Virtual Reality and Tele-Operation: a Common Framework

Didier VERNA
LRDE / EPITA
14-16 rue Voltaire,
94276 Le Kremlin-Bicêtre, France
http://www.lrde.epita.fr/
<didier@lrde.epita.fr>

ABSTRACT

This paper proposes an overview of a study that conceptually unify the fields of virtual reality and tele-operation, by analyzing the notion of "assistance" to the operator of a virtual reality or tele-operation system. This analysis demonstrates that cases of assistance that are usually considered to belong to virtual reality are not conceptually different from what has been done in tele-operation since long before virtual reality appeared. With this common framework for virtual reality and tele-operation, we hope to provide a theoretical formalization of many ideas acquired empirically, and hence a basis onto which further discussion could be undertaken in a constructive manner.

Keywords: Virtual Reality, Tele-Operation, Assistance

INTRODUCTION

Virtual reality and tele-operation have been getting closer to each other these last years, on two different plans. The first plan is related to the notion of immersion: it is now possible, thanks to virtual reality devices, to make the operator have the feeling of being physically present in the distant working environment. This brings interesting opportunities to improve the operator's efficiency in performing his task. The second plan is related to the notion of assistance: one major problem we are faced with, considering immersion, is that current immersive technology is heavy, expensive, and can be a handicap instead of a help for the operator. The question of knowing whether immersion is essential or not brought up interesting debates [3]; people demonstrated that partial immersion is often enough, if not better than full immersion [16], people also demonstrated that there is a difference between subjective and objective presence, which actually means that cognitive immersion is not the panacea [14].

One important relation between the notions of immersion and assistance is that assisting the operator is, among other things, a way to compensate for the lack of efficiency when interacting with a complex immersive system. Currently, scientists are acquiring many empirical results related to this idea, and make the notion of assistance a crucial one.

In this paper, we also manipulate these ideas, but from a conceptual point of view. Namely, we ask ourselves what exactly are the conceptual relations between virtual reality and tele-operation, and what exactly is the status of assistance, when tele-operation applications use virtual reality concepts. The analyzis we provide for the notion of assistance to the operator demonstrates that cases of assistance that are usually considered to belong to virtual reality are not conceptually different from what has been done in tele-operation since long before virtual reality appeared. In a first step, we propose to analyze several known cases of assistance in virtual reality systems. In a second step, we show how these cases of assistance revert to ones that have been known in tele-operation for a long time.

THE ***L_iSA*** MODEL

In order to analyze the assistance processes in virtual reality systems, we need to describe such systems. The model we use is called ***L_iSA*** (acronym for "Localization and Semantics of Assistance") and is shown in figure 1.

This model is actually well known in robotics: a tele-"operator" is using an "interface" to control, through a computer and / or network "system", a robotic "manipulator" in a distant or inaccessible "environment". However, we interpret this model in a more general fashion: this model is not only suitable to describe tele-operation situations, but also virtual reality systems implementing synthetic worlds: in that case (in which the interface is very likely to be the same), the "manipulator" would stand for the operator's avatar in the virtual world, and the "environment" would be the virtual one.

Another difference with the traditional interpretation of this model is related to the notion of assistance: we are more interested in the information conveyed

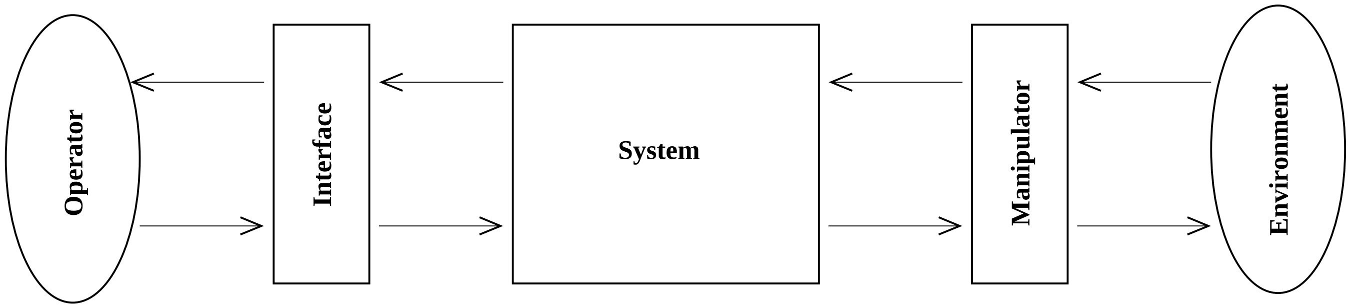

Figure 1: The ***LiSA*** model

through the model's components than in the components themselves. More precisely, this model will be used to analyze the notion of assistance as follows: consider a simple situation described by the ***LiSA*** model, in which no assistance process exist. Interaction between the operator and the system results in information being conveyed across the model. Consider now that a certain assistance process occurs. This results in a modification of the information conveyed across the model. We hence analyze the notion of assistance in two ways:

- the **semantics** of assistance: which kind of modification does the assistance process imply on the conveyed information,
- the **localization** of assistance: where in the model does the assistance process modify the conveyed information.

CASES OF ASSISTANCES

Here, we analyze some common cases of assistance encountered in virtual reality systems.

Perception Generation

This is perhaps the most common case of assistance, the one that is at the basis of augmented reality: the idea is to dynamically add perceptive information on top of the normal perception. Systems can then provide textual annotations [13, 12] on top of books, help navigating in buildings or nuclear plants by providing virtual maps or signs [4] etc.

One shall notice that the added perception is not originally present in the environment, but is actually *generated*, from its own knowledge of the situation, by the system itself. This assistance process is localized on figure 2.

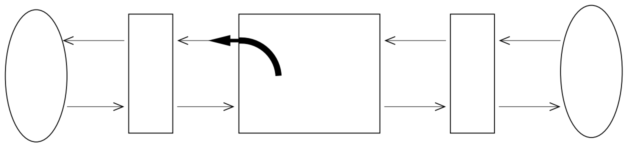

Figure 2: Perception Generation

Perception Transmodalisation

Another well know case of assistance in augmented reality consists in presenting perceptive information under a different modality from which it was acquired. For instance, in [10], a visual feedback of objects collision is provided as no force feedback device is available. In [11], a system for blind people is presented, in which the distance to a potential obstacle is rendered as an audio signal.

Contrary to the previous case of assistance, the affected perception does exist in the environment. Only it is displayed in a different modality, it is transmodalized. This assistance process can be localized in the interface itself, as conceptually speaking, only the way to display the perception is modified. This is represented in figure 3

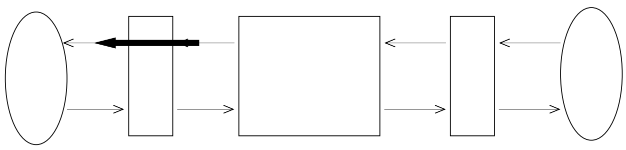

Figure 3: Perception Transmodalisation

Perception reconstruction

This case of assistance aims at reconstructing perceptions that happen to be missing for some reason. A typical example is that of submarine tele-guidance, as described by [2, 6], where the real underwater visual scene is replaced by a simulation. Another example lies in the medical field [1], where a virtual view of a fœtus is reconstituted thanks to ultrasonic captors.

The particularity of these cases of assistance is that the original perception is unavailable (because the underwater environment is too dark, or because the pregnant's womb is hidding the fœtus). However, it is possible to use a substitution perception (from position or ultrasonic captors), in order to reconstitute the missing one. In terms of localization, additional work is needed at the manipulator level in order to acquire the substitution perception, and additional work is needed in the system to convert this information into the missing one. This is represented in figure 4.

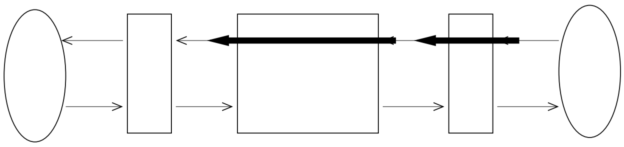

Figure 4: Perception Reconstruction

Virtual Execution
As a last example of assistance, consider the case of path or task planning [9], in semi-autonomous robotics. The operator is given the ability to prepare a mission, but also to test it before requiring its execution. The test phase usually involves a virtual simulation of the task, allowing the operator to check the validity of his instructions.

This kind of assistance involves a rather complex process because the system has to simulate both the environment, the manipulator, and the interaction between each other. As for localizing this assistance process, it has the particularity of cutting all information paths at the right of the system. This is represented in figure 5.

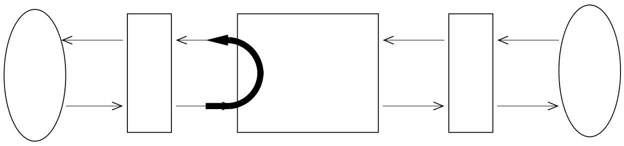

Figure 5: Virtual Execution

Summary
Many other cases of assistance could be analyzed in the same fashion [19, 18]. The result, presented in figure 6, still remains the same: when we think of how virtual reality can be used to implement assistance features, we generally adopt an egocentric point of view. As we can see, few cases of assistance take into account the operator's actions, and all of them affect the information in the perception sense.

THE OTHER WAY AROUND

To correct this imbalance, one has to notice the central symmetry of the ***LiSA*** model: the operator and the environment play analogous roles; the same applies to the interface and the manipulator. Given this symmetry, we should be able to turn the preceding assistance cases the other way around, and obtain new examples which would not be conceptually different. This is what we propose to do in this subsection.

Action Generation
The counterpart of perception generation is action generation. According to what has been said in the preceding section, the idea is to dynamically add actions generated by the system on top of those requested by the user, as illustrated on figure 7.

This kind of assistance process actually corresponds to the idea of "adaptive robotics", where for instance robotic arms are capable of automatically grasping objects. In such a process, the operator has not the control: the system itself generates the required actions. This also suggests, as the original examples (perception generation) were taken from augmented reality applications, that the expression "augmented reality" itself can be use to describe augmented actions as well as augmented perceptions.

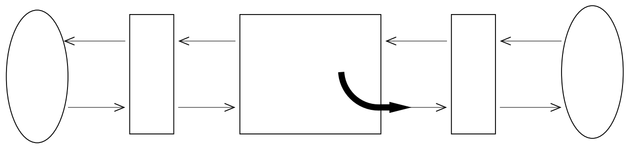

Figure 7: Action Generation

Action Transmodalisation
The counterpart of perception transmodalisation is action transmodalisation. According to what has been said in the preceding section, the idea is to present actions under a different modality from which they were acquired, as represented in figure 8.

This kind of assistance process actually corresponds to a known problem in tele-operation, namely the "transposition" problem. In [8, 7] Kheddar describes the concept of "hidden robot" which principle is to hide the complexity of the real task by giving the operator the feeling of acting in a natural manner. As a consequence, the correspondance between human actions and robot actions is not isomorphic, and actions must be transmodalized. Another good example is that of vocal commands. The actions come from an audio signal and must be converted to physical ones.

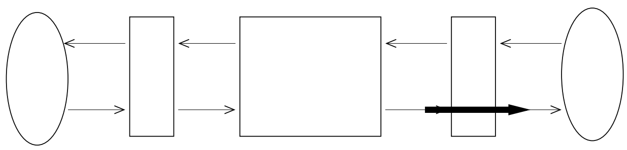

Figure 8: Action Transmodalisation

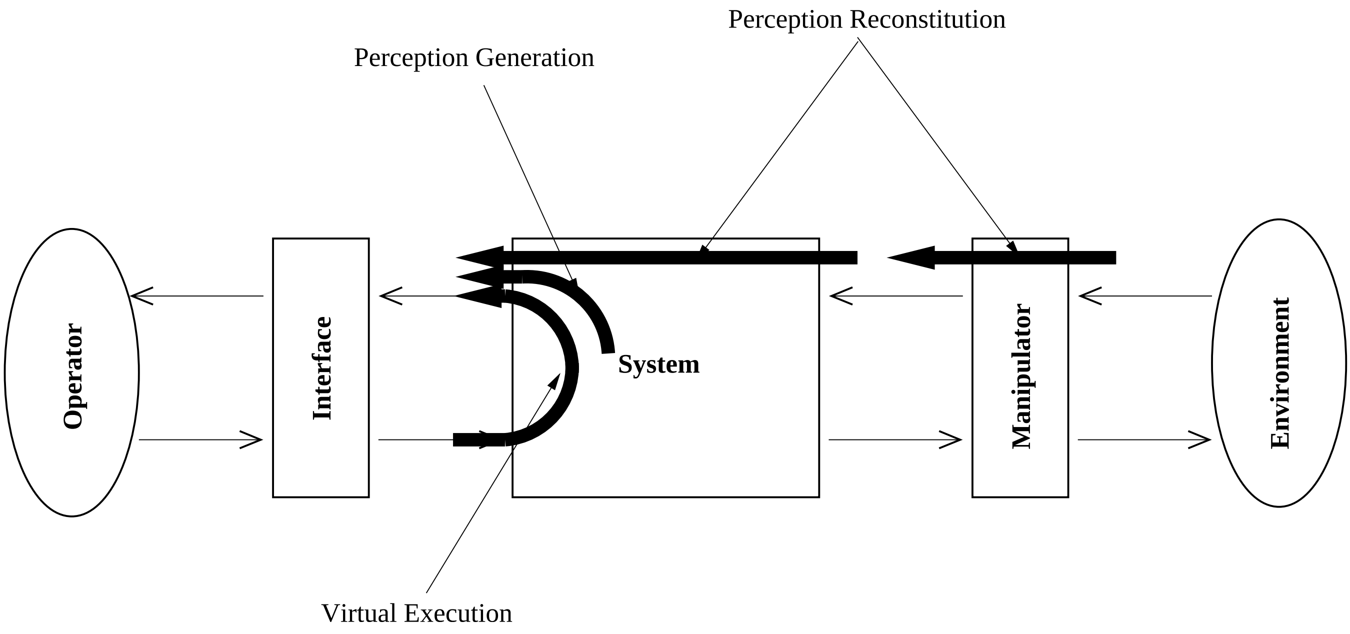

Figure 6: Summary

Action Reconstruction
The counterpart of perception reconstruction is action reconstruction. According to what has been said in the preceding section, the idea is to reconstruct actions that happen to be missing for some reason, by using a substitution action instead, as shown in figure 9.

We believe that the category of systems providing such assistance processes is actually very broad, as it includes all systems using non-immersive input devices, or controlling non-anthropomorphic manipulators: if you only have a joystick to control a robotic arm, or if a handicap [17] prevents you from controlling it in an immersive manner, then we can consider that the original action (the real operator's arm movement) is missing, but that a substitution action (the joystick movement) can be used to reconstruct the missing one. Similarly, if you have to control a complex device (for instance with too many degrees of liberty), then you will necessarily have to perform a substitution action to control it. A good example of this is the control of a virtual creature thanks to a whole hand input device, described by Sturman[15].

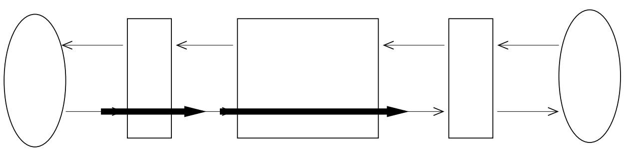

Figure 9: Action Reconstruction

Virtual Command
The counterpart of virtual execution is virtual command. According to what has been said in the preceding section, the idea is to cut all information paths at the left of the system, thus simulating the interaction an operator would have with it, as shown in figure 10.

Here again, the category of systems providing such assistance processes is actually very broad, as it includes all developments in autonomous robotics. More precisely, robots belonging to this category are the fourth class robots according to the classification from Giralt[5]: contrary to purely reactive autonomous robots, task programmable autonomous robots must have the ability to make decisions in case of unexpected events, and thus must be provided with operator-like capabilities.

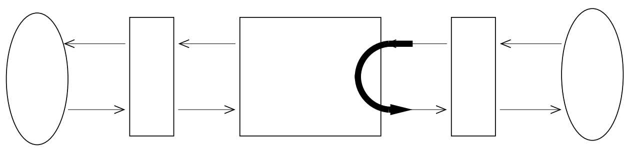

Figure 10: Virtual Command

Summary
The preceding assistance cases, along with their counterpart are summarized on figure 11, which provides a more balanced view on the notion of assistance. This analysis clearly demonstrates that whereas the initial cases of assistance are regarded as virtual reality, they are not conceptually different from their counterparts well known in robotics long before virtual reality concepts appeared.

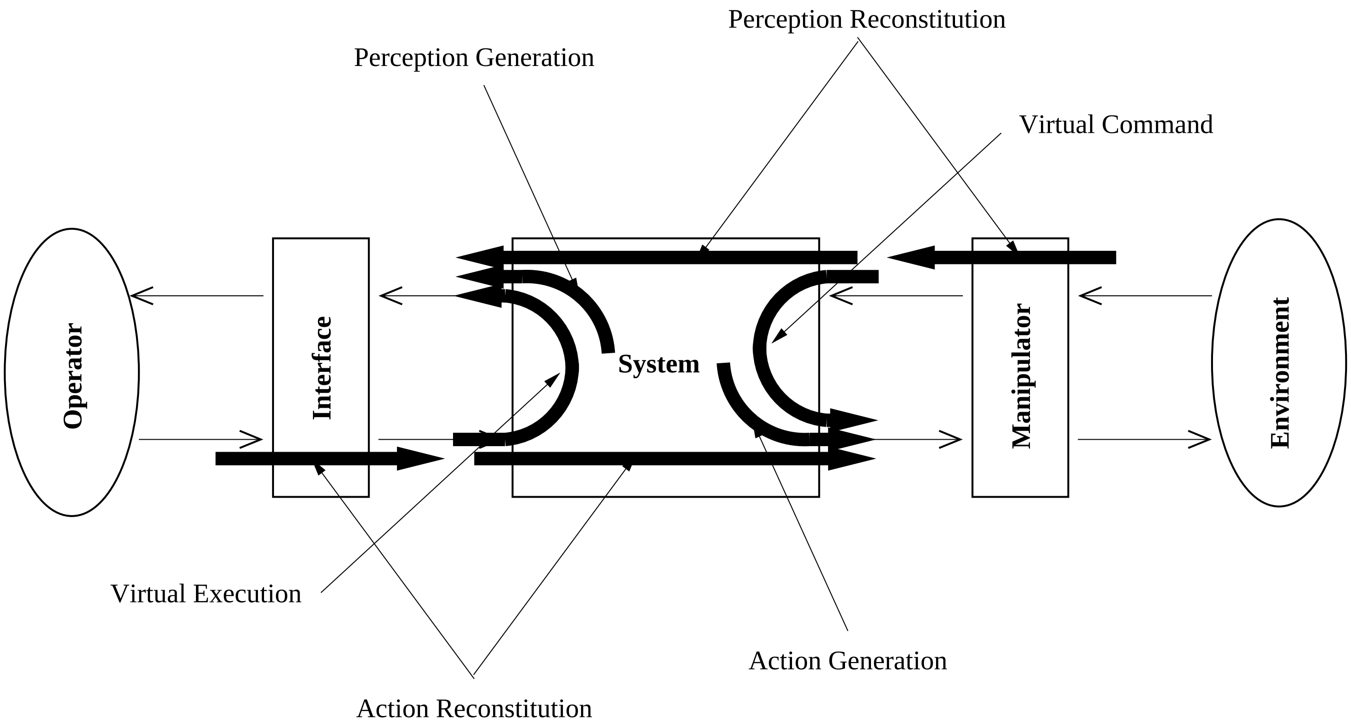

Figure 11: Global Summary

CONCLUSION

In this paper, we have presented an overview of a theory aiming at formalizing the relations between virtual reality and tele-operation at the conceptual level. We proposed a theoretical analysis of the notion of assistance, based on a model called ***L_iSA***. Provided with this model, we were able to represent the different kinds of assistance processes found in current virtual reality systems. By turning this analysis the other way around, we fell back on common assistance processes found in robotics, but not labeled as virtual reality assistance processes. As a consequence, we demonstrated that, in terms of assistance, the relations between virtual reality and tele-operation extend farther than what is usually thought.

We believe that this analysis provides a clear demonstration of the tight relations unifying virtual reality and tele-operation on a conceptual plan, and allow to formalize ideas that are currently manipulated on an empirical basis. We thus hope to have provided a formal ground on which further discussion could be undertaken.

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