3D SURFACE RECONSTRUCTION FOR LOWER LIMB PROSTHETIC MODEL USING MODIFIED RADON TRANSFORM

SITI SYAZALINA BINTI MOHD SOBANI

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Biomedical Engineering)

Faculty of Biosciences and Medical Engineering
Universiti Teknologi Malaysia

AUGUST 2017

Dedicated especially to my beloved late father, Mohd Sobani bin Bahrom,
my beloved late mother, Siti Zabedah binti Ab. Hamid,
also family and friends.

ACKNOWLEDGEMENT

Praise to Allah S.W.T, the Most Gracious, the Most Merciful, for blessing and guidance that always helped me through my life. I am so fortunate to be given the opportunity and strength to live and to accomplish the Ph.D project. The pleasure to be able to breath until the day that I finished this book of thesis.

In particular, I wish to express my sincere appreciation to my supervisor, Assoc. Prof. Dr. Nasrul Humaimi bin Mahmood then, and my co-supervisor, Dr. Nor Aini binti Zakaria for their wisdom, critics and advices. I am thankful to their guidance to the success of this study. Without their continuous supports and interests, this thesis would not have been the same as presented here.

My sincere appreciation also extends to all my family and colleagues who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my beloved family members whom without their constant support and encouragement, I would not be able to make it this far.

ABSTRACT

Computer vision has received increased attention for the research and innovation on three-dimensional surface reconstruction with aim to obtain accurate results. Although many researchers have come up with various novel solutions and feasibility of the findings, most require the use of sophisticated devices which is computationally expensive. Thus, a proper countermeasure is needed to resolve the reconstruction constraints and create an algorithm that is able to do considerably fast reconstruction by giving attention to devices equipped with appropriate specification, performance and practical affordability. This thesis describes the idea to realize three-dimensional surface of the residual limb models by adopting the technique of tomographic imaging coupled with the strategy based on multiple-views from a digital camera and a turntable. The surface of an object is reconstructed from uncalibrated two-dimensional image sequences of thirty-six different projections with the aid of Radon transform algorithm and shape-from-silhouette. The results show that the main objective to reconstruct three-dimensional surface of lower limb model has been successfully achieved with reasonable accuracy as the starting point to reconstruct three-dimensional surface and extract digital reading of an amputated lower limb model where the maximum percent error obtained from the computation is approximately 3.3 % for the height whilst 7.4%, 7.9% and 8.1% for the diameters at three specific heights of the objects. It can be concluded that the reconstruction of three-dimensional surface for the developed method is particularly dependent to the effects the silhouette generated where high contrast two-dimensional images contribute to higher accuracy of the silhouette extraction. The advantage of the concept presented in this thesis is that it can be done with simple experimental setup and the reconstruction of three-dimensional model neither involves expensive equipment nor require any service by an expert to handle sophisticated mechanical scanning system.

ABSTRAK

Bidang teknologi komputer kini memberi fokus yang tinggi kepada kajian dan inovasi mengkonstruk permukaan tiga-dimensi yang lebih tepat dan konsisten. Walaupun telah banyak penyelidik berjaya menemukan pelbagai penyelesaian baharu dalam bidang ini, namun kebanyakannya dihasilkan dengan menggunakan peranti canggih yang mahal. Langkah-langkah penyelesaian untuk penambahbaikan harus dikenal pasti dengan mengarang algoritma baharu yang berupaya untuk menghasilkan keputusan dalam masa yang lebih singkat dan juga mengambil kira penggunaan peranti mampu milik. Oleh itu, tesis ini menghuraikan idea penghasilan model tiga-dimensi kaki kudung menggunakan teknik pengimejan tomografi dengan strategi yang diterima pakai berkaitan penglihatan kamera dalam pelbagai pandangan dan meja berpusing. Permukaan sesebuah objek dikonstruk semula daripada imej-imej dua-dimensi diperoleh daripada 36 unjuran yang berbeza tanpa ditentu-ukur dengan menggunakan algoritma transformasi Radon dan juga bentuk-dari-bayang. Keputusan kajian membuktikan bahawa kaedah yang dicadangkan dalam tesis ini untuk mengkonstruk permukaan tiga-deminsi sesebuah model kaki kudung telah berjaya mengkonstruk permukaan tiga-dimensi dan mendapatkan ukuran digital sesebuah model kaki kudung dengan ketepatan yang munasabah sebagai permulaan untuk mengembangkan bidang kajian ini dengan menganalisis ralat dalam pengiraan yakni peratus tertinggi yang diperoleh adalah 3.3% untuk ukuran ketinggian manakala 7.4%, 7.9% dan 8.1% untuk tiga diameter pada ketinggian tertentu. Bagaimanapun, kaedah yang dicadangkan amat sensitif kepada imej bayang yang dihasilkan menunjukkan bahawa imej berkontras tinggi menyumbang kepada ketepatan dalam menghasilan imej bayang. Projek ini dapat dilaksanakan secara ringkas dengan penyusunan alat-alat eksperimen yang mudah dan tidak memerlukan mana-mana mesin yang memakan kos yang tinggi atau pengedalian oleh individu yang pakar.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

1D	-	One-dimensional
2D	-	Two-dimensional
3D	-	Three-dimensional
CAD	-	Computer-aided Design
CAM	-	Computer-aided Manufacturing
CIRBM	-	Combination of Image and Range-based Modelling
CT	-	Computed Tomography
DOF	-	Depth of Field
FOV	-	Field of View
IBM	-	Image-based Modelling
IBR	-	Image-based Rendering
JPEG	-	Joint Photographic Experts Group
MHD	-	Modified Hausdorff distance
MRF	-	Markov Random Field
MRI	-	Magnetic Resonance Imaging
MSE	-	Mean squared error
PNG	-	Portable Network Graphics
POI	-	Point of interest
PSNR	-	Peak signal-to-noise
RAM	-	Random-access Memory
RBM	-	Range-based Modelling
RGB	-	Red-Green-Blue
RT	-	Radon Transform

LIST OF SYMBOLS

°	-	Degree of angle
θ	-	Angle
%	-	Percent
bit	-	Basic unit of digital information, binary digit
cm	-	Unit of length, centimeter
dpi	-	dot per inch
f	-	focal length
GB	-	Unit of digital information, gigabyte
GHz	-	Unit of frequency, hertz
mm	-	Unit of length, millimeter
ppi	-	pixel per inch

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Backgrounds

Amputation is the removal of all or certain part of a limb from one body through surgical operation. Limb or extremity is classified into two parts which are upper and lower limbs, also known as the arms and the legs. There are several unfortunate causes that encourage an amputation such as loss from severe trauma or to supplement defective body parts due to either serious illness or infections. For example, lower limb amputation of a diabetic patient to prevent the infection from spreading all over his body, because the high blood sugar level has damaged the nerves of the patient and reduced the sensation on his feet, which may become injured or develop foot ulcers without one realizing the situation. Injury damaging the blood vessel contributes to reduction of the blood supply to the feet and causes the wound to take longer time to heal and get infected. Amputation cases have occurred every year worldwide and millions of individuals currently live in unfortunate lives with limb loss, many of which are cases where amputations are at the lower limb. In medicine, an artificial device used to replace amputated body parts of a person either from amputation or birth defects is known as a prosthesis or prostheses in plural. The term “prosthesis” is originated from the Greek word, where “pro” means “in place of” and “thesis” means “the action of placing” [1]. Figure 1.1 illustrates the meaning of the prosthesis. Some amputees choose to continue their daily activities by wearing an artificial device called prosthesis that requires them to face the challenge in the process of rehabilitation. The prostheses have to be designed and customized specific to one's anatomical shape. Hence, the design cannot be simply designed and manufactured through mass production or modular products since it is specific to each person, and each individual is different from another. However, as the number of amputees increase, the demand on prostheses has also increased and it is necessary to realize ad-hoc and high precision design methodologies [2, 3] as a proper guideline to be referred by prosthetists. A prosthetist is a person who specializes in the detailed measuring, designing, fabricating and fitting of prosthesis prescription. In addition, optimal design of prosthesis is very important for each amputee. This restores and encourages functional muscular activity, relieves pressure-sensitive areas, and maintains proper attachment of the prosthesis during ambulation [4].

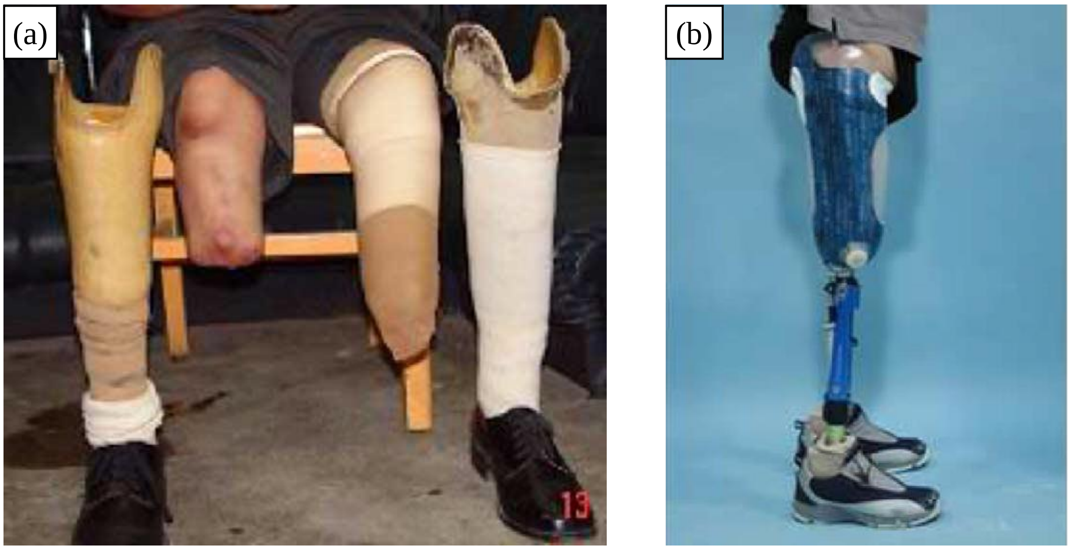

Figure 1.1: Example for (a) a patient with residual limb below the knee [5], and (b) trans-femoral prosthesis [3].

Today, technological developments of three-dimensional (3D) imaging are highly sophisticated, centered on the digital models of the human body and the use of 3D reconstructive prosthetic design through the reconstruction of 3D surfaces of the residual limb, which have overcome the limitations of the plaster-casting method in traditional prosthetic socket fabrication. Furthermore, it provides a scientific basis for the individualization of prosthetic design and avoids making a positive mould in manual modifications for prosthesis fitting[6, 7]. In 3D reconstruction, there are two different systems known as calibrated and uncalibrated systems. Calibration is an initialization step required in data acquisition system that provides corresponding information between real worlds coordinates and two-dimensional (2D) image coordinates. Consequently, the image acquisition devices are restricted to fixed locations after the calibration is done, while this process is not required for uncalibrated systems. As an alternative, 3D reconstruction is achieved by extracting information from digital images to infer particular features for corresponding coordinates and 3D structure of an object. The image data can be acquired in several forms, such as a set of image sequences or a video, views from multiple cameras set up, or multi-dimensional data from a scanner. Prior research has sought and demonstrated various methods to realize an accurate 3D reconstruction of a surface aiming to assist the prosthethist in designing a proper prosthetic part for a specific patient to recover and live a normal daily life. Various methods have been introduced to improve the quality of 3D image reconstructed and acquisition time of the system and application. Computer-aided design and computer-aided manufacturing (CAD/CAM) accompanied with medical imaging technology has been introduced in prosthetic practice [8] where the image of a certain part of a patient is captured using X-ray computed tomography scan (CT-scan), magnetic resonance imaging (MRI), or ultrasound imaging [9, 10]. However, capturing images using such devices are very expensive and the processing task requirements are enormous. The medical device is also required to be operated by an expert in a specifically designated room. It is also bulky and taking up a large space to be assembled. The outcome from this project is expected to be able to compute and overcome possible constraints in the production of prosthetic part which is practically cost-efficient.

As the first step in a research, it is necessary to determine a possible method and compare with other existing methods related to 3D surface reconstruction of amputated lower limb models. 3D reconstruction in computer vision field is a process of recovering and converting the shape and appearance of an object into digital data form or so called 3D model to be effectively manipulated in virtual world [11]. 3D models are mostly realized from detailed information of an object as input data. The input data can be acquired either by active or passive sensing method which both are non-contact system based on illuminations [12, 13]. Active sensing method or also known as range data method is a sensing and scanning technique that actively interfere with the object to be reconstructed to pick up the depth map of the scene. Active sensor provides range data with the 3D coordinates covering the point cloud which usually defined by x, y and z coordinates represent the external surface of an object. Examples for 3D scanning technology established are time-of-flight laser range finder, structured light, and modulated light scanner [14-16]. Even though these 3D scanners are mostly high quality in capturing detailed information that contributed to high accuracy in the measurement of the reconstructed 3D surface, unfortunately active sensing method is not always viable for modelling distant or huge or fast-moving objects [17, 18]. There are few other limitations on encountering optical difficulties with transparent, shiny, and reflective objects which is not desirable in some cases for 3D reconstruction for example, human recognition applications, plus they are very disadvantageous in term of cost efficiency [19]. On the other hand, the passive sensing method is relatively low cost and the research on this method has been intense recently. Although passive sensing method not as efficient as the active sensing method in the reconstruction quality and accuracy, its non-intrusive properties is more reliable for robotic vision, reconnaissance, surveillance, recognition applications. Passive sensing method in 3D reconstructions does not interfere with the object which only measure the illumination emitted or reflected on the object in the scene in order to process, analyse, and acquire the 3D structure of an object [20-22]. Passive sensor provides image data as the impression of an object that needs further processing on the images to locate and originate the 3D coordinates. Generation of meshes connect the 3D coordinates and constructs a polygonal surface of the object. The polygonal surface is then textured and shaped to realize 3D surfaces of the object. Therefore, this project aims to reconstruct 3D surface of lower limb models based on the passive approach where the input data is 2D image sequences of amputated lower limb models captured by multiple-view camera and a turntable setup in specified projections as the first step in adapting to the research field.

1.2 Problem Statements

Although many researchers have come up with various novel solutions and some even proved the feasibility of their findings, most require sophisticated devices. Research for prosthetic design by [5] has successfully reconstruct 3D structure of residual limbs with 0.01*mm* accuracy by using CT-scanning device for data acquisition, but costed a lot and may not be affordable to some amputees. It is also computationally complex which took eighteen hours of processing time for a skilled operator compared to the traditional process that took twelve hours to build a solid model but resulted to slightly higher error which is 0.25*mm*. A suitable algorithm has to be configured for 3D surface reconstruction in order to resolve the reconstruction constraints which involves huge amount of data which consumes a lot of time to compute the whole process and also computational expensive. Thus, a proper countermeasure is needed to resolve the reconstruction constraints and create an algorithm that is able to do considerably fast reconstruction by giving attention on devices available with appropriate specification, performance and also practically affordable.

Passive methods is indeed cost-effective and for example, it has been proposed in [7] that 3D surface reconstruction from digital images taken in multiple-views with turntable system also yields significant low errors in the measurements. In medical imaging, tomography is a technique that display layers of cross-section of a part of human body estimated from a finite number of projections [23, 24] which provide multiple-views of an object and it is often relates with Radon transform algorithm. Another research which is also cost-effective by [25] has shown that reconstruction of 3D surface from Radon transform algorithm can be achieved by using a digital camera as the device for data acquisition. However, the data acquisition was done in a completely dark environment where a light beam is projected onto the object providing a substantial contrast between the object and the background. It is not a good idea to deal with an object in a dark room where grain noise may present in the image captured. Plus, taking 2D images using a turntable setup is actually quite a challenging task and is practically inefficient to perform the data acquisition in a dark room, so it is suggested to capture the images in a well-lighted area instead.

Thus, the method for this thesis is focused on passive sensor to generate surface of an amputated lower limb model using 2D image sequences as the input data without any complicated calibration performed on the digital camera to simplify the data acquisition process. In addition, the concept of tomographic imaging is adopted to construct layers of cross-sections of an object to recover possible obscured side curve of the object from the camera view. 3D reconstruction is computational and also practically expensive [26]. In particular, many researchers have claimed that reconstructing 3D surface from uncalibrated 2D images is an ill-posed problem and prone to errors [27, 28]. However, it is not impractical and still has a possibility to be improved and fill the gap by capturing image in multiple-views to cover hidden or unseen parts of an object. Thus, each 2D image is captured by a digital camera using a turntable in order to acquire sufficient information of an object by capturing more than one 2D image at different angle of projections. The idea of multiple-views or different projections of an object in the scene is a compliment to the tomographic imaging technique in order to provide corresponding information between projections.

This thesis also seeks the comprehension of the related literatures in order to understand and make contributions to the body of knowledge based on the objectives, and significance of study listed in the following sections. In fact, the component of prosthesis requires a very high customization level in order to suit both functional and comfort requirements. It is vital to measure the reconstructed 3D surface and compare with the real object since the accuracy in the measurements of the feature have to be as precise as possible. The recovery of an amputee depends on how the prosthesis is fitted since the prosthetic fitting affects the degree of comfortability, energy expenditure and utility [29], consequently the amputee can continue with his normal daily activities [5, 30]. Hence, the developed method must be analysed by reconstructing various shapes of objects to verify the capability the method used. The reconstructed 3D surface is compared with the actual model of residual limb to analyse and evaluate the relevance of the results obtained for any inaccuracy in the measurement.

1.3 Objective of Study

3D surface reconstruction is indeed an intriguing topic and currently receiving increased attention in the research field. The main purpose of this project is to develop 3D imaging algorithm that reconstructs 3D surface of an object from 2D images. The 2D images are obtained from an uncalibrated digital camera. The whole experimental configuration needs to be as simple as possible and easy to be set up in order to create a procedure with high repeatability and reproducibility test. It is also important to consider the cost of equipment and devices involved for an affordable 3D surface reconstruction system. Hence, the objectives of this thesis are as follows;

1. To reconstruct 3D surface using multiple-views from a digital camera and a turntable with the concept of tomographic imaging technique.
2. To develop a new algorithm based on Radon transform for image-based 3D reconstruction from uncalibrated 2D image sequences.
3. To test and verify the proposed method on amputated lower limb models for prosthetic design application.

1.4 Scope of Study

This thesis has developed a combination of existing methods to tackle the problems identified in prior research related to 3D reconstruction of prosthetic model from different perspective by focusing on passive method. It has positively identified from the reviews that the procedure of image-based 3D reconstruction is practically cost-effective for example as proposed in [25], data acquisition is performed in a dark room with light beam is projected on the object resulted to high contrast images. However, in case of prosthetic design, it is not suggested to deal with a patient in a dark room and it is also practically inefficient. It is also important to make sure the patient is in healthy mental condition and comfortable during the process of data acquisition. Although this thesis only focused on reconstructing 3D surface of residual limb model, but it is important to consider and solve such problem which is also contribute to generate input image free from grain noise. Thus, in this study, 2D images are simply taken in a well-illuminated room where an object placed on a turntable which involved a simple experimental setup. The experimental objects are designed and carved as amputated lower limb which requires high reconstruction accuracy and also very challenging to reconstruct a 3D surface of such object in detail. The size of the models can be measured and compared for the consistency of the computation. The 3D surface reconstruction of residual limb model is acquired using uncalibrated digital camera fixated on a tripod stand. It is simpler and affordable compared to expensive medical imaging devices which requires an expertise in the process of handling. The camera is set to focus on the object which is placed on a manually rotated turntable in front of black colour background as an alternative to create a better contrast between the object and the background instead of performing the image acquisition in a dark room with projected light beam. Henceforth, the 3D surface of an object is reconstructed from the collected data by using tomographic reconstruction approach based on shape-from-silhouette methods supplemented with Radon transform in order to generate the 3D model layer by layer. The geometric features of reconstructed 3D surface for example, the height and the diameter are extracted and analyzed to estimate the computation errors of the developed algorithm in order to understand the factors causing the inaccuracy of the computation that set off the differences between the measurement of the real model and the reconstructed 3D surface.

1.5 Significance of Study

Developments in the technology of 3D imaging have been focused on fitting artificial limbs. The use of 3D reconstruction in prosthetic design has overcome the limitations of the plaster-casting method in traditional prosthetic socket fabrication and avoid making a positive mould by the way of manual modifications. In addition to this, it can provide a scientific basis for the individualization of prosthetic design [9]. On the other hand, financial constraints are among the stresses that may complicate adjustment to limb loss. This project is conducted to contribute new cost-efficient system for design as well as to reduce the cost of production. Moreover, there are some potential benefits for a person with comfortably fitted prosthesis, for example [4, 31]:

1. The person is able to avoid from developing medical complications or difficulties, such as joint contractures, pressure ulcers, and orthostatic hypotension.
2. The person is able to lowers the stress on the joints of the opposite leg, which are adversely affected by both compensatory actions as well as by the forces applied during static single-limb weight bearing.
3. The person will be financially benefit society, not only in terms of restoring someone to a productive life but also because people fitted with prostheses are more likely to leave the nursing facility and return home.

1.6 Thesis Outlines

This thesis is organized and separated into five main chapters. Starting with Chapter 1 which is assigned for general introduction based on the title of this project. It consists of the project background, problem statements, objectives, scopes, significance and contributions of the study. Chapter 2 contains literature reviews and relevant theories that gives brief explanations on the process of prosthetic design and fundamental of 3D reconstruction methods established. It also explains the related approaches to the proposed method of this study. Chapter 3 concentrates on methodology regarding the experimental set up for image acquisitions and system implemented to reconstruct 3D objects from multiple views of uncalibrated 2D image sequences. Chapter 4 presents the results for the 3D surface reconstruction of amputated lower limb models attached with some analysis and discussion that provide reasoning for the results obtained. Chapter 5 conclude the findings and contributions from the study in this thesis to the society including the limitations with some recommendation for the possible future work as a continuation may arise to this study.

REFERENCES

1. Bordenave, L. Nuclear Medicine Serving Prostheses and Biomaterials. *ITBM-RBM*. 2005. 26(3), 206-211.
2. Senin, N. and Groppetti, R. Surface Microtopography Design and Manufacturing through Topography Descriptors: An Application to Prosthetic Implant Surfaces. *Computer-Aided Design*. 2005. 37(11), 1163-1175.
3. Colombo, G., Filippi, S., Rizzi, C., and Rotini, F. A New Design Paradigm for the Development of Custom-Fit Soft Sockets for Lower Limb Prostheses. *Computers in Industry*. 2010. 61(6), 513-523.
4. Frieden, R. A., Brar, A. K., Esquenazi, A., and Watanabe, T. Fitting an Older Patient with Medical Comorbidities with a Lower-Limb Prosthesis. *PM&R*. 2012. 4(1), 59-64.
5. Shuxian, Z., Wanhua, Z., and Bingheng, L. 3d Reconstruction of the Structure of a Residual Limb for Customising the Design of a Prosthetic Socket. *Medical Engineering & Physics*. 2005. 27(1), 67-74.
6. Mahmood, N. H. and Tjahjadi, T. 3d Reconstruction from Multiple Views for Orthotic and Prosthetic Design: An Overview. *4th Student Conference on Research and Development*. 27-28 June 2006. 2006. 70-75.
7. Mahmood, N. H. and Tjahjadi, T. 3d Reconstruction for Prosthetic Design. *Second International Conference on Computer Engineering and Applications (ICCEA)*. 19-21 March 2010. 2010. 431-435.
8. Knopf, G. K. and Al-Naji, R. Adaptive Reconstruction of Bone Geometry from Serial Cross-Sections. *Artificial Intelligence in Engineering*. 2001. 15(3), 227-239.
9. Kurazume, R., Nakamura, K., Okada, T., Sato, Y., Sugano, N., Koyama, T., Iwashita, Y., and Hasegawa, T. 3d Reconstruction of a Femoral Shape Using a

Parametric Model and Two 2d Fluoroscopic Images. *Computer Vision and Image Understanding*. 2009. 113(2), 202-211.

10. Shah, P., Mahajan, S., Nageswaran, S., and Paul, S. K. A Novel Way to Acquire Foot Contour Measurements of Remotely Located Patients Having Foot Deformities. *IEEE First International Conference on Control, Measurement and Instrumentation (CMI)*. 8-10 Jan. 2016. 2016. 211-214.
11. Huang, J. and Cowan, B. Simple 3d Reconstruction of Single Indoor Image with Perspective Cues. *Canadian Conference on Computer and Robot Vision (CRV)*. 25-27 May 2009. 2009. 140-147.
12. Yao, K. and Dong, J. A Simple and Fast Framework of Computing Relative Height in 3d Reconstruction. *9th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*. 29-31 May 2012. 2012. 1694-1697.
13. Khilar, R., Chitrakala, S., and SelvamParvathy, S. 3d Image Reconstruction: Techniques, Applications and Challenges. *International Conference on Optical Imaging Sensor and Security (ICOSS)*. 2-3 July 2013. 2013. 1-6.
14. Stoykova, E., Alatan, A. A., Benzie, P., Grammalidis, N., Malassiotis, S., Ostermann, J., Piekh, S., Sainov, V., Theobalt, C., Thevar, T., and Zabulis, X. 3-D Time-Varying Scene Capture Technologies: A Survey. *IEEE Transactions on Circuits and Systems for Video Technology*. 2007. 17(11), 1568-1586.
15. Hu, X., Xiong, N., Yang, L. T., and Li, D. A Surface Reconstruction Approach with a Rotated Camera. *International Symposium on Computer Science and its Applications*. 13-15 Oct. 2008. 2008. 72-77.
16. Kasuya, N., Sagawa, R., Kawasaki, H., and Furukawa, R. Robust and Accurate One-Shot 3d Reconstruction by 2c1p System with Wave Grid Pattern. *International Conference on 3D Vision (3DV)*. 29 June-1 July 2013. 2013. 247-254.
17. Ballan, L. and Cortelazzo, G. M. Multimodal 3d Shape Recovery from Texture, Silhouette and Shadow Information. *Third International Symposium on 3D Data Processing, Visualization, and Transmission*. 14-16 June 2006. 2006. 924-930.
18. Ballan, L., Brusco, N., and Cortelazzo, G. M. 3d Passive Shape Recovery from Texture and Silhouette Information. *Second IEE European Conference on Visual Media Production (CVMP)*. 30 Nov.-1 Dec. 2005. 2005. 36-43.

19. Uchida, N., Shibahara, T., Aoki, T., Nakajima, H., and Kobayashi, K. 3d Face Recognition Using Passive Stereo Vision. *IEEE International Conference on Image Processing*. 11-14 Sept. 2005. 2005. II-950-3.

20. Sadjadi, F. Passive 3d Reconstruction Using Polarimetric Infrared Imagery. *20th IEEE Lasers and Electro-Optics Society (LEOS) Annual Meeting Conference*. 21-25 Oct. 2007. 2007. 80-81.

21. El-Hazzat, S., Saaidi, A., and Satori, K. Multi-View Passive 3d Reconstruction: Comparison and Evaluation of Three Techniques and a New Method for 3d Object Reconstruction. *International Conference on Next Generation Networks and Services (NGNS)*. 28-30 May 2014. 2014. 194-201.

22. Proesmans, M. and Gool, L. V. A Sensor That Extracts Both 3d Shape and Surface Texture. *IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems*. 8-11 Dec. 1996. 1996. 485-492.

23. Wei, X. K. and Jinxiang, C. Modeling 3d Human Poses from Uncalibrated Monocular Images. *IEEE 12th International Conference on Computer Vision*. 29 Sept.-2 Oct. 2009. 2009. 1873-1880.

24. Sadjadi, F. and Ribnick, E. Passive 3d Sensing, and Reconstruction Using Multi-View Imaging. *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*. 13-18 June 2010. 2010. 68-74.

25. Pintavirooj, C. and Sangworasil, M., 3d Shape Recovery Based on Radon Transform, in *Digital Image Computing Techniques and Applications*. 2002: Melbourne, Australia.

26. Favaro, P. and Soatto, S. A Geometric Approach to Shape from Defocus. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 2005. 27(3), 406-417.

27. Wandt, B., Ackermann, H., and Rosenhahn, B. 3d Human Motion Capture from Monocular Image Sequences. *IEEE Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*. 7-12 June 2015. 2015. 1-8.

28. Rother, D. and Vidal, R. A Hypothesize-and-Bound Algorithm for Simultaneous Object Classification, Pose Estimation and 3d Reconstruction from a Single 2d Image. *IEEE International Conference on Computer Vision Workshops (ICCV)*. 6-13 Nov. 2011. 2011. 553-560.

29. Colombo, C., Marchesin, E. G., Vergani, L., Boccafogli, E., and Verni, G. Design of an Ankle Prosthesis for Swimming and Walking. *Procedia Engineering*. 2011. 10, 3503-3509.

30. Minnoye, A. L. M. and Plettenburg, D. H. Design, Fabrication, and Preliminary Results of a Novel Below Knee Prosthesis for Snowboarding: A Case Report. *Procedia Engineering*. 2010. 2(2), 3133-3141.

31. Yong, C. Y., Chew, K. M., Mahmood, N. H., Sudirman, R., and Omar, C. Prosthetics: Health Quality of Life Effects of Limb Loss. *4th International Conference on Biomedical Engineering and Informatics (BMEI)*. 15-17 Oct. 2011. 2011. 1333-1337.

32. Short, A., Gill, H. S., Marks, B., Waite, J. C., Kellett, C. F., Price, A. J., O'Connor, J. J., and Murray, D. W. A Novel Method for in Vivo Knee Prosthesis Wear Measurement. *Journal of Biomechanics*. 2005. 38(2), 315-322.

33. Goh, J. C. H., Lee, P. V. S., Toh, S. L., and Ooi, C. K. Development of an Integrated Cad–Fea Process for Below-Knee Prosthetic Sockets. *Clinical Biomechanics*. 2005. 20(6), 623-629.

34. Mueller, A. A., Paysan, P., Schumacher, R., Zeilhofer, H. F., Berg-Boerner, B. I., Maurer, J., Vetter, T., Schkommodau, E., Juergens, P., and Schwenzer-Zimmerer, K. Missing Facial Parts Computed by a Morphable Model and Transferred Directly to a Polyamide Laser-Sintered Prosthesis: An Innovation Study. *British Journal of Oral and Maxillofacial Surgery*. 2011. 49(8), 67-71.

35. Święszkowski, W., Skalski, K., Pomianowski, S., and Kędzior, K. The Anatomic Features of the Radial Head and Their Implication for Prosthesis Design. *Clinical Biomechanics*. 2001. 16(10), 880-887.

36. Rovetta, A., Wen, X., and Cosmi, F. Realization of a Prosthesis of the Lower Limb: Development of Kinematics. *Robotics and Computer-Integrated Manufacturing*. 1991. 8(3), 137-142.

37. Cohen, T. L., Altiok, H., Tarima, S., Smith, P. A., and Harris, G. F. Creep Evaluation of (Orthotic) Cast Materials During Simulated Clubfoot Correction. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. 28 Aug.-1 Sept. 2012. 2012. 3352-3355.

38. Achouri, S., Redjel, B., Bourebia, M., Berdjane, D., and Bouhouche, S. Fracture Behavior and Mechanical Characterization of a Composite

Orthopedic Use in the Two Direction of Flow Molding. *International Conference on Industrial Engineering and Operations Management (IEOM)*. 3-5 March 2015. 2015. 1-6.

39. Gonz, J., x00E, lez, Garc, G., x00Ed, Su, E., x00E, rez, Salazar, A., and Bravo, R. Novel Cost-Efficient Techniques for Treatment and Fixation of Upper Limbs Fractures. *3rd IEE Seminar on Appropriate Medical Technology for Developing Countries*. 4 Feb. 2004. 2004. 341-344.

40. Andreetto, M., Brusco, N., and Cortelazzo, G. M. Automatic 3d Modelling of Palatal Plaster Casts. *Fourth International Conference on 3D Digital Imaging and Modeling (3DIM)*. 6-10 Oct. 2003. 2003. 132-138.

41. Brusco, N., Andreetto, M., Carmignato, S., and Cortelazzo, G. M. Metrological Analysis of a Procedure for the Automatic 3d Modeling of Dental Plaster Casts. *2nd International Symposium on 3D Data Processing, Visualization and Transmission (3DPVT)*. 6-9 Sept. 2004. 2004. 592-599.

42. Yadollahi, M., Proch, A., zka, Ka, M., parov, Vy, O., and ata. Separation of Overlapping Dental Objects Using Normal Vectors to Image Region Boundaries. *International Workshop on Computational Intelligence for Multimedia Understanding (IWCIM)*. 29-30 Oct. 2015. 2015. 1-4.

43. Yan, G. D., Liao, W. H., Dai, N., Yang, L., Gao, Y. G., Zhu, S. Y., and Cai, Y. H. The Computer-Aided Design and Rapid Prototyping Fabrication of Removable Partial Denture Framework. *2nd IEEE International Conference on Computer Science and Information Technology (ICCSIT)* 8-11 Aug. 2009. 2009. 266-268.

44. Soltaninejad, M. R., Zoroofi, R. A., and Shirani, G. Automatic Crown Surface Reconstruction Using Tooth Statistical Model for Dental Prosthesis Planning. *19th Iranian Conference of Biomedical Engineering (ICBME)*. 20-21 Dec. 2012. 2012. 218-222.

45. Elangovan, P. T., Ghista, D. N., and Alwar, R. S. Computer Design Synthesis of a Below Knee-Syme Prosthesis. *Computer Programs in Biomedicine*. 1979. 9(2), 169-210.

46. Gefen, A., Kottner, J., and Santamaria, N. Clinical and Biomechanical Perspectives on Pressure Injury Prevention Research: The Case of Prophylactic Dressings. *Clinical Biomechanics*. 2016. 38, 29-34.

47. Jia, X., Zhang, M., and Lee, W. C. C. Load Transfer Mechanics between Trans-Tibial Prosthetic Socket and Residual Limb—Dynamic Effects. *Journal of Biomechanics*. 2004. 37(9), 1371-1377.

48. Helgason, B., Pálsson, H., Rúnarsson, T. P., Frossard, L., and Viceconti, M. Risk of Failure During Gait for Direct Skeletal Attachment of a Femoral Prosthesis: A Finite Element Study. *Medical Engineering & Physics*. 2009. 31(5), 595-600.

49. Vargas, J. A., Zurek, E. E., Torres, J. E., and Hernandez, R. J. Methodology to Develop an Intelligent Transfemoral Prosthesis. *IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*. 13-16 May 2012. 2012. 1045-1049.

50. Portnoy, S., Yizhar, Z., Shabshin, N., Itzchak, Y., Kristal, A., Dotan-Marom, Y., Siev-Ner, I., and Gefen, A. Internal Mechanical Conditions in the Soft Tissues of a Residual Limb of a Trans-Tibial Amputee. *Journal of Biomechanics*. 2008. 41(9), 1897-1909.

51. Brutto, M. L. and Spera, M. G., Image-Based and Range-Based 3d Modelling of Archaeological Cultural Heritage: The Telamon of the Temple of Olympian Zeus in Agrigento, in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. 2011: Italy. 515-522.

52. Blockley, P. and Morandi, S. The Recording of Two Late Roman Towers, Archaeological Museum, Milan 3d Documentation and Study Using Image-Based Modelling. *17th International Conference on Digital Heritage*. 28 Sept.-2 Oct. 2015. 2015. 103-106.

53. Deng, C., Zhou, Z., Li, W., and Hou, B. A Panoramic Geology Field Trip System Using Image-Based Rendering. *IEEE 40th Annual Computer Software and Applications Conference (COMPSAC)*. 10-14 June 2016. 2016. 264-268.

54. Guthe, S., Schardt, P., Goesele, M., and Cunningham, D. Ghosting and Popping Detection for Image-Based Rendering. *3DTV-Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON)*. 4-6 July 2016. 2016. 1-4.

55. Remondino, F. and El-Hakim, S. Image-Based 3d Modelling: A Review. *The Photogrammetric Record*. 2006. 269–291.

56. Vagharshakyan, S., Bregovic, R., and Gotchev, A. Image Based Rendering Technique Via Sparse Representation in Shearlet Domain. *IEEE International Conference on Image Processing (ICIP)*. 27-30 Sept. 2015. 2015. 1379-1383.
57. Telle, B., Aldon, M. J., and Ramdani, N. Camera Calibration and 3d Reconstruction Using Interval Analysis. *12th International Conference on Image Analysis and Processing*. 17-19 Sept. 2003. 2003. 374-379.
58. Liu, Q. and Su, H. Correction of the Asymmetrical Circular Projection in Dlt Camera Calibration. *Congress on Image and Signal Processing (CISP)*. 27-30 May 2008. 2008. 344-348.
59. Ikram ul-Haq, Chen, J., Dou, L., and Shahzad, A. Two Stage Camera Calibration Modeling and Simulation. *6th International Bhurban Conference on Applied Sciences & Technology*. 19-22 Jan. 2009. 2009. 231-237.
60. Liu, M., Li, K., Cai, H., and Song, P. Vision Measurement Method for Impact Point in Large Planar Region. *International Conference on Intelligent Control and Information Processing (ICICIP)*. 13-15 Aug. 2010. 2010. 379-383.
61. Yang, Z. and Kong, W. Subspace Projection Technique Applied to Camera Self-Calibration and 3d Reconstruction from Single-View. *International Conference on Mechatronics and Automation*. 25-28 June 2006. 2006. 183-188.
62. Wang, H., Han, L., and Zhang, S. Research of Camera Calibration Algorithm in the Auto Rack Girders Detecting System. *International Conference on Mechatronics and Automation*. 9-12 Aug. 2009. 2009. 3369-3374.
63. Yu, Z., He, D., Chen, Q., and Gong, M. Research on Camera Internal Parameters Self-Calibration Method for Mobile 3d Coordinates Vision Measurement System. *2nd International Congress on Image and Signal Processing (CISP)* 17-19 Oct. 2009. 2009. 1-4.
64. Feng, N., Hao, J., Bin, Y., and Yin, Y. A Method of Vehicle Camera Self-Calibration. *3rd International Congress on Image and Signal Processing (CISP)*. 16-18 Oct. 2010. 2010. 2449-2453.
65. Chenxi, W., Qing, H., Ning, W., Wei, L., Chao, H., and Meng, M. Q. H. A New Calibration Method Used in the Infrared Ray Environment. *IEEE International Conference on Information and Automation (ICIA)*. 6-8 June 2011. 2011. 480-484.

66. Wang, Q., Liu, Y., and Shen, Y. An Accurate Extrinsic Camera Self-Calibration Method in Non-Overlapping Camera Sensor Networks. *IEEE Instrumentation and Measurement Technology Conference (I2MTC)*. 10-12 May 2011. 2011. 1-6.

67. Liu, D., Wang, X., Liu, S., and Guan, Q. A Practical Method for 3d Reconstruction with Uncalibrated Image Sequences. *Chinese Conference on Pattern Recognition (CCPR)*. 21-23 Oct. 2010. 2010. 1-5.

68. Li, C., Zheng, J., Dang, C., and Zhou, H. A Method of 3d Reconstruction from Image Sequence. *2nd International Congress on Image and Signal Processing (CISP)*. 17-19 Oct. 2009. 2009. 1-5.

69. Zhao, L., Liu, S., Li, J., and Xu, H. An Approach for 3d Reconstruction from Uncalibrated Images. *International Conference on Challenges in Environmental Science and Computer Engineering (CESCE)*. 6-7 March 2010. 2010. 390-393.

70. Bourgeois-Republique, C., x00E, publique, Dipanda, A., and Koch, A. A Structured Light System Encoding for an Uncalibrated 3d Reconstruction Based on Evolutionary Algorithms. *International Conference on Signal-Image Technology & Internet-Based Systems (SITIS)*. 2-5 Dec. 2013. 2013. 124-129.

71. Park, S. W., Jingu, H., and Savvides, M. 3d Face Reconstruction from a Single 2d Face Image. *IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*. 23-28 June 2008. 2008. 1-8.

72. Häne, C., Zach, C., Cohen, A., Angst, R., and Pollefeys, M. Joint 3d Scene Reconstruction and Class Segmentation. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)* 23-28 June 2013. 2013. 97-104.

73. Audley, D. and Lee, D. Ill-Posed and Well-Posed Problems in Systems Identification. *IEEE Transactions on Automatic Control*. 1974. 19(6), 738-747.

74. Yue, M., Qiuqi, R., and Xiaoli, L. 3d Face Reconstruction Using a Single 2d Face Image. *International Conference on Educational and Information Technology (ICEIT)*. 17-19 Sept. 2010. 2010. V3-32-V3-36.

75. Segundo, M. P., Silva, L., and Bellon, O. R. P. Improving 3d Face Reconstruction from a Single Image Using Half-Frontal Face Poses. *19th IEEE International Conference on Image Processing*. 30 Sept.-3 Oct. 2012. 2012. 1797-1800.

76. Moeini, A., Moeini, H., and Faez, K. Pose-Invariant Facial Expression Recognition Based on 3d Face Reconstruction and Synthesis from a Single 2d Image. *22nd International Conference on Pattern Recognition (ICPR)*. 24-28 Aug. 2014. 2014. 1746-1751.

77. Moeini, A., Moeini, H., and Faez, K. Expression-Invariant Face Recognition Via 3d Face Reconstruction Using Gabor Filter Bank from a 2d Single Image. *22nd International Conference on Pattern Recognition (ICPR)*. 24-28 Aug. 2014. 2014. 4708-4713.

78. Moeini, A. and Moeini, H. Pose-Invariant Gender Classification Based on 3d Face Reconstruction and Synthesis from Single 2d Image. *Electronics Letters*. 2015. 51(10), 760-762.

79. Li, C., Mu, Z., Zhang, F., and Wang, S. A Novel 3d Ear Reconstruction Method Using a Single Image. *10th World Congress on Intelligent Control and Automation (WCICA)*. 6-8 July 2012. 2012. 4891-4896.

80. Guan, Y. Automatic 3d Face Reconstruction Based on Single 2d Image. *International Conference on Multimedia and Ubiquitous Engineering (MUE)*. 26-28 April 2007. 2007. 1216-1219.

81. Widanagamaachchi, W. N. and Dharmaratne, A. T. 3d Face Reconstruction from 2d Images. *International Conference on Digital Image Computing: Techniques and Applications (DICTA)*. 1-3 Dec. 2008. 2008. 365-371.

82. Pan, Y., Zhou, M., Fan, Y., Zhang, D., and Zheng, X. A Weighted Color Mrf Model for 3d Reconstruction from a Single Image. *International Conference on Virtual Reality and Visualization (ICVRV)*. 14-15 Sept. 2013. 2013. 21-28.

83. Simões, F., Almeida, M., Pinheiro, M., Anjos, R. D., Santos, A. D., Roberto, R., Teichrieb, V., Suetsugo, C., and Pelinson, A. Challenges in 3d Reconstruction from Images for Difficult Large-Scale Objects: A Study on the Modeling of Electrical Substations. *14th Symposium on Virtual and Augmented Reality (SVR)*. 28-31 May 2012. 2012. 74-83.

84. Kanawong, R. and Madarasmi, S. Shape from Contour by Generating Synthetic Texture Patterns. *IEEE International Conference on Industrial Technology (ICIT)*. 2002. 2002. Vol.1 399-404.

85. Wuhrer, S. and Shu, C. Shape from Suggestive Contours Using 3d Priors. *Ninth Conference on Computer and Robot Vision (CRV)*. 28-30 May 2012. 2012. 236-243.

86. Ulupinar, F. and Nevatia, R. Shape from Contour: Straight Homogeneous Generalized Cylinders and Constant Cross Section Generalized Cylinders. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 1995. 17(2), 120-135.

87. Bai, S., Wang, X., and Bai, X. Aggregating Contour Fragments for Shape Classification. *IEEE International Conference on Image Processing (ICIP)*. 27-30 Oct. 2014. 2014. 5252-5256.

88. Wang, X., Sohel, F., Bennamoun, M., and Lei, H. Heat Propagation Contours for 3d Non-Rigid Shape Analysis. *IEEE Winter Conference on Applications of Computer Vision (WACV)*. 7-10 March 2016. 2016. 1-7.

89. Kaleem, M. and Mahmood, M. T. Combining Focus Measures through Genetic Algorithm for Shape from Focus. *International Conference on Information Science & Applications (ICISA)*. 6-9 May 2014. 2014. 1-4.

90. Tseng, C. Y. and Wang, S. J. Shape-from-Focus Depth Reconstruction with a Spatial Consistency Model. *IEEE Transactions on Circuits and Systems for Video Technology*. 2014. 24(12), 2063-2076.

91. Muhammad, M. and Choi, T. S. Sampling for Shape from Focus in Optical Microscopy. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 2012. 34(3), 564-573.

92. Mahmood, M. T. Shape from Focus by Total Variation. *IEEE Image, Video and Multidimensional Signal Processing Technical Committee (IVMSP) Workshop on 3D Image/Video Technologies and Applications*. 10-12 June 2013. 2013. 1-4.

93. Karthik, S. and Rajagopalan, A. N. Underwater Microscopic Shape from Focus. *22nd International Conference on Pattern Recognition (ICPR)*. 24-28 Aug. 2014. 2014. 2107-2112.

94. Hariharan, R. and Rajagopalan, A. N. Shape-from-Focus by Tensor Voting. *IEEE Transactions on Image Processing*. 2012. 21(7), 3323-3328.

95. Mahmood, M. T., Choi, Y. K., and Shim, S. O. Estimating Shape from Focus by Gaussian Process Regression. *IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. 14-17 Oct. 2012. 2012. 1345-1350.

96. Muhammad, M. S., Mutahira, H., Choi, K. W., Kim, W. Y., and Ayaz, Y. Calculating Accurate Window Size for Shape-from-Focus. *International*

Conference on Information Science & Applications (ICISA). 6-9 May 2014. 2014. 1-4.

97. Lenz, M., Ferstl, D., M. Rüther, and Bischof, H. Depth Coded Shape from Focus. *IEEE International Conference on Computational Photography (ICCP)*. 28-29 April 2012. 2012. 1-8.
98. Torreao, J. R. A. and Fernandes, J. L. Single-Image Shape from Defocus. *XVIII Brazilian Symposium on Computer Graphics and Image Processing (SIBGRAPI)*. 9-12 Oct. 2005. 2005. 241-246.
99. Favaro, P., Soatto, S., Burger, M., and Osher, S. J. Shape from Defocus Via Diffusion. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 2008. 30(3), 518-531.
100. Salih, Y. and Malik, A. S. Depth and Geometry from a Single 2d Image Using Triangulation. *IEEE International Conference on Multimedia and Expo Workshops (ICMEW)*. 9-13 July 2012. 2012. 511-515.
101. Asif, M., Malik, A. S., and Tae-Sun, C. 3d Shape Recovery from Image Defocus Using Wavelet Analysis. *IEEE International Conference on Image Processing*. 11-14 Sept. 2005. 2005. I-1025-8.
102. Lou, Y., Favaro, P., Bertozzi, A. L., and Soatto, S. Autocalibration and Uncalibrated Reconstruction of Shape from Defocus. *IEEE Conference on Computer Vision and Pattern Recognition*. 17-22 June 2007. 2007. 1-8.
103. Martino, G. D., Simone, A. D., Iodice, A., Riccio, D., and Ruello, G. On Shape from Shading and Sar Images: An Overview and a New Perspective. *IEEE Geoscience and Remote Sensing Symposium*. 13-18 July 2014. 2014. 1333-1336.
104. Tozza, S. and Falcone, M. A Semi-Lagrangian Approximation of the Oren-Nayar Pde for the Orthographic Shape-from-Shading Problem. *International Conference on Computer Vision Theory and Applications (VISAPP)*. 5-8 Jan. 2014. 2014. 711-716.
105. Martino, G. D., Simone, A. D., Iodice, A., Riccio, D., and Ruello, G. Sar Shape from Shading in Suburban Areas. *Joint Urban Remote Sensing Event (JURSE)*. 30 March-1 April 2015. 2015. 1-4.
106. Richter, S. R. and Roth, S. Discriminative Shape from Shading in Uncalibrated Illumination. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. 7-12 June 2015. 2015. 1128-1136.

107. Barron, J. T. and Malik, J. Shape, Illumination, and Reflectance from Shading. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 2015. 37(8), 1670-1687.

108. Chaudhari, N., Ludu, A., and Demirkiran, I. A Novel Approach for Reconstructing Water Surface Using Shape from Shading Technique. *IEEE SOUTHEASTCON*. 13-16 March 2014. 2014. 1-4.

109. Lin, H. Y. and Wu, J. R. 3d Reconstruction by Combining Shape from Silhouette with Stereo. *19th International Conference on Pattern Recognition (ICPR)*. 8-11 Dec. 2008. 2008. 1-4.

110. Watanabe, T. and Tanaka, T. Free Viewpoint Video Synthesis on Human Action Using Shape from Silhouette Method. *Proceedings of SICE Annual Conference*. 18-21 Aug. 2010. 2010. 2748-2751.

111. Mikhnevich, M. and Hebert, P. Shape from Silhouette under Varying Lighting and Multi-Viewpoints. *Canadian Conference on Computer and Robot Vision (CRV)*. 25-27 May 2011. 2011. 285-292.

112. Mikhnevich, M. and Laurendeau, D. Shape from Silhouette in Space, Time and Light Domains. *International Conference on Computer Vision Theory and Applications (VISAPP)*. 5-8 Jan. 2014. 2014. 368-377.

113. Salvador, J. and Casas, J. R. Joint Estimation of Shape and Motion from Silhouettes. *IEEE International Conference on Image Processing*. 26-29 Sept. 2010. 2010. 4069-4072.

114. Tabb, A. Shape from Silhouette Probability Maps: Reconstruction of Thin Objects in the Presence of Silhouette Extraction and Calibration Error. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. 23-28 June 2013. 2013. 161-168.

115. Haro, G. Shape from Silhouette Consensus and Photo-Consistency. *IEEE International Conference on Image Processing (ICIP)*. 27-30 Oct. 2014. 2014. 4837-4841.

116. Davis, L. S., Janos, L., and Dunn, S. M. Efficient Recovery of Shape from Texture. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 1983. PAMI-5(5), 485-492.

117. Super, B. J. and Bovik, A. C. Shape-from-Texture by Wavelet-Based Measurement of Local Spectral Moments. *IEEE Computer Society Conference*

on Computer Vision and Pattern Recognition (CVPR). 15-18 June 1992. 1992. 296-301.

118. Bujnak, M., Kukelova, Z., and Pajdla, T. 3d Reconstruction from Image Collections with a Single Known Focal Length. *IEEE 12th International Conference on Computer Vision*. 29 Sept.-2 Oct. 2009. 2009. 1803-1810.

119. Mandun, Z., Lichao, Q., Guodong, C., and Ming, Y. A Triangulation Method in 3d Reconstruction from Image Sequences. *Second International Conference on Intelligent Networks and Intelligent Systems (ICINIS)*. 1-3 Nov. 2009. 2009. 306-308.

120. Yang, C., Zhou, F., and Bai, X. 3d Reconstruction through Measure Based Image Selection. *9th International Conference on Computational Intelligence and Security (CIS)*. 14-15 Dec. 2013. 2013. 377-381.

121. Habert, S., Habert, S., Dahdah, N., and Cheriet, F. A Novel Method for an Automatic 3d Reconstruction of Coronary Arteries from Angiographic Images. *11th International Conference on Information Science, Signal Processing and their Applications (ISSPA)*. 2-5 July 2012. 2012. 484-489.

122. Kamencay, P., Zachariasova, M., Hudec, R., Benco, M., and Radil, R. 3d Image Reconstruction from 2d Ct Slices. *3DTV-Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON)*. 2-4 July 2014. 2014. 1-4.

123. Deguchi, K., Noami, J., and Hontani, H. 3d Fundus Pattern Reconstruction and Display from Multiple Fundus Images. *15th International Conference on Pattern Recognition*. 2000. Vol.4 94-97.

124. Kothari, N., Bhateshvar, Y. K., Katariya, A., and Kothari, S. 3d Image Reconstruction Using X-Rays for Ct Scan. *International Conference on Computational Intelligence and Communication Networks (CICN)*. 7-9 Oct. 2011. 2011. 6-10.

125. Hong, D., Tavanapong, W., Wong, J., Oh, J., and Groen, P. C. d. 3d Reconstruction of Colon Segments from Colonoscopy Images. *Ninth IEEE International Conference on Bioinformatics and BioEngineering (BIBE)*. 22-24 June 2009. 2009. 53-60.

126. Zia, A., Liang, J., Zhou, J., and Gao, Y. 3d Reconstruction from Hyperspectral Images. *IEEE Winter Conference on Applications of Computer Vision*. 5-9 Jan. 2015. 2015. 318-325.

127. Brahim, N., Gu, D., x00E, riot, Daniely, S., and Solaiman, B. 3d Reconstruction of Underwater Scenes Using Image Sequences from Acoustic Camera. *IEEE OCEANS Conference*. 24-27 May 2010. 2010. 1-8.

128. Jain, N., Kumar, S., and Kumar, A. Analysis of Edge Detection Techniques Using Soft Computing Approaches. *IEEE Students' Conference on Electrical, Electronics and Computer Science (SCEECS)*. 5-6 March 2016. 2016. 1-4.

129. Rahmat, M. F. and Sabit, H. A., Flow Regime Identification and Concentration Distribution of Solid Particles Flow in Pipelines Using Electrodynamic Tomography and Artificial Neural Networks, in *International Conference on Mechatronics Technology*. 2005: Kuala Lumpur, Malaysia.

130. Hunziker, P., Morozov, O. V., Volosyuk, O. V., Volosyuk, V. K., and Zhyla, S. S. Improved Method of Optical Coherence Tomography Imaging. *IEEE International Conference on Mathematical Methods in Electromagnetic Theory (MMET)*. 5-7 July 2016. 2016. 421-424.

131. Wang, Y. and Li, B. Evaluation of Modulation Transfer Function on the Optical Tomography Imaging System. *8th International Congress on Image and Signal Processing (CISP)*. 14-16 Oct. 2015. 2015. 717-721.

132. Lee, S. H., Jang, W. D., Park, B. K., and Kim, C. S. Rgb-D Image Segmentation Based on Multiple Random Walkers. *IEEE International Conference on Image Processing (ICIP)*. 25-28 Sept. 2016. 2016. 2549-2553.

133. Zhou, X. and Liu, B. A Study on Peripheral Nerve Image Segmentation Algorithm. *IEEE Information Technology, Networking, Electronic and Automation Control Conference*. 20-22 May 2016. 2016. 864-868.

134. Wang, Y., Sun, Z., Liu, C., Peng, W., and Zhang, J. Mri Image Segmentation by Fully Convolutional Networks. *IEEE International Conference on Mechatronics and Automation*. 7-10 Aug. 2016. 2016. 1697-1702.

135. Heimowitz, A. and Keller, Y. Image Segmentation Via Probabilistic Graph Matching. *IEEE Transactions on Image Processing*. 2016. 25(10), 4743-4752.

136. Sharifi, I. and Ghasemzadeh, M. Design and Evaluation of an Expert System Based on Histogram Shape for Image Thresholding. *9th International Conference on e-Commerce in Developing Countries: With focus on e-Business (ECDC)*. 16 April 2015. 2015. 1-5.

137. Sesadri, U. and Nagaraju, C. Optimal Thresholding for Enhancement of Low Contrasted Images Using Soft Computing. *Conference on Power, Control,*

Communication and Computational Technologies for Sustainable Growth (PCCCTSG). 11-12 Dec. 2015. 2015. 273-277.

138. Sezgin, M. and Sankur, B. l. Survey over Image Thresholding Techniques and Quantitative Performance Evaluation. *Journal of Electronic Imaging*. 2004. 13(1), 146-168.

139. Ranefall, P., Sadanandan, S. K., C, W., and hlby. Fast Adaptive Local Thresholding Based on Ellipse Fit. *IEEE 13th International Symposium on Biomedical Imaging (ISBI)*. 13-16 April 2016. 2016. 205-208.

140. Sandhu, H. S., Singh, K. J., and Kapoor, D. S. Automatic Edge Detection Algorithm and Area Calculation for Flame and Fire Images. *6th International Conference on Cloud System and Big Data Engineering*. 14-15 Jan. 2016. 2016. 403-407.

141. Ju, W., Liu, J., and Jin, S. An Improved Clustering Based on Edge Detection Method. *35th Chinese Control Conference (CCC)*. 27-29 July 2016. 2016. 4026-4030.

142. Agarwal, A. and Goel, K. Comparative Analysis of Digital Image for Edge Detection by Using Bacterial Foraging & Canny Edge Detector. *Second International Conference on Computational Intelligence & Communication Technology (CICT)*. 12-13 Feb. 2016. 2016. 125-129.

143. Hai, S. and Jianyu, Z. Sub-Pixel Edge Detection in the Application of the Deformation Measurement Technique. *12th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP)*. 18-20 Dec. 2015. 2015. 241-246.

144. Kaur, B. and Garg, A. Mathematical Morphological Edge Detection for Remote Sensing Images. *3rd International Conference on Electronics Computer Technology (ICECT)*. 8-10 April 2011. 2011. 324-327.

145. Ren, H., Liu, W., Shi, T., and Li, F. A Biomimetic Adaptive Fuzzy Edge Detection Method Based on Visual Features. *35th Chinese Control Conference (CCC)*. 27-29 July 2016. 2016. 3902-3906.

146. Wang, Z., Su, J., and Zhang, P. Image Edge Detection Algorithm Based on Wavelet Fractional Differential Theory. *35th Chinese Control Conference (CCC)*. 27-29 July 2016. 2016. 10407-10411.

147. Recker, S., Hess-Flores, M., and Joy, K. I. Statistical Angular Error-Based Triangulation for Efficient and Accurate Multi-View Scene Reconstruction.

IEEE Workshop on Applications of Computer Vision (WACV). 15-17 Jan. 2013. 2013. 68-75.

148. Kajak, B., Gewali, L., and Selvaraj, H. Ear-Slicing and Quality Triangulation. *21st International Conference on Systems Engineering (ICSEng)*. 16-18 Aug. 2011. 2011. 194-199.

149. Zhang, X., Li, G., Zhao, J., and Hou, Z. New Triangulation Method for Surface Scattered Points. *IEEE International Conference on Mechatronics and Automation*. 3-6 Aug. 2014. 2014. 541-546.

150. Peng, K., Hou, L., Ren, R., Ying, X., and Zha, H. Single View Metrology Along Orthogonal Directions. *20th International Conference on Pattern Recognition (ICPR)*. 23-26 Aug. 2010. 2010. 1658-1661.

151. Guanghui, W., Yihong, W., and Zhanyi, H. A Novel Approach for Single View Based Plane Metrology. *16th International Conference on Pattern Recognition*. 2002. 2002. Vol.2 556-559.

152. Huang, G. S. and Cheng, C. E. 3d Coordinate Identification of Object Using Binocular Vision System for Mobile Robot. *International Automatic Control Conference (CACS)*. 2-4 Dec. 2013. 2013. 91-96.

153. Ulupinar, F. and Nevatia, R. Using Symmetries for Analysis of Shape from Contour. *Second International Conference on Computer Vision*. 5-8 Dec. 1988. 1988. 414-426.

154. Neelamani, R., Queiroz, R. d., Zhigang, F., Dash, S., and Baraniuk, R. G. Jpeg Compression History Estimation for Color Images. *IEEE Transactions on Image Processing*. 2006. 15(6), 1365-1378.

155. Mao, H., Hu, Z., Zhu, L., and Qin, H. Png File Decoding Optimization Based Embedded System. *8th International Conference on Wireless Communications, Networking and Mobile Computing (WiCOM)*. 21-23 Sept. 2012. 2012. 1-4.

156. Jain, A. and Jain, V. Png Image Copyright Protection and Authentication Using Svd Hash and Aes. *International Conference on Advances in Engineering and Technology Research (ICAETR)*. 1-2 Aug. 2014. 2014. 1-6.

157. Barbhuiya, A. H. M. J. I., Laskar, T. A., and Hemachandran, K. An Approach for Color Image Compression of Jpeg and Png Images Using Dct and Dwt. *International Conference on Computational Intelligence and Communication Networks (CICN)*. 14-16 Nov. 2014. 2014. 129-133.

158. Huang, D. S., Zhang, X., Garcia, C. A. R., and Zhang, L. *Advanced Intelligent Computing Theories and Applications: With Aspects of Artificial Intelligence: 6th International Conference on Intelligent Computing, Icic 2010, Changsha, China, August 18-21, 2010, Proceedings*. Springer. 2010.

159. Burger, W. and Burge, M. J. *Digital Image Processing: An Algorithmic Introduction Using Java*. Springer London. 2016.

160. Mohan, P. G., Prakash, C., and Gangashetty, S. V. Bessel Transform for Image Resizing. *18th International Conference on Systems, Signals and Image Processing (IWSSIP)*. 16-18 June 2011. 2011. 1-4.

161. Mishiba, K. and Ikehara, M. Image Resizing Using Improved Seam Merging. *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*. 25-30 March 2012. 2012. 1261-1264.

162. Gour, P. N., Narumanchi, S., Saurav, S., and Singh, S. Hardware Accelerator for Real-Time Image Resizing. *18th International Symposium on VLSI Design and Test*. 16-18 July 2014. 2014. 1-6.

163. He, Z., Gao, M., Yu, H., Ye, X., Zhang, L., and Ma, G. A New Improved Seam Carving Content Aware Image Resizing Method. *IEEE 8th Conference on Industrial Electronics and Applications (ICIEA)*. 19-21 June 2013. 2013. 738-741.

164. Nagabhushana, S. *Computer Vision and Image Processing*. New Age International. 2005.

165. Choras, R. S. *Image Processing and Communications Challenges 5*. Springer International Publishing. 2013.

166. Nixon, M. *Feature Extraction & Image Processing*. Elsevier Science. 2008.

167. Upton, G. and Cook, I. *Introducing Statistics*. OUP Oxford. 2001.

168. Pan, J. S., Chen, S. M., and Nguyen, N. T. *Computational Collective Intelligence. Technologies and Applications: Second International Conference, Iccci 2010, Kaohsiung, Taiwan, November 10-12, 2010. Proceedings*. Springer Berlin Heidelberg. 2010.

169. Kaur, B. and Majumder, M. K. Novel Vlsi Architecture for Two-Dimensional Radon Transform Computations. *1st International Conference on Recent Advances in Information Technology (RAIT)*. 15-17 March 2012. 2012. 570-575.

170. Chandra, S. and Svalbe, I. A Fast Number Theoretic Finite Radon Transform. *Digital Image Computing: Techniques and Applications (DICTA)*. 1-3 Dec. 2009. 2009. 361-368.

171. Venkatraghavan, V., Rekha, S., Chatterjee, J., and Ray, A. K. Modified Radon Transform for Texture Analysis. *Annual IEEE India Conference*. 16-18 Dec. 2011. 2011. 1-4.

172. Zakaria, Z., Jaafar, N. H., Yazid, N. A. M., Mansor, M. S. B., Rahiman, M. H. F., and Rahim, R. A. Sinogram Concept Approach in Image Reconstruction Algorithm of a Computed Tomography System Using Matlab. *International Conference on Computer Applications and Industrial Electronics (ICCAIE)*. 5-8 Dec. 2010. 2010. 500-505.

173. Punarselvam, E. and Suresh, P. Edge Detection of Ct Scan Spine Disc Image Using Canny Edge Detection Algorithm Based on Magnitude and Edge Length. *3rd International Conference on Trendz in Information Sciences & Computing (TISC)*. 8-9 Dec. 2011. 2011. 136-140.

174. Zhao, H., Qin, G., and Wang, X. Improvement of Canny Algorithm Based on Pavement Edge Detection. *3rd International Congress on Image and Signal Processing (CISP)*. 16-18 Oct. 2010. 2010. 964-967.

175. Tang, Z. and Shen, D. Canny Edge Detection Codec Using Vlib on Davinci Series Dsp. *International Conference on Computer Science & Service System (CSSS)*. 11-13 Aug. 2012. 2012. 221-224.

176. Shang, J. and Jiang, F. An Algorithm of Edge Detection Based on Soft Morphology. *IEEE 11th International Conference on Signal Processing (ICSP)*. 21-25 Oct. 2012. 2012. 166-169.

177. Wencheng, Y., Hu, J., and Stojmenovic, M. Ndtc: A Novel Topology-Based Fingerprint Matching Algorithm Using N-Layer Delaunay Triangulation Net Check. *7th IEEE Conference on Industrial Electronics and Applications (ICIEA)*. July 18-20 2012. 2012. 866-870.

178. Nguyen, V. S., Bac, A., and Daniel, M. Triangulation of an Elevation Surface Structured by a Sparse 3d Grid. *IEEE Fifth International Conference on Communications and Electronics (ICCE)*. July 30 2014-Aug. 1 2014. 2014. 464-469.

179. Melkemi, M. and Elbaz, M. A Simple and Efficient Algorithm for Dot Patterns Reconstruction. *IEEE International Conference on Image Processing (ICIP)*. Oct. 27-30 2014. 2014. 4727-4731.

180. Dubuisson, M. P. and Jain, A. K. A Modified Hausdorff Distance for Object Matching. *Proceedings of 12th International Conference on Pattern Recognition*. 9-13 Oct 1994. 1994. Vol.1 566-568.

181. Wang, Y., Li, J., Lu, Y., Fu, Y., and Jiang, Q. Image Quality Evaluation Based on Image Weighted Separating Block Peak Signal to Noise Ratio. *International Conference on Neural Networks and Signal Processing, 2003. Proceedings of the 2003*. 14-17 Dec. 2003. 2003. Vol.2 994-997.

182. Korhonen, J. and You, J. Peak Signal-to-Noise Ratio Revisited: Is Simple Beautiful? *2012 Fourth International Workshop on Quality of Multimedia Experience*. 5-7 July 2012. 2012. 37-38.

183. Najafipour, A., Babaee, A., and Shahrtash, S. M. Comparing the Trustworthiness of Signal-to-Noise Ratio and Peak Signal-to-Noise Ratio in Processing Noisy Partial Discharge Signals. *IET Science, Measurement & Technology*. 2013. 7(2), 112-118.

184. Lee, E. J. and Jin, K. C. Comparative Analysis of Sinogram Interpolation Methods for Computer Tomographic Images. *2015 International Symposium on Consumer Electronics (ISCE)*. 24-26 June 2015. 2015. 1-2.

185. Powers, G. and Press, I. *Trigonometry for Engineering Technicians*. Industrial Press. 2012.

186. Sthitpattanapongsa, P. and Srinark, T. A Two-Stage Otsu's Thresholding Based Method on a 2d Histogram. *IEEE 7th International Conference on Intelligent Computer Communication and Processing*. Aug. 25-27 2011. 2011. 345-348.

187. Belhedi, A. and Marcotegui, B. Adaptive Scene-Text Binarisation on Images Captured by Smartphones. *IET Image Processing*. 2016. 10(7), 515-523.