UNIVERSITI PUTRA MALAYSIA

3D SURFACE RECONSTRUCTION OF CORONARY ARTERIES FROM CARDIOVASCULAR ANGIOGRAPHY TO DETECT LOCATION OF HEART VESSELS

HASAN HADI KHALEEL

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By

HASAN HADI KHALEEL

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of Requirements for the Degree of Doctor of Philosophy

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Dedicated to my parents, siblings, and good friends

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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Chairperson: Rahmita Wirza O.K. Rahmat, PhD

Faculty: Computer Science and Information Technology

Complications and difficulties are common in the medical field. One of the important difficulties that a surgeon may face nowadays is that when a vessel or more vessels goes inside the surface of the heart. Coronary artery vessels naturally lie on the surface of the heart but sometimes a coronary artery vessel goes inside the heart muscle and stays there for awhile and then comes out again. In this case a surgeon will not be able to locate the artery during a bypass operation. Working on 2D projections can easily mislead the comprehension and the interpretation of the structures like in the case of stenosis quantification. Different acquisition techniques make it possible to obtain 3D models of the vessels network reconstructed from 2D angiographies. The problem is that the coronary angiograms can show the arteries through contrast dye projection but still cannot show the exact location of a coronary artery vessel.

The proposed procedure to solve this problem in this thesis consists of three steps. The first step is the coronary artery trees extraction. We proposed an algorithm to extract tree vessels from cardiovascular angiography by removing the background and highlighting the coronary artery tree vessels. The second step is 3D reconstruction for coronary artery tree vessels. Since extracted vessels from step one will be in 2D which will offer little information to surgeons and is difficult to study as well, we need to reconstruct them in 3D to simplify their diagnosing and analyzing. The third step in the procedure is the surface fitting. The 3D model reconstructed from step two will offer more information about the coronary artery tree vessels but it will again be difficult to decide whether a vessel is in or out the heart's surface. Therefore, we need to build a 3D surface out of the 3D cloud of points obtained from step two to simplify the detection of said vessels.

To best confirm the location of a vessel and determine the depth of that vessel inside the heart, we added a step at the end of the research to measure the curvatures of the reconstructed surface and the maximum depth of a vessel inside that surface as well. This step will measure the depths of all curvatures and highlight the maximum. To surgeons, 1 cm (10 mm) depth of a vessel inside the heart could cause a problem during surgery; therefore, our approach would set out an alarm to warn the surgeon if that depth (10 mm) or more is present. We have tested the approach to raw of clinical data sets and the results show that our proposed approach is capable of detecting the location of vessels in about 98%. From those results we can conclude that our approach is robust and can act as a tool in surgery planning and scientific researches purposes.

Abstrak of tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah dari Doktor Falsafah

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Oleh

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Mac 2012

Pengerusi: **Rahmita Wirza O.K. Rahmat, PhD**

Fakulti: **Sains Komputer dan Teknologi Maklumat**

Komplikasi dan kesukaran merupakan perkara biasa dalam bidang perubatan. Salah satu kesukaran yang sering dihadapi oleh ahli bedah masa kini ialah apabila satu atau lebih saluran memasuki dalaman jantung. Saluran arteri koronari umumnya berada pada permukaan jantung tetapi dalam keadaan tertentu, saluran arteri koronari memasuki ruangan otot jantung, menetap sementara dan keluar semula. Dalam kes ini, pakar bedah akan gagal menentukan kedudukan arteri semasa pembedahan pintasan jantung. Pengunjuran 2D boleh mengakibatkan kesalah fahaman dan kesilapan interpretasi terhadap struktur sebagaimana penjumlahan kes aliran keluar berbalik. Teknik perolehan yang berbeza memungkinkan imej 3D bagi rangkaian saluran vesel dibina semula daripada Sinaran-X imej 2D angiografi. Masalahnya ialah, koronari berupaya menunjukkan arteri melalui unjuran pewarnaan, namun ia tidak dapat menunjukkan lokasi sebenar saluran arteri koronari.

Prosedur yang dicadangkan bagi mengatasi permasalahan ini dalam tesis ini terdiri daripada tiga langkah. Langkah pertama ialah pemisahan pepohon arteri koronari. Kami mencadangkan satu algoritma untuk memisahkan pepohon saluran vesel dari angiografi kardivaskular dengan menyingkirkan latar belakang dan menonjolkan saluran pepohon arteri koronari. Langkah kedua adalah pembangunan semula 3D untuk saluran pepohon arteri koronari. Memandangkan saluran yang diekstrak/pengasingan daripada langkah pertama merupakan 2D, yang akan menawarkan sedikit maklumat kepada pakar bedah dan agak sukar untuk dikaji, kita perlu membangunkan semula 3D bagi memudahkan mereka mendiagnos dan menganalisa. Langkah ketiga dalam Prosedur adalah padanan-permukaan. Pembangunan model 3D daripada langkah kedua menawarkan lebih banyak maklumat berkenaan saluran pokok arteri koronari tetapi sekali lagi menjadi sukar untuk menentukan samada saluran tersebut berada di dalam atau di luar permukaan jantung. Oleh itu, kita perlu membangunkan permukaan 3D di luar daripada titik awan 3D yang diperolehi daripada langkah kedua untuk mengesan lokasi saluran dengan mudah.

Untuk memastikan secara optimum lokasi saluran dan menentukan kedalaman saluran dalam jantung, tambahan satu lagi langkah di penghujung penyelidikan iaitu mengukur lengkungan yang membina permukaan dan juga kedalaman maksimum sesuatu saluran di bahagian dalam permukaan. Langkah ini akan mengukur kedalaman bagi setiap lengkungan dan mengetengahkan nilai kedalaman yang maksimum. Menurut ahli bedah, 1 cm (10mm) kedalaman saluran dalam jantung boleh memberi masalah untuk membuat pembedahan, maka, pendekatan kami akan menetapkan suatu penggera untuk memberi amaran kepada ahli bedah sekiranya

mencapai kedalaman 10 mm atau lebih. Kami telah menguji pendekatan terhadap beberapa set data mentah klinikal dan keputusan menunjukkan pendekatan yang kami cadangkan mampu mengesan lokasi saluran sekitar 98%. Daripada keputusan ini, kita boleh membuat kesimpulan bahawa pendekatan ini kukuh dan boleh bertindak sebagai alat dalam pengurusan pembedahan dan kegunaan penyelidikan saintifik.

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Hasan Hadi Khaleel

I certify that a Thesis Examination Committee has met on 1 March 2012 to conduct the final examination of Hasan Hadi Khaleel on his thesis entitled "3D Surface Reconstruction of Coronary Arteries From Cardiovascular Angiography to Detect Location of Heart Vessels" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P. U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

HASAN HADI KHALEEL

Date: 1 March 2012

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