Stereo 3D Displays and Telemedicine

How to Select Stereo 3D Technology for Telemedical Applications

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Abstract — **The aim of this paper is to present some ideas and results of a current research related to using stereoscopic equipment meeting the requirements of telemedical applications. The target of the presented preliminary tests and investigations are 3D teleconference and telepresence. This investigation is the result of joint work with physicians from the Medical University Sofia.**

Keywords-stereo 3D display; telemedicine; active glasses; passive glasses; autostereoscopy

I. INTRODUCTION

Telemedical applications have the potential to reduce differences in the people's quality of life because they allow the treatment of patients over long distances. This is the main goal of Telemedicine - to provide permanent and rapid access to physicians at distance using telecommunications, computer and information technologies, regardless of the patient's and the physician's locations:

- E-Doctors at telemedical centres (via telemedical equipment) offer easy and almost immediate or at least very simple access.
- It is quite common for serious medical conditions to be diagnosed at a later stage because it is often difficult for patients in rural areas to travel to large cities to get medical consultations in a tertiary hospital. Telemedicine enables and/or increases the access to an expert physician.
- Patients may require further monitoring and consulting after the treatment they have received in hospital at their first visit. Telemedicine is becoming a reasonable alternative to hospital physician visits and helps monitor chronic conditions. This increases patient's mobility and quality of life in post-hospital stages of the treatment.

Using up-to-date technologies is of crucial importance for telemedicine. The video, as a kind of data and information exchange and/or communication, has an important role in videoconference and telepresence [1].

Three-dimensional (3D) graphics has created new possibilities to present visual data and information. These opportunities add many new ideas in the field of Telemedicine: the 3D visualization of human internal organs of the human in their actual size and shape, and the analysis and manipulation of 3D structures from the captured 3D image(s). This is significant for a number of diagnostic and therapeutic applications, but this is an off-line activity. Surgical telemonitoring, emergency telemedicine and telepsychiatry are examples of the medical activities that require real-time action. The real-time 3D vision is one of solutions to increase the quality of these medical activities.

Though the term "3D" is ubiquitously used today, one can find two types of displays/monitors on the market: stereoscopic and holographic.

- Stereoscopic (binocular) vision is the result of the fusion of the two images (an image per eye) in the brain: although two eyes look in the same direction, they deliver two slightly different perspectives of the scene. Convergence, focus and physiological diplopia are the three components of stereoscopic vision.
- Holographic displays have the ability to provide all four eye mechanisms [6]: binocular disparity, motion parallax, accommodation and convergence. For marketing purposes or other reasons, the term 'holographic display' is often misused and applied in some cases to name systems, which are not truly holographic in the sense of video-holography. Even volumetric displays that create light spots somewhere within their volume are called in many cases 'holographic' [5].

The most notable difference between these two types of stereo 3D displays is that the observer lacks any freedom of head movement and the freedom to increase the amount of information about the 3D objects in the scene: holographic displays do not have this limitation but on the market the term "3D" is used to refer to stereoscopic 3D (dual 2D images as being "3D").

The ideas and results presented in this paper concerning the characteristics of current stereoscopic 3D displays are part of our joint projects and collaboration with physicians from the Medical University Sofia. We are investigating and testing some of the available systems and displays, and analyzing their characteristics and abilities for telemedical purposes. These activities are based on the aims and objectives corresponding to the government strategy “2020” concerning Telemedicine.

This present paper is structured as follows. Section II looks into the pros and cons of current stereoscopic display technologies. Section III analyses the opportunities for a new type of imaging provided by 3D stereo technologies in telemedical applications. Section IV presents the conclusion.

II. Pros and Cons of current stereoscopic display technologies

3D photography gives an impression of depth, which is less convincing than real life. People looking at a stereoscopic picture may find that the third dimension only develops slowly. The longer they look, the more computation the brain does and the 3D impression improves with time. Stereoscopic vision is partly a learned response [7]: those who have looked at many 3D pictures seem to handle the computations with increasing rapidity. In fact, all visual interpretation is learned in infancy, especially the binocular interpretation.

Having in the three basic components of stereoscopic vision (convergence, focus and physiological diplopia) the following problems can be considered:

- Proprioception: the eye muscles must give accurate information about which direction the eye is oriented to.
- The eyes alignment: when looking into the far distance the optical axes must be parallel if the eyes are aligned correctly.
- The movement parallax cannot be used to sort out areas when viewing photographic stereo pairs.
- The dominant eye vision: the brain must not suppress the image obtained from one of the eyes.
- The eyes “autofocus” and 3D information: focus does not give 3D information although the eyes automatically focus to prevent the world becoming a blur. This is the result of the difference between the convergence information about distance and the sharpness of the image (the eyes lenses change shape independently, until the blur is removed). Stereo pairs are always presented on a flat surface and so, focus information and binocular information are never in agreement, which is a defect of stereoscopic displays.
- The brain training: the 3D impression from bumping into things and manipulating them can combine with binocular visual information.

Nowadays, three main versions of "3D" (stereoscopic) technology are of interest to the market:

- Active Stereo 3D: Shutter glasses are used to produce the 3D effect for the user and actively separate the images seen by the left and right eye.
- Passive Stereo 3D: There are two types of passive systems on the market.
  - Some passive displays are created using dual display technology: two displays present images with different polarization, and they are typically aligned with a half-mirror that permits the light from both displays to be presented together to the user’s eyes. This approach allows stereo images to be presented to the user with full brightness and full resolution but it is too expensive.
  - The single display method is a more common method: special films are applied to the screen instead of producing 3D effect, and polarized glasses separate the images for the left and right eye.
- Autostereoscopic 3D: This means that no glasses are required.

For decades the Active Stereo 3D technology has been the standard solution for stereo 3D molecular visualization on the desktops and is still widely used. Many manufacturers use this technology. It is strongly promoted by NVIDIA with "3D vision technology" for desktop LCD displays [10]. Today for computer monitors AMD also offers a similar method, and for the LCD TV Samsung, Sony and Panasonic use this technology as a preferred method of delivering 3D to consumers.

There are several factors that should be taken into consideration when this technology is used. From computer engineering, point-of-view the pros and cons of the Active Stereo 3D technology are:

- Pros:
  - A 120 Hz input frequency: This helps to improve objects motion on LCD displays and to smooth high-speed motions (the perception of motion increases). It also helps users running competitive or high end computer graphics applications.
  - The full HD 3D: the full 1920 x 1080 resolution (of a 1080p image) is transmitted to each one of the eyes.
- Cons:
  - There is no defined industry standard at present, which means that maybe each pair of glasses (and vendors’ methods) will only work with a small set of compatible devices, and not when paired with other vendors equipment.
  - Crosstalk: Overlapping of the left-side and the right-side images. As a result some times 3D images can look artificial.
  - Eye Fatigue: High input frequency flickers are part of this technology. Users don’t see flickers, but the brain understands that flickers exist. This can lead to eye fatigue, dizziness and/or even headaches.
  - Image brightness: The brightness of the image is reduced when comparing 2D content with a 3D image (as a result, active glasses are already tinted).

The Passive Stereo 3D (the so-called polarized 3D) is oriented to glasses that aren’t the active element in the creation of the 3D content on the display: glasses handle

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polarization of the generated image to uncouple images for the left and for the right eye. This is based on the idea of the projection of two images (one for the left and one for the right eye) onto the screen and the use of polarization in a different direction for each image. The main manufacturer oriented towards this technology for the production of monitors/TV's is LG (Film-type Patterned Retarder (FPR) technology [8]).

From computer engineering point-of-view, the pros and cons of the Passive Stereo 3D technology are:

- Pros:
    - Glasses are very cheap: they do not need additional electronic and power supply.
    - This is a flicker-free technology: glasses don't receive 60 flashes per second. As a result, many users find these displays easier to look at for prolonged periods of time.
    - Image brightness: the brightness of the image is higher when compared to active stereo 3D.
    - Each of the eyes receives a non-breakable light stream.
    - No crosstalk: this technology separates left and right images more purely.
- Cons:
    - Aliasing and resolution of image: each eye is exposed to every second line of resolution (half of the frame) by this technology. It is a significant detractor from image quality (small objects and fine details are strongly affected by this) [9]. The closer you get to the screen, the more obvious this effect becomes. The loss of resolution is more pronounced for computer displays than it is for 3D TVs.
    - Motion blur: 60 Hz is the standard input for this technology and sometimes this produces perceived motion blur. Recently, to reduce this, manufacturers have started to announce 3D TVs with 240 Hz input.
    - View angle: the polarized filter is the active element for this technology and it is placed on the screen. This means the device has an optimal viewing angle (severe anomalies like ghosting start cropping up, making the output intolerable).

Autostereoscopic 3D displays are special displays which allow many different types of 3D content (objects, pictures, videos, animations) to be seen spatially in 3D: glasses free 3D visual technology. This is achieved by the so called parallax barrier technology and elements that make sure that each eye of the viewer sees a slightly different perspective. Nowadays, there are two main types of devices on the market:

- Single Viewer: devices work with two perspectives built up approximately 70 cm in front of the display.
- Multi Viewers: a number of different perspectives are projected in front of the screen. Since these perspectives are horizontally spread, many users can see a 3D image irrespective of the position in front of the screen while standing/sitting comfortably around the display.

From computer engineering point-of-view, the pros and cons of the Autostereoscopic 3D technology are:

- Pros:
    - Glasses free technology
    - Resolution per eye: compared to other 3D display technologies the 'Single viewer' autostereoscopy has a higher reachable resolution per eye and gives a better image separation of the different perspectives. For many applications where 3D precision is a key factor this feature is a major advantage: this provides the possibility to create content with a higher depth disparity and/or very low depth differences can also be visualized spatially.
    - It is really possible to walk around an object based on the 'Multi viewers' autostereoscopy.
- Cons:
    - They are prohibitively expensive at the moment.
    - No standard: manufacturers are oriented to a short list of video-card vendors.
    - The time for training users to view stereo 3D is longer compared to other technologies.

The comparisons and characteristics presented in this section are not aiming at an exhausting overview of the existing technologies, but they are provided to help non-technical people to receive in-depth information concerning 3D imaging devices.

III. TELEMEDICINE AND 3D STEREO TECHNOLOGIES

For Telemedical purposes video is used as a kind of data and information exchange and has an important role for videoconferencing and telepresence [1]:

- The main goal of video-conference applications in Telemedicine is to provide real-time visual and audio patient assessment. This type of applications was developed to connect physicians with patients located in isolated areas where climatic or geographical conditions render provider or patient transportation difficult and costly, resulting in inequalities in patient care. Teleconsultation, telepsychiatry and tele-education are well-known examples.
- In general, Telepresence means projecting virtual images of the operative field to remote sites. Surgical telementoring, teledermatology, teleophtalmology, teletrauma, and emergency telemedicine are some of the examples of telepresence practice in telemedicine.

Unfortunately, we were not able to find any overview of 3D imaging subjective perception and comparison of available 3D imaging technologies related to this case.

Two elements of the current video communication technology have critical importance for Telemedicine: peripherals (sensors, devices) and the video-audio-data transfer.

Our tests and analyses show that video-audio transfer is not the major problem for using new 3D vision technologies in Telemedicine: today's technology allows transferring of high-quality video and audio data over extremely short delay times (latency).

The main problem is with the devices. We split our investigation into two separate directions: devices for capturing real 3D and devices for 3D visualization. During the tests we ascertained the fact that the input of the 3D visualization device is the dominant characteristic for the 3D vision system.

The first part of the tests was oriented to 3D capturing devices. We investigated 3 different technologies for capturing 3D content and its transfer to the output device (different 3D displays). The additional information for that can be found in [2].

The second part of tests was oriented to 3D displays. We investigated and analyzed the existing information about available computer displays from the described above three main groups: with active glasses, with passive glasses and glass-free displays. The evaluation procedure of the result was expert-based: we used physicians to evaluate the quality of the 3D display and the ability to use them for medical purposes.

The next element for testing was the perception evaluation of 3D images by users with different eye problems: our investigation was oriented to evaluate the influence of the ability to generate stereoscopic content on the display with classical eyeglasses. We started this group of tests because self-tests hinted that:

- The length of the time for training eyes to perceive a 3D content is different.
- There is a difference between understanding of the 'normal' perception of a 3D content when the convergence is changed from low to high, and when the parallax is changed from positive to negative.

We tested the following kind of users with eyeglasses: single lens (with low, middle and high diopters, with nearsightedness or farsightedness without or with astigmatism) or a progressive lens with middle value diopters.

The results from our two groups of tests can be summarized as follows:

- The glass-free technologies are the future of 3D displays for telemedical applications:
  - If we need a simulation of a 'tête-à-tête' visit, this technology will be the only solution.
  - If we need to simulate a walk around an object or a group of objects this technology will be the only solution.
  - The influence of eyeglasses manifests itself in the extension of training time to start a 'normal' perception of 3D content.
- If we want to use glasses-based 3D stereo displays the active glasses are more suitable for Telemedical application:
  - New technologies reduce flickers and crosstalk (example: the last generation of NVIDIA 3D Vision).
  - The ability to show up small details and/or objects many times, determines the quality of diagnosis.
- The passive 3D stereo technology can be applied in education, teleconference, VR and other kinds of simultaneous activities: the architecture of this type of systems will be similar to that in [3][4].

IV. CONCLUSION

The movie "Star Wars" (1977) changed the understanding of computer graphics and animation. The industries that didvnot understand this lesson lost market positions dramatically.

The movie "Avatar" (2009) changed the understanding of 3D video and audio realism. Today, many industries change their 2D-based tools and applications to 3D- and 4D-based ones. This is the future and it is coming fast in our life. Telemedicine is part of this life and it is under pressure to shift its human interactions basis from 2D to 3D.

In this papers, we did not discuss one of the most important questions – how to educate people to understand 3D artificial images correctly. It is subject of other research work.

Our world is computer-based. We need to understand computer limitations and we need to understand the future of computer technologies. Doctors want to be only doctors (not technicians) but computer technologies can increase doctors' sensing. Researchers and industry need to create and implement new computer technologies for medical application that can increase the quality of the diagnoses and treatment. The presented here ideas, observations and results are part of this scientific and technological support.

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