DISPLAY TECHNOLOGIES (ICT AND VISUALIZATION)

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Contents

Summary

The advancements in the last part of the twentieth century in information and communication technologies (ICT), if properly utilized, can lead to improvement of quality of life for a vast majority of mankind. To be successful, ICT requires relevant information as well as technologies like computer and communication systems and human-computer interface. These interfaces are the electronic displays which are

subject matter of this chapter.

The basic workhorse for electronic displays for the last one hundred years has been the Cathode Ray Tube (CRT) invented in 1897. Since the late twentieth century, however, many more technologies have appeared as competitors to CRT. Prominent amongst these are Liquid Crystal Displays (LCD), Plasma Display Panels (PDP), Organic Light Emitting Diodes (OLED), and a few more.

The emergence of these electronic displays, along with the development in computer hardware, software and graphics, has made the evolution of modem technologies of visualization possible. Basically, visualization is a mapping from data to picture. In today's world, huge amounts of data flow into information systems. The Encyclopedia of Life Support Systems (EOLSS) with its vast content, itself, is an example of huge data published on the Internet at (www.eolss.net). Developments in computer-aided visualization, such as, context and focus, concept map and so on promise to make the material of EOLSS like-data-banks available to users in a more comprehensible manner. A very brief sketch of these developments in visualization is also included in this chapter.

1. Introduction

Impressive developments have taken place in design and manufacture of display systems in the twentieth century. Starting with the invention of Cathode-Ray-Tube (CRT) by Braun (in 1897) to the quality of flat panel displays available today; it has indeed been a momentous journey. During this period technology has been building on technology; sometimes augmenting an old technology and sometimes displacing it. This has resulted in existence of several viable technologies such as CRT, Liquid Crystal Display (LCD), Plasma Display Panels (PDP), Organic Light Emitting Diodes (OLED), Field Emitter Displays (FED) and many others.

Similar advances have taken place in drive electronics also. Initially the electronics was built using the available technology of the day - vacuum tubes. By the middle of 1950s, change took place to discrete semiconductor devices and by 1970s to semiconductor integrated circuits. Today the level of integration and versatility of functions in semiconductor electronics, through Very Large Scale Integration (VLSI) and availability of Digital Signal Processing (DSP) chips, have reached an unbelievable stage of development. The dream of engineers to build a gadget that will take ‘no space’, which will respond ‘instantaneously’, will cost ‘nothing’ and will perform any action that is asked, has almost come true. The irony of the situation is that while drive electronics is shrinking, the demand on larger and larger display screens is increasing

1.1. Display Systems

The display screen and its associated driver electronics do not stand on their own, but are part of an information system. Depending on the context, it has become customary to associate the display with the system to which it caters, such as television (TV) displays, avionic displays, medical displays, military displays, gaming displays and the like. Each of these classes of displays is associated with an application segment and has its own special requirements based on the information content, the environment in which it operates and more importantly on the man machine interface requirements. Among all these classes of displays the volumes and the prices in the market place differ depending on the application. For example, the displays associated with that of television and computers have become commodities selling in millions at low prices, whereas the avionic displays are very high price low volume but with very demanding specifications. At present the largest selling displays are associated with televisions for entertainment, monitors for computers and cell phones for communication.

Features of displays systems specific to TV, computer and cell phones are described as illustrative examples in the following sub-sections.

1.1.1. Display System: TV

The monochrome television appeared around 1935 using CRT of Braun. It peaked by the beginning of the 1950s followed by arrival of color television in mid 1950s. At present monochrome television is at the obsolescence stage but CRT based color television still occupies a major portion of the television market. Flat panel TVs based on LCD, PDP and Projection are in the market and growing but the volumes are still small.

There are two basic television systems - analogue and digital. The classical television signal is an analogue video signal and is made compatible to the scanning associated with the CRT. Analogue Television Standards evolved over time, like National Television System Committee (NTSC) in the United States of America (USA), Système Électronique pour Couleur avec Mémoire (SECAM) in France and Phase Alternating Line (PAL) in Germany and are accepted by various countries. As the digital technology and concurrently digital communication evolved and progressed, higher picture resolution with this technology became a reality. As a result, the world is gradually moving towards the widespread use of digital television (DTV) and high definition television (HDTV). Interestingly the new display technologies, such as LCD and PDP, are inherently pixel based matrix structures and are logical fit to the digital television.

The CRT televisions and Flat panel televisions have sizes, normally specified in diagonal inches (or centimeters) ranging from 14” to more than 70”. The size of the television gets decided by the viewing distance, human eye resolution and the signal format. Larger sizes are required for larger viewing distances and vice versa. The specification on performance criterion like resolution, brightness and contrast are intimately connected with viewing distance, psycho-visual behavior of human eye and the viewing environment.

The aspect ratio for television picture has been 4:3 and is now moving to 16:9 with the advent of HDTV. The reasons attributed are that the eye has larger horizontal field of view than vertical field of view and hence 16:9 is logical.

The operation of a TV requires a combination of a video and an audio signal recorded in a studio, modulated over a carrier through analog modulation schemes such as amplitude modulation or frequency modulation or through various digital modulation schemes and transmitted. This process requires a certain bandwidth which is a scarce resource. Hence, historically, a great deal of effort has gone into research into designing the TV signal. For example when color television was proposed, in spite of the fact that it carries three equivalent monochrome signals, the bandwidth allocated was almost the same as that of a monochrome TV. Moreover, the color signal was to be compatible with existing monochrome TV receivers. Researchers had to find - and found - elegant ways to solve the problem. Similar was the situation when moving from low definition television to HDTV with issues related to bandwidth conservation and compatibility. In parallel, a great deal of research has gone into schemes for bandwidth compression to reduce the bandwidth required for transmission/storage without affecting the quality of audio/video signal. Such efforts resulted in MPEG standards in use today.

1.1.2. Display System: Computer Monitor

Computers are the work-horse of the on-going IT revolution. Computer display monitors – as the display associated with a computer system is usually referred to, have become the most favored output port for computer-human interactions. In the case of computer system there is usually no long distance transmission involved between the display and the computer hardware that drives it. Hence, modulation and demodulation of the signal between the computer and the monitor is not required. In this case, the signals coming out of computer are inherently digital, but the display systems based on CRT are inherently analogue. To handle this situation, interfaces to convert digital format into analogue format to drive the display were incorporated in the monitor (the same is being done to see a DTV signal on an analogue TV). However, with the availability of matrix format flat panels, notably LCD based, such interfaces are not required.

The display resolutions in computers also have undergone changes over time depending on the resolutions required to represent graphic images. The following table-1 gives the evolution of graphic display standards.

Standard	**Description**	**Resolution**
CGA	Color Graphics Adapter	640 x 200 (monochrome) 320 x 200 (4-color)
EGA	Enhanced Graphics Adapter	640 x 350 (4-color)
VGA	Video Graphics Array	640 x 480
XGA	Extended Graphics Array	1024 x 768
SXGA	Super Extended Graphics	1280 x 1024
UXGA	Ultra Extended Graphics	1600 x 1200
WXGA	Wide Extended Graphics	1366 x 768
WSXGA	Wide Super Extended Graphics	1680 x 1050
WUXGA	Wide Ultra Extended Graphics	1920 x 1200

Table 1. Graphic Display Standards

When a computer output with a certain resolution is to be seen on a flat panel with a different resolution matrix format there is an incompatibility and the input to the flat panel monitor has to be scaled up or down without creating distortions in the image displayed. The user, however, need not be aware of all these issues and the methods adopted to overcome this incompatibility by appropriate hardware and software should be transparent to him/her during the normal course of usage of the system.

Most display systems are designed to accept video signals in various formats, digital as well as analogue. These input signals have to be matched to the format of the display device. The necessary signal processing is accomplished in the front-end video processing card. Often the signal processing algorithms may require storing one or two frames which require internal memories. For example one frame in a VGA format requires approximately 1 megabyte of memory. Fortunately with the dramatic progress in memory technology, the physical size as well as the cost of such high density memories is no longer an issue which has lead to increasing resolutions in displays.

1.1.3. Display System: Cell phone

Historically the cell phone display was a simple monochrome alpha numeric display to display the caller identity and later the short message service (SMS) text messages. From such simple displays, the cell phones today have moved to higher resolution multicolor displays with capability to show moving images. This is necessitated as new features get incorporated into the cell phone as a result of user demands as well as due to manufacturers wanting to have an edge for their products over those of their competitors. The typical display in a high end cell phone today is of 2” diagonal AMLCD with QVGA resolution (320×240) which provides at least 6 bit color. It can show video pictures from internet or from a DVD.

The critical requirement of the cell phone displays beside the cost is power consumption. The mean time between charging of the battery is to be high. Hence, the display should limit the power consumed to a bare minimum. For sunlight readability, however, it must have adequate brightness requiring higher input power that conflicts with the need to low power usage. As time passes there will be demands for higher resolutions as required by the more sophisticated functions it will be expected to perform. Many of these requirements are expected to be satisfied by OLEDs and they are catching up with AMLCDs. Already a few of the high end cell phones have OLED displays and it is expected that many more will follow suit..

1.2. Computer-assisted Visualization

Simultaneous with developments in consumer electronics, there has been a small, but critical and demanding segment of use of display technologies in the area of ‘visualization’. It is important to note here that the meaning of the term display in the community of ‘designers of TV, computer monitors and mobile phones’ and the community of ‘developers and users of visualization tools’ is very different. For the former display technologies would have something to do with CRT, LCD, PDP, OLED, active matrix, passive matrix, drive electronics, and the like. For the users of visualization it would mean scientific or information visualization - in both, one has to handle large volume of raw data and transform it to a visual form at the output. This is done to exploit the extraordinary flexibility of human beings to locate patterns and discover relations using visual cues.

The emphasis in scientific visualization is on physical objects like medical images of human organs, parts of machine in engineering and so on. The designer of scientific visualization engine has to master geometric modeling, computer graphics, image processing, software engineering and implementation of 3-D displays, either directly or using projection methods from 3-D to 2-D. The emphasis in information visualization is on handling multidimensional data like the web pages; contents from the libraries and conferences; contents like EOLSS and so on. The difficulty in creating useful visual images in this case appears because one can not see the whole picture of data and small details in the image on limited size display screens. Focus and context solutions for this are proving to be very useful in Information Visualization. Many other techniques like fisheye view, fractal structure, spider-web representation, etc. are evolving at this stage. A glimpse of this is provided in Section 4.

2. Performance Requirements and Specifications for Display Screens

The image on a display screen designed by engineers is ‘seen’ by a person through his/her eyes. The display screen designer should be in a position to harness the potential of the state-of-the-art of material and process capabilities and then attempt to meet the perceptual demands of the viewer. This effort towards understanding and using the man-machine interaction started in 1930s with the development of CRT for black and white TV. With available technologies, materials and processes and the then-understanding of visual perception of humans, displays were manufactured and marketed. Since 1930s, more research on technologies and visual perception has been going on, but even today difficulties in design of display screens are being faced.

This makes one marvel the ingenuity of those pioneer display engineers and scientists who made functioning display screens with ‘so little knowledge’ as was available at that time. The importance of high brightness, high resolution, good contrast, large viewing angle, fast response, reasonable power consumption, low cost and acceptable physical shape, weight, and volume was well understood and met. But as time went by and technology matured, due to various reasons, it was the volume of the unit, for a given screen size that became the determining factor in the evolution of this industry.

The volume of a display unit is determined by the dimension of its face (display screen) and its depth. The screen has a width and a height. But instead of specifying two lengths, it became customary to specify the length of the diagonal and mention the form-factor, which is the ratio of width to height. The depth of the display unit is also very important. As experience has shown, users would prefer a display unit of even lower performance, if its depth was small. This preference of user has encouraged the growth of Flat-Panel-displays in the last two decades. Since the Cathode Ray Tube displays are well known, in this section we consider only the Flat-Panel Displays.

2.1. A Simple Flat Panel Display

A schematic view of the flat panel display (FPD) is shown in Figure 1.This consists of a screen and associated driver electronics with a row driver, a column driver, and a display controller. The screen is composed of M×N array of picture elements (pixels). Pixels, which have been represented by crosses in Figure 1, play a crucial role in the performance of a display. Also, like the blind men and the elephant, a pixel means different things to different persons depending on the focus of their profession, whether they are scientists, device engineers, display manufacturers, image scientists, computer-graphics experts, human-computer interaction experts, camera specialist or others. Some of the perspectives are mentioned below.

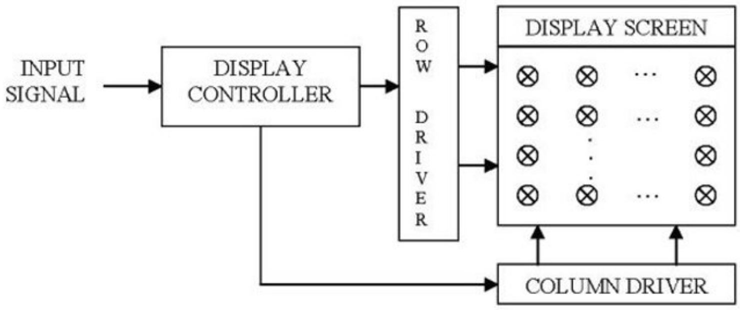

Figure1. Schematic diagram of a display screen and associated electronics

1. In every display technology, there is a fundamental physical principle specific to the microscopic device constituting the pixel which converts the radiant energy impinging on the pixel into illumination. The device engineer treats the pixel as an electro-optical transducer and attempts to model it to get a better understanding. Here the pixel consumes electrical power (say, in watts) and gives optical power measured in watts (in radiometric unit) or lumens (in photometric unit). The understanding gained by modeling helps in obtaining high electro-optical conversion efficiency. This means more luminous (output) power for less electrical (input) power. Smaller input power provides two main advantages. It keeps the pixel temperature low leading to longer lifetime, and makes the design of drive electronics (row and column drivers and display controllers) simpler. This is also attractive where low power consumption is needed at the system level, such as portable electronics. Different technologies achieve this electro-optical conversion in different ways, each with its own set of trade-offs. These will be discussed in the next section.

2. The display engineer is interested in selecting a suitable device structure to act as a pixel, and fabricate it using available materials and processes. His/her concerns are the shape (circular, square or hexagonal), size, and separation of pixels. Obtaining high quality and performance at low cost and high throughput are major concerns of a manufacturing engineer.

3. The scientist is interested in advancing the frontiers of knowledge and discovering new physical mechanisms to provide electro-optical conversion. Some of these new discoveries act as disruptive technologies replacing the old ones. Nano-emissive

technologies using field emission from carbon nanotubes is an example.

4. An image scientist considers the pixel to be a point sample of a mathematical function which can only have positive values because the intensity of light can not be negative. Hence, the luminous power emitted by a pixel is denoted as $C(x_i, y_i, t, f(\lambda))$, where x_i, y_i locate the pixel in $M \times N$ array, t is time and $f(\lambda)$ is the spectrum of the emitted light which manifests as color. The specification of the display screen thus has to consider spatial (x_i, y_i); temporal (t), optical (C) and color ($f(\lambda)$) demands made by the user.

Ultimately the display is judged by the viewer and there are an accepted set of specifications describing the performance of the display which inter se compare the performance of various technologies that go into the displays.

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[General guidelines: (i) This bibliography contains two categories of papers: one set of fifteen papers is related to displays and the other set of six papers is related to visualization. The 'Display Set' consists of [1, 3, 5, 8, 9 to 17, 20, 21], and the 'Visualization Set' consists of [2, 4, 6, 7, 18, 19] (ii) The Institution of Electrical and Electronic Engineers (IEEE), inter alia, publishes Proceedings of IEEE, and IEEE Spectrum. The articles in Spectrum are meant for technical generalists, whereas those in Proc IEEE are for somewhat specialized readers. In this bibliography there are six papers from Proc IEEE and two from IEEE Spectrum. Of these, four papers [8, 12, 17, 21] are from single issue of Proc IEEE, Vol. 90, April 2002, which is a special issue on Flat Panel Displays. (iii) SID and John Wiley have brought a special series of books on display technologies for easy availability of literature on display. Books belonging to this series are referred as 'SID-Wiley series in Display Technologies' in the following. These books provide a good starting point to learn about displays. (iv) The discipline of computer aided visualization and data mining have started only recently, as compared to electronic displays. An early paper (reference 7) had appeared in IEEE Spectrum, whereas a 2006 year paper discussing the concerns and state-of-the-art of visualization is reference 18. Together they give an idea of evolution of visualization.]

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Biographical Sketches

Raghubir Sharan is a Distinguished Professor at LNMIIT, Jaipur since 2004. From 1969 to 2004, he was a faculty in the Electrical Engineering Department at IIT Kanpur. He obtained a Bachelor's Degree in Telecommunication Engineering from the Bihar Institute of Technology, Sindri in 1961 and Master's and Doctoral Degrees in Electrical Engineering from the University of Waterloo, Canada in 1964 and 1968 respectively. He joined as a faculty member at IIT Kanpur in 1969, where he became a Professor in 1977, Head of the Department in 1980, and Dean of Academic Affairs during 1982 – 85. Dr. Sharan retired from IIT Kanpur in 2002. He fondly remembers the last phase at IIT Kanpur (1999 – 2002) which was very fruitfully spent in overseeing the formation of Samtel Centre for Display Technologies. He is a Fellow of the Institution of Engineers (India), Fellow of IETE (India), Senior Member of IEEE and a Member of SID. At the present, he is Vice President of India Chapter of SID.

Sarma K. R graduated from the Indian Institute of Technology Kharagpur with B. Tech (Hons) in Electronics and Communication Engineering in 1957 with First Class standing first in class and M.Tech in Microwave Engineeringin 1958. He went to US on Technical Cooperation Mission Scholarship of US Government in 1958 and received Ph.D. from Cornell University in 1961. He joined Indian Institute of Technology Kanpur in June 1961 and continued there till 1988. He served as Professor, Head Electrical Engineering, and Dean Research and Development. He was instrumental in setting up Advanced Centre for Electronic Systems, sponsored by Ministry of Defence Govt. of India. He also set up CAD Centre funded by Department of Electronics Govt of India. He was the founding member of Centre for Laser Technology, Robotics Centre and Television Centre. During 1988-91, he served as Adviser at the Department of Science and Technology Government of India responsible for the national program on Instrumentation. From 1991-1997 Dr. Sarma was Director Central Scientific Instruments Organisation Chandigarh, a laboratory under the Council of Scientific and Industrial Research. During this period he has guided development of many analytical, medical, optical and seismic instruments Since 1997 he is Adviser Technology to Samtel Group of companies heading the R&D of the Group to develop new products and technologies in area of Electronic Displays. He led a team which successfully developed the Plasma Display Technology. He played an important role in setting up the Samtel Centre for Display Technology at Indian Institute of Technology Kanpur , an Industry-Academia R&D centre to undertake development of Organic Light Emitting Diode (OLED) technology.

Baquer Mazhari was born in India, on February 07, 1966. He received the B.Tech. degree in electronics and electrical communication engineering from the Indian Institute of Technology Kharagpur, India in 1987 and the M.S. degree in electrical engineering from the University of Maryland, College Park, USA in 1989. He got the PhD degree in electrical engineering from the University of Illinois at Urbana Champaign, USA in 1993. In that year, he joined the Indian Institute of Technology where he is currently a Professor in the department of Electrical Engineering. He spent a year as visiting faculty member at Amman national University in 1997 and is currently a visiting professor at American University of Sharjah. His research interests include device modeling and analog circuit design. In the last few years, he has been engaged in research and development work in the area of display circuits, organic light emitting diodes, organic thin film transistors and in organic solar cells at the Samtel Centre for Display Technologies. He has authored/coauthored over 44 research papers and supervised about 40 post graduate students in their thesis work. Prof. Mazhari is a member of IEEE (USA) and of Society for Information Display.

S. Sundar Kumar Iyer did his early schooling at Calcutta, India. He received his B.Tech. degree in Electronics and Communication Engineering and M.S. degree in Electrical Engineering from the Indian Institute of Technology Madras, India in 1990 and 1993 respectively. He completed his PhD degree at the University of California at Berkley, USA in 1998. His thesis work focused on fabrication of silicon on insulator by high throughput oxygen ion implantation by plasma immersion ion implantation. He joined the Microelectronics Division of IBM Corporation at Hopewell Junction, New York, USA in 1998, where he worked as a Staff Engineer and latter as an Advisor Engineer till 2004. In these years, he was involved in developing electrically programmable fuses, especially for embedded DRAM applications. In July 2004, he joined the Indian Institute of Technology Kanpur, India as an Assistant Professor in the Department of Electrical Engineering. He works with a team of multi-disciplinary faculty researchers at the Samtel Centre for Display Technologies at this institute on organic electronics and its applications in solar cells as well as in displays and printable electronics. He has authored/coauthored several papers in journals including IEEE Electron Device Letters, IEEE Transactions on Plasma Science and Applied Physics Letters. He has also presented at various national and international conferences and Meetings, including the International Electron Device Meetings. He has 16 US patents issues in his name as an inventor / co-inventor. He received several awards including the "Fourth Plateau Invention Achievement Award" in 2002 and the "One team award for eFUSE Development and Implementation" in 2004 from the IBM Corporation. He has also got commendations from the Indian Institute of Technology Kanpur for his teaching of semiconductor device and processing related courses. Dr. Iyer is a member of the Society for Information Displays and a Senior Member of Institute of Electrical and Electronics Engineers, Inc.