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EDITORIAL PREFACE

This is *Fifth* Issue of Volume *Five* of International Journal of Human Computer Interaction (IJHCI). IJHCI is an International refereed journal for publication of current research in Human Computer Interaction. Publications of IJHCI are beneficial for researchers, academics, scholars, advanced students, practitioners, and those seeking an update on current experience, state of the art research theories and future prospects in relation to applied science. Some important topics covers by IJHCI are affective computing, agent models co-ordination and communication, computer mediated communication, innovative interaction techniques and user interface prototyping for interactive systems etc.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Started with Volume 5, 2014, IJHCI appears with more focused issues related to human computer interaction studies. Besides normal publications, IJHCI intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

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Multi Robot User Interface Design Based On HCI Principles

Sidra Naveed *sidra.mscs18@students.mcs.edu.pk*
Department of Computer Software Engineering,
National University of Sciences and Technology (NUST)
Rawalpindi, 46000, Pakistan.

Naveed Iqbal Rao *naveedi@mcs.edu.pk*
Department of Computer Software Engineering,
National University of Sciences and Technology (NUST)
Rawalpindi, 46000, Pakistan.

Barbel Mertsching *mertsching@upb.de*
GET Lab,
Universität Paderborn,
Paderbon, 33098, Germany.

Abstract

Robot User Interface (RUI) refers to a specialized User Interface (UI) that intrinsically supplements the virtual access phenomenon of human operators with robots working in complex and challenging scenarios such as rescue missions. The very nature of complexity and attributed information overload can potentially cause significant threat to survivor’s life expectancy, especially when the Human Computer Interaction (HCI) has to play its optimal role. Keeping in view the seriousness of scenario and associated complexities, the current UI problems are firstly highlighted in RUIs. Afterwards, the surfaced UI design issues are tackled through application of established heuristics and design elements. A new interface is designed based on the design heuristics. This newly developed RUI has been tested on the available autonomous rescue robot, GETbot. The usability evaluation and heuristic based evaluation principles are applied in greater depth to establish marked improvement in UI design, with reference to its previously faced usability issues.

Keywords: Human Computer Interaction, Robot User Interface, Robot Control User Interface, Mobile Exploratory Robot

1. INTRODUCTION

The exploratory robot systems have various usages in numerous areas. For instance, these are used in hazardous environments [6][7][8] for exploring the position of victims after some natural disaster and also for the scientific explorations [9] [10] [11]. Moreover they are also used for tactical military reconnaissance [12], field surveys [13] and security petrol [14]. Their usage as spying agents [15] by military and law enforcement agencies [16] is also a modern time application.

Robot user interfaces (RUIs) are developed and deployed to play the crucial role of controlling a team of Mobile Exploratory Robots (MER) that is operated in high risk disaster stricken scenarios via remote interface. For the sake of properly maneuvering and operating these MERs, the usability optimization of user interfaces is of particular importance. RUIs are designed to provide the location, state and situation of initial survivors or wounded people to the control center so that the human effort could be mapped and directed precisely thus increasing the survivability chances of victims.

For multiple robot systems, MERs may be controlled and navigated through a RUI by a single operator. The multiple sensor data streams coming from many MERs greatly increase the level of operational complexity for a human operator. For such inevitably crucial reasons streamlined information needs to be provided to the human operators so that multiple MERs could be operated with same efficiency. The RUI should be well designed and appropriately interfaced to help the operators by decreasing their cognitive workload [1].

The current RUIs are often difficult to understand and handle as they require some training and learning for the human operators. These interfaces are usually designed and developed by the same individuals who developed and built the robot. This usually results in un-intuitive and non-standardized interfaces and creates cognitive handling issues for the operators [2]. The situation gets even adverse when a single human operator has to control the navigation of multiple MERs simultaneously. One way to tackle with the issue might be to provide the operator with only relevant information by eliminating redundant data [3]. As a general observation in previous MER interface designs it was noted that the live video presentation results in the operator neglecting other critical decision making details and hence not optimally using the RUI [4]. If there is one operator controlling multiple robots then a robot must be able to compensate for the period of neglect by the operator without immediately ceasing to operate [5]. Therefore for easy inter-operability the operator must be able to switch amongst various robots and their modes [2].

2. RELATED WORK

Designing efficient and well manageable user interfaces for human-robot interaction is a topic of interest for researchers working in the field of user interface and robot design. However, some of these interfaces are designed to allow human users control a single robot either manually or autonomously operated [2] [4]. Various other interfaces enable controlling multiple MERs simultaneously through the user interfaces [3] [5] [17] [18].

Shahar, et. al. [19] presented asynchronous techniques for managing multiple robots, by presenting the recorded imagery to the operator instead of using live videos. Reid, et. al. [20] made use of an integrated system for simultaneously controlling multiple MERs through the playbook concept. E. Vincent, et. al. [22] came up with a cognitive facilitation centric interface design to further facilitate interactions between single human operator and a robot team. M. Waleed, et.al. [2] presents a design and implementation of a user interface based on HCI in order to maximize effectiveness and minimizing learning time. Holly,et.al [4] has presented an interface in which a keyboard is used to control all the functions and their operations.

For evaluation of such RUI's, many researchers have proposed methods and metrics based on HCI and HRI design heuristics. Keyes, et.al [23] has evaluated the Human Robot Interface design to improve the awareness for robot rescue operations by providing some guidelines for HRI. Tsui, et.al [24] has developed a set of heuristics focusing a more specific area of assistive robots by examining Nielsen's heuristics [28] [29]. Chen, et.al [25] have examined human performance issues in tele operation by identifying factors that decrements the performance. Clarkson, et.al [26] has presented a work that provides a set of heuristics for HRI systems for their evaluation for showing the effectiveness of these systems.

3. EMPIRICAL INVESTIGATION: RESCUE ROBOT USER INTERFACE

Here we present a concise survey on design principles that could evaluate RUIs both subjectively and objectively. Apart from gathering the design principles used by other researchers, the proposed research has contributed some new metrics for interface evaluation. The existing RUI of rescue robot, GETbot, is taken for analyzing its current intuitive operability weaknesses and later on incorporating HRI and HCI principles in the User Interface (UI) design for design improvements. Section 3.1 shows existing interface design of GETbot while highlighting different UI design problems.

3.1. Current RUI of GETbot

The current RUI of GETbot is designed through multi windowed approach providing three different information views. Using the sensors data of a single robot, the interface searches for the affected victim in the real environment. Three different views of the interface are the operator view, victim found view and the map view. Operator view allows the human operator to control the robot using its camera view and communicating data coming from various MER sensors. The Victim Found View inherently depicts the task of automatically representing detected victims. It readily pops up to manifest the detection of a new victim found during the wandering and search tasks. Map View is designed to allow the human MER operator have sight on complete environment, along with marked victim positions. The Map View inherently performs the task of printing the previously scanned environment along with all of its artifacts. Main operator view of the GETbot is shown in Figure 1.

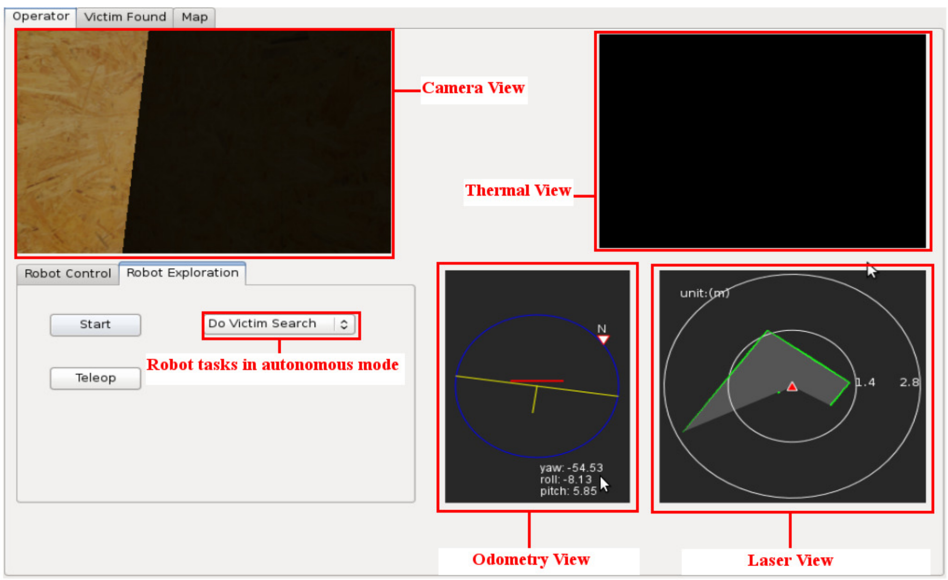

FIGURE 1: Current Operator View of Rescue Robot (GETbot).

3.2. Problems with the Current RUI of GETbot

The human operators using current RUI of GETbot experienced numerous hitches while operating in practical emergency scenarios. As part of the main hurdle, UI is unable to establish operator control over multiple MERs simultaneously. Moreover, the map view, camera view and laser data do not appear concurrently in the same window as per the current UI. The continuous switching and shuffling of numerous windows not only bring down the pace of navigation but also cognitively overloads the human attention. This leads the human operator to making erroneous judgments and slowing down the human-robot interactivity through exhaustive set of steps. Another disadvantaged aspect is the inability of map view to switch automatically to victim found view if and when the MERs find a victim. The current victim found window requires the human operator to confirm the victim marked by MER for further rescue processes to proceed. GETbot does not indicate the motor speed through its current RUI. A drastic situation may arise if GETbot gets tangled in a deadlock situation without indicating about it to the human operator. The operator in such a scenario would be unable to know of the deadlock state that the MER is in.

4. RUI DESIGN PRINCIPLES

Researchers working on design of RUIs have proposed various principles for improving effectiveness and usability. Avoiding the use of multi window approach and providing all the significant information on single display, is the most common design principle proposed by various researchers [27][31][32][35]. This also helps in reducing the eye movements and the number of interactive steps [36][37] thus enhancing the system performance. It has been proposed by RUI researchers that the interface should have a user centered design rather than developer centered design [27]. Well-adjusted presentation and positioning of sensor information and size of interface elements [3] helps in reducing the cognitive overload from the operator [4] [28] [29] [31] and helps in enhancing the system efficiency. To avoid any deadlock circumstances, visibility of system status [28] [29] [33] and the mode switching option [34] plays a vital role when the robot has the ability to work autonomously as well as manually controlled. In case of a standstill situations faced by the robot, the operator should be alerted by providing good error messages and notifications [28] [29] in order to keep him updated. In case of victim found notification, operator must be involved in deciding the potential victim thus allowing human decision making principle [30]. According to various researchers, the RUI design must be evolving allowing the support of multiple robots and tasks [4] [23] [31] [32]. There are two existing objective evaluation factors that have been used for the evaluation of the new design. These factors are Interactive Steps [36] [37] and memory load [33]. Where interactive steps are defined as the number of steps needed to complete a specific task. And memory load is defined as a number of information that needs to be remembered.

Apart from the above mentioned heuristics for designing and evaluating RUIs, the conducted research has further proposed two factors, namely, saccade length minimization and access time reduction. Saccade length is defined as the true distance between two points on the screen and is given by the formula $Dr = Dp * T/R$. Where Dr is the true distance between two points on the screen and is calculated in mm, Dp is the distance between two points on the screen and is calculated in pixels, R is the resolution of the used direction either vertical or horizontal and is calculated in pixels, T is the size of the screen in the used direction and is calculated in mm. Access time can be defines as the time taken by the operator to access a specific functionality. Access time is directly proportional to interactive steps.

5. PROPOSED DESIGN

After identification of design principles, a new design is proposed according to the evaluation factors which improve the system performance. The interface design of GETbot is proposed with the intent of controlling multiple robots simultaneously without overwhelming the operator with enormous data. All the information and entities in the proposed design are placed by following some design heuristics and usability principles of HRI and HCI. The main operator view of the new interface is shown in Figure 2.

The obstruction faced in operating the old GETbot interface with information on various windows has been vanquished in the new design by providing all the relevant information on a single display [35]. As arrangement of elements on the screen should be according to user's consideration so all the sensors data of MER is placed in prioritized form in a symmetrical balance thus reducing the overall number of eye and manual control movements [36][37]. Providing fused sensor information in the interface design reduces the cognitive overload on user [4][31] therefore multi robot user interface is designed by combining map view, video, laser and odometry data and status information, to tackle the issues related to cognitive overloading of the operator. It shows the live camera views received from various MERs attached to the system. Each live video serves as a click-able window. The idea is taken from the interface proposed by E.Vincent [22]. As interface should provide the system status [28] [29] and should implicitly allow the switching between autonomy modes [34], therefore on clicking the live video of any MER, its complete sensor data along with the robot name, its current mode of operation (autonomous or manually operated), its current status (victim search, wander around, exploration or victim search with wander around) and the motor speed is displayed.

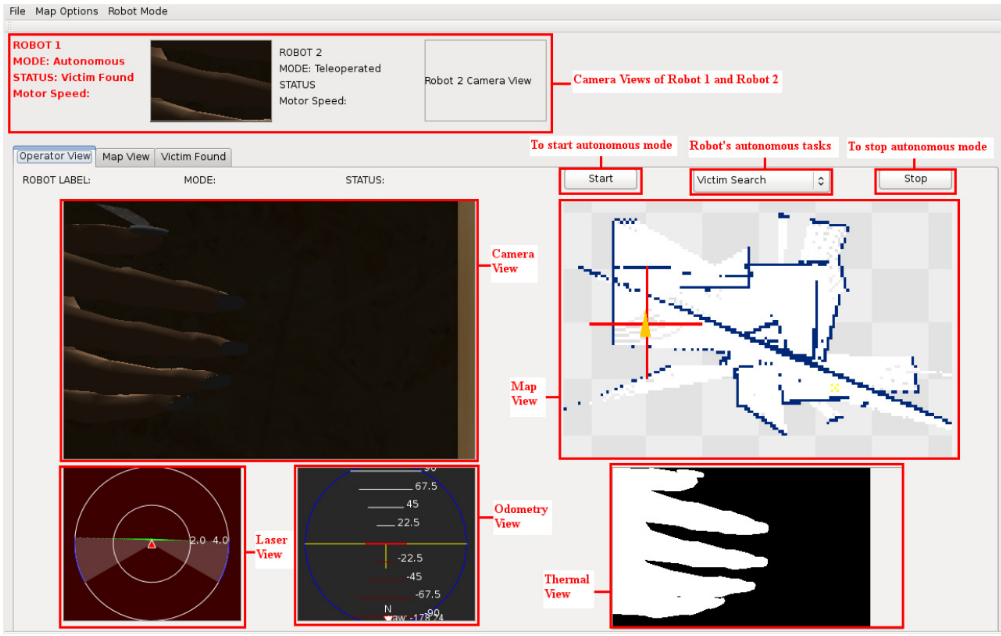

FIGURE 2: Main Operator View.

A separate tab is provided to display the enlarged view of the map containing detailed information regarding the selected robot. Position of the found victim is marked on to the map after confirmation by the human operator. The third tab is provided to show detailed sensor reading about the victim that is detected and being focused by the robot. Whenever a victim is found there is a clear indication of it without distracting the operator from doing his current task. In the live camera view with views from multiple MERs, the text color of the single MER that has found a victim gets highlighted. This hence eliminates the problem of not immediately notifying human operator about any new victim found. The additional functionality is provided at the top using the menus. The main advantage of using menus is that they reduce the cognitive overload from operator, as user does not have to remember the item or functionality but only needs to recognize it [32]. Mode of MERs can be changed from manually operated to autonomous or vice versa by use of menu option of Robot Mode.

6. Evaluation

The new RUI design of GETbot has been evaluated both subjectively and objectively based on the design heuristics proposed by other researchers. Table 1 shows the comparison of the existing RUIs proposed by other researchers with the old GETbot RUI and the new proposed RUI. This comparison has been conducted based on the evaluation factors mentioned in section IV. A quantitative analysis has been conducted between the old GETbot interface and the new GETbot interface based upon the evaluation factors of interactive steps, memory load, and saccade length, to show that how new design is more efficient and effective. These metrics have been applied on three different functionalities present in the GETbot system i.e. Mode switching, victim found and status identification.

RUI Factors	Existing RUI's						Old GETbot RUI	New GETbot RUI
	[19]	[17]	[5]	[3]	[22]	[4]		
Use of multi window approach	✓	✓	✓	-	✓	-	✓	✓
Important information on single display	-	-	✓	-	✓	-	-	✓
Visibility of system status	✓	✓	-	✓	✓	✓	-	✓
Mode switching option	-	✓	-	-	-	-	✓	✓
Good error messages	-	-	-	-	✓	-	-	✓
Human decision making	-	-	-	-	-	-	✓	✓
Support multiple robots and tasks	✓	✓	✓	✓	✓	-	-	✓
Provision of target points	✓	✓	-	✓	✓	✓	✓	✓

TABLE 1: Comparative Analysis of Existing RUIs with GETbot RUI.

Objective evaluation factors	Mode switching		Victim found		Status identification	
	Prior GETbot RUI	Proposed GETbot RUI	Prior GETbot RUI	Proposed GETbot RUI	Prior GETbot RUI	Proposed GETbot RUI
Interactive steps	3	2	2	1	3	1
Memory load	2	0	1	1	3	0
Saccade length (Monitor size in diagnol: 48.1cm)	114.66 mm	173.16 mm	177.5 mm	126.42 mm	114.66 mm	72.324 mm

TABLE 2: Result of Objective Evaluation.

Table 2 shows the result of objective evaluation for the above mentioned metrics. In order to change the mode of the robot, 3 interactive steps are required in the prior GETbot interface, 2 interactive steps are required for victim found notification and 3 steps are required for status identification of the robot. These steps have been reduced to 2, 1, and 1 in the new proposed design. Similarly the values of memory load have been calculated for both the interfaces for all the above mentioned 3 functionalities. As saccade length is the true distance between two points on the screen. If the value is large there will be more eye movements required by the operator to access the functionality hence slowing the input process. The value is calculated by taking the center point of the screen and calculating its distance from the center point of the above mentioned 3 functionalities. The value of saccade length in case of mode switching functionality for proposed interface is greater than the prior interface. The rest of the two calculations for victim found and status identification functionality is reduced for the proposed design as compared to the prior design. As the clear visibility of the important information is of a great value for navigating a robot through unpredictable environment, so the important information should be presented in an appropriate manner with prominent visibility. An interface element covering a greater percentage of the screen is more likely to be clearly visible. As the map view and the camera view plays a key role for navigating the robot through the unknown environment, so the camera and map view should cover the major portion of the screen display i.e. 60-70 percentage of the overall screen, making 30-35 percentage for each view. In case of the victim found situation, thermal view plays a major role that helps in deciding the potential victim. So it should also cover a large portion of the screen display for clear visibility i.e. 20-25 percentage of the overall screen. Laser view and odometry data should cover 5-10 percentage of the screen based on their level of importance during the robot navigation task.

Figure 3(a) presents the distribution of screen elements in the prior RUI which is improved to a more balanced and effective distribution as shown in figures 3(b).

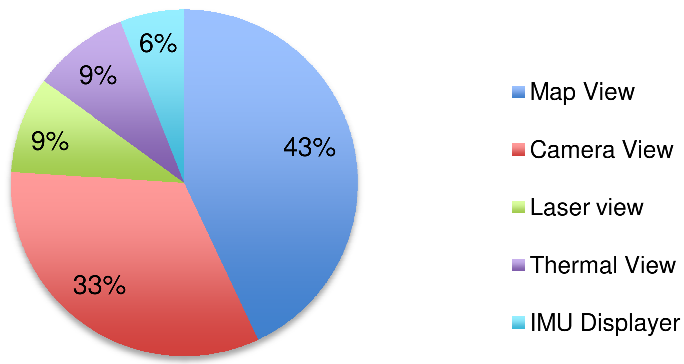

FIGURE 3 (a): Screen Percentages of major interface elements in prior GETbot Interface.

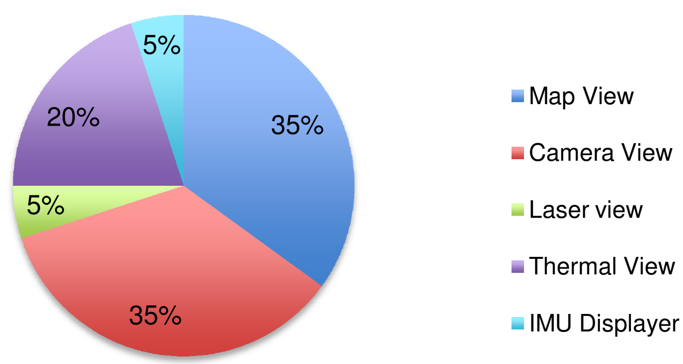

FIGURE 3 (b): Proposed Screen Percentages of major interface elements in new GETbot Interface

7. CONCLUSION

MERs need to be autonomous and user friendly for usage in many applications. This necessity becomes crucial in critical scenarios where rescuing the human lives is involved. The RUI of such rescue MERs needs to be efficient for optimal performance acquisition from the human operators. It would result in the UI contents and options getting easily manipulated by the human operator to speed up the rescue mission. The analysis described various current RUI design setbacks that were creating operational difficulties for human operators of GETbot. The surfaced issues were then tackled via HCI and HRI principles where a new RUI design is proposed that enables multiple MERs to work in tandem and simultaneously. Subjective and objective evaluation techniques were used for evaluation of newly proposed and implemented RUI. Subjective evaluation was conducted through a team of evaluators. The results indicated sufficient improvement in usability of new RUI, which would directly have an impact on raise in victim survival rate.

8. ACKNOWLEDGEMENT

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IJHCI addresses the cognitive, social, health, and ergonomic and other aspects of interactive computing including cognitive ergonomics, collaborative design, ergonomics & human factors, legal, ethical & social aspects of IT, human computer interaction, ergonomics, human computer interaction and user interface. IJHCI emphasizes the human element in relation to the systems in which humans function, operate, network, and communicate, including software, hardware, and their various contexts of use.

To build its International reputation, we are disseminating the publication information through Google Books, Google Scholar, Directory of Open Access Journals (DOAJ), Open J Gate, ScientificCommons, Docstoc and many more. Our International Editors are working on establishing ISI listing and a good impact factor for IJHCI.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Starting with Volume 6, 2015, IJHCI will appear with more focused issues. Besides normal publications, IJHCI intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

We are open to contributions, proposals for any topic as well as for editors and reviewers. We understand that it is through the effort of volunteers that CSC Journals continues to grow and flourish.

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- Computer Supported Cooperative Work
- Design and Evaluation of Innovative Interactive Sy
- Empirical Studies of User Behaviour
- Graphic Interaction
- Human language Technologies and Machine Learning i
- Human-Computer Interaction Theory
- Innovative Interaction Techniques
- Intelligent Tutoring, Coaching and Debugging Syste
- Intelligent user Interfaces
- Interaction in Mobile and Embedded Systems
- Interactive Decision Support Systems
- Interface Design and Evaluation Methodologies
- Knowledge Acquisition, Discovery, Modeling and Man
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- Multimodal Interaction
- Natural language interaction
- Peer to Peer Communication Between

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- Presence
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CONTACT INFORMATION

Computer Science Journals Sdn BhD

B-5-8 Plaza Mont Kiara, Mont Kiara

50480, Kuala Lumpur, MALAYSIA

Phone: 006 03 6204 5627

Fax: 006 03 6204 5628

Email: cscpress@cscjournals.org

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50480, KUALA LUMPUR

MALAYSIA

PHONE: 006 03 6204 5627

FAX: 006 03 6204 5628

EMAIL: cscpress@cscjournals.org