RE-ENVISIONING THE OPERATOR CONSOLE FOR DHRUVA CONTROL ROOM

S. Gaur, P. Sridharan, P. M. Nair, M. P. Diwakar, N. Gohel, C. K. Pithawa
BARC, Mumbai, India

Abstract

Control Room design is undergoing rapid changes with the progressive adoption of computerization and Automation. Advances in man-machine interfaces have further accelerated this trend. This paper presents the design and main features of Operator consoles (OC) for Dhruva control room developed using new technologies. The OCs have been designed so as not to burden the operator with information overload but to help him quickly assess the situation and timely take appropriate steps. The consoles provide minimalistic yet intuitive interfaces, context sensitive navigation, display of important information and progressive disclosure of situation based information. The use of animations, 3D graphics, and real time trends with the benefit of hardware acceleration to provide a resolution-independent rich user experience. The use of XAML, an XML based Mark-up Language for User Interface definition and C# for application logic resulted in complete separation of visual design, content, and logic. This also resulted in a workflow where separate teams could work on the UI and the logic of an application. The introduction of Model View View-Model has led to more testable and maintainable software.

INTRODUCTION

With years of Dhruva reactor operation, a need for up gradation of some of the instrumentation was felt in the data acquisition and processing systems, due to either obsolescence or for augmenting the facilities provided by the existing systems. Hence, taking due care of the retrofitting problems, some PC based systems have been implemented and others are being implemented in Dhruva. The Operator Consoles for these systems in Dhruva Control room have been upgraded with the latest UI design trends and technologies and created intuitive and flexible UX models. The computer based user interfaces with consistent and large screen overview displays have been introduced which has replaced the existing recorder-based displays.

DHRUVA OPERATOR CONSOLES

The Operator Consoles has been developed for continuous monitoring of nuclear, process parameters, radiation parameters and relevant status signals of Rector Trip Logic System, Alarm Annunciation System, Emergency Core Cooling System and Start-up Logic System. The OCs acquire the data from the corresponding embedded systems via dual redundant Ethernet links. The primary function of OCs is data reception, storage and display in various formats.

They provide:

- Multiple views of plant state for quick assessment of situation.
- Alarm Visualization(Analysing, organizing, filtering, viewing alarms)
- Archival of Periodic Data, Alarms, Diagnostics with a data life cycle of 5 years.
- Logging and reporting with data export to Excel.
- Real-time and historical data trending.

DESIGN APPROACH

The OC has been designed keeping in mind the common requirements across systems of similar categories while allowing the UI to be tailored to specific requirements of the system. This has resulted in a common OC platform. Variability between these applications were analysed and addressed through configuration points. A flexible XML schema was designed to describe configuration information related to UI. Windows Presentation Foundation (WPF) helped in separating design and code, and provided comprehensive binding framework, command infrastructure, specialized layout builders for flexible UI creation. Loose coupling of the View from the supporting logic and data (Model) was achieved through the Model-View-View Model (MVVM) pattern. Asynchronous invocation, thread pooling and object pooling resulted in efficient use of multi-core hardware to achieve the required performance. Use of lightweight embedded relational storage engine resulted in high performance concurrent storage and retrieval system.

The design of UI was mainly focused to achieve visually appealing, feature oriented, intuitive, and less cluttered graphical user interface. The rest of the paper describes the UI concepts that were used for building the user interface of Operator Consoles.

Separation of Concerns

Model-View-ViewModel (MVVM), a design pattern for UI development consists of three conceptual parts - Model, View and ViewModel. The Model is the data, completely UI independent that stores the state and does the processing. The View consists of visual elements. The ViewModel is an abstraction of the view, but it also provides a specialization of the Model that the View uses for data-binding. This resulted in complete separation between visual design, content, and logic. The separation of concerns enabled UI Unit-testing, designer-developer workflow and decoupling. The layers could be developed and changed independently of one another, resulting in parallel development. View-Model classes are easy to unit-test since they have no specific dependencies on visual elements.

ISBN 978-3-95450-124-3

Figure 1: Alarm Windows for RTLS.

Configurability

The data model for plant data acquisition systems was captured using XML technologies such as XML schema and XPath. With its flexible tree-like data structure framework, XML provides more natural alternative for knowledge representation as compared to traditional databases. XML schema with its strong type sensitivity and capability to define new complex types allowed capturing the data model accurately. Structured hierarchal in-memory representation of XML data and use of Language Oriented Query technology (LINQ) resulted in a declarative, query processing.

Modernization of User Interface

The Operator Console is built around the minimal interface principle such that it contains only features that are absolutely necessary for users to complete the activity the application is meant to support; supports the user's mental model of what it does. It contains uniformly designed interface elements, but leverages on irregularity to create meaning and importance.

Info Graphics

Visual metaphors have been provided to traditional and familiar objects to make the interface more intuitive. The OCs use monochromatic icons and simple solid colours for its new interface. The alarm windows from the Alarm Annunciation System that consists of alarms for the particular OC are represented in the same format and colour definitions as its available to the operators in the Control Room (see Fig. 1).

Laser Focus

Laser focussed interfaces helped to put visual focus on the most important details. The most valuable information like current alarms remains permanently available, while there is a shared area which is used for viewing specific in-detail data and for executing commands. The key benefit of this approach is simplicity. The Ribbon framework has been used to implement a command UI that is an alternative to the layered menus, toolbars, and task panes of traditional Windows applications. The tabs are used for displaying different peer groups of content or functionality. The application features are organized into a series of ribbon tabs at the top of a window for each kind of visualization: Trend, Alarm, Configuration, Health Messages and Snapshot. This has increased discoverability of features and functions, enabled quicker learning of the program as a whole, and made users feel more in control of their experience with the application (see Fig. 2).

Context Sensitive Navigation and Collapsed Content

The OC implements Context sensitive navigation and collapsed content to de-clutter the design. Thus, only the required navigation elements are present on screen all the time and others are shown only in certain situations. Figure 3, which shows the Trend Page where group selection panel automatically collapses, providing more space for trend viewing.

Content Chunking

Content chunking has been provided for presenting a large number of alarms in smaller visual chunks so its easier for operators to understand and interpret.

- The current alarms display is designed to provide a consolidated highest priority status (ORing of three channels alarm status); so that any signal causing system disturbance can be easily identified.
- Trend view supports "Recently viewed trends" along with the signals selected for trending. This feature provides the last three recent trends that have been selected to be viewed at a coarser resolution.

Attachment Boxes

They are an alternative to popup boxes with certain benefits. The Attachment boxes are tied to the form/ button and can be located on of its edge; as against pop up boxes that open up anywhere on the screen. This retains the context on which it was opened. It supports Hidden Navigation (Dont Leave the screen principle). The pop-up boxes have to be closed explicitly whereas the attachment boxes are hidden as the cursor is moved out. The Date Time Change, user login and shut down are provided in the form of Attachment Boxes (see Fig. 3).

Windows Presentation Foundation

Windows Presentation Foundation (WPF) has been used for UI design and development and provides the following advantages:

- Hardware acceleration: The OC workstations are provided with high end graphics that incorporates parallel computing architecture and supports Microsoft DirectX. WPF built on top of DirectX allowed fast data acquisition rate, archiving and responsiveness to the

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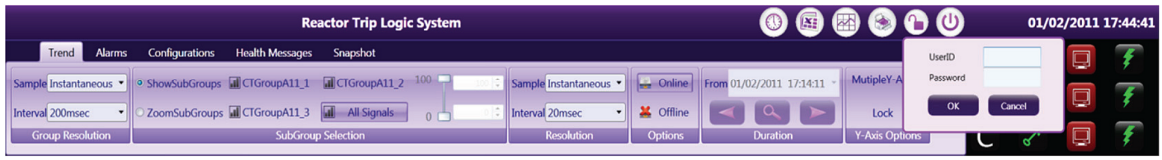

Figure 2: Ribbon View/Attchment Box for Login.

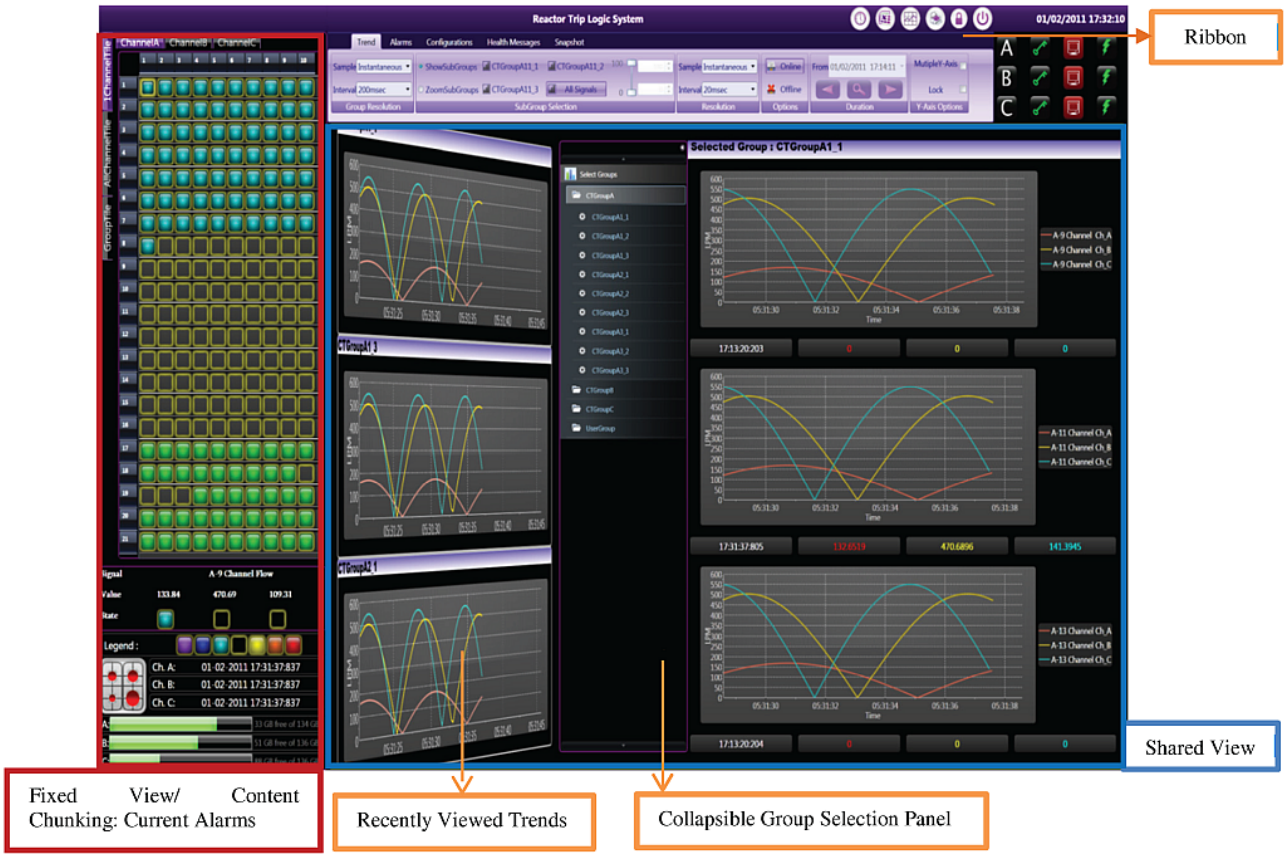

Figure 3: Operator Console for RTLS.

operator, permitting smoother graphics and enhanced performance.

- Resolution independence: WPFs vector graphics allowed the same user- interface to be designed for different monitor sizes of the control room(20 inch and 30 inch)
- Declarative programming: Extensible Application Mark-up Language (XAML) declarative programming was used to define the layout of application objects. This has now become a common trend in UI development for the design / code separation. This allowed parallel workflow of UI design and logic by different team members. Also, tool support helped complete an iterative lifecycle of design development and testing.
- Data Binding: OCs use the data binding capability of WPF, look-less control model and data templates, to achieve strong separation of display from state and behaviour promoted by MVVM.
- Rich composition and customization: The OCs for different systems of Control room featured the same design and layout but were customised through themes and skins to create a radically different look.

CONCLUSION

OCs have been successfully developed for Reactor Trip Logic System, Alarm Annunciation System, Start-up Logic system and Emergency Core Cooling System for Dhruva Reactor. OCs were designed with continuous discussion and suggestion with the operators and maintenance staff, so as to provide user-centric visualization to effectively cope up with the increasing complexity of the processes to be monitored.

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