A cooperative teleoperation research tool

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Introduction

Cooperative teleoperation or telesystems are designed to assist humans in executing tasks to provide functionalities such as safe exploration, object recognition and manipulation. These systems try to improve the teleoperation process by supplying aid to the operator. Assistants robots can be used and controlled in very different ways, therefore developers need flexible tools to create and evaluate their applications in an efficient manner. This paper describes our work on the development of a testbed platform for experimentation and prototyping in cooperative teleoperation. This system, called ASSET, provides an environment for the application development and testing supporting teleoperated, autonomous and semi-autonomous entities. It provides management of interaction and acting devices, 3D rendering and easy integration of user components.

Background

Telesystems have long been recognised as a very useful technology for space exploration, and they can be integrated to a variety of applications such as manipulation in nuclear processing plants, rescue, fire fighting, intervention operations in hazardous environments, security, surgery and rehabilitation[1]. Assistance robots complement human faculties and allow systems to take advantage of the computer's capacities to achieve repetitive tasks and physically hard work, and to use as better as possible the expert dexterity to look and to react at the right time. The assistant can be a real machine as robots used for shared manipulation of heavy or long objects[2], teleoperation tasks, aid for disabled people and rehabilitation, in which technology is used to train a user in certain tasks and give practice and strengthening exercise. The assistant may also be virtual like virtual humans used to support team training[3]. They serve as instructors allowing students to practice tasks when some or all human instructors are unavailable.

Technologies such as virtual reality and artificial intelligence have shown their benefits when applied to telesystems context. Virtual reality enables to build systems that enhance communication by facilitating information display. In teleoperation applications, virtual reality improves task performance thanks to intuitive manipulation and exploration of working environment. Moreover, an interactive 3D simulation allows to give "virtual assistance" to the operator by adding guides or actors, present or not in the real world, which aid the operator in task learning or execution. Different projects following this direction[4,5] have shown that virtual reality interfaces can improve the operator task knowledge and provide valuable tools to understand and analyse the remote environment. On the other hand, increasing the robot's artificial intelligence reduces the demands on the operator by allowing different control schemes. It also provides behaviours enhancing applications as in the case of instructors cited above.

Issues in telesystems development include simulation, 3D modelling and rendering, behaviour descriptions, graphic interfaces, network communications and management of devices. Adequate development tools are necessary to allow researchers to focus on their particular problems: they must be able to explore and test new ideas in an independent way without affecting the integration process and the final application. Our research focuses on providing a tool for helping development of telesystems supporting the different possibilities for human-robot collaboration, able to create prototypes quickly and to explore different design alternatives. Our system ASSET is a set of reusable components, easily configurable that can be used as a testbed for evaluation of 3d scenes, IA behaviours, new devices or interactions techniques. This is done by providing a basic teleoperation

system architecture and by allowing addition or changing of modules in a dynamic way. An additional objective in the ASSET implementation is to have a low cost, lightweight, object-oriented system developed with open source products. For this reason, we have chosen Java and Java3d to develop our system, so that it can run on any platform without further changes.

System Overview

ASSET is a set of reusable Java components providing a testbed for experimenting in cooperative teleoperation research. The approach taken in this project is to abstract mechanisms presented in all teleoperation applications such as network communications, graphics user interface, user-simulation communication and device management. All these mechanisms are implemented using an object-oriented software design that assures encapsulation of components and modularity of the entire system. This allows users to decrease the time spent on prototype evaluation because they can test their modules without having extensive knowledge of the underlying mechanisms controlling the whole application. For example, for testing behaviours, the developer only needs to provide a geometric model and a control class for his entity: ASSET supplies the necessary components for application execution. This feature reduces the time of development and provides a realistic testing environment.

Dynamic reconfiguration in ASSET provides an environment to easily experiment with different implementation possibilities. All the specific information and application data resides in a configuration file loaded at initialisation. This file contains information about simulation objects (geometry and behaviour), devices and network information. In this way, a wide variety of modifications can be done without changing or recompiling all application modules.

The ASSET's architecture consists on three modules:

- User Interface Manager. The User Interface Manager (UIManager) is responsible for the communication between the system and the user, it handles the local simulation and the interaction devices.
- Real System Manager. This module controls the real system. It is very similar to the UIManager, but it controls the sensors and effectors of a real robot. Real System Manager (RSManager) executes the commands and manages coherence between the real state and the simulated state in order to update the user's simulations.
- Administrator. The administrator coordinates the interactions between the participating entities, users and robots. It transmits commands to the real system and the information from the real system to the users. It has a Coordination component to solve conflicts raised by orders of different users.

A real case test bench implementation

We have used ASSET to develop a cooperative teleoperation environment called ROVE. In this system, a common task must be carried on by an autonomous robot and a teleoperated one. The autonomous robot is controlled by a behavioural simulation system called A3, which has been developed in our laboratory. For this application we use two Khepera robots, a Logicad 3d Spacemouse Classic and a Microsoft Side Winder Force Feedback Joystick. To control the Khepera robot we can switch easily between the Spacemouse and the joystick, showing that changes in hardware configuration do not require any change in the application code. For the same reason, we are investigating the use of other mini robots instead of Khepera ones.

With the architecture and mechanisms defined in the ASSET system, we have achieved important requirements like extensibility, adaptability and a highly configurable system that can integrate available resources.

Conclusions

We have presented in this article ASSET, a support environment that serves as a testbed for the cooperative teleoperation systems development. In this experimental environment, the developer can test new simulation models, behaviours and devices. This feature facilitates the utilisation of ASSET in the creation of new telesystems and in making rapid tests and prototypes. Current work includes improvements of the collision detection engine used in simulation, enhancements to multi-users coordination and study of behaviours and interactions within the ROVE system.

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Keywords: *teleoperation, testbed, autonomous robots, virtual environment, simulation*