Display Wall Efficiency Capabilities

MAXWELL R. MORIN
University of Maine
and
PHILLIP DICKENS
University of Maine

My CAPSTONE experience consists of working in Dr. Dickens' supercomputing lab on a project to reconfigure a display wall located in Neville room 120. The project consists of a custom built full tower computer running Ubuntu with four NVidia Titan cards each with four display outputs connected to a 12-unit display wall (4X3 configuration). Each monitor has a native resolution of 1280X720 (15360X8640 total), our intention is to first configure an efficient way to setup the display wall (on Ubuntu) to display a single desktop image across all 12 monitors. The current configuration has an inefficient implantation with highly outdated drivers and software that causes an unacceptable level of resources spent just on displaying the image alone. The outcome to this project is to have a display wall that will be used by multiple departments for such applications such as Google Earth, video, presentations, and studying high resolution images.

Additional Key Words and Phrases: Display wall, Ubuntu, Google Earth, NVidia Titian.

1. INTRODUCTION

Initiating the project on September 10th with a meeting between Dr. Dickens and myself we concluded that our intention is to take a custom tower received from a prior grant and get it functional by displaying to the display wall.

Display walls, commonly called monitor walls, and video walls, is the use of multiple displays, such as monitors, televisions, and projectors, used to increase the visual area available for programs executing on a single computer. Currently the three popular versions of operating systems (Windows, OSX, and UNIX) all support multiple monitor setups. It wasn't long ago when a dual-display setup required proprietary video drivers built for expensive selective video cards. The support of dual-displays varies per company. Even though the first adaptation of dual-display was first seen with Microsoft in Windows 98, Apple had the support in the Macintosh II in 1987, but wasn't really seen again until the release of OS X in 2001.

9X Media, Arguably one of the founding promoters of mult-display setups wrote an article back in 2002 discussing the origins and its rapid incline in popularity. They go on to mention figures such as "According to a recent Jon Peddie and Associates Muti-Display Setudy, Multiple monitor computing increased from 5.622% from 1992 to 1999" and "supported video card sales increased 450% from 1992 to 1999".

Typically the financial and design fields have been and continue to be the primary fields to support and use multi-display setups and through the period of 1992 to 1999 they were almost the exclusive users. Furthermore in the early stages of multi-display setups the price was a major inhibitor for the rapid expansion. It wasn't until after the .com boom when the cost of CRT monitors and supported video cards prices decreased.

There are numerous benefits of using a muti-display setup. Muti-tasking allows users to run multiple applications at the same time. Typically users must maximize/minimize windows and tab through them on a single-display setup. The act of constantly rearranging windows while working on multiple programs is an inefficient use of time. With a muti-display setup the user would benefit from the additional screen space.

Dickens and I are scheduled to meet with someone from the Climate Change Institute later this week to discuss another part of the project. The Climate Change Institute has images in the form of GIFs that they would like to have used in a program to demo their work. Furthermore, the Climate Change Institute would like to use the benefits of the display wall for conferences/presentations. My thought is that they most likely have a cache of data in the form of images and GIFs. Making an assumption, I can envision them requesting a program to be made that will house their data in a user-friendly manner. This program could easily consist of a UI that will display a visualizer (display the GIF) with a options to choose certain simulations/data sets to be displayed. The program would also have a data structure to house/maintain all the images/data. This would have to be configured efficiently because the data would consist of large high resolution images that would need to be displayed quickly/efficiently and potentially be passed over Ethernet to run across campus. Continuing speculation, the program will either have to run on the custom computer running the display wall or on a supercomputer (either from Dickens' lab or Climate Change Institute) and passed over Ethernet to the display wall across campus.

2. RELATED WORK IN VIDEO WALLS

Related material on display walls has been largely been through universities and select companies. Display walls should not be confused with 'video walls' which are low resolution tiles (NTSC) that one may find at an electronics store or at an airport. Video walls are used just as a television is to display video. They can be used for displaying arrivals/departures at an airport, or used at an electronics store to form a large display of a movie or television program. Display walls, however, are monitors driven either by a cluster or single computer. They can consist of LCD monitors or projectors and offer an affordable multi-megapixel display. Companies such as NEC, Matrox, Sharp, and Mitsubishi offer display wall solutions. Often, these solutions are comprised of unique monitors (often with thin bezels) that are connected to either a black box component or a computer (with black box style software) to accomplish the task. These solutions are often used by companies who need a complete display wall setup. This approach lacks the option for custom configuration and the customer is left with only the supported features offered by the vender. Other display wall configurations are found at universities. One university in particular, Brown University, has a display wall that supports gestures by a proprietary program and using a Microsoft Kinect like device. This has been demoed online before and shown to be useful for applications such as high resolution images.

3. DISPLAY WALL IMPLMENTATION

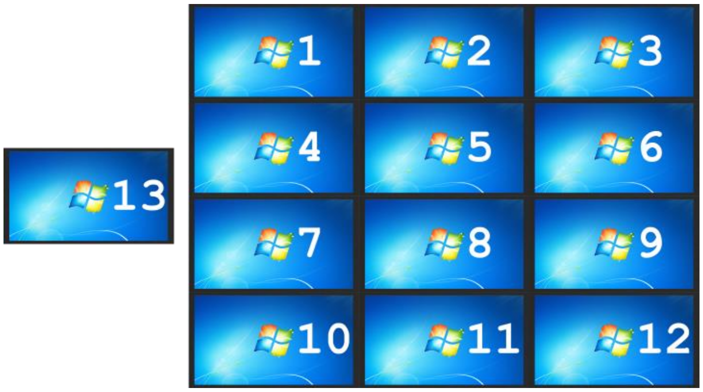


Figure 1

The display wall is going to consist of 13 1080p monitors that will be configured in a 4X3 setup with the 13th monitor acting as a terminal window allowing users to configure/navigate the computer without having to view it directly on the wall. The figure above visually demonstrates this configuration.

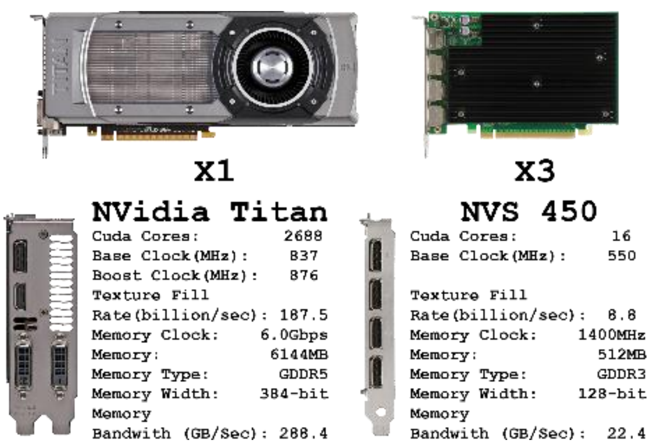
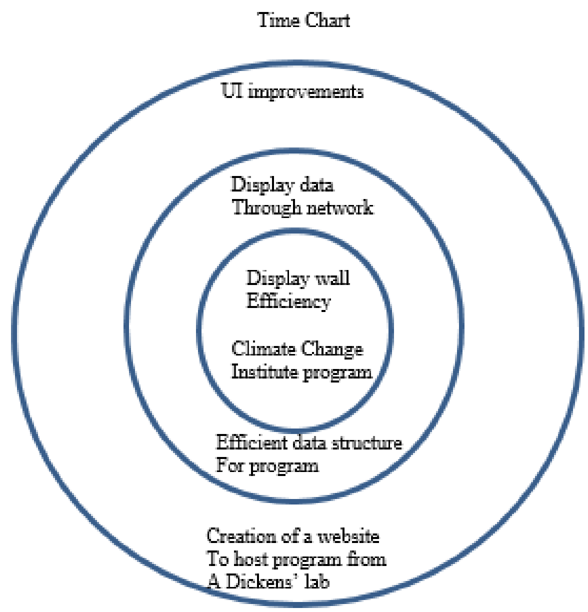


Figure 2

The specifications of the hardware we have is as follows. The computer is built upon an Asus Rampage III motherboard with an Intel 940 i7 (2.8GHz) quad core CPU, 12GB of DDR3 RAM, and a one terabyte 7,200RPM hard drive. There are also a total of four video cards, one NVidia Titan and three NVidia NVS 450 GPUs.

Our first goal is to implement the display wall efficiently. We will based this efficiency by quantifying the amount of resources (power draw, CPU/GPU time, thermal output) consumed by displaying a single desktop. We will try different approaches by varying the configuration such as different connections (VGA,DVI, DisplayPort), different drivers (NVidia or custom third party drivers), different tile assignments, and quantify how the resources required for each configuration. When we have found the most efficient setup our next goal is to have a supercomputer from the Dickens lab efficiently communicate (images/data) from the lab to the monitor wall in Neville. The primary purpose is to have the ability to have the supercomputer display a real-time image across campus. The benefit of this would allow a more suitable way to present data that would benefit from the larger display.

Once the display is functional, our efforts will shift to creating a suitable program for the Climate Change Institute. Development of the program will depend on a few factors that will be discussed in the upcoming meeting. One factor would be how the data is stored in its raw format. It was mentioned that some of the data is in GIF format, which consists of a slideshow of pictures (very similar to video). The data may also be in raw format, or JPG/PNG. That would alter how the program would be structured. We would test whether it would be more efficient to display the images independently or just play the GIF. It would also depend on whether the data would be static or change based on values of variables. Another factor to consider would be that this will be display wall, so resolution has a higher importance. It would be imperative to have the resolutions in raw format to allow them to take advantage of the added screen real estate. This poses challenges because raw images are often very large (easily 50+ MB each). Configuring a way to display them efficiently locally or remotely will be highly dependent on implementing optimal efficacy.



4. TYPES OF DISPLAY WALLS

The field of multi-display setups has been largely proprietary if you go with more than three displays. It has been more than 15 years since multi-display had widespread support but has largely been limited by two or three displays. Current display walls share similar characteristics while differing greatly in how they function.

4.1 Projector based

Project based display walls are the most expensive approach. Each monitor is instead a projector, easily costing well into the tens of thousands. The first generation of projectors were CRT projectors, which were very expensive and bulky. The second generation of projects used LCD or DLP technology which offered an increase in resolution and drop in price. The supported resolution of the project is also very important, the higher the resolution the clearer the images. This often comes down to price when choosing a project for a display wall because you are purchasing many instead of one.

Out of projectors there are two major types, LCD and DLP to choose from each with their own strengths. LCD projectors offer better or more accurate color, produce a sharper image, and offer more uniform illumination. DLP projectors offer less pixelization, and better contrast. They also suffer from the rainbow effect, so keep in mind what applications you intend to use in the display wall when choosing the projector.

When choosing a project there are several factors to pay attention to. Since the display wall consists of multiple projectors minimizing geometric distortion is very important. Projectors also tend to suffer from a varying level of illumination depending on the model/age of the bulb. So it is important that when choosing a project to purchase the same model and all at the same time. It is also important to keep in mind the resolution of the projector which will depend on the intended application use. The method in which you connect your project will also be important. Would you want to use an analog connection such as VGA or would you want to use a digital connection such as DVI or DisplayPort? Furthermore, the resolution will be important here again when choosing a connection type, each connection has its own range of support resolutions. Another factor easy to overlook is the expected life of the bulb in each projector. The cost of a bulb is usually close to ¾ the cost of a new projector so the life of a bulb is very important. Projectors tend to displace a lot of heat because of their bulb, that bulb also requires a decent amount of power. Multiply that by the number of projectors you are using and it becomes clear that the low power mode accompanying projectors is very important.

Projectors suffer from two unique issues that make them challenging to use for a display wall. First issue is the black level in the color. Even when using the same model projector the bulbs change their color output throughout their lives, often leaving a visual difference in color. Next issue pertains more to DLP projectors, and that is something called light leak. The boarders produced by DLP projectors often don't end abruptly, they tend to bleed over. When you have projectors that are positioned to boarder one another often those boarders will overlap, creating a distorted image.

Projector used in a display wall are usually fastened to a custom built frame that has individual slots that the projectors are placed in. Often, these slots consist of an adjustable platform that can be manipulated either remotely through a program or manually to make small corrections. The biggest reason why projectors are used for display walls is that they offer a seamless image that will not be effected by bezels like LCDs suffer from.

4.2 Monitor based

LCD based display walls have become more common over the past decade because of the lower cost and require less space compared to projector based setups. LCDs tend to offer more even light levels, require significantly less power, and produce much less heat. LCDs are typically bought together just as projectors are because each LCD monitor usually has different dimensions.

LCDs have become the standard when building monitor walls over the past decade because of a few reasons, one in particular is due to their wide range of supported resolutions. LCDs especially over the past five years have widened the gap between projectors in resolution output. Today, a user can purchase 4K monitors (3840 x 2160) to use for their display wall. LCDs offer the best flexibility when it comes to supported resolution outputs. LCDs also offer increased brightness and much better response times, which is important for video applications.

The major drawback to going with a LCD display wall is their issue with having bezels. Every LCD monitor has to have a bezel which creates a black bar that segments the image. To overcome this issue LCDs have been released with increasingly slimmer bezels, but that often is not enough. Having to account for bezel space there are two approaches on how to proceed. One method is to crop the image, where the image will stop at the beginning of one bezel and continue on the following bezel. This allows the image to be fully represented but the segmentation of the bezels does distort the image as a result. The other approach is to calculate the size taken up by the bezel and then remove that portion and continue on the following monitor. This produces an image that is not distorted, but any section that is covered by the bezel is simply not rendered (like looking out a framed window). Both techniques have their benefits and uses, so depending on the application you may want to choose a particular setup.

5. CURRENT STATUS

As of December the currently status of the display wall implementation is as follows. There are two bootable functioning partitions running on the computer, Arch Linux and Windows 7. The Windows 7 partition is fully updated with the latest Windows updates and newest NVidia drivers. Each display is correctly displaying a single desktop that spans across each monitor. Each monitor is setup in the correct orientation so that when a window is being dragged it will moved from display to display in the correct order. Preliminary performance testing has shown mixed results. This is because there is currently a two-step process when configuring a multi-display setup. First step is configuring an extended desktop environment where each monitor is a continuation of a single desktop environment and is shared across each display. However, there is another a following step that is equal important that provides added functionality and increased performance. This step is configuring the third party display driver settings from the video card manufacture (NVidia/AMD) through their respected technologies (Mosaic/Eyefinity). Both technologies are very similar in implementation and functionality making a distinction between the two irrelevant. This step allows the implementation of added functionality that provides necessary performance improvements and is the polish required to having an optimized environment. Of these added functions the two that are relevant is bezel correction and single desktop image. Bezel correction is important when dealing with LCD monitors. Unlike projectors which offer no bezels, LCDs have a bezel that breaks the image and results in the image being incorrectly displayed. This means that images, depending on how many monitors it covers, will often be too large because of the added space from the bezels. This is corrected through software where the video drivers take into account the bezel space and will remove that section of the image providing the image to be viewed as intended regardless of the monitors being used to display it. The best way to think if it would be image looking through a window pane. The other important feature is the single desktop image. Currently, step one configuration offers an extended desktop environment with is more of a quasi-single desktop environment where it is very similar to independent desktop environments that support limited sharing features such as copy/paste and dragging between displays. The negative of this setup can be seen when trying to maximize programs/windows where the program/window will only full a single display and requires manually sizing the window across all displays to truly maximize. The single desktop image functionality takes the extended desktop environment to the next level by collecting the displays and configuring them as a true single desktop. That means the task bar will display along the bottom row of monitors and the desktop background will be a single image split between all monitors. Essentially, this step changes the traditional approach of an extended desktop that offers multiple displays to share data and transforms those monitors into one. This approach on the surface appears to accomplish the same functionality that is built into Windows, but because of how Windows operates this provides a better experience as all operating systems unanimously struggle with more than two displays. This also is the same for Arch Linux and is the same program from the same third party company (NVidia/AMD).

Currently, due to Mosaic's limitations on supported hardware the current hardware provided only allows a maximum of eight displays. This means that the setup is functional but the performance and polish has room for improvement. Also with the nature of these programs there is little to no possibility to add this functionality personally and will require a future update from NVidia/AMD.

The next stage is to run diagnostics on the display to test for power draw, operating temperature, and system resource use on both operating systems for a baseline benchmark and stress benchmark. I will be conducting the tests using a suite of software and tools to collect the data. I will be using CPUz/GPUz to record the operating temperatures from the computer powering the display wall as well as a thermal gun to read the temperatures directly within the case to verify the readings. I will be using Prime95 to stress the CPU and 3D Mark to stress the CPU and GPU. I will also install and run a graphically intense program to stress the system using a real world approach and record the Frames per Second (FPS). This stage will also include testing different connection methods between the computer and the displays (HDMI, DisplayPort, and DVI-D). I will also be testing different driver versions and third party software in an attempt to acquire the best performance possible with the hardware we have.

While on holiday break we plan on writing a program that will take the GIFs provide from the Climate Change Institute and display them in an adequate function. Since the meeting has not taken place yet I can only speculate on the specifications that will be requested. It would not be difficult to image they may want to have multiple GIFs in the program to choose from so it may require a simple database system. This will aid in an efficient transfer speed as we suspect the file size may be quite large so performance is paramount.

There will be several unique challenges facing this project that will test and aid in the development of my troubleshooting, critical thinking, and problem solving skills. First unique challenge will be to efficiently run a display wall with such a high resolution without having to allocate a high level of system resources. While display walls are not unheard of they are, however, typically inefficient. Typical systems even those running 4K monitors are a fraction of the resolution this monitor wall will be tasked with displaying. Compound the fact that SLI/Crossfire (video cards running in tandem) yields mediocre performance gains. An example being say one video card gets you an arbitrary benchmark score of 500. Running two NVidia cards through SLI would typically grant you a benchmark score of 750. This gets compounded with every additional video card. Even through this rudimentary example it is easy to see that computers as of today are not optimized for such display setups. Another unique challenge will be achieving this through Linux. There is very limited resources for guidance as most implementations consist of very specific hardware configurations and custom code running it. The next major challenge will be the once again unique setup between Dickens' supercomputer in his lab and the connection to the Neville computer. The universities Ethernet cables range from CAT3-CAT5 depending on the building not to mention the wide range of switches the feed will pass through along the way. We will require a high throughput to achieve a stable image that has a high chance of being difficult to obtain.

With all factors considered I firmly believe that this project contains a high level difficulty in multiple disciplines within my framework of computer knowledge. There will be coding, networking, hardware, and server issues to name a few. Dickens and I have already discussed the off chance that if there is time we will continue implementing the ideas further as necessary. As I have mentioned though while the ideas can come off as simple it is the unique environment that will provide a high level of difficulty. Efficient monitor walls are not mainstream to the point where a consumer can just purchase black-box equip off the shelf. Each monitor wall environment is varies greatly due to its resolution which varies vastly because of the amount of monitors (vs standard monitor has a handful of typical resolutions, even those OS's have a hard time displaying correctly), the video cards powering them, the OS it is running on (nothing is simple in Linux), and even the choice of the type of connection plays a major importance (throughput varies vastly between HDMI and DisplayPort). I look forward to starting on this project and being able to implement what the university has taught me over the past two and a half years.

6. CONCLUSION

The focus of this CAPSTONE is to create an efficient display wall configuration that will serve as a benefit to any department that would profit from the use of a large display. Furthermore, the intent of this CAPSTONE is to work alongside with the Climate Change Institute to develop a visual solution to be used with their acquired datasets that will satisfy their required specifications and compatible with the display wall.

The next goal is to have the ability to have certain applications take full advantage (example: Google Earth) of the native (15360X8640) resolution when displaying high resolution images. The benefit of this would allow the unique opportunity to view such images in their entirety without being forced to zoom in on one section at a time. This will allow a distinctive advantage of getting a true bird's eye view. If the implementation goes according to plan Dickens intends to allow other departments who could use this setup the opportunity to use the monitor wall (departments like Geology/Astronomy).

Having a functional display wall will benefit man departments but will have a direct benefit for the computer science department. This project aims to transform hardware that was acquired by a grant into a functional setup that it was original intended for. This project will require a wide arrange of computer science disciplines such as programming, data structures, networking, graphics, and hardware. We are confident that the end result of this project will produce a fruitful tool that will be used by many and benefit all.

7. MISSING SECTION

This progress report is missing a few critical sections such as a more in-depth conclusion section and three figures that will consist of bar graphs displaying the running temperatures, power draw, and system resource load.

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