3D skeletal representation of specialised seating data

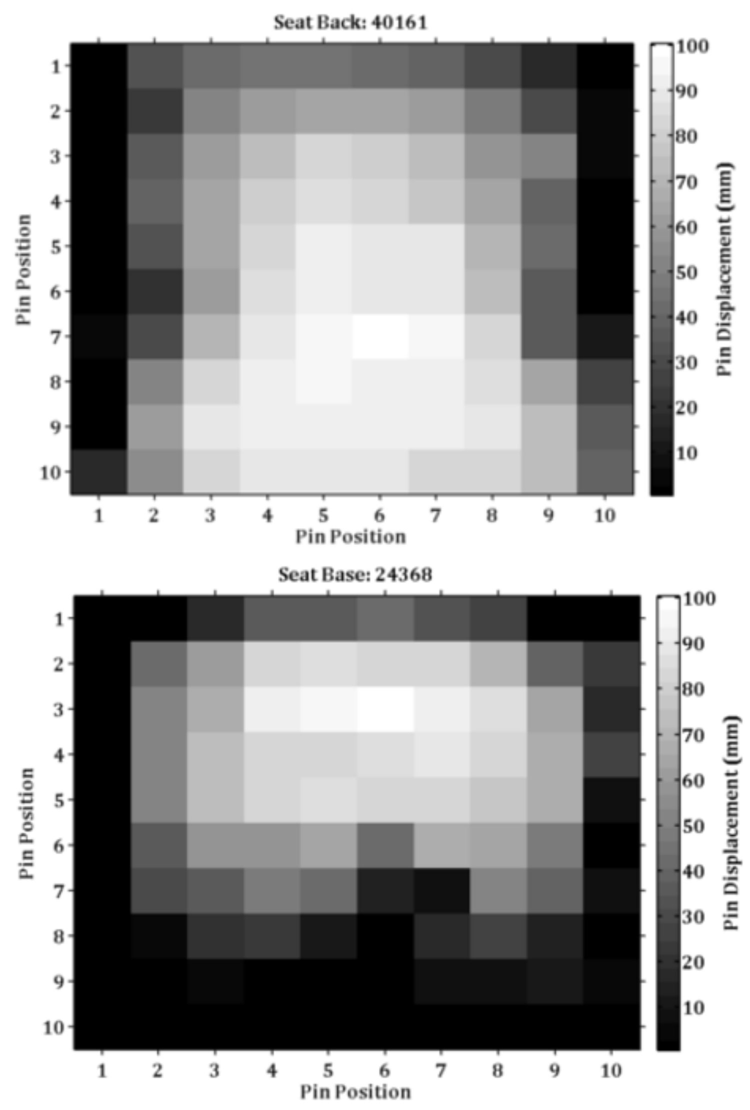
Summary

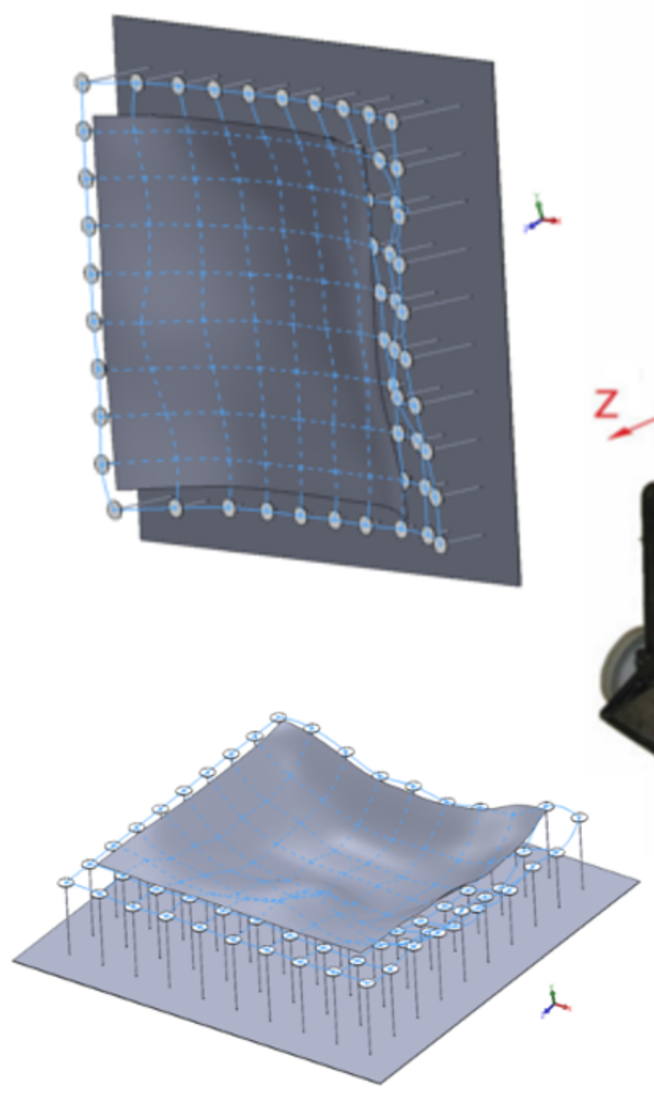
The body shape measurement is vital in determining the optimum design of custom contoured seating. Research commenced to produce an interactive 3D model of a human skeleton. Its purpose is to visualise the relationship between custom contoured seat shape and the underlying musculoskeletal deformities to aid clinicians in visualising and communicating a client's posture.

Background

Cardiff and Vale University Health Board's (UHB's) Rehabilitation Engineering Unit (REU) produce custom contoured seating systems for wheelchair users. Clients with severe musculoskeletal deformities require specialised seating to accommodate shape and evenly distribute pressure with a view to manage posture and improve function. The custom contoured seating systems are produced either by manipulating the seating material into an appropriate shape for a particular client's form (e.g. Vacuum casting Bag Technique) or by taking an impression of the client's 'shape' using body shape measurement systems such as Cardiff Body Match (CBM) system, scanned bag or Lynx and Matrix seating [1][2].

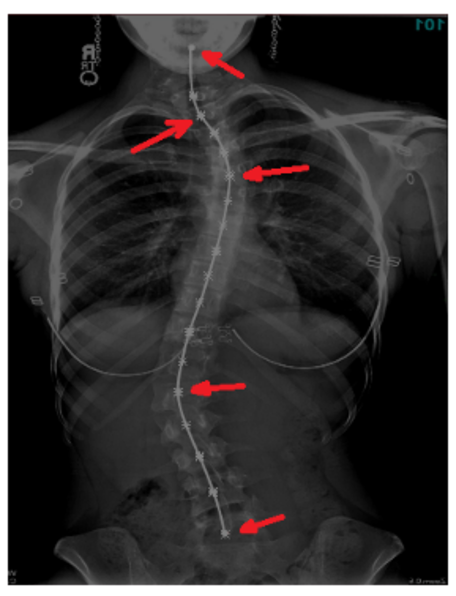
After the seat geometry has been carefully designed and optimised it is recoded on to a computer. It is difficult to infer and visualise client's posture from the recorded clinical data, especially in the case of clients with complex body shapes. Such visualisation would be very useful from the clinical perspective; it would assist clinicians in analysing and learning from past seating designs, monitoring the progression of client's musculoskeletal condition and promoting function and comfort of the individual. In order to assist clinical engineers in visualising complex seated postures from CBM measurements and to investigate the relationship between seat shape and musculoskeletal deformities, an interactive 3D computer model of a human skeleton has been developed.





Clinical Details & Preliminary Results

The Cardiff and Vale UHB's REU has a large database of hundreds of client shapes dating back to 1996 obtained via the CBM. These clients have a wide range of neurological, postural and musculoskeletal conditions (e.g. kyphosis and lordosis). An interactive 3D model is capable of representing the client's seated posture captured in the CBM system corresponding to different musculoskeletal conditions and postural characteristics. The prototype has two modes of operation automatic and manual. In automatic mode the CBM data is processed by the algorithm to produce the visual representation of the seated posture. In manual mode the model can be manipulated by entering clinical measurements taking during the seating assessment by the clinical engineer. Preliminary testing of the model has been completed and presented to Clinical Engineers who were very enthusiastic about the projects potential.



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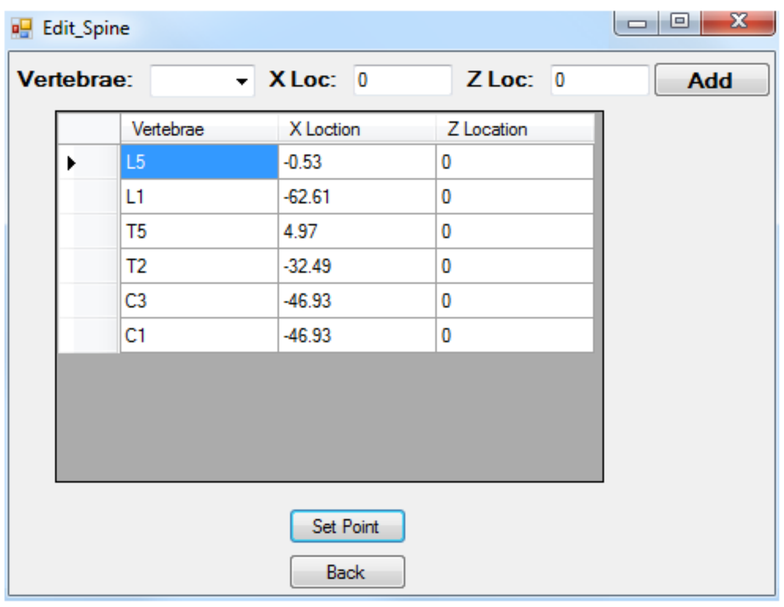
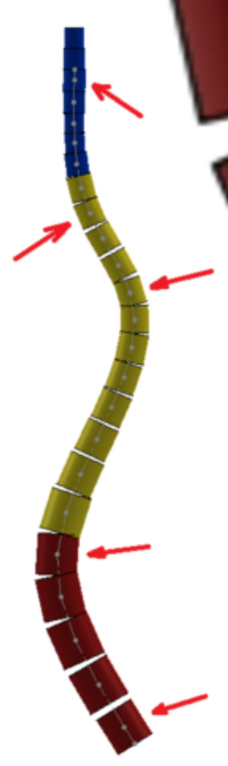


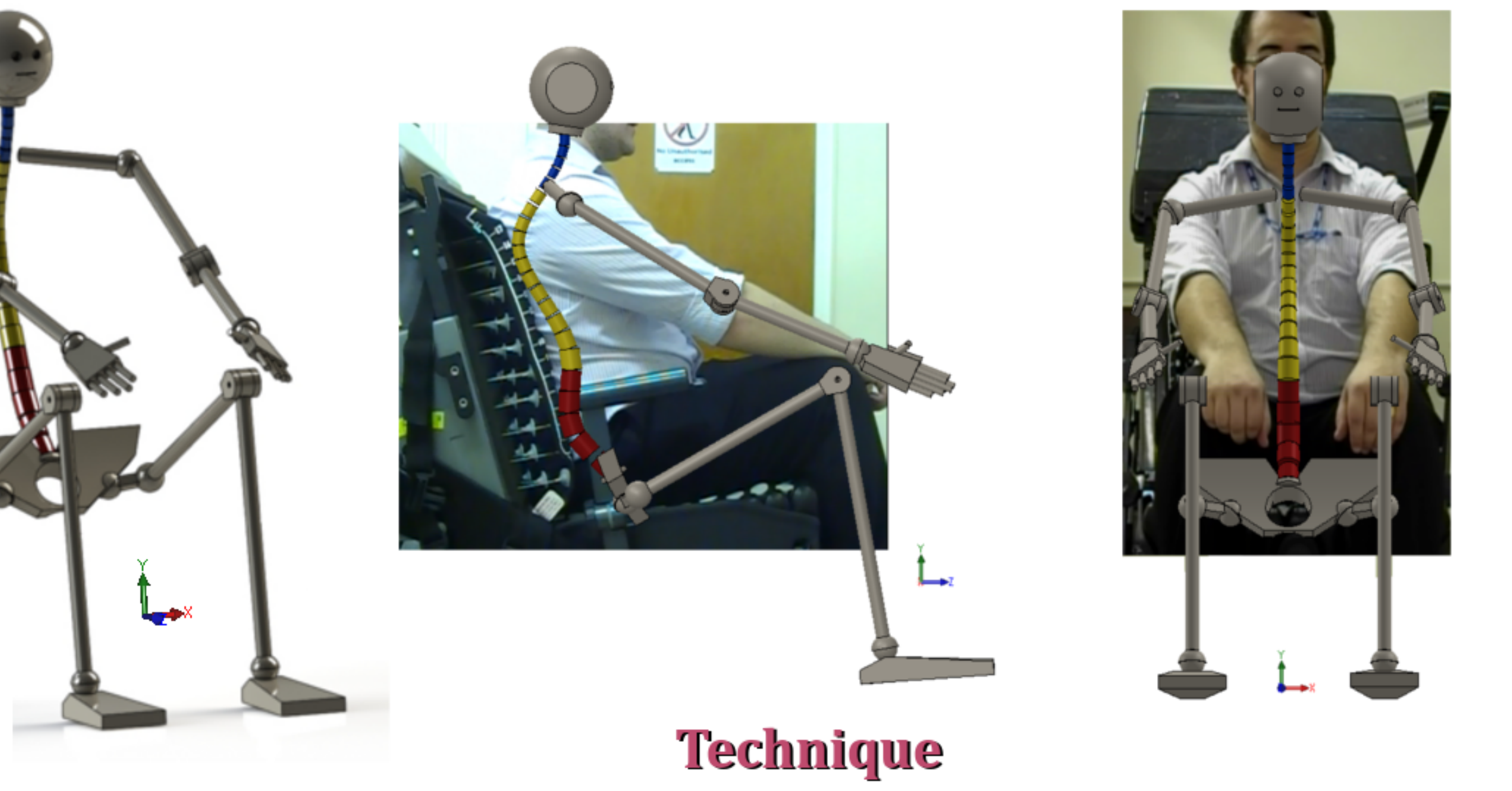


References

[1] Kulon, J., Partlow, A., Gibson, C., Wilson, I. and Wilcox, S. (2014). Rule-based algorithm for the classification of sitting postures in the sagittal plane from the Cardiff Body Match measurement system. Journal of medical engineering & technology, 38 (1), pp. 5--15.
[2] Partlow, A., Gibson, C., Kulon, J., Wilson, I. and Wilcox, S. (2012). Pelvis feature extraction and classification of Cardiff body match rig base measurements for input into a knowledge-based system. Journal of medical engineering & technology, 36 (8), pp. 399--406.
[3] Busscher, I., Ploegmakers, J., Verkerke, G. and Veldhuizen, A. (2010). Comparative anatomical dimensions of the complete human and porcine spine. European Spine Journal, 19 (7), pp.1104--1114.
[4] University of Utah Hospital, "X-ray of U.S. girl, age 16 years 8 months, with pre-operative scoliosis. Front, standing, clothed.," ed, 2009

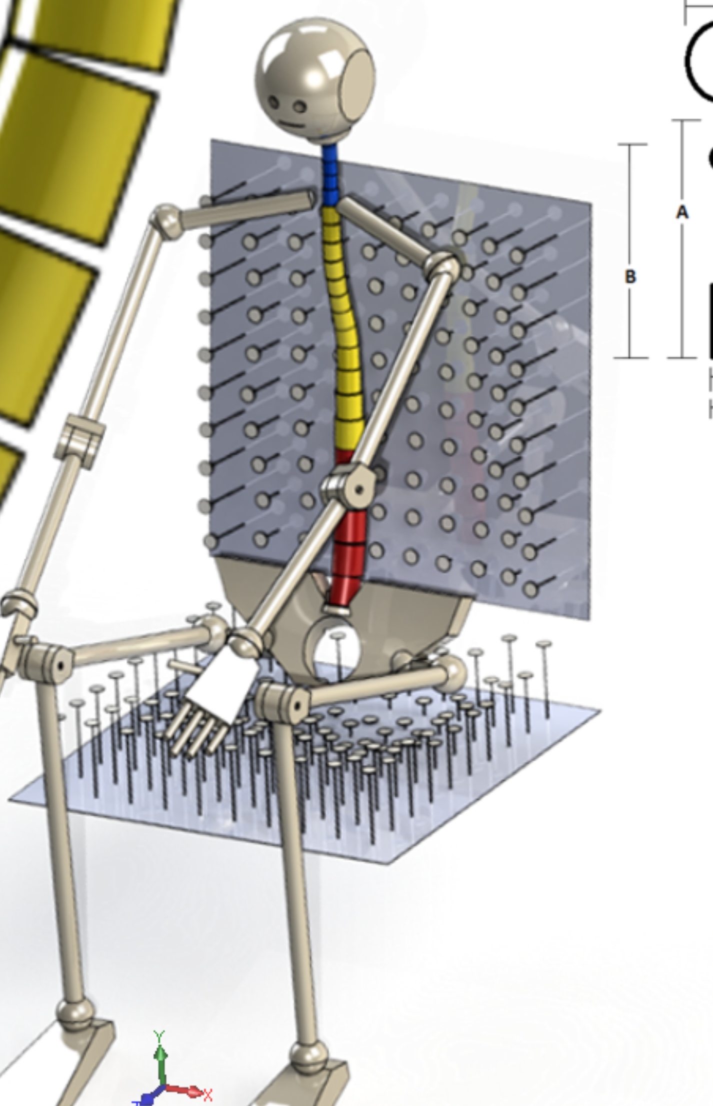
Aim & Objectives

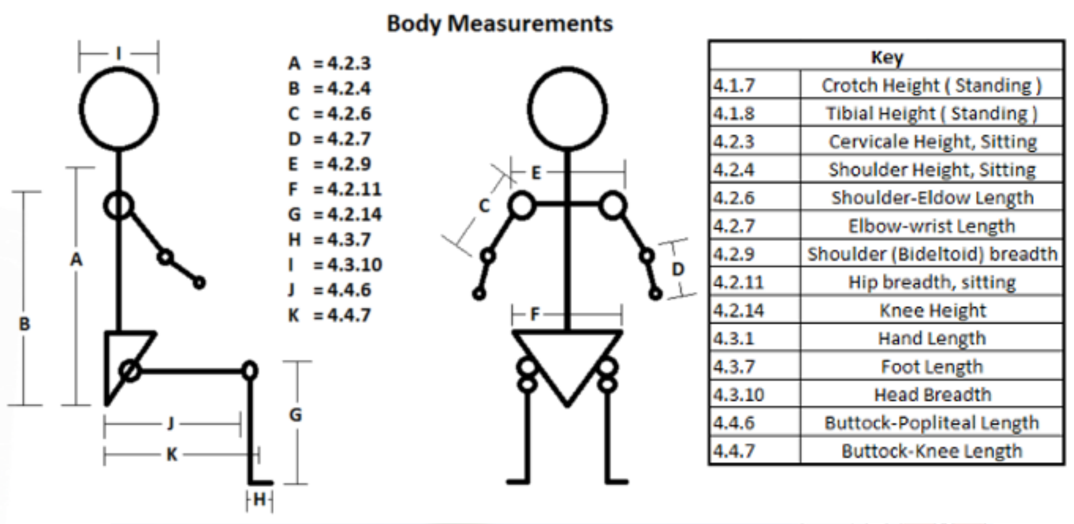
To produce an interactive 3D computer model of a human skeleton that can be used by clinicians to record and communicate a patient's particular posture. The model will be used in conjunction with the CBM system or independently, to visualise the relationship between custom contoured seat shape and musculoskeletal deformities. The software tool produced will interface the model with the CBM system and enable visualization of the clinical data.

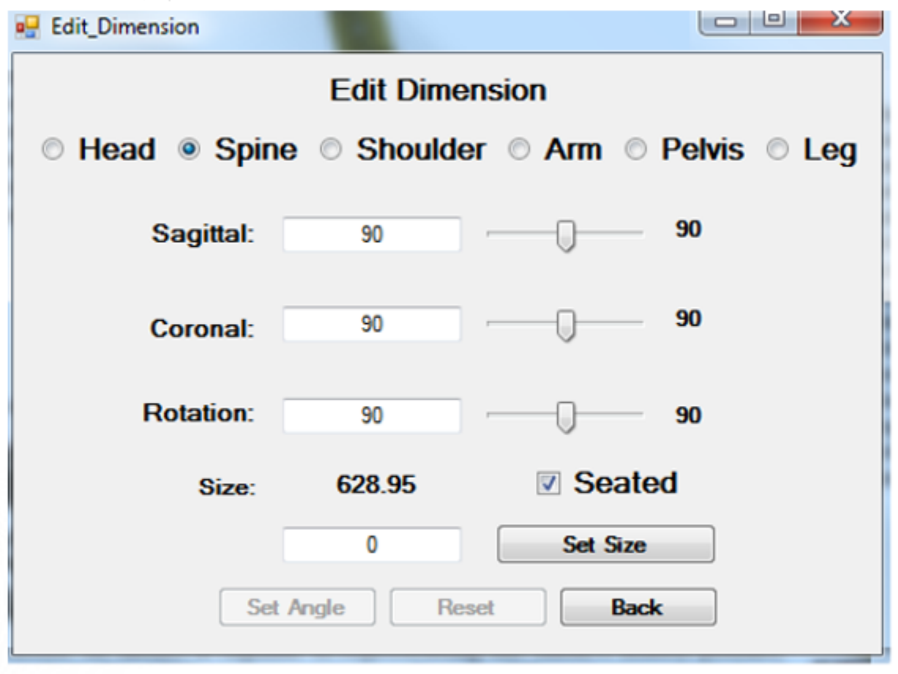


Technique

The interactive 3D model was developed in C# using a 3D CAD (SolidWorks®) package's API®. The model supports movement and deformation of body parts both in the coronal and sagittal planes. The dimensions and description of anthropometric measurements used in the model were based on ISO-7250-1:2008 standard. The human body was partitioned into several parts (head, arms, legs and spine). The spine contains 24 vertebrae representing the cervical, thoracic and lumbar regions. Each vertebrae dimension is based on a percentage from the spine length, each vertebrae being adjustable to different angles [3]. To move the model into specific positions, Denavit-Hartenberg inverse kinematics was used to correctly place body parts. For example, placing a foot at a certain x-, y- and z-location requires the algorithm to calculate the transformation matrices in order to determine the position and orientation of hip and knee angles along the hierarchy.







Discussion

In order to test the validity of the 3D model different postures were recreated in a series of control experiments. The known positions were captured using CBM system and recorded photographically. The control data include positions such as: normal sitting with minimal pelvic obliquity and a straight spine; subject leaning forward simulating different degrees of posterior displacement of the thorax relative to the pelvis; subject leaning to the left and right with slight torsion of the trunk, with as little pelvic obliquity as possible but displacing the shoulders laterally thus creating lateral spinal curvature.

Each time the control postures were captured in the CBM system the anthropometric measurements were also recorded, including pelvic orientation and the position of the anatomical landmarks.

The shape information from the CBM system in the form of back and seat impression together with the anthropometric data were subsequently processed by the bespoke feature extraction algorithm and input into the model. The preliminary findings from the control measurements showed that it is possible to visualise client postures through the 3D model. The user can separately manipulate the model to simulate different postural conditions and analyse the relationship between the seat shape from the CBM and its 3D anatomical representation.

The model is very useful from the clinical perspective; it will assist clinicians in analysing and learning from past seating designs, monitoring the progression of client's musculoskeletal condition. The model conveys the posture of the patient to other clinicians; thereby inform their clinical judgements on the effectiveness and safety of a range of interventions or indeed of no intervention. The next stage in development will be to obtain ethical approval for analysis with actual patient data.

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