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Eye Tracking Interface Design for Controlling Mobile Robot

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ABSTRACT

This thesis provides a baseline study for eye tracking user interface design for controlling a mobile robot. The baseline study is an experiment involving the use of a radio controller (RC) to drive the robot, while gaze data is collected from each subject monitoring the position of robot on the remote screen that displays the view for the turret-mounted video camera on the robot. Initial data from the experiment provides a foundation for interface design of actual control of the mobile robot by gaze interaction. Such an interface may provide Tele-presence for the disable. Patients with motor disability cannot use their hands and legs but only use their eye motions. Such applications of an eye tracking system can provide patients with much flexibility and freedom for search and identification of objects.

Keywords: Eye tracking system, User interface design, Mobile robot, Gaze plot, hotspots.

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CONTENTS

INTRODUCTION

Eye tracking technology history reveals back to 1800 century when simple methods of reading text and images were used to deduce facts about a reader's gaze. Steady development in the technology is now at its maturity level yet miles in the run to explode in the current society. There are multiple applications associated with this technology focus to limited group of individuals, e.g. mostly researcher's work in research projects related to patients with motor disability. These two key players have developed and utilized the technology to its maximum.

Mobile Robotics is also an old but promising field of science that deals in number of ways where it is implemented, since we understand the root cause for the mobile robot development was to assist humans working in non human environments in open and industrial situations. Not only for this reasons, mobile robots were focused, but also as the need to mobility evolved, thing turn to move the similar flow. Excitingly we see mobile robots around in three different moulds i.e. mobile robot in air, earth and water. Each set of defined mobile robots have specialized properties and functions address in development specifications. Basically application(s) necessity grew more enthusiastic challenges for the development teams, bringing more project and product in the society ever before.

Both technologies have sound current and future market existence(s), their role together will address some unique features in the near future. However, integration of both technologies will progress quest to manifest results in new application and product developments. Challenging phenomenon between the two technologies integration requires extensive efforts at each level of product development. To start with the software product base integration, both technologies have different mechanism of access control(s)/ operations. Uniqueness in mobile robot access control is vital to eye tracking interface design and development. Mobile robots might be portable in hardware but are strongly connected and dependent at the software modules; functions for controlling the mobile robot through eye tracking system incorporate effective, robust, reliable, accurate and consistent interface design parameters.

The interface design will focus the integrated technology control mechanism for motor disability patients enthusiastic to participate actively working with mobile robot control through eye trackers in their routines tasks, and reduce their dependability on other humans by utilizing mobile robots. Questioning about how well this technology integration will produce is quite early to answer at this stage but since every technology evolution had undergone through preliminary stages for working and survival and the contributions of researchers encircles the new technology philosophy integration it's admired to accept the facts associated in these technologies integrations.

The limitations encountered in the eye tracking technology involves users interest, experiences, power of learning, understanding and operating new applications, user and system physically located positions, systems implementation cost, patterns of system operation flexibility, reliability, effectiveness, response and performance. These limitations sometimes seems as a contradiction to the technology selection, however it’s not always the case for special users (patients) but simple user (normal persons) that will highly be synthesized and improved by the researchers. The technology constitutes of many dependent / independent modules combined by functionality and operations but through object oriented definition facility, software experts can develop more efficient, simple and robust applications architectures defined by quality researchers. Mobile robotic also adhere some limitation subject to the robot design, architecture and functionality, but normally we find this technology apparent to complexities.

Accurate user interface designs are necessary for an intermediate mobile robot control mechanism. By utilizing eye tracking system and mobile robot module and parameter descriptions we can develop consistent interface for specific application task(s). The combination of technologies produces striking results in the coming years with exclusive projection in new hardware/ software application developments. Principally applications designed for target groups involve patients with motor disability and single user multiple robot control applications e.g. industrial applications. Social environment will accept the new research technology integration with the passage of time until its benefits and requirement are more than its costs.

Chapter 1 will characterizes the background information in the study.

Chapter 2 will represent problem definition, motivation, research questions and outcome.

Chapter 3 will define the research methodology phase, the way we have conduct the research study.

Chapter 4 addresses theoretical background for eye tracking technology and mobile robot in terms of user interface design.

Chapter 5 produce the empirical study results for different scenario constructions in terms of general applications in effect with scenario 1 description, providing the basics for the experiment conduct. However it constitutes scenario descriptions division due to human and autonomy control procedure.

Chapter 6 depicts experiment details, results and the analysis portion of the research study.

Chapter 7 is the key chapter encompassing all the previous studies for designing user interface design specifically based on chapter 6 results.

Chapter 8 illustrates the discussion about overall research study and proposed user interface design issues.

CHAPTER 1: BACKGROUND

1.1 What is Eye Tracking Technology?

Eye tracking technology is the combination of specialized software and generalized systems developed with the essence to record and determine the user gaze behaviors. Main theme of the eye tracking technology is to analyze the point of gaze i.e. where we see or focus on the computer screen. Eye tracking system may consist of eye tracking processor, auto-calibration processor, video monitor and certain cables, etc and software with data acquisition, control, and analysis, etc. The purpose of the eye tracking device is to locate eye positions and their movements on the screen. Our main research is on Tobii 1750 eye tracking system because of the availability of this eye tracking system. It is simple to employ, useful to work and accurate to calculate. The Tobii eye tracking system has high and accurate tracking of the user eye focus position on a screen. Research areas involved in the emerging eye tracker technology are psychology, cognitive linguistics and visual system measuring of the eye movements in video images. History of the eye tracking technology reveals back to 1800s with improvement in the technology due to development of computing devices i.e. computers.

1.2 Eye tracking Versus Gaze Tracking Systems:

Eye trackers necessarily measure the rotation of the eye with respect to measuring system. If the measuring system is head mounted, as with Electro-oculogram (EOG), then eye-in-head angles are measured. Else, if the measuring system is table mounted, as with sclera search coils [1] or table mounted camera (“remote”) systems, then gaze angles are measured. Many applications uphold the strategy of fixing the head during eye tracking mechanism/operations, while head mounted camera provides great flexibility in head movements to the user but an extra burden on the user mind to fix the camera on the head instead of adjacent to the screen. It however improves efficiency at the software end but decreases usability. Application with head mounted cameras utilizes EOG and measure head angles. Gaza angles are measured when the system implements table or sclera search coil mechanism. Many applications require to keep the head position fixed through bite bar, forehead support, etc to obtain same eye and gaze positions. Head mounted systems use magnetic or video based head trackers to measure head movements and head positions where as head mounted trackers complement with an eye in head direction to determine gaze directions.

1.3 Usage of Tobii eye Tracking System?

Developers can develop demanding, secure, reliable and efficient applications for special and general user groups, and also researchers conduct research experiments in multiple areas, including the one explained latter in thesis report Chapter 6. General usage of the Tobii system could be accessing an email, internet surfing, game playing, learning education, and admiring the use of mobile robots. The main purpose of the Tobii eye tracking technology is for extremely restricted disabilities users. Such users who are very limited to use the computer machine due to spinal cord injury and brain injuries, patients of cerebral palsy and multiple sclerosis.

COGAIN is communication gaze interaction network and contains many research projects utilizing eye tracking systems e.g. research study based on illusion of color and shadows; color processing in the human LGN and Cortex measured with fMRI, color based object identification: Alternatives to inverse optics, working on fMRI &MEG; eye control development, education and support service application programs and games; and many other areas to conduct research and develop technology applications about eye gaze interaction.

1.4 Eye tracking System for Integration

Tobii is the technology standard with embedded eye tracking system openly available for the customers for the applications requiring technology integrations. Integrated system in Tobii Eye Tracker depicts technological evolution with accurate results. Tobii offers interface mechanism for computer control, human behavior detection and analysis. Advanced technology offer standard integration components which reduces new applications development cost and time i.e. gaming industry, medical equipments, and multiple research areas, etc. Tobii technology will profit through integrated systems, interfaces designs and new application/ product developments. Presently eye tracking applications produce important results for businesses and homes. It is required to work in this field of interest and conduct research and analysis to produce gaze interactive communication applications.

CHAPTER 2: PROBLEM DEFINITION/GOALS

2.1 Problem Definition:

Research area is about the interface design of a mobile robot where eye gaze control of the robot is required. It's important to understand the complexities for integrating mobile robot architecture interface with eye tracking technology-gaze base interface. Many individual interface implementations of mobile robots and gaze base control interfaces exist for major applications surrounding us. Problem addresses simple, user friendly, efficient, and accurate design of the user interface for controlling mobile robot.

2.2 Purpose:

The main purpose of the study is to deliver interface design for prototype model. However the research will encircle challenges comprising in the complex mobile control situations, define an exemplary application specific scenarios and brief tasks descriptions. The study will also summarize the important information about both technologies.

2.3 Objective/Goal:

In order to achieve the desired goal of the research study, we define certain objectives;

- To understand the architecture, functionality, operations, connectivity, and working of eye tracking technology.
- To understand the architecture, functionality, operations, connectivity, and working of mobile robot technology.
- To determine the principals and characteristics required/ necessary in the user interface designs.
- Importance of the technology integrations.
- To utilize experimental data and analysis results for interface design.

Goal of the research is to carry out small experiment, record and determine user gaze during several motions when controlling mobile robot through RC controller. Robot will be control through RC controller and turret mounted video camera will display the results on Tobii eye tracker screen. User gaze data needs to be recorded for analysis to design an interface of the user with gaze base interaction and control.

2.4 Research Motivation:

National health program aims to assist the patient through various information technology projects. E-health plays fundamental contribution in reforming traditional health approaches with the use of Information Communication and Technology (ICT). Motor neuron disabilities form a sub portion of the target groups for assistive technologies [2]. Severe motor disabilities in children utilized eye gaze [3, 4] user interface as an efficient means for communication. Eye gaze technology acts a useful communication tool [5] for peoples suffering from the motor neuron disease because mostly patients don’t suffer from eye motion and visual injuries/ deficiencies. Eye tracking systems provide a computer application interaction interface by measuring the eye motions to operate computers especially for those who can’t use their hands.

2.5 Research Questions

- How experiment is conducted to determine the user behaviour during certain robot motions?
- How user gaze base interface be designed to control a mobile robot?
- What are the main architecture and other differences in eye tracking system and mobile robot platforms?
- What is meant by an interface design?

2.6 Expected Outcomes

The research holds significant importance for providing the users with motor neuron disability for Tele-presence by utilizing state of the art technology integration. The study will produce simple, accurate, efficient, and effective interface design for users. This study will provide a foundation for building an interface in project phase 2 (beyond the scope of this thesis). However, it will be novel contribution in developing the complete working system for assisting humankind.

2.7 Limitations:

This thesis report will provide general information about eye tracking and mobile robot technology, and present some exemplary architecture and standard user interface principals defined in chapter 4 without targeting to single application. An interface design for prototype will only address sufficient information patterns associated to application scenario 1 defined in chapter 5. Interface design of scenarios 2-5 are out of the scope of this study.

CHAPTER 3: RESEARCH METHODOLOGY

Our research study intends to identify proposals for an effective interface design for integrating gaze tracking and mobile robot technologies. This will be done by both qualitative and quantitative study.

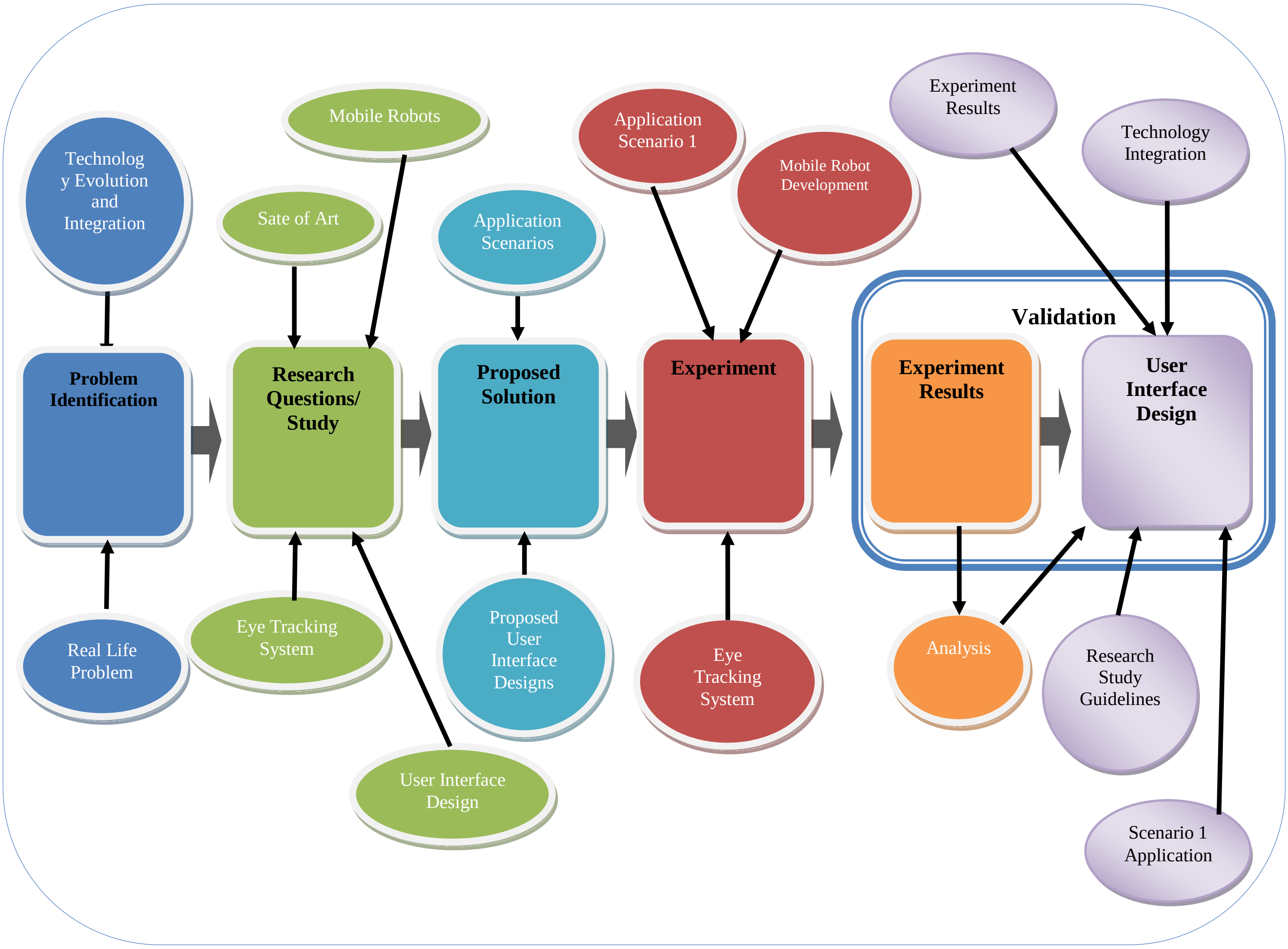


Figure 3.1: Research Methodology

The overall research methodology is shown in figure 3.1. Brief descriptions of the steps involved from left to right in the research methodology are provided below.

3.1 Problem Identification:

It's a first step, usually consists of concerned factors in the problem definition as described in section 2.1.

3.1.1 Technology Evolution and Integration:

Evolution of the Information Technology and computer Science provides underlies the high current potential of integration of eye tracking and mobile robot technologies. It causes a possibility and multiple interrelated applications developed before but the study needs to reconcile novel efforts to produce working interface design for product prototype 1.

3.1.2 Real Life Problem

Problems address in section 2.1 directly target motor disability patients and prototype will positively contribute in the development of medical health technology.

3.2 Research Questions/ Study:

To conduct research in any domain, it's extremely necessary to develop research questions that maximize possible outcomes. Since questions are necessarily to include in our research study because we are developing a new interface design for the eye tracking system in order to control mobile robot. By answers the research questions we can answer (design) an interface for the desire application. To use hypothesis is irrelevant at this stage, but once a prototype is developed and functioning we can use the hypothesis for the interface design to check for its efficiency, correctness/accuracy, simplicity, user friendliness, etc in terms of task completion during an experiment (usability study).

Our study contains four important research questions, first and second questions are primary while the other two are secondary questions. The significance of the research questions are concluded based on the following study domains:-

3.2.1 State of Art Technology:

It helps to formulate research questions with appropriate thesis theoretical background information, research and effective standardizations. We reference many research papers in chapter 4.

3.2.2 User Interface Design:

Since the domain of the research require an interface design, so it's important to make the primary question based on the user interface design, as stated in chapter2.

3.2.3 Eye Tracking Technology:

Eye tracking technology is major assets in this research for deriving an interface design requirements. User input is located at the front end to this technology.

3.2.4 Mobile Robots:

It's the necessity of the project experiment prototype, to validate the study it's important we perform an experiment based on the both technologies to produce accurate and relevant results.

3.3 Proposed Solution:

There may be an existing and applicable solutions to the scenarios described in Chapter 5. We have synthesized the application scenarios from scenario 1 to scenario 5, ranging from high human control towards high autonomy.

3.3.1 Application Scenario:

All the five application scenarios are discussed in this stage with general home and industrial examples, which explicitly defines mission, mission tasks, human task and robot in the scope of this thesis.

3.3.2 Proposed User Interface Designs:

Based on the experimental results and analysis for application scenario 1 and with the theoretical background study, we design proposed interface.

3.4 Experiment:

Experiment is the main portion for this research study. Details of how the study has been performed are presented in chapter 6 and analysis of each subject data is presented in chapter7.

3.4.1 Application Scenario 1:

The experiment is based on application scenario1, which includes: RC controller connected to control the mobile robot in the environment, and a camera mounted on the mobile robot to produce the environment location view for presentation to the human controller dynamically and in real time.

3.4.2 Mobile Robot Development:

The overall development of the mobile robot, including hardware/software and controlling functionality is explained in Chapter 6.

3.4.3 Eye Tracking System:

The output of the camera mounted on the mobile robot, and an input of the user gaze is captured by the eye tracking system to make analytical investigations.

3.5 Experiment Results:

Results from experiment stage are captured and recorded in the eye tracking system for each subject carrying out specific tasks.

3.5.1 Analysis:

It is a major section which addresses experiment results formulated in the form of gaze plots and hotspots after experiment for different motions.

3.6 User Interface Design:

Final output of the research is in the form of a proposed user interface design for controlling a mobile robot using an eye tracking system. The design relates the information obtained by following modules;

- Application Scenario 1:
- Experiment Results
- Technology Integration
- Research Study Guidelines

3.7 Validation:

Validation of the research involves the evolving technologies of gaze and mobile robotics, state of the art study and experiment results leading to the proposed "User Interface Design**".**

CHAPTER 4: THEORETICAL CONCEPTS

4.1 User Interface Concepts

The perspective of user interface consistently depends on user applications. User interface is most interesting and important component of the computer system that depicts clear vision about the application environment and its working. User interface is the only computer systems component visible to the user while programming functionality and computations are transparent. Graphical User Interface (GUI), command line interface and World Wide Web (WWW) [6] are dominant user interfaces. For common applications and operating systems GUI is acceptable while command line interface is usually used by experts in the field of computing, multiprocessing/ multi threading environments. Design and functionality of user interface had been criticized in number of ways by multiple groups of people gazing at the metaphors, widgets and controls, links and applets, while predicting to perform task specific functionality. Interface design for any application should be easily understandable, should have predictive functionality, reduce risks, and user friendliness. Studies on user's perceptions are conceptually drawn or calculated to maximize the interface impact and functionality along with applications usability. Human Computer Interface designing increases due to the intensive research until the end of 20^{th} century. Advance Projects Research Agency (DARPA) and Advance Research Project Agency Network (ARPANET) [6] developed first friendly user interface design of internet in 1991.

Variety of user interfaces styles have been implement from simple command line, menu selection, form fill-in, direct manipulation, anthropomorphic towards GUI with exciting ambiguities and salvation solutions. They are evaluated based on the memory recognition, interaction complexity, knowledgeable information and learning, typing efforts, screen show, format features, screen space, training, typing errors, design development complexity, visual aspects and remembrance, efficiency, simplicity, etc. The most currently adopted user interface is GUI, as the interface consists of collection objects of interest providing users actions upon them to manipulate accordingly. In [6], GUI systems adheres visualization and visual presentation, pick-in and click operations, object orientation functionality, memory recognition, performance evaluations, etc.

4.2 User Interface Design Principals

User interfaces are augmented with outmost user applications design delivery in an essence of quality improvements particular to each user interest domain. We realize diverse combinations of user interface principles in concatenation to user application limitations and flexibility. Referring to usage centric design principles, Constantine and Lockwood [29] define the following list of user interface design principles:-

- **Structure:**
  The design purpose of the user interface is meaningful and useful as an extension of a clear and consistent model. Users require object recognition

with related and unrelated objects, pattern similarly and separately, which forms the overall architecture of the user interface.

- **Simplicity:**
  User designs adhere simple to the common procedures for interactions, language and any opportunity to use shortcuts following longer procedures.

- **Visibility:**
  It is essential to clearly position critical, unambiguous, and needed information for the desired functionality in an interface design.

- **Feedback:**
  User's assertion about information in the interface design regarding any redundancy, ambiguity, confusing, exceptions, errors and language support, etc shall be positively admissible and corrected thereafter.

- **Tolerance:**
  Overall design should be flexible and tolerant such that it contain few mistakes and misuse operations with undoing/ re-doing options and errors prevention.

- **Reuse:**
  External components, internal component and behaviors shall be designed re-usable to provide consistency.

Mayhew [7] describe an alternative list of principles for user interface design and characteristics:

- **User Compatibility:**
  Interface design should focus on user cognitive psychology, mind set subject to common strength and weakness such that design is accepted by various users instead of limited users.

- **Product Compatibility:**
  Users have great use of other simpler or sophisticated systems by spending time and money, so the upcoming system design have interface compatibility with the existing systems in use to have higher degree of adoptability.

- **Task Compatibility:**
  A very important factor to reflect the efficiency, simplicity and user friendliness is that the task design should be incorporated in the same way as the system task are carried out, doesn't requiring the users to navigate between multiple tasks/actions for the completion of one task.

- **Work Flow Compatibility**
  Multitasking operation system support should be made achievable to have changeover in the tasks.

- **Consistency:**
  It is vital to develop similarities in same product instead of across products to allow peoples predict about the things that haven't been done before.

- **Familiarity:**
  Use of allied user familiar concepts, arrangements and terminologies in systems are admissible in the interfaces that existed before.

- **Simplicity:**
  Although designer could have all the functionalities available in a single interface but every user doesn't require the some functionality very often, its better make interface simple.

- **Direct Manipulation**
  Actions on visible objects are directly executed relative to interface design for programmers to provide parameters and handle objects difficultly.

- **Control**
  Designer need to comply with full operational control mechanism tools where users have strong control and freedom.

- **WYSIWYG**
  What You See Is What You Get; means the originality and validity of the depicted interface and resulted output.

- **Flexibility:**
  The interface design will allow more users to accommodate and control in addition with users skills.

- **Responsiveness:**
  The interface design to pose the possibility to users feedback and inform them about the progress.

- **Invisible technology**
  The interface design should be transparent to the users and users should only be able to know and work with the functionality of the system.

- **Robustness:**
  System should be able to tolerate common human errors, systems crash should be avoided, means of system recovery procedures to be implemented, and the possibility of user learning and efficiency should be increased.

- **Protection:**
  Systems should be very flexible when peoples make errors, so systems should prompt users about terrible mistakes and possess the open door for its recovery.

- **Ease of Use and Learning**
  Systems design should be easy learn and used by novice and expert users.

IBM has defined object oriented user interface design principles for their products by emphasizing disable peoples:-

- **Simplicity**:
  It illustrates the phenomena “don’t compromise with the usability over functionality”, make the interface design simple and clear understandable by keeping most often used basic task accessible simply while the advance tasks maybe little obvious for beginner.

- **Support:**
  The interface control shall allow users freely and don’t limit the user choices about correct sequences for competing tasks. System state should remain as it’s likely to be when users arrive back after certain period of time, feeling the system stability.

- **Familiarity:**
  Keenly observing the traditional system usage and deriving an interface design that has resemblance to reality working. Interface makes it possible to use the knowledge learned and utilizing it consistent for accomplishing larger tasks. Similar concepts and techniques should be applied in variety of situations, etc.

- **Obviousness:**
  Interface design should implement real world object representations, defining direct actions, posing familiarity in learning and use, conveying systems controls visible through icons. These visual representations help to better understand and remember the relationship and recognition of computer application.

- **Encouragement:**
  Interface adhere the freedom of acceptability revealing the outcomes of desired actions about users expectations. It requires the designer to study human behavior, mental situation, goals, and other different human circumstances. Apply certain images and terms relevant to user experiences, making user comfortable and confident to use and explore.

- **Satisfaction:**
  The interface should provide the user to see task progress and accomplishment. It will improve user responses to actions i.e. delay, errors, etc.

- **Accessibility:**
  Interface design offer full functionality in object utilization at all level of access without time constrained.

- **Safety:**
  Interface design hold criteria protecting users from errors, problem exceptions; bear visual objects for reminders, choice lists, and assistance agents to better recognize problems.

- **Versatility**:
  Interface should be implemented in open ended ways and hold significant situation in user's operations ands interactions. Offering multiple interaction methods which should comply with define user interfaces. Interface flexibility to admit user skills, method of interactions and user usage environments.

- **Personalization:**
  Interface design should be tailor able with user interest, needs, knowledge, sense, and desires. Not all the users are alike, every users is different than the other, so personalization will result in high productivity and great satisfaction.

- **Affinity:**
  Interface design should bring good object visibility design. Visual design support general user model and functionalities and produce intuitive results.

Brief description about interface standard guidelines supplies overlapping information, which is however necessary as the user applications vary and so does the users. Mostly defined guidelines will be utilized and discuss in our empirical study.

4.3 User Interface Design Process:

It involves number of phases or processes in designing user interface [30] and depends on the kind of application development, set of common processes are categorized in the below:-

- ### Functionality Requirements:

The term defines functionality of the software, system, its components or all of them in combination. It is described as a user input, behavior and an output. Functional requirements encompass relevant calculations, technical details of system/software, and processing [30]. A basic question of "what system is expected to accomplish" has to be included in the functional requirements.

- ### User Analysis:

The prospect of user requirements by negotiating with the concerned management/specialist or users of those systems itself in order to analyze following problems:

  - What are user's expectations from the system?
  - In which way system adjust working within user workflow?
  - What confidence level is likely to be achieved by the system for user and how it relates to other systems in use?
  - What is the impact of (new) interface design towards user?

These complex questions encircle around the whole system development life cycle. User involvement is very critical in situation where the product is totally dependent on the users, while if the product is specific user independent, it reduces complexity in the user analysis. The purpose of user analysis is to identify population characteristics such as cognitive and physical abilities and tendencies that influence the application adoptability, acceptance and effectiveness. Nielsen in 1993 describes the user analysis [8] on the basis of domain knowledge, application experiences, and computing practices. Human Computer Interaction (HCI) community thinks about "menu to novice users" as a new research domain. Researches in different psychology study procure factors of intelligence, mental disabilities, and abilities.

- **Information Architecture (IA):**

The ability to articulate a conceptual model of information with explicit details for each activity required in the complex systems. Activity can be considered as web development process, user interactions, databases design software, library systems, etc. Information architecture exhibits different meaning in each activity but some common characteristics like structural design and organization methods are similar. Information architecture institute define IA as [9];

> "IA is the art and science of organizing and labeling websites, intranet, online communities and software to support usability."

- **Prototype:**

It's the development of entity through logical or physical existence based on an idea or concept. Prototype is a complete product, develop at the intermediately stage in the system development life cycle. Prototype confirm the "does" or "doesn't" for use, cause, functionality, user expectation and usability tests. Interface prototype allows user to experience with the interface directly [30]. It's vital to include this in the product development to analyze the conceptual model working in reality and its limitations.

- **Usability Testing:**

The goal of non user (general) or user centric design product is to confirm the product development verification and validation for usage through performing user tests called usability tests. In the view of the developer the likeliness of every product is utmost important as the overall goal is to obtain higher degree of user confidence and satisfaction and to increase the product business. Usability evaluation is carried out through simple techniques i.e. questionnaires, video recording, code testing and provisioning, etc defined in [30].

- **Graphical Interface Design (GUI):**

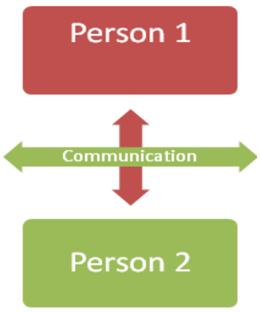
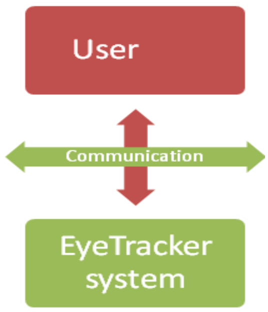
More likely ever user interface terms as a graphical interface, as depicts better usability options over the command line interface. GUI is available in maximum software's, except few where the need is not explicitly required. GUI designer have more user interface control, functionality, design options, screen length and size, user attraction and understand ability, empowering user adaptation and learning.

4.4 Eye Gaze Patterns:

Language is not an only communication medium between us, instead our gesturers face expressions, and eyes have significant role in creating the meanings to silence. The scenario of dyadic (two person) conversations by Kendon [10] as a common understanding depicts four functionalities:

- Providing visual feedback
- Regulating flow conversations
- Communicating emotions and relationship
- Concentration Improvement through restricting visual input

Argyle [11, 12] represents analysis of dyadic conversations involving 60% gaze and 30% mutual gaze. It's however different in multi user situations (more than two person's conversations) and thus have variable results defined in [13]. The impact of the person dyadic conversations resembles with the user-system approach Fig. 4.1 in a sense that the user have direct connection with the system through gaze, although the screen contains dynamic virtual environment but however connection is served as a One-way communication with the system. Some difference investigation between persons and things as been defined by Argyle [14], in "Looking at persons and looking at things".

	
Dyadic (traditional)	Dyadic (technological)

4.4.1 Eye Movement:

To monitor the user behavior and intentions relying on eye movements to certain wander random threshold have no implicit impact in a well structural tasks addressed by Carpenter and Just [15]. The eye moments reflect cognitive processes have been determined by studying various task process i.e. reading, user intentions, and diagnosing medical conditions. Eyes don't remain focus on the "Area Of Interest" (AOI) within the entire task duration. Iqbal and Brian [16] performed an experiment on the different eye moment patterns, four task categories were selected with two difficulty levels i.e. reading comprehension, mathematical reasoning, searching, and object manipulation which produce the results to illustrate that to identify each user task eye gaze pattern play significant role, gaze patterns are subject to the task category i.e. in simpler task users gaze focus in the AOI for less than 50 % while in difficult tasks a user gaze is at the screen for about 70% of the task time. Task complexity is determined in terms of gaze fixations at AOI, where as some AOI have been neglected during the task completions.

4.4.2 Area of Interest (AOI):

It is subject to individual task category and visual display for the users marked during the experiment study. Screen is divided in the multiple AOI's based on the each task and image on the screen.

4.4.3 Eye Fixation:

Fixation is referred to maintain the gaze in the constant direction and location on the screen, within specific limits. Eye tracker estimates the eye movement in time duration. Most of the eye tracking software's offer user define parameters, similar to the Clear view software used in our experiment.

4.5 Eye Tracking System:

Eye tracking technology identifies and measures human eyes position and movements on the screen and represents in different views. This new technology works in different beneficial ways like in the visual system and cognitive linguistics etc, it depends on the requirements of the today needs.

Eye tracking systems contain set of features and functionalities including added hardware to measures the eye movements through different analysis and evaluations metrics. Eye gaze measurements depend on location factors associated with eye tracking device mounted on the system. If measure system is table mounted [18], as with sclera search coils or table mounted camera like remote system then gaze angles are measured and subtract head direction form the gaze direction in order to resolve eye location in the head. The optical technique to measure the eye motion, light, typically the medium is infrared, eyes reflects infrared and is input through video camera or optical sensor for the desired system. The eye rotation is extracted through information input from the change in reflections. Video based eye trackers corneal reflection mechanism i.e. Purkinje image and the pupil centre is tracked with respect to time. Dual-Purkinje eye tracker is another kind of eye tracker in which uses cornea reflects infrared form front side and the behind the lens. A still more sensitive method of tracking is inside eye image features extraction i.e. retinal blood vessels. The researchers also get the desire mechanisms for the changing of the eye rotation, but the main theme for to analysis and estimate the specify gaze direction where the eye fixation is more component.

There could be different possibilities how user want to user this new eye tracking technology in different ways. On other hand that eye tracker does not provide exact gaze direction. But it could be estimated changes in gaze direction. To be able to know about the subject location on the screen, some calibration procedure is required in which subject gaze on the eye tracker screen mainly in the centre, left and right top and bottom corners in series. Eye tracker records calibrations points that are necessary to match gaze positions on the screen. Retina tracking techniques doesn't offer accurate gaze direction as it lacks the anatomical characteristic to mark accurate meeting point visual axis to retina. An accurate and reliable calibration is essential for accuracy and validity of gaze positions and requires re-calibration process for eye data. It is a significant challenge for peoples with unbalanced gaze.

4.5.1 System Architectures

As we already know that there are different eye tracking techniques and each has different mode of eye tracking mechanism, so we can only inexplicitly illustrate the generalized concepts of the systems architectures in use. In figure 4.2, head mounted eye tracking system [17] is described for motor disability patients constitute of two subsystems i.e. heads tracking subsystem and eye tracking subsystem for calculating user eye gaze directions by utilizing both subsystems. In [18], a more enhance gaze tracking system is proposed with two rotation cameras mounted on the active vision system similar to human head and eyes to afford the user little head moments, see fig1. Its architecture consists of two modules i.e. contains skin color based face tracking modules and face LAB tracking module, output concatenations of the skin tracking output and gaze direction to obtains active vision.

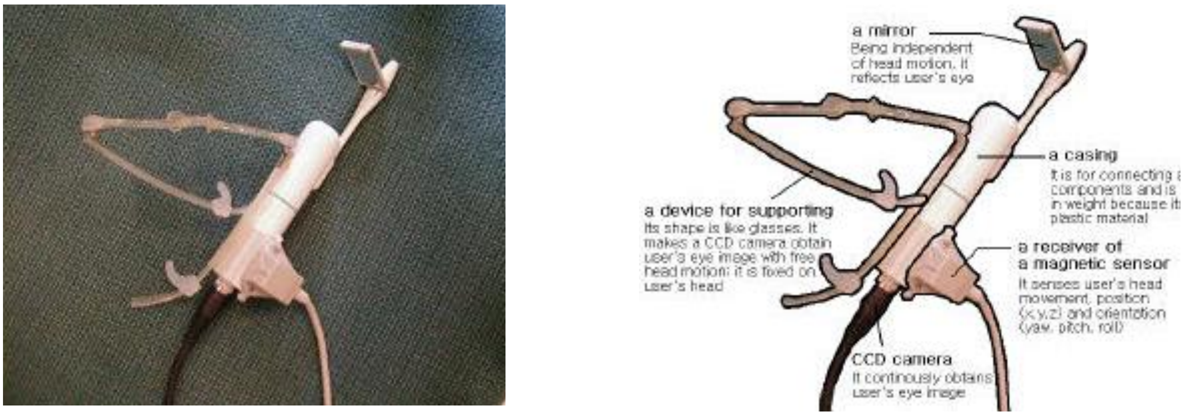
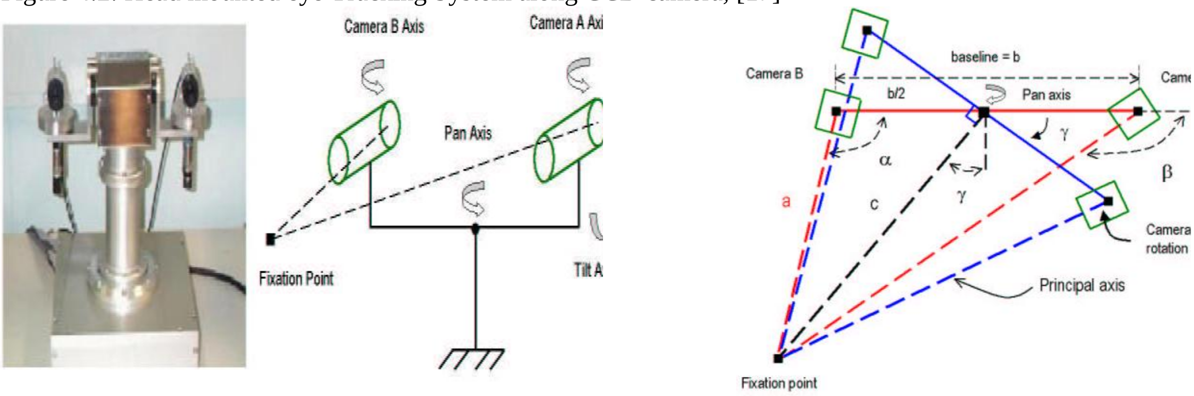


Figure 4.2: Head mounted eye Tracking System along CCD camera, [17]



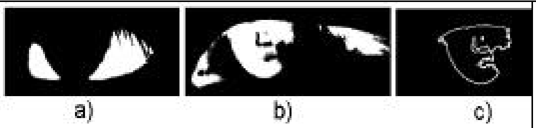
Top head view

4.5.2 Gaze Calculation Algorithm:

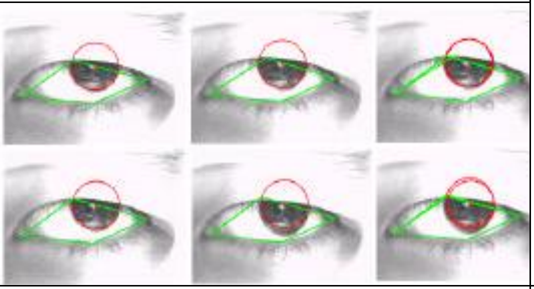
The term enlightens the phenomena of gaze calculation based on the system architecture. Reference [17] illustrates head mounted eye tracking system for extracting and tracking the eye moments through attached CCD camera and mirror on the head mounted system. The algorithm uses limbus boundary model by identification dark iris and white sclera area in the eye. The technique is quite efficient but difficult in precisely calculating in the vertical eye moment exists as eyelid up to some extent covers the limbus, thus making its appropriate eye location uncertain.

Algorithm defined in [18, 19] generate 3D head pose and gaze vector at twice video refresh rate, it further helps to calculate the gaze unable to be determined due to eye and lips corners, so its data is used to estimate gaze directions.

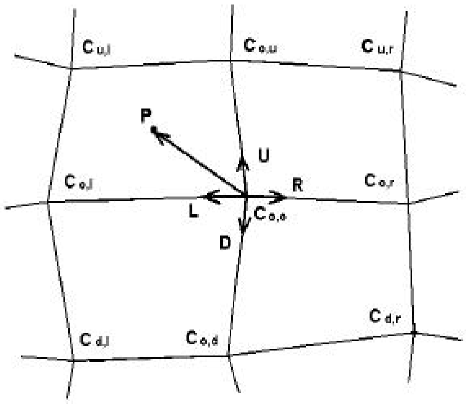
In [20] algorithm used to extract the locations of the pupils and Corneal Reflexes (CRs) from the camera image is based on the Starburst algorithm which was modified to fit the needs of the remote eye tracking setting. Pupil and CR location extraction algorithm mechanism extract the CR locations by applying a difference of Gaussians and searching for maxima to approximate pupil centre is determined through identification o f darkest pixel in CRs vicinity. Rays shot from pupil centre and secondary rays shot identify contour points and placing an ellipse fit at contour points. Gaze estimation algorithm engulf model physical eye.



Binarized peak, valley and edge eye images



An iris boundary (limbus) model



Eye moment calibration map

Figure 4.4: Head Mounted Eye Tracking System Gaze Calculation Algorithm, [17]

4.6 Eye Gaze User Interface

Eye interaction with eye tracking system is unnatural than common human- human and human computer interaction, as the modality of the user changes with respect to the available image, working conditions, applications, etc. A more vital prospect of the users interface is designs during the some specific application development. The purpose to know user gaze and fixation focus on which area on the screen and the kind of eye tracking application user is using. Because for different specification of the eye tracking systems, an application development field requires reasons to obtain more information about our analysis (application, user, system) to measure the user eye movement.

HCI is the study of the characteristics of human communication channels and skills and then develop devices, interaction techniques, and interfaces in bilateral/bidirectional communications effectively. Eye tracking technology requires the study of the characteristics of natural eye movements and an attempt to recognize appropriate patterns in raw data from, turning it in tokens in a high level meanings and design interaction techniques. Eye movement interfaces meshes within the field of virtual environments and other sophisticated interfacing approaches to utilize user skills and potentials.

4.7 Human Robot Interface (HRI):

It is vital to develop efficient, effective and usable HRI's which involves complete user participation in interface design and development process; often we see that interface design has been started in the middle or end of the development process ultimately decreasing user usability features and increasing development effort and time to re-do the work causing unwilling acceptance to the technology. This phenomenon has been replaced by User Centered Design (UCD) years before by deeming complex human machine systems research. GUI has higher inclusion exposure between human and machine interface designs principles define in [21] illustrate that concept of product development focus on the user irrespective of the technology explicitly. The significance is on user and user tasks rather than technology, confirm the task form users, reduce complexity in tasks, support learning, comprehend information, take user feedback and improve with positive reply and build prototype to understand deficiencies. Evocative approaches for HRI should be to "humane" interface design where humane interface is responsive to human needs and attentive about human frailties, [22] identify humane interfaces development as:

"An understanding of human and machine operations"

An idea behind UCD system is to recognize and determine expected user goals and tasks done through system by replacing user/s, [23] complements the definition as the philosophy of person replacement at the centre is a cognitive factors process during people playing with things. In [24], a further investigate guidelines about development of user interface process is describes by questioning developers with who/ what and how.

- User of the product.
- User tasks.
- User experience(s).
- User functional expectation from the product.
- User input criteria, information required.
- User perception about the product.
- Impact of product in user cognitive processes

When talking about the interface design, it's necessary to understand the user requirements and working conditions (environment) for better utilization of the information, guiding design and development process. There are several critical factors associated with users and needs to consider during interface development process.

4.7.1 Decision Making Embodiment:

The influences of human decision have great impact on HRI, as human make decision subject to their intelligence base on their cognitive situations. Some decisions are required in rapid and correctness otherwise persuade higher risk in high careful environments i.e. medical (surgical) operations/treatments, aircraft pilot take off and landing, industrial chemical process and leakage, etc. The replacement of the user in such high risky areas requires intelligent robot systems to cope with deadly situations. In [24], human rapid and effective decision study is analyzed through specific domain experts as firemen, nurse, pilot, and nuclear power plant users.

4.7.2 Vigilance:

The user behavior representing constant attention to the happening /occurrence to take appropriate actions but actually the occurrences are delayed unintentionally, unpredictably, and infrequently. The explicit definition of vigilance in [25] is stated as "sustained attention, signals, staying alert, in order to identify the target and maintain the performance."

4.7.3 Work Load on Operator:

Generally workload refers to mental, cognitive, physical and temporal workload and has direct impact on vigilance until person attempts to constantly maintain attention, accuracy, judgment, during time limitations. Every person has different intelligence, mental capacity and stress situations, information processing, etc, so high work load tends to increase certainty in incorrect decisions.

4.7.4 Situation Attentiveness:

It refers to the environment in which the user is working, the ability of the user to clearly, properly, and accurately understand the robot activities in current location. With implementations to the robot systems, the situational attentiveness is associated to the robot sensing capabilities. These significant cases are apart for the general interface design concepts illustrated in beginning of this chapter and their value is coherent to the user-robot tasks and working environments.

4.8 Mobile Robot Architecture

Mobile robot architecture explores the robot hardware and software layout and action selection methods for controlling the mobile robot and may relate to physical and logical components. In [26], mobile robot architecture is referred as "structure of the components their relationships". Development of mobile robots is complex because of a multiple integrating and interconnecting variety of hardware and then with desired software's. Robot architectures are task and domain specific to be able to tackle with appropriateness a broad range of applications. For example, an architecture well suited for direct teleportation tends not to be amenable for supervisory control or for autonomous use. One recent trend in robotic architectures has been a focus on behavior-based or reactive systems. Behavior based refers to the fact that these systems exhibit various behaviors, some of which are emergent. These systems are characterized by tight coupling between sensors and actuators, minimal computation, and task-achieving "behavior" problem decomposition.

Looking at the robot design, it's important to see whole system in context and study allowing all factors influencing the robot. Developers are required to concern with robot's functionality irrespective of its working with hardware or software. During designing a complete robot system, it is evident that all the aspects are considered, including architecture, learning, processing (centralized and distributed), robustness, learning, control system, reliability, etc. Mobile robot architectures consist of some common components identified through analyzing various robot architectures along with functions, as described in [27]. Figure 4.5 below describe basic architecture of mobile robots [31]:

- **Perception, Planning and Reasoning:**
  Perception is information about the environment provided by sensors including mapping, internal systems monitoring, fault detection, self perception, etc while sensing or sensation is an input form the environment in the form of raw data. Planning and reasoning is preparation of optimizing route between the goals set by the user.

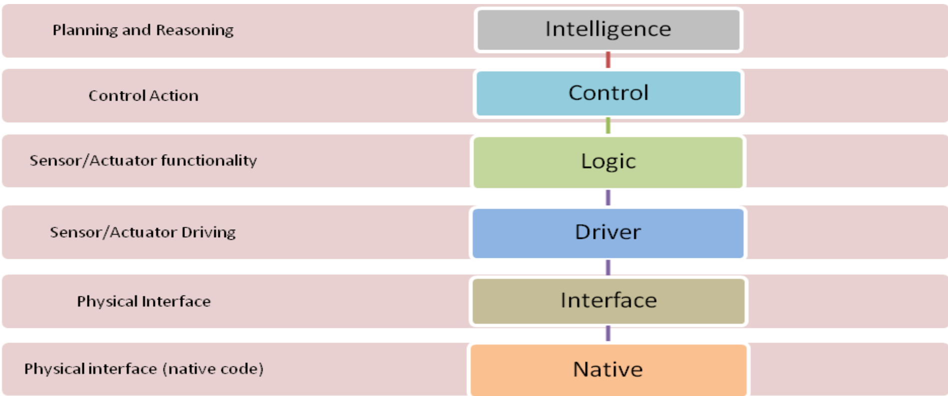


Figure 4.5: General Robot Architecture, [31]

- **Guidance/ Control Action:**
  The component to guide robot regarding current position/ location/ situation during environment task and providing input consideration perhaps to next tasks.

- **Sensor/Actuator Functionality:**
  An input supported by the action/ actuators resulting in manipulator motion.

- **Sensor/ Actuator Driving:**
  Sensor driving involves semiconductor integrated circuit driven by battery to provide specific output to the sensor.

- **Physical Interface:**
  It is the communication medium between robot and operator.

- **Physical Interface Native Code:**
  It is the development language for mobile robot to perform specific tasks.

CHAPTER 5: APPLICATION SCENARIO, TASKS AND PROPOSED INTERFACES

The chapter illustrates an indication about many different level application scenario descriptions, requirements, and utilization in practical environment/ daily life. Although many proposed scenarios are developed based on human and robot control terminology, we comprehend our ideas to vision our selected technologies (eye tracking and robot) involvement to vision detailed structure of each scenario. Figure 5.1 from left to right shows the scenarios starting from high human control at scenario1 and ending at high autonomy at scenario5.

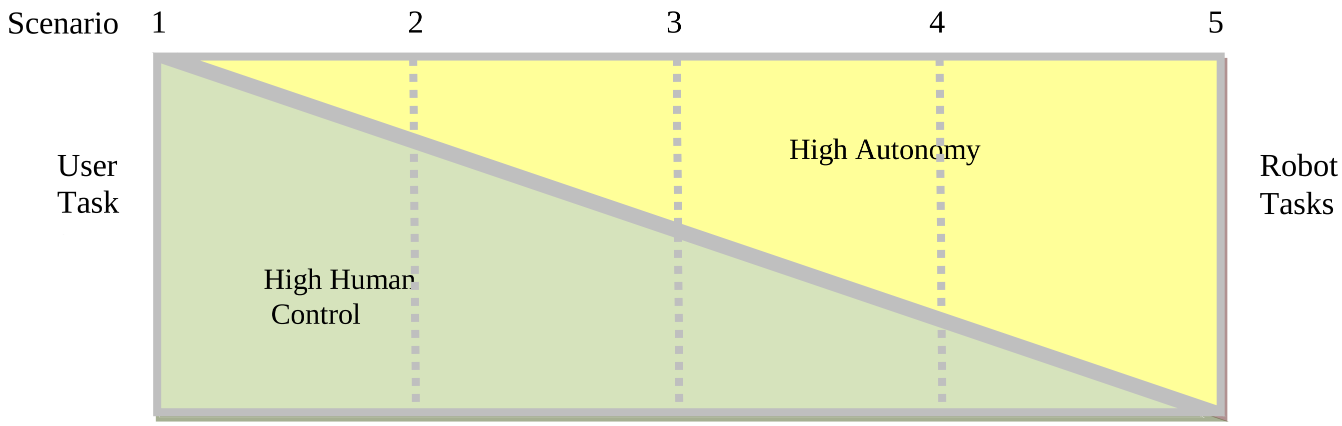


Figure 5.1: Application Scenario Spectrum

We define following general mission task that are necessary in entire scenarios and reuse it by referring backward within the same report.

5.1 General Mission Tasks:

a. Human Tasks (Information Input):

I. Switch ON the system (eye tracking + robot application)
II. Open the complete interface design menu/ window.
III. Move the eyes on the screen to follow the gaze pattern associated with the eye trackers interface design window (transparent to user). User can only see the video (capture) from the camera mounted on the mobile robot.
IV. Move the robot in straight, left, right, or turn 90 degree/180 degree as required.
V. Keep working with eyes on the screen in (IV) until object found/identified.

b. Robot Tasks (Action Outputs)

I. Start/Turn ON hardware and wait for user input.
II. Follow the user input by moving straight (front), backward, left and right turning and also move the turret camera in up/down and left right directions.

5.2 Scenario 1: High Human Control (Tele-presence)

5.2.1 Mission: Find, find and retrieve, and manipulate something in an environment.

Mission Tasks:

1. Find something (tea, flower, towel, tissue, food, ships, soft drink, rescue survival and bomb etc)

a) Human Task: Find Something

Steps (I) to (V) searching an object in the environment.

(Not involved in the current experiment)
VII) Prompt through UI to lift the object by gripping and holding through mounted arm, more efforts are required by the user to manage (object lifting capabilities) in order to determine the distance between robot and object(location, position and size), etc.

VII) Bring/take the object to desired location assisting robot at every location, stage and place/put the object accordingly.

b) Robot Task: Find Something

Steps (I) and (II) searching an object in the environment (robot tasks).

(Not involved in the current experiment)
III) Based on the user input to lift the object from the desired location and hold it firmly.

2. Find and retrieve something (switch ON/OFF TV, bulb/light, clean floor, open door, etc)

a) Human Task: Find and Retrieve Something

Steps (I) to (V) searching an object in the environment.

IV) Lifting/ moving robot arm to appropriate location and direction, input provided through user gaze.

V) Gaze on the "press button icon on the UI through eyes in order to provide input to robot.

b) Robot Task: Find and Retrieve Something

Steps (I) to (V) searching an object in the environment.

III) Move the robot arm in the defined direction.
IV) Process the "INPUT" movement and press button through robot finger to touch the object hard.

3. Manipulate something (moving, arranging, or operating mobile robot for specific tasks according to the need)

c) Human Task: Manipulate Something
Steps (I) to (V) searching an object in the environment.

IV) Repeat 1 and 2 several times.

c) Robot Task: Manipulate Something

Steps (I) to (V) searching an object in the environment.

III) Repeat 1 and 2 several times.

5.2.2 Why and when we required/need scenario 1?

Solution: Patients suffer with motor disability use their eyes, but are unable to move their self to work. A mobile robot with such capabilities afford the user to locate objects with in an environment and process them accordingly (bring something/do something).
Application scenario 1 mobile robot could involve working with patient as limited personal assistant helping for medication, alarming doctor in daily life routine tasks.

5.2.3 How will it work?

Solution: Off course, all the control is input/ processed by human device, so its highly human dependent. Unlike remote control or computer base user interface, it perhaps has some efficiency limitations subject to time constraints. Using such an application might require high vigilance all the time during operating, it will increase operator (work load) Cognitive or may become irritating due to lack of user experience in such kind of application usage or some criticism in future. Hardware structure of the mobile robot is very critical as it will further explore the task limitation, i.e. wheels cannot climb on the stair. Also robot arm, structure, size shape and its rotation flexibility in dimension (2D, 3D) etc will determine the description of the actual working and purpose.

5.2.4 What is required and what we can expect?

Solution: Scenario 1 required complete human control through eye gaze UI. UI design needs all the options information to fulfil task1 and task2 i.e. input of the video camera will display output results in the computer screen. UI design allows to switch between application and options to maximize/ minimize the UI/ screen size, allow easy visible toolbar from top/ bottom (recommended) for arm movement options (2D+3D), camera movement option, robot movement options (Left turn, Right turn, Straight, backward), etc subject to further empirical studies, a complete set of hardware for lifting, pressing, etc in necessary.

5.3 Scenario 2: High Human and Crucial robot Autonomy Control

5.3.1 Mission: Identification of obstacles and intelligently changing the path to avoid collusion.

Mission Task:

1. Identify Obstacles in the area during mobility controlled by the operator

    a) Human Tasks:
    Steps (I) to (V) searching an object in the environment.

    III) Follow the eye tracking screen to guide the wheel chair robot.

    b) Robot Task:
    Steps (I) and (II) searching an object in the environment (robot tasks).

    III) Sense the object through sensor attached to mobile robot.
    IV) Intelligent system module assists mobile robot movements to follow subsequent path to avoid collusion.

2. Changing the direction of the robot movement and continue searching until successful.

    a) Human Task:
    Steps (I) to (V) searching an object in the environment.
    IV) Identify an obstacle
    VI) No input required just wait for small delay/stop and start follow again.

    b) Robot Task:
    Steps (I) and (II) searching an object in the environment (robot tasks).

    III) Input provided through intelligent system, parallel with sensor sensing the obstacle, so either obstacle will move (mobile object) or change the direction.

5.3.2 Why and when we require/need scenario 2?

Solution: Mostly patients suffering from the back bone disease which are total devoted with wheel chair requires this kind of technology (Scenario 2) as it helps/guides the operator all the way and operator have maximum possibility from any accident that otherwise it could occur through other control mechanism. Although effort require from the user is above average, still reduction in any in certain situation decreases, users are looking at all the eye tracking screen to control the mobile wheel chair so it is quite obvious that they collapse with any obstacle on the way, but with “Intelligent obstacle detection” feature, they will operate and also be safe and secure.

5.3.3 How will it work?

Solution: Already described that sensors attached with the mobile robot will sense obstacles on the way/coming towards them (Doppler Effect), causing stop/ wait alert message and then intelligent system will define new path by passing obstacle.

5.3.4 What is required and what we can expect?

Solution: Scenario 2 requires considerable human control with mobile robot although eye tracking system UI expects the only phenomenon of obstacle through autonomy of this mobile robot. It is not necessary required to switch between the two tasks in UI, nor does the possibility in the UI design will be provided, otherwise it can cause severe outcome by accident, so its important to halt the mobile robot if another application is activated.

5.4 Scenario 3: Human-Robot Balanced Control

5.4.1 Mission: Train Robot to perform required tasks defined by the user.

Mission Task:

1. Move object from one location to another location.

   a) **Human Task:**

   Steps (I) to (V) searching an object in the environment.

   VI) Guide the robot through series of steps starting from object search and identification based on specific location A from available UI design containing robot training module i.e. identify location (navigation system), identify object (size, shape, color, etc) and memory for input of the task specification i.e. (new task). Steps (I) to (V) searching an object in the environment
   VII) Lift the object after identification
   VIII) Travel the robot through some area from A to B
   IX) Search and identify the location B.
   X) Place the object on location B.
   XI) Bring the mobile robot back to location A (Task completed)

   b) **Robot Task**

   Steps (I) and (II) searching an object in the environment (robot tasks).

   III) Accept the new task setup options and move/follow operator direction.
   IV) Repeat the task steps defined by user.
   - Search and identify location A,
   - Search and identify object at location A
   - Perform operation i.e. lift the object
   - Search and identify location B,
   - Perform operation i.e. drop the object

   V) Repeat (I to VII) until new task assigned or object finishes at location A, task to desired number of times, etc.

5.4.2 Why and when we need Scenario 3?

Solution: There is move over and equal participation of both human control and autonomy control that somehow makes it interesting to understand. Operator of the mobile robot will be any user who intends to duplicate same tasks (repetition) as per its requirements. As an industrial prospect, less human control intervention in mandatory while more autonomy control mechanism will involves, where as in daily life i.e. patients task does not remain the same and subject to change with respect to time and desired environment. So there is trade-off between some levels at either ends. Human task defines the complete list of steps one and the robot repeat them as the same input is supported. Robot requires to be autonomous enough to locate location A and B and respective object. Also major causes of sensor sensing obstacles are address through robot autonomous property.

5.4.3 How will it work?

Solution: The working of scenario 3 mobile robot is both for special purpose industrial environment as well as general home usage. The effectiveness of industrial applications is ranked more than homes because industrial environment have heavy workloads and repetition.

5.4.4 What is required and what can be expect?

Solution: With average autonomy, robot requires proper task saving management options along with intelligence. Moreover similar set of hardware will be required by improve system architecture, design and development. There will be more switching between different task and control mechanisms involved so software interface will be precisely design. Humans also require understanding robot working environment situation and in case of some problems during autonomy.

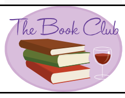
5.5 Scenario 4: Above Average Robot Control

5.5.1 Mission: Multiple robot control in an area

Mission Task: To Control more than one robot in home

a) **Human Task:**
Steps (I) to (V) searching an object in the environment.
VI) Train the robot from location A, B, C, etc
VII) Guide it the way to lift the object from where and take it where, etc.

Table 5.1: Object Descriptions

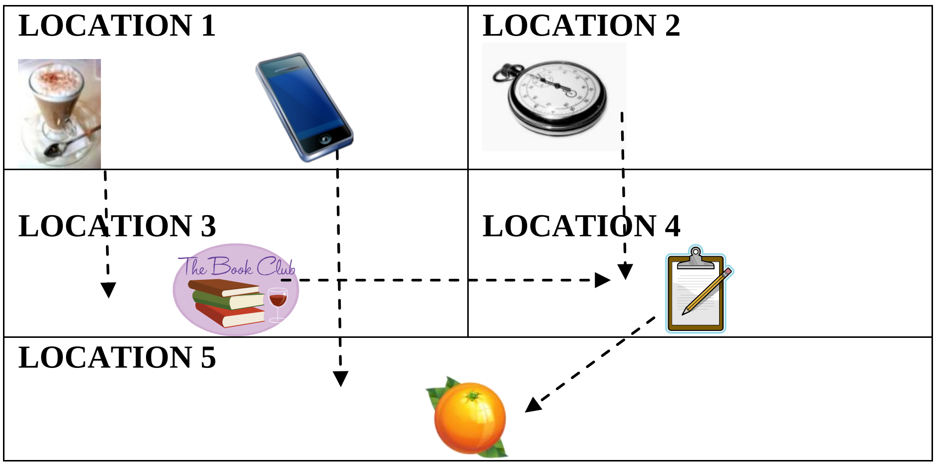
Task	lift object		Location	Drop Object	Location
1	A		1	A	3
2	B		1	B	5
3	C		2	C	4
4	D		3	F	4

5	**E**		**4**	**E**	**5**
6	**F**		**5**	**F**	**1**

b) Robot Task:
Steps (I) and (II) searching an object in the environment (robot tasks).

III) Take Human input and lift the object and place the object from one location to another location, while keeping track of the task options open to record the user guided path during initial path.
IV) Continue the process until an environment is successfully/ task completed.
V) Come back to the original location defined during the interface design and wait for other input by the user.
VI) Act upon input/output from the intelligence system in order to avoid obstacle during continuously sensing static and mobile objects/obstacle currently.
VII) Wait for any user input when confused/disturb/lost in the environment by promotion an error window blinking at bottom of the user interface screen.
VII) Develop a phenomenon to communicate with the existing mobile robots in an environment to avoid problems/collapse.

Table5.2: Objects Movement at different locations



The robots can perform quiet well.

a) Human Task:
Steps (I) to (V) searching an object in the environment.

VI) Operate the robot for training in the environment with assistance to the robot intelligent system guiding for object identification.
VII) Operate multiple robots to perform tasks in sequence
VIII) Provide input during (Promote of robot requirement).

b) Robot Task:
Steps (I) and (II) searching an object in the environment (robot tasks).

III) Take human input and learn tasks to perform
a) Lift object
b) Search object/ identify object.
c) Follow/travel from A-→B→C-> X.

IV) Perform the task until completion of lifting objects, travelling to different locations and searching objects/identify object.

V) Prompt output to use about the object identification (Successful/failure/Progress).

VI) Communicate with an intelligent system input instructions accordingly.

VII) Wait and prompt user for ambiguity.

VIII) Communicate with other robots (if implemented/involved) to avoid collision.

- Industrial Environment example:
- Reuse/Disaster recovery after
- Surveillance systems
- Factory operations (Loading / unloading) etc.
- Unsecure environment → (Earth quake occurrence)

1) **Mission Task:** To control more than one robot in an industrial environment.

a) Human Task: (Expert/experience operator)
Steps (I) to (V) searching an object in the environment.

VI) Train the robot developed for intended environment situation.

VII) Identify location, objection, track guiding path. From location A→X→Y→Z→, etc

VIII) Keep track/monitor each individual robot in the environment accordingly.

IX) Reply to any error message and assist robot similarly.

X) Control task for each robot in a sequence,
- Illustrate/measure the problems in an environment and reduce the collision deal optimize the robot functionality,
- Operator should be logically, technically, analytically be perfect to manage multiple robots.

b) Robot Task:
Steps (I) and (II) searching an object in the environment (robot tasks)

III) Learn the learning in multi robot environment i.e.
- Location movement
- Location identification
- Object searching and identification.
- Specific task to perform an object (Lift break etc)

IV) Want/and prompt for use input during disturbance.

V) Perform communication between other robots to/during location movement.

A) Surveillance System/Mobile security:

a) Human Task
Steps (I) to (V) searching an object in the environment.
VI) Train the robot for specific task e.g.
a) Location movement map
b) Search and identification of object (What kind is object to be afraid of searching)
VI) Manage multiple robots to perform tasks in a sequence.
VII) Promote input during (Prompt of robot requirement).

b) Robot Tasks:
Steps (I) and (II) searching an object in the environment (robot tasks)

III) Learn human input and perform object search.
IV) Prompt (Alarm signal or attention) during object identification.
V) Move in the environment location A, B, C, and X.
VI) Prompt user for any disturbance/ambiguities.
VII) Communicate with other robots (If possible and implemented).

5.5.2 Why and when we required/need scenario 4?

Solution: Application scenario 4 is necessary for the industrial purposes due to repetitive tasks. Patients with motor disability can use these kinds of applications but it seems more costly.

5.5.3 How will it work?

Solution: Explain earlier in the human and robot tasks, application dependent working is carried out in multiple environments.

5.5.4 What is required and what we can expect?

Solution: Scenario 4 requires expert users control options and acceptable autonomy in the mobile robot. Other details may change according to specific applications.

5.6 Scenario 5: High Robot Control (Autonomous)

5.6.1 Mission: Autonomous Robot control with single input.

Mission Task: To control robot to search and bring the object.

a) Human Tasks:
Steps (I) to (V) searching an object in the environment.

VI) Provide input to the robot for specific task.

b) Robot tasks:
Steps (I) and (II) searching an object in the environment (robot tasks)

III) Take input about the object task.
IV) Search the object according to the instructions.
V) Identify the object.
VI) Avoid collision through robot intelligent system.
VII) Perform action base on task object.
VIII) Prompt user at successful completion of task.

A) Mission Task: e.g. Bring mobile

a) Human Task

Steps (I) to (V) searching an object in the environment.
VI) Specify instructions about the task i.e. object name and action performing on it.

b) Robot Task:

Steps (I) and (II) searching an object in the environment (robot tasks)

III) Take user instructions about the task.
IV) Search /identify object (mobile) in the environment
V) Lift object (mobile)
VI) Come back to specified location with mobile
VII) Avoid any obstacles on the way.
VIII) On case of mobile at location A and robot at location B.
IX) Robot need to move b/w (A and B) continuously to bring the objects (flowers) multiple times as addressed.

Mission Task: (Industrial Environment)
Move objects b/w multiple locations

a) Human Task:

Steps (I) to (V) searching an object in the environment.
VI) Instruct robot about the task, e.g.

B) **Mission Task:** (Industrial environment)
Move objects between multiple locations.

Human Task:

Steps (I) to (V) searching an object in the environment.
V) Instruct robot about the task, e.g.

a) Move object A from location X to location Y subtask 1
b) Move object B from location Y to location Z subtask 2
c) Move object C from location Z to location Z subtask 3

Robot Task:

Steps (I) and (II) searching an object in the environment (robot tasks)
III) Take user instruction about the task.

- Perform subtask 1 according to instruction
- Location x to location Y: object A
- Perform sub task 2

- Object B: Location Y to location Z
- Perform sub task 3
- Object C: location Z to Location Y.

In each of the subtask perform;

- Identify (its location)
- Identify object and perform action (lift object)
- Identify 2nd location.
- Perform action (drop object).
- Follow the instructions unless task completed/error/ambiguities occurred.

5.6.2 Why and when we required/ need scenario 5?

Solution: We require scenario 5 applications for least human control intervention. Applications areas addressed focus on high mobile robot control, i.e. single input multiple outputs functionality. We believe that patients with motor disability highly require such application to use them in the daily life. Also, surveillance, security monitoring, rescue, etc applications sometimes need to be more autonomous. In industrial situations, mobile robots works in structure environments and the possibility to achieve high autonomy is high as compared to unstructured environment i.e. homes, as the environment changes dynamically with respect to time.

5.6.3 How will it work?

Solution: Mobile robot will have the complete description and information of the task accomplishments. Robot will be made will high processing phenomenon to use the operative features directly without maximum human control.

5.6.4 What is required and what we can expect?

Solution: High quality processing hardware and software is necessary to integrate technologies together and perform Scenario 5. As defined in the task descriptions, mobile robot will necessarily contain extra hardware and software processing and storing capabilities to take intelligent decision accordingly.

CHAPTER 6: EXPERIMENT / RESULTS AND ANALYSIS

Mobile Robot Experiment for Application Scenario-1

Experiment is based on the section 5.2 description, and involves the participation of four subjects and two environments.

6.1 Aims:

Aim of the experiment is to obtain video capture from mobile robot mounted camera, displayed on eye tracking system for complete set of actual experiment tasks (1-7). Measure and save each task details (gaze patterns and hotspot), environment parameters, subject descriptions, etc. Following are expected goals of the overall experiment.

6.2 Participant Goals:

- Search the object in the environment
- Identify the object in the environment

6.3 Experiment Goals:

- Track and record each subject gaze during the experiment tasks through Tobii eye tracker

6.4 Apparatus

Four wheeled camera mounted robot developed by Mr. Craig Lindley is used to perform the experiment for analyzing eye gaze through eye tracking system (Tobii 1750). RC controller is used to control the mobile robot to perform list of task in two environments (easy and difficult). The term "easy environment" is describe in terms of less obstacles and easy pathway toward object search and identification while "difficult environment" contains more obstacles and considerable search and identification effort and time.

1) Robot with camera mounted + RC controller
2) Tobii eye tracking system + other system

6.5 Method

Experiment should be performed in a laboratory controlled environment especially without any disturbance during subjects performing tasks.

6.6 Initial Preparations

1. Check complete mobile robot functioning and eye tracking software along with robot mounted camera.

2. Select 1-2 experienced persons to operate the eye tracking system to capture and save the results of each individual subject separately after successful completion of all tasks.
3. Validate each subject task after completing the tasks by the subject through rechecking the eye tracking system data files stored from the session, if there is anything missing, the task should be done again/repeated instantly.
4. One person should be noticing the time of each subject in completing all the tasks.
5. One person should be available to notice any disturbance if subject hits the obstacle hardly and move it from identified position.
6. In case of any other problem, task should be repeated from the start, as it's important to measure the complete task and save it in the eye tracking system.

6.7 Pre-experiment work (before subject arrival)

1) Set up each environment structure separately or one after another subject to space availability.
2) Prepare and verify general working of the mobile robot through controlling with RC controller, robot mounted camera image displaying on the eye tracking system, eye tracking system settings, etc.
3) Prepare and verify working of two cameras for capturing user face image and environment image similarly.
4) Calculate the dimensions of the environment distance in total square meter, path calculation, and picture of the environment setup.
5) Calculate the size of the obstacles, and its dimensions width, length, and height.
6) Calculate the size of the objects with respect to;
    - Size (big, normal, small, etc)
    - Shape (Square, Circular, Triangle, Rectangle etc)
    - Colour (white, green, red, multi colour)

6.8 Within experiment work (during and after subjects arrival)

1) Provide complete overview of the experiment details to the subject, ask for any question they have regarding the experiment, positive feedback needs to be appreciated and if possible be added with the supervisor permission.
2) Assign the experiment control task i.e. handling eye tracking system, environment disturbance situation responsibility, etc in rotation so everyone should have the possibility to perform experiment tasks.
3) Define a number of subjects to perform the experiment i.e. 5.
4) Number of tasks: 7
5) Measure and save the video capture of each subject gaze approximately 10 frames per second for analyzing subject behaviour based on individual task, user gaze plus fixation at certain positions during tasks and diagram.

6.9 Post Experiment work (after completion of all successful tasks by each subject)

1) Save and record complete data in multiple locations/devices for further processing.
2) Analyse each subject gaze patterns after successful completion of all tasks for interface designing.

6.10 Tasks Description

6.10.1 Initial Warm up Task:

Every subject will use the RC controller to get familiar with the robot in the normal circumstances for about 2 minutes by driving the robot in an environment openly, moving camera in every direction such that operator in an actual task need not to look at the RC controller to operate the robot which otherwise will disturb gaze data capturing.

6.10.2 Actual Experiment Tasks:

TASK 1: Move the robot little to front and back
TASK 2: Move the robot camera to see on left side and right side
TASK 3: Move the robot camera to see on up side and down side
TASK 4: Move the robot 180 degree either sides
TASK 5: Move the Robot 360 degree either sides.
TASK 6: Search and identify object A in the vicinity.
TASK 7: Search and identify object B in the vicinity.

6.10.3 Limitations/ Omissions:

- ➢ Robot communication irrespective of SNR, interference, audio/video input and output.
- ➢ We assume and believe that RC controller for mobile robot control will provide enough information in analyzing the operator gaze patterns.

Table 6.1: Object Description

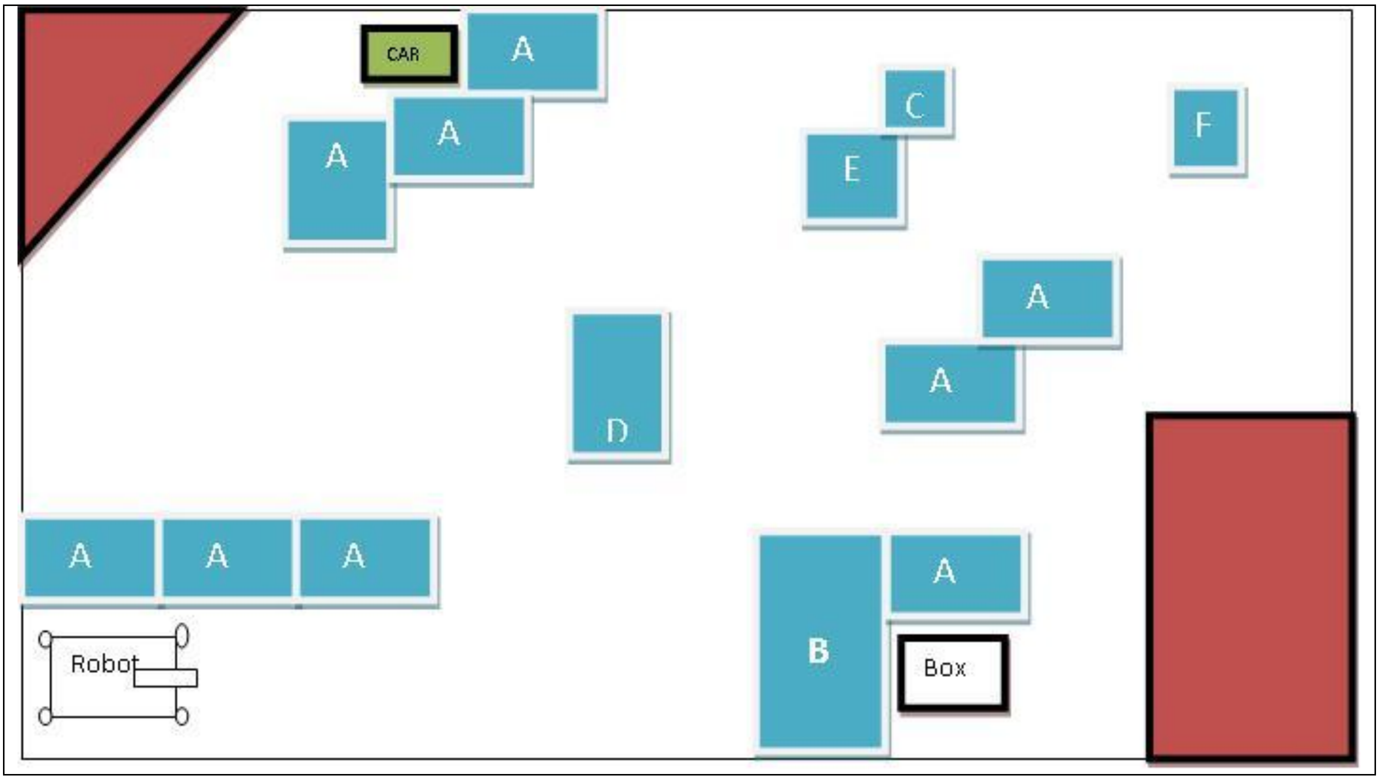
Object	**Name**	**Color**	**Length**	**Width**	**Height**
1	Box	white	90 mm	80mm	60mm
2	Car	Black-Green	195 mm	70 mm	40-60 mm

Table6.2: Obstacles Description

Obstacle Name	Length	Width	Height
Type A	580 mm	400 mm	365 mm
Type B	640 mm	280 mm	550 mm
Type C	310 mm	230 mm	170 mm
Type D	600 mm	225 mm	500 mm
Type E	440 mm	140 mm	330 mm
Type F	700 mm	450 mm	700 mm
Type G	500 mm	450 mm	650 mm

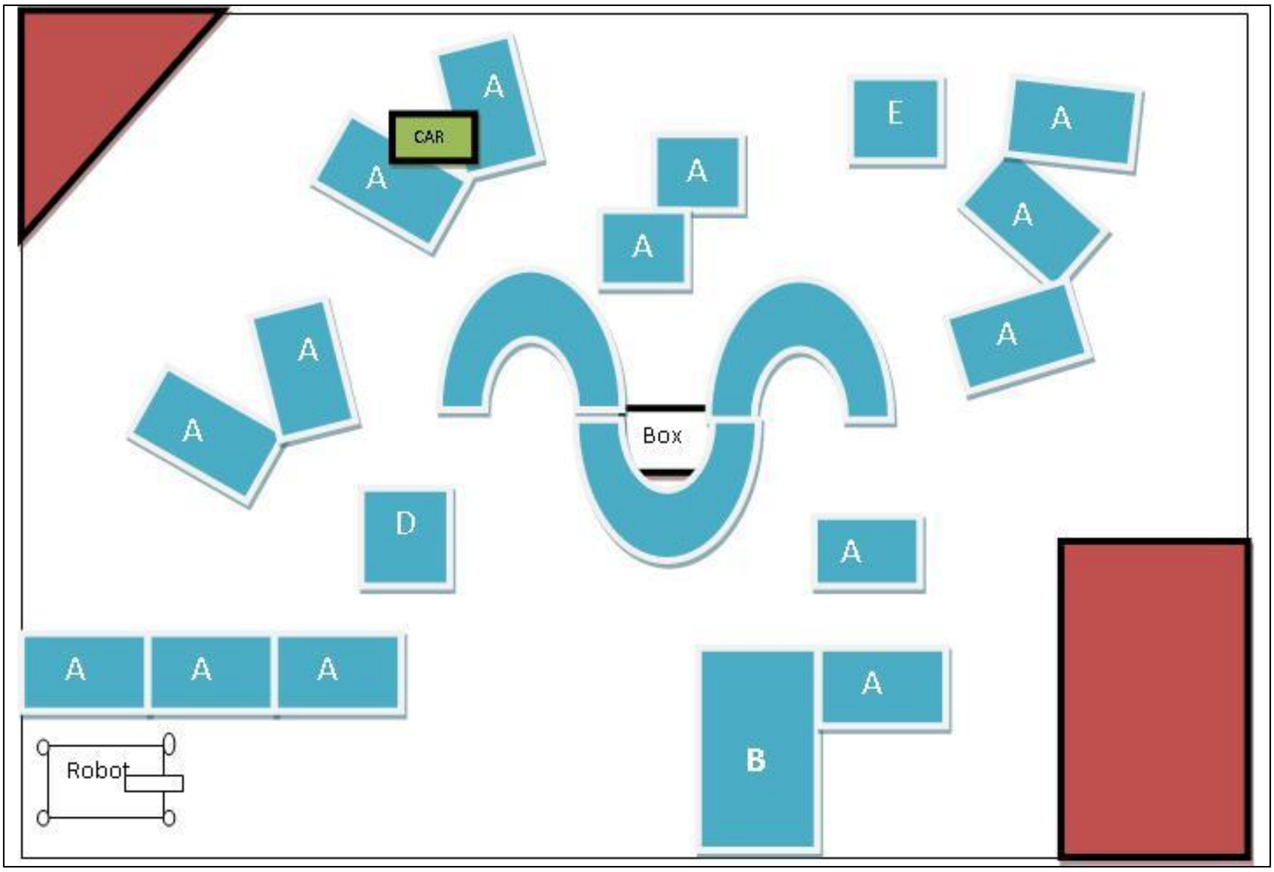
6.10.4 Easy Environment Structure 1: (Top View)

Description about the objects and obstacles please refer to table1 and table 2 accordingly.



6.10.5 **Difficult Environment Structure 2: (Top View)**

Description about the objects and obstacles please refer to table1 and table 3 accordingly.



6.11 Results:

Experiments results are recorded in the form of video and analyzed by conversion from video file to image frame extracted with complete subject gaze data through scene tool (option in the clear view software supported). Gaze data is displayed in the form of “Gaze Plot” and “Hotspots” or “Heat maps” for analysis. For each stimuli subject study we are focused to get eye direction on the screen defined in four motions:

1. Forwards Motion
2. Backward Motion
3. Left Turning
4. Right Turning

These motions are significant due to the fact that user will have only screen to identify the purpose of the gaze direction to accomplish/ perform something. We will display “Gaze Plot” of individual subjects and Hotspots of all the subjects together to see the density of the user gaze during performing four motions above during experiments. All the subjects are more or less use to the eye tracking system and the RC controller for mobile robot but eventually new to this experiment. Since Tobii eye tracking system for external video recording, records in frames per second. So we have chosen likely frames to the above motion and as assume that they contain enough information in designing the user interface for technologies integrations. Only four (4) subjects are selected for the study as advised by the expert because expected number of results obtain during complete experiment (1 & 2) will be eight (8) that are enough and consistent for information analysis.

Table 4: Subject’s Information

Subject	Name
Subject 1	Charlotte
Subject 2	Craig
Subject 3	Jan
Subject 4	Majid

6.11.1 Limitations:

Video capture is made respective to full human control movements in the real time environment and the estimations values i.e. selection of the motions through scene tool in the Tobii tracking software is very difficult to determine the exact start and end points (as these points are selected by us), so there may be some probability of error in choosing the correct start/end points, but the overall results provide us sufficient information about individual gaze patterns.

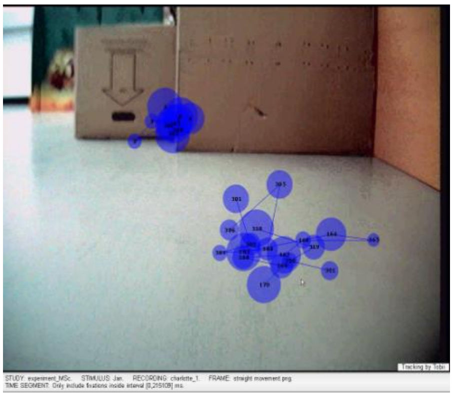
6.11.2 Gaze Plot of subject 1:

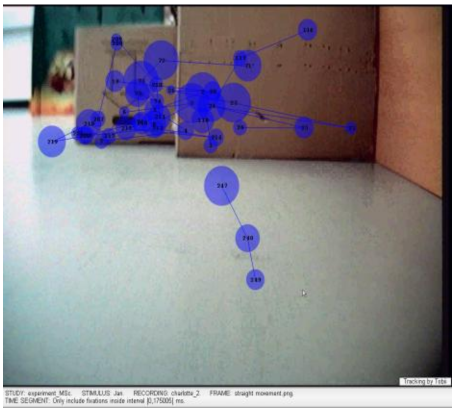
The gaze plot of subject 1 in the “forward motion” shows two different gaze positions around the centre of the screen i.e. on the near the middle of the screen and on the top left side from the middle. Experiment 2 gaze results presents close connection between the left turn results and middle which will however be more clarified during hotspot results. The reason for this ambiguity is due to the subject attention towards specific object during performing task i.e. confusion between identification of objects/

obstacles. In case of “backward motion” we see interesting gaze plots of experiment 1 and experiment 2, as the eyes doesn’t remain fix in the selected area but move around the screen in a random behavior but are still quite closer to the middle of the screen rather than extreme right/left/ top and bottom. Gaze plots for “left turning” and “right turning” motions are situated along sides with very few values starting/ending at the middle due to our selection of start/end points in the scene tool. Over all experiment by this subject hold significant gaze information in all directions.

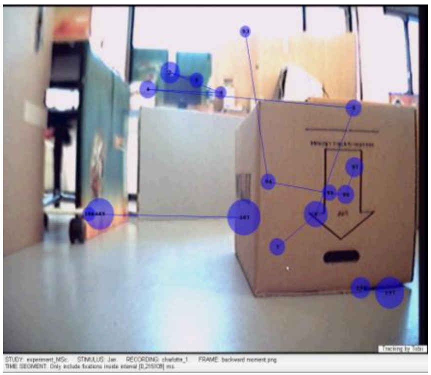
Experiment 1 | **Experiment 2**

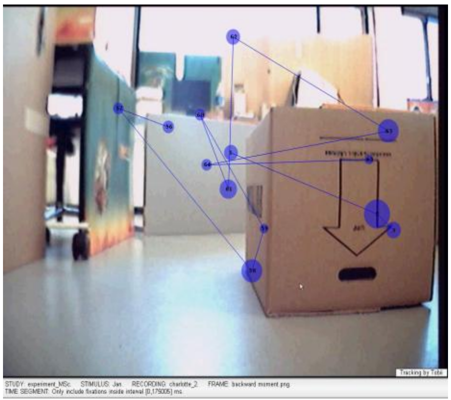
Forwards Motion



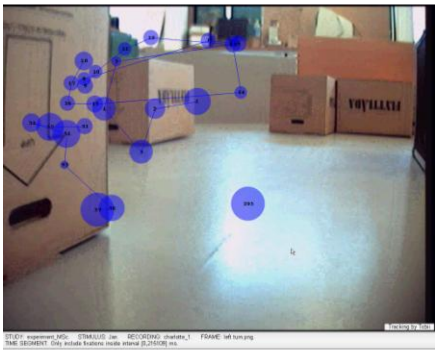


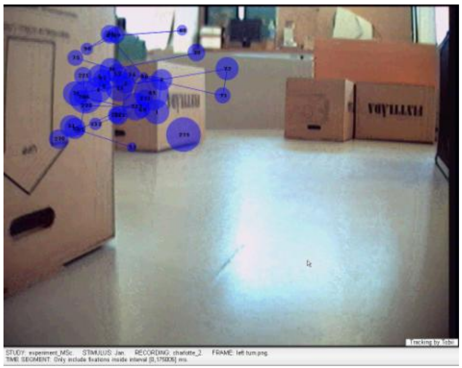
Backward Motion



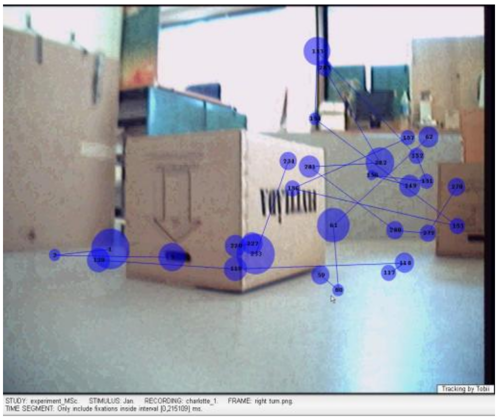


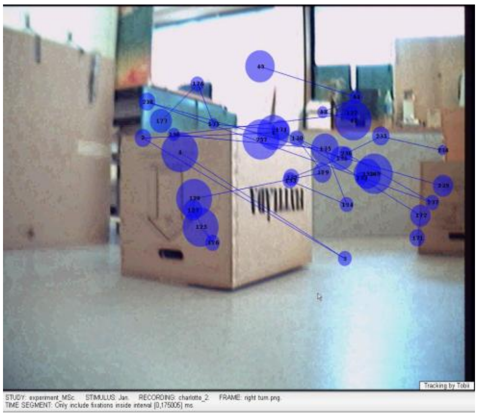
Left Turning





Right Turning





6.11.3 Gaze Plot of subject 2:

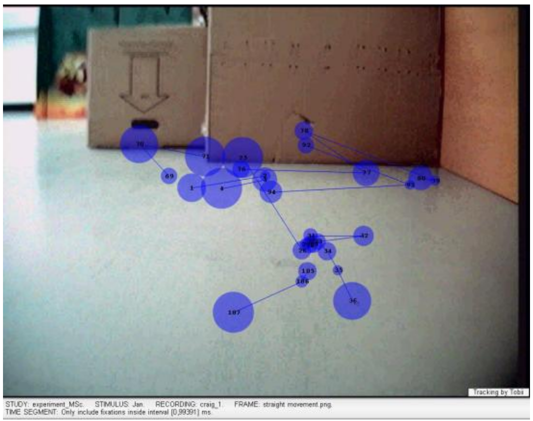
There was some problem in recording the gaze data for experiment 2, so we only consider experiment 1 for this subject. In the “forward motion” gaze points in and around the middle portion of the screen which is considered very good and similar gaze position is calculated when “moving backward”.

We encounter interesting gaze results for left turning and right turning, we see that gaze points are located near middle of the screen portion instead of extreme left and extreme right. Apart form limitations defined in section 6.11.1, the reasons for such gaze graphs are due to the subject usability and expertise in RC controller for mobile robot that causes the subject to see almost near to the middle portion during experiment.

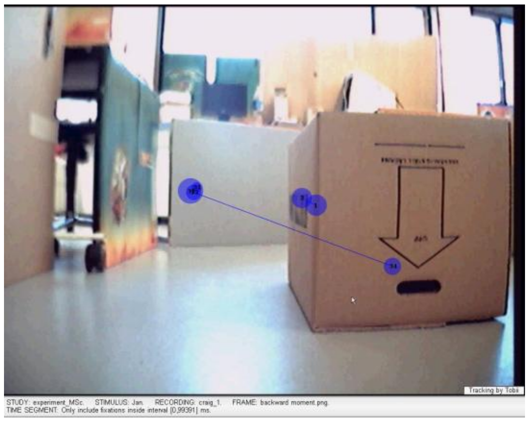
Another impact of the gaze plot i.e. saccades are because the fluctuations in the robot motions was quite higher as compared to the other subjects, so it’s harder to describe exact left and right frame instances through scene tool. Any how we analyze the forward and backward motion to be sufficient in this case.

Experiment 1

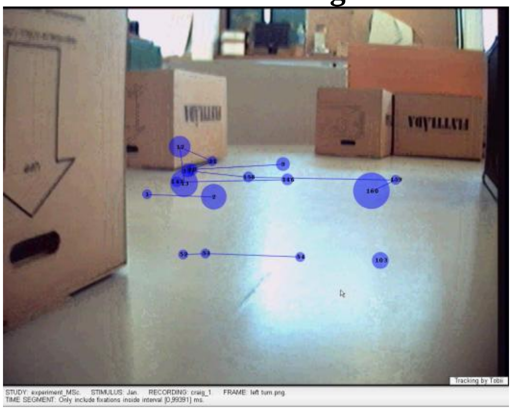
Forwards Motion



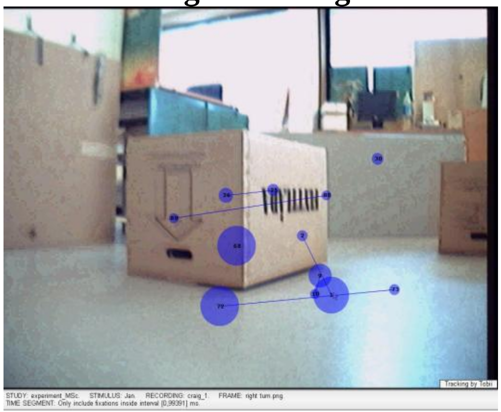
Backward Motion



Left Turning



Right Turning



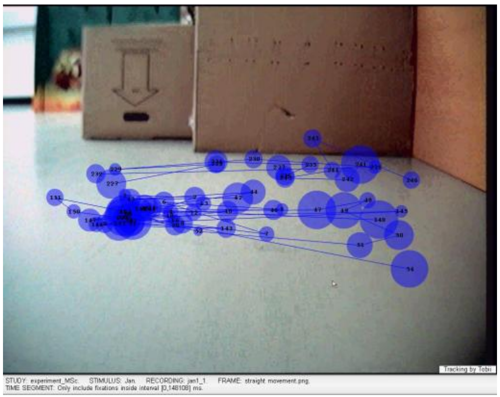
6.11.4 Gaze Plot of subject 3:

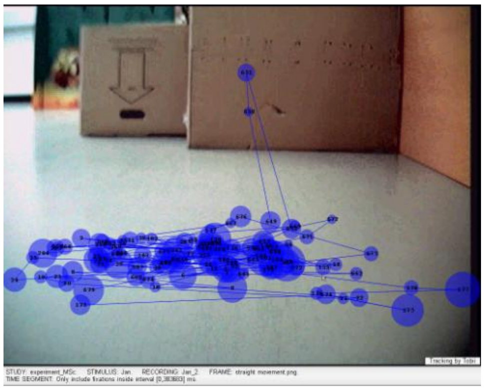
The gaze plot of subject 3 contains enrich information during "forward motion" depicted in experiment 1 and experiment 2, gaze positions around the centre of the screen i.e. middle of the screen and on the middle bottom that might suggest the user concentration during the robot controlling. For "backward motion" we cannot find enough information the reason is because subject is free to move in the environments to search and identify the object in the vicinity as other subjects which resulted no/small backward motion harder to detect during experiments by this subject.

In "left turning" the subject has shown expected results by looking at the middle left side of the screen in each experiment which is quite enough to estimate the gaze directions for this motion. During "right turning" in experiment, values are collected well that really show the middle right portion of the gaze direction, but in experiment 2 we also see minor saccades in the middle i.e. running from the start or ending at the ends in the screen middle portion, however much of the emphasis is done on the right most portion of the screen.

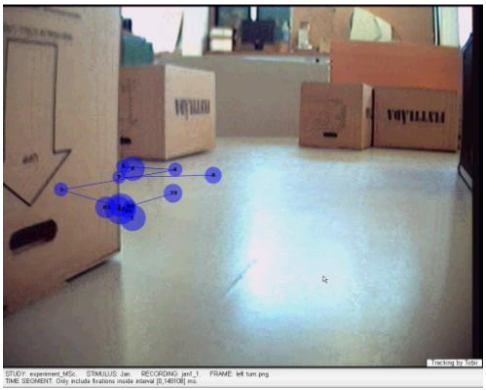
Experiment 1 | **Experiment 2**

Forwards Motion

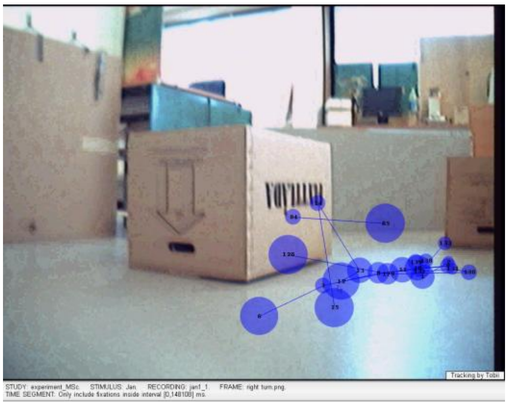


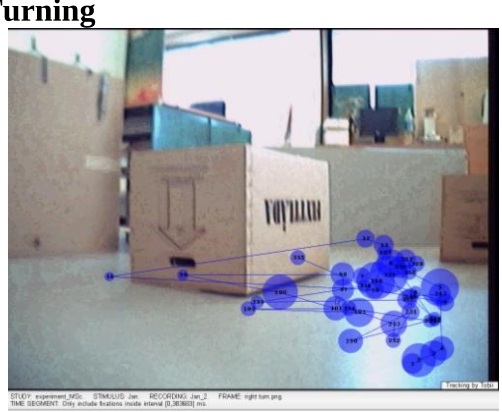


Left Turning



Right Turning





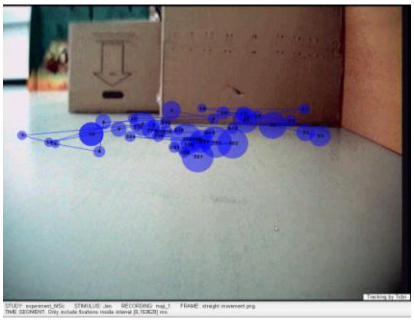
6.11.5 Gaze Plot of subject 4:

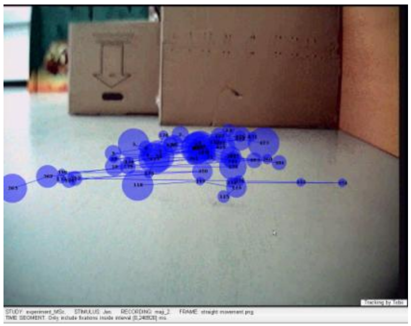
The gaze plot of subject 4 in the "forward motion" shows almost similar positions in middle portion of the screen. Some saccades are presented may be due to limitations explained in section 6.11.1, other wise the main theme of the subject concentration is gaze direction is same. During "backward motion" we see that there is insufficient gaze information during both experiments which is because of no backward motion performed by the user during experiment, however we will obtain healthy information in the hotspots for all subjects during backward motion.

Again for the “left motion” we see that the gaze data is moving form middle to left i.e. saccades in both experiment while same behavior is notified during “right motion” as the gaze direction is moving form middle to right i.e. saccades. This proved that subject is keenly looking at each portion of the screen then jumping form one place to other which is good. What we see here is the most of the time subject gaze is either towards left side or right side as required.

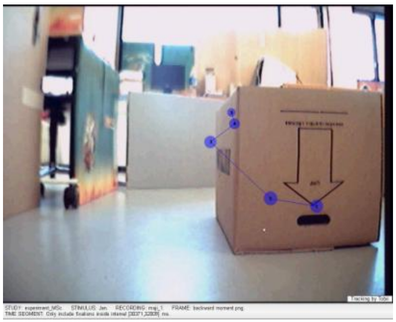
Experiment 1 | **Experiment 2**

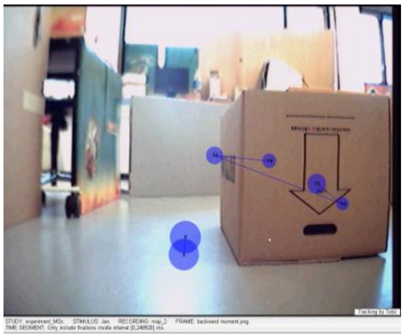
Forwards Motion



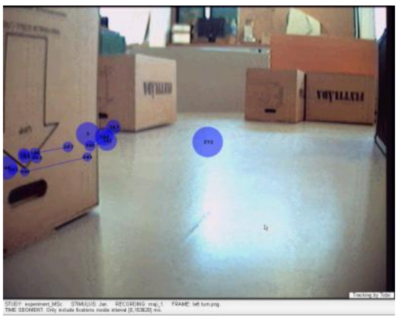


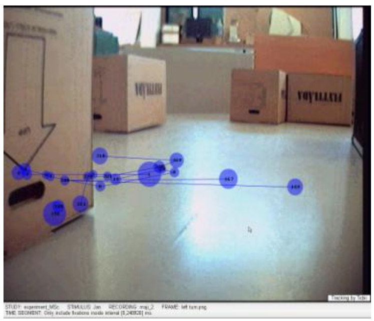
Backward Motion



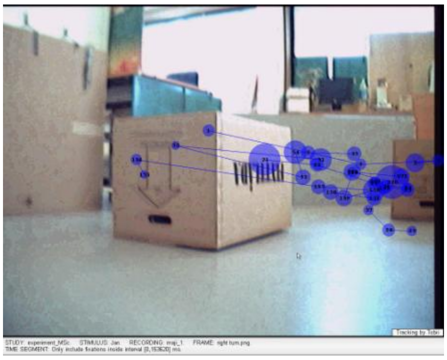


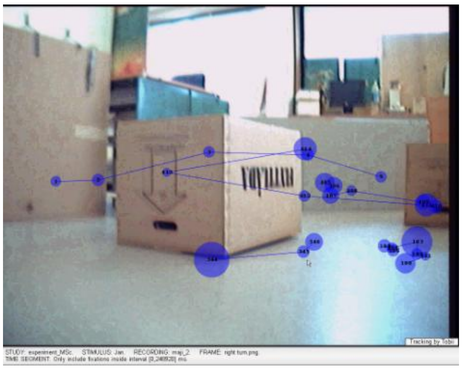
Left Turning





Right Turning





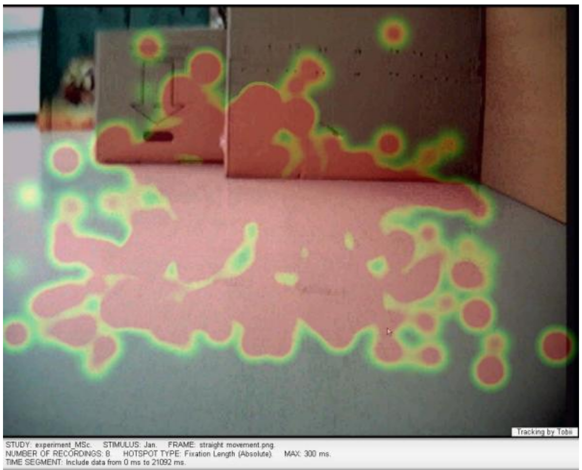
6.11.6 Hotspot of Experiment 1 &2:

We have obtained the hotspot of experiment 1 and experiment 2 form all the subjects and for all motions defined in section 6.11.

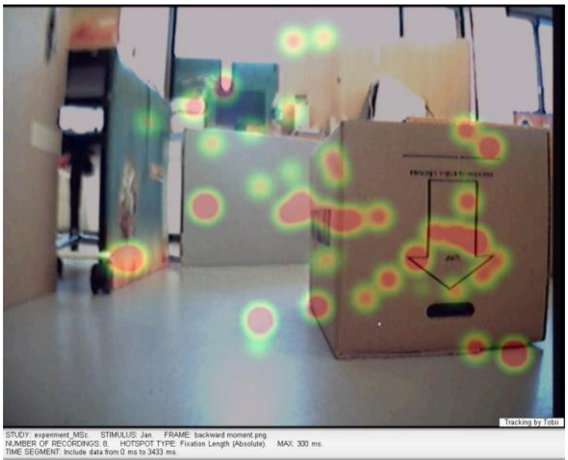
For the "forwards motion" hotspot represent density in the middle of the screen, all the surrounding area on the top, bottom, left and right are empty. In case of "backward motion we encounter small but random density apparent on the hotspot. Left turning hotspot is apparent on the middle-upper left portion of the screen while right turning hotspot presents the middle lower right portion of the screen. For both motions we expect the large screen section on both sides i.e. left and right.

We also see the impact of limitation discuss earlier in section 6.11 in the hotspots. However we can extract manageable information for these hotspots for desired user interface design. (For individual subject hotspots, please refer to Appendix A)

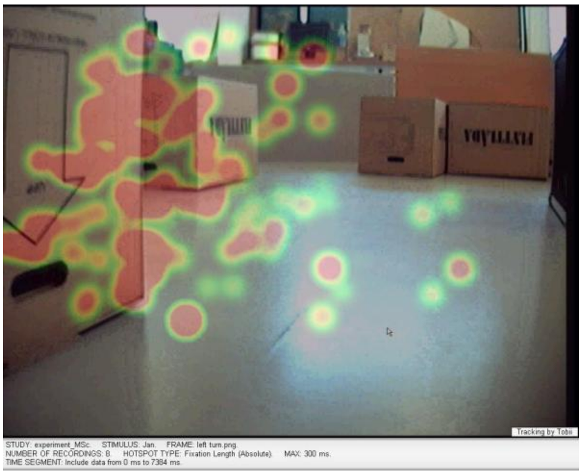
Forwards Motion



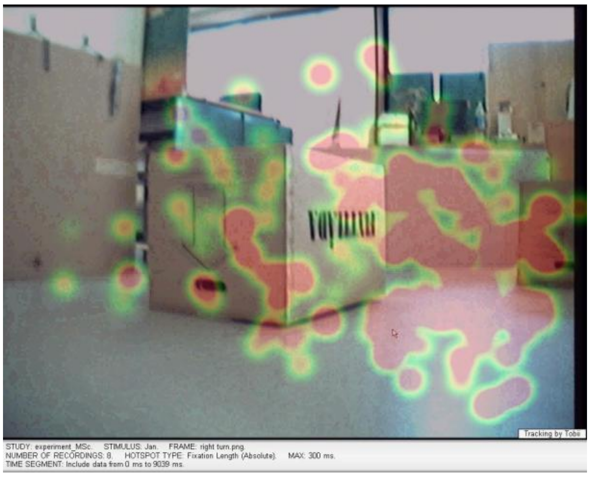
Backward Motion



Left Turning



Right Turning



6.12 Analysis:

We observed during the experiment that everything was working well except we have small difficulty in video capture during second experiment due to signal interference and was unable to detect it completely but to switch off and turn on the wireless hardware device and software for video capturing. Another problem encountered after the experiment was that for subject 2 gaze data was not collected by the Tobii system but only video capture was available. Due to time constrains and subject un-availability we were not able to repeat the second experiment for subject 2, however information prepared and recorded by other subjects and in both experiments are enough to design the user interface.

Hotspots doesn't scale the exact starting and ending points on the screen which are even not possible to get in this situation as we don't have control over the eye moments but we can use this information to model our interface design. It means that "forward motion" will require double space on the screen than for left/right motions and have to have small portions left empty at bottom and top of the screen that can be used for other function/applications latter in the future work.

The reason for the backward motion is that users don't have any side mirrors to see and look for possible obstacles as in the real cars, but accept the understanding of the mental ability to guide the robot in the backward motion by looking at any portion of the screen. Left and right motions have significant gaze density information, although there is no clear boundary between middle-left and middle-right but it is justified for the designer what he expects better for the interface design.

We suggest that experiment can be improved by recording subject control actions through webcam while it is difficult to distinguish and calculate between left/ right motions from the turret pan motions. However it is important to know how and why such turret motions are made. Subject 2 data recording depicts that user was looking mostly in the middle of the screen even turning left/right, so we consider the following hypothesis:

H0: Subject 2 is more used to controlling a robot using RC controller.

H1: Subject 2 behaves due to learning first person shooter video games.

If necessary, another experiment can be conducted to test hypothesis H0 and H1, to see which one is more acceptable statement.

CHAPTER 7: USER INTERFACE DESIGN

This chapter is the most important chapter as complete research study is carried out to design user interface for eye tracking system for controlling mobile robot based on scenario 1 describe in section 6.2.

7.1 User Interface Design:

Our user interface design will consist of small information on the visible display due to simplicity, easiness and understands ability during controlling the robot. The proposed interface design has three pages described below:

7.1.1 Main Menu:

This is the first interface page for the user when running application software. It contain information regarding the other two pages i.e. robot mode and camera mode, “Y” implies yes or “N” implies no, exit the application and help menu. “Y” and “N” are kept on the top of the screen to be easily accessible and are separated with enough distance so the users gaze can locate the exact choice and should not be confused/ mistaken.

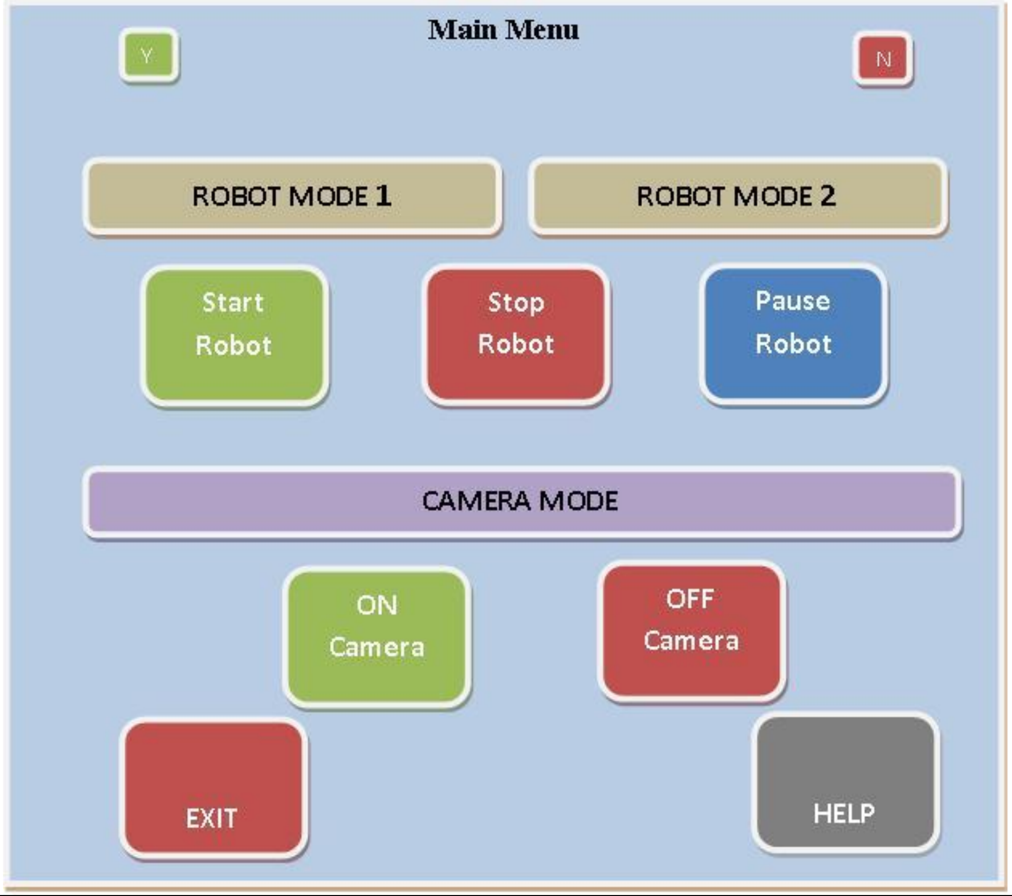


Figure 7.1 a) Main menu of proposed User Interface Design

Another important feature is that both modes of operations are separated with the possibility to move to the robot mode or camera mode or choose in between the quick launching option i.e. start robot, stop robot, pause robot, On camera and Off camera. More functionality can also be added in the future like robot arm control option.

Another important function in this interface is the selection of the modules through gazing at desired box, after few mini seconds (defined latter in the programming) the box will become big and interface request for an input form the user with "Y" or "N". There with be small clock associated will each "Y" and "N" as soon as the user gaze at them and count for between 1-3 seconds (defined in the programming), which will show the status of the action and the completion of the desired task. Gazing at each module should perform certain set of task in execution of the input.

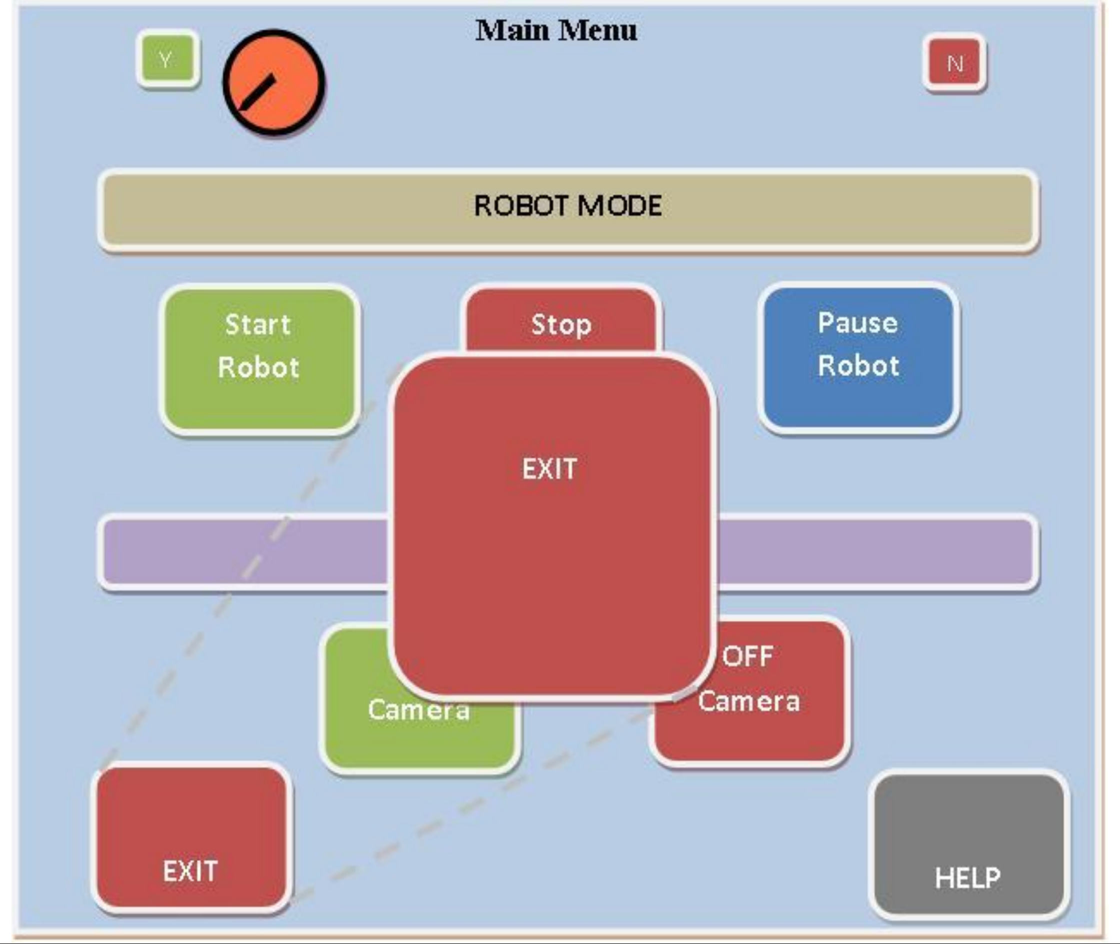


Figure 7.1 b) Main menu of proposed User Interface Design

- Robot Mode will directly locate to the robot mode, an option to automatically activate wireless link will be setup, and also turning the camera ON is interesting to notice at this stage.
- Camera Mode will locate to camera mode interface but before that it will activate the wireless link to robot and wait for further instruction form the user.
- Start Robot will require activating wireless link, switching ON the camera, switching ON robot hardware and changing the mode from inactive to active. It should be noticed that robot mode and camera mode will be inactive by default unless activated.

- Stop Robot will turn off the camera, inactive the robot mode and turn OFF robot hardware.
- Pause robot means to stop the robot and keep the environment held by inactivating the robot mode while allowing the camera and robot (ON/OFF), as it is.
- ON camera will activate the wireless link and activate the camera mode for user input.
- OFF camera will only turn off the camera.
- Exit will exit the application as required.
- Help will provide information about the software just like software manuals.

7.1.2 Robot Mode:

It is the main interface for controlling the mobile robot motions i.e. forward, left and right but not backward. The reason is that the information gathered for backward motion during experiment gaze plot and hotspots results an overlapping area for forward, left and right motion areas on the screen which means that users gaze can be directed to these areas instead of bottom middle, which is commonly considered as interesting area of interest for backward direction. So analyzing the subject gaze we concluded that user backward motion should be defined in another mode but similar to the existing mode except the motion will occur in the backward direction. To differentiate between the two modes we use “1” and “2” and in order to switch between these modes an orange box with “C” states convert. This option is present in both modes and thus user will switch between the two modes easily and even have the same set of option available.

We can see that all the functions present here are already discussed in the previous section except “Active” and “Inactive” operational modes. These modes are present in contradictory nature, if first one i.e. “Active” is working the other will be OFF and if other is working first one will be OFF.

7.1.3 Camera Mode:

The robot contains one camera mounted on the front of robot, which provides original external video of the surrounding. It’s possible to move the camera in the following directions:

- Left
- Right
- Up and down

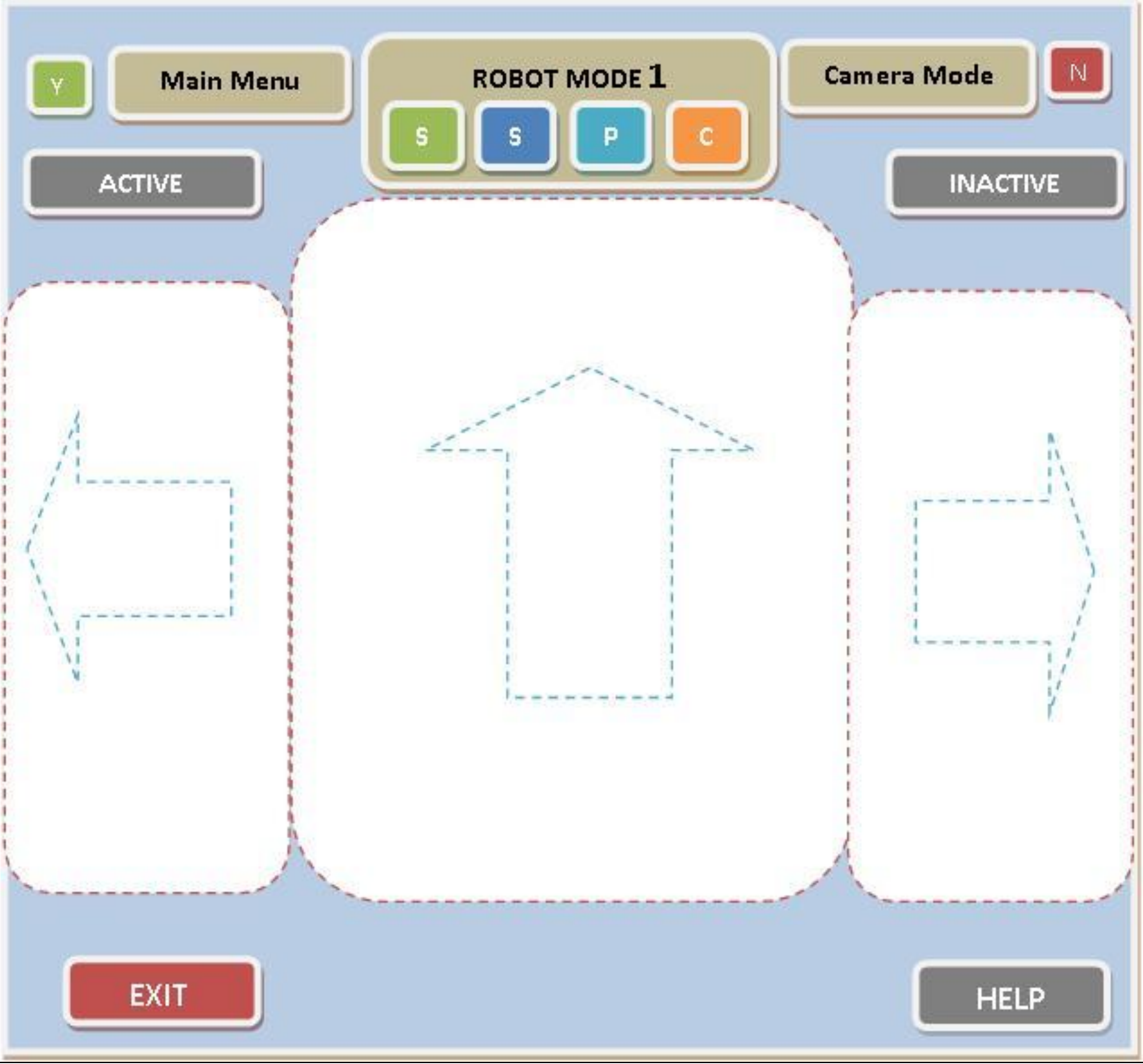


Figure 7.3 Robot Mode I of proposed User Interface Design

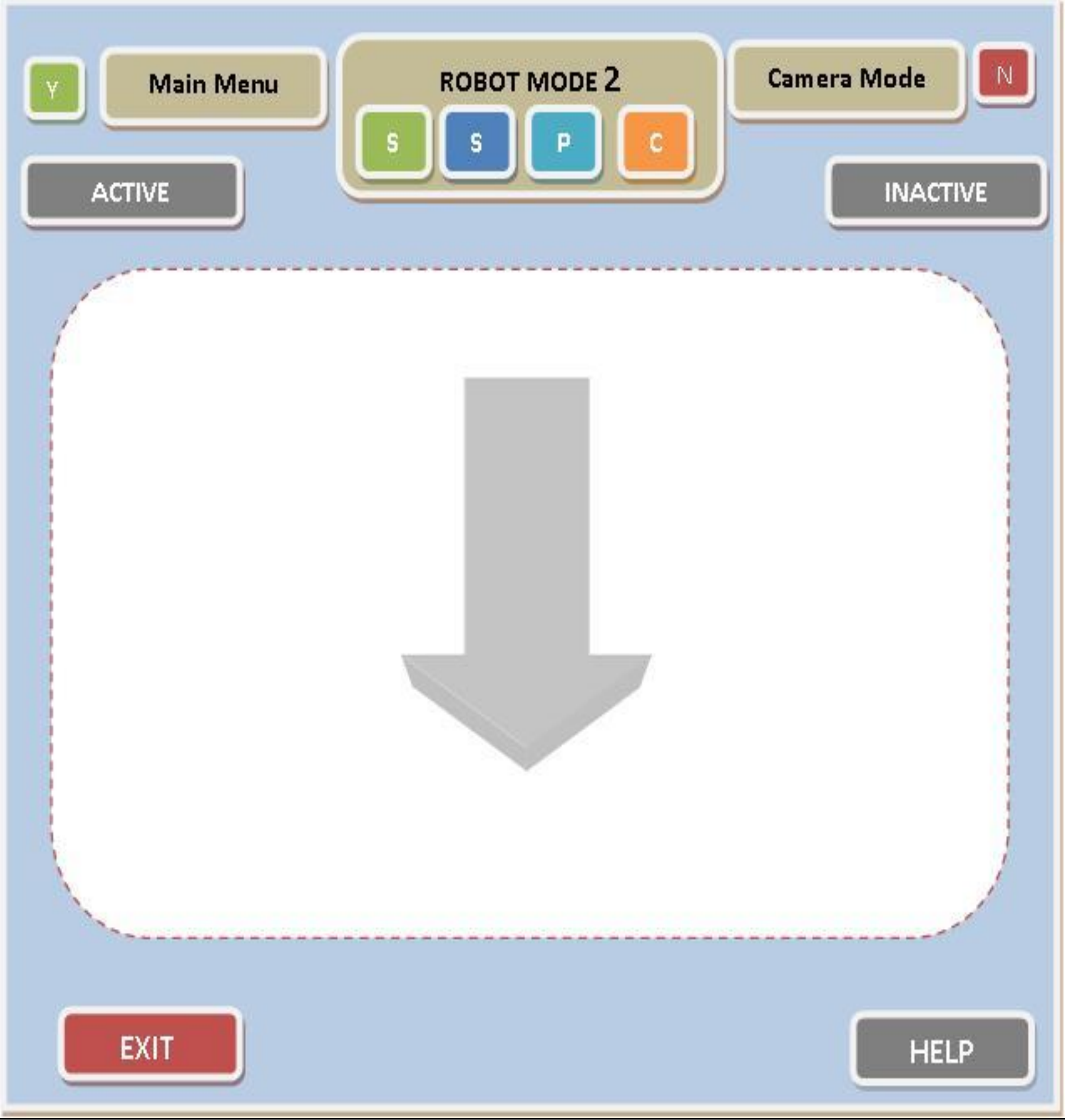


Figure 7.4 Robot Mode II of proposed User Interface Design

The direction is limited to 180 degrees angle along each side and the visibility area is depicted in the figure 7.5.

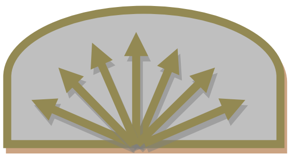


Figure 7.5 Robot Camera 180 degree visibility

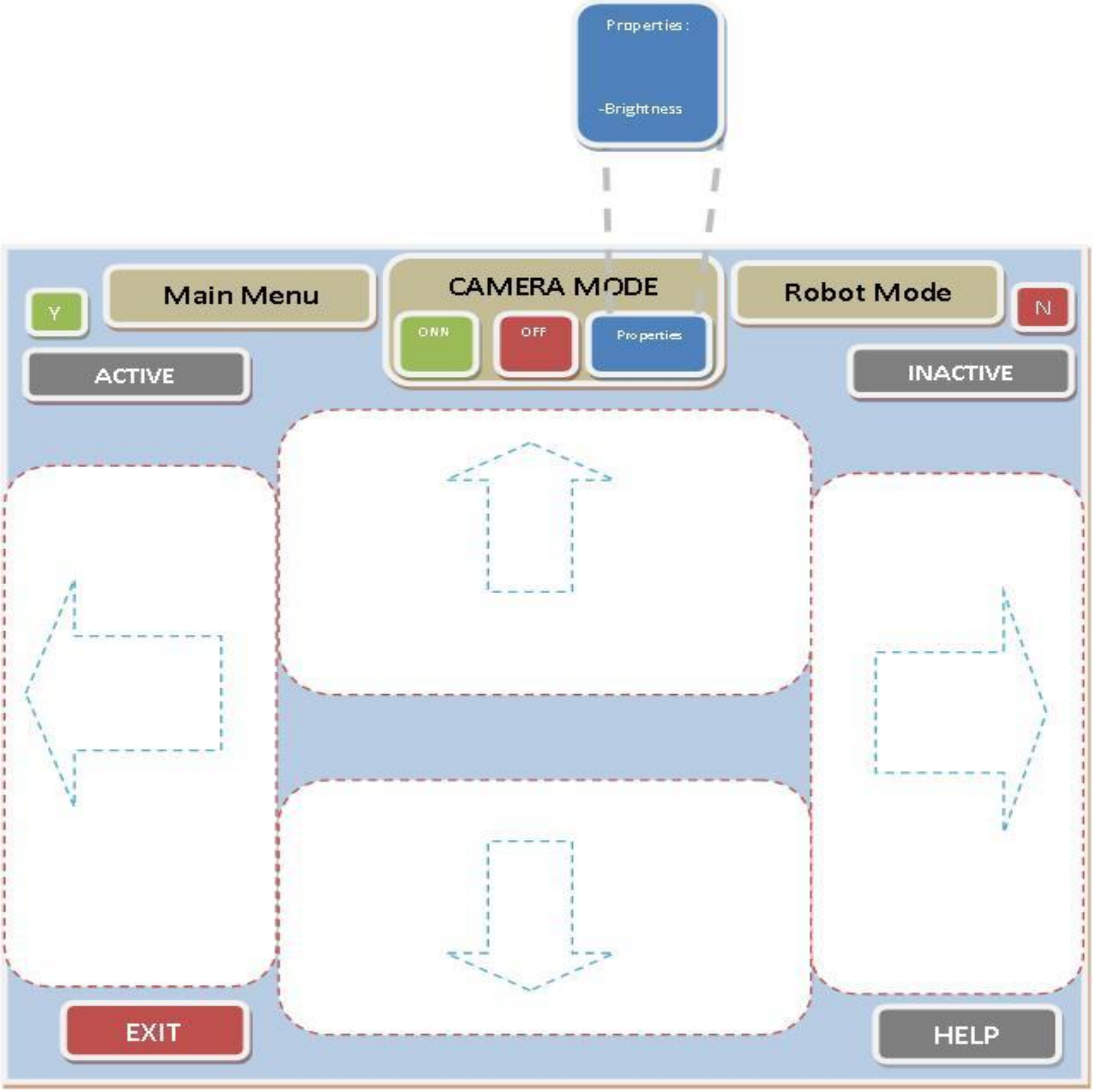


Figure 7.5 Camera Mode of proposed User Interface Design

The properties parameters of the current camera are optional depending upon the programming efforts and hardware compatibility for zoom in and out. This mode contains ON and OFF options and other options are discussed earlier.

For the proposed user interface design, we provide list of interface design of which follow the standard interface defined earlier in section 4.2.

- **Structure:**
  The structure of the proposed interface depicts apparent model with individual mode and parameters selection separately.

- **Simplicity:**
  This phenomenon illustrates about shortcuts to keep the interface design simpler but in our case it is not possible to apply because gaze direction is difficult to capture to shortcuts like keyboard instead shortcuts is available at each design window to switch between multiple windows and even perform most common task in the main menu.

- **Visibility:**
  Since the interface design has less data/information on the page so everything is clearly visible to the user without ambiguity.

- **Tolerance:**
  This principal will be calculated after development of complete prototype model of mobile robot control through eye tracking system.

- **Reuse:**
  This part also concerns the programmer area and by utilizing object oriented languages the components design is become more usable.

- **User Compatibility:**
  Since the experiment results are analyzed for the development of any interface design which mean users cognitive ability and mental situation had been observe through different subjects.

- **Product Compatibility:**
  Since an integration of eye tracking system with mobile robot control applications is a new direction of research while the products available in the market are very few and users have less access due to high cost but still their lie a probability of the interface acceptability and adaptability when put into the practical environment specially during usability testing.

- **Task Compatibility:**
  Application scenario 1 illustrates the controlling of mobile robot for identification of certain objects in vicinity in the information present at the proposed interface design is sufficient to address maximum likelihood for task completion.

- **Familiarity:**
  Familiarity of the proposed interface is accomplished by designing interface based on experiment results. User’s perception about robot motion is similar to our conceptual model and physical reality except for backward motion users normally create logically understandings and believes impractical situation.

- **Direct Manipulation**
  Since the robot is moving in real time environment with proposed interface and the task is not clearly determinable as moving, searching and identifying objects solely depends on the user. The only manipulation present is the implementation process/progress is clock when users keep constant/still gaze at Yes after performing some action.

- **Control**
  The interface provide user with high human control over the mobile robot motions. Users are free to use the mobile robot in any environment capable to meet the desired task and have maximizing freedom of camera control with 180 degree angle alongside.

- **Flexibility:**
  Since this interface is design only for single user access and control at a time however the features of facilitating more users is not present at the moment.

- **Invisible technology**
  Although major control motions are known to the users and there are very few features associated with current interface, so it's hard to hide the functionality and control of the technology integration but however the programming and low level control mechanisms are transparent to the users.

- **Robustness:**
  The interface design for only suggest and guides through the control process while the possibility in application robustness will tend to reside in the programmer end. Simple errors pertaining incorrect command selections will be prompted by the application.

- **Ease of Use and Learning**
  The interface design view represents everything in the clarity, symbols use in the design have clear vision of the working mechanism. Help menu will contain information and guidelines/ manual for the beginners and important information about over all functionality.

- **Obviousness:**
  Interface design contains arrow keys and symbols for the main menu, help and exits. These icons presentations define directions; easy understanding in learning and familiarity in use.

- **Affinity:**
  Interface design clear, icons are at prominent places, controlling section is defined to the middle, left and right side of the screen.

7.2 Proposed Interface Design Process:

The proposed interface design process includes number of phases/modes, each will some differences and unique functional characteristics described below.

7.3 Functionality Requirements:

Following is the list of functionality requirements of the user interface design.

7.3.1 System Functionality:

In our interface design concept, the function of the overall integrated technology is required to control mobile robot through user gaze direction on screen of the eye tracker. The functionality of the software system will be address the issues describe in chapter 7 i.e. different user interface design modes and their descriptions. Input is provided by the user gaze on the Tobii screen, while TET server will analyze the gaze direction and process the application output accordingly i.e. robot motions or camera motions. Figure 7.6 depict the system functionality and work flow.

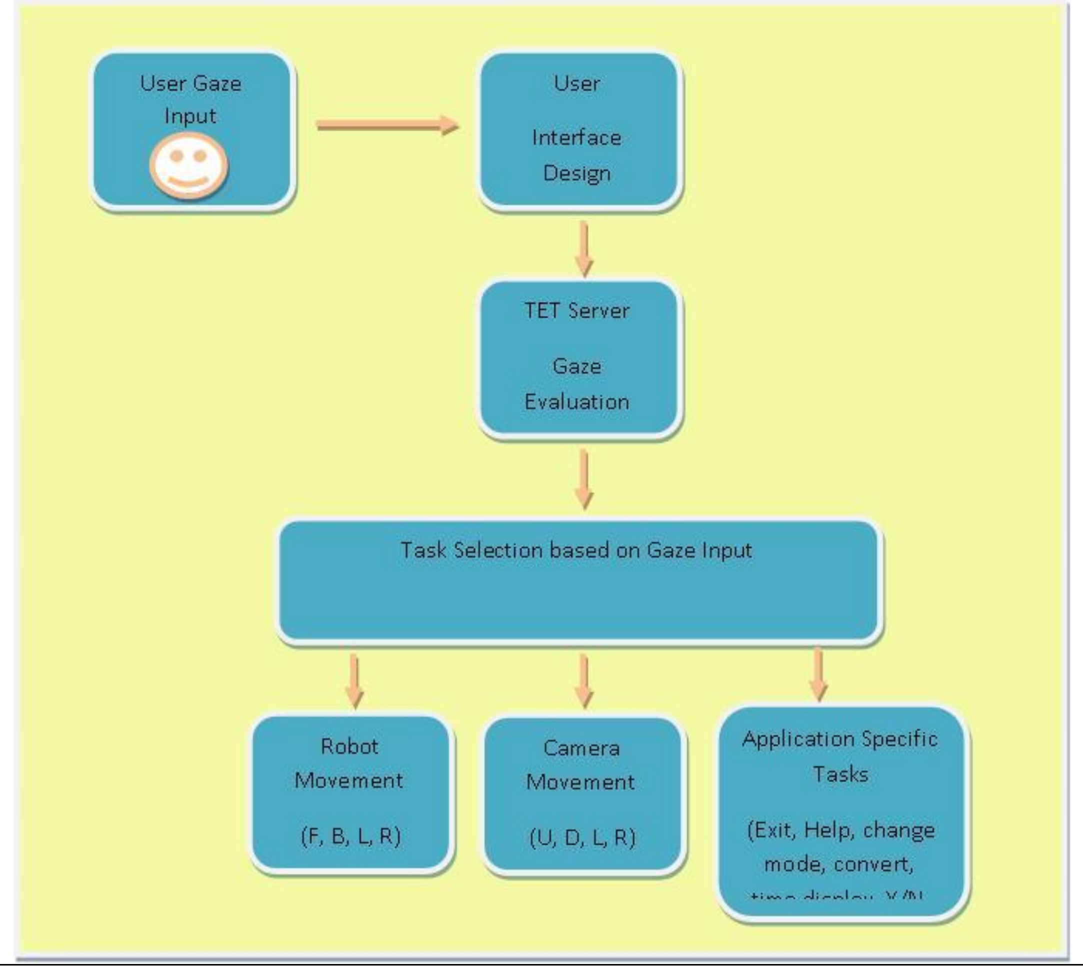


Figure 7.6 System Functionality and work flow

7.3.2 User Analysis:

This term is essential in software development as user centric products are mainly focus these days, but innovative ideas can also emerge through research studies. Our study is also an emerging field of research with application development for specialized users. The first prototype of the research study will produce the high human control robot control through eye tracking system. In latter versions of the product, variations in the additional features like robot arm, more advance robot motions, detection of obstacles, and an increase in the robot artificial intelligence can be expected.

Since the product prototype goal is only to search and identify objects in the environment through gaze control, user requirements and expectations form the desired system/interface.

- User expect simple, easy and user-friendly interface design
- Interface design requires the integration of robot and eye tracking architecture to control the mobile robot.
- The confidence level based on this interface design is higher due to less and simple offered functionalities, there are not standard interface for the said scenario but specific tasks remain the same for every interface design for application scenario1.
- As the existing interfaces are still under usability study and lack of standard interface design are not present, this interface might bring up with effective results as the interfaces is deduced for the real experiments results.

7.4 Information Architecture (IA):

High level information architecture conceptual model for integrated technology platform is shown in figure 7.7. Application programs are develop and executed on the TET server, which makes the connection with eye tracker system through USB and fire wire cable. Complete details of each set of operating systems are described below:

7.4.1 Eye Tracker System:

Eye tracking system is the collection of hardware i.e. Tobii 1750 and software for controlling hardware and user gaze point on the screen. It consists of infrared diodes implemented to generate user eyes corneas reflection patterns and other data through camera. For detail hardware specifications please refer [28]. In the figure 7.7 we see that user input is collected through input module i.e. camera mounted on the Tobii screen and the output is produced to the TET server to recording and analysis through Clear View software. Communication module provides complete communication between eye tracker system and TET server.

7.4.2 Tobii eye tracker server (TET server):

It is a server connected to the eye tracker with USB and fire wire cable containing specialized software i.e. “Clear View” for preparing, recording and analyzing user gaze during study/ experiment. In the functionality module, processing of the user gaze input is obtained and processed for the output task and acts as transparent bridge between eye tracker system and mobile robot while communication module maintain bi-directional communication i.e. radio TX and video RX with mobile robot.

7.4.3 Mobile Robot

The hardware of the mobile robot was interface with multiple motors for controlling the direction/motion of the robot. It contains central controller for controlling the motors and sensors mounted afterwards. Wireless radio receiver is attached to the robot for receiving information and control signals during communication. On the either side wireless radio receiver will be attached with TET server that will perform task and send information messages after evaluation user gaze direction from eye tracker and task to be performed discussed earlier in section 7.3.1. Mobile robot also contain wireless mounted camera on the front side of the mobile robot to send back the video capture to the eye tracker.

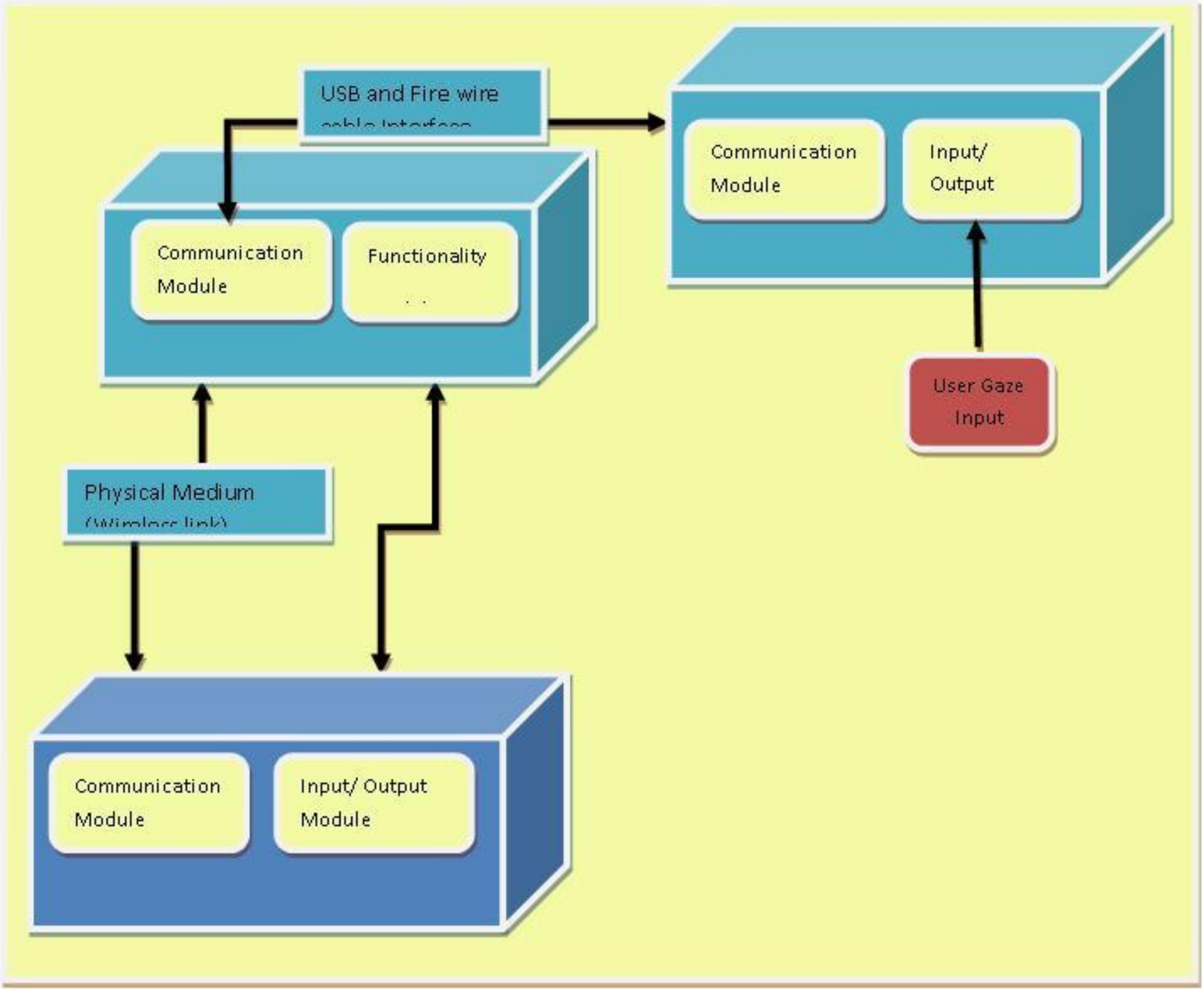


Figure 7.7 High level conceptual Model of TET and mobile robot architecture

CHAPTER 8: DISCUSSION ANALYSIS

In the beginning sections we describe the need to develop an interface design for motor disability people and continue to provide the background knowledge of the technologies that can integrate to develop more necessary applications in this research domain. We then produce our research goals and objectives and built research questions that will be important to answer in and after the research completion. The research was carried out in exactly described in "Research Methodology" chapter.

It was necessary to provide detail knowledge about the user interface design, eye tracking technology and mobile robot technology, as they will be integrated to provide solution to application scenario1.

Chapter 5 is based on the empirical study about between high human control and high robot control tradeoffs and here he was able to figure the details tasks present in each application scenario. Chapter 6 is the vital chapter as we have performed an experiment and analyze results from Tobii 1750 eye tracking system. An interesting thing to determine during the experiments was that saccades and fixation on certain location and time stamps illustrate the mental stress and ability to identify the objects and obstacles in the environment. We are able to address two assumptions for the subject;

- Extreme Saccades: Confusions/lost
- Extreme Fixations: Processing/Recognizing/Thinking/Identification

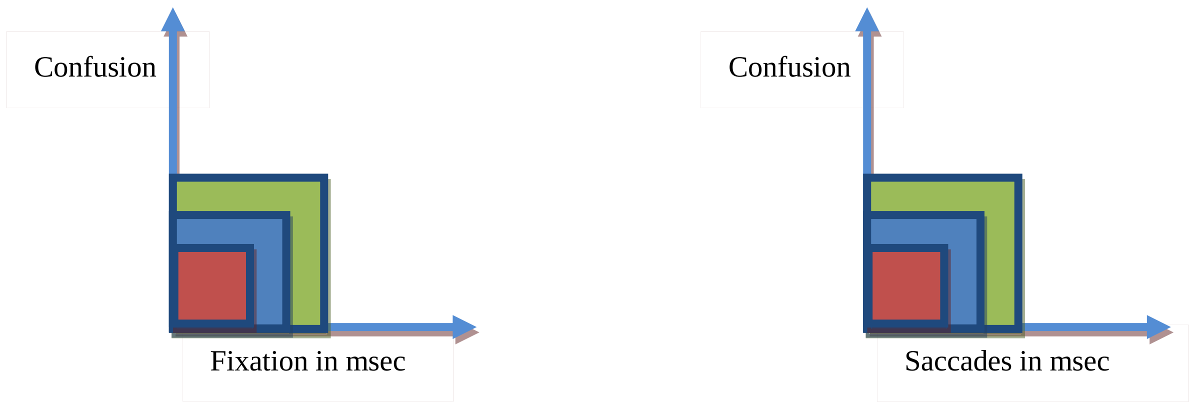


Figure 8.1: (a) Relationship between fixation and confusion (b) Relationship between saccades and confusion

The above figures present relationship between "confusion" with "fixation" and "Saccades". It means that if the subject fixations are increasing irrespective of the surrounding environment, the probability of confusion is increasing and if the saccades are increasing, same phenomenon applies in both cases. We also see that the read triangle is the limitation for object identifications and depends on individual subject and environments; however their actual measurements are out of the scope of this study and can be done separately.

Results of experiment from chapter 6 are analyzed for designing user interface and details description is present in chapter 7. Regarding our research questions 3 and 4, theoretical state of the art study answers the questions. Chapter 6 describes the complete procedure and hardware/software involved in the experiments, which is an answer to our first research question while question 2 is answered in chapter 7, through user interface design.

8.1 Future Work

Interface is designed for mobile robot prototype-1, so primary work will involve developing and designing software for interface design to control mobile robot. It requires programming languages and expertise in software development to organize and integrate functionality associated within technologies. After prototype development, usability testing can be carried out for different purposes i.e. simplicity, robustness, learning, etc. We can use the interface to repeat the same experiments to find problems and make necessary improvements in the interface deign. An interface can be evaluated through metrics evaluation metric mechanism to find task complexity, effectiveness, etc. following

H0: Is interface user-friendly, simple and easy to use.
H1: Is interface complex, non-robust, and difficult to use.

On higher research level and through low level hardware programming in mobile robot development, it is also possible to append the proposed interface for controlling the speed of the mobile robot.

According to scenario 2-5, similar experiments can be conducted based on human control and robot autonomy features until desired scenario 2-5 mobile robot are developed. It will be valuable to conduct some experiments based on scenario 2-5 and then to design separate user interface designs. An extreme case could be to develop an interface design that collectively support all the application seniors (1-5)

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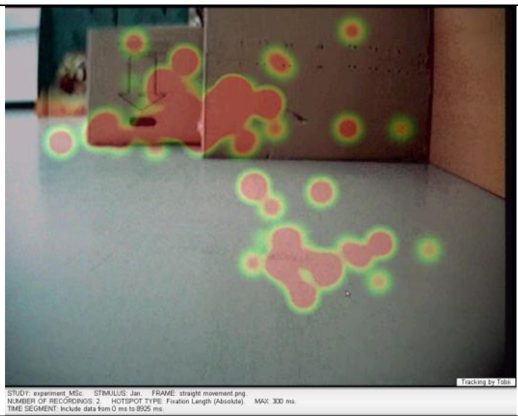
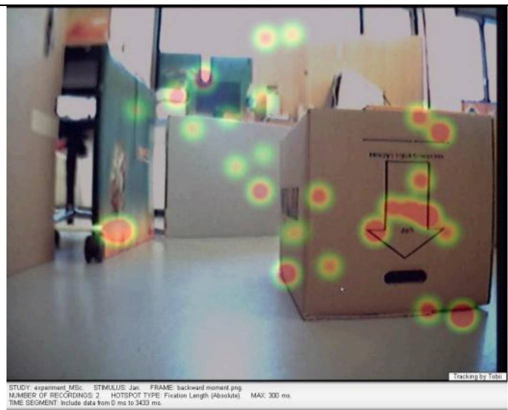
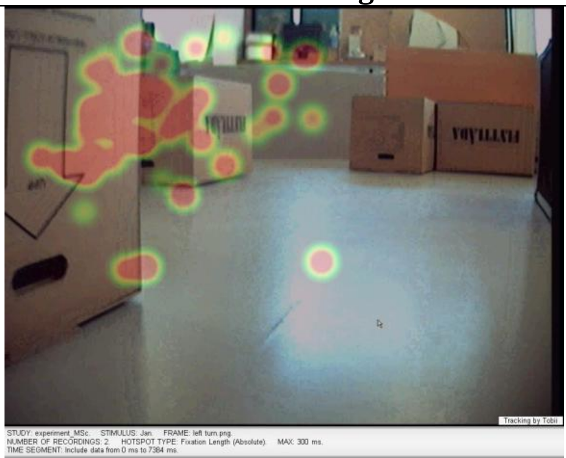
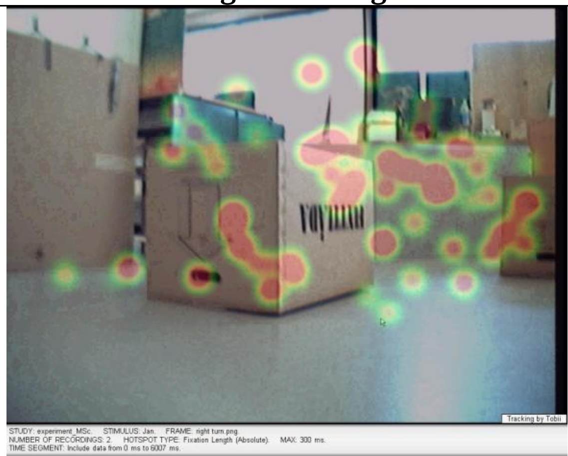
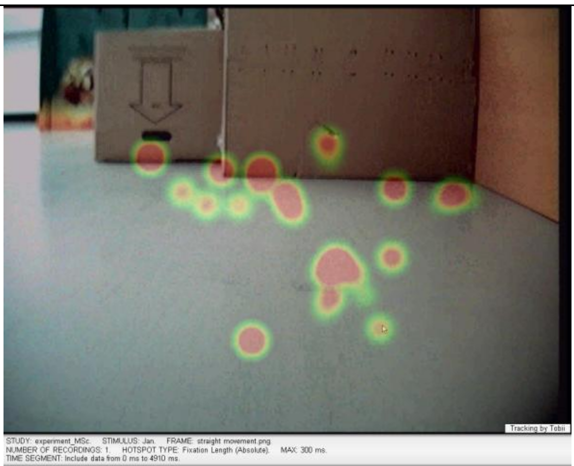
APPENDIX A: HOTSPOT OF EXPERIMENT 1 & 2

Subject 1

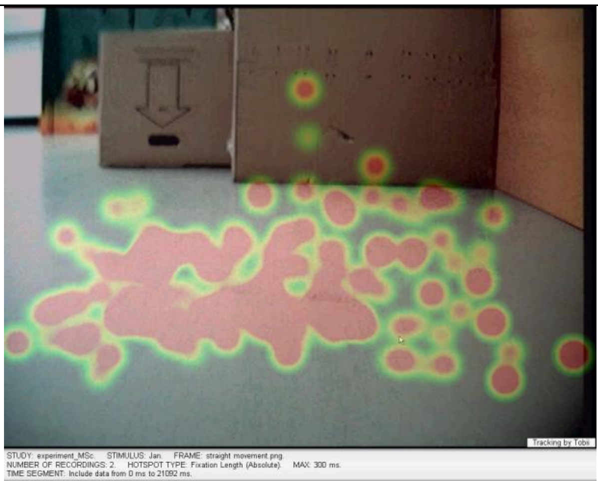
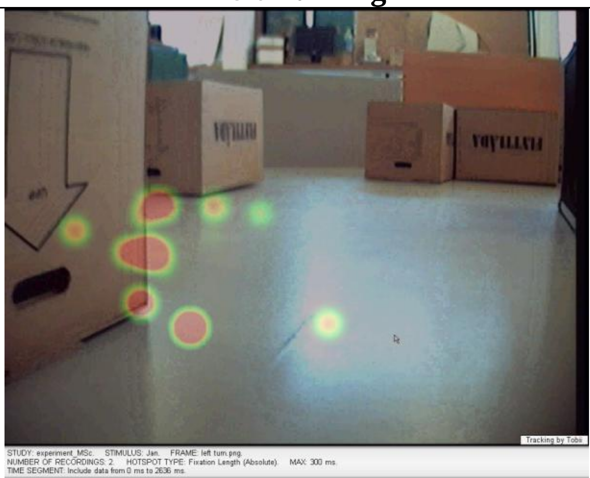
Forwards Motion	Backward Motion
	

Left Turning	Right Turning
	

Subject 2

Forwards Motion	Backward Motion
	

Left Turning	Right Turning
	

Subject 3	
Forwards Motion	**Backward Motion**
	**NOT AVAILABLE**
Left Turning	**Right Turning**
	

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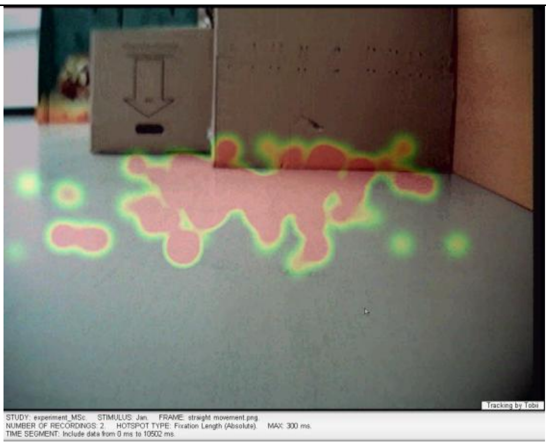
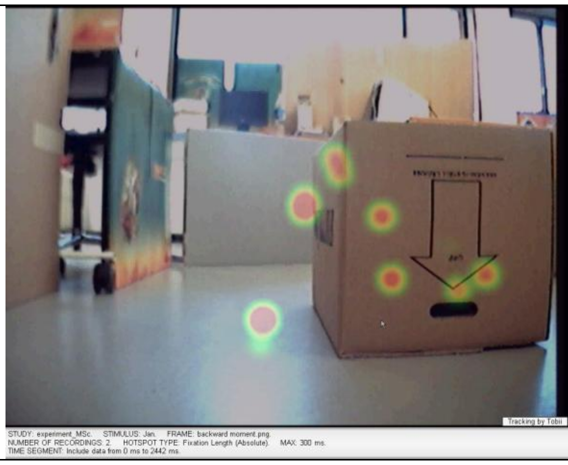
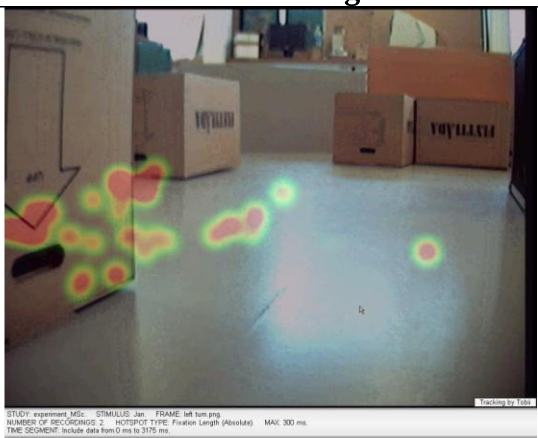
<tr><td>
</td><td>
</td></tr>
<tr><td></td><td></td></tr>
<tr><th>Left Turning</th><th>Right Turning</th></tr>
<tr><td>
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APPENDIX B: MOBILE ROBOT, RC CONTROLLER AND TOBII EYE TRACKER

<table>
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<tr><td></td><td></td></tr>
<tr><th colspan="2">Tobii Eye Tracker 1750</th></tr>
<tr><td colspan="2">
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APPENDIX C: EXPERIMENT ENVIRONMENT IMAGES

Experiment 2 Actual View