Distance robotics learning using Hybrid Simulating Testbed

***Abstract*—The authors examined the issues of building and educational use of Hybrid Simulating Testbed (HST) for robotic manipulator (RM). HST is based on the hybrid RM models, including computer models and physical RM models based on the serial industrial robots. The HST is controlled remotely. The HST user has the possibility to remotely select the structure and parameters of the MR control and simulation systems and to program it to solve particular problems.**

***Index Terms*—manipulator dynamics, orbital robotics, remote laboratory, robot control.**

I. Introduction

Students that study robotics should receive not only theoretical but also practical training in the field of robotics. Robotics equipment is quite expensive by itself, so it is hardly possible to provide each student with a personal robot. At the same time, an industrial robot (IR) is a product that needs to be tuned differently for different tasks, including regular IR tasks, i.e. software should be developed, attachments provided, etc. That is, industrial manipulator per se is not able to solve complex problems, especially to be a part of educational process [1, 2].

The obvious solution is to provide remote access to a robot equipped with robotic attachments and related methodological support and software.

On the basis of Hybrid Simulating Testbed (HST) of the Laboratory of Special Robotics and Mechatronics in Dmitrov Branch of Bauman University created online "Robotics" laboratory [2, 3] that provides the possibility to carry out complex remote laboratory courses on real sophisticated robotics equipment by means of network access technologies.

II. Hybrid Simulating Testbed

The HST is a hybrid (i.e. with hardware-in-the-loop) complex, which includes a number of personal computers linked into a network, industrial robots, man-machine interfaces, sensing tools and multimedia systems with sound and image transmission via the Internet (Fig. 1).

Using HST for space robots simulation is an effective tool for research on a wide range of space robotics problems (human-machine interface, robotic assembly technology and maintenance, etc.). HST can serve as the core for building cosmonauts training devices and for the preparation and adjustment of robotic operations in space.

HST allows you to:

- simulate real-time dynamic control processes of various RM both in virtual and physical form including those performed during contact operations and operations using the actual guidance systems equipment, tools and a variety of Human-machine interfaces;

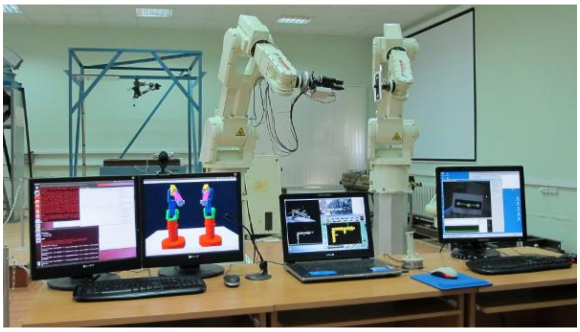

Figure 1. HST equipment

- customize your RM model;

- prepare, develop and verify control algorithms and programs of RM action ("autosequentions");

- maintain registration of the dynamic processes and logic operation; perform evaluation of the control effectiveness of the RM operators, develop and implement effective methods of training for RM operators;

- provide remote access to the control of HST equipment (via Internet) using videoconferencing.

HST hardware foundation consists of three industrial robots: two IR KAWASAKI FS-020N, with capacity of 20 kg each, one IR KAWASAKI FS-003N, carrying capacity of 3 kg.

Instrumental flanges of industrial robots FS-020N are equipped with six-component force-torque sensors (FTS). Robot arm grippers of different types are mounted on the FTSes: three-fingered centering electric gripper for power capturing of cylindrical objects, three-fingered hand with tactile sensitization to capture delicate objects with complex shapes.

The HTS is equipped with a variety of computer vision systems (CVS): monoscopic CVS mounted on the one of the IRs FS-020N effector, stereoscopic removable CVS, system building depth map of the scene based MS Kinect, installed on the IR FS-003N.

Software control panels, gamepads, joysticks, voice control are used as means of control.

III. Real-Time Modelling System

The core of the HST is a modeling real-time system (MRTS) invariant to the simulated RM. It is a universal system for modeling RM in real time.

MRTS provides automatic generation of RM equations. The arm in MRTS can be formed as a mechanism with open kinematic chain, with unlimited number of links jointed with each other by 5-class kinematic pairs, the links considered to be elastic bodies. The each DOF driver models are also generated automatically. Then the models of arm mechanisms and drivers are combined and completed with models of control mechanisms.

The resulting model equations are presented in the normal Cauchy form and then integrated with numerical methods of solution. The RM model generation procedures and the procedures of obtaining solutions for generated model are optimized for time reduction.

The safety software of HST prevents collisions of robot links with environment objects or other links of arm. In case of high probability of danger both the model and the IR will automatically stop.

IV. Organization Of Remote Access To Mathematical Models And Equipment Of Internet Laboratory

The virtual part of the Internet Laboratory comprises the Web-server and Model-server (Fig. 2). The remote control interface is a Windows application which can be downloaded by a user from the Laboratory site after agreeing with the Internet Laboratory administration on the conditions of the remote experiment.

At the agreed time a remote user is connected via the Internet to the Laboratory Web-server where he is granted authorization. Then the server sends to the Model-server the sequence of control commands in accordance with the mission generated by the user.

Working with a virtual robot, the Model-server implements the commands set by the user for the MRTS, and feeds back the virtual robot state parameters with the frequency of about three times a second. These data received by the Web-server are then transmitted to the client user interface (Fig. 3) via the Internet [3].

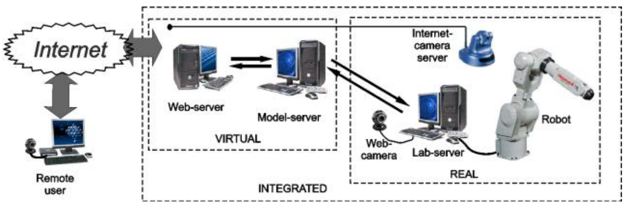

Figure 2. Flowchart of the Internet Laboratory “Robotics”

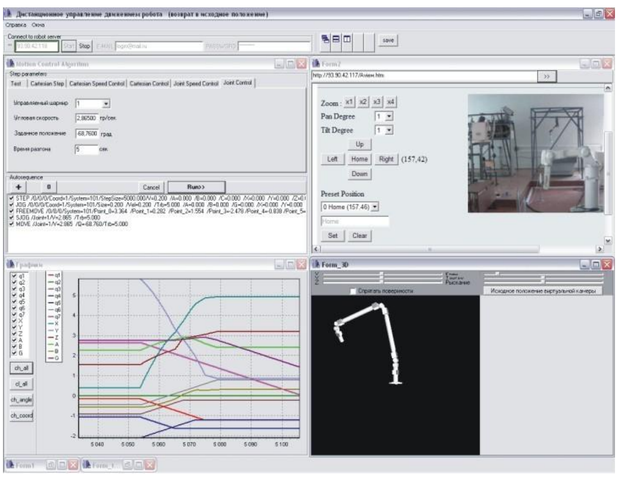

Figure 3. User interface for remote control of robotic equipment

Working with a real robot, the state parameters of the robot mathematical model are continuously transmitted from Model-server to Lab-server that controls the robot.

The main task of the Lab-server is moving the Kawasaki robot tip in accordance with the coordinates and speeds of virtual robot end effector received from the Model-server, on condition of their feasibility. As we have to deal with highly sophisticated robotic equipment, the main requirement to the remote control system is protection from the scenarios that could damage electronic or mechanical robot systems. Therefore, provision is made for a multi-level system to check the feasibility of control commands at each stage of robot operation. Since the program system of the Lab-server has the widest possibilities of robot control, one of the main functions of the Lab-server is automatic cancellation of the remote user commands that could lead to breakage of expensive equipment.

V. Remote Control Of Dual-Armed Robot

As mentioned above, the HST is equipped with three IR. Two IR form dual-armed robotic system. The third IR is equipped with a video camera.

A remote user can control the coupled movement of two arms of the HST. The operator can set the arms movement in the six coordinates, as well as to vary the distance between the arms in order to capture the various objects.

The operator controls the complex using the gamepad. Remote control software translates the deflection of the gamepad handles in the velocity of the arms. As a feedback the operator receives information about the positions and velocities of the end-effectors of both arms, joint positions and velocities of each arm, the power and torque of the pressure on the arms effectors. Remote control cycle for dual-armed robot lies within 0.1 seconds on average.

VI. Conclusions

It is important to give students practical skills to work with robots. Hybrid Simulating Testbed allows to develop such skills as working with serial industrial robot and with complex space robotic systems that can not be exploited in terrestrial conditions.

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