Challenges with Life Surface Imaging

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DOI: 10.15221/18.064 http://dx.doi.org/10.15221/18.064

Abstract

Stereo photogrammetry has a clear role in clinical research, treatment planning and effectiveness assessment within the domain of medicine and dentistry. Recently more computational automatic 3D facial analysis methodology has emerged to increase the efficiency for data processing, this is particularly beneficial for clinical trials as if often request large data size. The quality of automation is depend on two aspects, the algorithm/program need to be robust enough to cope the variance from the individuals and scenarios, and the raw data capturing need to be accurate. To the latter aspect, despite practical guide has published on top of the manufacturer suggestions, a detailed understanding of the error causation are requested, to eliminate further to the uncertainty from the process of facial surface capturing. This paper presents challenges of life surface capturing due to its dynamic nature and proposed a possible and practical solution.

Keywords: 3D facial imaging, 3D facial scan, 3D facial measurements, life surface capturing, life surface dynamics

Introduction

Stereo photogrammetry has a clear role in treatment decision and planning [1]; It is commonly used in maxillofacial surgery treatment plan (T.J Maal et al 2011, Van Loon et al 2010); 3D facial asymmetry analysis provided the soft tissue deficit distribution and magnitude prior to the facial reconstructive operation to head and neck cancer patients (Kansy K et al 2018); facilitating treatment plan for Cleft patients (Zhang C et al 2018); management decision based on quantitative facial image analysis of patients with facial dysmorphophobia and hypertrophic muscles of mastication (LHH Cheng et al, 2011, L Collier et al 2009). Moreover, Craniofacial researchers make heavy use of the facial morphometric analyses (Metzler P et al, 2012, Toma AM et al, 2008, Kau CH et al 2007, Aldridge K et al 2005, Moss JP et al 2003, Altobelli DE et al 1993), and Genome association to the facial morphology has its increased attention in recent years (Kraemer M, et al 2018; Shaffer JR et al, 2016; Boehringer S et al, 2011).

Accuracy and reproducibility of 3D facial scanning systems were investigated by number of researchers (Lubbers HT et al 2010, Heike CL et al 2009, Toma AM et al 2009, Weinberg SM et al 2006, Aldridge et al, 2005). 3dMDface is one of the favourable 3D facial surface capturing device, due to its fast speed of capturing (0.25s) and the linear accuracy of 0.2mm.

A practical guide to facial image acquisition was published (Heike CL, 2010), that reviewed the common issues affect the accuracy of the data capturing and solutions to achieve optimal performance on top of the manufacturer's recommendation in practice. Despite the elimination was made in possible movements from body and face, policy of avoiding the artefacts as well as the environmental control. The dynamics of the life surface are inevitable and it need to be aware and considered properly for facial image analysis and data interpretation for an objective quantitative information.

The dynamics of life facial surface

A temporal facial surface capturing device 3dMDface.t system was used to capture a sequence of 3D facial surfaces at the rate of 6 frames per second at high resolution for 20 seconds, this permit the selection of appropriate or specified posture or moment of facial image; The sittings of the device was completely satisfied the requirements from the manufacturer; an adjustable chair for patient to sit, which can be moved freely to justify the distance from patient to the camera units and height according to the size of the face and height of the body from each individuals in relation to the device; the same set of instructions were given to every individuals for a neutral body and head posture after the justification of the height and distance to be within the depth of view to the two modular camera units; a back teeth occlusion lightly applied.

Subjects were NHS patients who participated the clinical trial (COCR00013) or NHS patients referred by maxillofacial consultant; during the facial image analysis process, four cases were identified as examples for the presentation of the dynamics of life surface that are inevitably adhered (1) breathing, (2) emotion, (3) occlusion and (4) facial hair.

Four adhered causation for uncertainty

(1) The inhaling and exhaling motion brought depth difference of 0.07mm at most facial areas and 1.34mm at the left and right alar as well as upper and lower lips (Fig.1 Left), while the images between the breaths for 3 seconds the depth difference can be reduced to 0.01mm over the whole face accept eye lids (Fig.1 Right).

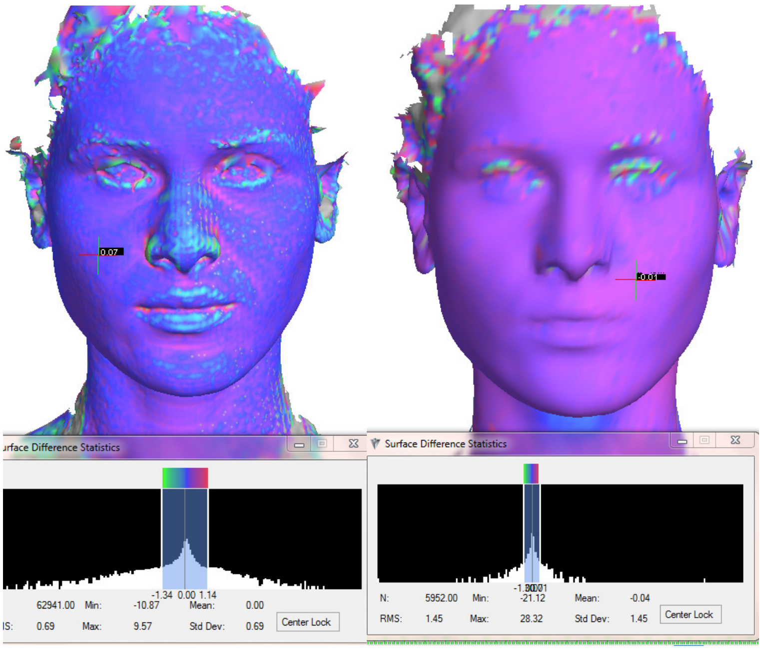

Fig.1 Demonstrates the effect of breathing on the left image with 0.07 mm at the cheek and 1.34mm at the alar; When between the breathe the depth difference reduced to 0.01mm

(2) To give the same instructions to one subject at the same visit and take two sequences of facial scans, select one image from each sequence, a slight emotional differences were captured and expressed by a concentrated differences around two corners of the mouth, to be at the negative difference of 1.48mm, and penetrated to the cheek at the positive difference of 0.32mm (Fig.2).

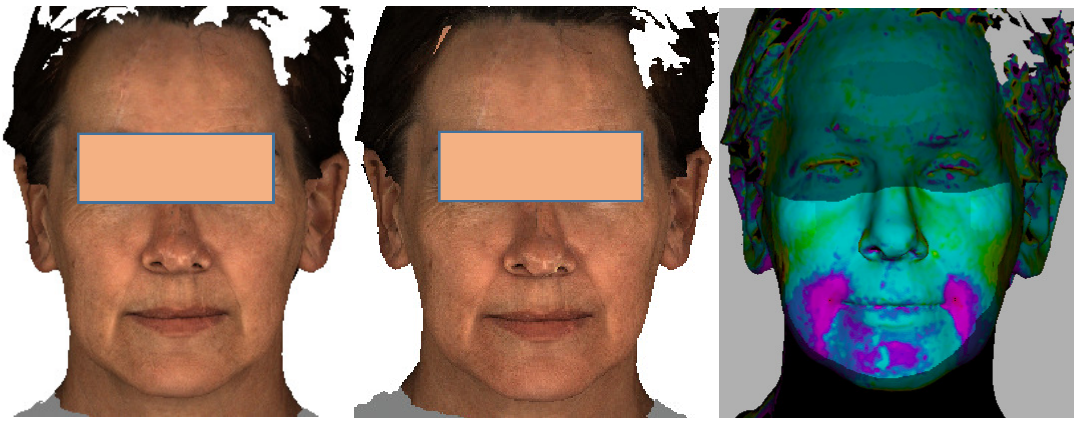

Fig.2 Demonstrates the effect of emotion changes of 0.32mm at cheek and 1.48 mm at corner of the mouth

(3) Despite an instruction of light occlusion at back teeth was give, the facial difference purely caused by the mandibular position was found from two images of one captured sequence, to be as large as 1.04mm at middle of the chin and 0.02mm at cheek where showed no effect (Fig 3).

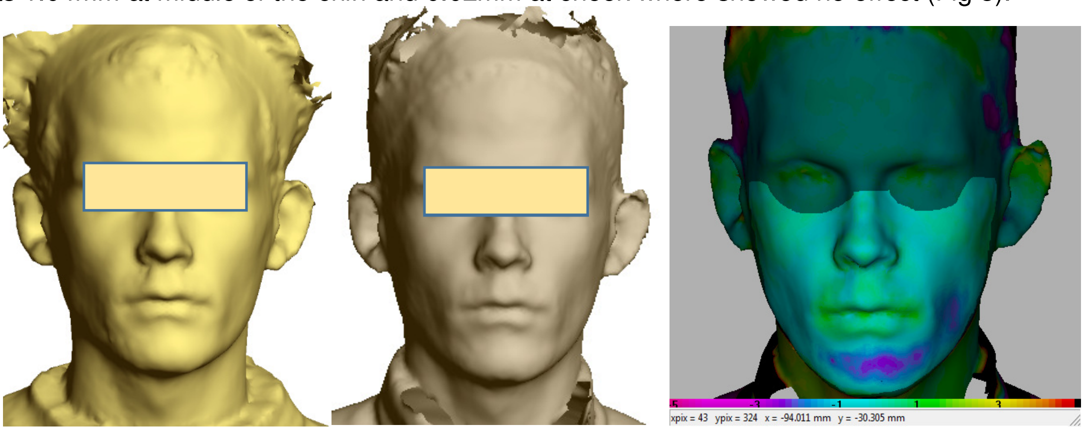

Fig.3 Demonstrates the effect of mandible positioning at 1.04 mm depth difference in the middle of chin while the cheek area has no effect with difference of only 0.02 mm

(4) Facial hair is an obvious factor which can be easily controlled theoretically, however it is still appeared to be one of the often occurred error sources, can be as large as 1.41mm Fig.4.

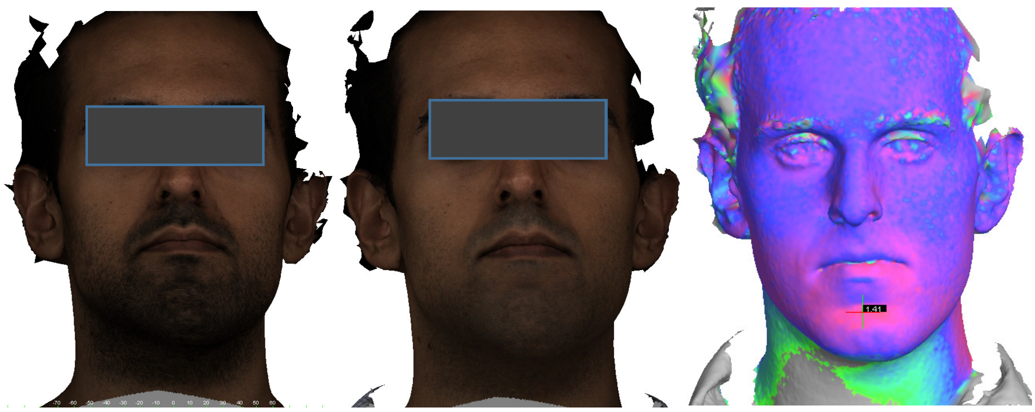

Fig.4 Demonstrates the effect of facial hair at 1.41mm depth difference

One approach to the solution

Four cases demonstrated four random possible error sources when facial image was captured, due to its uncontrollable nature, particularly to the clinical trial that requests multiple consecutive facial image captures at difference health and emotional conditions, different days and times. To eliminate the random errors as shown above, image averaging technique can be one effective approach. Particularly, if the averaging process can be based on an automatic marking process.

The facial averaging process involved with removal of translation, rotation and size differences, and the method of averaging is made along the surface norm. The initial step is based upon a set of critical markers on every 3D facial images [24].

The facial landmarks may be used to warp the template mesh to each individual face using a method known as the thin plate spline warp, to achieve close alignment of the template mesh to the subject's face that matches exactly at the landmarks, and approximately elsewhere. The vertices of the template mesh are then projected onto the subject face by finding the closest point on the subject face to the given vertex. Finally, a smoothing procedure is applied to vertices of the template mesh to ensure an even distribution of vertices on the subject face, excluding those directly adjacent to a landmark and those on the boundary of the template mesh. The smoothing procedure consists of a Laplacian smoothing operation, followed by projection to the closest point on the subject face and repeated until the maximum change of combined smoothing plus projection operation is below a pre-defined threshold.

The manual annotation of landmarks is a known source of variance and it is labour intensive. Siang S et al [25] introduced an improved method for automatically detect landmarks on 3D human face data by three steps: First, geometric information was used to locate 17 prominent points. Then a deformable transformation between target mesh and data mesh determined 20 established landmarks and located them more accurately than with the geometric method alone. This method has an average error of 2.64 mm over a sample of 115 heads.

Further studies need to implement this proposal and to conduct a though evaluation before it applied to clinical studies.

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