Virtual Stomach Visualization and a Stomach Tumor Detection System

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Abstract—**Anatomy, the study of the structure of the human body is a fundamental of medical education. The main techniques and tools which are used in studying human anatomy are the traditional dissection of the human body and 2-dimensional diagrams in text books. However, a natural abhorrence towards dissection, emotional concerns, incapability of repeating the dissection, limitations in the number of cadavers and difficulty of capturing the real view of human anatomy presented in a text book plague traditional learning.**

This paper investigates the possibility of building an interactive Augmented Reality system which enables users such as medical students to practice dissecting a stomach with a great deal of freedom whilst enjoying a nearly real enhanced learning experience. The prototype which is developed using Goblin XNA, can be used as a learning tool which helps in traditional dissection and provides capability for identification of abnormalities in endoscopic images in which users can upload an endoscopic image and the system will automatically segment the abnormal area. Three image segmentation algorithms such as Watershed, Normalized Cuts and Topological derivatives are implemented using Matlab in order to find the best approach.

Keywords-component; Augmented Reality, Medical Image Processing, Watershed, Normalized Cuts, Topological Derivative.

I. INTRODUCTION

Augmented Reality (AR) enhances a user's perception of and interaction with the real world. The virtual objects display information that the user cannot directly detect with own senses. The information conveyed by the virtual objects helps a user perform real-world tasks. Augmented Reality is a specific example of what Brooks and Frederick [1] call “Intelligence Amplification (IA): using the computer as a tool to make a task easier for a human to perform” [1].

The most important aspect of AR is, it can be used in many areas like medical visualization, AR learning systems, maintenance and repair, annotation, robot path planning, entertainment and military aircraft navigation and targeting.

Among these areas, AR in medicine plays a major role. Further AR applications for learning human anatomy have become an essential aspect as anatomy is a cornerstone of medical education. The main techniques and tools which help in learning human anatomy is the dissection of the human body. It gives an opportunity to learn a wide range of variability presented in a real human body that is difficult to capture in a textbook and specimen. However, there are some obvious problems with traditional dissection such as cadavers storing, issues of morality, and public perception.

The aim of this project is to design, build and evaluate an interactive AR system which enables users such as medical students, teachers as well as school children to dissect the human stomach with a great a deal of freedom whilst enjoying a nearly real enhanced learning experience and also use endoscopic images to detect the presence of stomach tumors which will help to reduce the probability of missing some abnormalities if the abnormalities cannot be detected by naked eye.

II. RELATED WORK

Augmented Reality Technology and computed tomography together with newly emerging technology in 3D visualization have brought anatomical education into a new era. As a result of that, lots of interactive AR systems for learning human anatomy have been implemented.

At UNC Chapel Hill, a research group has conducted trial runs of scanning the womb of a pregnant woman with an ultrasound sensor [12].They have generated a 3-D representation of the foetus inside the womb and display that in a see-through Head Mounted Device (HMD). Another similar project is carried out by the same research group for a needle biopsy of a breast tumor [13]. It is predicted that trial runs of scanning the womb would be a 3D stethoscope one day and both applications can be used as visualization and training aid for surgery and learning anatomy.

A system called “Anatomic VisualizeR” is presented for learning modules in anatomic education [11]. In this system, they have provided a virtual dissection room in which students and faculty can directly interact with three dimensional models of human anatomy and also concurrently provision access for supportive curriculum material as well. This system has overcome previously mentioned issues in traditional dissections as it has provided a broad range of virtual exploratory tools enabling users to investigate structures in ways not possible in the real world. Meantime, a similar implementation of a three-dimensional visualization system called "Armed" [9] is developed to improve education at medical schools and facilitate preparation of surgery interventions where 3D models can be obtained with standard reconstruction of medical images such as X-ray, magnetic resonance, computer tomography.

Additionally a project called EKGAR [5] allowed medical students to explore patient's specific cases of cardiac diseases in 3D while providing the tangible interaction. Natural interaction is provided through a joystick (interaction tool) enabling the users to flip and turn the 3D heart. An AR system for a 3D skull structure is developed [2] with visual support. This system is based on a complete structure of the skull which can be decomposed and reassembled.

Further a Liver visualization of a mixed reality system was implemented to facilitate the communication between radiologists and surgeons [3]. The users of this system can interact with virtual and real objects with full stereoscopic view with a set of fiducial markers on it. This mechanism facilitates the communications in understanding problems and finding appropriate solutions. An AR system for learning anatomical structures of a virtual human abdomen is implemented [8]. In this system, user is prompted to open the abdomen of a virtual body of a female or male. However it would have been better if more organs are added to be displayed in this system.

On the other hand a number of researches have been done in endoscopic images in order to extract stomach tumors. The morphological watershed segmentation approach is presented for the segmentation and analysis of possible presence of abnormality in endoscopic images [4]. The watershed segmentation is carried out on the pre-processed image and the number of regions is counted and is compared with the threshold value. Another algorithm called normalized cut criterion method is used to perform the segmentation of abnormal region [6]. This method performs segmentation of the images through hierarchical partitioning instead of performing single flat partition. Topological derivatives based on discrete approach are presented for the segmentation of tumors [7]. In this method the topological derivatives are used here as a descent direction to minimize the associated cost function. Similarly, Continuum approach is also presented to compute the topological derivative for an appropriate functional and a perturbation given by the introduction of cracks between pixels [10].

III. WORK FLOW OF THE PROTOTYPE

The overall design of the prototype is consisted of two main sub systems as AR System and Endoscopy Test and seven sub modules in those sub systems. The work flow between these modules is as follows.

A. *AR System*

- 3D models of stomach will be created which will be used for virtual dissection. Further, fiducial markers will also have to be created in order to track the 3D models.
- In the next module, the created models will be imported to the AR development environment and a marker tracking library will be used to manipulate markers attached with 3D models.
- Then, the virtual dissection module will handle the logic related for displaying, flipping and turning of the stomach, opening the slice of stomach, removing each layer and zooming them.
- A quiz and supportive materials will be implemented in the next sub module.

B. *Interface*

- This module will act as a bridge between the AR system and Endoscopy system. The integration of those two main systems will be handled in this module.

C. *Endoscopy Test*

- The endoscopy image will be uploaded to the system. Then in the next main module, the pre- processing of the image will be done in order to get a clear image to be processed at the segmentation module. Although the pre- processing of the images is categorized as a separate module in the design, the appropriate pre- processing techniques are carried out in different ways depending on the algorithm that is going to be used.
- The isolation of objects in the endoscopy image will be implemented in the image segmentation module in order to extract the tumor areas in endoscopic images. Three types of algorithms will be used for above mentioned purpose and the best approach for endoscopy image segmentation will be presented depending on the final results.
- Finally the tumors of the input endoscopy image will be displayed.

IV. IMPLEMENTATION

As discussed in the Design, the implementation of virtual stomach can also be divided in to four sections as further described.

A. *AR System*

a) *Creation of Stomach 3D Models*

The 3D models of virtual stomach are created using Autodesk Maya 2012. The reason for above choice is GoblinXNAv3.6 framework supports "fbx" format which is a Maya interchangeable model format. The creation of stomach 3D models is done with the use of textures created using Adobe Photoshop.

b) *Marker Creation*

Several fiducial markers are used externally. Since GoblinXNAv3.6 framework uses ALVAR Marker Tracking library for marker tracking, Sample Marker Creator Application provided by ALVAR 1.5, is used to create the markers. ALVAR produces the image of the related marker to be printed.

c) Importing Models

The stomach model in fbx format is loaded in to the Goblin XNA framework using the "(Model)loader.Load" function. Then a geometry node should be created to assign the loaded model in order to be overlaid on top of the marker. Materials are applied to the loaded model by setting the "UseInternalMaterials" to true. The transformations of x, y and z axis are given in order to place the model on the marker correctly. All the other stomach models are also imported to the Goblin XNA framework using above method.

d) Marker Tracking

Marker tracking is performed using ALVAR 1.5 library. First, a marker node should be created to be able to track the marker. Then, marker should be added to the scene graph of Goblin framework. The translation of the stomach should also be added to the scene. Marker tracking for other images is also done by as above theory. The marker tracking logic is written corresponding with the game time. When the camera is turned on and the marker is detected while the application is running, the virtual stomach will be displayed.

When the corresponding marker for flipping is detected, the flipped stomach will be displayed and with a label stomach is flipped. The same marker used for flipping will be used for turning the virtual stomach as well. When the marker is tuned 90 degrees to the left, the stomach will be turned and posterior of stomach will be displayed. The two markers for slice opening are recognized by the system, the slice opened stomach will be displayed on the screen separated with the removed slice.

The functionality to see the main layers of a human stomach which are Circular muscle layer and Oblique muscle layer is also provided. In addition, users are able to see the zoomed view of the stomach layers. A level based quiz is also developed using C# windows forms in order to test the users' knowledge on stomach anatomy.

B. Endoscopy Test

In endoscopy test system, previously mentioned three algorithms are implemented in terms of finding the best approach using Matlab. User can upload an endoscopy image and then system will segment the abnormal area automatically. An additional feature is developed, in which user can provide a location where series of endoscopy images are stored of a particular patient and also the destination location to store the segmented images. Then system will segment the abnormal area of those images if they exist and show the segmented images. The performance specifics of three algorithms were evaluated against each other for this purpose. The results are discussed in the next section.

V. TESTING

In developing this research prototype, testing has been applied in four steps. They are unit testing, integration testing, acceptance testing and system testing. Unit testing was performed in the early iteration of the system focusing on the smallest testable elements of the prototype. In Integration process, testing was done to evaluate the interaction between software components, hardware component to ensure that a unit works together when they are integrated. System testing was done to ensure that the functionality specified in requirement specification works. At the final stage, acceptance testing was carried out based on specifications of the end user. It determines whether or not a system satisfies its acceptance criteria. Further, AR system was tested under different lighting conditions, distance from the camera and the marker and time of the day. The test results for above two features are shown in the following Table I. Then optimum distance for marker detection is obtained by inspecting results as shown in the Table II.

20 abnormal images and 5 normal images were tested with each algorithm for tumor detection. Testing is carried out by inspecting the final segmentation output received from the algorithms. Results received from Normalized Cut algorithm are very satisfactory since it segments the abnormal area for almost all endoscopy images. 85% of segmentation accuracy is given for tumor detection in endoscopy images which is approximately 50% higher than the accuracy level of other two approaches. However, Watershed method did not give better results for most of the images as segmentation accuracy is 30%. Having examined the final output, it is found that, this algorithm does not give satisfactory results for very bright images. Since most of endoscopy images are full of bright spots, the algorithm did not give expected results.

Efforts have been taken to reduce the brightness of those images using Photoshop. But that approach also did not work properly. This could be a reason for not giving better results for some of the images with Topological segmentation as well. Further ideas were gathered regarding this issue from a Radiologic Technologist. As a result, it was found that, the quality of the images will pose a challenge in this area. Many endoscopic studies are done using fluoroscopy, so there can be a lot of variables in image quality.

Following Table III depicts the results gained for the set of sample images. Fig 1 and 2 illustrate the proposed system's main user interfaces and how it works. Fig 3 elaborates the results received from Normalized Cut algorithm which are very satisfactory since it segments the abnormal area for almost all endoscopy images. Fig 4 shows the series of images segmented at once using Normalized Cut.

VI. CONCLUSION AND RECOMMENDATIONS

A system is not complete if it has not been evaluated appropriately by its target audience and experts. The results were obtained by distributing the questionnaires after a demonstration of the prototype. Separate questionnaires were prepared for both portions of the system based on categorization of the evaluators. Further interviews were also carried out with some of the evaluators. The evaluation has been done by set of people grouped according to the following category as elaborated in Table IV. The evaluation process should cover all phases of the system including the concept, development and the idea behind it to create. Therefore, the evaluation criteria which are presented in the Table V were used to assess the proposed system.

The concept of the project is evaluated as an innovative idea for the medical field since both portions of the system can be very useful to the medical students to improve their knowledge and also to radiologists to reduce the time consumption for diagnosing stomach abnormalities. Especially, the non- technical evaluators were impressed having seen how easily the system could be operated.

Question was raised to verify whether scope of the overall project is acceptable for the BSc level of degree. Most of the evaluators said that project was up to the standard of BSc level since this is an individual project and selection of image processing as a part of the final year project is excellent since, it is an acceptable area for Ph.D. candidates as well.

The evaluation was carried out to evaluate the design and implementation of the project by technical evaluators, since it helps to improve the quality of the system. Evaluators stated that .NET is a good platform to choose since it supports OOP. Therefore, the design of the system will be very clean.

The problem and solution were presented to the relevant evaluators. They mentioned that Goblin XNA framework is a good virtual navigation tool since it can be used to develop AR applications with less effort and also the choice of Matlab is wise, since it is a very powerful tool in terms of image processing. In addition, they stated that Autodesk Maya is appropriate for 3D modeling since it is a powerful tool and also mentioned that 3D modeling is a nice concept which will increase the simulation power.

The prototype was evaluated by technical and non technical people. Effectiveness of the entire system was evaluated by 13 of evaluators. 10 of them which is 76% stated the concept of project was very effective where as 3 of them, which is 24% stated the concept as effective. Usefulness of the prototype was assessed by intended users like Medical Students, and Radiologist. 5 out of 6 which, is 83% stated it is very useful while 1 of them which is 17% mentioned useful. The entire project could be evaluated as a success as it has effectively achieved its potential. Suggestions for future enhancements are very important since they give an idea on how to take the system to a next level. Similarly drawbacks are also important since they can be overcome in the future. Important suggestions were received from various evaluators in terms of enhancing the system as mentioned below.

- Implement the system in a manner that it can be used to manipulate human cadavers generated from actual images.
- The AR system can be enhanced to a next step that it will handle actual images of human cadavers. The images taken from CT scans can be used having performed volume rendering on them in order to get 3D images as the final outcome.
- Implement the system with more organs

The AR tool can be improved further by presenting more organs in the stomach in order to provide a very descriptive knowledge on stomach anatomy.

- Implement the Endoscopy test system as an intelligent system which classifies the type of the stomach tumor.

Since the system is not developed up to a level that it will classify the type of stomach tumor, the system could be taken in to a next level by implementing it as decision support system. The methods, Classification, Decision making and Patient data archival can be applied after the segmentation process.

- Improve the Endoscopy test system as it can support in a web interface.

This can be implemented as Matlab supports HTML.

TABLE I. TEST PLAN FOR MARKER DETECTION

Test Case	**Measurement**	**Expected Output**	**Actual Output** (is Virtual stomach displayed?)	**Result**	**Accuracy**
Distance from the camera and the marker.	15 cm (intial set up of the application)	Virtual stomach should be displayed	Yes	Pass	75%
	25 cm		Yes	Pass	
	35 cm		Yes	Pass	
	45 cm		Yes	Fail	
Lighting	Lamp aimed directly as close as to the video camera.	Virtual stomach should be displayed	Yes	Pass	100%
	Lamp aimed at the video camera with a considerable distance.		Yes	Pass	
Time of the day	Morning (8.00am–12.00p.m)	Virtual stomach should be displayed	Yes	Pass	75%
	Evening (12.00pm.-6.00pm)		Yes	Pass	
	Night (6.00pm onwards)		Yes (Provided required light)	Pass	
	Night (6.45pm onwards)		No (No artifical light provided)	Fail	

TABLE II. BEST PERFORMANCE FOR MARKER DETECTION

Tesitng Case Description	Measurement
Distance from the camera and the marker(initial setup of the system)	15 cm (intial set up of the application) – 30 cm
Lighitng	Lamp can be either aimed directly as close as to the video camera or aimed at the video camera with a considerable distance
Time of the day	8.00am –6.00p.m with natural light and 6.00pm onwards with artificial light

TABLE III. TEST RESULTS OF ABNORMALITY DETECTION

Algorithm	Expected Output	Actual output	Accuracy and Variance
Normalized Cuts	Abnormal area should be segmented in all 20 images	Abnormal area is segmented in 17 images	85 % - Approximately 50% better than other two methods
Watershed Method		Abnormal area is segmented in 6 images	30%- 50% of less accuracy compared with Normalized Cuts
Topological Segmentation		Abnormal area is segmented in 7 images	35%- 50% of less accuracy compared with Normalized Cuts
Normalized Cuts	Number of segmented objects should be ideally one(only the background)	Only the background is segmented in 4 images	80% - 60% better than Topological Segmentation and 20 % better than Watershed method
Watershed Method	Number of watershed Areas will be less than five approximatel y	Number of watershed areas found is less than 5in 3 normal images	60% - 20% of less accuracy compared with Normalized Cuts and 40% better than Topological Segmentation
Topological Segmentation	Number of segmented objects should be ideally one (only the background)	Many objects are found in 4 normal images	20% - 60% of less accuracy compared with Normalized Cuts

TABLE IV. EVALUATOR'S CATAGORY

Evaluator	Technical Aspect	Domain
Medical Students	Non-Technical	Intended User
Radiologist/Doctors	Non-Technical	Domain Expert in Endoscopy and human anatomy
Software Engineers/Architectures	Technical	Technology and the Software Quality
AR Professionalist	Technical/Non Technical	Existing AR systems on human anatomy learning systems Experts on AR
Professor or Graduate in Mathematics and Statistics (Matlab)	Technical	Experts on Matlab

TABLE V. EVALUATION CRITERIA

Criteria	Description	Type
The Concept and the whole project	Since the concept of the project is innovative, the project should gain comments, and practical criticism on the whole project itself.	Technical/Non-technical
Scope	The scope of this project is a very important area. Therefore, getting comments on academics on the project is very vital.	Technical
Design and Implementation	This criterion is used to evaluate whether the design of each module is described completely and justification of the design decisions taken is acceptable.	Technical
The Solution and Technologies	Evaluate to verify whether the solution proposed was appropriate in addressing the problem domain technically and non-technically.	Technical/Non-technical
The Prototype (Features presented, Usefulness, Effectiveness and Accuracy	The evaluation of the prototype to decide whether the prototype acts as a verification of the concept as proposed. It also needs an opinion of the product's features offered, usability and effectiveness	Technical/Non-technical
	Features Provided: Evaluate the features provided by the system.	Technical/Non-technical
	Usefulness: The judgment of usefulness of the system.	Non-technical
	Effectiveness and Accuracy: The evaluation of how objectives are achieved and the accuracy of the results generated from the system.	Non-technical
The Future Enhancements, Shortcomings and Potential	Future enhancements must be a very important consideration due to the limitations that occurred in the current application. The shortcomings should also be overcome to make it a future enhancement. Although this project is carried out for academic purposes, there is possibility of being a commercial product for hospitals and for students as well.	Technical/Non-technical

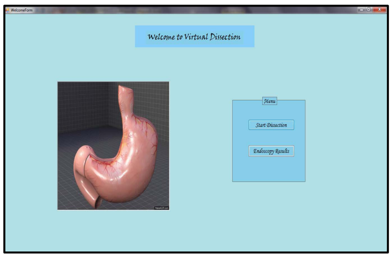

Figure 1. Main UI with two main systems

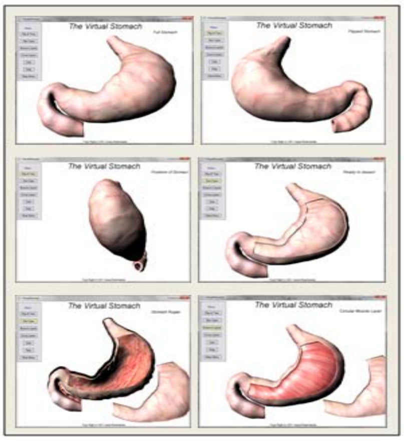

Figure 2. System features: flipping, turning, slice opening, removing layers of Stomach

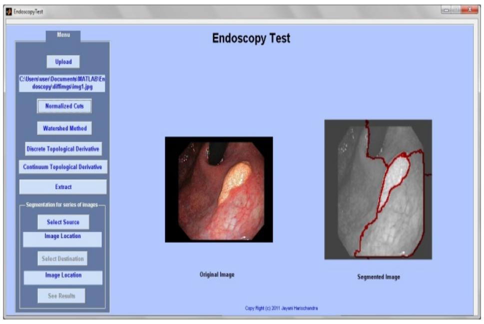

Figure 3. Segmented Image with Normalized Cut

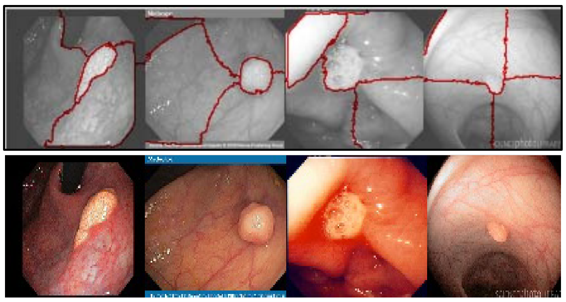

Figure 4. Series of Segmented Images using Normalized Cut

REFERENCES

[1] Brooks and Frederick P. Jr., (1996). *The Computer Scientist as Toolsmith II* [Online] ACM, Inc. Available from: <http://www.cs.unc.edu/~brooks/Toolsmith-CACM.pdf> [Accessed 15 August 2011].

[2] Chien, C., Chen, C and Jeng, T., (2010). *An Interactive Augmented Reality System for Learning Anatomy Structure* [Online] Hong Kong: Proceedings of the International MultiConference of Engineers and Computer Scientist 2010 Vol I. Available from: <http://www.iaeng.org/publication/IMECS2010/IMECS2010_pp370-375.pdf> [Accessed 20 August 2011].

[3] Choy, C., (2007). *Consulate General of France in Hong Kong & Macau Cultural and Scientific Department* [Online] Hong Kong: Available from: <http:// www.consulfrance-hongkong.org/IMG/pdf/Virtual_and_Augmented_Reality_in_Hong_Kong_-_Final.pdf> [Accessed 27 August 2011].

[4] Dhandra, B.V and Hegadi, R.S., (2010). *Classification of Abnormal Endoscopic Images using Morphological Watershed Segmentation* [Online] India: Proceedings of the IEEE International Conference. Available from: <http://kud.academia.edu/RavindraHegadi/Papers/239267/Classification_of_Abnormal_Endoscopic_Images_Using_Morphological_Watershed_Segmentation> [Accessed 08 October 2011].

[5] Hedegaard, H and Dahl, M. R., (2001). *EKGAR: Augmented Reality Support for Learning of Electrocardiography (ECG) Analysis* [Online] Available from: <http://www.daimi.au.dk/~kgronbak/homepage/pubs/EKGARedmedia_rev_03-FINAL.pdf> [Accessed 27 August 2011].

[6] Hegadi, R. S., (2010). *Identification of Abnormality from Endoscopic Color Images using Normalized Cuts* [Online] India: Proceedings of the IEEE International Conference. Available from: < http://kud.academia.edu/RavindraHegadi/Papers/645288/Identification_of_Abnormality_from_Endoscopic_Color_Images_Using_Normalized_Cuts> [Accessed 16 September 2011].

[7] Hegadi, R. S., (2010). *Segmentation of Tumors from Endoscopic Images using Topological Derivatives Based on Discrete Approach* [Online] India: Proceedings of the IEEE International Conference. Available from:< http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5697441> [Accessed 16 September 2011].

[8] Juan, C., Beatrice, F and Cano, J., (2008). *Augmented Reality System for Learning The Interior of the Human Body* [Online] Available from: <http://users.dsic.upv.es/~mcarmen/docs/HumanBody.pdf> [Accessed 22 August 2011].

[9] Nikolić, N., Nikolić, S., Radenković, P and Agatonović, L., (2010). *ARMed* [Online] USA: Available from: <http://msacademic.rs/download/imaginecup/2011/projects/01%20AdHoc%20Team%20-%20ARMed.pdf> [Accessed 29 August 2011].

[10] Radha, V and Krishnaveni, M., (2009). *A Topological Derivative Based Image Segmentation for Sign Language Recognition System using Isotropic Filter* [Online] Available from: < http://arxiv.org/ftp/arxiv/papers/1001/1001.1968.pdf> [Accessed 22 August 2011].

[11] Rigamonti3, D., Bryant, H. J., Bustos, O., Moore, L and Hoffman H, M., (2000). *Implementing Anatomic VisualizeR Learning Modules in Anatomy Education* [Online] Available from: <http://www.nlm.nih.gov/research/visible/vhpconf2000/AUTHORS/HOFFMAN/HOFFMAN.PDF> [Accessed 22 August 2011].

[12] State, Andrei, Chen, T. D., Tector C., Brandt, A., Chen, H., Ohbuchi, R., Bajura, M and Fuchs, H., (1994). *Case Study: Observing a Volume Rendered Foetus within a Pregnant Patient* [Online] Washington: Proceedings of IEEE Visualization '94. Available from: <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.18.258> [Accessed 14 July 2011].

[13] State, Andrei, Hirota, G., Chen, T. D., Garrett, T and Livingston, M., (1996). *Techniques for Augmented-Reality Systems: Realizing Ultrasound-Guided Needle Biopsies* [Online] Proceedings of SIGGRAPH '96. Available from: <http://dl.acm.org/citation.cfm?id=237283&dl=ACM&coll=DL&CFID=55797730&CFTOKEN=15781618 > [Accessed 14 September 2011].