Assessment of the Use of a Human-computer vision Interaction Framework

Pere Ponsa†, Cristina Manresa-Yee‡, David Batlle†and Javier Varona‡

Abstract — **The main goal of this work is to present an integrated framework between vision based interfaces and human-centered design approaches. The final issue is to study the interaction between humans and devices in order to improve the performance of the human-computer system designed, and apply this taxonomy to develop future applications for people with special needs in smart home environments.**

Keywords — **Display design, hands-free interfaces, smart home, automation, display, usability.**

I. Introduction

A recent study on the impact and wider potential of information and communication technologies [1], [2], [3], [4] outlines the needs of the growing market of older people and people with disabilities:

-SMS-based emergency services are useful for deaf people
-Adaptable and adaptive user interfaces will make systems easier to use by people with disabilities
-The potential of ambient intelligence to help people with disabilities is considerable.

One of the main difficulties we need to solve in this domain is related to the design problem. In the sense that the design is not so concerned with the creation of new technical devices as it is with their effectiveness and integration [5], [6], [7]. To some extend this can be reduced to fix the interaction between subsystems such as:

-People with special needs (brain palsy, multiple sclerosis)
-Visual-based interfaces (eye and eye-gaze tracking, nose tracking)
-Home display (switches, lights, devices)
- Human supervision (traded control, shared control, human in the loop)

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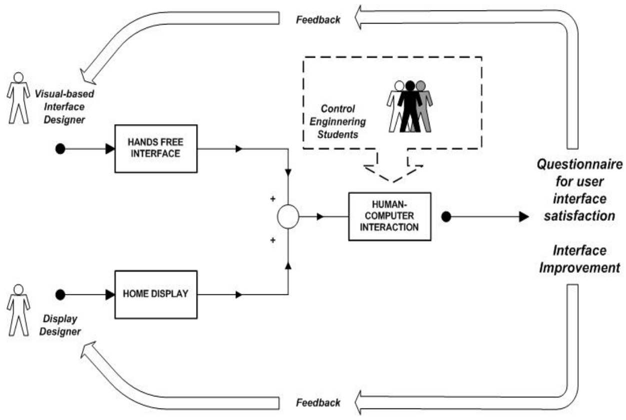

Fig. 1. Human-computer vision interaction framework. Collaboration between computer science researchers and engineering systems researchers.

We are interested in the relationship with these subsystems in order to improve the effectiveness of the human-computer system [8]. The task to carry out in our work is the evaluation of a group of persons performing several tasks on a home display such as activate and deactivate home devices or navigate around the different rooms accessing this display through a vision-based interface. In this sense it's necessary to develop a complete set of subsystems:

- Vision based interface
- Graphical display to simulate the home automation task
- User satisfaction questionnaire
- Usability metrics in order to measure effectiveness, efficiency and satisfaction
- User experience (engineering students, people with specifics needs)
- Field study: the user doing the task inside a home automation system

Vision-based interfaces use computer vision techniques for human-computer interaction (HCI) purposes and are a kind of Perceptual User Interfaces (PUIs). These interfaces seek to make user interfaces more natural and compelling by taking advantage of the ways in which people naturally interact with each other and with the world [9].

The importance of vision-based interfaces grow when a user can not use his upper body limbs efficiently (i.e. brain palsy, multiple sclerosis) and can not make use of the traditional devices such as a mouse or a keyboard. In order to achieve a human-computer interface by means of

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computer vision and for it to be efficient and suitable, it has to encounter several requirements referring to speed, accuracy and robustness.

This subsystem can help in the e-accessibility component of the e-inclusion by offering a hands-free access to the computer. Moreover it is a low cost subsystem and no cumbersome device is attached to the user making him or her feel more natural in their communication with a computer.

From the point of view of the usability engineering is necessary to study the user satisfaction with these new interfaces, the fatigue, and the human error, in order to improve the efficiency and the effectiveness of this human-computer system [10]. Therefore, collaboration between human factors experts and computer vision engineers is very important. It is necessary to validate the method before taking it to a real operation environment. Fig. 1 shows the taxonomy of the process' cycle used in this research.

The Universitat de les Illes Balears, UIB, has provided us with a vision-based interface prototype called 'Advanced Natural Interaction System' (SINA in Catalan language) [11, 12].

In this paper, a human-computer vision interaction framework is presented in the areas of computer vision and human-centered design. In the next section we describe the hands-free interface and a set of previous ergonomic recommendations. Section 3 explains the application of an ergonomic guide in the design of home displays. Then, in section 4 a qualitative experimental study is presented in order to assess the satisfaction in the use of the hands-free interface, a home display and a human control task. Section five shows the usability engineering approach in order to define objective usability metrics. Finally, the conclusions and future lines are presented.

II. Hands-free Interface

The hands-free interface (see Fig. 2) used in the evaluation of the home automation interface is a Vision Based Interface (VBI) that uses face feature tracking for achieving a HCI system. The system's feedback is in real-time, accurate and robust. A standard USB webcam will provide the images to process; therefore it will allow the achievement of a low cost system. Finally, the last system's feature is that the user's work environment conditions are normal, that is, with no special lighting or static background.

When a user is sitting in front of a computer with a webcam over the screen, the face can be assumed to be visible. Then, a system based in head or face feature detection and tracking can become a very effective human-computer interface. Different approaches have been used for non invasive face/head-based interfaces. For the control of the position some systems analyze facial cues such as color distributions, head geometry or motion [13]. Other works track facial features or gaze including infrared lighting [14]. In this work we will use as facial feature the nose.

The developed techniques have been applied in conjunction to build an application, whose objective is to

Fig. 2. Hands-free interface. Through head movements, the user chooses one option (left mouse button, double click, right mouse button, etc. similar events as a mouse).

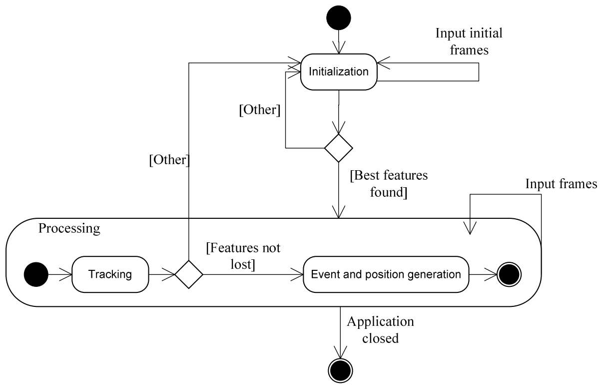

Fig. 3. Face based interface: Initialization and processing modules.

Fig. 4. (left) Best feature selection using symmetrical constraints; (right) Mean of al features: nose point.

completely replace the traditional mouse device functionality.

The implementation of this interface is based in a new mixture of several computer vision techniques, where some of them have been improved and enhanced to reach more stability and robustness in tracking for achieving our purposes. In order to develop a usable, easy and friendly-use system, this one is divided in two modules: Initialization and Processing (see Fig. 3).

The Initialization module is a totally automatic learning phase, responsible of extracting the user's distinctive facial features: face location and the initial facial features position and their properties.

The face is detected automatically by means of a real-time face detection algorithm and it is divided in three sections based on anthropometrical measurements: eyes and eyebrows, nose, and mouth region. For face tracking, over the nose region, we look for the good features to track, (see Fig 4) [15]. However, some found features will be not positioned over corners or nostrils due to lighting.

Therefore, an enhancement and a reselection of the found features are carried out having into account symmetrical constraints respect to the vertical axis. This reselection process will achieve the best features to track and it will contribute to the tracking robustness. The Fig. 2 illustrates the final point considered, that is, the mean point of all the final selected features that due to the reselection of points must be centered on the nose.

The Processing module carries out the tracking of the facial features. The important positional results for our system are reported by the nose tracking algorithm, where the selected features in the Initialization process are used. In this case, the spatial intensity gradient information of the images is used for finding the best image registration. As it was before mentioned, for each frame the mean of all features is computed and it is defined as the nose position for that frame. The tracking algorithm is robust for handling rotation, scaling and shearing, so the user can move in a more unrestricted way. But again lighting or fast movements can cause the lost or displacement of the features to track. As only the features beneath the nose region are in the region of interest, a feature will be discarded when the length between this feature and the mean position, the nose position, is greater than a predefined value. Detailed technical information on these algorithms and a complete description can be found in [12].

In order to smooth the motion of the mouse's cursor when mapping the tracked nose point, we use a smoothing algorithm based in the motion's tendency of the nose position. A linear regression method is applied to a number of tracked nose positions through consecutive frames. The computed nose points of n consecutive frames are adjusted to a line, and therefore the nose motion can be carried out over that line direction. For avoiding discontinuities the regression line is adjusted with every new point that arrives.

The mouse's events are carried out by means of a graphical event keyboard and the way for selecting a desired event is by click-and-wait, that is, place the cursor on the event button and stay on it for a particular number of frames. For executing the event, similar action is needed.

The interface is currently being tested in two centers from the Balearic Islands which work with disabled people; one centre works with users with cerebral palsy and the other one is for users with multiple sclerosis. In both cases, the main comments of the therapists tutoring the users are related to the interface's usability for improving the user's performance.

The most important conclusion offered to us by the therapists is that users (mainly the child) are really excited about accessing the computer. In addition, users with reduced head mobility have improved their mobility by means of using this interface, proving its potential as a rehabilitation tool.

TABLE 1: ERGONOMIC RECOMMENDATIONS

VBI Prototype: SINA	*Ergonomic recommendations*
Calibration/Recalibration	
The calibration process is too difficult to understand for very young children	Reduce the calibration process at minimum in order to obtain a natural interface
A heavy calibration can influence in the user' satisfaction	Training the user with useful tasks or games
Graphical Tool Bar	
A graphical tool bar is more intuitive that a text tool bar	Improve the location and visibility of the graphical tool bar
The navigation inside a text tool bar can be difficult for some users	The tool bar must be easy to understand and use
Head Movements	
The repetitive head movements of the user can increase the fatigue	It is necessary a correct relationship between the head movement of the user and the pointer movement on screen
Some users have reduced head mobility	It is necessary to guarantee a good performance with a low number of head movements
Feedback	
The user action and the consequence of the action are linked in a correct interaction	Quickly transition between the action and the consequence of the action (fast speed and robustness of the tracking algorithm)
The user must have the total control of the software application	In some cases it will be necessary the aid of the caregiver or an artificial software assistant

In order to improve the effectiveness, before applying the VBI on a user, it is necessary to validate the prototype. Some factors to study are: the calibration of the VBI, the user-oriented graphical tool bar, the head motion and the feedback.

During the year 2007 the vision-based interface was tested and evaluated by the authors' from the Automatic Control Department and in Table 1 their ergonomic recommendations are summarized.

The next section shows that the authors have been working in a home display in order to allow the user to carry out tasks by themselves (entertainment, healthcare, security, communication, control). The first step for integrating both interfaces is detailed in the next section where the human-computer interaction approach allows us to design the best ergonomic displays.

III. Display design

The 'ergonomic guideline for supervisory control interface design', GEDIS guide, is a method that seeks to cover all the aspects of the interface design, in order to improve the effectives of human-computer interaction applied to supervision tasks [16], [17].

The GEDIS guide offers design recommendations when creating an interface. It also offers improvement recommendations for existing interfaces. The GEDIS guide is composed by two parts: the description and the measurement of ten indicators. The method to be followed for using the GEDIS guide is: analyze the indicator, measure the indicator, obtain the global evaluation index and finally offer improvement recommendations.

The indicators are: architecture, distribution, navigation, color, text font, status of the devices, process values, graphs and tables, data-entry commands, and finally alarms. Each indicator in Table 1 can be splitted in several subindicators. Equation 1 calculates the numeric value of each indicator.

$$Indicator = \frac{\sum_{j=1}^{J} w_j Subind_j}{\sum_{j=1}^{J} w_j} \quad (1)$$

where, Subind= subindicator and w = weight.

In this example, we are considering that all subindicators have the same weight (w1 = w2… =wJ = 1). Each indicators in Table 2 is measured in a scale from 1 to 5. The indicators' values can be grouped, therefore the GEDIS guide can offer a global evaluation of the interface and it can be compared with others interfaces. Equation 2 calculates the GEDIS guide global evaluation index.

$$Global\_evaluation = \frac{\sum_{i=1}^{10} p_i ind_i}{\sum_{i=1}^{10} p_i} \quad (2)$$

where, ind = indicator and p = weight.

We[1] have developed a graphical display representing a complete home (bathroom, kitchen, bedrooms, dinning room, etc.) using the GEDIS guideline for obtaining an ergonomic display design: good architecture, a correct objects' distribution inside the screen and a clear navigation system among screens. The GEDIS assess the designer to choose the best display prototype in order to improve the interface and prepare future usability tests. Detailed technical information and a complete description of the GEDIS guide can be found in [16]. A good ergonomic design reduces the workload of the user and it is totally suitable for applying it on assistive technologies interfaces: interfaces mustn't be a barrier between the user and the system.

[1] Electronic engineering students within the 'Teleoperation systems' subject at the Technical University of Catalonia

TABLE 2: SOME GEDIS INDICATORS

Indicator name and Subindicator name	***Numeric value a appropriate m medium na no appropriate***
Architecture	
Map existence	[Yes, No] [5 0]
Number of levels le	[le<4, le>4] [5 0]
Division: home, area, room, team	[a m na] [5 3 0]
Distribution	[a m na] [5 3 0]
Model comparison	[clear medium no clear]
Flow process	[5 3 0]
Density	[a m na] [5 3 0]
Navigation	
Relationship with architecture	[a m na] [5 3 0]
Navig. Between screens	[a m na] [5 3 0]
Color	
Absence of non appropriate combinations	[Yes, No] [5 0]
Color number c	[4<c<7 c>7] [5 0]
Blink absence (no alarm situation)	[Yes, No] [5 0]
Contrast: screen versus graphical objects	[a m na] [5 3 0]
Relationship with Text	[a m na] [5 3 0]
Text font	
Font number f	[f<4 f>4] [5 0]
Absence of small font (smaller 8)	[Yes, No] [5 0]
Absence of non appropriate combinations	[Yes, No] [5 0]
Abbreviation use	[a m na] [5 3 0]

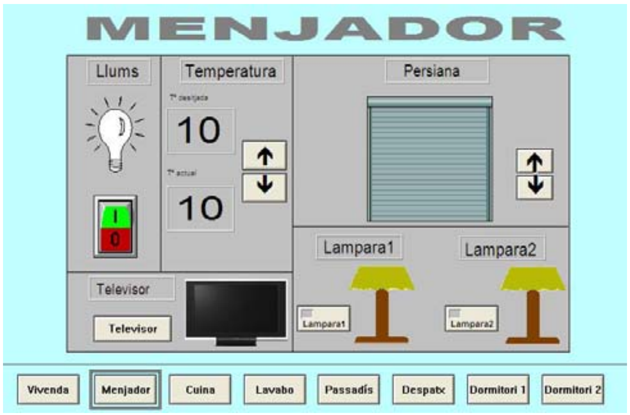

Fig. 5. Dinning room display. The navigation menu below all screens. It is easy for the user to choose and change from one device to another one, or from one room to another one of the house (computed simulated task).

In this work we will focus on the dinning room (see Fig. 5) in order to carry out a qualitative experimental study integrating home automation tasks carried out through the home display together with the use of the VBI detailed in the previous section.

In the dinning room the user can control several devices: switch on/off the light, change the set point of the temperature loop, turn on/off the TV, open or close the blind or choose between Sheridan's control modes: manual or automatic [18], [19]. All the events applied to a device offer a graphical and/or audible feedback.

IV. Qualitative Experimental Study

The validation phase has been carried out whit the next following components:

- Camera Quickcam Logitech 4000 pro
- Vision-based interface prototype SINA
- 'Dining room' display created developed with Intouch of Wonderware (a supervisory control and data acquisition software)
- MORAE by Techsmith (an usability software)
- 8 users: control engineering students

The webcam selection took into account the easiness to adapt itself to the environmental conditions of light and the easiness for the facial pursuit.

As the hands-free interface, SINA, detailed in section 2 incorporates an event graphical toolbar that appears on the screen's right side; the "dining room" display's size has been adapted (see Fig. 6). Moreover, it has been done a study of the compatibility between the possible actions to do with SINA and the events needed to generate an operation on all the devices in the "dining room". As the home display was designed to work with the standard mouse, the use of SINA has not encountered any problem.

Before starting the test task, the participants receive a brief explanation of the functioning of the vision-based interface. Then the users carry out several head movements to check if SINA follow their nose movement (we have to take into account that this was the first time users were having contact with this interface) and it allow them to control the objects on the screen.

The experimental task has consisted in presenting the interface 'dining room' to the user and to request him to execute diverse actions. There were a total of eleven actions distributed in:

- six control actions (activate/deactivate a device)
- three navigation actions among screens of the application
- two operation mode selection actions

When the user makes a direct action such as activate or deactivate a device, for example switch on or off the light of the dining room: the switch changes position and the light changes color to inform the user of this fact. When the user access to the navigation menu he can move from a generic point of view of the house towards a concrete room and device or vice versa. For example, the user can begin with the house, continue with the dining room and finally access to a third level where there is a device, in example a television.

Fig. 6. Home automation task simulated. Through head movements, the user can switch on the light one. This figure is capture by MORAE software.

It is interesting to mention the different control modes proposed by Sheridan:

- Supervisory control. The user watches over the process that is being controlled by an automatism, the user can decide in what moment to take part.
- Traded control. In this mode, the manual control is switched with the automatic control, so that the user performs intermittent actions (human in the loop, or human out the loop)
- Shared control. In this mode, some variables are regulated by the user, and others due to their complexity are regulated by the automatism

Although in this work and for facilitate the user's task, in this experimental study the user has the total control of all the devices.

The experimental session was carried out in the usability laboratory at the Technical University of Catalonia in November 2007, the eight users participated in the SINA's settings configuration phase, the use of the display 'dining room', and they answered a questionnaire about user interface satisfaction. The average duration needed for the test was of 96 seconds, the minimum length was 82 seconds and the maximum length was 103 seconds.

The questionnaire of the user interface satisfaction has been based on diverse classic references in this type of tools, in example the QUIS questionnaire [20]. The questionnaire has six questions related to the task where the user answers in concordance with the scale of Licker with four answer options per question. Moreover, two more questions have been added where the user assesses in a qualitative way the quality of the graphic display (see Fig. 7) and the use of the hands-free interface (see Fig. 8).

The six questions considered were:

- The task was difficult to understand
- The task has been long
- I have been confused, without having clear what it was necessary to do

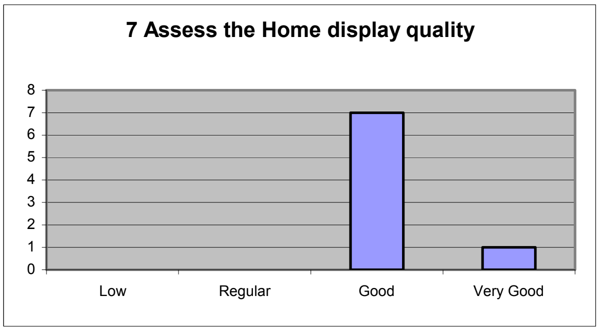

Fig. 7. Seventh question. Seven users have a good assessment of the home display quality.

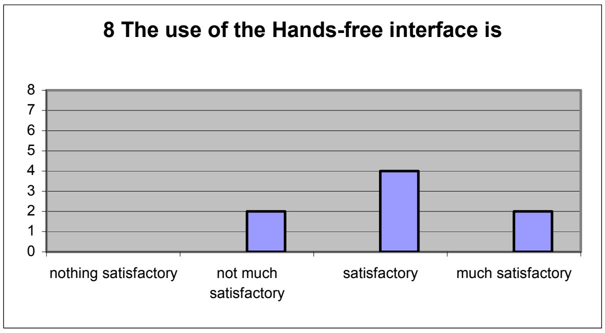

Fig. 8. Eighth question. Six users have a good level of satisfaction.

- I needed to be very concentrated to carry out the task efficiently
- I have been pressured by the time
- I think that my performance has been correct

In general, users find the task easy to carry out and it is not a great effort for them. In the qualitative assessment about the quality of the interface two users over eight consider that it is necessary to apply changes for the improvement of the functionality of some devices (increase the size of the object, change a graphical icon for another). The authors are working in order to improve the use of the graphical objects of the Dinning room display with the hands-free interface.

In the assessment of the use of the hands-free interface in the eighth question, six users over eight consider that it is necessary to improve the accuracy of the movement of the pointer, although it is necessary to emphasize that in the sixth question in the one that the use of the hands-free is assess, six over eight users assess that the use of this interface is satisfactory or very satisfactory. The authors are working in order to improve the tuning of hands-free interface parameters (movement time, speed, accuracy).

The next section shows a more complete usability study in order to add the measure of efficiency, effectiveness and usability metrics.

V. Usability Engineering Approach

An example of methodological framework is the Process Model of the Usability Engineering and the Accessibility MPIu+a developed by Toni Granollers which gathers together all the cycle phases: requirements' analysis, design, implementation, launching, prototyping, evaluation and user, [21].

In the evaluation phase, and for the usability measure, it is necessary to have the contribution of the experimental studies carried out in the usability laboratories.

The analysis of requirements is a necessary previous research work in order to establish the best relationship among the human, the interface, and the task. For example, which is the user's profile?, which is the user's kind? Some previous research works are focused in particular cases:

- Example 1: people (children with cerebral palsy), VBI (Corneal and pupil reflection), Task (Computer Access)
- Example 2: people (children with cerebral palsy), VBI (Nose tracking), Task (Computer Access)

The problem is that cerebral palsy is a group of chronic conditions affecting body movement and muscle coordination and therefore, it causes disorders in the development of movement and posture, so it isn't correct to group users with different diagnostics in the same experimental task. Another problem is: which is the best interface, from the point of view of the user's experience? Some interfaces are appropriate for a few users but not for all users.

It is difficult to obtain generic conclusions, though it's a fact that experiences with vision-based interfaces are very encouraging. The computer vision authors of this paper are working in collaboration with caregivers of two centers from the Balearic Islands in order to prepare usability test for children with cerebral palsy and improve their quality of life.

In human-computer studies it is necessary to define qualitative and quantitative performance rates. Following some ideas of the experts in usability studies and field studies, the tasks presented in the previous section demand a high level of activity planning that involve reasoning and decision making.

It is possible to follow different approaches: the individual differences approach, the case study approach and the system characteristics approach. In this paper we follow the first approach. The studies of user's differences have diverse goals:

- To find ways of predicting performance
- To find and characterize individual variability. To find not only differences in the degree to which users are able to reach the goals, but also differences in how they perform, i.e. decision making strategies and user satisfaction

From the point of view of usability engineering the proposed performance method can summarize in four steps [22], [23]:

- Effectiveness measure
- Efficiency measure
- Users' satisfaction measure
- Usability metrics

TABLE 3: FROM QUANTITATIVE INFORMATION TO QUALITATIVE INFORMATION

Effectiveness	***Success rate sr***
1	$sr = 11$
0,5	$11 < sr \leq 5$
0	$sr < 5$

The MORAE software allows including the satisfaction questionnaire presented in the section three of this paper. And then, MORAE software helps in obtaining information about the success rate and the time task [24, 25]. With the following approach it is possible to transform this information and obtain measures of effectiveness, efficiency and satisfaction.

For example, in table 3, if the success rate of an user is 8 (the total number of actions in this task is 11, see fourth section), the Effectiveness has a numeric value 0,5.

Finally it is possible to define a usability metrics. The number of attributes in usability engineering is three.

Attributes A = [Efficiency Effectiveness Satisfaction]

$$Usability = \frac{\sum_{i=1}^{m} A_i}{m} \quad (3)$$

where m=3; all these attributes have the same weight.

The results obtained in the first experimental study with 8 users and gathering qualitative and quantitative data has helped us to define this usability metrics. Moreover, a new experimental session with seven users was carried out in November 2008 at the Technical University of Catalonia. We applied this metric in the same task (use of the second version of SINA, the "dining room" display, and answer a satisfaction questionnaire) and we obtained data that shows that these seven users present medium-high values of usability (see Fig. 9).

VI. CONCLUSIONS

Towards an inclusive future in smart homes it is necessary to establish the relationship between diverse domains: computer vision, automation, electronics and usability engineering. From the point of view of Sheridan, it is necessary to study the interaction between human and machines. For this reason, this paper tries to integrate a vision-based interface (VBI) with a home display and the user's experience. The hands-free interface is an example of a vision based interface designed to achieve computer accessibility for disabled users with motor impairments.

The qualitative experimental study of this work shows that the users employ the hands-free interface for controlling the home automation interfaces in a natural way.

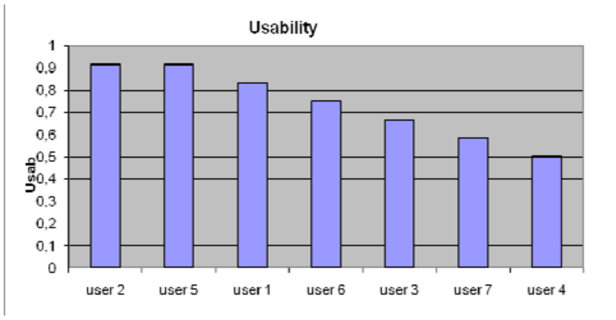

Fig. 9. Usability metrics. All the users have a medium-high values of usability.

With the aid of the usability engineering it is possible to assess the effectiveness, the efficiency and the users' satisfaction. In future studies it is necessary to define a measure of distance:

- Manhattan distance: in order to compare the usability measure of an user with a reference pattern (best efficiency in minimal time and good satisfaction)
- Mean distance: in order to compare the usability measure of an user with the mean distance of the group

Finally, in a future work it is possible to translate the experimental study from the usability laboratory to a real smart home environment and assess the satisfaction of people with special needs [26].

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