A pilot study: 3D stereo photogrammetric image superimposition on to 3D CT scan images – the future of orthognathic surgery.

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INTRODUCTION

A 3D image of skeletal hard tissue can be obtained using computerised tomography (CT) or Magnetic Resonance Imaging (MRI).
The most promising method of soft tissue capture at present is stereophotogrammetry (C3D image based capture system)[1].

AIMS

The aims of this study were,

- to develop a process which allowed the registration of the 3D geometry of the soft tissue / air boundary (acquired by photogrammetry) with a 3D image of the underlying skeletal hard tissue generated by a CT scanner, and
- to assess the accuracy of the superimposition methods.

MATERIALS & METHODS

DATA ACQUISITION

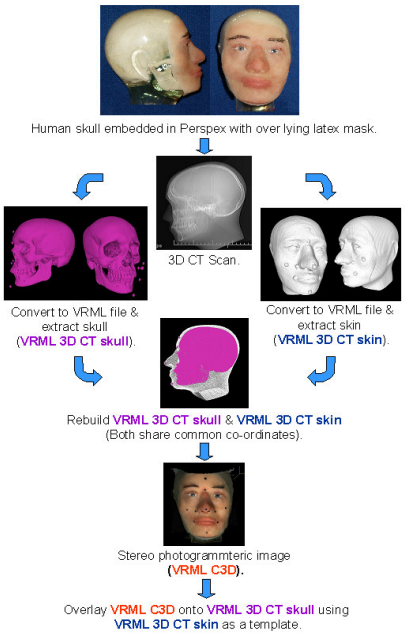


IMAGE REGISTRATION

1. Procrustes superimposition using the set of 10 artificial landmarks.
Identification of ten artificial landmarks on both the VRML C3D image and the VRML 3D CT skin image, followed by superimposition using Procrustes registration.

2. Procrustes superimposition using anatomical landmarks.
Ten anatomical landmarks were identified (corners of the eyes, nostrils, mouth, forehead and chin point) on both the VRML C3D image and the VRML 3D CT skin image. Registration was performed using Procrustes registration.

3. Procrustes superimposition using anatomical landmarks and then registration completion by HICP.
A partial registration was performed using ten anatomical landmarks and Procrustes registration. A region around the nose was chosen and an automatic HICP registration performed[2] (Figure 1).

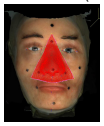
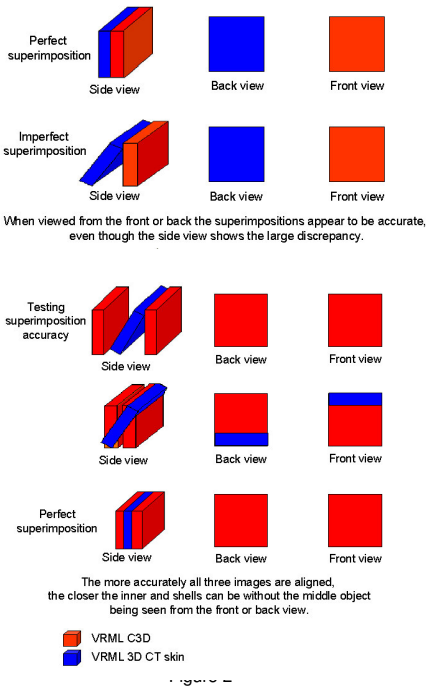


Figure 1

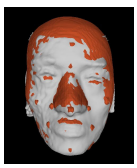
ASSESSMENT OF ACCURACY

The accuracy of registration of the C3D image and the VRML 3D CT skin image over one another was evaluated by comparing the distance between the two surfaces. Ideally the two skin surfaces should overlie one another with no space between them. The accuracy of superimposition was assessed by replicating the C3D image from the registered image and using this to create an inner and outer shell i.e. two C3D images either side of the VRML 3D CT skin image. As the distance between the inner and outer shells was reduced an optimum point was reached whereby the registered image was neither visible from the front or the back (Figure 2)

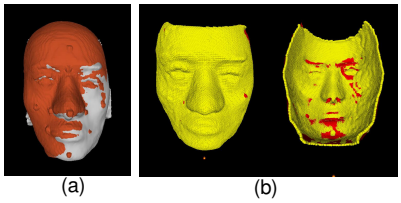


The distance between the inner and outer C3D images was set at 2 mm, 1.5 mm, 1.25 mm and 1 mm. The two C3D images and the registered image seen from the front and back of the head were then displayed.

RESULTS



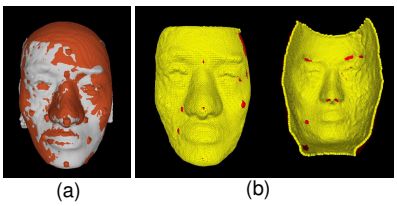
Procrustes registration based on 10 artificial landmarks.



(a) (b)

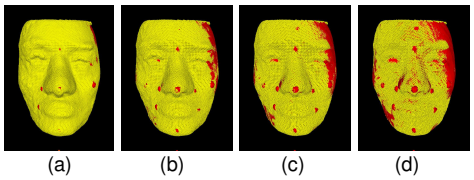
(a). Procrustes registration based on anatomical landmarks

(b). Errors, in red, at 2mm separation between the registered images

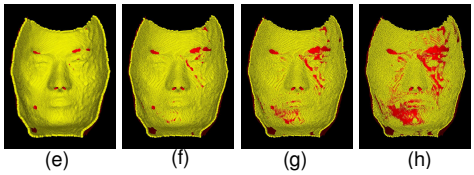


(a) (b)

(a). Procrustes registration based on anatomical landmarks and HICP.
(b). Errors, in red, at 2mm separation between the registered images.



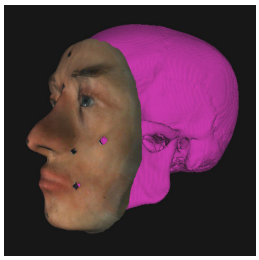
(a) (b) (c) (d)



(e) (f) (g) (h)

3D models showing the errors, in red, at different distances of separation between the registered image and its parallel copy using Procrustes analysis and HICP for superimposition at,
(a), (e) 2 mm separation,
(b), (f) 1.5 mm separation,
(c), (g) 1.25 mm separation,
(d), (h) 1 mm separation.

FINAL SUPERIMPOSITION



Superimposition of the C3D stereophotographic image over 3D spiral CT scan image of the skull (VRML 3D CT skull).

CONCLUSIONS

- The superimposition of two 3-dimensional images obtained by two different modalities, stereo photogrammetry and a 3D spiral CT scan is possible.
- Registration accuracy of between 1.25 and 1.5 mm is achievable using Procrustes superimposition based on anatomical landmarks followed by registration completion by HICP.

REFERENCES

1. Ayoub AF, Siebert JP, Wray D, Moos KF. A vision-based three dimensional capture system for maxillofacial assessment and surgical planning. Br J Oral Maxillofacial Surg 1998; 36: 353-357.

2. Haralick RM., Joo H, Lee C, Zhuang X, Vaidya V, Kim M. Pose estimation from corresponding point data. IEEE Transactions on Systems, Man and Cybernetics. 1989; 19: 1426-1446.