The IMP: An Intelligent Mobile Projector

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Abstract

The IMP (Intelligent Mobile Projector) is a low-cost platform for exploring mixed-reality interaction, structured-light range sensing, and human-robot interaction. The platform combines recent advances in mobile robot and projector-camera systems research. The low-cost platform is composed of an iRobot Create robot, two servo motors, a netbook, a webcam, a laser pico projector, and a laser pointer. The software is written in the Processing development environment.

Motivation

Mixed Reality (MR) and Augmented Reality (AR) are technologies that blend the normally quite distinct physical and virtual worlds. An augmented reality application might overlay virtual information (e.g. a plane blueprint) onto our physical world (e.g. a plane being serviced by a mechanic). Recent advances in smart phones (e.g. LCD, GPS, and CMOS camera technology) have led to a surge of AR interest and applications.

Rather than viewing the AR-world through a small smartphone display, another option is to use a projector to overlay information onto the physical world. Coupling the projector with a camera can provide a large interaction surface available to multiple users at the same time. Projector-camera systems have also found use in range scanning. Image processing becomes easier when a known, controlled image is projected into the environment. Leveraging this insight, researchers (Blais 2004) have developed methods for recovering 3D scene geometry from camera-projector systems.

Projector-camera approaches to AR and range scanning have limitations. Past projectors have been bulky and power hungry, and thus relatively immobile. Although still a nascent technology, mobile LED-powered projectors are small, energy efficient and effective in low-light environments. *Mobile projector-camera systems* are now becoming a reality; however, most of the research relies on the systems being carried by the user (i.e. wearable) (Kushal et al. 2006; Mistry and Maes 2009) restricting the range of mobility.

Using a projector as a means for robots to communicate with users has recently been investigated (Matsumaru 2006; Kwon and Kim 2010) as well as using projector-camera systems for human-robot interaction (Machino et al. 2006; Park and Kim 2009). Placing a projector-camera system on a mobile robot has a variety of uses. First, the robot can use the projector-camera system as an inexpensive range scanner to detect obstacles or build realistic 3D maps. Second, the projector-camera system can provide new ways of interacting with a robot. Third, a mobile robot can actively reorient the projector to follow a moving person or find suitable projection surfaces. Finally, by exploiting the autonomy of the IMP, a new type of mixed reality lets the robot control not only what is projected, but also where the scene is projected.

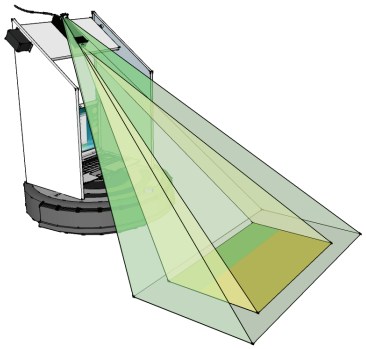
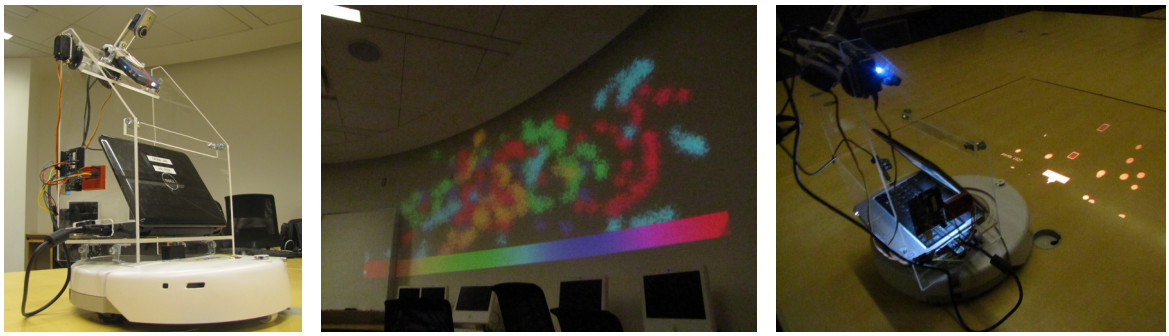


Figure 1: The IMP concept

Approach

The IMP is a low-cost platform for exploring mixed-reality interaction, structured-light range sensing, and human-robot interaction. The platform combines recent advances in mobile robot and projector-camera systems research. The platform (see Fig. 2(a)) is composed of an iRobot Create mobile robot, two pan-tilt servo motors, a Dell Mini 9 netbook, a Logitech webcam, and a Microvision laser pico projector. The software is written using the Processing programming environment. The entire platform can be created for around $1,000 making it accessible to a large audience.

The IMP follows the approach of (Sukthankar, Stockton, and Mullin 2001) for computing the homography relating the points in the camera frame to points in the projected im-



(a) (b) (c)

Figure 2: (a) The IMP (b) An expansive multi-user drawing application (c) A mixed-reality vacuuming game.

age. Two types of calibration procedures are used, one in which the users selects the four corners of the projected image with known locations, and another that automatically finds the projector boundary using image processing.

Once we can relate points in the camera to points in the projected image, the user can meaningfully interact with projected image. Users interact with the system using laser pointers. Relying on laser pointers as the primary form of interaction has multiple benefits (Kemp et al. 2008; Ishii et al. 2009) including making the image processing (detection and tracking) easier and allowing interaction from a distance. Interaction from a distance is particularly important in our system because close interaction with the projected image often results in shadowing. The laser pointers and tracked and offered as Processing primitives similar to those of the computer mouse.

The IMP is able to project onto flat surfaces almost anywhere using its pan-tilt-move interface. We have created a few applications that demonstrate the IMP's capabilities:

- **Projector Paint** – Multiple users can draw on a physical wall virtually using different shapes and colors.
- **Robot Graffiti** – Multiple users can virtually spray paint on a long wall; the robot moves the projector to uncover parts of the wall. (Fig. 2(b))
- **Create Controller** – The user controls and views the status of the robot via a projected image on the ground.
- **MR Vacuum** – A mixed-reality game where you drive the roomba through the real world to vacuum real and virtual dirt. Other players can help by moving the dirt closer to the robot or antagonize it by placing obstacles. (Fig. 2(c))

Future Work

We plan to investigate structured light methods as a way to recover range information for obstacle detection, localization and mapping. Moreover, if the IMP had a better localization system, more sophisticated AR applications would be possible. Other research directions include automatically searching for suitable projection surfaces and performing better geometric and photometric calibration.

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