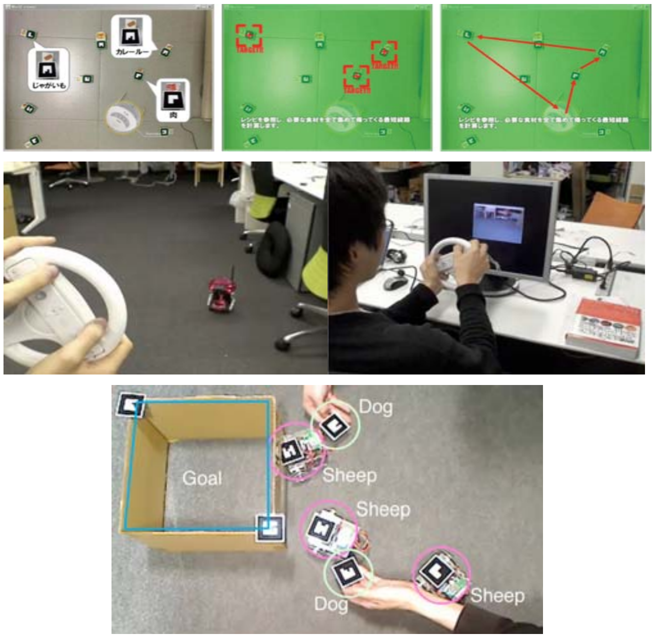

Figure 3 Robot applications that students created

CONCLUSION

We proposed a toolkit for mobile robots that uses vision markers and a ceiling camera as a vision sensor. It allows non-robotics experts such as software engineers, interface designers, and interaction designers to develop their own robot applications. The key aspect of our system is that the physical locations of robots and objects are defined in the screen space and the programmer can handle them seamlessly with GUI events. This significantly lowers the barrier while still supporting a large variety of applications. We provided the toolkit to the computer science graduate students, and they successfully developed interesting robot applications.

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