Robot Gaming and Learning using Augmented Reality

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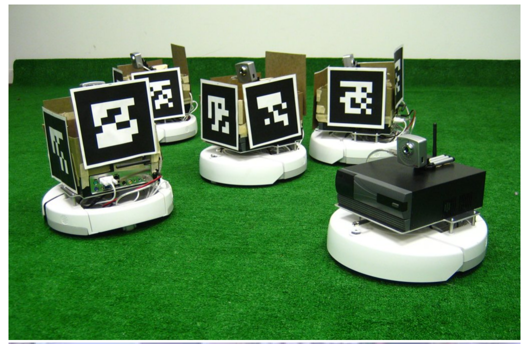
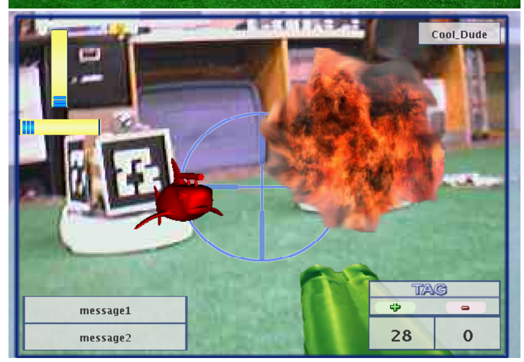
Towards accessible teaching of robots from demonstration, we describe a prototype mixed-reality distributed multi-player robotic gaming environment. Our goal is to provide robot learning researchers with a means to collect large corpora of data representative of human decision making. Robot control by a human operator (or teleoperation) is cast in a video game style interface to leverage the ubiquity and popularity of games while minimizing tedium commonly associated with robot training.

Background Despite tremendous advances in robotics, we have yet to realize truly personal robots that serve as a medium for common users to express themselves, through desired robot behavior, in the real world. Analogizing to graphics, robotics lacks the basic tools for creating physical content (that is, robot decision making) the same way tools such as OpenGL and Maya serve to render and animate virtual content. Teleoperation and programming (via computer programming languages) are classical methods to control robotic systems, but they often require a combination of constant human supervision, a high level of expertise, and continued reprogramming to new tasks and environments. Techniques from machine learning, such as supervised regression and reinforcement learning, offer a promising avenue for robots to learn policies from observing user behaviour and incorporating user feedback. Development of robot learning from demonstration, however, has been limited mostly because it is a data-driven process that lacks representative data. This circumstance stems from the fact that collecting data from human performance is difficult due to the expense of robot maintenance and lack of compelling interfaces.

Online robotic gaming involving a massive number of people and tasks is the path to viable robot learning. Our work, in particular, aims to provide persistent online robot gaming presence (24/7/365), similar to a robotic XBox-Live system, that immerses the user in the process. We have developed a client/server robot gaming system that consists of Java-based teleoperation clients that use augmented reality overlays to drive low-cost commercial robot platforms (e.g. iRobot Create) at selected game severs, moderated by automated referee observers. Our system logs control pairs (perceived robot states S and human control actions A) into a database that will eventually be used to learn a decision making function $f(S) \rightarrow A$.

Robot Platform/Server We have currently implemented a robot game server and clients for playing the example game of "RoombaTag."[1] Our robotic platform, named "Smurv," is based on an iRobot Create robot with a mounted Mini-ITX form factor computer. The Smurv also has a Unibrain Fire-I camera as a visual sensor and an infrared (IR) emitter that functions as an "IR cannon." The ITX machine runs Linux and Player/Stage robot server [Collett et al. 2005] from a CompactFlash memory card, allowing both control of the robot's hardware via TCP/IP over wireless and access to the onboard robot controllers. Game state shared between multiple Smurvs is implemented in a game server, which acts as a mediator, a referee and a switchboard between the set of physical robots and the users controlling them through the Internet. Users control a robot through a client-side Java application that communicates with the game server.





Augmented Reality It is crucial for the robot learner and human teacher to have the same awareness of the robot's state S, which has recently been explored through cartoon-like "robot expressionism" [Young et al. 2007]. In cases of learning, the human's actions should not be based on observations unavailable to the learned decision making policy. Thus, providing the robot's camera image directly to the human teleoperator is not sufficient. Instead, we present the robot's perceived state to the user using augmented reality. The environment and other robots are tagged with fiducial markers; the fiducials are tracked using the ARTag library [Fiala 2005], and associated 3D model overlays are displayed to the user. Eventually, the user will only see these overlays, so that the effect of the human's more advanced perceptual abilities is minimized.

COLLETT, T. H., MACDONALD, B. A., AND GERKEY, B. P. 2005. Player 2.0: Toward a practical robot programming framework. In *Proc. ACRA'05*.

FIALA, M. 2005. Artag, a fiducial marker system using digital techniques. In *Proc. CVPR'05*, vol. 1, 590 – 596.

YOUNG, J., XIN, M., AND SHARLIN, E. 2007. Robot expressionism through cartooning. *ACM SIGCHI/SIGART Human-Robot Interaction*, 309–316.

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[1] The weapon-based nature of this game will removed before the official public release of the game server.

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Motivation

Despite tremendous advances in robotics, we have yet to realize truly personal robots that serve as a medium for common users to express themselves, through desired robot behavior, in the real world. Analogizing to graphics, robotics lacks the basic tools for creating physical content (that is, robot decision making) the same way tools such as OpenGL and Maya serve to render and animate virtual content. Teleoperation and programming (via computer programming languages) are classical methods to control robotic systems, but they often require a combination of constant human supervision, a high level of expertise, and continued reprogramming to new tasks and environments. Techniques from machine learning, such as supervised regression and reinforcement learning, offer a promising avenue for robots to learn policies from observing user behaviour and incorporating user feedback. Development of robot learning from demonstration, however, has been limited mostly because it is a data-driven process that lacks representative data. This circumstance stems from the fact that collecting data from human performance is difficult due to the expense of robot maintenance and lack of compelling interfaces.

Robotic Gaming

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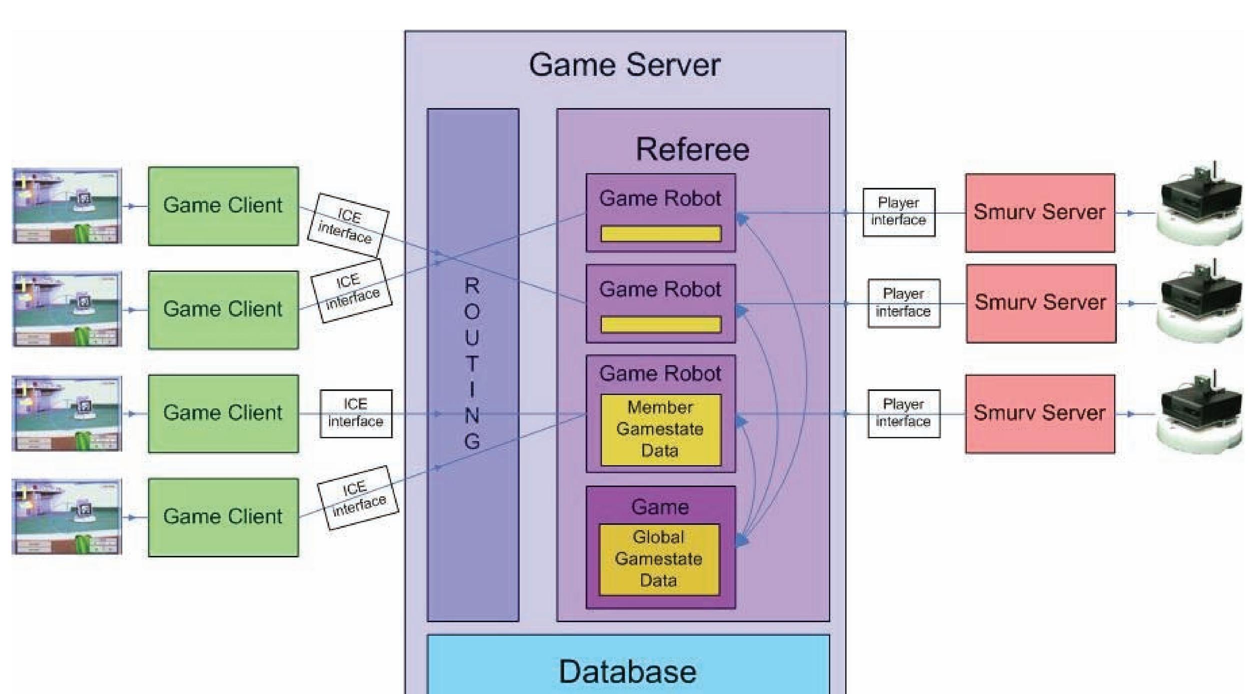
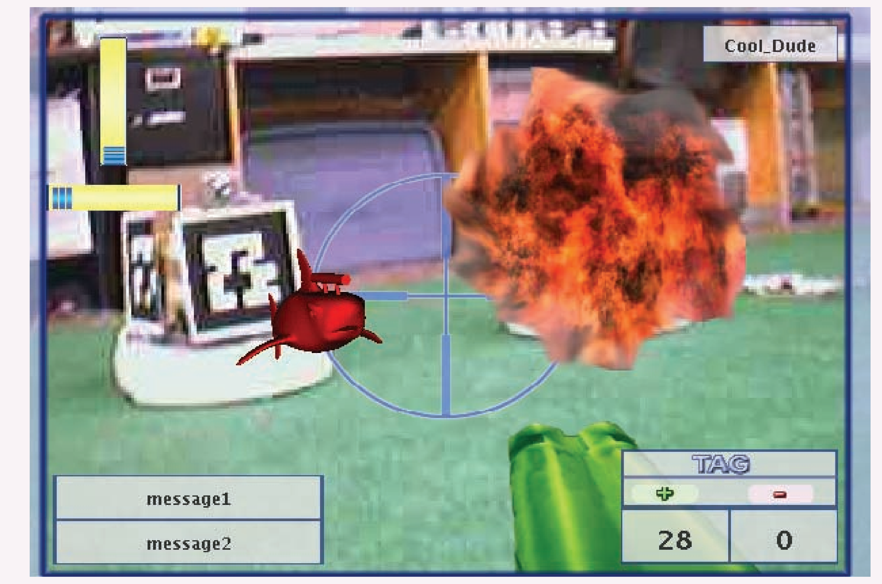


Game state shared between multiple players is implemented in a game server, which acts as a mediator, a referee and a switchboard between the set of physical robots and the users controlling them through the Internet. Users control a robot through a client-side Java application that communicates with the game server.

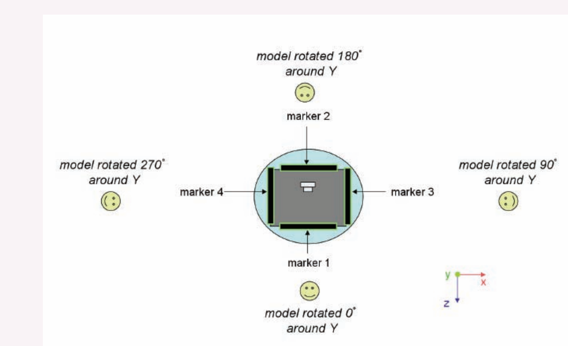
Game Interface



The current implementation of a multiplayer networked game, RoombaTag, provides each player with a graphical interface similar to a first-person shooter.* A player's goal is to "tag" (shoot) other robots in the game, while avoiding being tagged. Other players are represented with 3D avatars overlayed in locations corresponding to real robot positions.

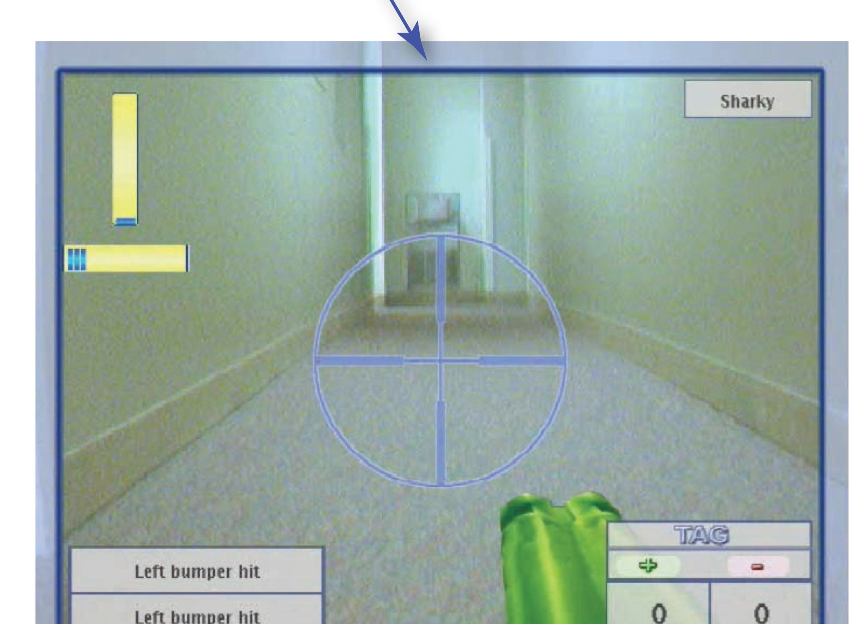
*The weapon-based nature of this game will be removed before the official public release of the game server.

A pose for a 3D avatar is determined by a set of fiducial markers. When a marker is detected in the camera feed, the associated model is positioned on the screen according to the appropriate object transformation derived from the image.



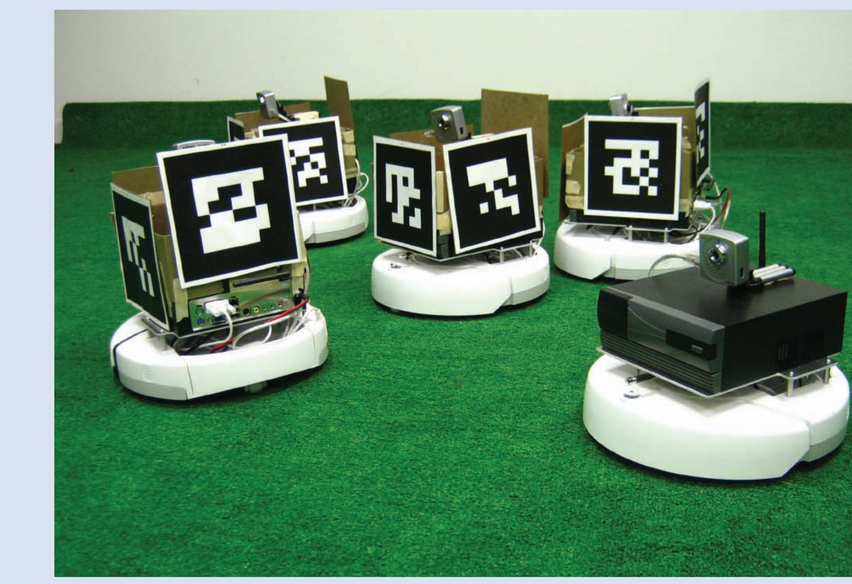
Overhead camera view

Game Player A



Game Player B

Robotic Platform



Our platform, named "SmURV" (Small Universal Robotic Vehicle), is based on an iRobot Create robot with a mounted Mini-ITX form factor computer. The SmURV also has a Unibrain Fire-I camera as a visual sensor and an infrared (IR) emitter that functions as an in-game "IR cannon." The ITX machine runs Linux and Player/Stage robot server[1] from a CompactFlash memory card, allowing both control of the robot's hardware via TCP/IP over wireless and access to the onboard robot controllers.

Augmented Reality

It is crucial for the robot learner and human teacher to have the same awareness of the robot's state ***S***, which has recently been explored through cartoon-like "robot expressionism[3]." In cases of learning, the human's actions should not be based on observations unavailable to the learned decision making policy. Thus, providing the robot's camera image directly to the human teleoperator is not sufficient. Instead, we present the robot's perceived state to the user using augmented reality. The environment and other robots are tagged with fiducial markers; the fiducials are tracked using the ARTag library[2], and associated 3D model overlays are displayed to the user. Eventually, the user will only see these overlays, so that the effect of the human's more advanced perceptual abilities is minimized.

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[2] FIALA, M. 2005. ARTag, a fiducial marker system using digital techniques. In *Proc. CVPR'05*, vol. 1, 590–596.
[3] YOUNG, J., XIN, M., AND SHARLIN, E. 2007. Robot expressionism through cartooning. *ACM SIGCHI/SIGART Human-Robot Interaction*, 309–316.

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