Integrated Approach to Recognize Square-ROI in Breast Cancer Augmentation

Rechard Lee

Faculty of Science and Natural Resources
University Malaysia Sabah

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RECHARD LEE

FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITY MALAYSIA SABAH
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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

15 July 2014 ____________________

Rechard Lee

PS20118253

CERTIFICATION

NAME :**RECHARD LEE**

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1. **SUPERVISOR**
   Dr. Abdullah Bade   Signature

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The ultimate goal of an AR system is to create a mixed-digital environment such that the computer–generated objects mixed into the real-world environment as one of its entities. Thus, the object must be visually registered in every point the user sees. To maintain the user's illusion that the virtual objects are part of the real world requires a consistent registration of the virtual world with the real world, and this stringent requirement of the system is one of the challenges in developing an AR system (Klein, 2006; Xu *et al.,* 2003; Azuma, 1997).

Various studies have been conducted to study and explore the fundamental concept and unique potential of Augmented Reality (AR) technology to be applied in mainstream application such as in medical, visualization, maintenance and repair, annotation, robot path planning, entertainment, and military aircraft navigation. This technology combines the field of Computer Vision (CV) areas such as marker and markerless tracking, features detection and image processing (Siltanen, 2012). Number of attempts had been proposed to manipulate and utilize Augmented Reality technology to generate a 3D representation of the human organ, investigating and displaying MRI images or CT-scan data and directly registered onto the patient.

Considering the AR potential opportunity as mentioned in the previous study (Dixon *et al.,* 2013; Siltanen, 2012; J.-D. Lee *et al.,* 2012; Krevelen and Poelman, 2011; Kroeker, 2010; Trevisan *et al.,* 2008; Bianchi *et al.,* 2006; Azuma, 1997), clearly we can apply AR technology to aid the surgeon and the patient to better understand and have in depth visualization about their sickness in which human senses are not able to detect. Therefore, this thesis will investigate the feasibility of real-time marker-less square-ROI recognition based on the integration of contour-

LIST OF FIGURES

LIST OF PUBLICATIONS

- Rechard Lee, Abdullah Bade, Salina Sulaiman, & Siti Hasnah Tanalol. 2013. "RPMS: Detect a hand-drawn square-ROI in uneven lighting condition". 2nd International Conference on Interactive Digital Media (ICIDM 2013). 3-4 Dec 2013, Kuching, Malaysia.

- Rechard Lee and Abdullah Bade. 2013. "Real-Time Non-Printed Markerless Identification for Breast Augmentation by Combining Contour-Corner Approach". International Journal on Interactive Digital Media vol. x(x), ISSN 2289-4098, e-ISSN 2289-4101. Accepted.(to be published)

- Rechard Lee & Abdullah Bade. 2013, "Real-Time marker-less Square-ROI recognition based on Contour-Corner for breast augmentation", Journal of Computing, Volume 5, Issue 2, February 2013. IF 0.21. eISSN: 2151-9617.

- Rechard Lee, Abdullah Bade, Salina Sulaiman, & Siti Hasnah Tanalol. 2013. "Real-Time Pre-place Marker-less Square-ROI verification system based on Contour-Corner approach for breast augmentation". International Journal of Medical and Bioengineering (JOMB), Volume 2. No 1, March 2013. ISSN: 2301-3796.

- Rechard Lee, Abdullah Bade, Salina Sulaiman, & Siti Hasnah Tanalol. 2012. "Real-Time Non-Printed Markerless Identification for Breast Augmentation by Combining Contour-Corner Approach". 1st International Conference on Interactive Digital Media (ICIDM 2012). 3-4 Dec 2012. Langkawi, Malaysia.

- Rechard Lee, Abdullah Bade, Salina Sulaiman, & Siti Hasnah Tanalol. 2012. "Using Computer Vision Techniques to Recognize Hand-Drawn Square-ROI as a Marker in Augmented Reality Application". 10th Annual Seminar on Science and Technology 2012 (SNT 2012). 1-2 Dec. 2012. Kota Kinabalu, Sabah.

- Rechard Lee & Abdullah Bade. 2011. "Augmented Reality: The Technology you should know". 9th Annual Seminar on Science and Technology 2011 (SNT 2011). 17-18 Dec. 2011. Kota Kinabalu, Sabah.

corner detection approaches as the fundamental component to register the virtual imagery with its real object. We believe the so-called visualization of a real-time synthetic 3D breast cancer model using square-ROI as a marker could be materialized.

1.2 Motivation

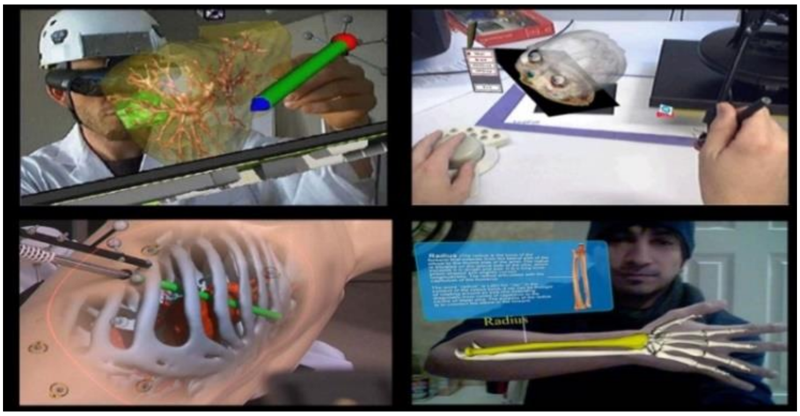
Comport *et al.* (2006) and Mellor (1995) found that the use of computers in medicine has increased dramatically. This is due to the rapid development in computer processing power, display technology and needs among medical practitioner to properly plan a safe and friendly surgical operation (Fischer *et al.,* 2004). Behringer *et al.* (2007), mentioned that AR not only useful to visualize 3D medical data, but can be taken up as a tool to support surgical procedure. This will allow the surgeon to simultaneously examine the data and the patient.

Medical practitioner, surgeons and the public can no longer ignore the impact of this technology in patient treatment. With the used of AR, computer-generated virtual organ will be superimposed onto the surgeon's view of the patient, giving spatial information about the organ relative to the patient's body (see Figure 1.1). During a surgical procedure, CT-scan, MRI or other imaging methods are used to obtain critical data to aid in surgical planning. However, these images can only be used as references prior to the actual operation. There are several situations where surgeons need to define Region-of-Interest (ROI). It can be drawn manually by hand or digitally by using a specific image processing technique. ROI is most commonly used for medical imaging as a subset of an image or as a contour defining a physical object that is of concern during a diagnosis. The ROI drawings can be used as two major functions (Oakes, 2008): (i) to examine the morphological properties of anatomic structure, and (ii) to extract data for a specific structure. And it also defines a specific shape (square or circle) which can be integrated with the AR technology as the fiducial marker (see Fig. 1.3).

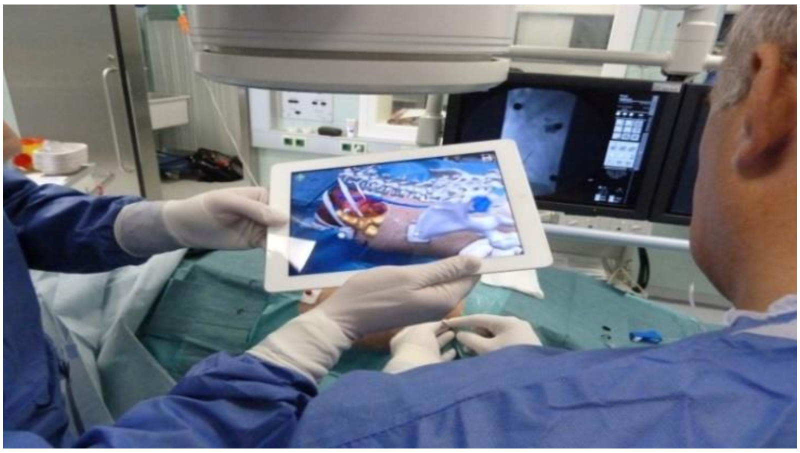
Owen *et al.* (2002) conclude that, an ideal fiducial marker should produce at least four points which are approximate a square. The straight edges of a square, allowing corners to be computed with sub-pixel accuracy. Four points not in the form of a square decreasing tracking accuracy due to poor resolution and orientation. Based on these findings, we believe that, ROI in the shape of a square will be an ideal marker for a surgeon in medical application.

With AR system, the surgeon's vision will be enhanced and improved (Fischer *et al.,* 2007) for example the 3D volume of the organ can be seen (Martens *et al.*, 2004), tissue that needs to be treated can be identified, sensitive healthy areas can be avoided (Tang *et al.*, 1998), and it also enhancing medical consultations between patient and doctor (Bluteau *et al.*, 2005).

(a)



(b)



(c)

Figure 1.1: Example used of AR in medicine (a), (b) and (c).

AR is still in development stages and not yet use in clinical applications, but attempts to apply AR in surgery have been successful and promising (Uneri *et al.*, 2014; Shuhaiber, 2004). Neurosurgery (Sauer, 2005), otolaryngology, endodontic (Bruellmann *et al.*, 2013) and maxillofacial surgery (Trevisan *et al.,* 2008; Shuhaiber, 2004), are amongst the main disciplines that have used AR technology. Other examples and studies where AR technology becomes the fundamental component are in image integration for cardiac ablation, needle biopsy of a breast tumour (State *et al.*, 1996), generating a 3D representation of a foetus inside the womb (Bajura *et al.*, 1992), in digestive surgery (Soler *et al.*, 2004), in computer assisted surgery module, interactive 3D patient- image registration (Vogt *et al.*, 2006), and in an automatic registration method for image guided surgery.

AR techniques not only provide convincing "X-ray Vision" (Blackwell *et al.*, 2000) but also a promising interface for human computer interaction (HCI). Yao *et al.* (2008) in their paper have presented a natural way of interaction to help users become familiar with AR system. Within the current clinical setting, medical imaging is a vital component in not only within diagnostic settings, but also prominently in the areas of planning, carrying out and evaluating surgical procedures for surgical decision (Paolis *et al.*, 2011; Wirth *et al.*, 2003).

Consider a scenario, where a medical student who studied and trained to become a surgeon for several years. Rather than simply gained knowledge from lectures, textbooks and medical videos, the student can actually apply his or her knowledge in an augmented reality surgery simulation. With this digital technology aids, the real working medical operation can thus be simulated using computer-generated images of a patient and a haptic device medical tool as a means to provide more valuable near to real experience. However, if the registration or the alignment mechanism employed by the augmented reality surgery simulation were inaccurate, the student will only develop skills that would be ineffective in a real world operating room.

Therefore, in this thesis, the proposed integrated square-ROI recognition approach can be applied to define a marker, before visualizing the breast cancer in an augmented view. The augmentation of breast cancer can aid the surgeon, doctor and patient to understand and to visualize breast cancer in seamless perspective. Since this technique is the integration of two feature detection steps, contour detection followed by corner detection, the technique is effectively combining two feature detection strategies and advantages. The first step defines a square, and then the second step uses this defined square to search for corner points.

1.3 Problem Background

As shown in Fig. 1.2, to blend virtual content with the existing reality, a typical AR system needs to utilize an element or combined elements in virtual content (i.e. global position, orientation, feature points[1], and metadata) as the key to perform the registration process so that the enhanced reality called AR could be achieved.

Blackwell *et al.* (2000) state that, inaccuracies are caused by; incorrect registration, changes in patient's anatomy, improper calibration, and user's stereoscopic perception. By definition, registration referred as a way to properly align the real and virtual object in the mixed reality environment.

[1] In this thesis, feature points (i.e. corner and edge) will be use to verify a square marker.

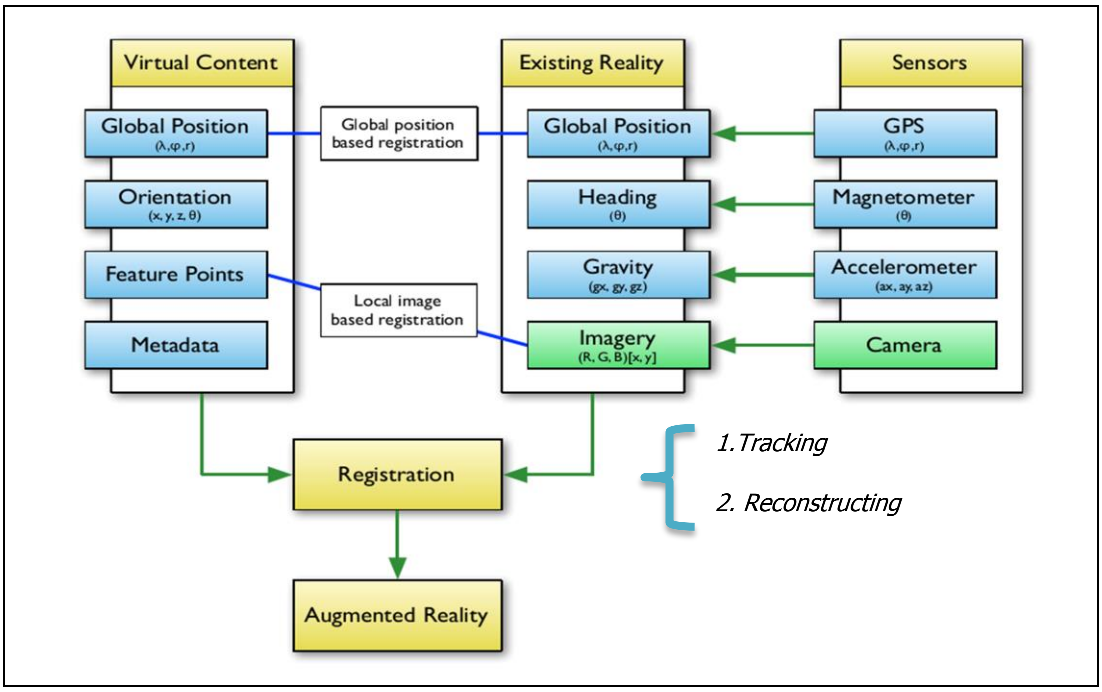


Figure 1.2: An overview of a typical augmented reality system.
Source: William (2012)

Registering an object consists of two stages (Carmigniani *et al.*, 2010):

i. Tracking[2]
   - Make use of feature detection, edge detection or other image processing method to interpret the video feed by detecting fiducial markers or interest point (corner).

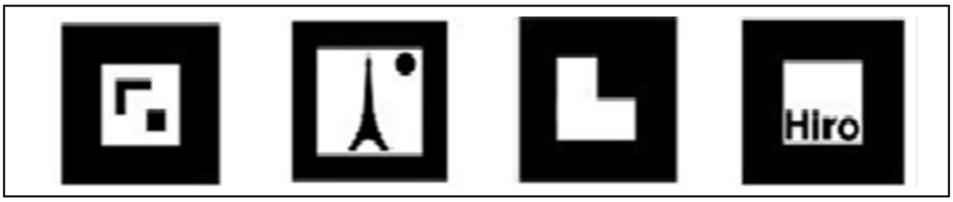
ii. Reconstructing
   - Uses the data obtained from the first stage to reconstruct a computer generated object in real world coordinate system.

There are two ways of registration employ in AR development; (i) Marker-based and (ii) - Markerless-based (Siltanen, 2012; Gutiérrez *et al.,* 2008; Malik, 2002). Used of marker-based method have been discussed in (Siltanen, 2012; Kato and Billinghurst, 1999; Rekimoto, 1998;). Whereas, (Lee and Hollerer, 2008; Skrypnyk and Lowe, 2004; Klein and Murray, 2007; have established a markerlesss-based method for unprepared environment, but still unreliable (Park and Park,

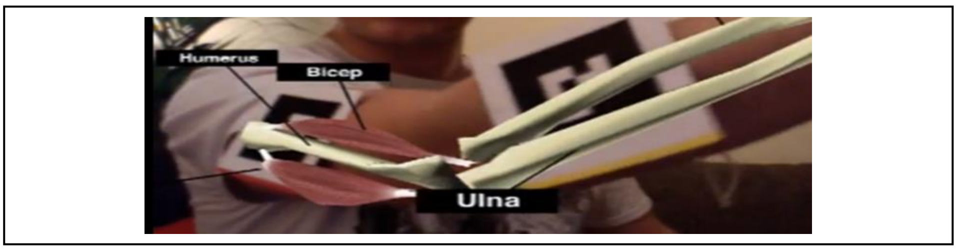
[2] Our proposed technique aim to deal with the first stage in the registration process

2004). That is why most researchers opted for marker approach, since it is more accurate and reduce computation-resources (Ismail and Sunar, 2013; Zhou *et al.*, 2008). However, the used of printed square marker (see Fig. 1.3) or customized pattern which is located physically on top of the target area or workspace in the medical field is not practical and not user-friendly (Mellor, 1995). Lepetit (2008) added, marker approach is a limited solution and end-users often reluctant to use it. A visible marker is distracting in AR applications aiming for realistic high-quality visualizations. One solution to achieve natural visualization is to get rid of the markers completely, and use some marker-less tracking methods. Another option is to use a marker-based system and then remove markers from augmented view (Siltanen, 2012). This marker is invisible to the user (Park and Park, 2004).

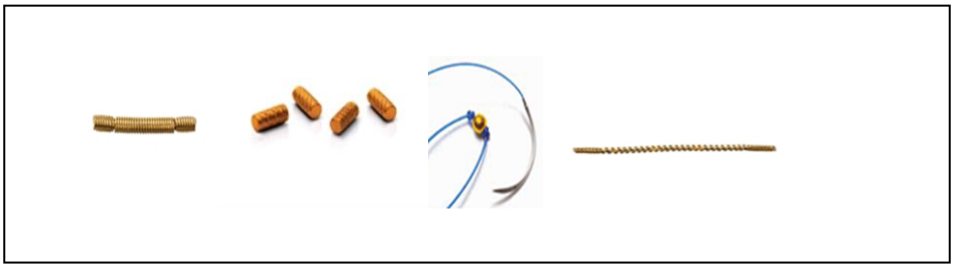
In today medicine practices, there are two types of marker used by surgeon (Balachandran *et al.*, 2014;Augdal, 2005; Maintz and Viergever, 1998) either by using anatomical landmarks (non-invasive) or fiducial marker (invasive). For better precision, easy, fast and non complex algorithm, fiducial marker is the common approach apply during the procedure. However, this method will require an additional surgery in order to attach or to insert the fiducial marker (see Fig. 1.3 (c)) to the patient. It is not only time-consuming, but also invasive and it might cause trauma to the patient. Patel *et al.* (2014) added, creation of a new foci of disease may be rare, but is a serious complication of fiducial marker placement. Hence, innovations in the current insertion techniques of the fiducial marker may improve its accuracy, reduce its risks, and enhancing comfort for the patient.



(a)



(b)



(c)

Figure 1.3: (a) Example of printed marker, (b) Used of marker on human's hand, (c) Breast marker used in surgery.

Common fiducial markers used in surgery are gold seeds or stainless steel screws that are implanted in and/or around a soft tissue tumour, or within the bony spine, to act as a landmark with millimetre precision. Its feasibility and reliability are essential for precise setup and real-time tumor tracking (Shirato *et al.*, 2003). Due to its invasive implantation procedure (Wang and Song, 2008) and the price of gold seeds are significantly higher (Coles *et al.*, 2011), it is our aim to develop an alternative form of marker for cheaper, but efficient, robust and more patient-friendly technique through AR.

To further complicate the challenges, the process to correctly register or combining the real scene with virtual objects depends greatly on Computer Vision (CV) potentials and techniques to detect features either naturally from the desired region of interest (ROI) or based on the fiducial marker that present to the visual sensor. Idris *et al.* (2009) considered the use of CV techniques as a starting point in detecting a fiducial marker or natural marker in order to solve the registration and tracking issue in AR application. Edge detection, corner detection/interest point, blob detection, and optical flow are current available techniques that can be used to detect features.

A comprehensive discussion on available feature detector such as Moravec (Moravec, 1977), Harris (Harris and Stephens, 1988), Shi-Tomasi (Shi and Tomasi, 1994) and Canny's operator (Canny, 1986) can be read in (Ruby *et al.,* 2011; Awrangjeb *et al.,* 2010; Chen *et al.,* 2009; Maini and Aggarwal, 2009; Alexandrov, 2002; Schmid *et al.,* 2000).

As discussed in (Maini and Aggarwal, 2009; Wang and Fan, 2009), the performance of the traditional Canny operator influenced by the standard deviation and the threshold values. This implies that, for noisy images, the standard deviation value must be larger to create more blurring images. However, this scenario will degrade the accuracy of the Canny method in edge localization. The dual-threshold is difficult to determine and at some point, multi-point response will appear. As stated in (Bansal *et al.*, 2012), an adaptive edge-detection algorithm is necessary to help in distinguish valid image contents introduced by noise.

Whereas, in corner point localization, the traditional Shi-Tomasi technique which is typically done at interger coordinates (Shi and Tomasi, 1994) suffer from poor corner localization accuracy. It is very important to detect all the true corners at their locations and not detect any false or weak corners on a curve. In order to achieve all the true corners, the curve should be smoothed with an appropriate smoothing-scale.

Tuytelaars and Mikolajczyk (2007) recommended combining different detector since number of quality features (e.g. edge and corner) found may vary due to lack of robustness in current individual method and increasing amount of data to process. Wang *et al.* (2005) presents content-based image retrieval approach based on edge and interest point and it is found to be efficient, reliable and robust in the researched area but not in square detection. Coleman *et al.* (2007) proposed other integrated edge and corner detection that has near-circular gradient operator which can reduce the computational time. In 2012, Kim (Kim *et al.*, 2012) combine the advantages of both edge and corner approach in detecting a square but unable to detect edge point around the corners of the square.

In short, although there exist integrated methods for square detection and corner tracking, it is still not efficient in terms of computation time and not robust to square detection.

Table 1.1 shows a comparison of techniques for square detection of the previous works that are reviewed.

Table 1.1: Techniques for square detection

Author	Title	Limitation
Wang *et al.* (2005)	Square detection based on distance distribution	Unable to detect edge point around the corners of the square. Not robust in square detection.
Coleman *et al.* (2007)	Integrated Edge and Corner Detection	High in computation time (detect corner in 27.78s) Not robust in square detection.
Kim *et al.* (2012)	Feature Point Detection by Combining Advantages of Intensity-based Approach and Edge-based Approach	Only for corner detection Not for square detection

Given the shortcomings of current techniques, there is a need to apply feature detection approach which consists of interest point and edge detection technique in the proposed markerless recognition technique in order to achieve natural visualization for the unprepared environment (T. Lee and Hollerer, 2008; Klein and Murray, 2007; Skrypnyk and Lowe, 2004) such as in medical (Simon and Berger, 2002).

Failure to properly define the geometric registration relationship between the virtual and physical objects (Vallino, 1998) appears to the user as inconsistencies in the appearance or errors in registering the virtual object into the real world (Holloway, 1995).

As described in (Azuma, 1997) sources of registration errors fall into two groups: static and dynamic error.

Static. Errors that occur when the user's viewed from different viewpoints without moving their base position. This error caused by:-

- Optical distortion
- Tracking errors
- Mechanical misalignment
- Incorrect viewing parameter

Dynamic. Occur when either the user's view starts to move and caused the augmentation being out of synchronization. This caused by:-

- End-to end system delay

Both errors are further discussed in Chapter 2.

1.4 Problem Statement

As identified in section 1.3, there are several issues that must be taken into consideration related to the integration of corner and contour approach. Previous findings showed that the traditional Canny approach still lacks in edge detection accuracy and suffer from high computation time, due to its dependency on the standard deviation and the threshold values (Maini and Aggarwal, 2009; Wang and Fan, 2009). Whereas, the traditional Shi-Tomasi technique which is typically done at integer coordinates (Shi and Tomasi, 1994) suffer from poor corner localization. As recommended by Tuytelaars and Mikolajczyk (2007), several researchers, have made an effort to integrate the corner - contour approach with the perspective to define detected edges as a square. But, until recently, the results showed that, it is still not efficient in terms of computation time and it also not robust to square detection.

Our research on the medicine practise of the fiducial marker has until recently concentrated on the tangible fiducial marker which is invasive, but better in term of precision, easy, fast and non complex algorithm. However, this method will require an additional surgery in order to attach the fiducial marker to the patient. It is not only time-consuming, but also invasive and might cause trauma to the patient. And in some cases, it will lead to the creation of a new foci of disease when placement involves going through the tumour focus. It may be rare, but is a serious complication of fiducial marker placement. Hence, innovations in the current techniques for the insertion of the fiducial marker may improve its accuracy and reduce its risks, and enhancing comfort for the patient. For this reason, it is our intention to apply the integrated contour-corner method with the hand-drawn ROI as a marker, in order to develop a patient-friendly marker recognition technique as an aid in breast cancer visualization.

Considering these issues, our main research question is, therefore, *"can the marker recognition technique integrated with contour and corner approach be used to define a hand-drawn square-ROI marker, hence allowing the development of medical visualization aid for breast cancer"*.

Few questions need to be details up as follows:-

1. *"How to develop a square-ROI marker recognition technique which consists of the advantages of corner and edge detection?"*
2. *"Is the integrated square-ROI marker technique shows better performance in terms of computation time, robustness and accuracy?"*
3. *"How to improve the proposed square-ROI contour detection method"*
4. *"Is the improved square-ROI contour shows better performance in terms of computation time and robustness?"*
5. *"How to enhance the proposed corner detector based on Shi-Tomasi technique?"*
6. *"Is the enhanced square-ROI corner shows better performance in terms of computation time and corner localization?"*

1.5 Research Aim

To present a real-time pre-placed markerless identification technique by integrating edge and corner approach to detect a square-ROI as the fundamental component in registering the virtual imagery with its real object without the needs to use conventional marker.

1.6 Research Objectives

There are several objectives need to be achieved, which are:

1. To improve the proposed square-ROI contour detection in terms of computation time and robustness based on the Canny algorithm with adaptive thresholding technique and smoothing.

2. To enhance the proposed square-ROI corner detection in terms of computation time and corner localization based on Shi-Tomasi detector with subpixel technique.

3. To integrate the improved square contour detector with the enhanced corner point detector in order to develop a real-time markerless square-ROI recognition technique with low computation time, robustness and high in accuracy.

1.7 Research Scope

The scopes for this research area:

- The proposed method focus on investigating square contour based Canny approach and enhancing Shi-Tomasi corner detection algorithm.

- The proposed method mainly focuses on the real-time markerless recognition process based on enhanced Shi-Tomasi corner detector combined with the Canny's operator to detect square contour.
- 3D projection matrix is not calculated, since this study only focused on marker-less identification and verification phase.
- 2D circle used as an example to visualize the mixed reality environment in a given scenario.
- This research used a mannequin and hand-drawn Square-ROI to test and to evaluate the proposed technique.
- The proposed technique uses no sensor except the web video-camera.

- This research does not focus on occlusion, interaction, alignment, devices, user interface, visual perception, content creation, and camera calibration.

1.8 Thesis Outline

The rest of this thesis is organized as follows:

Chapter 2 reviews previous work underlying augmented reality and computer vision technology.

Chapter 3 discusses research methodology and testing procedure for the proposed technique.

Chapter 4 details the improved square-ROI contour detection based on Canny's operator, adaptive threshold and smoothing.

Chapter 5 details the enhanced square-ROI corner detection based on Shi-Tomasi detector and extended with subpixel accuracy.

Chapter 6 analyses and evaluates the implementation of the real-time markerless square-ROI (RPMS) recognition technique in terms of computation time, accuracy and robustness.

Chapter 7 concludes the thesis by summarizing the contributions made, results and proposing areas for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the background study of the proposed title that carried out before we develop our technique. It is meant to give an overview of Computer Graphics (CG), Augmented Reality (AR), and Computer Vision (CV), as a research field and breast cancer in brief. The chapter narrows the discussion down to the core issues of the thesis by discussing the markerless AR approach in section 2.4.3. Fig. 2.1 depicts the taxonomy of computing methodologies.

2.2 Computer Graphics

Computer graphic is a set of technologies used to represent a geometric data in 3D and at the same time to create an art with computers. Computer graphics can be divided into several areas which are real time 3D rendering, computer animation, video capture and video creation rendering, special effects editing, image editing and modelling. Ivan Sutherland (Sutherland, 1968) was the first person who developed the first Graphical User Interface (GUI) program named the Sketchpad. It was able to create precise drawings and marked the important innovations in memory structures and ability to zoom in and out. Recently, computer graphics are very important and widely used in medical, animation, entertainment, games, architectural and cultural application. A developer can create an interesting graphics application by representing the data graphically using many methods in computer graphics so that the data can be easily understood by the user. Therefore, computer graphics are one of the powerful tools to create a critical application. As depicted in Fig. 2.1, focused research areas in this thesis are indicated by the red square.