Approximating the Position of the Ischial Tuberocities in CBM Measurements using Physics Simulation

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Abstract

Cardiff and Vale University Health Board's (UHB's) Rehabilitation Engineering Unit (REU) perform clinical assessments on clients with neurological, musculoskeletal and/or other conditions that result in limited movement, complex body shapes and poor posture. Some data collected at a clinical assessment is subjective and is susceptible to inter-observer errors. Using Cardiff and Vale UHB's REU's Cardiff Body Match (CBM) shape sensor it is possible to capture the shape of a client's body. The shape data captured using the CBM shape sensor can be analysed and anthropometric measurements can be extracted from the measurements [3] [4].

The position of the ischial tuberocities when in a seated position can be used to determine the orientation of the pelvis. Recording this information can inform a clinical engineer as to what shape a custom contoured seat should be or used to monitor the progression of musculoskeletal conditions relating to the pelvis. An algorithm has been developed to automatically locate the position of the ischial tuberocities using physics simulation.

A previous algorithm that was designed to extract pelvis features from CBM measurements performed poorly when a CBM measurement contained a pelvis that was not parallel to the front of the CBM shape sensor [3]. A new approach was tested using physics simulation to locate the most significant clusters which would contain the position of the ischial tuberocities. The position of the ischial tuberocities can be used to calculate the orientation of the pelvis and estimate the position of the sacral region of the spine.

The algorithm was developed in C++ and using rigid body physics calculates the path of a rolling sphere. The simulation places spheres at uniform and random intervals on a 3d surface which has been constructed using CBM measurement data. The resting points of the spheres are located and through cluster analysis the two most significant clusters are denoted as the position of the ischial tuberocities. The 3d positions of the centroids of the two most significant clusters are used as the estimated positions of the ischial tuberocities.

The outputs from the algorithm can be used to monitor the progression of clients' musculoskeletal conditions over time and inform clinical engineers as to the position of a client seated in the CBM shape sensor. Further testing of the algorithm is planned through a clinical trial whose participants will be clients of Cardiff and Vale UHB's REU.

The algorithm was tested by capturing measurements in the CBM shape sensor of people with low complexity musculoskeletal conditions or no musculoskeletal conditions. The positions of the ischial tuberocities at the time the CBM measurement was captured and were recorded. The proximity of the ischial tuberocities output by the algorithm were compared to those captured in the CBM shape sensor and are presented in this paper.

The results of the testing show that the algorithm is able to correctly identify the locations of the ischial tuberocities. This facilitates the recording of the pelvis' orientation to a high degree of accuracy and repeatability. The algorithm can be used to objectively measure the position of the ischial tuberocities; eliminating the inter-observer errors which can be associated with different clinicians performing the same measurement. When a seating assessment/review is performed the orientation of the pelvis is recorded. If the same client is then measured after a period of time has elapsed it is possible to quantify the effect that the clients care has had on their pelvis' orientation and determine whether the care has resulted in improved or worsened posture.

The positions of the ischial tuberocities and the orientation of the pelvis can be used as features for input into a Knowledge Based Engineering System. A system is being developed to aid clinical engineers in the manufacture of custom contoured seats for clients with severe neurological and musculoskeletal conditions that result in poor posture. The custom contoured seats will promote improved function and comfort levels and often provide therapeutic benefits such as improving the client's posture.

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Purpose and Significance

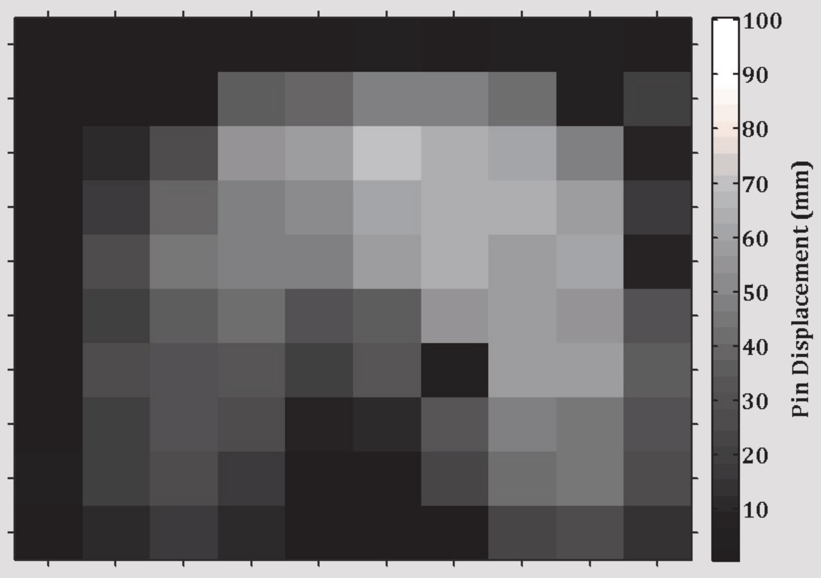
CBM shape sensor

The purpose of this research is to develop an algorithm that is able to approximate the position of the ITs; bony prominences that transfer the weight of the upper body to the sitting surface when in a seated position.

The simulation can be repeated with different starting points and/or different sized spheres to achieve a more accurate approximation of the position of the ischial tuberocities, and uses the assumption that the ITs are usually located at the areas of most displacement/pressure [1][2].

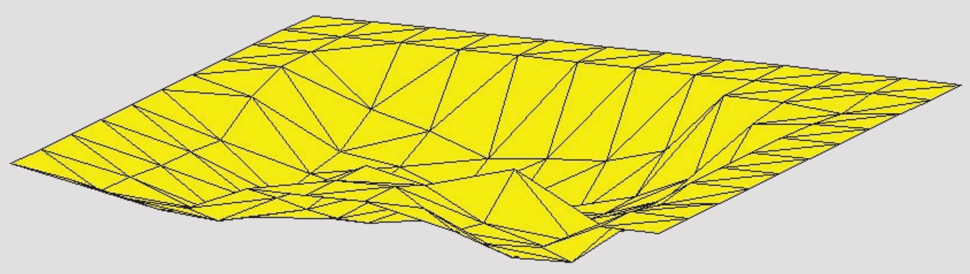
Locating the ITs in CBM measurements will allow a clinical engineer to objectively record the orientation of the pelvis. This will eliminate inter-observer error during clinical assessment of the pelvis which enables reliable monitoring of a client's conditions over time. In-turn, this will facilitate the research and development of a system by which the progression of a client's conditions can be monitored over time to assess whether the care being received by the client is effective or requires review.

Back



Front

A CBM seat-base measurement visualised as a displacement map



Triangle mesh, generated from the CBM measurement above

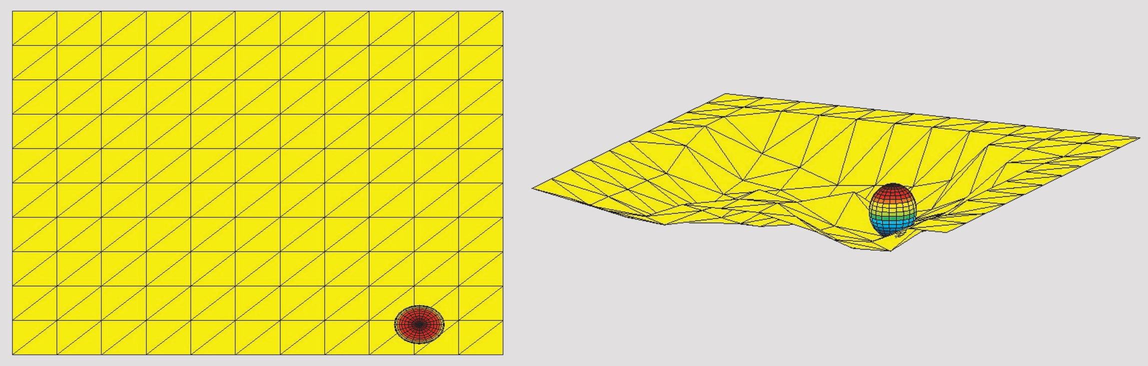
Method

The technique was developed in C++ and simulates the path of a rolling sphere on a 3d mesh which has been computed from the contours of a CBM measurement.

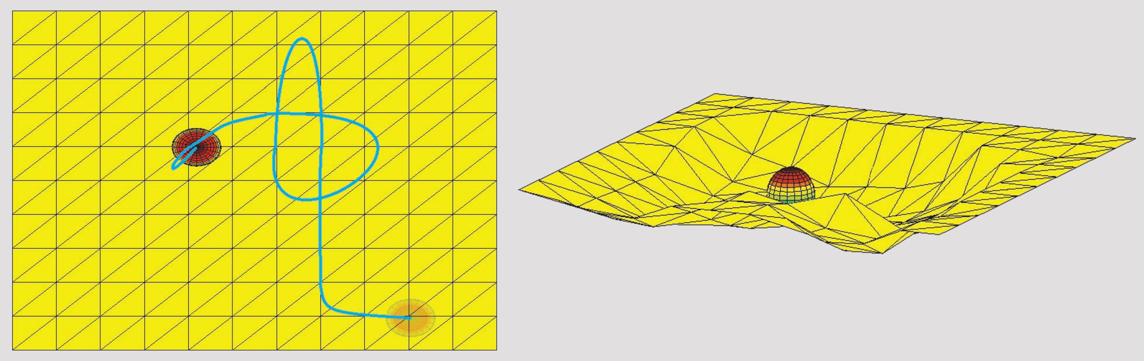
First the 3d mesh is calculated using the displacements of the pins from a CBM measurement. This produces a 3-dimensional triangle mesh that can be used for the physics simulation.

Secondly, a sphere of predefined size and mass is placed on the mesh. The motion of the sphere rolling around the surface is then simulated and the resting position is recorded. This can be repeated any number of times to increase the cluster densities.

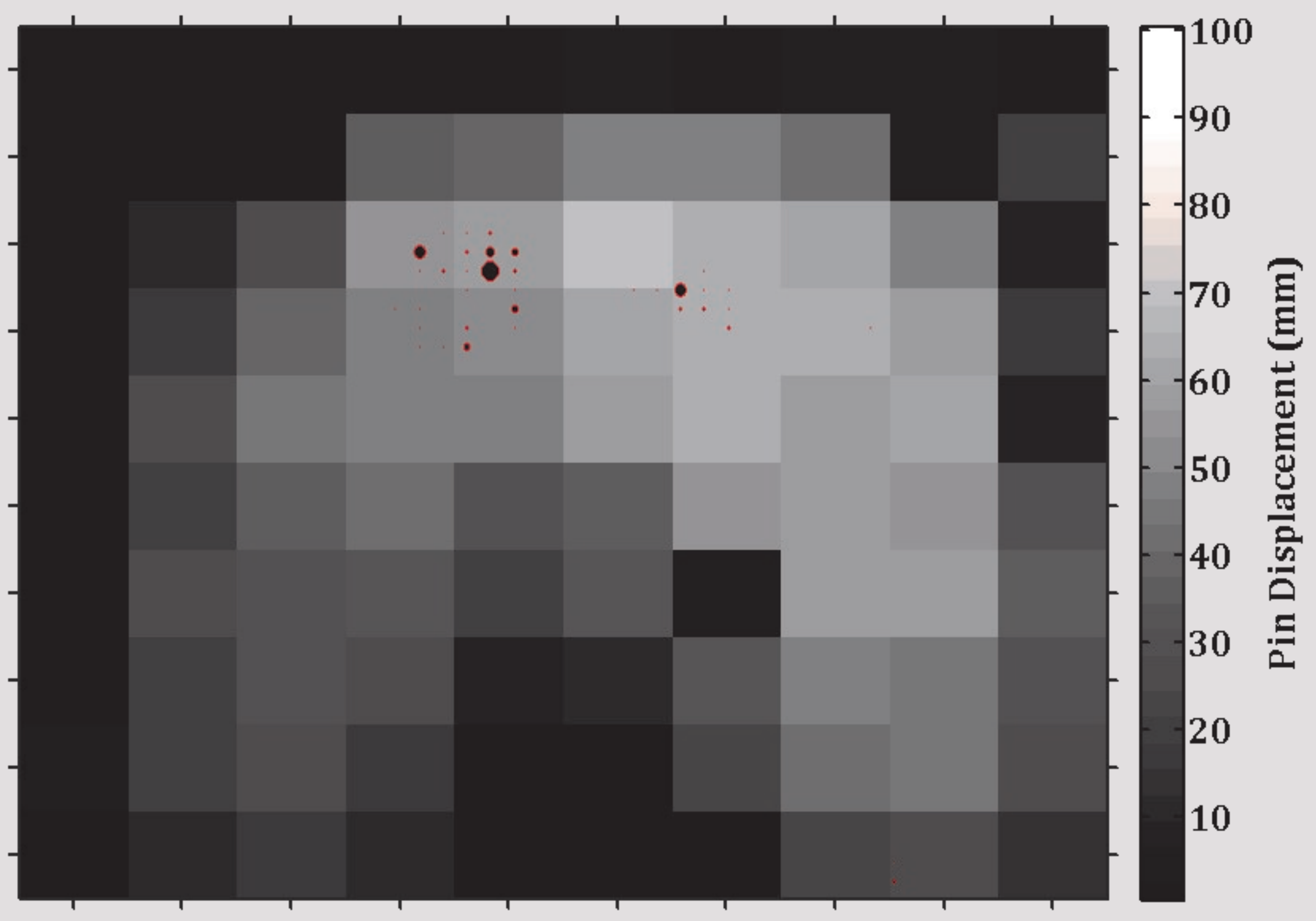
Finally, cluster analysis is applied to the resting positions of the spheres to identify the two most significant clusters. The two most significant clusters' centroids are calculated and these are denoted as the approximate location of the ITs.



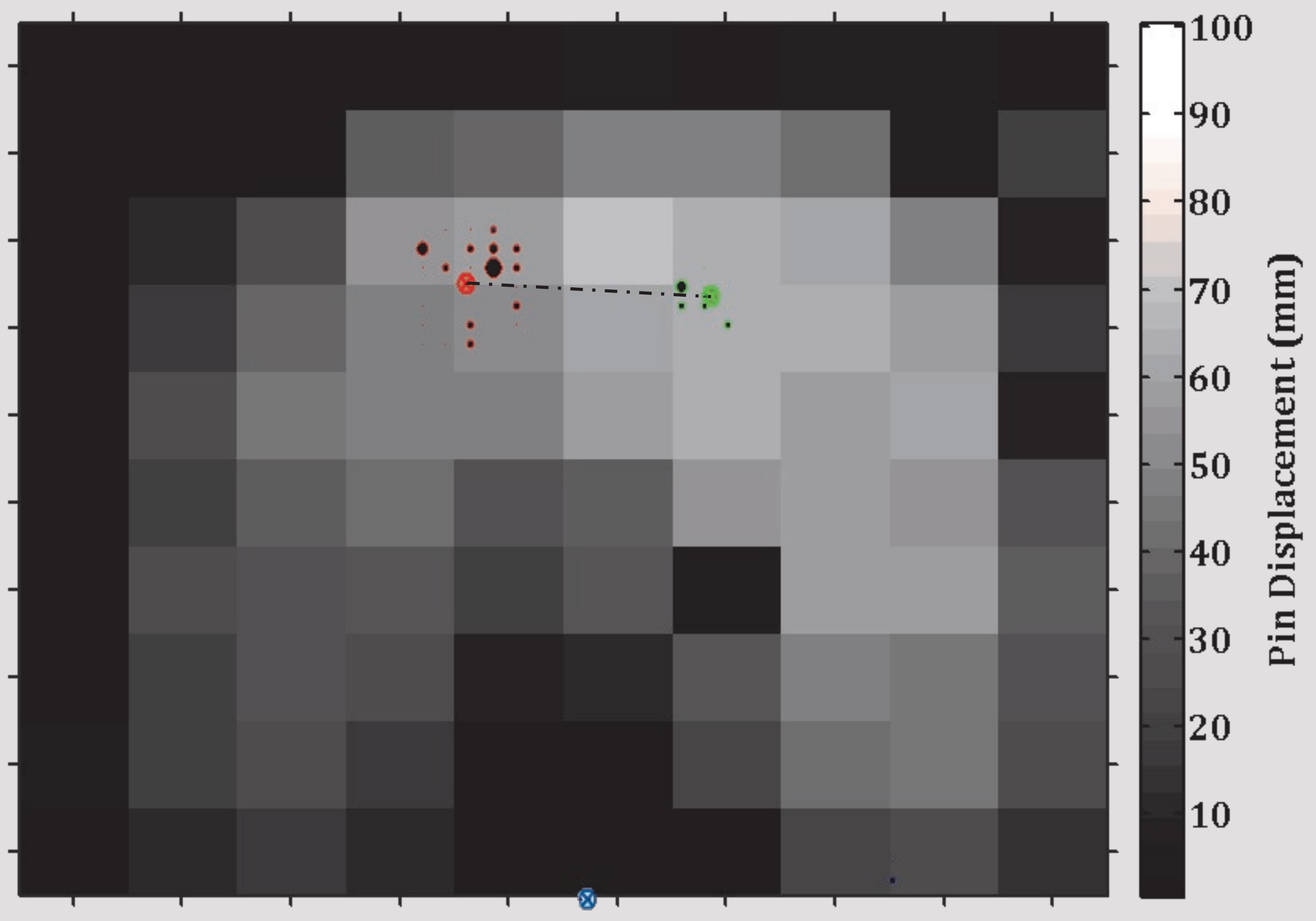
Starting position of a single rolling sphere



Final resting position and path taken



Resting positions of spheres in a CBM seat-base measurement after 100 iterations, two significant clusters have emerged. Larger circles denote a higher number of spheres resting at that location



Centroids of the two most significant clusters connected with a dashed line

Conclusion

This technique facilitates the recording of a client's pelvic orientation of their 'habitual' posture when seated in the CBM shape sensor. This will enable clinical engineers to monitor the degree of pelvic obliquity and rotation over time. The technique also removes the subjective component from monitoring a client's pelvic orientation that is associated with clinicians measuring a client on a plinth.

This technique produces an output that are the coordinates of the ITs which can be used to calculate the pelvis' orientation but also can be used as an input into other systems such as the system described in [5].

References

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