Achieving a uniform and consistent Graphical User Interface for a major railway system

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Abstract

The Kowloon-Canton Railway Corporation (KCRC) West Rail commissioned a five year ergonomics study in 1998 to assess four of their rail control systems. This study, focusing solely on ergonomics issues, was the first study of its kind in Hong Kong. West Rail, a new extension line to KCRC's existing network, East Rail, recognised the need to consider the 'human' aspect in their operations and aimed to achieve a uniform and consistent Graphical User Interface (GUI) with the existing systems and between the new systems being developed. With a uniform GUI, the benefits are manifold; an overall integrated company aesthetic, the reduction of the probability of human error during operations, less rigorous training requirements, and the potential for promoting multi-tasking abilities amongst the different operators.

With the increasing number of new railway lines planned for the future, there is a need to determine the standardisation requirements and to examine what level of integration would be the optimal solution for a railway. This paper discusses the approach that was taken to achieve a uniform GUI for West Rail systems and the way forward in which ergonomics should be applied for future railways.

1 Introduction

Building a sophisticated real time control system for a mass transit railway that transports millions of passengers each day and ensures that the railway can be operated as smoothly and efficiently as possible is a critical task. In addition, such control systems are expected to facilitate timely recovery of incidents to

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minimise the delay so incurred and hence minimise any unnecessary inconvenience to passengers. This will in turn gain the confidence of the passengers in using this mode of transport under a competitive environment.

With the advancement of computer technologies in both hardware and software, the most challenging task in building real time control systems with complicated integrated functions is the development of a fit-for-purpose Human Computer Interface (HCI). The success of such development works depends on a number of critical factors which are beyond the computer / control system engineers' usual approach in designing and delivering these control systems. They are:

1. Cultural Influence
2. Ergonomics Consideration
3. User Acceptance
4. Consistency and Non-ambiguity

This paper briefly introduces GUI design and its key components; the problems encountered in developing GUI, the approach taken by West Rail to achieve the objective of having a consistent and ergonomically sound GUI implementation and shares with the readers the lessons learnt in this process. Learning from this process, areas of improvement are identified so as to make the next railway control HCI design even better in an effort of continuous improvement.

2 Key components of Graphical User Interfaces

The key components of a successful GUI interface can be divided into those which concern the structure of the interface and those which are relevant to the format and presentation of the interface.

2.1 Structure - interface depth, navigation and complexity

Within GUIs the menu based systems and guided selections can result in functions being buried deep within menus and sub-menus. This element of GUIs is often inevitable and assists in providing a structured and uncluttered interface. However, it is important to note that usability is potentially harmed if functions are not carefully organised and distributed. Within GUIs controlling safety critical systems, the ease with which operators can navigate through the system must be maximised. Of particular importance is the requirement for users to be able to easily access those functions which they require frequently or during emergency/degraded operations.

2.2 Tolerance of error

Tolerance of error within a GUI design can be facilitated by the use of features which limit the possible interaction variables. A sample of requirements to consider during the development of a GUI will include:

- Where practical, errors should be highlighted or prohibits set;

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- Prompts should be provided to verify the user's desire to perform a critical function; and
- Data entry shall be bounded (e.g. not permitting alphabetic characters to be entered into numerical input fields).

2.3 Consistency

Throughout all aspects of a GUI it is of great importance that features, functions, coding systems and protocols are consistent. Without this consistent functionality and presentation the user will be hindered in his use of the system through needing to continually re-orientate himself to the exact workings of the area of the GUI which he is presently working in resulting in higher rate of errors, especially during emergency scenarios or during degraded operations.

2.4 Presentation of alarms

All GUI systems must present some sort of alarms or warnings. For safety critical systems the warnings and alarms may refer to critical system functions. It is therefore imperative that a GUI is able to present alarms and warnings to the user in a way which draws attention to them but does not hinder operator actions. When developing alarms for use in a GUI controlling a safety critical system it is important that the following aspects are taken account of:

- Terminology used in alarm text should be concise and consistent, clearly identifying the problem and its seriousness;
- Any colour coding shall be consistent and in line with traditional expectancies;
- New alarms shall be presented promptly to the operator and announced by both visual and auditory means;
- Auditory alarms should not compromise other auditory information such as voice communications; and
- A simple and clear alarm prioritisation system is used which is aligned to operational requirements rather than system outputs.

2.5 Grouping and partitioning of information

The usability of a GUI can be improved if information and functions are grouped suitably. Grouping can be developed based on either frequency of use or functionality, the exact requirement dependent on the specific system under development. Grouping aids the user by facilitating the rapid identification of information without the need for extensive navigation through the system.

2.6 Format

There are a number of other factors that require consideration in order to optimise user interaction with the system. These factors cover text style and size, use of colour, screen layout, information density, iconography and terminology. The published guidelines have to be translated into practical design

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solutions by the human factors consultant when developing a specific system application that has unique user requirements and system demands. There are no robust short cuts that by-pass a good understanding of operating demands and requirements in facilitating the development of a user friendly GUI.

3 Problems arising from designing and implementing a "User-friendly" GUI – case study in West Rail

In 1998 when most of the system based contracts were still in tendering phase, the need for a consistent, ergonomically sound and unified HCI was identified. This was judged as extremely important when considering that the GUI would be used for monitoring and controlling mission critical rail operations. Although a railway operator for nearly 100 years, KCRC was not experienced in building a modern railway system from scratch. West Rail is the first new heavy rail based network that KCRC has constructed since its first operation in 1910. It was realised early on that a full suite of problems was lying ahead when this new railway started to be designed and built. Those problems that are specifically related to GUI design and implementation are outlined below.

3.1 Lack of corporate GUI design standard/criteria

KCRC operated as a suburban railway for more than 50 years, and hence, the HCI of various control systems ranged from conventional push-button based panel systems to text based CRT terminals to the modern colour rich GUI workstations. This is a result of continuous upgrade of the old systems over the years in a rather ad hoc manner – a typical situation for most railway companies with this kind of operational history. As a result, there existed no corporate standard in terms of GUI design or a well documented GUI Design Manual which should clearly spell out the GUI requirements to the Contractors.

3.2 Non unified view on HCI / GUI design

When the Operation Planning section was set up at the inception of the West Rail Project, the team was made up of operators coming from various KCRC Operating divisions as well as operating staff from the Mass Transit Railway Corporation (MTRC), the other railway operator in Hong Kong. Since they were all coming with different background knowledge and experience, their views and hence expectations of the GUI design for West Rail systems were very diversified and resulted in conflicting requirements. Managing these non unified views and expectations under a tight timeframe project schedule did not help in producing good specifications and hence good final control systems for this new railway.

3.3 Rapidly changing GUI technologies

The rapid advancement of computer technologies is providing a great spur to GUI design innovation. However, this also causes difficulties in defining and

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incorporating user requirements for the GUI, as whatever is specified today is going to be outdated by the time the contract is awarded and may become obsolete when the actual system is delivered for day one operations. It is nearly impossible to catch up with the pace of GUI development in the market. Identifying an appropriate way in defining GUI in the Specification becomes one of the biggest challenges in this exercise.

3.4 Multiple contractors on control systems delivery

For West Rail, like many other railway projects, the whole project was sub-divided into a manageable number of key packages which would be awarded to the best specialist supplier of a particular discipline. As such, seven different contractors were appointed to provide the key seven control and monitoring systems in West Rail. The contractors/systems were as follows:

a. Train Control System (to be provided by Alcatel Canada)
b. Main Control System (to be provided by Siemens Germany)
c. Public Announcement System (to be provided by AV Digital Austria)
d. Passenger Information Display System (to be provided by Roctec Hong Kong)
e. CCTV System (to be provided by COE UK)
f. Fare Collection System (to be provided by Thales France)
g. Access Control System (to be provided by TAC Australia)

As one can observe, these seven suppliers come from different countries and their approach to HCI and GUI design proved to be rather different. Unifying their designs so as to ensure that a consistent and look-alike GUI is made available to a single operator sitting in front of a console with a bank of monitors is beyond doubt a very difficult task.

4 Ways to achieve uniformity, consistency and seamless integration of GUI

A description of the approach adopted by the ergonomic consultant for the West Rail GUI design review is given below, which resolved many of the problems raised above. This approach necessitates close teamwork among the Client, Consultant and Contractor, a formal review and recommendation logging process. Close participation between the Client, Consultant and Contractor is considered a necessity as each not only needed to understand their role within the project, but the roles of the other parties in order to make meaningful contributions.

4.1 Client role

The Client was the focal point for the various parties and acted as a liaison between the Consultant and the Contractors. Their main responsibility was to ensure that not only did the Contractor's design meet their functional

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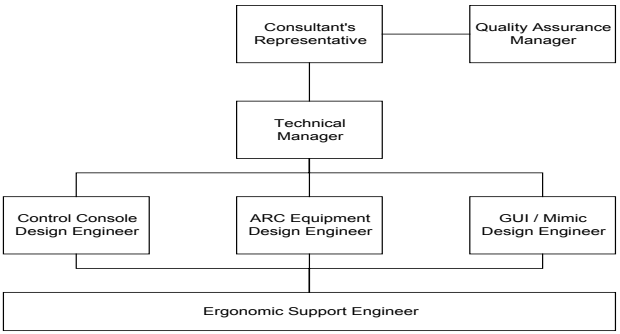
specifications, but that the designs adhered to ergonomics 'best' practice principles and industry standards. The Client project team was responsible for reviewing the reports submitted by the Consultant and providing their comments.

4.2 Consultant role

A project team of human factors Consultants was established whereby some Consultants were based in Hong Kong and others in the UK. The Consultant's Representative provided a steady local presence in Hong Kong and was responsible for liasing between the local Hong Kong Consultants, the Client and the UK Consultants. The organisational structure set up for the Consultants is shown below.



4.3 Contractor role

The Contractors involved have to be familiar with the concept of ergonomics so that they would participate and support the prototype/mockup trial process. They had to understand not only what was required of them, but also the objectives and activities required to complete the ergonomics reviews.

4.4 The West Rail ergonomics review process

A three tier approach was implemented for the ergonomics review process in West Rail. This method included:
Development of general GUI guidelines
Review of design submissions
User trials

4.4.1 Stage 1 development of general GUI guidelines

Prior to the commencement of the review works, the human factors consultant conducted a review of the 'KCRC MMI Style Guide' before its issue to the various Contractors concerned. The Style Guide was reviewed to ensure that the contents adhered to internationally accepted ergonomics guidelines for HCI design and industry best practice and was issued to all Contractors at the commencement of the contract.

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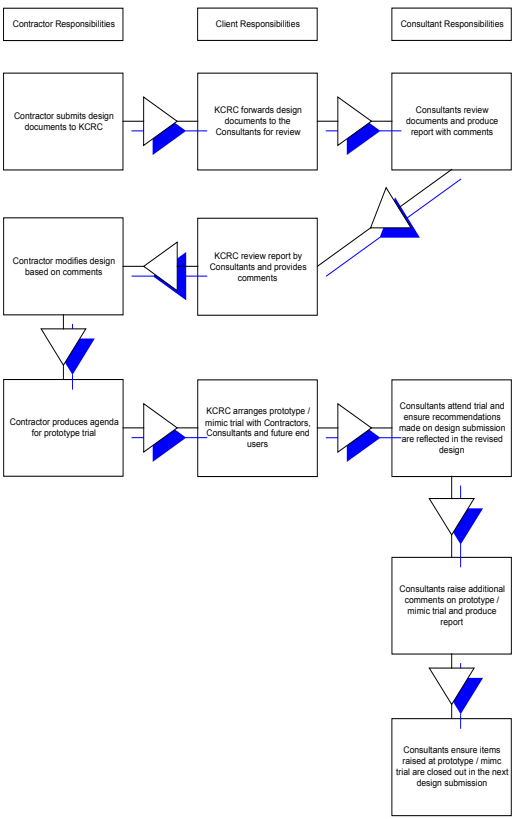
4.4.2 Stage 2 review of design submissions

An iterative design process was planned whereby the contractor design submissions were reviewed at three key design stages. Following each design submission review a prototype or mock-up was developed and a user trial conducted for each system. Design submissions were reviewed against recognised HCI guidelines and standards. A GUI Design Review Log was produced which summarised the comments arising from the review and kept track of the status and criticality of each comment/observation based on predefined criticality classifications. The flow of activities for the project is shown below and was repeated for each stage of the design and for each system.



4.4.3 User trials

User trials were conducted after each review of the design submission in the form of prototyping and were attended by the Client's project team, the Contractor, the Consultant, and the future end users. It provided a forum in

which the various parties were able to gain an actual 'look and feel' of the proposed design and give comments on aspects which can be improved prior to a design freeze. From the Contractor's point of view, they were given an opportunity to present their design in an interactive format which is much more self explanatory than the two dimensional screen shots given in the design submissions.

4.5 Lessons learnt from the West Rail ergonomic review process

Ensuring a consistent approach to GUI design and development among different contractors proved to be a difficult task. Learning from the WR experience, the following actions are proposed for any future works:

a. It will be beneficial to hold briefing workshops with the Clients and Contractors with the aim of explaining the concept of ergonomics, the approach that will be taken and the objectives of the ergonomics review process. The human factors Consultant should act as the facilitator for the workshops. This will align the Contractors with the process and alert them to the required Contractor scope of involvement.

b. A formal working group comprising the project engineers, relevant Contractors and Consultants should be formed to specifically address the recommendations raised in the GUI Design Review Log. They should meet regularly to ensure all actions identified are closed out to the satisfaction of the Client.

c. It is also suggested that entire screen navigation for approximately half of the functions be completed before the first design review / prototype takes place. This will enable the human factors Consultant to envisage the look and feel of the system as well as to gain a good understanding of the design and function of the system. It is also early enough for the Contractors to make any necessary drastic changes without doing too much re-work.

5 Ways forward

For West Rail, a process which involved the end users, the system designers, the Contractors and a group of specialist human factors Consultants has been tried out and was proven to be quite successful in delivering a suite of control systems by a number of different suppliers and achieving a consistent and uniform GUI on time and within budget. However, the end result cannot be regarded as perfect. This implies that there should be plenty of room for improvement for the next railway to be constructed, whether it be in Hong Kong or elsewhere.

The authors, having gone through this process in setting up the West Rail Model, believe that the following points are worthy of consideration in order to streamline the process and to fine-tune the model to be used for the next railways to be built. These areas of improvement (AOI) are categorised as organisation based and industry based.

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5.1 Organisation based AOI

5.1.1 Setting up of an ongoing task force on HCI/GUI design requirements formulation and review

As the GUI/HCI design is culturally related - corporate culture, industry culture as well as racial culture, it is considered necessary to set up an ongoing task force within the railway organisation in formulating and maintaining the HCI/GUI design requirements for all control systems. This will facilitate a consistent and uniform HCI to be developed and implemented for any railway line within the company and to ensure all operating staff, including the new hires, have a clear understanding of operating the railway lines, thus enabling cross line job rotation.

5.1.2 Setting up of an internal GUI development team to enable flexible in-house GUI development and modification

As GUI technology and design is a dynamic area, in order to produce an interface which fully satisfies all users, last minute changes or modifications to what has been specified comes as no surprise to any GUI system designers and implementers. In order to allow this to happen without going into any unnecessary and non productive contractual negotiations and bargaining, it is considered worthwhile to set up a small yet expert in-house team of GUI developers to perform all GUI design and development tasks including the up-keep of all the operational systems. The teams can be set up as part of the company organisation or as out-sourcing from another outside GUI design firm with a long-term renewable contract.

5.2 Industry based AOI

5.2.1 Improvement of rapid prototyping tools for GUI development

Rapid prototyping is one of the keys to success for any GUI design as it allows the end users to visualise the end products before they are fully developed. This saves a lot of time and money in achieving a high level of customer satisfaction. However, the current GUI rapid prototyping tools available have drawbacks of either being not very efficient in generating the graphics or not easy to convert the prototype GUI into the final graphical packages that the suppliers can use for their SCADA front-end. The purpose of having WYSIWYG through this prototyping process may be defeated as the colour, font size or even the shape of the symbols may change as a result of this conversion. Improvement of these prototyping tools is inevitably required to make the prototyping process smoother and more beneficial.

5.2.2 The development of a universal GUI interface standard/protocol

In order to allow the various SCADA suppliers to retain their own unique SCADA features in their systems while keeping the GUI design independent to the SCADA layer so as to maintain product differentiation among the various SCADA packages, it is important to develop some form of universal vendor (SCADA) independent GUI interface standard / protocol so that user developed

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GUI can be plugged into the selected SCADA platform to operate. In this case, the Client can develop their GUI to their own standard under a SCADA platform which is most suitable to the intended application.

5.2.3 Establishment of an international industry wide cross-cultural working group on the standardisation of HCI Design

The rail industry is very unique, just like any other industry with a long history which could potentially have significant impact on the well being of mankind. It has been identified that a significant number of accidents in the railway industry were caused by human errors as a result of operators and/or drivers misinterpreting the information being presented to them at the time of the accident. While computer based GUI is being used to replace the traditional hardwired control buttons in operating this safety critical industry, designing a suitable and "user friendly" GUI for the operators and drivers bears a very high degree of significance to the community as a whole. As the world is getting smaller and trains are going to be run from country to country in Europe, America and Asia as well as from continent to continent, such as from Europe to Asia / (London to Hong Kong), the need to form an international industry wide working group to establish standards for HCI design is now in need of attention. The authors are convinced that such a working group comprising of control system experts, GUI designers, railway operating personnel, human factors specialists and safety engineers from various railway companies, railway regulators, railway consultants and relevant academic institutions, should be formed, possibly under a neutral professional body, with the aim of producing the first international railway GUI design guideline by the end of this decade.

6 Conclusion

It is now widely accepted that major projects in the rail industry should incorporate a Human Factors Integration (HFI) plan to ensure issues such as user requirements, ergonomics design, training needs, workload, staffing levels etc, are properly assessed and considered in the system design. Indeed, companies like LUL and Network Rail have now developed such HFI standards to ensure project requirements are clearly understood by suppliers, consultants and the client alike. These HFI plans are good frameworks but inevitably the devil is in the detail and such frameworks can be enhanced by more specific GUI related design processes as outlined in this paper. With the prospect of wide scale rail expansion and international integration, future work needs to consider international rail operating requirements and how human factors assessment and GUI designs can support this development.

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