Development and Experimental Evaluation of a Remote Laboratory Platform for Teaching Robot Manipulator Programming

C.S. Tzafestas, M. Alifragis, N. Palaiologou,
S.C.A. Thomopoulos, M. Brahman, A.-E. Exarchou

Introduction

In this paper we describe the development and experimental evaluation of a "**remote laboratory platform**" in the field of robotics. The system in its current configuration aims at enabling distance training of students in real scenarios of **robot manipulator programming**.

The graphical user interface of the platform integrates concepts and techniques inspired from related work in the field of **telerobotics and virtual reality**.

A **pilot experimental study** was conducted to evaluate system performance in remotely training students to program robot manipulation tasks. The experiments were conducted according to a special evaluation protocol designed for this purpose. Analysis of the experimental results obtained from this pilot study is encouraging, providing guidelines for developing and deploying such remote laboratories effectively in real training scenarios.

Aim

(a) We aim to develop virtual and remote laboratory platforms for training in the operation and programming of complex mechatronic devices, such as "robot manipulators".

(b) From a technological point of view, our research focuses on the adaptation of concepts and technologies developed in the field of telerobotics and virtual reality, and on exploring their implementation in such remote laboratory settings.

(c) In our evaluation approach, we give emphasis on the didactical perspective of such systems, based on specific experimental protocols, combining qualitative and quantitative metrics; a further aim is to assess the effectiveness of these new media compared with traditional hands-on laboratory training scenarios.

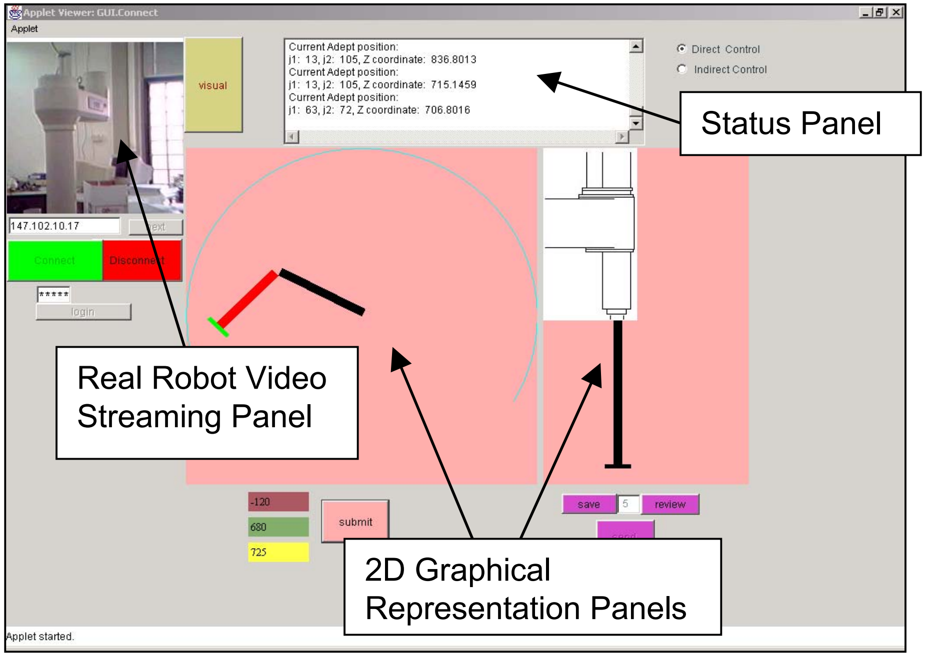
Technological Approach

The **graphical user interface** is developed based on Java technologies and incorporates mainly:

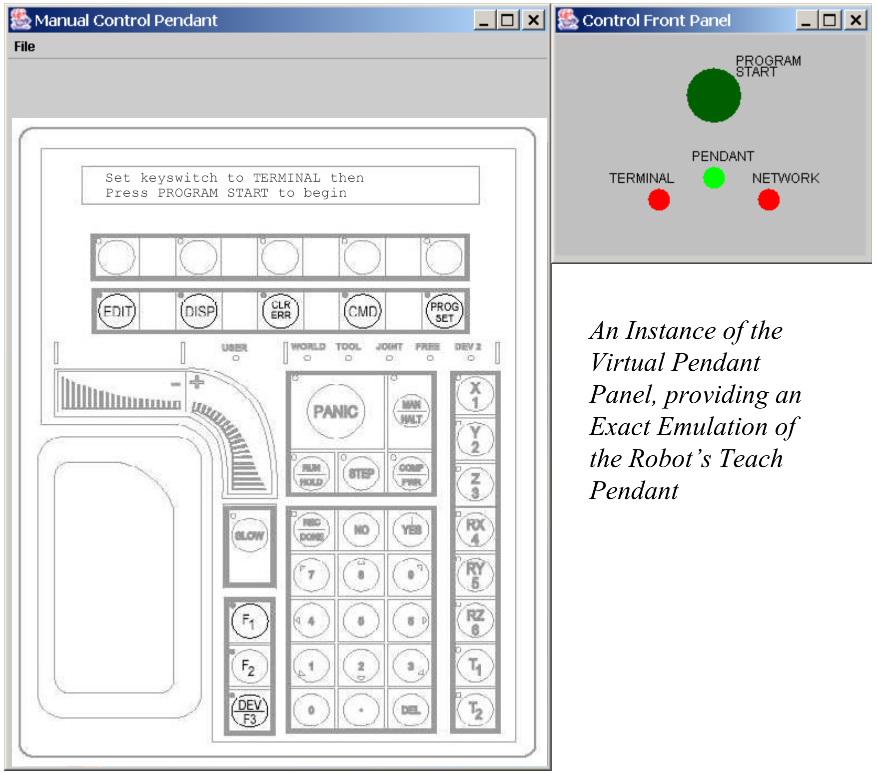
(a) 2D **graphical representation** (top-view and side view) panels, visualizing both actual and commanded/ robot configurations,

(b) a **real-time video streaming panel**, which is based on RTP and implemented using JMF, showing (when on-line) the real remote manipulator in motion, and

(c) an interactive panel providing an exact emulation of the robot's Teach Pendant, called **Virtual Pendant**.



The graphical User Interface of the Remote Robotic Laboratory Platform



An Instance of the Virtual Pendant Panel, providing an Exact Emulation of the Robot's Teach Pendant

Learning Aim: enable students to remotely practice real robot-manipulator programming tasks; offer possibilities to learn how to program a real robot, without having one at proximity, in such a way that closely resembles the real programming operations and procedures. In this way, we can really refer to the platform as providing real "distance training", instead of simple "familiarization" with robot motion principles.

Evaluation Method

We have designed a **special experimental evaluation protocol**, which was used consistently throughout the experiments. According to this protocol, the students participating in the laboratory training course (that completes a theoretical introductory course on robot kinematics, path-planning and control) were divided in two main groups:

• **group-I** (local) was trained the "traditional way" on the real robot, while

• **group-II** (remote/experimental) was trained using the virtual/remote laboratory platform.

Each group was subdivided in five teams of three to five students. The total number of the sample of this pilot study was 40 (N) students. Both groups of students had undergone the same training phases and were exposed to exactly the same educational material by the trainer during each experimental session, with the only difference between the two groups being the direct contact (physical presence), or lack of it, with the real robot on-site.

By the end of each training session, students of both groups completed their training by performing a specific experimental evaluation test on the real robot (**final test**): perform a robot programming task → program a pick-and-place operation using the real robot teach-pendant.

In order to assess students' performance a **scoring chart** was used by the trainer during the experiment.

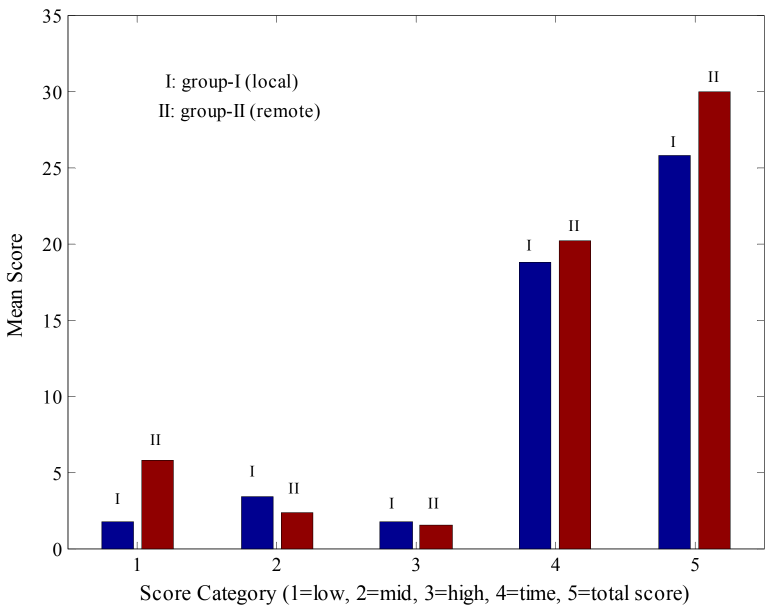
The errors were classified to **three categories**, namely: low-level technical skills, mid-level skills, and higher-level understanding, with different weights assigned to them.

The method used to consistently grade students' performance consisted of assigning a pre-specified "**penalty grade**„ for each specific error committed.

Moreover, teamwork between students was qualitatively monitored, while total time needed to complete each phase of the test was also recorded. All these scoring items (indicating the frequency of the different types of mistakes) were coded in real-time on the scoring chart by the tutor monitoring the experiment, and were subsequently decoded to compute the final values for the different scores.

Results

Statistical analysis (t-test) of independent groups was followed, to find out whether there exists statistically significant difference ($p<0.05$) between the Means of the various test scores (low, mid, high, time and total) for the two groups (group-**I**: local and group-**II**: remote).



Mean Scores of the two Groups in the Final Assessment Test

Main Result: Despite some apparent differences for the "low" score category, no statistically significant differences were found between the two groups.

Conclusion

The proposed remote laboratory platform, with its graphical user interface, created a virtual training environment, which on its whole (integrating the various interactive control and visualisation panels) provided adequate learning elements, as related particularly to mid and high level skills, compensating for the lack of direct physical presence on the real robot site.

Acknowledgements

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Authors' Affiliations:

- **C.S. Tzafestas** (contact author), **M. Alifragis**, National Technical University of Athens, School of Electrical and Computer Engineering, Division of Signals, Control and Robotics, Zografou 15773, Athens, Greece. Email: ktzaf@softlab.ntua.gr
- **N. Palaiologou**, University of Piraeus, Department of Technology Education and Digital Systems, Piraeus, Greece
- **S.C.A Thomopoulos**, NCSR "Demokritos", Institute of Informatics and Telecommunications, Athens, Greece
- **A.-E. Exarchou**, IS Integrated Product Information (K-DOE-5), VW Group, Wolfsburg, Germany
- **M. Brahman**, Inferta GmbH, Magdeburg, Germany

International Conference on Engineering Education

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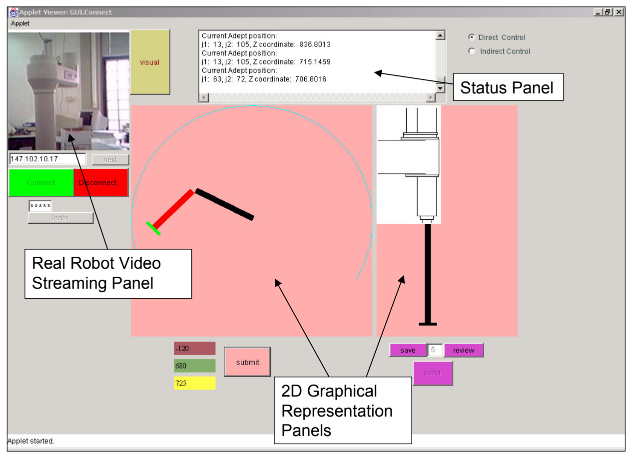

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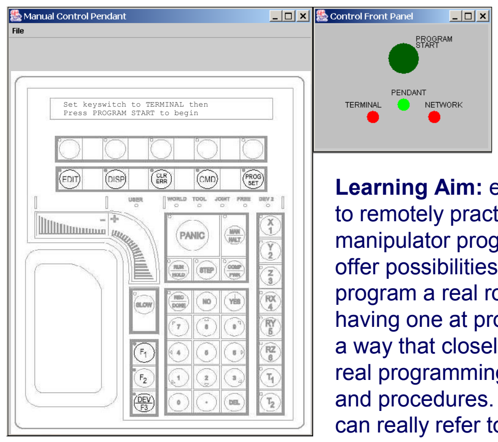

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Both groups of students had undergone the same training phases and were exposed to the same educational material by the trainer during each experimental session.

By the end of each training session, students of both groups completed their training by performing a specific experimental evaluation test on the real robot (**final test**):
→ program the real robot to perform a pick-and-place operation using the real teach-pendant.

In order to assess students' performance a **scoring chart** was used by the trainer during the experiment. The errors were classified to **three categories**, namely: low-level technical skills, mid-level skills, and higher-level understanding, with different weights assigned to them.

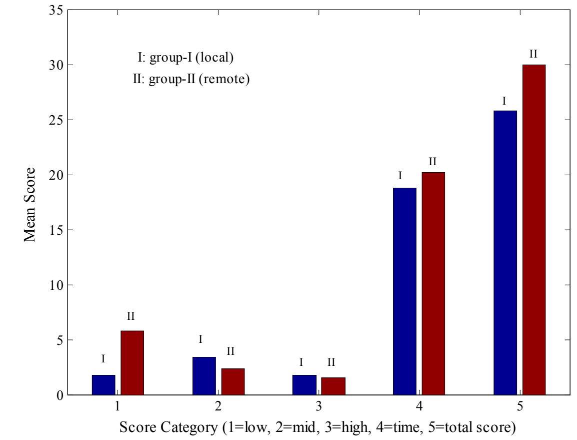
The method used to consistently grade students' performance consisted of assigning a pre-specified "**penalty grade**„ for each specific error committed.

Phases	Steps	Final Test Scoring Chart (2/3) (Group-2, Team 1, 3 pers.) — Scoring Categories: Low-Level Technical Skill		Mid-Level Skill	Higher-Level Understanding	Team Work	Overall (Start/End Time)	Comments
Phase 2: Robot Motion Planning - Move robot & record positions	1: MAN JOINT/WORLD/TOOL	✓ (M)		*	*	3 persons	17:44	* Joint space control
	2: pick-and-place - Move to Point B', ('X,1'/'Y,2' , '+'/'-') - Open Gripper	X1/Y2 +/-	✓*(E)	Pick from B **	✓			* no save at B' ** gripper closed?!
		T1, +/-	✓**					
		REC	✓					
	- Move to Point B, ('Z,3' , '+'/'-') - Close Gripper	Z3, +/-	✓ *					
		T1, +/-	✓					
		REC	✓					
	- Move to Point B', ('Z,3' , '+'/'-')	Z3, +/-	✓	Place to C ✓	✓			
		REC	✓					
	- Move to Point C', ('X,1'/'Y,2' , '+'/'-')	X1/Y2 +/-	✓					
		REC	✓					
	- Move to Point C, ('Z,3' , '+'/'-') - Open Gripper	Z3, +/-	✓					
		T1, +/-						
		REC	✓					
	Move to Point C', Move to Point A	Z/X/Y, +/-		Park to A *			17:58	* no REC!
		REC	*					
	RECord waypoints				---			
Comments		M*E**= 8		** + * = 5 + 2	*		Partial time	Partial Score
Score value		8		7	3		14 min	18+14 = 32

An instance of a scoring chart used to code and assess student performance

Results

Statistical analysis (t-test) of independent groups was followed, to find out whether there exists statistically significant difference ($p<0.05$) between the Means of the various test scores (low, mid, high, time and total) for the two groups (group-I: local and group-II: remote).



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[1] Contact Author: C.S. Tzafestas, Lecturer,
National Technical University of Athens,
School of Electrical and Computer Engineering,
Zografou Campus, Athens 15773, Greece
Email: ktzaf@softlab.ntua.gr