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# Empirical Evaluation Assistant Tool for 3D Interaction Techniques

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## Abstract

*Designing usable and effective 3D Interaction Technique (IT) for Virtual Environment (VE) is very challenging for system developers and human factors specialists. Indeed, time consuming empirical evaluation is necessary to have an idea about the goodness of an IT at the end of its development lifecycle. This may induce a huge loss of time if the result appears to be under expectations at the end.*

*We have developed an Empirical Evaluation Assistant (EEA) to rapidly gather significant feedbacks about the usability of a 3D IT during its development lifecycle. Thus, it may be possible to enhance iteratively the 3D IT before it would be classically evaluated by ergonomics experts at the end of its development lifecycle.*

*EEA has been used to gather feedbacks about a 3D IT developed at IBISC laboratory, called Follow-Me, which is still under study. Results show that EEA has permitted to refine some characteristics of this 3D IT.*

**Keyword:** Human computer interaction; 3D Interaction; Empirical evaluation; Usability.

## 1. Introduction

At IBISC laboratory, we have been creating 3D interaction models and techniques for our semi-immersive Virtual Reality/Augmented Reality EVR@ platform, especially dedicated to robot teleoperation and collaborative telework.

The most important constraint we are facing is the usability of our techniques. However, there exist no true guidelines to fulfill this constraint when building and implementing 3D IT on a VR/AR platform. Thus, the only choice we had was to validate our 3D IT by ergonomics experts at the end of their development lifecycle. But this validating phase takes a long time and if it appears at the end that the result is poor, the validation feedback comes too late.

Our idea is to build an Empirical Evaluation Assistant (EEA) in order to perform *light* evaluations of a 3D IT during its development lifecycle, without

the need of being an ergonomics expert. We want this tool to:

- Bring assistance to fasten the preparation of the validating experiments;
- Bring fast feedbacks about a tested 3D IT during the validation experiments;
- Collect the data and enrich a database to increase the laboratory knowledge about 3D IT behaviors, after the validation experiments.

We hope the EEA system permits to improve the quality of our 3D IT, leading in most cases to positive final evaluations by ergonomics experts.

This paper is structured as follows. Section 2 will briefly review the classical kinds of ergonomic evaluations. The EEA system is developed in section 3. Section 4 gives some insights about the feedback given by EEA with the *Follow-Me* 3D IT.

## 2. Related work

Ergonomic evaluation is a mandatory step to detect usability problems for creating intuitive and transparent interactions for users. 3D Interaction Techniques (IT) are completely different from 2D IT. 2D IT is typically used with a keyboard and a mouse to manipulate graphical interface (WIMP paradigm). Whereas their exist guidelines based on predictive models to build effective 2D IT, it is not the case for 3D IT. The main reasons are: no strong models, new interfaces and devices, fewer experts. Indeed, two kinds of evaluation approaches exist for 3D IT:

- The *analytical approach* compares the behavior of the interaction to a reference model, which describes the conditions to obtain a good interaction (heuristic evaluation, summative evaluation). There are tools dedicated to this approach like the MAUVE system [1], which provides a structured approach for achieving usability in VE system design and evaluation.

- The *empirical approach* measures the performance of different users that are using the 3D interaction in the VE [2].

Due to a lack of norms and ergonomics experience, analytical approaches cannot be used to evaluate 3D IT

[2]. Indeed, empirical evaluation needs to be carried out for evaluating 3D interaction (see [2], [5] and [6]). Empirical evaluations are complex to perform due to main difficulties: large list of parameters like users' profile, users' questionnaires, conception of scenario. Nevertheless [3] and [4] have pointed out lists of heuristics for evaluating 3D IT in VEs. Our EEA system integrates these heuristics.

### 3. Empirical Evaluation Assistant (EEA)

#### 3.1. Hardware and software context of the EVR@ platform

IBISC Lab. owns a semi-immersive VR/AR platform called EVR@. It permits stereoscopic display, wireless hand/head/fingers tracking and force feedback. Each device is associated to a specific server which is accessed via the C++ *VRPN* library by clients. The interactivity between the user and the VE is done by using *Virtools 4.0* as a front-end. *Virtools* is a good 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.

#### 3.2. Specification of the EEA

EEA is intended to be used during the development lifecycle of a 3D IT by non experts of ergonomics. Typically, it is dedicated to 3D IT developers. It has no aim to bypass a complete evaluation process made by ergonomics experts.

The main objectives of the EEA system are:

1. To assist experimenters *before the experiment* :
  - Help for selection of pertinent variables to be traced during the experiment and submitted to statistical analysis after the experiment (correlation detection, hypothesis testing by using ANOVA);
  - Help for selection of known or personalized protocols to be applied in the experiment;
  - Help for selection of known or personalized qualitative questionnaires given to the users.

This assistance is carried out by using a *database* which centralizes the knowledge acquired during past experiments.

2. To assist experimenters *during the experiment* :
  - Trace of pre-selected variables during the whole experiment in a log file;
  - Real time display of pre-selected variables.

The aim is to permit an *easy debugging* and to detect erroneous behaviors of the users.

3. To produce a feedback about the studied 3D IT *after the experiment* :
  - Results of statistical analysis made over traced quantitative variables and qualitative variables (questionnaires);
  - Possibility to replay the experiment off-line;
  - Integration of the whole experiment results in the *database*.
4. To permit collaborative work over the *database* data:
  - Share the results of 3D IT experiments with experts outside the Lab;
  - Annotate the experiments.

#### 3.3. Software architecture of the EEA

In order to achieve the specification of the EEA system, we have built two distinct tools and utilized an existing free software. The global architecture and software implementation is given in figure 1.

The first tool is dedicated to *Experimental Protocol Conception*, which we call *EPC* tool. It includes paragraphs 1. and 4. of our objectives. The *EPC* tool permits the access to the *database*. We fulfill paragraph 4. by choosing a WEB based architecture centered on an *Apache 2* server. The database is implemented with a *MySQL* server which is accessed via *SQL* queries from the *EPC* tool written in *PHP* and *AJAX*.

The second tool is dedicated to *Measurements and Debugging*, which we call *MD* tool. It includes paragraph 2. of our objectives. It has been implemented by making specific *Virtools building blocks* that we call *Probes*. The probes may be connected to building blocks which output has to be measured, traced and displayed in real time. Figure 2 shows 4 probes connected to the tested 3D IT given in section 4. They permit to measure the duration of a user's experiment and how many mistakes he has made. A *Core* component permits to initialize the measurement schema of all pre-selected variables by using a configuration file created by the *EPC* tool before the experiment (curved arrow in figure 1). It also permits to synchronize the data gathered by the different probes, by using dedicated modules (figure 3). The *Synchronization* and *Wait* modules permit to synchronize probes and core. Probes send synchronization messages to these modules. When the synchronization is done the core launches a module (e.g. "Speed" or "Acceleration") for computing speed or acceleration of specified object on the virtual environment.

The fulfillment of the objectives of paragraph 3. is done by using the log files produced by *MD* tool during the experiment and configured in the *EPC* tool before the experiment. These files are read by *R software*

scripts that produce the results (correlation detection, hypothesis validation).

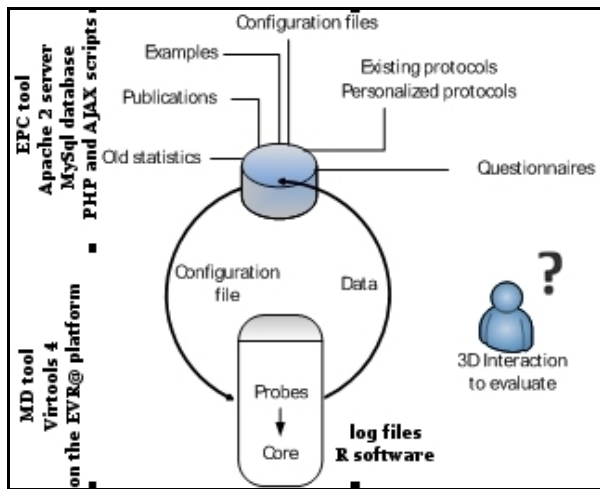


Figure 1. Software architecture and implementation of the EEA system. Statistical analysis is done by the R software from the log files generated by the MD tool.

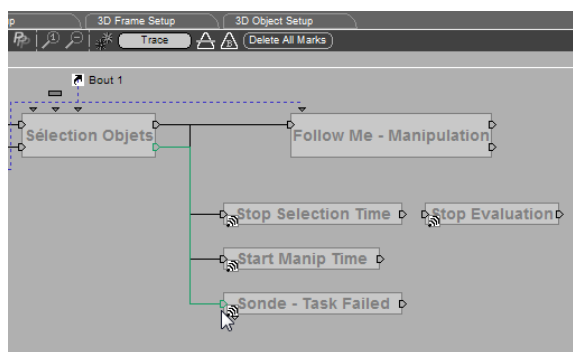


Figure 2. View of four probes connected to a tested 3D IT (Follow-Me Manipulation block) in the Virttools 4 framework.

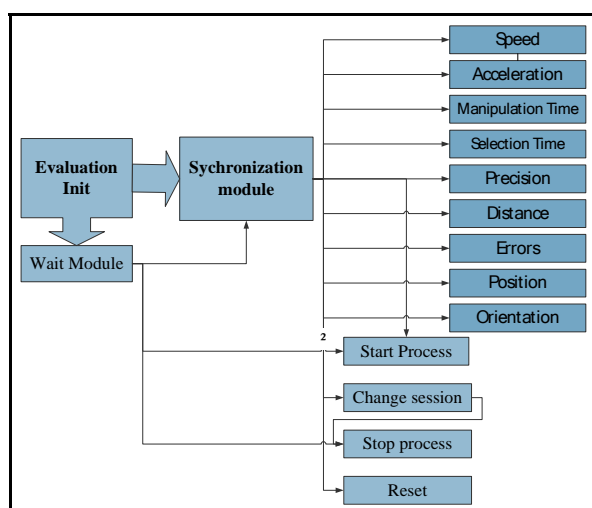


Figure 3. Architecture of the Core module of the MD tool. The boxes at the right correspond to the pre-selected variables the experimenter wanted to trace in the 3D IT *Follow-Me* testing.

### 3.4. Experimental protocol design with EPC tool

Three steps are required for creating your own experimental protocol. The first step consists in choosing properly the indicators and variables (main ones are described in [2]). The experimenter is helped during this process. Each parameter (indicators and variables) may be associated with many publications, examples and different help messages. Variables and indicators are gathered in different categories.

The next step is the creation of evaluation scenarios. The experimenter chooses the good disposition of the different parameters. The final step is the questionnaires' step. The experimenter has to choose the automatic or semi-automatic mode. The automatic mode permits to create questionnaires directly by the parameters chosen. Semi-Automatic creates questionnaire directly but the experimenter may modify, add or delete questions.

### 4. Preliminary empirical evaluation with EEA System

We have experienced our EEA system to refine the condition of use of a 3D IT we have developed, called *Follow-Me* (see [7] for the *Follow-Me* model). The model had been roughly tested before without the EEA system. However, some results we had were put into questions and some questions remained unanswered.

The particularity of *Follow Me* is its use of *virtual guides* to reduce the number of degrees of freedom in VE when approaching an object to be selected and when manipulating it. Thus, the system *anticipates* what the user may do to lessen his need for concentration. But this system may puzzle the user if its anticipation is wrong. Moreover, we already knew that *Follow-Me* behaves well for selecting far and small objects comparing to classical tested 3D ITs.

Our questions were:

- Is there a real benefit of using *Follow-Me* if the object is near from the user in VE?
- Is there a real benefit of using *Follow-Me* for a user who is an expert of VEs?
- How is *Follow-Me* perceived by users (helpful, disturbing, neutral)? Is there any difference in this perception if the user is a novice or an expert?

These questions have implied the creation of specific qualitative questionnaires given to the users after the experiment. It has been done with the help of the EPC tool. They also implied the nature of the probes utilized in the experiments which were traced in a log file and statistically analyzed after the experiment (see figure 2 and the right side of figure 3).

Figure 4 shows our experimental setting using the EVR@ semi-immersive platform. We have performed

a comparative evaluation of *Follow-Me* and two other classical 3D IT over 15 users. Each user had to select a book on a shelf and put it on another shelf as fast as possible. The device used to interact with the VE was a wireless Flystick which position and orientation were captured by two infrared cameras situated at each side of the wide screen.

Two days of work for one experimenter were necessary to:

- build and implement the experimental protocol depending on the questions we were asking [the *EPC tool* configures the probes and deliver questionnaires in PDF format];
- do the experiment in itself with 15 users (an average of 30 minutes per user was necessary) [*MD tool* produces a dated trace of all probes];
- analyze the collected data to produce a feedback [dated trace and qualitative data from questionnaires are submitted to a script that uses an ANOVA procedure in the *R* software].

EEA permitted us to know that *Follow Me* is favorably accepted by novices in VE and permits faster selection and manipulation than other 3D IT whereas experts are puzzled by *Follow Me* and prefers classical 3D IT. This feedback will be utilized in the future to refine the use of virtual guides in the *Follow Me* model.

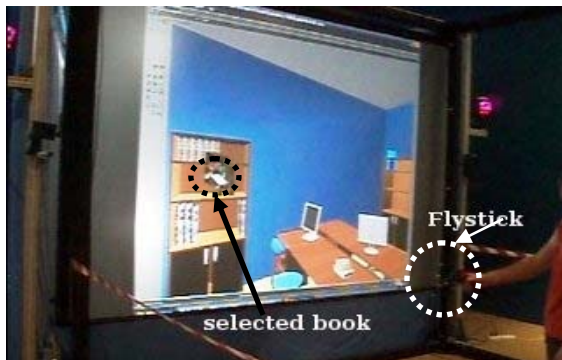


Figure 4. Experimental setting using the semi-immersive EVR@ platform to test the 3D IT *Follow-Me* for a book selection and manipulation task in VE.

## 5. Conclusion

We have described a tool called *Empirical Evaluation Assistant*. This tool is dedicated to *light* evaluations of 3D Interaction Techniques during their development lifecycle. It may be used by non ergonomic experts. The aims of this tool are:

- a fast design of an experimental protocol by using pre-existing protocols stored in a database;
- debugging and trace facilities during the experiment;
- statistical analysis of the inter dependence of pre-selected variables after the experiment.

The core idea is to get fast feedbacks in order to improve the tested 3D IT. In order to accumulate

knowledge about our 3D ITs, the whole experiments may be stored into a database which may be accessed worldwide via a WEB interface, whereas the debugging tool is connected to our VR/AR platform and is implemented in *Virtools*.

We have used our EEA system to test a 3D IT we have developed recently. The feedback we obtained in only two working days permitted us to build an evolution of our 3D IT.

Future work on the EEA will concentrate on:

- the interface with MATLAB do get statistical analysis online (via MEX codes);
- the collaboration with ergonomic experts to improve our software and share the data collected during the experiments.

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