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VIDEO WALLS IN CONTROL CENTER SCADA SYSTEM

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TIIVISTELMÄ

Tekijä	Lauri Runola
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Nykypäivänä videoseinistä on tullut tavallinen osa valvomoympäristöä, erityisesti työpisteisiin perustuvissa valvomoissa, joissa videoseinillä on tärkeä osa oleellisen tiedon esittämisessä.

Projekti asiakkaiden kiinnostus on kasvanut suuresti videoseinäratkaisuja kohtaan. Tästä syystä on todettu tarve tutkia mitä vaatimuksia ja asioita pitää huomioida kun rakentaa videoseinäsovellusta. Tässä opinnäytetyössä suoritettiin myös käytännön testaus videoseinäsovellukselle, joka oli rakennettu Matrox Mura-videoseinäohjainkorttien ympärille.

Työn tulokset osoittavat, että parhaiten videoseinän ominaisuuksia pystytään hyödyntämään kun esitetään yleiskuvaa, joka tukee päätöksentekoa, niin kuin myös muuttuvaa informaatiota sekä esittää hälytyksiä ja vikoja tavalla joka on helppo havaita. Videoseinän tärkeä ominaisuus on myös auttaa käyttäjää saamaan nopeasti tarvittavaa tieto käyttöön sekä tukea käyttäjien yhteistoimintaa antamalla tietoa mitä muut käyttäjät samanaikaisesti tekevät.

Avainsanat Videoseinä, Matrox Mura, LCD-näyttö, Käyttöliittymä

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ABSTRACT

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The project customer's interest has increased towards video wall solutions. For this reason, there was a need for investigation, which studies what different requirements and things have to be taken into account when building a video wall solution. In this thesis the objective was also to carry out a practical test with a video wall solution, which was built around the Matrox Mura video wall controller board.

The thesis results shows that the efficient way to benefit from video wall features is when it is used for supporting the decision-making process by providing an overview of the task, as well as changes of the information, faults and alarms in a way that it is easy to detect. Also, the video wall helps the user quickly to move to desired data as well as to supports collaboration and co-operation by providing information about what others operators are doing.

Keywords Video wall, Matrox Mura, LCD-display, User interface

CONTENTS

TERMS AND ABBREVIATIONS

CPU	Central Processing Unit
cd/m^2	Candle-power per square meter
DVI-A	Digital Visual Interface-Analog
DVI-D	Digital Visual Interface-Digital
DVI-I	Digital Visual Interface-Digital and Analog
DIP	Dual in-line Package
HVDC	High Voltage Direct Current
FACTS	Flexible Alternative Current Transmission Systems
SCADA	Supervisory Control and Data Acquisition
LAN	Local Area Network
IED	Intelligent Electronic Device
RTU	Remote Terminal Unit
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
ArcM	Arc per Minute
LCD	Liquid Crystal Display
VGA	Video Graphics Array
GB	Gigabyte
MHz	Mega Hertz
Hz	Hertz

HMI	Human Machine Interface
RGB	Red, Green, Blue-color code chart
PCI	Peripheral Component Interconnect
IP	Internet Protocol
iOS	Apple’s mobile operating system

LIST OF FIGURES AND TABLES

1 INTRODUCTION

1.1 Thesis Topic And Work Structure

This thesis has been ordered by ABB Substation Automation Systems.

Nowadays, video walls have become a regular part of the control room environment, especially, on workstation based control rooms, where video wall has important part presenting essential information. The SCADA project customer's interest towards video wall solutions has increased. For this reason, ABB was interested to do an investigation, which studies what different requirements and things have to be taken into account when building a video wall solution and do a practical test with a video wall solution which was built around the Matrox Mura video wall controller board.

The purpose of the thesis was to investigate what have to be taken into account when building a video wall solution and how a chosen solution affects the final result. The practical test section studies the compatibility of the equipment and different video wall controlling solutions. The practical testing mainly focused on the equipment compatibility and usage of the Matrox Mura video wall controller board.

The structure of the thesis is the following: Chapter 2 introduces SCADA and MicroSCADA in brief. Chapter 3 discusses the theory of usability and user interface. It includes among other things the definition of usability and criteria for a good user interface. Chapter 4 is about the control center and video wall designing, which involves designing guidelines, ergonomics and content specifications. Chapter 5 introduces the video wall systems and its benefits and disadvantages to the user. Chapter 6 is about practical testing. Chapter focuses on test arrangement, hardware solution and different controlling software.

1.2 ABB

ABB is a multinational corporation which operates mainly in the power and automation technology areas. ABB was founded in 1988 as a merge of Asea and Brown, Boveri & Cie. The ABB Group companies operate in 100 countries and in 2011 employed 133,600 people. Since 2008 the group CEO has been Joe Hogan and the company's headquarters are located in Switzerland (Zurich). In 2011 ABB revenue was 40 billion US dollars. /1/

In Finland, ABB operates in over 30 locations; there is production in Vaasa, Helsinki and also Porvoo. ABB Oy’s core business is on power products, power systems, discrete automation and motion, low voltage products and process automation. The following products and services are manufactured by the above-mentioned factories: motors, special transformers, low-voltage and switchgear, medium-voltage products, power transmission and distribution systems, power generation systems, industrial electrification and projects, electric machines, drives and marine. In 2011 ABB Finland employed over 7000 people and the revenue was 1, 7 billion Euro./2/

1.3 Power systems

The power systems division delivers solutions across the power value chain. This includes system solutions for power generation, transmission technologies, such as HVDC and FACTS, substations and distribution technologies for network management. The scope of a typical turnkey project includes design, system engineering, supply, installation, commissioning and testing./1/

2 SCADA AND MICROSCADA

2.1 SCADA

SCADA, Supervisory Control and Data Acquisition is type of industrial computer software that is also known as PC control room system. SCADA is not a full control system, but more focused on the supervisory level for example measurements and gathering information. The SCADA software contains a central host or master, one or more field data gathering and control units or remotes and a collection of standard and custom software used to monitor and control remotely located field data elements. The software is usually used by various industrial fields such as electricity and natural gas utilities, water and sewage utilities, railroads, and other critical infrastructure organizations./4/

SCADA consist of Master Terminal Units (MTUs) which the operators utilize to monitor and control a large number of Remote Terminal Units (RTUs). SCADA equipment, such as switches, can be linked to provide real-time monitoring and control. Communications may be via a local area network (LAN), and is reliable and high speed (the most still using radio via 9600 baud). The SCADA system gathers information, such as where has fault occurred, transfers the information back to a central site, alerting the home station that the fault has occurred, carrying out necessary analysis and control, such as determining if the fault is critical, and displaying the information in a logical and organized fashion. Briefly, the SCADA system monitors the behavior of the process, and performs inspections and historical data. However the most important feature is the event list and processing. /4/

2.2 MICROSCADA

MicroSCADA is software which is designed to monitor and control in real time the primary and secondary equipment’s in electrical power transmission and distribution substation. With MicroSCADA different objects, for example circuit breakers, disconnectors and tap changers can be controlled. The software also

allows creating additional control functions. The software interacts with protection and control IEDs, and also the, process via the operator's workplace. The software gives right tools to correct actions and helps to maximize the usability of power system. MicroSCADA is compatible with the IEC 61850 standard for substation automation. It can operate together with IEC 61850 compliant IEDs, tools and systems./19/

The software package contains engineer tools set, connectivity packages libraries including symbols and control dialogs. The program gives possibility to access parameter settings and handle disturbance information in IED's. The MicroSCADA system utilizes and process important information. Important data collection is supported by a program classification and prioritization function. For example, intuitive and consistent icons with selectable and pre-defined color schemes enhance the comfort for the operator, which is significant part of the process observation. The meaning of the symbols and colors explained later in the thesis./19/

3 USABILITY AND INTERFACE

3.1 Usability

Usability describes the ease of use to achieve set objectives. The object can be accessory or other manufactured item, service, environment or measurement method for accessibility. The production environment, usability refers to system technical performance and functionality of degrees. /21/

Usability refers to how well the application meets the user expectations for a particular task, and as well as what kind of skills its use requires. Briefly, usability describes how well the user is able to use the product and how user will be able to use the application effectively to achieve the objectives./21/

3.1.1 Definition of Usability

This chapter discusses the definition of usability through ISO standard 9241-11 and Jakob Nielsen's theories. These two sources are considered pioneering and the most obvious source of defining usability.

Jakob Nielsen (1993) describes usability as follows: "Usability is not a single, one-dimensional property of a user interface. Usability has multiple components and is associated with five usability attributes: Learnability, efficiency, memorability, errors and subjective satisfaction." These usability attributes will be clarified in the following sections./21/

Learnability

Learnability is to some extent determined to be most readily definition of usability, since all computer programs should be easy to learn, and because the majority of the cases, the first experience with new hardware or software is learning how to use it. Of course, there are computer programs that need plenty of exercise, but in most cases the user interface should be intuitive. Easy learnability points out the novice user's experience in first part of learning curve. A highly

learnable system has a steep rise in the first part of learning curve and it helps the user achieve a moderate level of learning in short time. In practice all user interfaces learning curves start with the user being able not to do anything on timeline zero. These above-mentioned issues are presented in Figure 1./21/

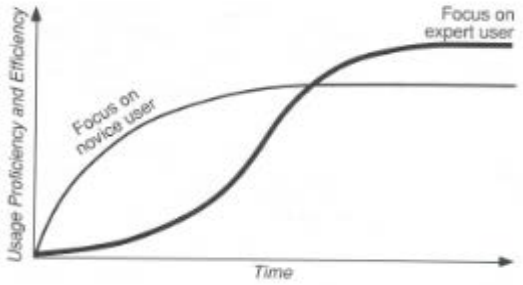

Figure 1. Usability learning curve./21/

When analyzing learnability, it should be taken into consideration that normally the user does not fully study the interface or software before taking it into use. Accordingly, the user usually begins using the software or interface when he has learned some part of the software./21/

Efficiency of use

The learning curve steady-state refers the expert user's performance efficiency at the moment when curve flattens out (see Figure 1). It also has to be noticed that user can take a long time to achieve the peak of performance. Also, some users will continue learning indefinitely in addition to use, but there are also users whose development level starts to decline or remain the same after they achieve certain level./21/

A typical way to measure the efficiency of use is to define some level of expertise, and measure how long it takes for the user to achieve this level on test task./21/

Memorability

The software should be easy to remember, in a way that when an ordinary user returns from a longer break, the person does not need to study the software again.

A large improvement in learnability also usually helps the memorability of the user interfaces./21/

Interface memorability is rarely tested as thoroughly as the other usability attributes, but there are two ways of measuring it. First is to perform a (standard user test) test with casual users who have been away from the system for a specific amount of time, and measure the time they needed to perform test task. Alternatively, it is possible to conduct a memory test with users after they finished a test session with the system and have them to explain the effect of various commands or to name the command that does a certain things. The interfaces score for memorability is then the number of correct answers given by the users./21/

Errors

Using the system the user should make as little mistakes as possible. Typically, an error is counted every time when any action does not meet the desired function and the program error rate is defined by the numbers of errors when making a specific task./21/

“Simply defining errors as being any incorrect user action does not take the highly varying impact of different errors into account.” Some of the errors the user is able to correct right away and they do not harm the software or the process itself, the effect is only on user efficiency. Such errors do not need to be counted separately, because they should be better taken into account when measuring effectiveness than error receptivity./21/

Some errors are much more catastrophic in nature, because either the user does not notice them, and the result is an incorrect, or it destroys the user’s work, which is difficult to restore. Such errors should be counted separately from minor faults, and special action should be taken in order to minimize their influence./21/

Subjective satisfaction

"The system should be pleasant to use, so that users are subjectively satisfied when using it."/21/

The user's subjective satisfaction can be measured simply by interviewing the users about their experience and satisfaction about system. From the single user's perspective, the answers to such questions are subjective, but when the numbers of user's answers are averagely consistent, the result is the objective measure of system satisfaction./21/

3.2 User Interface

This section discusses the user interface generally from the control room automation point of view and all examples are about control room solutions.

The interface (which named HMI in SCADA systems) or user interface is software, device or any other part of the product that allows a user to use the product. Messages and practical component part such as menus, buttons and screens consisting of package can be called as a user interface. The software product know-how is based on the interface detection and understanding. In order for a person to interact with the machine, he has to also understand the user interface, as well as able to interpret the verbal, visual and vocal messages. /9/

The use of speed combined with necessary amount of the directions of use; is a good measure of the level of the user interface. /9/

3.2.1 Interface

The user interface is a set of two-way interaction channels, the manifestation of which is for example information and control options on the display panel, process space or visual contact with outdoor region and hearing voices from the area, monitor lamps, control switches and telephones. The display page is a typical interaction channel in an information technology applied automation system. The above-mentioned elements are also great ways for a designer to

create a good user interface. This is the reason why the designer should be familiar with the mentioned possibilities and limits of the elements. /9/

User interfaces are different from each other to some extent, but there are also a lot of common features and concepts. There are also different standards to unify the different user interface types. Work desks, screens, display systems, alarms and events, history and reporting tools, collaboration tools and instructions are typical interfaces related concepts. Under this paragraph Figure 2 describes the interaction channels of the user interfaces. /9/

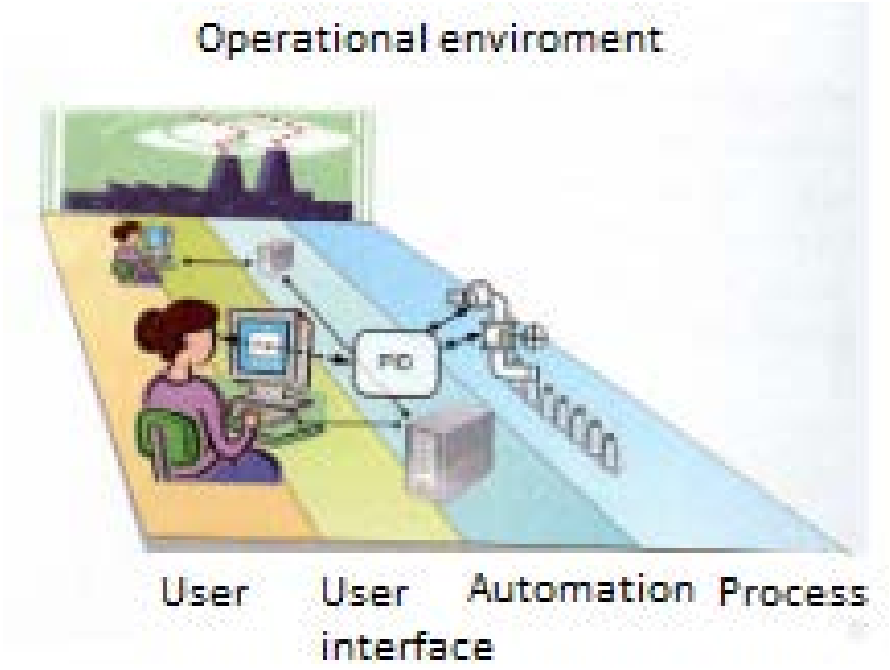

Figure 2. Interaction channels of user interfaces. /9/

3.2.2 Criteria for a Good User Interface

Designing a good user interface for control environment causes some problems. The biggest problems are caused by the contradictory of the requirements and recommendations. An example of above-mentioned inconsistency is when efficiency advocates simplicity of the appearance and operation, whereas learning ability and safety calls for more operation steps, which in turns reduces the efficiency. There is not a single correct solution to the conflict, but when making a

solution attention must be paid to the operator's characteristic and intended purpose. The good user interface features are listed below which are based on the principles of basic usability. /9/

Criteria and Outline

Especially the main controlling page or so called process page of the user interface should be clear and easy to understand. Clarity is formed on how fast and well we are able to perceive the screen. Perceive follows certain principles that are good to take into account when designing a user interface. General and key information should be placed in the upper left corner, because the person will read/decode information at reading direction, for example western people from the top left to the bottom right. Instructional horizontal and vertical lines can help reading and decode display page. The upper edges and the left sides of the elements should align, because the reading direction gaze collides first at top and left sides of the text. /9/

The user looks relevant information from the content. For this reason the display page should be divided into sections relevant to the job. Close one another existing objects are perceived to belong together. Visibility can be highlighted, for example by leaving empty space between the elements; in this way relating to the same entity separated from the adjacent entity. /9/

The colors are a strong factor in perception, but can also break grouping reached by the positioning of elements. The display page colors should be used in small amounts and consistently, also the colors should be subdued. Excessive use of bright colors makes the page look cluttered. Too much of emphasis causes so called Las Vegas phenomenon, which means when over-emphasizing, it affects the way that nothing stands out. For example, commonly used red or yellow for detecting exceptional circumstances and consideration would be much more difficult if many different strong colors were used as well. /9/

Reliability

The most important factors of the user interface clarity are information, simple readability and easy identifiability. Reliability is accomplished by sufficient size, clear style, right choice of colors as well as a sufficient contrast with background. /9/

The standard ISO 9241-3 instructs of the size of text in relation to viewing distance. The text readability depends on the selected font. Different kind of display device has to take account when selecting the font and text size, for example wide screen displays and laptops. The accuracy of laptops and wide screen displays can differ significantly from the control room or the designer's own screen. /9/

Characters and symbols need to stand out from the screen background. Nowadays, when the devices are of high resolutions and the display has flash-free surfaces, background colors are recommended to be light colors. By far most reliable solution is considered black text on a light color background. /9/

A human being is not able to recognize and remember multiple shades, and therefore it is recommended that not over seven relevant colors in addition to black and white shades are used. In the design of the user interface the possibility of the user's color vision impairment must be taken into account. This means the information must stand out more than color. The standard ISO 9241-12 explicitly instructs not to use only color-based expression. Examples of a proper way to increase the visibility are using text or symbol background fill color, change of brightness or change of the form of symbols. The ISO 9241-12 standard explicitly says that the only color-based mode of expression should not be used. /9/

Identify, consistency and distinctiveness

Displayed information must be easily identified and understood. For example, symbols which are presented as part of process or equipment are recognizable based on shape, color, size and mutual location. Information should be presented as same as possible in all contexts in which it occurs. This means, for example a

graphical characters, colors, terms and operating principles. On the other hand, two separately different things have to be presented in a clearly different way. Graphical symbols should be easily recognizable, which is why it is considered to be a good solution to use established symbols on basic shapes, such as a circle, square and triangle. The best way they can be distinguished, when many properties differ from each other at the same time. /9/

With uniformity, the interface creates clear rules for the user, and facilitates learning. However, these rules should be of limited amount. This kind of uniformity creates the user's expectations, which makes work efficient and pleasant. /9/

4 DESIGNING VIDEO WALL

4.1 Designing Guidelines

The video wall should help the user to quickly perceive relevant objects. Certain requirements have to be set when planning displays for the control room, which makes possible for the video wall to present a good overview of task. For a start, information has to focus on the essential so that it serves its purpose, even if presented in a small place. Secondly, information has to be of general concept. Details can be left out but information should be presented in such a way that it tells the state of process in a relevant way. Thirdly, the video wall must contain information on the changes and the direction of changes. Overall, it must contain information that helps the user in each operation. Therefore, the video wall should help the user to constantly monitor how the task is processing, and at the same time when the user's concentration is oriented on some other task. /10/

An overview picture on the screen also has special function. It should help the user to perceive, where they are in relation to the so called information space. It should be like a map, which tells the user location, where the user is coming from and where it could access. In order the overview picture display to show this function, it should be satisfyingly linked to other displays. It should give tips and remind the user, to which place it can move, and help the user to connect and insert information while moving between the screens. In order the overview screen to serve this task, it should be on sight all the time and offer relevant information on the other task views. /10/

Key issues, which concern the video wall designing, are its shape, number of displays, layout, way of interaction and amount of displayed information.

When designing the video wall one has to think how many displays are needed on the wall. The number of displays depends on among other things process complexity, visibility and also the user's wishes. The number of displays

information details depends on the screen size and also the distance between screen and workstations./10/

The video wall should among other things support natural interaction between the users and also smooth transmission from one action to other. Also they should allow the users alignment on the wall, which support work execution and provides many users to use the video wall at the same time.

4.1.1 Number and Placement of Displays

In order for the video wall to be able to support control room operations, the size of the wall or the number of displays has to be sufficient. Many control room operated processes are complicated, and that is why the video wall should be large enough to display information clearly and with enough details. No specific recommendation of the video wall screen size or numbers of screens are defined in literature, but the decision is usually made case by case basis. /10/

When considering the distance of the screens from the user, it should be taken into consideration, which kind of information is displayed, how operators use information, how the users are placed in relation to the displays and if the part of information presented on the video wall is also on workstations desktop. The screen should be sufficient to the user, so that the image details can be seen clearly. On the other hand, the screen should not be too close to the user. The recommended minimum limit is half of the screen height or width, depending on whichever is the larger. /10/

The room height generally can be the first limiting factor on the monitor placement. The screen should not be too high, so that the user does not have to look up, but also on other hand it is important that the screen is high enough, so the user has a clear view to the screen from all over the control room. /10/

The screen should be set in front of the user workstation, so that the user’s gaze is perpendicular to the screen. Certain operator required information should be placed, so that operator does not have to look too much to the side. This can for example distort the picture dimension. If a high-reflectance display is used, and it

is viewed from the side it may also decrease the brightness of images, and also colors may become distorted. Literature recommends that the maximum deviation from the perpendicular direction would be 10-30 degrees. A curved video wall can help the user to utilize information more efficiently on the edge parts of wall. /10/

4.1.2 Contents

The video wall should support for decision-making and perception memory of process. The principle should be, that the video wall shows information for example alarms, but it does not show information details like for example reasons for the alarm. Normally task-specific information is shown on the operator's own workstation display. However, task-specific information can be shown on the video wall if it helps to coordinate tasks or if it is suitable for the used software. /10/

At least one video wall screen should display an overview of the most important tasks, without the user having to move to another window. The information of alarms and systems status should be graphically shown in the overview image. The state of system devices or components should also be shown on the video wall overview image. The video wall should also have area, where the user can open or remove windows and navigation links to other available windows. The operating list can also be shown on the wall, where instructions for particular task are. /10/

The objective of the video wall design should be the uniform information presentation would be uniform. Not too much information should be presented on the display in order not to lose clarity. An important factor is also that all users can see alphanumeric signs and graphic symbols on the video wall, despite where they are located in the control room. It is recommended that the minimum size of alphanumeric signs size would be 14 ArcM, but in average the size should be 22 ArcM. The above mentioned details are literature values. When designing the size of alphanumeric signs size, should also take into account the operator's distance from the wall should be taken into account, as well as viewing condition. The luminance of characters should be 17-70 cd/m^2 and brightness contrast at least

1.5:1. These features can be commonly justified (character luminance and bright contrast) in different displays and for example, the background should be of neutral colors if the color code is used. The visual display information will be discussed more in the following chapter. /10/

4.1.3 Content Management

The video wall display management should be executed in a way that different user interaction can be carried out as flexible as possible. Essential management related issues are for example, how many operators are in interaction with the display at the same time. This affects the decision which user interface solutions are selected. For example, the number of simultaneous video wall users determines the number of used cursors. In case where the solution is able to show separate windows, various users can operate displays at the same time, provided that actions are directed to separate windows. /10/

It is important that a single user has the main responsibility for what kind of content is shown on the video wall. The interaction should be as easy and natural as possible, because the video wall user's attention is only partly directed to the data presented on the video wall. /10/

Information transfers from the workstation displays to the video wall and back should be made as easy as possible. The user should have a possibility for example to transfer certain items to the workstation display with a mouse. The cursor detecting and movement to a different place should be facilitated in all possible ways, for example by growing the cursor size. /10/

4.2 Ergonomics

Ergonomics concerned the interaction between the worker and the job. The easiest definition of ergonomics is "the application of human sciences to the optimization of peoples working environment". Ergonomics gives tools to improve the match between the task and user's physical abilities, information handling and workload capacities. /8/

A variety thing has to be considered when designing a control room taking ergonomics into account. Display solutions are in a big role when designing control room ergonomics. Visual and anthropometrical issues have to be considered. Regarding eye height, for example, it has to considered if the displays are viewed standing up or sitting down. “Eye height measurement and the cone of vision will help determine the proper display location”. Human biomechanics has important role when designing ergonomic issues. /22/

4.2.1 Human Biomechanics

Human field of vision is averagely 160° horizontal and 80° vertically. However, human vision of fine detail is only about 1°. Human viewing is divided into two parts. The first one is what can be seen by the central part of retina which is referred to as foveael vision and the other one is what can be seen by the rest of the retina, called as peripheral vision. The peripheral vision is sensitive to flicker and motion. Angular magnitude measures the visual field, which describes the space the human eye is able to see, when the head and eye are absolutely still. The central field vision is 60° in both directions, which is indicated in Figure 3. In this field, sharp images are transmitted to the brain, depth occurs and color discrimination is possible. As previously mentioned, the sharpest focused area is proximately 1 degree either side of the sight line. Colors begin to disappear between 30° and 60° off the line of sight. As following picture shows, the line of sight is horizontally on 0°. However, human natural line of sight is below the horizontal line depending on the individual and whether the person is standing or sitting. /22/

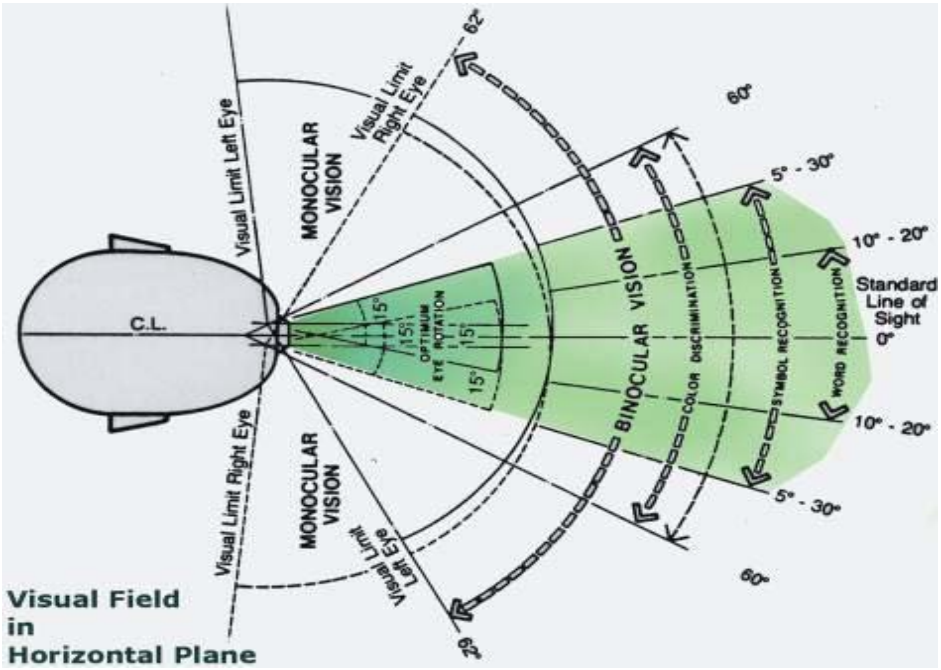

Figure 3. Visual field in horizontal plane. /22/

The distance from the floor to the center of the person's eye is so called sitting eye level. When planning the displays height, it has to be remembered that the smallest user must be able to look over workstation and see bottom of the display wall. Figure 4 shows an example of a sitting person eye height and eye visual limits. /22/

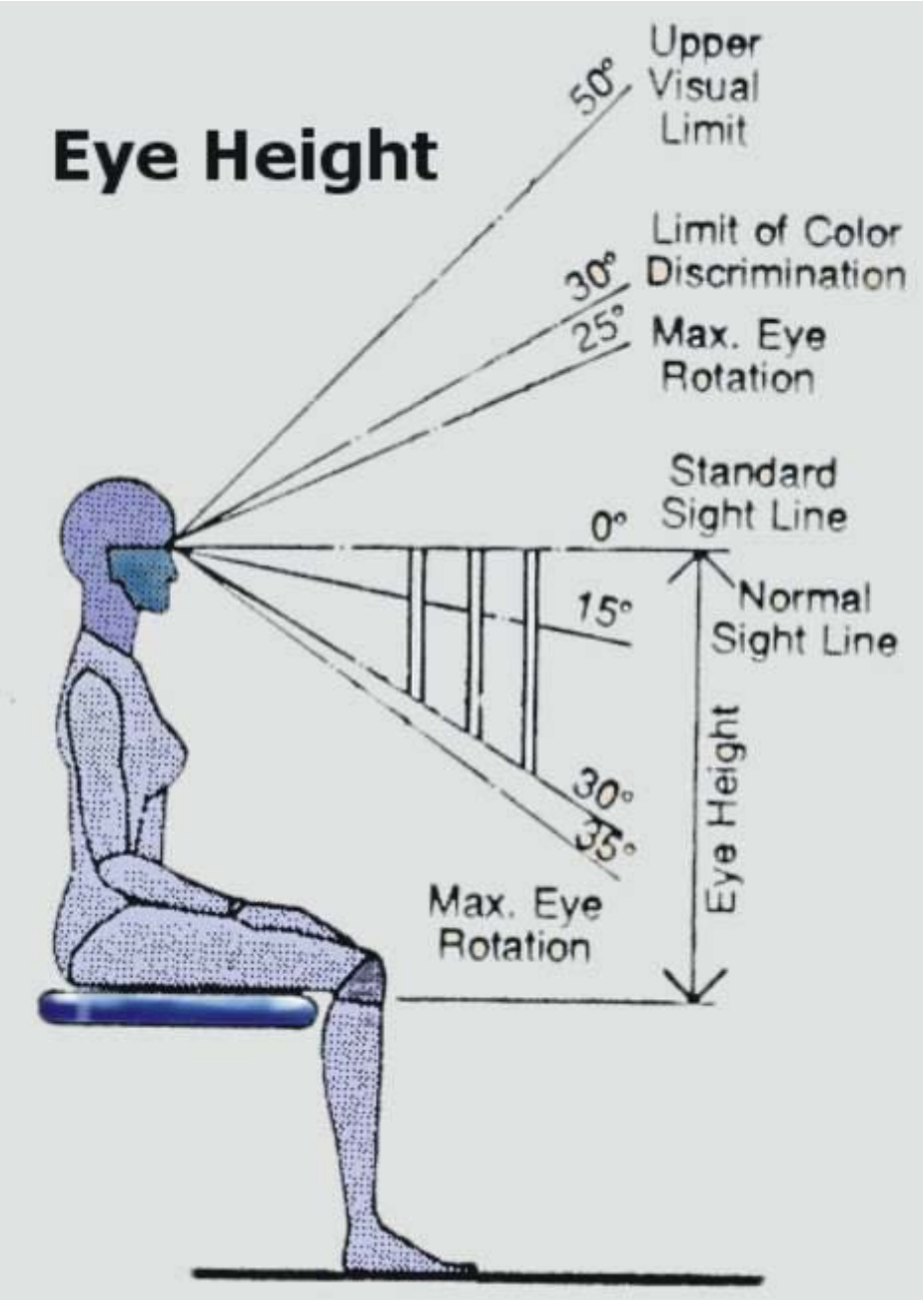

Figure 4. Sitting person eye height and visual limits. /22/

4.2.2 Visual Design

Designing large screen displays requires information on the content and graphic style of the displays. The optimal viewing area is based on displaying the same information that would be viewed on a desktop monitor. For example, a 20 inch display should to be viewed from 33 inch (0.8 meter) distance. Viewing areas for the video wall displays would be counted using the same proportions. /22/

The best way to create legibility is create strict criteria related information, and then create displays based on these criteria. For example, better legibility can be established by minimum text height for different types of messages, recommended colors, fonts, spacing between lines, and arrangement on the screen and so on. /22/

In the following paragraphs different ways to influence visual side of displays is discussed. Below listed literature values are defined on 6 meters viewing distance.

4.3 Content Specifications

4.3.1 Resolution

The amount of needed resolution depends on the viewing circumstances. Normal human eye sight can resolve items separated one minute of arc (minute of arc is unit of angular measurement equal to one sixtieth of one degree ($^{circle}/_{21,600}$), or ($^{\pi}/_{10,800}$) radians). With this information the required resolution can be determine for viewing display at a particular distance and find out the right minimum character size. Figure 5 shows an example of one arc minute sight range. /22/

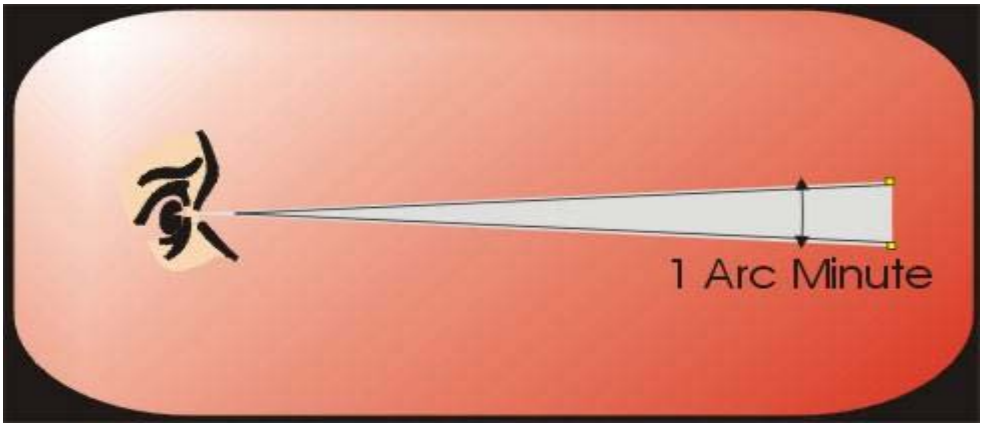

Figure 5. Normal human eyesight resolve items separated one arc minute. /22/

4.3.2 Character Size

Ten minutes of arc is the minimum subtended angle for a character to be viewed on the display. The smallest pixel subtends 1arc minute, but the minimum should

not be used in practice when the information is important or when the display is viewed for long periods. The recommended ArcM is 14-22, width to height ratio 0.75 and the ratio of height to thickness between 10:1 and 6:1. The character size can be determined by using the formula X=2*Y*tan(ArcM/120), where X is the character size and Y is the viewing distance, for example using 18 ArcM, the viewer from 6,1 meters requires the character height of (minimum) 1,26 inch. From a three meter distance the 30 mm size character can be seen but from 5.5 meter distance the same size character becomes a strain to look. When the amount of information needed to display at the same time, which is needed to display at the same time, exceeds the wall capacity, it becomes necessary to increase the number of displays. Figure 6 shows an example of the character size. /22/

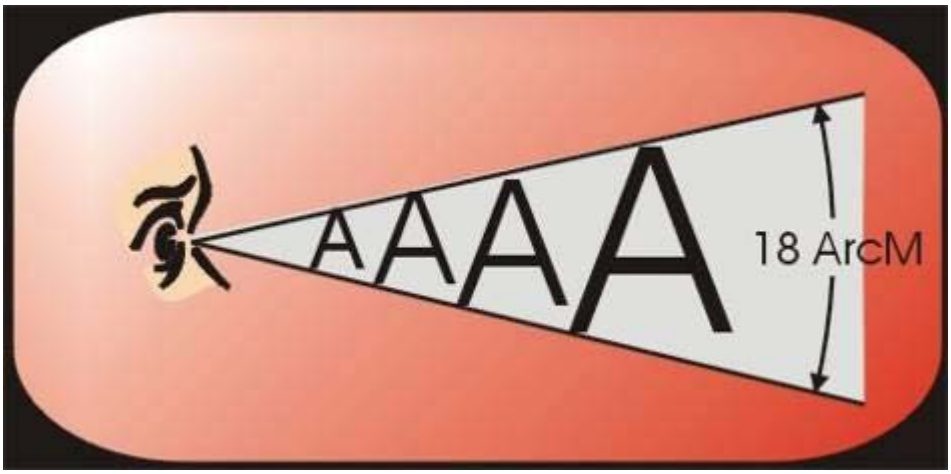

Figure 6. Example of character size. /22/

4.3.3 Contrast and Format

94% is the optimal characteristic contrast but 90% is still acceptable. /22/

Text paragraphs should be displayed in columns that are max 12.12 cm wide. This arrangement helps reading process. Wider columns cause difficulties to read text from line to line. /22/

4.3.4 Color

Using colors can be an effective way to provide contrast, variety or by coding purposes.

It is advised not to use high intensity colors on the video wall, for example as backgrounds colors and filling maps. Information on map should be displayed with high intensity colors. Used colors should be chosen depending on the message. For example, red should be used in critical tasks and green on normal situations. Also have to consider cultural differences when choosing used colors. Many cultural differences exist on perceived color personality, meaning, and preferences./22/

4.3.5 Brightness

To ensure legibility there must be a visual contrast between alphanumeric characteristic and background. Under normal conditions dark characteristic against light background should be used. When devices are in dark environment, light characteristic should be used. The character should be twice as light or dark as the background. The significance of the contrast is more all the more important when the observer has impaired vision, if viewing conditions are difficult or the user is under high physiological stress. Nowadays, in some displays (for example Samsung UD55A display) has the night and day mode where the display automatically inverts the display brightness depending is it night or day. This mode should be considered to be used when displays are used in darkness and when interference with the user's night vision is an issue. /22/

5 VIDEO WALL

5.1 Introduction of Video Wall

Large format displays, or so-called video walls are different kinds of video projector systems or large walls, constructed of many small LCD displays, in which the information is provided to multiple users simultaneously, and content can be modified and changed, for example by using a mouse. Video walls have become common display solutions in control room environments. They can be used to show information, for example systems key parameters, such as trends and alarms.

The video wall can reduce the tunnel effect, which is a result of the use of workstation and in that way help users to maintain an overall picture of the operation better. As the video wall shows the main parameters of the process and the status of devices for all operators simultaneously, it gives an idea what other operators are doing in the process at the same time. Thus, the video wall can improve the interaction between operators, co-operations and also communication.

5.2 Definition of Video Wall

The video wall generally means a physically large wall display, which is a projected image from the front or back. The video wall can also be built by combining several smaller screens. These integrated displays can, for example, be ordinary LCD displays. When the desktop monitor picture is reflected on the video wall, the picture is larger in size but has a lower quality than the desktop screen, because the number of information is the same on both screens. However, by merging LCD screens, a video wall can be built, whose information amount is truly higher compared to normal screen image. Video walls or so called large format displays can be divided into different class, by following features such as image quality, user and viewer distance and level of interaction. Table 1 shows the above mentioned division. /10/

Table 1. Large format displays, classified by display quality, location and the mode of displays interaction. /10/

Image quality	2D-displays, with mediocre resolution	Screen produced with a single projector
	2D-displays, with a good resolution. - Screen produced with multiple projectors.	2D-displays, with a good resolution. - Display modules, build combining LCD displays
Display location	Displays relatively far from viewer.	
	Displays relatively close to viewer.	
	Peripheral displays	- The user surrounded displays (ambient). - Alarming displays.
Way of interaction	Screens for only viewing	
	Interactive displays	Embedded screens Separate displays - Whiteboards - Tabletop displays
	Integrated systems	

Video wall can be divided in to two main groups, image accuracy to average displays, where the image is produced with a single projector and also screens with high resolution image. The second group includes among other things, modules built of several LCD screens and systems where the screen is produced by multiple projectors. The video walls can also be divided to two groups according to their ability to create a three-dimensional effect or not. /10/

The screens in second group have characteristic that the resolution of the images is the same on each point of display wall. Instead, the picture resolution of so called mixed form displays is higher in areas where the user wants to see more details. The advantage of such a solution is the easiness to observe desired information, because this solution displays more closely the area where the user is likely to focus its attention. Such mixed displays can be divided into several categories based on which technology is used to improve the main area screen accuracy in the displays. More specific information can be displayed on mixed displays, for example, information in smaller separate boxes, which appears on top of the main screen. Part of the view can also be presented in an enlarged size in the same window. So called peripheral displays form their own group; they are not intended to be in the user attention all the time and can be far away from the user. Peripheral displays can be divided into two groups: user surrounding screens, which all the time shows the certain state of information system and which the user may, if necessary, to follow it without interfering the main task. Cautionary and alarming indicators, alert the user of the certain state of situation, and force the user to direct their attention to it. Often peripheral systems are also based on sound and touch information. /10/

The video walls are used in different ways. Often, the video walls are simply information presentation platforms, which are intended for passive viewing. However, in work environments it is important, to be able to influence the content of the video walls, for example, transfer table displays image to the video wall and back, or make controls through video wall. Interactive displays can be divided to three different groups: embedded displays, where display is the largest part of the physical state, interactive displays, which are positioned to existing facilities and

integrated systems, which are used parallel and consists of several displays of different size. /10/

Figure 7. Example of a video wall built by four narrow frame LCD's. /11/

Figure 8. Example of front projected video wall system. /18/

5.3 Benefits and Disadvantages

5.3.1 Usefulness

In examining the usefulness of large screen displays, the question arises if the benefit is only on the bigger image size, or if it is also due to the fact of larger amount of information or pixels. When the computer image is projected on the

wall with a single projector, the image is bigger in size, but the amount of information stays the same. If several projectors are used or a wall built from the number of LCD displays, the image is not only larger but it also contains more pixels. Studies have shown improvement on different tasks when using video walls. The video wall improves, for example, recognition memory (the ability to maintain certain observation image) and awareness of information on the peripheral vision area, performance on multi-task environment, utilization on complex data visualization as well as situational awareness. The reason for improvement on situational awareness may simply be result of shorter execution time on secondary tasks, because information can be represented more at the same time on the video wall, the user does not need to scroll the screen, open multiple windows or move the screen to the other. The video wall can improve to some extent the team work and co-operation between people. Because the video wall can present information concerning the state of the systems, it can encourage people to discuss more with each other. With the help of the video walls shift changes and work meetings can be supported. /10/

In summary, the above mentioned studies shows the usefulness of video walls in different tasks. However, the task performance may not necessarily improve all that much. /10/

5.3.2 Utilization of the Display Surface

As mentioned previously, the information amount does not increase, when the desktop PC image is projected on a wall. The amount of information increases only if the screen resolution is improved. A human eye sets limits on the display accuracy. The distinguishing ability of the human eye depends on the viewing distance and the amount of the light. Also, the distinguishing ability of the human eye is more accurate in the middle of sight and lower on the periphery. When designing or updating video walls, it is important to take into account at which point the resolution improvement of the display is useful and when not. Large part of the video wall information is lost, because most of the video wall content information remains in the region, where the ability of the human eye to receive data is low. /10/

A human being cannot deal with all the observational information what it sees at the same time. When the size of video wall screen increases or more screens are installed, with one glance the user cannot get more information than earlier. The user has to move his eyes and turn his head to receive more new information, which can strain the user physically, but it is still a more efficient solution compared to scrolling the screen or moving from one screen to another. Usually the information presented on the video wall does not differ visually from the information presented on smaller screens. It might be useful to shape the video wall content in light of human vision characteristic; for example, on the edge of the display, the information should be larger than information on the central part of the display. /10/

5.3.3 Usability Problems

Multiply research shows the usefulness of video wall solutions in different tasks. The biggest problem in a video wall solution appears on its usability and ergonomics. /10/

The main ergonomics problems in the video wall are that they are big, placed high and are viewed from a relatively far distance. A good example of this kind of a problem is a control room situation where the operator uses video wall and workstation display simultaneously. When the operator needs general state information of the system, he/she uses the video wall and the workstation display when looking more detailed information. The continuous gaze may strain the operator’s eyes and decrease the concentration. /10/

The bigger the increase in the screen size, the more difficult it is to find the desired information or combine the information of several displays. The user can, for example, be difficult to compare two cases, whose relevant information is located far away from each other. The problems increase if the user moves closer to examine the situation. /10/

The video wall consisting of several LCD screens has specific problems. Discontinuity can occur in the border points of the displays picture, which may be

experienced as disruptive. Also the cursor movement may be different than the user assumes, when moving the cursor to the next display. /10/

Problems related to the video wall configuration are bigger than with screen of physically smaller size. The above mentioned problems are mainly in the system management of video walls built of separate screens. For example, removing one screen in many cases requires the reconfiguration of the equipment. /10/

Despite some technical problems and improvements, the largest problem is related on the user habits. The function of the video wall is to support the user's co-operation, but still the users may not necessarily work together on the video wall and so the video walls co-operation supports remains unused. /10/

6 PRACTICAL TESTING

The purpose of the test section was to examine the equipment and software which were used on the video wall. The testing focus was mainly on the functions of the Matrox Mura board but also compatibility of the equipment, usability and what kind of issues turn out during the testing.

The testing module consist of two Matrox Mura MPX-4/4 video wall controller boards, Dell Precision T3600 computer, Sony snc-ep ip-camera, Dell Optiplex 3010 and Apple iPad. The video wall was built up of 8 pcs 24” Lenovo LCD screens. More detail information about the equipment is given in the following paragraphs. Figure 9 shows the hardware setup which used in the video wall in the thesis.

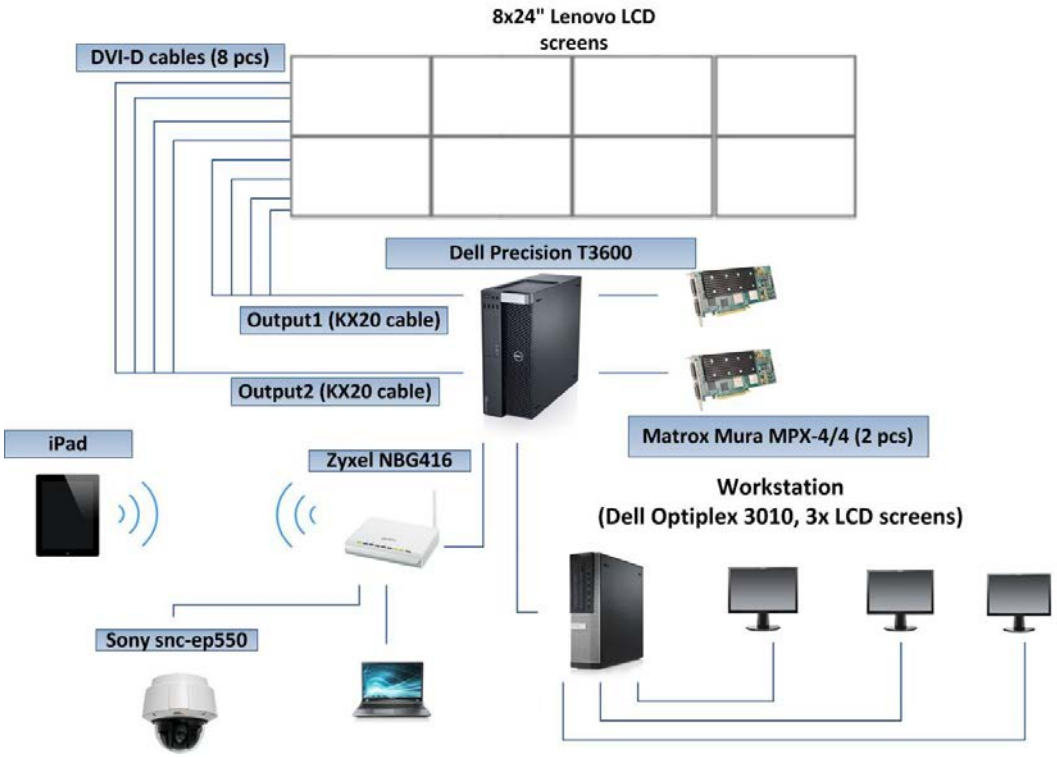

Figure 9. Video wall hardware setup.

6.1 Hardware

6.1.1 LCD-Displays

The video wall for practical testing was built up of 8 pieces of 24” Lenovo LCD screens. Normally when building a video wall of LCD screens, the displays are larger and with a narrow frame. The Lenovo screens were selected for this thesis, because they save space and costs compared to bigger LCDs and it is also possible to simulate and test everything needed in this practical testing.

The Lenovo LCD screen has a 24-inch widescreen with 1920x1200 resolution and 16:10 ratio. The screen includes VGA analog and DVI digital video inputs. Table 2 shows specific information of the displays.

Table 2. The Lenovo display specific information. /12/

Monitor size	24.0-inch (610mm) LCD
Viewable image size	24.0-inch/610mm
Maximum viewable area	518x324 mm
Native resolution	1920x1200
Video input	VGA analog, DVI-D digital
Brightness(typical)	300 cd/m2
Contrast(typical)	1000:1
Colors	16.7 million
Viewing angle	Horizontal 170 degrees (10:1 contrast ratio)
	Vertical 160 degree (10:1 contrast ratio)

6.1.2 Matrox Mura MPX-4/4

The Matrox Mura MPX-4/4 video wall controller board is designed for the management of the video wall and wall matrix. MPX-4/4 is a single-slot board which supports four HD inputs and four HD outputs on the same PCI express x16

Gen2 board. The MPX-4/4 board has an input channel support for digital and analog video signals (DVI, RGB/VGA, Component, S-Video & Composite), and it displays each signal at full true color. The MPX-4/4 video wall controller board can be combined with other MPX series cards. More specific information of MPX-4/4 board can be found in table below and the feature image of MPX-4/4 board in Figure 10. /15/

Table 3 Matrox Mura MPX-4/4 specifics. /15/

Graphics memory	2 GB
Bus interface	PCI Express x16 (Gen2)
Data transfers	64 Gbit/sec
Output formats	SL-DVI, RGB(VGA)
Input formats	SL-DVI, RGB(VGA), Component, S-Video, Composite
Output resolution	Maximum output resolution of 2048x1152 (SL-DVI), 2048x1536 (RGB/VGA) per display.
Input resolution	Maximum input resolution of 1920x1200 (SL-DVI, RGB/VGA), 1920x1080i (Component),NTSC/PAL/SECAM (S-Video, Composite) per input.

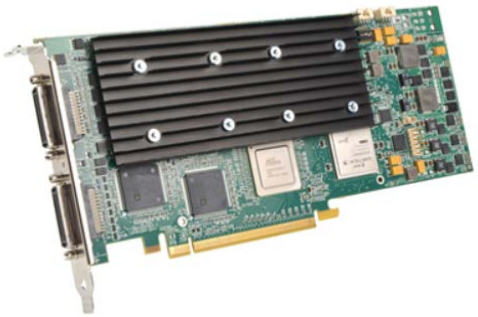

Figure 10. Matrox Mura MPX-4/4 card. /15/

6.1.3 Sony snc-ep550 ip-camera

The Sony snc-ep550 network camera was used in part of the practical testing. Usually, in these kinds of solutions network cameras or CCTV-cameras are used. The Sony network camera was chosen because of its flexible operating possibilities throughout the workstation and it was suitable for testing visual image of the camera on the video wall.

The Sony snc-ep550 network camera is connected to the network with assigned IP address and operated on the web browser. The camera needs ActiveX or some same kind of program to operate correctly and in order to get best possible image quality.

6.1.4 Computers

In this test Dell Precision T3600 and Dell Optiplex 3010 computers were used.

Dell Precision T3600 was used as a so called video controller on the test system. The Matrox Mura card was mounted in T3600 and controlled the video wall. Table 4 shows T3600 technical specifications.

Table 4. Dell Precision T3600 technical specifications. /6/

Processor	Intel XEON_8
Operating system	Windows 7 professional, 64-bit
Chipset	Intel C600 series chipset
Memory	Up to 64 GB DDR3 at 1600Mhz-4 Dimms
Hard drive	Up to 3000 GB SATA hard drive

Dell Optiplex 3010 was the chosen computer for the workstation in the practical testing. Optiplex 3010 was chosen for its performance and because it has a multiple desktop screen connection possibilities. Table 5 shows Optiplex 3010 technical specifications.

Table 5 Optiplex 3010 technical specifications. /6/

Processor	Intel Xeon processor
Operating system	Windows 7 professional, 64-bit
Chipset	Intel H61 Express chipset
Memory	Two DIMM slots, Non-ECC dual channel 1333MHz, up to 8GB
Hard drive	3.5” Hard Drives: 1TB 7200 RPM SATA 3.0Gb/s

6.1.5 Cables

The workstation displays and monitors of the video wall are connected using DVI cables. Information on different DVI cables and length etc. is given below.

DVI means Digital Visual Interface. DVI was developed to create an industrial standard for the transfer of digital video content. DVI is designed to transmit uncompressed digital video and can also be configured to support multiple modes like DVI-D (digital), DVI-A (Analog) and DVI-I (Digital and analog). /3/

DVI-D cables are used for direct connection between the source, for example video card and LCD monitors. This digital cable gives a faster image and higher quality image compared to an analog cable. The DVI-D cable improves the connection between the source and display because there is no need for the analog conversion process which lowers the connection quality. DVI-A cables are usually used when transmitting a DVI signal to an analog display. Usually DVI-A cables are used to connect a VGA device because they carry the same signal. Digital-to-analog-conversation causes some quality loss; that is why it is recommended to use a digital signal if possible. The DVI-I cable is a so called integrated cable which can transmit either a digital to digital or analog to analog signal. /3/

DVI-D and DVI-I cables are also available as single or dual link format connectors. These cables use transmission minimized differential signaling so called TMDS for transferring information. The single link cable uses one TMDS 165 MHz transmitter and the dual link uses two. A 60 Hz LCD can display a 1920x1200 resolution with a single link, and while using a dual link the displayed resolution can be 2560x1600. /3/

The maximum length of DVI cables is not specified because it is dependent on the pixel frequency and bandwidth requirements, which is the function of resolution and refresh rate. Generally, the 10 meter cable length will work for displays with 1920x1200 resolution if a proper cable is used. It has been tested that a 12 meter cable length results in an unusable image on the display and signal noise. For a longer cable length it is recommended to use a powered DVI signal booster to reach the guaranteed signal quality. /3/

6.1.6 Power Supply

The power supply must provide power for whole Mura MPX based system, including CPU, all add-in cards and any peripheral connectors. To determine the power supply size, power requirements of all devices must be considered, as well as power rails where the current is drawn.

Every power supply provides different voltages with varying load capacities, depending on system usage. For example, 12V supply can exceed 50A capacity in many mid-sized power supplies. /13/

The Mura cards are PCI Express-based, so they draw power from the 12V supply. Although an approximately 0.1A is drawn from the 3.3V supply, +12V supply rail power supply capacity must be sufficient. When selecting the power supply, it has to be taken into account that each different Mura card model has slightly different requirements on the power supply. /13/

When selecting the size of power supply, the power requirements of all devices must be added separately for each supply rail and then choose the right power supply. For example, Mura MPX-4/4 consumes approximately 3.5A from +12V supply. So, the two MPX-4/4 cards used in this test would use 7A from this supply. This +12V requirement is an addition to the pre-existing motherboard system for example CPU, motherboard, hard disk drives, etc. For example, if the system requires 15A from the +12V supply and two Mura cards needs 7A, then the power supply must provide 22A on the +12V supply rail for system to work correctly. /13/

Adequate power supplies rarely are sufficient because most power supplies operate optimal efficiency at 50-60% of their power load. A commonly used habit is to ensure that the power supply can supply beyond what is required in typical use. For ensuring the maximum efficiency and reliability, the minimum 50% of the power supplies rating have to be provided. For example, if the system requires +15A and 7 MPX-4/4 needs 24,5A, this would make a total of 39.5A which means that +12V rail would require approximately 475W and assuming another

50W for the +3.3W rail, +5V rail needs 10W. In this example the total system need is 535W. 50% margin on the power supply (535W*1,5=802,5W) means specifying the supply to 800W. The selected 800W power supply can provide at least 60A on the +12V supply. /13/

6.2 Video Wall Solution Assembly, Installation and Configuration

This following chapter deals video wall equipment's, assembling, installation and configuration step by step.

6.2.1 Assembly

The assembly of the video wall solution was started by building the video wall first. The video wall was built of 8 Lenovo LCD displays and in 4x2 formats. Figure 11 shows the image of above mentioned 4x2 video wall formats.

Figure 11. 4x2 Lenovo 24 inch video wall format.

All eight video wall displays are connected with own 5-meter long DVI-D dual link cables. Two Mura MPX-4/4 cards were used to control this 8 display video wall solution. Four video wall displays are connected to both MPX-4/4 cards through KX20 cable. Figure 12 shows image of KX20 cable, which is used to connect input and outputs to MPX-4/4 card.

Figure 12. KX20 cable.

Each Mura MPX-4/4 input channel is possible to connect with 4 input signal, and it is also possible to combine cards, which gives the possibility to connect more input and output signals. In this test arrangement two MPX-cards were used, which gave possibility to connect the maximum of 8 input signals. The workstation computer Optiplex 3010 and laptop, where the ip-camera operations are carried out, were selected to input sources. The input signals are connected to the Mura card input channel with the DVI-D cable through KX20 cable. The workstation displays were connected to the workstation computer Optiplex 3010 with the DVI-D cables.

The Dell Precision T3600, laptop computer, Sony snc-ep550 ip camera were connected with the Ethernet cable to the Zyxel NBG416 router, which forms a connection with the correct ip addresses. iPad was connected wirelessly to the router with the correct ip address.

6.2.2 Installation

In this thesis two pieces of Mura MPX-4/4 cards were installed to the Dell Precision T3600 computer. Precision T3600 is a newer model of T3500 (T3500 manufacturing has ended) which both are nowadays validated platforms for Mura MPX cards. The installation of the Mura cards started by setting cards to order, which was carried out by setting the DIP switches in right order. The first card

was set to 0 and it means that card will be the first one used, and the second card was set 1 and so on. Figure 13 shows an example of 8 card DIP switch order./14/

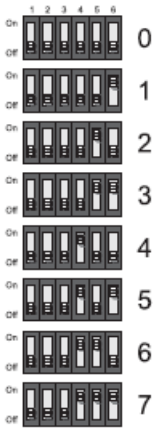

Figure 13. DIP switch order when using 8 cards. /14/

The second task was to remove all display drivers of Precision T3600 computer. Display drivers can be removed by using computer programs and features in the Windows Control panel. After that the system can be opened and existing cards replaced with the Mura cards. The Mura cards have to be installed on the PCI Express slot depending on the type of used card. In this solution two PCI Express slots x16 were used. The Mura cards were installed into T3600 system board slots 5 and 3. Figure 14 shows image of T3600 system board.

Figure 14. Dell Precision system board. /7/

When using multiple Mura MPX cards, as in this solution, all outputs can be synchronized by interconnecting cards with the genlock cable. The cable is connected to the connector label out on the first card and connector label in on the second card. Figure 15 shows image of connecting two cards with the genlock cable./14/

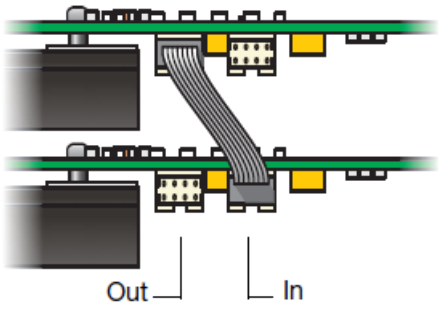

Figure 15. 2 Mura card output synchronize with genlock cable. /14/

The next task was installing the Mura drivers to the Precision T3600 computer. The latest Mura MPX driver version was selected for this task, which is compatible at T3600 and MPX-4/4 cards.

6.3 Mura Control Software

6.3.1 Matrox PowerDesk

Matrox PowerDesk is control software, which provides multi-display controls to configure and manage windows. This management software gives wide range of utilities and management of pop-up messages and window positioning. With the software it can be controlled how windows are maximized and which dialog- and messages box appears. The Matrox PowerDesk software is also able to use with the Mac operating system. /20/

In this test PowerDesk software was tested with the Windows OS software and controlled Matrox cards locally on the Precision T3600 computer (controller). Figure 16 shows the multi-display settings of the software.

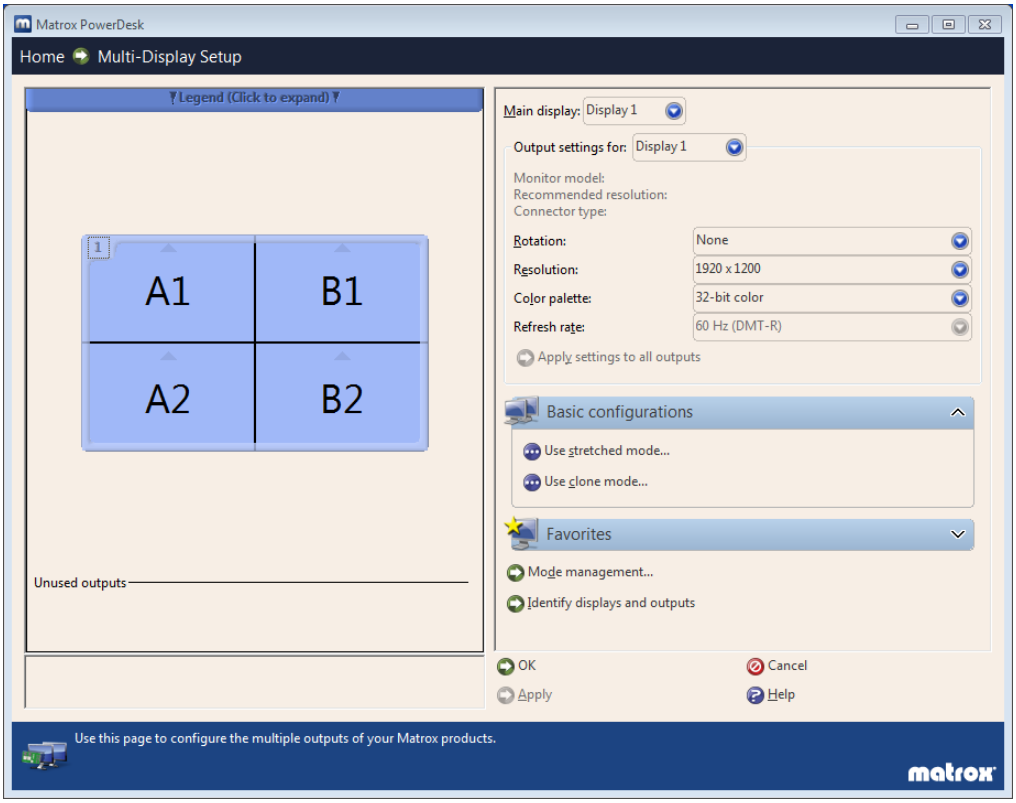

Figure 16. Matrox PowerDesk multi-display settings.

6.3.2 Matrox DWC-Manager 2.1

The Matrox DWC-Manager software is locally operated Mura control software. With this software, different display wall layouts can be controlled, modified and saved. Figure 17 shows different function possibilities of the software and Figure 18 shows how to create layout with the DWC-manager software.

Figure 17. DWC-Manager software function categories.

Figure 18. Creating display wall layout.

6.3.3 Matrox MuraControl for Windows

Matrox MuraControl for Windows is software that enables managing the Matrox Mura MPX-based display wall. To able to run MuraControl locally or remotely, the software's shown in Table 6 have to be installed.

Table 6 Needed following systems to operate MuraControl software locally and remotely./17/

Local system (controller)	• Matrox network API • Microsoft Windows 7 (64 bit) or Windows Server 2008 R2 • Matrox display driver version 2.02 or later
Remote system (for example workstation)	• Microsoft.NET Framework 4.0 • Microsoft Windows XP (32-bit or 64-bit), Windows 7 (32-bit or 64-bit) or Windows

	Server 2008 R2

The MuraControl software can create, save and edit source layouts in various ways. With the MuraControl software the following features can be operated:

- Run software locally or remotely
- Create, modify and save layouts
- Import or export layouts
- Positioning, re-size, crop and label windows anywhere on the video wall
- Adjust source-specific hue, saturation, brightness and contrast
- Customize gridlines.

/17/

The MuraControl for Windows software was connected to controller with IP address. Figure 19 shows the image of software taking connection to controller with IP address.

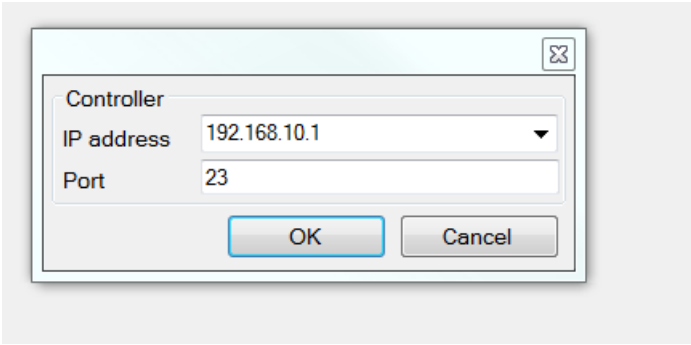

Figure 19. MuraControl connecting to controller with IP address.

6.3.4 Matrox MuraControl for iPad

MuraControl for iPad enables the user to switch, scale and manage the Matrox card input sources remotely. The simulated version of the video wall displayed on the iPad enables the user to control the wall in real time. MuraControl is compatible with all Matrox Mura MPX video wall controller boards, for example, for using two Mura MPX display wall controller boards with the validated system

(computer) and installing Network API program to create video wall controller which is controlled from iPad. MuraControl for iPad requires iOS 5 software (or later model) on iPad./16/

MuraControl for iPad has, for example, following features:

- Zoom in or out of the simulated video wall layout
- Add or remove inputs by tapping
- Manually resizing inputs, and entering the custom input size using four separate fields

/16/

The software has almost the same functions as MuraControl for Windows but modified for the iPad solution. The software is compatible with iOS 5 and iPad 3. Figures 20 and 21 show an example of video wall controlling with iPad.

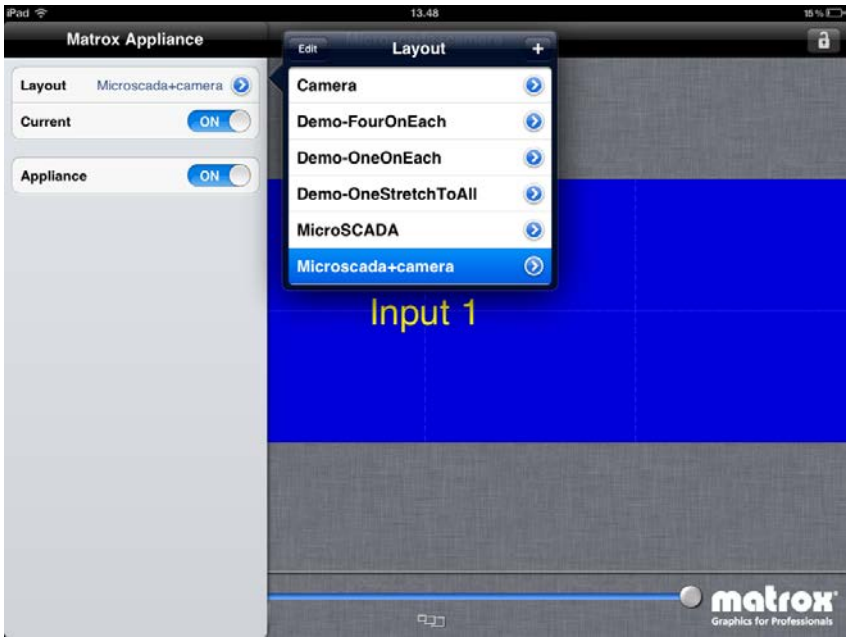

Figure 20. Controlling video wall layouts with MuraControl for iPad software.

Figure 21. Modifying video wall layout with MuraControl for iPad software.

6.3.5 Controlling Video Wall with MicroSCADA

In the practical test section theoretical possibility to create controlling path to video wall with MicroSCADA was also studied. This controlling path should work side by side with the Mura control software.

In summary, the control path would be carried out in the following way: With MicroSCADA command procedures written with Scil programming language, for example, the video wall layout controlling commands would be created (layout change and selection commands. The control commands would be transferred through Telnet to the controller (Dell Precious T3600) where Network API would detect, modify and transfer the commands for the Mura video wall controlling boards. Figure 22 shows the theoretical route of the video wall control commands theoretical route from MicroSCADA to Mura MPX.

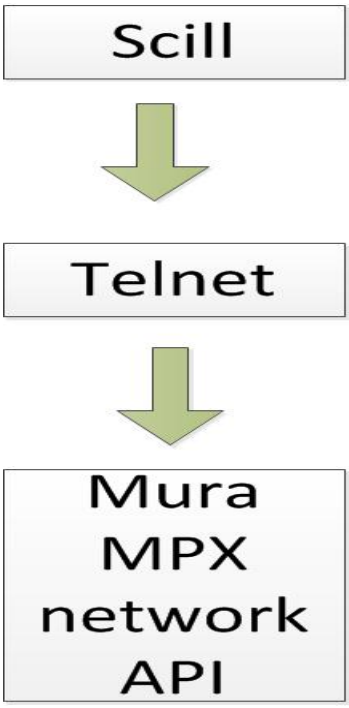

Figure 22. Route of video wall controlling commands route from MicroSCADA to Mura MPX.

So that it is possible to control the Mura cards the Mura MPX Network API must be installed on the controller system in order to use the MuraControl software. This Mura MPX Network API software can be used when designing control path to the Mura cards. In short, API is Application Programming Interface, which enables software applications to communicate with each other.

The transfer route/program to be used between MicroSCADA command procedures written with Scil programming language and Matrox MPX Network API is Telnet. Telnet is a network protocol used on the Internet or local area networks to provide a bidirectional interactive text-oriented communication facility using a virtual terminal connection. On the Matrox webpage it is possible to download Network API SDK, which includes among other things model examples of codes/commands between Mura MPX network API software and Telnet.

6.4 Test Results and Future Possibilities

The practical testing mainly focused on testing the functionality of the Mura cards with the other equipment and its various controlling and usability possibilities. In this section it was tested among other things how equipment are compatible with the Mura cards and what different kind of controlling possibilities the Mura controlling software (PowerDesk, DWC-manager, MuraControl for Windows or iPad) have. Different DVI splitters, adapters and the effect of the cable length effect on the DVI signal were also tested.

The test showed the versatile and flexible possibilities of the Mura cards to connect different kind of equipment as a part of video wall solution. Also, the increase in the amount of equipment was possible to carry out easily by combining the Mura Cards with the genlock cable. The difference of using DVI and VGA cables was also tested. The biggest difference was detected when studying the display at close range. VGA connected display had some ripples on image while the DVI connected displays image was clear and interference-free. The combined influence of adapter's, splitters and cable length on the DVI signal was tested as well. The test showed that the signal was too weak for creating an image on display, when using a splitter, number of cable connections and approximately 10 meter length DVI cable. Normally a proper DVI cable can carry the signal approximately 10 meters but in this setup, where used splitters and cable connections which weakened the signal in such way that creating an image was impossible. In this kind of setup an DVI splitter with powered DVI signal booster must be used (built-in signal amplification), which amplifies the signal in such matter that it is able to create clear image on display screen.

The Matrox Mura controlling software proved to be a very logical and easy to use. With Mura PowerDesk it was possible to locally control, organize and add equipment. The software gives a possibility to create different kind of display orders on the video wall, for example, 4x2, 2x4 display orders and etc. Also PowerDesk gives an opportunity to control bezels. With this bezel management

the physical borders of screens and displays can compensate for, (bezel management is controlled through the Matrox PowerDesk software interface, where user specifies the total width between monitors and so the image remains continuous between monitors). While testing the DWS-manager software difficulties with software usability was observed. The software only operated locally and layout controls and editing function did not operate very smoothly. In my opinion this software is best suited to so called backup program. The testing showed that MuraControl for Windows and MuraControl for iPad functions were logical and easy to use. The layout creation could be operated logically by feeding values or expanding input images with the mouse. While testing the MuraControl for iPad software, it was revealed that every time when changing the layout, has to be activated layout manually. This slightly reduces the software usability. This same function problem does not appear in the Mura control for Windows software.

The future development idea could be making a video wall control path through MicroSCADA in parallel with the Mura control software and create backup program which would keep the process overview image on the video wall if the main control software crashes down. In the future, the focus could be on developing even better interaction techniques, for instance, utilizing voice tags and humans movement (motion control).

7 CONCLUSION

Video walls have become all the more common feature in control rooms, and nowadays are exposed to high expectations. Video wall potential has not yet been fully exploited.

In general, the video wall should support the decision-making process by providing an overview of the task, as well as changes of the information, faults and alarms in a way that it is easy to detect. Also, an important feature is that the video wall can reduce the tunnel effect, which is a result of the use of workstation and in that way help users to maintain an overall picture of the operation better. With the video wall it is possible to show the main parameters of the process and the status of devices for all operators simultaneously and that way it gives an idea what other operators are doing in the process at the same time. Thus, the video wall can improve the interaction between operators, co-operations and also communication.

Interactive, high quality video wall development affiliated a number of different kinds of challenges, although easily configured, high quality video wall solution development is complicated. Many different researches show that it is difficult to build video wall solutions, in a way that it supports all potential of the video wall. In the future, focus should be on developing even better interaction techniques, for instance, utilizing voice tags. Also, proving usability and ergonomics should be one of continuous improvement targets in the video wall technology.

The practical testing showed the high usability of the Matrox Mura cards when building video wall system around it. The Matrox Mura cards may be built around a versatile and flexible system, which also includes effective video wall control software. A future development step could be, for example, building a suitable and practical video wall controlling software or path to MicroSCADA, which would work side by side with the Matrox Mura video wall control software.

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