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A Comparative Study of 3D Endoscopic Tele-operation Techniques

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Abstract

Augmented reality is a technology which uses both real and virtual environments and club them together to form a single view. This is enabled with the help of supporting technical equipment or gadgets. This topic has its reach everywhere, majorly in the field of medicine, technology, education, entertainment and business. This paper focuses on the various techniques and models of 3

Dimensional Endoscopic Tele-operations and compares the majorly available imaging techniques used in 3D Endoscopic tele-operations.

Keywords: Aesculap, Einstein Vision, cool light, sterile drape.

I. INTRODUCTION

In the Earlier years, surgeries were performed with great difficulty, by surgical incision of the patient's target region with loss of excess blood and concluded with stitches. [1] After the surgery, normally the patients are advised for a bed rest along with medication for a longer period of time as blood lose used to be more and surgical cuts are wider and deeper. In most cases, the patients end up with adverse side effects including somnolence and post-operative pain. The most difficult situation is when the scar marks are left behind after surgery. With the entry of Endoscopic Tele-operation, most of the problems related to post-operative pains have been taken care; including sutures, stitches and staples. Since endoscopy is performed in most of the cases by inserting

the equipment to victim's target region through natural openings. Even when surgical incisions are required, a small opening is created that is hardly equal to the width of the equipment being inserted. Since the evolution of technology, human beings developed a tendency to enable the machines to assist them in all their day-to-day needs; This idea or thought has been successfully implemented in almost all the spheres of man's life right from entertainment to medical care. Machines are capable of replacing the manual labor with higher accuracy rate. But they do create adverse effects such as generation of noise and air pollution; Investment and maintenance of these machineries are also too expensive. Automation has become prevalent in all the fields, including medicine, industry, business, entertainment etc. Majority of the work places where man power was utilized got replaced with small and giant machineries. In the beginning, human replacement was only confined to the areas where mechanical works were carried out. Later, with the rise in technological advancements, automation extended its reach everywhere, even in the fields were there was huge requirement for complex computations and decision making; especially when it comes to the field of medicine where high risk was involved. Doctors are being replaced by Expert Systems, surgeries are performed using robotic equipment in order to meet higher accuracy and open surgeries are being replaced by endoscopic tele-operations. In the recent times, endoscopic tele-operations have moved one step ahead with the combination of augmented reality and (normal) 2D endoscopy, higher level of accuracy can be attained as compared to 2D endoscopy, which has a restricted level of viewing. In order to go ahead, medical image-registration techniques have been utilized. 2D Endoscopy is very common in medical field which is used to view the inner body for medical reasons using an endoscope. Endoscope is an instrument used to check the interior of hollow organs; unlike most other medical devices imaging endoscopes are directly inserted into the organ. Endoscopy is performed by a doctor or a surgeon. 3D endoscopy is also performed by a surgeon who is trained for it, considering the various factors like field view loss and equipment knowledge. The main difference between 2D and 3D endoscopy is the level of accuracy. [2] 3D endoscopy is very efficient when it comes to viewing depth, thereby reducing the risk of damaging sensitive tissues of the patient because 3D vision is generated with the help of advanced equipment, 3 dimensions are presented before the surgeon (length, breadth and depth). In the case of 2D vision depth is not available due to the restricted view on 2D screen. Image rendering and filtering are the two main activities involved in endoscopy. Medical image registration techniques are used for carrying out these activities. Cavity of the body.

II. LITERATURE SURVEY

When the concept of Endoscopy got introduced, it was in the form of 2D endoscopy. Rigid endoscopes are small tubular telescopes that allow physicians to look inside joints and body cavities. The rigid endoscopes are useful for diagnostic purposes like Exploration and biopsy of the abdomen, examination of the thorax and chest, exploration of the joints.

Flexible endoscope on the other hand is, used for surgical purposes. The equipment's flexibility enables it to penetrate into depth areas of the target regions of the patient. The camera as well as surgical equipment will reach the site of surgery with ease, using the movements of distal ends in different directions. There are certain rules to be followed during endoscopic tele- operations. The first stage of examination is to take valuable feedback from the patients about their present health condition with the help of patient's medical history, this procedure is to understand weather the patient is asthmatic, allergic to certain drugs and to check whether the patient had the any heart failure because the patient might be unconscious during the entire procedure, certain sedation drugs are useful for making the process much easier. After consulting with Mr. Santosh Jena (Territory Sales Manager, Surgical technologies and Spine Neuro, B .Braun Medical (India) pvt. Ltd Aesculap), the following information were provided by him. According to him, 3D Endoscopes offer two types of 3D vision, i.e. progressive 3D vision and interlaced 3D vision. The cost of the 3D equipment may vary according to the vendor and method of 3D rendering. For instance, In India if the vendors are selling 3D endoscopy equipment which uses interlaced 3D rendering (1080i) ,it will cost around 1 crore INR, while other vendors who are using progressive 3D rendering (1080p), it may cost above 3 crore INR. The main reason being the quality of 3D image generation, progressive 3D processing will result in a perfect image for the surgeons with almost negligible side effects including epilepsy and other problems related to eye strain. B.Braun technologies pvt. Ltd. Aesculap is example for progressive 3D equipment vendor. The interlaced 3D will result in a 3D image which is not perfectly suited for prolonged 3D viewing. The after effects of interlaced 3D may include epilepsy eyestrain and headaches for the surgeon. Olympus 3D is an example for interlaced 3D equipment vendor. After consulting with (CEPD Department, Al Baraha Hospital, Dubai, United Arab Emirates) and ENT Department Al Baraha Hospital, there were some useful information collected which shows that even today, 2D endoscopy has more preference than 3D endoscopy by the patients due to the cost effectiveness. Endoscopy statistics from [4] Al Baraha Hospital:

1. Sinus Endoscopy in operation theatre Monthly 4-6 cases.
2. Flexible Laryngoscopy in outpatient clinic 50/60 cases in a month.
3. Rigid bronchoscopy 120 cases in a month.
4. Rigid Esophagus copy 20 cases in a month.
5. Stroboscopy for throat checking depends on the cases.

From the statistical report of 2D endoscopy, over the last few years, it was very clear that even in the developed countries 3D endoscopy is very slowly gaining its popularity. The above mentioned hospital has 3D endoscopy facilities, yet 2D endoscopy has more preference because of the reasons. 3D endoscopy is very expensive, besides being an efficient method. This is the key reason why 3D endoscopy is only advised for complicated surgeries. The other reason being it's less popularity among the middle class and lower class section of the society because of these reasons

patients may feel that 3D endoscopy is involving high risks. Moreover, surgeons should be given proper guidance on factors like field view loss while performing diagnosis. There are discussions going on about bringing down of expenses. The need for qualified surgeons in the field of 3D Endoscopic tele-operations will help a lot in bringing down of surgery-related expenses. Nowadays, there are more trained surgeons for 3D endoscopy than past 2 years. In coming years, there are expectations that at least one 3D endoscopist will be available per hospital where 3D endoscopy facility is available. Even though, the introduction of 3D endoscopy in India was only a few years back, the popularity was reduced because of rumors spread among the different levels of hospital departments and cost reason. [3]Opioids Narcotics and Benzodiazepine are such categories, others including Analgesics for pain killing, Anxiolytics for anxiety reduction, and Amnestics for the patients' memory reduction of the procedure involved. Once procedure gets over, the effects of sedatives should be reversed. In normal situations, patients will recover from the effect of sedation at a slow pace but in some situations, certain antagonists are available for reversing the effect of sedations. Even today, most of the hospitals and diagnostic centers worldwide have less exposure to 3D endoscopy, the main reason being lack of qualified surgeons and high expense of the equipment.

III. 3D TECHNIQUES

Active or passive 3D technologies using shuttered glasses running on batteries are used in most of the hospitals [8]. The existing 3D endoscopes consist of the following parts. A light System for Light delivery, a tube which is flexible or a rigid system of lenses and an eye piece and other terminal surgical equipment. The eye piece attached to the camera captures the 3D image, which is the result of capturing by the two lenses fixed on the terminal end. The light delivery system also reaches the terminal which lights up the area where diagnosis is performed. The light source used is commonly referred as cool light which won't concentrate heat on the soft human tissue and damage it, because normally when light is concentrated, heat also gets concentrated. The light source used is good enough to reproduce colors so that surgeon can distinguish the areas properly when depth is generated. The intensity of light source should be close to that of visible light or white light (close to 6500 kelvin temperature), but this temperature will damage tissues thus other sources of light which are almost close to the visible light is used. For clearer understanding, let's consider the example of B.Braun Aesculap Einstein Vision 2.0. (The leading vendors of active 3D laparoscopes) uses 300 W Xenon light source, they wraps up the area of camera and its cable inside a sterile drape, which is light-weight and germ resistant.

Thus it is sterilization free. Single stranded fiber optic cables used for light cable which is directly connected to camera head which reduces the number of cables, hence weight and number of cabling required is considerably reduced. The 30^{o}camera system used, inversion of scope is made by 180^{o} in order to correct the field of vision. Anti-fog system is fixed to the endoscope's distil tip in order to avoid fogging of endoscope

when introduced to a warm body. 32'' Full HD monitor for displaying the image and finally 3D polarization glasses (standard/deluxe) for 3D viewing.

Which Filtered Lenses are least preferred and not at all preferred for 3D Endoscopy?

Apart from the above 2 types there are other methods which are less or not at all used for 3D endoscopic vision. They are Filtered lenses RED/CYAN anaglyph 3D and Polarized lenses.

1. **RED/CYAN anaglyph 3D or Classic 3D**

[5][6]Chromostereopsis is the method which creates an impression of depth for an existing 2D image so that it seems to look like a 3D image. This process is carried out using colors like red, cyan, blue, green etc. which are having different wavelengths.

This method uses filtered lenses to generate a 3D image from an existing 2D image which is superimposed with red and cyan. This method follows Snell's Law of Refraction. The colors having longer wavelength is scattered more when compared to shorter wavelength colors.

Red color is scattered less when compared to rest of the colors in visible light spectrum. A process known as positive chromo stereopsis is experienced, where red color appears to come in front of cyan color and gives an impression of depth for different parts of the same image which is having more red areas.

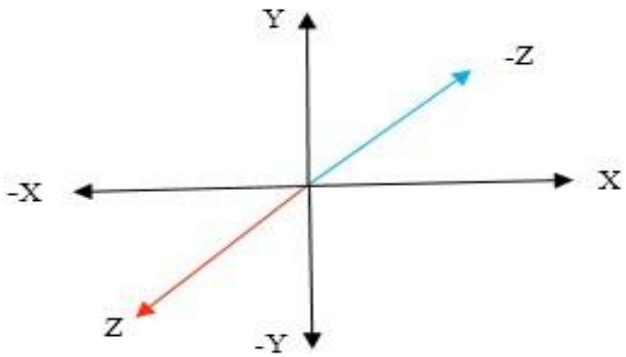

Fig 1 Working of Anaglyph 3D with Snell's Law of Refraction

Snell's law clearly describes the relationship between angle of incidence and angle of refraction. Whenever a ray of light advances from less dense medium (i.e. Air) to more dense medium (i.e. glass, water etc.), it tends to deviate from its actual path. This phenomenon is applicable for meta-materials as well. Meta-materials are materials which are designed to exhibit special properties which are not part of its normal nature.

Composite materials including metals, plastics are assembled for the making of meta-materials.

$$n = \sin \theta a \quad / \sin \theta p$$

Refraction for shorter wavelength colors will be less when compared to longer wavelength colors. Therefore a blue ray of light tends to bend more while passing through plastic or glass lenses when compared with red ray of light.

Figure 1 gives way for a visual illusion called **positive chromo stereopsis** which means red color will appear in front of the rest having longer wavelength.

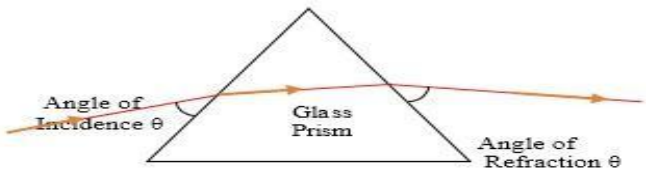

Fig 2a: Refraction for blue ray of light which has shorter wavelength

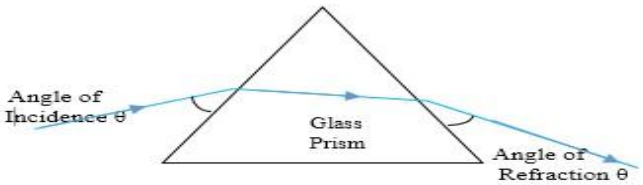

Fig 2b: Refraction for blue ray of light which has shorter wavelength n sinθi = sin θr n = sin θr/sin θi

This condition of light will also give way for **chromo stereopsis,** which means blue color will appear behind the screen when compared to the rest having shorter wavelength).

Simple Explanation of Anaglyph 3D

When a stereogram - an image which is a combination of two

superimposed images, with red and blue area is observed through red/cyan filtered lenses, the parts of the image with red areas will appear in front of the screen while blue areas of the image appears behind the screen. Fig 2a and Fig 2b depict this scenario.

Advantages

Easiest and least expensive method for depth generation from a 2D image. The equipment used for 3D viewing is also inexpensive, normal transparent colored slits can be used instead of tinted glass or polarizing filters.

Limitations

Loses the impression of depth whenever the person tilts his/her head, prolonged exposure results in eye strain. The 3D image generated will not remain steady. The situation will lead to high risks during surgeries. Thus this method is not preferred for medical purpose.

2. Polarized 3D glasses

Circular Polarization. The behavior of light as 2D transverse waves. Snell's Law [7] in action for one of the two rays when non-polarized beam of light is incident on crystals like quartz, calcite etc.

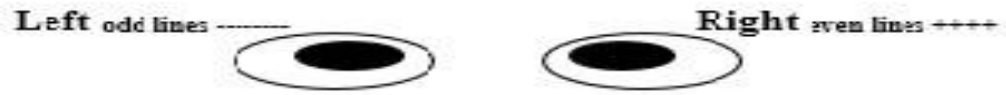

Fig 3 Working of Polarized 3D

[8]Once light is passed through various polarizing filter, similarly polarized waves are allowed to pass through them while non-polarized waves are blocked. Image begins to fade in and out, resulting with an impression of depth.

Advantages

Corrects the disadvantage of RED/CYAN filters. Even when head is tilted focus is not lost because in this case wavelength difference of colors is not the factor taken into account for creating the impression of depth. Thus the amount of work done by the brain for making sense will be comparatively less when compared to classic 3D or Anaglyph 3D.

Limitations

The image will experience reduced brightness to almost 50%. Thus prolonged exposure results in vision problems and headache. Hence this is less preferred. A small amount of dimness will be experienced by both the eyes which after sometimes will reduce the concentration level of the endoscopist.

Scope for Improvement:

From the above explanations, it is clear that both filtered lens approaches will reduce the quality of generated 3D image. There are more chances for the surgeons to lose focus of the work if image is blurred into half or distorted when the glasses are tilted.

More than the side effects for surgeons, the patient's life is in for a toss. Thus, for avoiding such heavy risks, among filtered lenses anaglyph 3D glasses are not at all preferred for 3D endoscopy.

3. ACTIVE SHUTTER GLASSES

[9]Motion parallax. Active Shutter glasses Follow motion parallax law when same image is switched between eyes for some fixed time intervals repeatedly At a time, one shutter will be open and other will be closed and vice versa. Therefore 60 or 30 frames are received by an eye for some microseconds, immediately the shutter for one eye is closed and other is open and similar process is repeated at fixed intervals and an illusion of depth is created by brain.

Advantages

If the system is actually active shutter 3D the image will be reproduced in Full HD will less harmful even with flickering effect.

Limitations Power required, Expensive, In case of passive 3D, when head is uncontrollably tilted bleeding may be experienced for portions of the image.

Inference

[10]Active shutter glasses are expensive when compared to filtered lenses mainly because they are powered by batteries. Still they are preferred in the field of 3D endoscopy because of the perfection of 3D image generated using them. There amount of accuracy attained will be much higher. Apart from the problems like field view loss up to some 52%, they are very useful for trained or qualified 3D endoscopy surgeons.

4. WORKING OF PROGRESSIVE AND INTERLACED 3D IMAGE PROGRESSIVE 3D

Progressive 3D or active 3D makes use of shuttered glasses powered by batteries, since the shutters are rapidly being switched (open and closed alternatively), this situation will create an illusion of depth. Theoretically, All the information targeted for the right eye will be obstructed by left eye by the closing the shutter on left eye and vice versa. The primary goal of the display device is to perform fast refreshing so that 60 fps is received by each eye. At the same time camera's shutter speed will be configured in such a way that they are quick enough to capture the two lenses information. Progressive 3D will process the full image in 1920x1080 resolution and display the output on FULL HD 3D display, i.e. complete image 120 fps is received by both the eyes (minimum of 60 fps per eye) and is somewhat similar to normal binocular vision generated by the brain for human eye.

Interlaced or Passive 3D

This is the common method used in theatres for 3D movie viewing experience. But In case of 3D endoscopy, Interlaced 3D will split the derived images from camera lenses into two separate images for left and right eye respectively, then combine those images into one single 3D image after processing it in 750 X450 resolution, then views it on monitors having high a resolution 1920X1080. 1080i ('i' stands for interlaced).Thus it results in a superimposed left eye - right eye image after getting processed. This method is not an effective method for prolonged 3D viewing since only one half of the complete image is received by both the eyes.

The left eye information is blocked by right eye shutter by being closed or opaque at that instance, similar case will happen for the left eye when right eye receives some information. I.e. 60 fps for both the eyes. When shutters for left eye is closed right eye will receive 30 frames per second and vice versa. This type of viewing will not provide a 100 % binocular vision and long Lasting use will result in many health problems like eye strain.

Scope for Improvement:

The passive 3D endoscopy equipment is less expensive when compared to active 3D equipment but considering the after effects for surgeons like long term health issues related to eyes and if same surgeon is performing continuous 3D endoscopy it will affect the patient, it will be wiser to go for active or progressive 3D equipment.

METHODS USED IN MEDICAL IMAGING:

3D Image rendering using Filtered Back Projection Method

Assumption: Finite projections can be generated over an object using exposure of a radioactive element. [11]

Approach: These radioactive projections on the object will lead to the regeneration of almost accurate shape of actual objects with blurred edges due to distortions.[12]

Advantages: Less expensive to implement.

Limitations: Ramp filter is used to remove the distortion patterns which slows down the real time process.

3D Image rendering using Philips Iterative Reconstruction Method

Assumption: By using less radiation the most of the factory protocols can be regenerated in less than 60 seconds. Approach**:** ICT's advanced technology is used, 64 families of scanners are used to reconstruct image.

Advantages: This method is 57% more efficient when compared to Filtered Back Projection method, Less dosage of radiation is required for generating clear output so that victim has reduced exposure to radiations.

Limitations: Expensive to implement.

ALGORITHMS USED IN IMAGE FILTERING

3D Image Optimization using K-SVD (Singular Value Decomposition) Algorithm

Domains: [13] [14] [15] Synthetic Dictionary Recovery Problem & Medical Image Processing.

Approach: Trains dictionary by understanding the number of iterations, reconstruction using rank sparsity determination.

Advantages: Removal of white Gaussian noise (additive in nature) from image sequence.

Limitations: The main drawback of this algorithm is minimization of image. Less efficient than Approximate K- SVD algorithm.

3D Image Optimization using AK-SVD (Singular Value Decomposition) Algorithm

Domains: [16] Synthetic Dictionary Recovery Problem and Medical Image Processing.

Approach Motion estimation and real time parallel filtering.

Domains: Synthetic Dictionary Recovery Problem and Medical Image Processing.

Methods Involved: Motion estimation and real time parallel filtering.

Advantages: Naturally fit for GPUs and intensive computation tasks.

Limitations: The main drawback of this algorithm is minimization of image.

3D Image Optimization using T-SVD (Truncated Singular Value Decomposition) Algorithm

Domains: [17] Synthetic Dictionary Recovery Problem & Medical Image Processing, Study of gene samples.

Methods Involved: The dimensions are compressed by applying SVD to a sample matrix, then represented using vectors, finally truncated space which are having low dimensionality are studied.

Advantages: The results are promising for grouping, T-SVD can be applied to multiple data sets.

Limitations: More processes are involved and so it consumes more time when compared to A K-SVD and K-SVD. **Inference:** When it comes to medical image registration, there are lot of factors to be considered other than the affordability. There are factors like safety, perfection and timeliness of image being rendered in real time. Unlike entertainment field, safety and perfection will dominate the tendency to opt for cheap affordable technologies, which is the key reason behind neglecting anaglyph 3D imaging from medical image registration. It is not necessary that all the methods resulting in faster outputs are always accurate. There will be situations when small differences in time efficiencies have to be compromised for attaining higher accuracy and before choosing a method for image filtration all such factors have to be taken into account. After going through various journals and references, I was able to reach a conclusion that TSVD, besides being a little time consuming process is an optimal Image filtering algorithm as compared to many others including KSVD and AKSVD.

FUTURE ENHANCEMENTS

[18]After the launch of EinstenVision 2.0, Aesculap has reduced the size and weight of their camera by feeding the light cables directly to camera head through endoscope. Recently, an Editorial on neurosurgical technique, has mentioned about developing UHD (7680X4320 resolution) 3D endoscopy. This involves multiplication of FULL HD by 16 pixels that is extremely useful for reproducing crystal clear, Ultra High Definition image and hence making the work much easier for surgeons. The editorial also states about reduction of camera size and weight since it helps in further penetration of endoscopic equipment into depth areas. The article also hangs on to its expectation that in the future, diagnosis can be performed without using googles. Therefore such effective practices by the organizations are extending great possibility for adding future enhancement to the existing system.

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