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Citation:

ALI, Ridita, SAATCHI, Reza and RAHMAN, Mohammed Rezwan (2014). Development of an ultrasound based 3D facial scanning system. In: 2014 IEEE MTT-S International Microwave Workshop Series on RF and Wireless Technologies for Biomedical and Healthcare Applications (IMWS-Bio). IEEE International Microwave Workshop Series Conference Proceedings ; Bio 2014 . IEEE, 1-3. [Book Section]

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Development of an Ultrasound Based 3D Facial Scanning System

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***Abstract*— A low-cost ultrasound transceiver was used to scan the faces of two manikins. Each manikin's head was placed on a computer controlled turntable. The transceiver was mounted in front of the manikin's head at a distance of 20 cm and the scanning was performed from forehead to the chin by turning the table. After a single horizontal scan, the sensor moved down by 1 mm. Three dimensional views of the two faces were produced from the data, although the quality of scans produced in this study was coarse.**

***Keywords* — Ultrasound sensing, three-dimensional scanning, facial scanning, sensors, image processing**

I. Introduction

APPEARANCES of a face vary significantly when imaging conditions such as pose and illumination change. These create several technical challenges in recognising the face. Additionally illumination changes affect the distinctive nature of individual features, resulting in degrading performance of 3D scanning. Thus effective scanning systems are required to deal with these limitations.

Humans identify a face very effectively and efficiently, but a computer will find this task difficult as it cannot relate the prior knowledge about the subject with the current observed information as effectively. The purpose of this study is to develop a low cost, ultrasound based, 3D facial scanning system and to evaluate its scanning performance on manikins' faces. There are ongoing studies to improve facial scanning to develop methods that are safe, cost effective and robust in operation.

In facial scanning 2D, 2.5D and 3D volume data of a face can be produced. A laser based facial scanning method is reported in [1] and some limitations of the laser scanning approach are indicated in [2].

Manuscript submitted for Review: 05 August, 2014.

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There a number of facial recognition methods. They include Facial Expression Recognition and Analysis (FERA), Facial Action Coding System (FACS), Action Unit (AU) detection and discrete emotion detection [3]. Some facial recognition algorithms identify face by extracting landmarks or features and create matching features. Other algorithms normalise numerous face images, compress the face data, and save them as images that are useful for face detection [4].

We used an ultrasound transceiver to produce a safe and highly cost effective approach for scanning faces (or objects) in 3D. The interim results for evaluating this approach are provided in this paper.

II. Face Models

Modelling and animation of deformable objects have been applied to different fields. Various researchers have addressed the issue of 3D face modeling. Some goals in facial modeling and animation are:

- Creating a realistic model
- Real time operation
- Automated process
- Ease of adaption to different faces.

III. Ultrasound

An ultrasound transceiver (transmitter/receiver) facilitates a wide range of innovative techniques for various industrial applications such as non-destructive evaluation, industrial cleaning, therapeutic ultrasound and dental ultrasonic and imaging [5].

Electrostatic ultrasonic transducers are used for the detection and generation of ultrasonic waves [6]. These transducers consist of a thin dielectric membrane stretched across a conducting back plate, which is often rough or grooved in order to trap air beneath the membrane and reduce the membrane's rigidity [7].

The ultrasound transmitter and receiver can be two separate devices (pitch-catch method), but in some applications (such as the one in this study) it is more advantageous when both reside in the same device (pulse echo method) [8]. Many factors, like its dimension, supply voltage, etc. in the transducers design will affect it performance.

IV. Methodologies

The ultrasound transceiver sensor used in the study is shown in Fig.1.

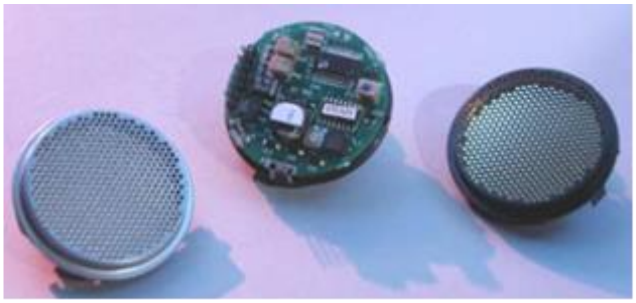

Fig. 1. MINI-A Electrostatic Ultrasonic sensor.

To examine the sensitivity of the sensor, a flat metal plate was placed in front of it and then it was gradually moved back horizontally in steps of 1 mm till the plate's distance to the sensor was 25 mm. For each distance the sensor output was recorded and the readings were plotted against actual distances.

A number of different experiments were conducted for the 3D scans. These included testing the system on two manikins' faces whose faces are shown in Fig.2. A face was made from PVC and the other was polystyrene

Fig. 2. Manikin faces scanned

Initially the experiment was carried out using a simple manual setup where the sensor was moved horizontally from left ear to right ear very slowly by means of hand. The vertical distance was varied by taking a set of readings starting from forehead to the chin. The device attached to the sensor shown in Fig. 3 was moved vertically by 5 mm roughly and each set of readings were acquired in the form of voltage.

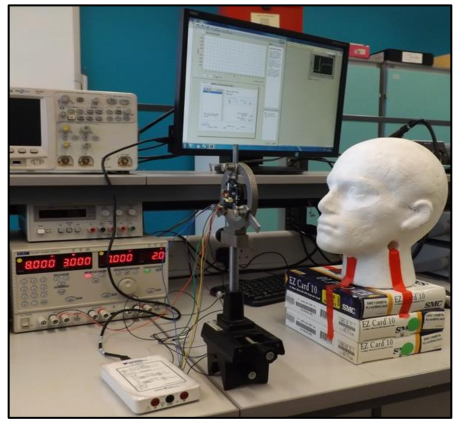

Fig. 3. The initial manual setup

A second experiment was conducted using the first head shown in Fig. 2. The manikin's head was placed on a turn table that was rotated by a computer controlled stepper motor. Scanning was performed from forehead to chin like done in the previous experiment, as the head was rotated on the turn-table. The ultrasound sensor was attached to a stand surrounded by a polystyrene shield. To scan the face of a person, the sensor can be moved while the face remains stationary.

The horizontal scan was performed by turning the manikin's head from left ear to right ear. The stepper motor had a step size of 7.5°. To reduce this rotation angle a gear box was used that reduced this scanning angle to 7.5°/60. After a single horizontal scan, the sensor moved down by 1 mm and the scanning continued until the full face was scanned. repeated.

Data were collected in the form of voltage readings that corresponded to the distance of the sensor from the focus point of the ultrasound wave to the face. The complete experimental setup is shown in Fig.4.

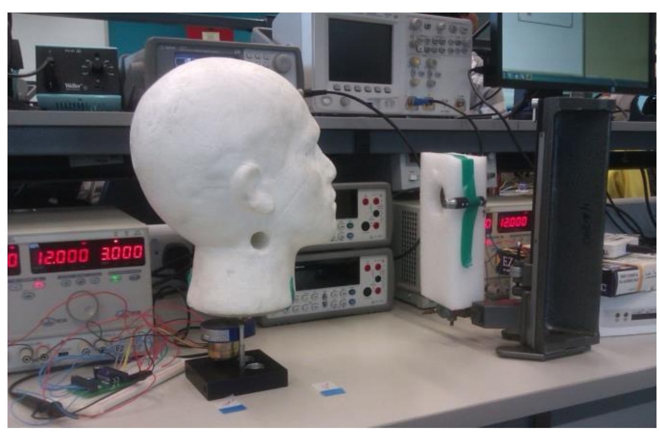

Fig. 4. The complete automated experimental set up

V. Results And Discussion

The plot of the ultrasound sensor output as its distance to the metal plate increased in steps of 1 mm is shown in Fig.5.

The results indicate that there is a linear relationship between sensor output and the object's distance to the sensor. The relationship between the sensor output and its distance to face was: *sensor output= 0.0156× actual distance + 0.0185.*

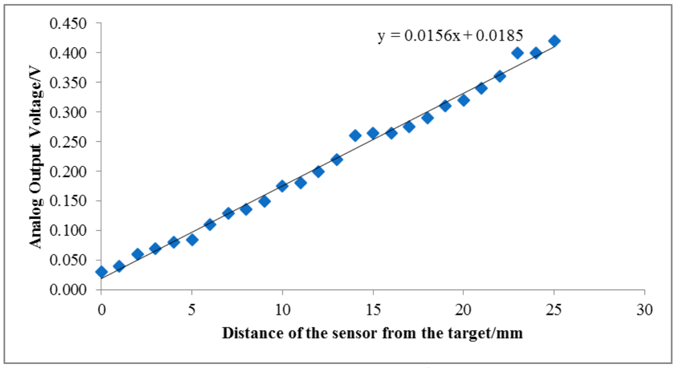

Fig. 5. Sensor output versus sensor distance to a flat target.

The facial scanning results for the two manikins are shown in Figs.6 and 7. The features of the two faces such as nose and mouth are visible in the 3D volume data.

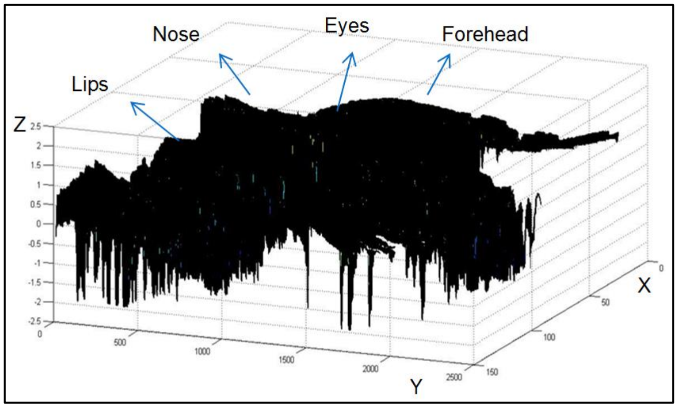

Fig. 6. 3D facial scan of the first manikin.

In this study is was more convenient to move the head while the sensor was stationary, however, human facial scanning the ultrasound sensor needs to be moved while the person is stationary. The results can be significantly improved by using ultrasound transceivers that provide a higher accuracy of measurement. The sensor used in this study has an accuracy of 0.5 mm. Techniques to reduce noise from the data can help making the 3D volume much more clear.

The results in this article outline our preliminary work and findings and extensive further work is possible. In some human face identification scenarios, the whole face does not need to be visualised and key features or facial points may provide sufficient discriminatory information. To measure these key features it may be possible to place a miniature ultrasound transceiver to each facial point of interest and then transmit its beam to a flat surface in front of it. The distances measured between the sensor and the surface may provide sufficient information to discriminate a face.

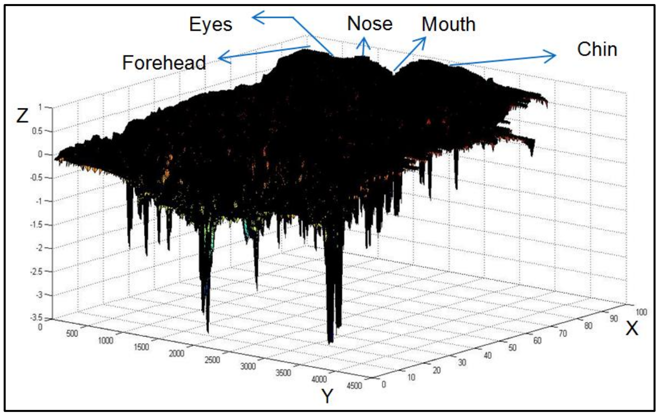

Fig. 6. 3D facial scan of the second manikin.

A more detailed study could also be carried out on the focus point of the beam and including the information in the manner measurement are carried out.

VI. Conclusion

The results indicated a low cost ultrasound transceiver can scan the face in such a way that its features become visible. The method is safe and easy to implement. Extensive further work to improve the quality of the scan is possible.

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