BASIC STRATEGIES TO ENHANCE TELEOPERATION PLATFORMS THROUGH THE INTERNET

J. J. Escribano, J. A. Cerrada, S. R. Gómez
Dpto. de Lenguajes y Sistemas Informáticos UNED
c/ Juan del rosal, 16 - 28040 Madrid (Spain)

C. Cerrada
Dpto. de Ingeniería Eléctrica, Electrónica y de Control UNED
c/ Juan del rosal, 12 - 28040 Madrid (Spain)

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Abstract: This paper shows in a schematic way the basic objectives to enhance teleoperation platforms, that have been achieved in the PhD Thesis (Escribano, 2003). These objectives are the result of acquired experience working with the teleoperation platform developed by our research group in teleoperation. The objectives carried out have been formulated after analyzing the performance of the initial platform and detecting some restrictions in several key parts of its design. Specifically, three basic improvement areas have been take into account. The enhance objectives have been focused in aspects such as the operating system, the human-machine interface and finally, in aspects regarding to the communication between the master and the slave. In this paper the main detected problems are introduced as well as the chosen solutions in each case. Experimental results regarding to the last enhancement objective are finally shown.

1 INTRODUCTION

Most of teleoperation platforms have been developed under this thinking: the more capabilities you put, the better results you will obtain (Antal K. Bejczy and Schenker, 1994), (W. J. Book and Obergfell, 1996), (Luo and Chen, 1997). Various strategies to enhance teleoperation platforms through the Internet are shown in this paper. These strategies are inspired in the application of low cost philosophy in both software and hardware components. Low cost does not mean bad performance or poor results, but it means to invest as much money as the research need and no more(Gomez S. R. and C., 1999).

The starting point of this work has been the previous experience acquired in the research line of teleoperation existing in our group. As a result of this research activity, we already had a teleoperation platform. The first step was to analyze performance capabilities of the platform in order to identify its main limitations. Three major areas of improvement were detected corresponding to the three enhance objectives taken into account in this work. These objectives will be shown in the next sections.

This paper is organized as follows. The capabilities analysis of the previous platform is presented in the second section. The third section shows the three enhance objectives considered. Experimental results of implemented solutions are presented in the fourth section. The conclusions are shown in the last section.

2 CAPABILITIES EVALUATION ANALYSIS

During the experimentation with this platform several limitations have been brought forth. These constraints have induced the research work carried out. Although the different strategies developed to enhance this platform will be described in the next section, here we present the detected limitations. Suggested actuation lines are also introduced.

2.1 Operating system

Human-machine interface, control system and master-slave communication system were running under a no real time operating system. Therefore, critical time measurements were not reliable, making very hard to evaluate platform performance and to implement realistic control strategies.

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2.2 Human-machine interface development tool

The main constrains of the previous human-machine interface will be shortly described. The origin of these limitations were located in the utilization of a commercial software called VRT from Superscape as developing tool for this interface. They can be summarized as follows:

- It is a commercial and closed software.

  Due to this, support can disappear any time, making impossible the adaptability to any later on requirement. Our proposal was to develope software of our own allowing the addition to the system of any new capability.

- It has no 3D information extraction capabilities from 2D images.

  The used environment did not have any special device to showing three dimensional visual information. A solution to this problem could be adding projected shadows to the 2D generated scenes, but the software tool did not have this capability. It should be very interesting to include this capability because projected shadows allow to the operator extracting the third dimension from a 2D image.

- The collision detection is acomplished by means of bounding boxes.

  Any object must be included inside a box (bounding box). If the bounding box of an object fits to it very well, the bounding box allow to calculate collisions well, but in the case of irregular shaped objects, it would seem that the collisions do not happen in the objects surface. As a solution to this problem we suggest to use the own object surface for collision detection.

2.3 Master slave communication system

The communication with the slave system was being carried out thought an standard RS232 serial port. Due to this fact the slave system must be very near to the master system. It should be very advantageous to implement the communication through the Internet. In this way both systems could be located at any place of the planet.

3 IMPLEMENTED STRATEGIES

From the previous study a set of enhance strategies have been proposed and implemented in our experimental platform. They can be classified in the same three categories of the earlier analysis. This section is devoted to describe the enhancements implemented in each category.

- Operating system
  - RTLinux (FSMLabs,) has been selected and used as real time operating system to substitute the previous version that was developed under Windows 9X. With this transformation the teleoperation platform behaves as a synchronous system that works with a period t controlled and stable. In this way, platform capabilities have enhanced thanks to the improvement of the critical time measurement processes, so necessary to analyze and evaluate the actual teleoperation platform performance. Additionally, the use of a real time operating system allows to include more reliable controllers that enhance the time response of the operator, the slower part of all the involved in a teleoperation system.
  - A new algorithm that allows to fit the data reading speed from the used Spacemouse to any period t, in spite of the Spacemouse is only able to provide data every 112 msec., has been implemented.
- Human-Machine Interface
  - By using the OpenGL library as a base, a C++ classes library that allows to make 3D scenes and to render them in few milliseconds has been implemented.
  - A collision detection free library (van den Bergen,) has been used to implement a new algorithm of maximum nearness to objects in case of collision with the robot tool.
  - The inclusion of a projected shadows algorithm has allowed to demonstrate by means of an experimental analysis that virtual environments shown in monoscopic diplays allow to reach better performance that if they are shown with stereovision in virtual teleoperation platforms. This study was presented in a more detailed way in (J. J. Escribano, 2000). This performance enhancement is obtained by adding projected shadows to virtual environment. An example of developed virtual environment that includes projected shadows is shown in the figure 1.
- Connection of master and slave systems
  - An statistical module has been developed to analyze the Internet segment that communicates the master system to the slave system by means of port 7 UDP. This module allows to know the current state of the segment and to proceed accordingly.
  - An Internet segment simulator that introduces a time delay d in the receipt of packets, following d a normal ditribution $N(\mu, \sigma)$ (μ and σ are

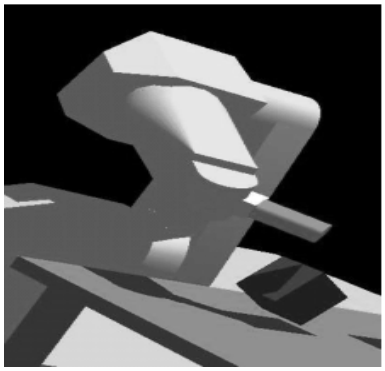

Figure 1: Virtual environment with projected shadows

modifiable), and that takes into account packet loss (also modifiable), has been implemented. It has allowed to experiment with several distances between master and slave systems.

– Several methods that try to avoid the double problem related to communication through the Internet (delay and packets loss) have been implemented. Modifications of these methods have been accomplished with the purpose of improving them. A comparative study between original methods and modified methods, similar to the study of projected shadows, has been realised. As a result of this study it has been demonstrated that the modified methods present important enhancements with respect to the original ones. Part of this study is shown in the next section.

4 EXPERIMENTAL RESULTS

In this section it will be shown the main results of the above mentioned comparative study concerning to master slave communication system through the Internet. Part of the obtained experimental results regarding to collisions measurement, backward movements and times to complete a task of several methods of teleoperation through the Internet (Oboe and Fiorini, 1998), (Brady and Tarn, 1998), (Oboe, 2001) implemented in the PhD thesis (Escribano, 2003) are presented here. Thirty tries for each of the considered typical cases of connections through the Internet were done. The mean and the standard deviation of the delay for each considered case were extracted from the table (Oboe and Fiorini, 1998) (see the table 1).

To avoid the effect of the operator acclimation to the methods, the four cases were not tested in the same order for each method. They were done in the order presented in the table 2.

Next, the case 1 will be commented. In the case

Table 1: Delay parameters in typical connections through the Internet

Case	remote machine location	Distance (Km)	μ(ms)	$\sigma(ms)$	% loss
1	Different continent	10000	326.3	27.20	41.4
2	Different city	150	17.20	9.74	0.80
3	Same domain	30	8.10	5.35	0.08
4	Local	0.05	0.998	0.715	0.00

Table 2: Case order for each method in the experiments

Cases	1	2	3	4
Analitic expression	1	9	13	5
Kalman	14	6	2	10
Enhanced Kalman	11	3	7	15
Enhanced buffer	8	16	12	4

1, i.e. different continent connection, it can be observed that enhanced Kalman method behaves much better than Kalman method, both in collisions and backwards movements (see figures 2 and 3). In the figure 4 it can be seen that analitic expression method detaches from the other three methods, because of its worse behavior in completion task time. In the figure 5 it can be seen in detail that behavior of the other three methods is similar in completion task time.

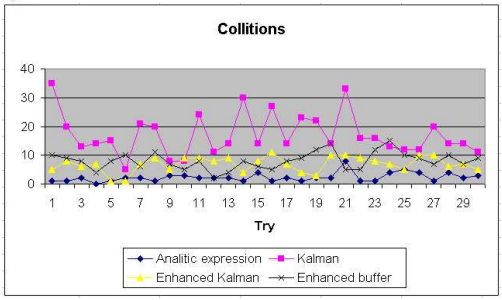

Figure 2: Collitions in case 1

As conclusion of this comparative study the methods can be ordered according to their behavior. This behavior is significatively different when distance connection increases. In such situations, the method that has a better behavior is enhanced buffer method, next method is enhanced Kalman, after this is the Kalman method and the last method is analitic expression method. As it can be observed, it is not necessary to use sophisticated method as a Kalman filter in order to obtain good results in teleoperation through the Internet.

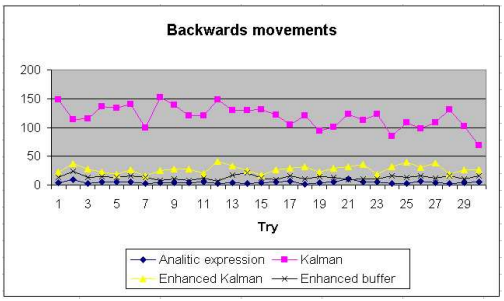

Figure 3: Backwards movements in case 1

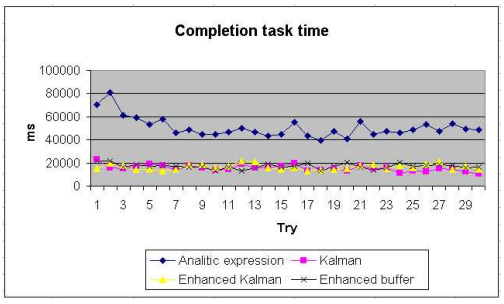

Figure 4: Completion task times in case 1

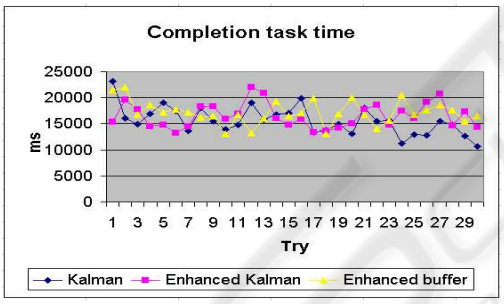

Figure 5: Detail of completion task times in case 1

5 CONCLUSIONS

The strategies of enhancement of teleoperation platforms through the Internet developed in the frame of the PhD thesis (Escribano, 2003), have been shown in a schematic way. These strategies are based on the acquired skill working with the teleoperation platform developed by our research group. Specifically, three basic strategies have been taken into account. These strategies are focused on the initial operating system that was not a real time operating system, so it imposed hard restrictions with regard to time measurements in critical processes, on the human-machine interface that was very constricted to accomplish contrasted performance analysis, and at last on the communication between master and slave systems, that was not implemented through the Internet in the initial design. In this paper the main detected problems are introduced as well as the chosen solutions in each case. More explicitly, experimental results have been shown regarding to the last enhancement strategy.

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