Strategies for Haptic-Robotic Teleoperation in Board Games: Playing checkers with Baxter

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***Abstract*—Teleoperating robots is quite a common practice in fields such as surgery, defence or rescue. The main source of information in this kind of environments is the sense of sight. The user can see on a display what the robot is watching in real time, and maybe also a visual representation of the robot surroundings. Our proposal involves the use of haptic devices to teleoperate a robot, Baxter, in order for the user to obtain haptic feedback besides visual information. As a proof of concept, the proposed environment is checkers playing. Our goal is testing if the inclusion of the sense of touch improves the user experience or not.**

***Index Terms*—JoPhA, journal, LaTeX, paper, template.**

I. Introduction

TELEOPERATING robots is quite a common practice in many fields such as surgery, defence or rescue [1]. The reason is simple: assisting a person to perform and accomplish complex or uncertain tasks in some environments may mean the difference between failure or success.

Enhancing the user experience is a key aspect in teleoperation. These systems use different interfaces (e.g. cameras, microphones or input devices) to provide sensory information to the operator, and thus, improving the user experience. Traditionally, video feedback from an on-board or front-mounted camera is limited by technical constraints [2], [3] like a restricted field of view or poor resolution. In some scenarios, these constraints makes difficult for the operator to be aware of the robot's proximity to objects [4], causing a decrease in performance. To alleviate such limitations, at least partially, haptic cues (either by force or tactile feedback) have been shown to be useful in some applications [5], [6], [7], especially when the operator performs manipulation tasks [8], [9].

In recent years, haptic devices are playing a superior role over vision or audio, particularly in applications that involve touch.

The motivation behind this paper is to test whether or not the sense of touch improves the user experience in teleoperation. To achieve this, we propose an experiment: teleoperate a robot for playing a board game. The scenario will have two players and one game. One player is located at the game's place while the other is away, teleoperating a robot which is "physically" located at that same place. The teleoperation system consists of a Geomagic Touch haptic interface (that acts as a master device) and a Baxter robot (which acts as the slave device). The board game chosen to play is "checkers", as it is...

This paper is organized as follows. Section II shows the architecture of the environment by describing the basic elements of the system. Section III describes how the experiment has been carried out. . . . Finally, the paper ends with our conclusions.

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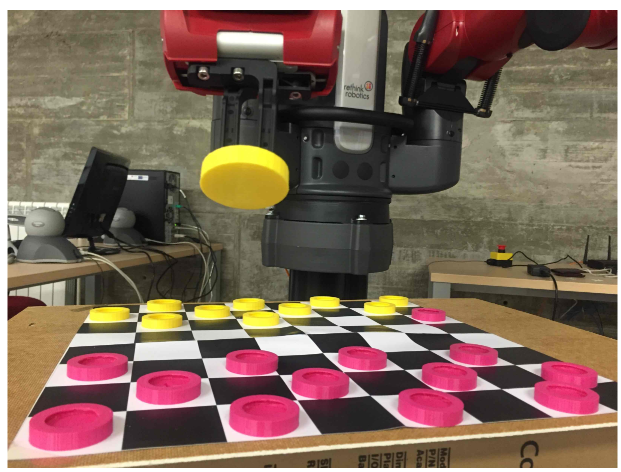
II. Environment description

A basic telemanipulation system consists of a master robot manipulated by an operator and a slave...



A. Slave: Haptic Device

Haptic feedback takes advantage of the human sense of touch by recreating forces, vibrations or motions to the user. An haptic device allows to feel a feedback from virtual or real objects and produces a realistic touch sensations to a user. The PHANToM Omni is a 6 DOF haptic device that applies haptic feedback.

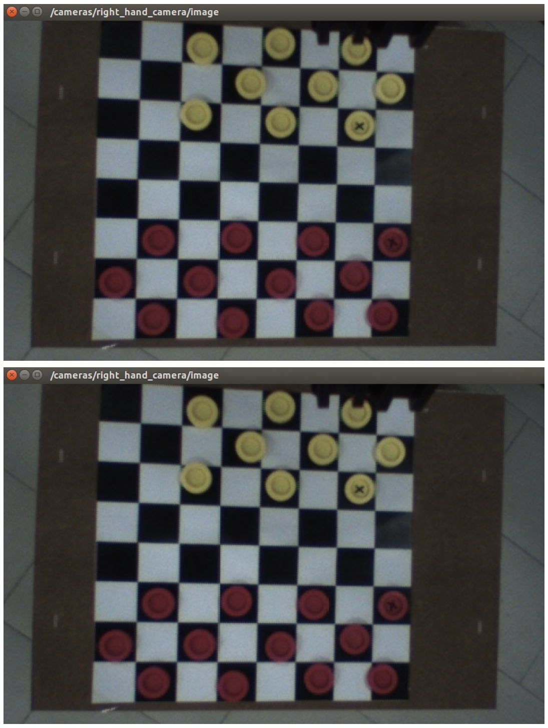


TABLE I
CORRESPONDING JOINTS BETWEEN ROBOT AND HAPTIC DEVICE.

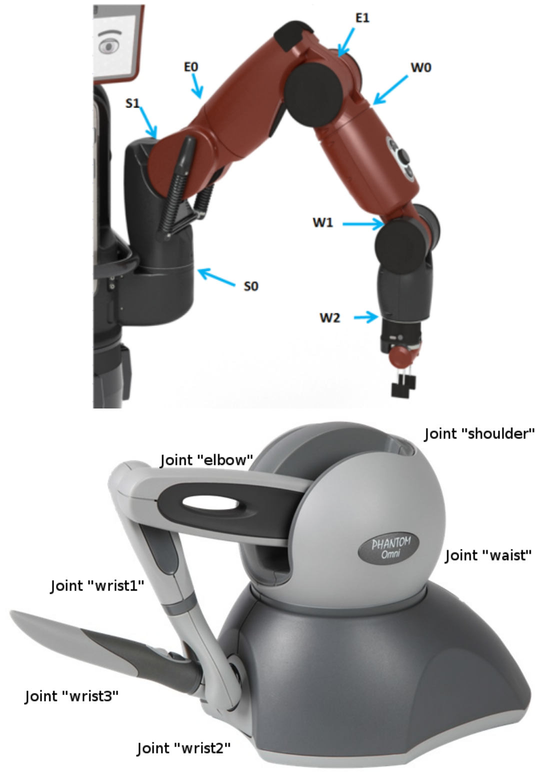


TABLE II
CORRESPONDING JOINTS BETWEEN ROBOT AND HAPTIC DEVICE.

It has 3 actuated DOF associated to the armature which provides the translational movements (X, Y, and Z Cartesian coordinates) and other 3 non-actuated DOF associated to the gimball that gives the orientation (pitch, roll and yaw rotational movements). The characteristic of this device allow to offer a feedback up to a maximum of 3.3N.

B. Master: Baxter

Subsubsection text here.
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C. Controller

Hay que adaptar a nuestro sistema

To use this device for the six DOF robot, the robot was broken into two sets of three degrees of freedom. The first system is determined by the Cartesian coordinates of the wrist joint.

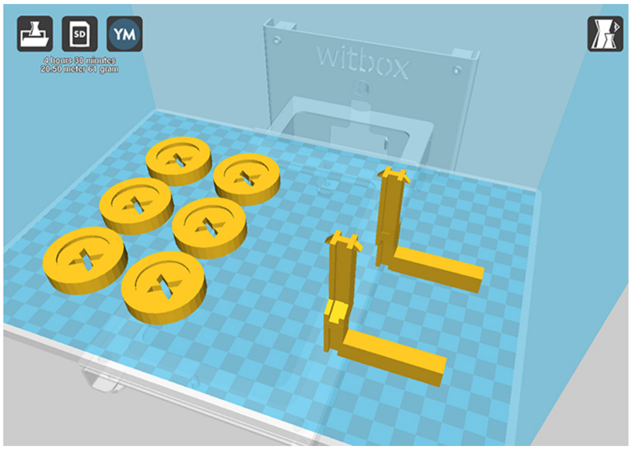
The rotation of the gimbal is then used to correspond to the three rotational degrees of freedom (Rx, Ry, and Rz) of the forearm of the robot. By doing this, the problems associated with multiple solutions to larger order degree of freedom robotic systems are mitigated. It is approximated that the three axese intersect at the wrist despite the length of the link between the lower arm and forearm. This is justified due to the relatively short length of this link and the fact that the robot is controlled based on the vision of a surgeon, allowing for intuitive compensation by the surgeon to position the end effector. This visual compensation is also used to mitigate the effects of motor backlash propagation through the robot, although solutions to reduce backlash are being attempted.

III. EXPERIMENT

A. Game description

Checkers is a strategy gameboard for two players that play on opposite sides of board. It can be played on a 8x8, 10x10 and 12x12 checkerboards. There are two kind of pieces: the dark pieces and the light pieces. The game consists on move a piece diagonally to an adjacent unoccupied square. If the adjacent square contains an opponent's piece, and the square immediately beyond it is vacant, the piece may be captured and take away from the board by jumping over it. During the game each player alternate turns.

B. Board adaptation



C. Evaluation

For evaluation of our experiment we used the Guideline for Ergonomic Haptic Interaction Design (GEHID) developed by L. M. Muoz, P. Ponsa, and A. Casals [10]. The guide provides an approach that relates human factors to robotics technology and is based on measures that characterize the haptic interfaces, users capabilities and the objects to manipulate. We chose this guide as it is a method that aims to cover aspects of haptic interface design and human-robot interaction in order to improve the design and use of human-robot haptic interfaces in telerobotics applications.

The method to be followed for using the GEDIH guide consists in forming a focus group composed of experts and designers in order to: analyze the indicator, measure the indicator, obtain the GEDIH global evaluation index and finally offer improvement recommendations in the interface design. After the GEDIH validation a users experience test can be prepared in order to measure human-robot metrics (task effectiveness, efficiency and satisfaction) [11].

In a first step we detailed a set of selected indicators that provide a quantitative and/or qualitative measure of the perceived information by the user from the teleoperated environment. In this case we selected the following indicators:

- **ReactionForce/Moment**, this indicator measures the variation in the force or moment perceived when contacting with an object or exerting a force over it.
- **Pressure**, in this case the variation in the force perceived under a contact with a surface unit it is measured.
- **Rigidity**, measure the absence of displacement perceived when a force is exerted.
- **Weight/Inertia**, this indicator measures the resistance that is perceived by user when an object is held statically or is displaced from one place to another.
- **Impulse/Collision**, in this case the indicator measures the variation of the linear momentum that happens when colliding with objects in the teleoperated environment.
- **Vibration**, this indicator measures the variation in the position perceived when an object is manipulated by user.
- **Geometric Properties**, in this case is necessary the perception of the size and shape of the manipulated objects in the teleoperated environment.
- **Disposition**, it is also necessary to measure the perception of the position and orientation of objects.

In the next stage we identified two different ways of moving the game pieces; one is to drag the tab on the board and another is to raise the piece and move it to the target position. The next step is a tasks allocation for these ways of moving objects.

In the first case, the sequence of basic task involved are:

1) Presence. In order to determine if the object is near the grasping tool.
2) Grasping. Is the task that allows the operator to grab an object.
3) Push. Is the task that allows the user to move a game piece by applying a force over it and move it on the board.
4) Assembling. In order to put the object in the target position.
5) Grasping. In this case to release the object.
6) Presence. In order to release the object.

In the second case, we identified the following basic tasks:

1) Presence. In order to determine if the object is near the grasping tool.
2) Grasping. Is the task that allows the operator to grab an object.
3) Translating. In order to move the object towards the target place.
4) Assembling. In order to put the object in the target position.
5) Grasping. In this case to release the object.
6) Presence. In order to release the object.

In both cases we observed that previous to the first and last task, the movement of the teleoperated does not requires haptic feedback.

The third step is to establish a clear relationship between selected indicators and basic haptic tasks. Table III show this relationship. The first column shows the basic tasks involved in our experiment and the specific indicators are placed in the second column. But also we consider for the design of haptic interface that different tasks have different requirements, both the haptic device as the robot. For example, in the translating task we need game piece weight perception that gives haptic force sensor and grasping force provided by the corresponding robot sensor. Moreover, in our experiment, we use a visual feedback provided by two cameras in the robot to determine the position of the game pieces and the operator can determine the necessary directions and trajectories to perform the desired task.

D. User experience

From the point of view of usability and using as reference the definition provide by the international standard ISO 9241-11 [12] that define usability as The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context

TABLE III
BASIC TASKS AND GEHID INDICATORS.

Basic task	**Indicator**
Presence	Collision on 3D movement
Grasping	Rigidity on the the grasping tool
Push	Vibration on 3D movement
Translating	Weight on 3D movement
Assembling	Collision on 3D movement

of use, we measure these aspects for our experiment. But we need to include other aspects such as the haptic environment conditions in this classical model approach. L. M. Muoz, P. Ponsa, and A. Casals [10] describes in their research a human-robot metric classes that shows table IV.

TABLE IV
HUMAN-ROBOT METRIC CLASSES

Metric classes	**Description**
Task effectiveness	Human-robot system performance parameters
Automation behaviour efficiency	Robot behaviour, Interface behaviour
Human behaviour efficiency	Information processing, decision making, action
Human behaviour precursors	Mental workload, fatigue
Collaborative metrics	Human-robot interaction, human-haptic interaction

In order to improve the use of our haptic interface we will test the haptic device for a set of expert's evaluators (3-5 people). We will prepare a user's experience test in order to measured human-robot metrics defined above. We designed a scenario in our usability laboratory in order to apply useful evaluation methods and to improve the human-robot interaction.

IV. CONCLUSION

The conclusion goes here.

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REFERENCES

[1] J. Vertut and P. Coiffet, *Teleoperation and Robotics. Applications and Technology*, Spring Netherlands. Vol. 3B, 1985.

[2] D.D. Woods, J. Tittle, M. Feil and A. Roesler, *Envisioning human-robot coordination in future operations*, IEEE Transactions on Systems, Man and Cybernetics: Part C (Applications and Reviews). Vol. 34, no.2, pp. 210–218, 2004.

[3] D. Woods and J. Watts, *How not to have to navigate through too many displays*, In Handbook of Human-Computer Interaction.estricting the field of view: Perceptual and performance effects. 2nd ed, M. Helander, T. Landauer and P .Prabhu, Eds. Amsterdam, The Netherlands: Elsevier Science, pp. 1177–1201, 1997.

[4] P.L. Alfano and G. F. Michel, *Restricting the field of view: Perceptual and performance effects*, Perceptual and Motor Skills. Vol. 70, no. 1, pp. 35–45, 1990.

[5] H.I. Son, A. Franchi, L.L. Chuang, J. Kim, H.H. Bulthoff and P.R. Giordano, *Human-Centered Design and Evaluation of Haptic Cueing for Teleoperation of Multiple Mobile Robots*, IEEE Transactions on Systems, Man and Cybernetics: Part B (Cybernetics). Vol. 43, no. 2, pp. 597–609, 2013.

[6] M. Sitti and H. Hashimoto, *Teleoperated Touch Feedback From the Surfaces at the Nanoscale: Modeling and Experiments*, IEEE ASME Transactions on Mechatronics. Vol. 8, no. 2, pp. 287–298, 2003.

[7] N. Diolaiti and C. Melchiorri, *Tele-Operation of a Mobile Robot Through Haptic Feedback*, In Proceedings of the IEEE International Workshop on Haptic Virtual Environments and Their Applications (HAVE 2002). , Ottawa, Ontario, Canada, 17-18 November, 2002.

[8] C.H. King, M.O. Culjat, M.L. Franco, C.E. Lewis, E.P. Dutson, W.S. Grundfest and J.W. Bisley, *Tactile Feedback Induces Reduced Grasping Force in Robot-Assisted Surgery*, IEEE Transactions on Haptics. Vol. 2, no. 2, pp. 103–110, 2009.

[9] A. Kron, G. Schmidt, B. Petzold, M.I. Zah, P. Hinterseer and E. Steinbach, *Disposal of explosive ordnances by use of a bimanual haptic telepresence system*, In Proceedings of the IEEE International Conference on Robotics and Automation (ICRA 04). pp. 1968–1973, 2004.

[10] L.M. Muñoz, P. Ponsa and A. Casals, *Design and Development of a Guideline for Ergonomic Haptic Interaction*, In Human-Computer Systems Interaction: Backgrounds and Applications 2: Part 2, Z. Hippe and J.L. Kulikowski and T. Mroczek, Eds. Springer Berlin Heidelberg, pp. 15–19, 2012.

[11] B. Andonovski, P. Ponsa and A. Casals, *Towards the development of a haptics guideline in human-robot systems*, Human System Interactions (HSI), 2010 3rd Conference on, Rzeszow, pp. 380–387, 2010.

[12] ISO, *ISO 9241-11:1998 Ergonomic requirements for office work with visual display terminals (VDTs) part 11: Guidance on usability*, 1998.