INTRODUCTION

• Human face is a complex surface, with different depth and texture.

• For medical purposes (such as craniofacial reconstruction), human faces need to be measured and modelled accurately.

Normal Faces

Abnormal Faces

INTRODUCTION

• A multidisciplinary research (2002-2005) is established between Universiti Teknologi Malaysia (UTM), Standards & Industrial Research Institute Malaysia (SIRIM), and Universiti Sains Malaysia (USM).

• Expertise: UTM (imaging of soft tissue, database), SIRIM (Rapid Prototyping, database), USM (imaging of hard tissue, craniofacial surgeons).

• Research funded: Ministry of Science Technology & Innovation (MOSTI) Malaysia.

• Research focus: The development of a surgical planning system for craniofacial reconstruction (for both the soft and hard tissues).

• Deliverables: imaging technology, craniofacial database, surgical planner.

• UTM: Real time image capturing system of craniofacial.
**UTM: Project 2**

- The focus: Development of real-time image capturing system (close range) & information system for craniofacial soft tissue.

**METHOD: IMAGING SYSTEM**

- **3D Modeling of Human Face**
  - On-going research (world wide)
  - Requires modern and advanced technology
  - Modeling of facial soft tissue and hard tissue (skull)
  - Imaging Techniques (soft tissue): Stereo photogrammetry, Coded Light Range Scanner, etc.
  - Imaging Techniques (hard tissue): CT Scan, MRI, etc.
  - Application: Craniofacial Planning Surgery, Forensic Study, etc.

**Objectives: UTM**

1. To develop a craniofacial data acquisition system for reconstructive surgery based on stereophotogrammetry and laser scanning technique.
2. To evaluate the reliability, accuracy and outlier detection of the technique based on advanced statistical deduction.
3. To develop and evaluate a new algorithm for image matching technique between stereophotogrammetry and laser scanning data for a complete 3D craniofacial soft tissue models.
4. To develop an efficient method for measurement of anthropometric landmarks.
In this presentation we report our experience using Vivid910 in modeling of human face for medical application (cranial surgical planning study).

The study comprises of six steps:

- **Data Acquisition Setup**
  - Two VIVID 910 3D digitizers
  - Object distance: 0.7 meter
  - Lens: Middle Lens

**Methodology**

- **Data Acquisition Setup**
  - Two VIVID 910 3D digitizers
  - Object distance: 0.7 meter
  - Lens: Middle Lens

**HARDWARE & SOFTWARE**

- Minolta Vivid 910 & PET software: 3D model
- Camera: photogrammetric data
- Control frame
- Rapidform software: process scanned data, 3D modeling
- Austral software: camera calibration
- DVP software: process photogrammetric data
- Computer

**3D Surface Laser Scanning System**

- Minolta Vivid 910
- Eyesafe laser scanner
- Exchangeable lenses
- Operating using laser triangulation light block method
- Capture mode: fine (2.5 sec) and fast (0.3 sec)
- Points closed: 30,000 (Fine), 77,000 (Fast)
- Precision in depth: ±0.008 mm
- Scanning accuracy: ±0.08 mm (Vivid 16 mm)
- Object distance: 0.6 m to 2.5 m

**3D Measuring of anthropometric landmarks**

- Running one after another
• Scanning of human face
  - Fine mode
  - on-line method (via cable)
  - Off-line method (using Scan Button and Compact Flash Memory Card)

• 3D Registration and Merging Process
  - Registered two scanned images automatically using RapidForm software
  - Method - initial image registration based on selected corresponding points (via Active Chosen Point Algorithm)
  - Merging process involves 3D merging of scanned images and texture

• 3D Editing and Modeling
  - The scanner is sensitive to black features on the face such as hair, eye brows, eye balls and beard
  - This factor will generate errors in the scanned images and represented as holes
  - RapidForm software is capable of finding holes and eliminating them by adding new points and polygon => the local curvature of the mesh is preserved.

• Measurement of anthropometric landmarks
  - The measurement of human face soft tissue data is important in planning craniofacial surgery
  - The measurement involved straight and curve distances, and an angle
  - 46 anthropometric points located on different part of the face
  - Conventional method:
    - Uses calipers (tape, sliding caliper, level and angle finder)
  - Disadvantages: contact measurement

• 3D smoothing process
  - Scanning errors (holes)
  - Correction of scanning errors
In RapidForm software, the distances and angles are computed automatically according to the points selected by the user.

Two methods of measurement:
1. Point to point mode
2. Automatic Measure Function

- Validation study
  - To validate the non-contact method in measurement of anthropometric landmarks
  - Number of points involved:
    - 7 points (ex, en, ch, sn, obi, obi, obi)
  - Differences:
    - Straight distances: ex, en, ch, sn
    - Curve distances: obi
  - Comparison with conventional method

<table>
<thead>
<tr>
<th>Points</th>
<th>Difference (mm)</th>
</tr>
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<tbody>
<tr>
<td>1 ~ 2</td>
<td>0.00 ± 0.06</td>
</tr>
<tr>
<td>6 ~ 7</td>
<td>-2.05 ± 0.00</td>
</tr>
<tr>
<td>10 ~ 11</td>
<td>0.99 ± 0.00</td>
</tr>
<tr>
<td>4 ~ 3</td>
<td>-2.86 ± 0.00</td>
</tr>
<tr>
<td>3 ~ 9</td>
<td>-2.05 ± 0.00</td>
</tr>
<tr>
<td>1 ~ 3</td>
<td>-1.74 ± 0.00</td>
</tr>
<tr>
<td>2 ~ 3</td>
<td>-1.08 ± 0.00</td>
</tr>
<tr>
<td>10 ~ 3</td>
<td>-0.90 ± 0.00</td>
</tr>
<tr>
<td>11 ~ 3</td>
<td>-1.03 ± 0.00</td>
</tr>
<tr>
<td>9 ~ 5</td>
<td>-1.10 ± 0.00</td>
</tr>
</tbody>
</table>

The project accuracy requirement was 0.7mm (from literature)

Table 1. Comparison of results

The difference between the conventional and the digital technique was less than 0.7mm. Therefore, the accuracy of the digital technique satisfy the project requirement.
**3D Matching between stereophotogrammetry and laser scanning method for development of complete 3D Model of Craniofacial Data**

- **Conclusion/imaging**
  - The use of laser scanning system in modeling human face was found to be excellent and effective.
  - **VIVID 910**:
    - **Advantage**: Fast 3D data collection
    - **Disadvantage**: Sensitive to black features
  - The scanning errors can be corrected and improved up to 70% closer to real object.

- **On-going Works on laser scanning**
  - Laser Scanner Synchronization (reduce scanning time)
  - Laser Scanner Calibration (evaluate the accuracy)
  - Precise 3D Registration Method (increase accuracy)
  - Texture Mapping (register photorealistic images on 3D data)

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**METHOD: INFORMATION SYSTEM**

- **Objectives**
  1. To develop 3D raster-based and vector-based data models
  2. To develop algorithms for the retrieval and manipulation of spatial information for craniofacial reconstruction
  3. To evaluate the reliability of the developed craniofacial spatial information system

**Outcome of System**

1. To view a patient stereo-craniofacial images, 3D craniofacial surface model and 3D hard tissue model.
2. To manipulate the data of (1) to obtain 3D vector information, anthropometric measurement and soft tissue data.
3. To view attribute information.
4. To obtain statistical information on postoperative development and quality information on the surgical operation.

**Related Works**

- Some projects in images medical database (PACS), Anthropometric Databases, Clinical Information System and GIS (Geographic Information Systems) database
- Research in 3D modeling, mesh data structure for elastic surface
- Research in 3D object database, similarity search and indexing system
- Research in Shape analysis
Design Issues

- Automation: Every function available to the user must require a simple, logical, and modular approach to 3D data processing, making it easy to implement.
- Ease of use: The application must incorporate a simple, clear user interface and must be accessible to non-expert users in order to facilitate a smooth transition between tasks.
- Reliability: The application must be capable of processing almost every dataset mentioned in the specification. In case of failure, it should provide feedback and inform the user of the nature and reason for the failure, suggesting possible actions in order to resolve an operation successfully.

Database Design

- At the analysis phase, UML class diagrams are used to create the conceptual schema, ensuring that UML is the standard language for object-oriented system design.
- The design phase is divided into two stages:
  - Specific design, in which the design for a specific product, for example, Craniofacial Tools, is developed. This includes the development of specific products.
  - General design, which is the design for a general purpose, for example, Craniofacial Tools, Glasses.
- The implementation phase includes the physical design tasks. These can be divided into processes detailed in the previous phase that are refined to improve the performance and storage space according to the specific needs of the application.
Overview of prototype system

Data set

- Data for information system: 3D soft & hard tissue models.
- 3D craniofacial skin surface scan using laser scanner (3D soft tissue model, UTM).
- Anthropometric landmark measurement with stereo-photogrammetry, UTM.
- Hard tissue landmark measurement from CT scan - SIRIM.
- Dental landmark measurement of the dental cast, UTM.

User Interface Design

- Uploading Tool: a ‘Loader’ program that copies scans, measurements and patient data into the database.
- Query Tool: Queries in system are structured along the lines of relational logic or navigation. Queries are executed by grams based on simple multiple hierarchical elements without knowing any low-level elements such as ‘join’ and ‘select’. 
- Reporting Tool: The reporting tool allows the user to navigate through a hierarchical system. In particular, from a high-level object (e.g., patient), the user can drill down to lower-level objects that comprise the higher-level similarly from a low-level object the investigator can drill up to higher-level objects.
- Analysis Tool: The analysis tool aggregates low-level data and provides summary information. In this way, the user can further open forms to observe lists and view their graphically on one form or request aggregate data in a group of patients.

Data Base Management System

- PostgreSQL is an open-source descendent of the original Berkeley (University of California) code. It supports SQL92 and SQL99 and offers many modern features: complex queries, foreign keys, triggers, view, transactional integrity, and multiversion concurrency control.
- Also, PostgreSQL can be extended by the user in many ways, for example by adding new data types, functions, operators, aggregate functions, index methods, and procedural languages.
- And because of the liberal license, PostgreSQL can be used, modified, and distributed by everyone free of charge for any purposes, be it private, commercial, or academic research.

Thin Client Application

- The application connects to the database via local area network (LAN) or private TCP/IP connections.
- Purposes:
  - Loading data from some data sources to database.
  - Query
  - Visualization
  - Editing, either textual or graphical data.
  -抗体配对，mRNA sequencing, full genome analysis, and whole genome sequencing.
- Tools for development:
  - Borland Delphi
  - GLScene (open-source), GLScene is an OpenGL-based 3D library for Delphi. Borland C++ Builder.
  - iOs/iP (open-source), iOs/iP is an Open Source project supporting application developers with toolset collection for high-quality native database access across different platforms.
Web-based Client Application

- Purposes:
  - Query
  - Visualization
  - Data distribution
- Tools for development:
  - PHP scripting language, PHP is a widely-used general-purpose scripting language that is especially suited for Web development and can be embedded into HTML.
  - Apache web server software

Class Objects Package

- There are four groups of class objects that support the database: they are 3D spatial, craniofacial anatomical data acquisition and clinical classes objects group. 3D Spatial group has own independency structure from others group and this take as a super group in global diagram. Classes in this group are 3D graphic/geometric primitive and there are some topological relations between them.

Clinical Classes

- There are four groups of clinical classes objects support the database.

Data Acquisition Classes

- There are four groups of data acquisition classes objects support the database.

3D Spatial Classes

- There are four groups of 3D spatial classes objects support the database.

Craniofacial Anatomical Classes

- There are four groups of craniofacial anatomical classes objects support the database.
CONCLUSIONS

- A multidisciplinary research is established between UTM, SIRIM & USM.
- Research focus: The development of a hybrid planning system for craniofacial reconstruction for both soft and hard tissues.
- The research (UTM) works on the development of a close range image capturing system and information system for craniofacial.
- The image capturing system combines the laser scanning and photogrammetric techniques for acquiring high-resolution 3D models of craniofacial soft tissues.
- The information system is used for managing and visualizing the craniofacial data.
- On-going multidisciplinary research works

The progress!

- Imaging system, calibration, 3D modeling, database design
THANK YOU!
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