Introduction to ARC e-Research Project

Developing an E-Platform for Application of Clinical Management in the Human Respiratory and Vascular System

August 2006
Aims

The present project aims to develop an E-PLATFORM that will provide a simulation-based virtual reality environment for clinical management and therapy treatment in the human respiratory and vascular system. This platform will rely on many facets of advanced computational and mathematical approaches for simulating airflow/blood flow in order to treat diseases of the respiratory and vascular system of a patient. Through this E-PLATFORM, the techniques and tools to be developed within this framework aim to assist doctors in answering "what ifs" rather than "what’s there" through the current practice of performing diagnostic evaluation on patients.
Human Respiratory and Vascular System

- Nasal cavity
- Sphenoidal sinus
- Frontal sinus
- Nasal conchae
- Tongue
- Hyoid bone
- Larynx
- Trachea
- Bronchus
- Right Lung
- Left Lung
- Bronchioles
- Diaphragm

- External jugular vein
- Internal jugular vein
- Subclavian vein
- Superior vena cava
- Pulmonary artery
- Inferior vena cava
- Pulmonary vein
- Aorta
- Brachial artery
- Radial artery
- Ulnar artery
- Femoral vein
- Femoral artery
- Great saphenous vein
- Iliac artery
- Iliac vein
- Anterior tibial artery
- Posterior tibial artery
- Small saphenous vein
Developing a VR-Based Respiratory Treatment Planning System

- Surface Extraction (SJTU)
- Grid Generation
- CFD Simulation
- Experiment (CSIRO)
- Comparison
- Virtual Treatment
- VR Visualization

MRI Scans From RuiJin Hospital China
Developing a VR-Based Vascular Surgical Planning System

MRI Scans From Monash Medical Centre → Surface Extraction → Grid Generation → CFD Simulation → Comparison → Experiment

Surface Extraction → Grid Generation → CFD Simulation → Virtual Surgery → VR Visualization
A New Clinical Management System

Grid computing- & Web-based services

- Image reconstruction (CAD modeling)
- Advanced CFD simulation
- Database system (Data mining)
- Previous knowledge

KIR system

Doctors

Traditional medical service

- CT, MRI

Decisions
Progress Report I

Geometric Reconstruction and CAD Modelling
Example --- Human Nasal Cavity

CT data from Shanghai RuiJin Hospital
Example --- Human Upper Airway

CT data from Alfred Hospital
Example --- Human Carotid Artery

MRI data from Monash Medical Centre
Progress Report II

Modelling of Air/Particle Flow in Respiratory Systems
Simulation of Air/Particle Flow in Nose

Simulated flow field in human nasal cavity

Computational Mesh
Simulation of Air/Particle Flow in Airway
Experimental Validation

Experimental set-up

PIV spray image

Spray analysis

PIV flow measurement

Particle deposition comparison
Progress Report III

Modelling of Blood Flow in a Vascular System
Simulation of Carotid Artery Stenting
(Anatomical Segment from Monash Medical Centre)
Before and After Carotid Artery Stenting

Figure Comparison of the wall shear stress distribution in the stenosed (upper) and the re-constructed (lower) normal carotid bifurcation in a cardiac cycle
Before and After Carotid Artery Stenting

Figure: Comparison of the streamline of the blood flow in the stenosed (upper) and the reconstructed (lower) normal carotid bifurcation within a cardiac cycle
Progress Report IV

Development of a Web-Based Interface and Recommendation System
Interface Development

- Can be used by Doctors, CFD engineers, Teachers, Students.
- User-Friendly.
- Easy to search information about diseases, diagnostic information, education on the knowledge database.
- Development tools: Java script (free), MySQL (free)
Initial Information about a Patient

Initial Diagnosis Information

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<tr>
<th>Date</th>
<th>12-Aug-1990</th>
<th>22-June-1999</th>
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<tr>
<td>Blood Pressure</td>
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<td>Pulse</td>
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Initial Report

The MRI and CT pictures show that the patient’s airways...

The detection analysis...

\[ v = 5.5 \text{ m/s} \]
\[ \rho = 1.32 \times 10^5 \text{ kg/m}^3 \]
\[ \beta = 3500 \]
CFD Modelling and Simulation
CFD Analysis

CFD Simulation of Airflow Recirculation in Miotic Trachea

Graph showing data with x-axis labeled 'Distance from Model Exit' and y-axis labeled 'Flow Rate'.

Image of trachea model with labeled 'Miotic' and 'Normal'.

Knowledge-based Interpretation and Recommendation Diagnostic System 1.1.
Full Diagnostic Information
Upgrade the Web Database
Open Questions and Suggestions on Future Work?
### Project Budget

**Total ARC Funding:** $111,000

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<th>Salaries:</th>
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<tr>
<td>Dr Cheung (Full time)</td>
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<td>Dr Xu (Part time)</td>
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<tr>
<td>Mr Choi (Part time)</td>
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<tr>
<td>Mr Chu (Part time)</td>
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| Workshop:                    | $18,000|

**Total**                        | $118,000|