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Utilization of Human Scale SPIDAR-G in the framework of Assistance to 3D interaction in a semi-immersive AR/VR platform.

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Abstract

We have developed a generic assistance paradigm to 3D interaction that uses virtual guides to constrain the output of classical 3D interaction techniques, in order to satisfy the requirements of particular applications. In this article, we present this paradigm and its application to three different projects, dealing with robot teleoperation (constraints over precision and security), complex molecules manipulation (biological constraints over the plausible space configurations) and precise 3D navigation in underwater sites.

Within these projects, we have used a human scale SPIDAR-GH in a semi-immersive AR/VR platform for assisted selection, manipulation and navigation tasks. Tracking and force feedback capabilities have been tested and some quantitative and qualitative results are presented.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Picture/Image Generation—Interaction techniques

1. Introduction.

Since the 90', the Augmented Reality and Collaborative Tele-work (ARCT) team of IBISC laboratory has been developing methods and algorithms to provide assistance to workers or group of workers.

A kind of applications area explored by the ARCT team is tele-work and, most particularly, teleoperation of robots. In this case, the assistance consists in providing suitable feedbacks and command controls to achieve a remote task as easily and precisely as possible.

Of course, it may be possible to use a simple PC connected to internet as the master site to tele-operate a robot with guaranteed security ([OMKC00b]). However, the interaction between the worker and the remote site is limited and may not be accepted by the worker himself for all day working.

That is why, since 2004, we are involved in the study of the impact of a better immersion of the operator on the quality of his work by using an Augmented and Virtual Reality platform equipped with several sensing devices. Our two main hypotheses are:

- on one hand, the gestures and the feedbacks received by

the worker during his interaction with the remote site must be as natural as possible for him in order to permit him to only concentrate on the task ;

- on the other hand, developed methods and algorithms must be as device independent as possible .

To be more precise on the first hypothesis, our platform must own multi modality to provide various sensing feedbacks to the user when needed, depending on the specificity of the task he is performing. These feedbacks (sound, force feedback, video incrustations) are not intended to be very realistic but to give appropriate informations to the user at the appropriate moment.

In this article, we first give an insight on our assistance framework. Second, we describe our technical platform, which includes a Human-scale SPIDAR-GH for force feedback and tracking. In a third section, we show how we have taken benefit of such a device in the context of our assistance framework, for three kind of applications: teleoperation of a remote robot (ARITI project [ARI]), 3D navigation in a VR underwater site (Digital Ocean project [DIG]) and con-

strained manipulation of complex molecules (IM-Mo-Bio project).

2. Assistance framework for 3D interaction.

2.1. Main concept and tools.

A lot of 3D interaction techniques dedicated to selection, manipulation, navigation or control application, already exist in the literature (see [BKL05] for a review). They are mostly generic methods which are constructed to statistically behave well for rough categories of situations. However, they do not guaranty for instance the precision of a selection task nor the security of a manipulation task. In the case of teleoperation, there exists some constraints on the precision or security of a task, which are induced by the use of a real robot in a real environment. If they are not guaranteed, the mission may fail.

Our idea is to put constraints, when needed, on the relation between the movements of the user and the outputs of classical 3D interaction techniques in the virtual or remote world (see fig. 1). For example, in the case of teleoperation tasks, when a robot arm is approaching an object to grab it with its grip, a determined precision is required. So, if the user is manipulating the remote robot with a virtual hand technique, the gain between the user's movements and the robot movements must be adapted when entering an area around the object to seize. In some cases, the reduction of the number of degrees of freedom may be necessary to achieve the task with high precision. The constraints put on the 3D interaction technique are geographically situated in the virtual environment (see fig. 2). In the free manipulation zone around an object, constraints are not utilized and the classical interaction technique applies as is.

So far, the mathematical objects, described as assistant tools in the figure 1, which are used to guaranty the constraints put on the 3D interaction technique, are virtual guides [OMKC00a] (see fig. 3). They act as force fields to modulate the output of a 3D interaction technique (e.g. change of position or orientation of a virtual object) at each point of the virtual space.

2.2. Utility of sensory feedback in the assistance framework.

The assistance framework may create discontinuities in the relation between the movement of the user and the movement of objects in the virtual world (for example, when a reduction of degrees of freedom in the virtual world is processed or when an attractive or repulsive virtual guide is fired). As the brain mostly anticipates about what shall happen, those kind of discontinuities are puzzling for the user and may induce undesired behaviors.

In our framework, we propose two combined solutions:

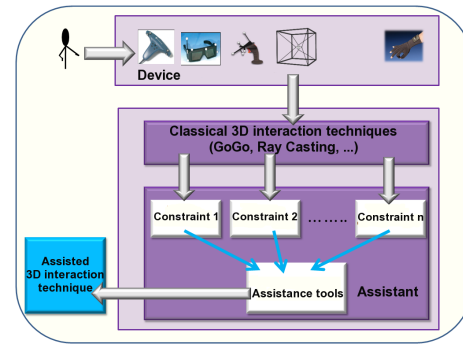


Figure 1: Assisted 3D Interaction diagram.

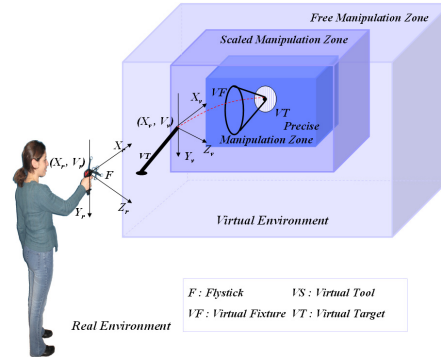


Figure 2: Three geographical zones around a selectable object are created to handle three different behaviors of the 3D interaction technique when approaching the object.

- the visualization of the virtual guide shape is processed before the user enters its zone of activation, in order to warn and help him to anticipate (see fig. 4) ;
- a force feedback that materialize the force fields of the virtual guides (feeling of attraction to an object or repulsion).

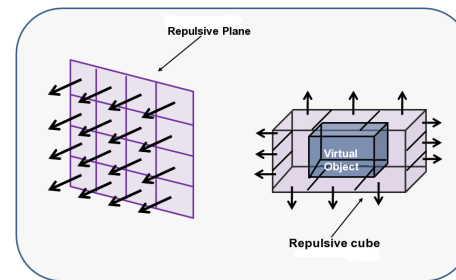


Figure 3: Repulsive virtual guides permit to avoid the user from approaching too close to a virtual object.

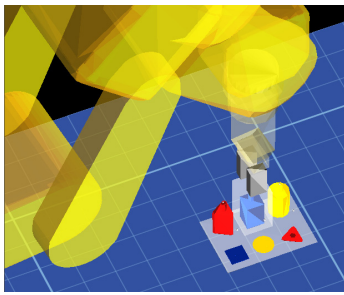


Figure 4: Manipulation of a virtual 6 dof FANUC LRMate 200i. Attractive virtual guide appears when the grip is near an object (taken from the ARITI project).

3. Technological aspects.

IBISC laboratory owns two AR/VR platforms. One is called *EVR@* for *Virtual Environments and Augmented Reality* and is human scale. The other, called *EVR@-Mobile*, is smaller but owns most of the sensing capabilities of *EVR@*. The two platforms, connected to the internet, permit to locally validate collaborative tele-work researches even if collaborative tele-work with other labs or institutions is planned in a near future.

3.1. The *EVR@* and the *EVR@-Mobile* platforms.

The main characteristics of the *EVR@* platform are (see fig. 5):

- Visualization capabilities: the platform is composed of a 3,20m x 2,40m screen where images from a 3-DLP projector are displayed. Active stereoscopy is enabled.
- Tracking capabilities: two ARTTrack1 infrared cameras are disposed on both sides of the screen, which permits to track in real time gestures from users. Two wireless Flysticks 1 and different kind of markers are available. Moreover, 5DT wireless data gloves permit to track fingers mutual positions.
- Force feedback capabilities: force feedback is rendered by a Human scale SPIDAR-GH [CWS97], [KIKS00]. The 8 MAXON motors/encoders are placed at the corners of a 3 meters width cube.

The *EVR@-Mobile* platform (see fig. 6) is composed of a 1,50m x 1,3m screen associated to active stereoscopy capabilities. A SPIDAR-GM (M stands for medium size) permits to track the user gestures and to render force feedback. The 8 MAXON motors/encoders are placed at the corners of a 1,5 x 1,5 x 1,3 meters structure.

3.2. Software.

Each device is associated to a specific server which is accessed via the C++ VRPN library by clients. The interactiv-

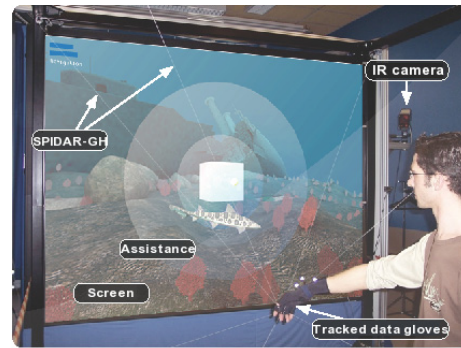


Figure 5: The AR/VR *EVR@* platform permits Human Scale interaction with a virtual or remote environment.

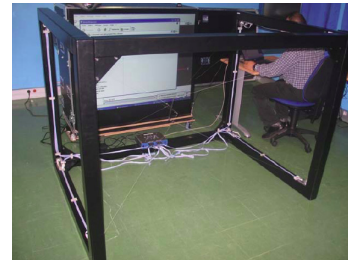


Figure 6: The *EVR@-Mobile* platform. The display system may be packed in an easy transportation flycase

ity between the user and the VE is done by using 3DVIA-Virtools 4.1 as a front-end. In this context, interface with SPIDAR-G has been created. 3DVIA-Virtools is an efficient software for prototyping and testing 3D IT because it offers a fast and graphical way to compute them and link them with hardware devices and VEs by connecting specific building blocks to each other.

4. Projects in which SPIDAR-GH is utilized: overview and results.

4.1. The ARITI project.

The Augmented Reality Interface for Teleoperation via Internet (ARITI) project has been initiated by S. Otmane during his PhD in 1999 [OMKC00a]. Its aim was first to teleoperate robots by using a simple PC connected to the Internet. Virtual guides were used to ensure security and lessen the need for concentration.

Follow-Me [ODOM06b], [ODOM06a] is a 3D interaction model dedicated to teleoperation tasks in a semi-immersive environment that completely includes the assistance concept described in section 2.

It considers three different areas around selectable and manipulable objects (see fig. 2) which are associated to three granularities of interaction. In the *free manipulation*

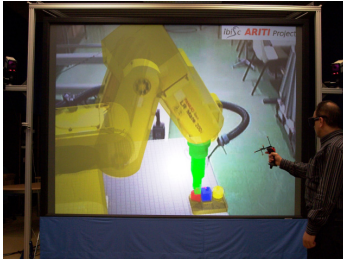


Figure 7: Teleoperation via internet of a 6 dof FANUC LR-Mate 200i by using and Flystick (see the video [ARI] for an overview of the ARITI project).

area, the virtual hand technique is applied (no constraints are considered because the grip is far from a selectable object). In the *scaled manipulation area*, the number of degrees of freedom of the movement of the grip is lessened to 1. In the *precise manipulation zone*, the grip is attracted to the object to seize and touches it with a null speed to avoid collision with the object (its speed is exponentially decreasing).

Force feedback utilization

In a first stage of experiments (E1), we use force feedback when the grip of the robot is in contact with object to seize or when manipulated objects are in contact with their base. In fact, this is utilized as a major cue for the user to have an idea about the depth of the grip.

In a second stage of experiments (E2), we use force feedback to materialize the virtual guides used with the *Follow-Me* method [UOO*09]: attraction to an object when entering the precise manipulation area of this object, repulsion to avoid collisions.

Comparison between the use of SPIDAR and ART Flystick for tracking in (E1) experiments.

In (E1), a study over 15 people have been made for selection and manipulation of 3 geometrical objects by a simulated FANUC LR Mate 200i robot. When tracking was done by the Flystick, Flystick was taken by the user in his dominant hand and the effector of the SPIDAR was taken in his other hand to feel force feedback. Whereas when tracking was done by SPIDAR, the SPIDAR was taken in the dominant hand of the user and the Flystick was taken in his other hand for application control (see fig. 8 and [FOL] for a link to a video). The results show that (see fig. 9):

- selection and manipulation duration with the *Follow-Me* method are not significantly different between Flystick and SPIDAR tracking (ANOVA $p=0.61$, Fisher $F=0.26$);
- precision obtained for selection and manipulation with the *Follow-Me* method are not significantly different between Flystick and SPIDAR tracking (ANOVA $p=0.20$, Fisher $F=1.66$).

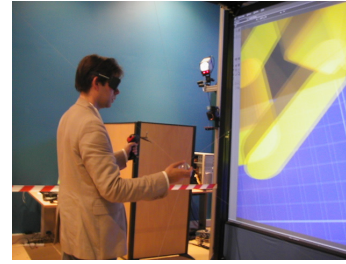


Figure 8: Manipulation of a virtual 6 dof FANUC LR-Mate 200i using the Follow-Me technique. Flystick is used for application control. SPIDAR-GH is used for right hand tracking and force feedback (the video [FOL] shows the SPIDAR in action).

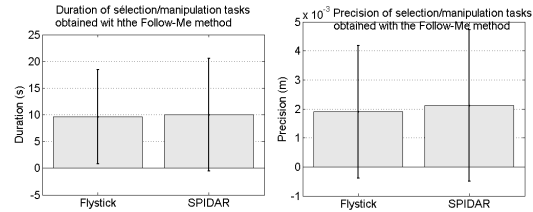


Figure 9: Comparison of Selection/Manipulation duration and precision when Flystick or SPIDAR is used for tracking.

Benefits of haptic guides in (E2) experiments.

In the *precise manipulation zone* of the *Follow-Me* method, attractive virtual guides are used. Figure 10 shows the improvement when the SPIDAR is piloted to make the user feel the attraction to an object. Experiments have been made over 20 people. The results show that the use of haptic guides is significant for conical virtual guides (ANOVA Fisher $F = 25.78$, $p < 0.005$) whereas it is not significant for spherical virtual guides (ANOVA Fisher $F=1.59$, $p > 0.05$). Results from qualitative questionnaires have shown good acceptance of users to the feeling haptic guide give to them (see fig. 11). Further details may be found in [UOO*09].

4.2. The Digital Ocean project.

The *Digital Ocean* project aims at creating interactions between people and realistic models of existing underwater sites for entertainments or education (see [DIG] for further details).

In this framework, we have been interested in the 3D navigation problem with the constraint that the interaction methods used in the project may be implied either on a simple PC or on AR/VR platforms. A 3D interaction model, called *Fly Over*, has been developed in that way [BOM08]. This method is based on the splitting of the 6D space needed to translate and rotate. *Fly Over* uses pointing over a

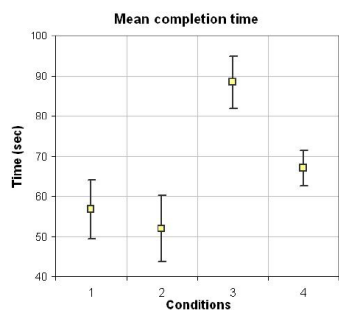


Figure 10: Influence of the presence of haptic guide for a selection task with the Follow-Me technique. 1: spherical guide+no haptic, 2: spherical guide+haptic, 3: conical guide+no haptic, 4: conical guide+haptic (extracted from [UOO*09]).

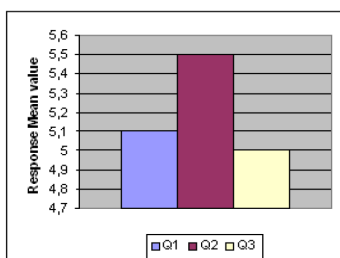


Figure 11: Mean results from questionnaires, from 1 (completely disagree) to 7 (completely agree). Q1: Easy selection?, Q2: Do you feel guided to the object?, Q3: Is the feeling realistic? (extracted from [UOO*09]).

blob containing two 3D spheres to select the amplitudes of translation and rotation. (see fig. 12).

SPIDAR has been used to navigate with the *Fly Over* technique in underwater virtual environments (see fig. 13 and video [FLY]). A SPIDAR-H would have been sufficient because *Fly Over* only needs the 3D position of a virtual pointer. Pre-tests have shown that it is quite easy to navigate precisely in 3D. Moreover, speed for translation or rotation seems to be easy to control.

4.3. The IM-Mo-Bio project.

The main goal the IM-Mo-Bio project is to produce interactive visualisation tools for biologists. One core issue consists in testing hypotheses on spatial conformation of complex molecules. In fact there exists physical and biological constraints (angle between two successive elements, global length of the molecule, etc.) that disable locally or globally a lot of spatial conformations. The bio-supervisor (see fig. 14) that has been created puts some local and global constraints on the manipulation of the molecule [EOHM09].

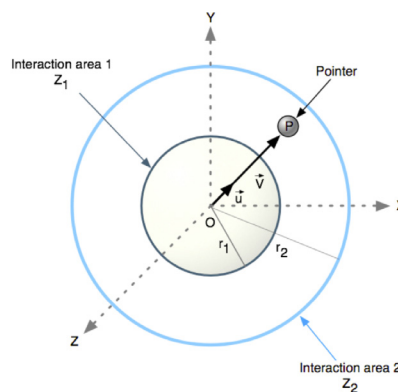


Figure 12: The Fly Over model. 3D pointing in one of the two spheres will generate a pure translation, a pure rotation or a mixture of the two. The position of the pointer in the spheres generate a specific magnitude of translation or rotation (extracted from [BOM08]).



Figure 13: 3D navigation by using the Fly Over technique (french ANR Digital Ocean project). See [FLY] to view a video of SPIDAR in action.

Virtual guides are generated online to ensure that the constraints are fulfilled at any time during the manipulation process (see fig. 15).

SPIDAR has been used to select an element of the molecule, manipulate (change the angle between the selected element and the successive elements of the chain) and navigate around the molecule (see the video in [IMM]).

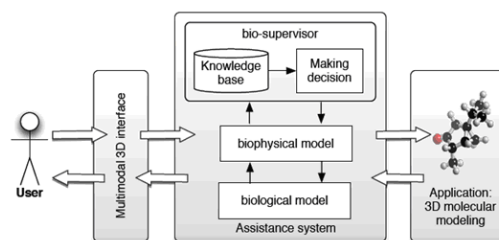


Figure 14: Hypotheses on biological constraints restrain plausible space configurations of a molecule (extracted from [EOHM09]).

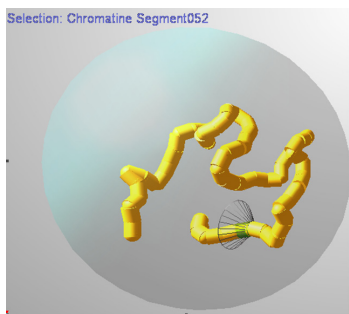


Figure 15: Selection and manipulation of a part of a molecule. The conic virtual guide indicates the biological constraints on the possible angles between two parts of the molecule (see [IMM] for viewing SPIDAR in action).

4.4. Conclusion and perspectives.

In this article, we have presented some results about the use of a human scale SPIDAR-GH in a semi-immersive AR/VR platform. The applications were taken from three different projects dealing with robot teleoperation, complex molecules manipulation and 3D navigation in underwater sites in which selection, manipulation and navigations tasks were implied. All the 3D interaction techniques employed in these experiments were derived from a paradigm of assistance to 3D interaction that uses virtual guides to ensure that some constraints needed by the application are fulfilled (e.g. precision and security for teleoperation). SPIDAR has been used as a force feedback to materialize these constraints.

As perspectives, we are working on two aspects on the SPIDAR. First, we study a possible association between SPIDAR and our infrared tracking (e.g. for calibration purpose or for constructing better models of the relation between the encoders values and the position of the effector). Second, we study the human scale SPIDAR/SPIDAR interaction for collaborative tele-work. For this purpose, a collaboration has started with LISA laboratory (Angers, France) and Tokyo Institute of Technology.

5. Acknowledgments

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