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Laser Technique for Shape and Size Reconstruction of Hearing Aids for The Human Ear Canal

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ABSTRACT

A hearing impairment occurs as a result of deterioration in the hearing system, often occurs to the elderly people due to ageing. The present work is aimed to design and construct a system used to capture an image of human ear canal to determine the dimensions of ear canal in order to design a hearing aid. This work was carried out in two parts, hardware and software. The system consists of: a Green laser source which has a wavelength of (532 nm), and of about (51 mw) power, a reflector with a thickness of (1 mm). Otoscope is made from stainless steel type (302). A MATLAB software (image processing) was used for determining dimensions of human ear canal by using algorithim, and for calculating the percentage of error (P.e.) for correcting the design of the hearing aid, a clear image of human ear canal has been captured using the proposed system. However, the dimensions of ear canal are measured taking an average time of (10 minutes). The P.e. of the length of the ear canal is (±0.72%), and P.e. of width ear canal is (±1.33 %). Finally, the results are considered as a proof-of-concept to measure the dimensions of human ear canal automatically for hearing aid production.

1. Introduction

The conversion of image dimensions (pixels) to real-world units (length), is an important technique in many machine vision applications. The measurement of human ear canal is essential for design of a CIC hearing aid. The classical direct measurements of ear canal, is the oldest and most unclear method, but is not applicable in many cases. Therefore various indirect measurements procedures have been developed in the centuries. Indirect dimensions measurement is the non-contact measurement of dimensions of the ear canal, as many technical applications require dimensions measurement without any physical contact between the dimensions centimeter and the measured ear canal. Therefore, from the beginning of the 20th century measurement procedures using sound waves and electromagnetic waves to transfer the distance information to the measuring instrument have been developed so in Sonar and Radar systems the distance between the device and an object is derived via Time of Flight (TOF) measurement [1].

The use of a camera and green laser provides a faster solution for capturing a clear image of human ear canal to determine the dimensions of ear canal compared to classical method [2, 3]. Hearing is the ability to hear sounds. The human ear is able to hear sounds at frequencies between (20-20,000) Hz. Hearing loss is the inability to hear sound frequencies within normal limits for the hearing. In 2008, more than 360 million person suffered with hearing impairment according to The World Health Organization (WHO) [4]. A hearing impairment occurs as a result of deterioration in the hearing system. Often, it occurs to the elderly people due to the ageing. Hearing impairment adversely affects the ability to communicate with people and society. Most cases of hearing impairment can be processed by hearing aids. A hearing aid is a device used to help the hearing impaired to hear the sounds better. In the middle 1980s, the first digital hearing aids was used [5, 6]. There are three kinds of hearing aids: One of these kinds is in the Ear (ITE), Behind the Ear (BTE), and completely in the Canal (CIC). In the design, a CIC hearing aids need more accuracy to fit human ear canal. So, there is a need for calculating the dimensions measuring of the human ear canal based on the results of the dimensions, the CIC hearing aid is designed to fit the human ear canal [7, 8].

2. Experimental Methods

2.1 The Device Parts

The device consist of [HD-camera, reflector (mirror), green laser, Otoscope, computer system and software. A green Laser: Used to irradiate the human ear. (Wave length of laser 532nm, max power ~50 mw. Reflector (mirror): A thin mirror is used to reflect the laser beam inside the ear. HD-Camera: High definition camera is used to capture images of ear canal.

The Otoscope consist of two parts and made from stainless steel (type of stainless, 302), as shown in Fig. 1.

Fig. 1 The otoscope

Fig. 2 The HD-camera

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One of these part is a tube, the green laser is placed inside the tube. The second part is the cylindrical part. The camera is placed in front of the first face for cylinder, as shown in Fig. 2.

The reflector is a thin mirror that placed at 45° angle to reflect the laser beam inside the human ear. The camera is connected to the computer for capture an image for ear canal and is saved immediately in the computer. A MATLAB software is used to determine the dimensions of the ear canal to design a CIC hearing aid. The complete device is shown in Fig. 3.

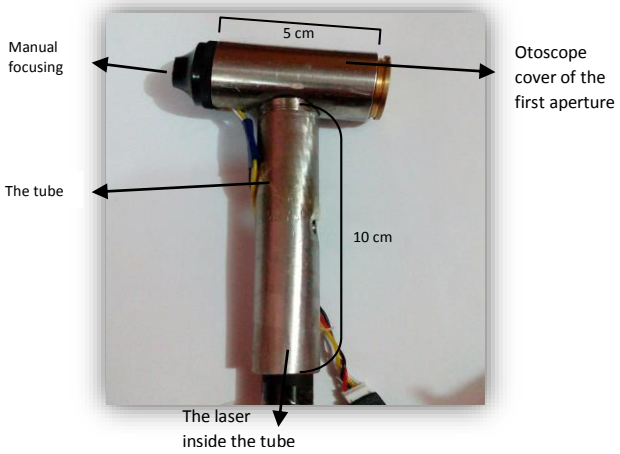


Fig. 3 The otoscopy device

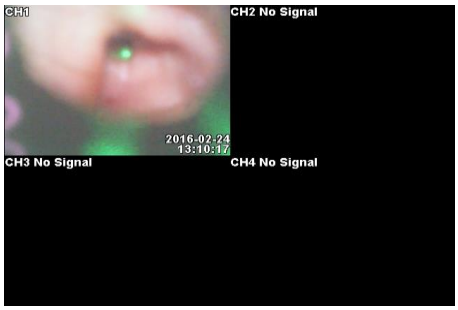


Fig. 4 The human ear canal

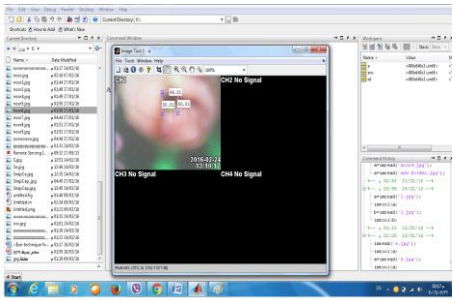
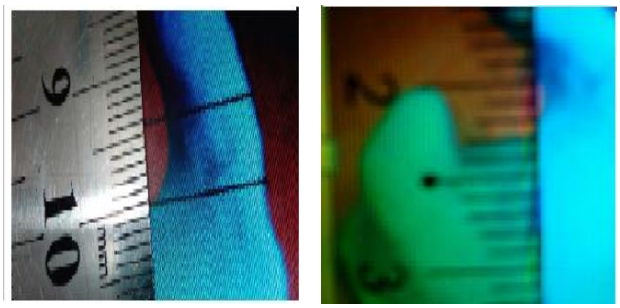


Fig. 5 The dimensions of human ear canal



(A) (B)

Fig. 6 Measured the dimensions of ear canal theoretically (A) width of ear canal and (B) length of ear canal

3. Results and Discussion

The ear canal is shown in Fig. 4. The ear canal dimensions were measured practically by using an algorithm, as shown in Fig. 5.

The width and length of ear canal was measured for the design of the CIC hearing aid (experimentally) as (0.5920, 0.9928) cm respectively.

The width and length of ear canal for design a CIC hearing aid was measured theoretically by taken an impressions of human ear canal, as shown in Fig. 6. The width and length of ear canal was measured for the design of the CIC hearing aid (Theoretically) as (0.6, 1) cm respectively.

The Percentage error (P.e.) between experimentally and theoretically was measured.

The percentage error between the experimental and theoretical width:

Percentage error (P.e.) = | [(Practical - Theory) / Theory] | * 100 %

P.e. = [(0.5920 – 0.6)/ 0.6] * 100 %

= ±1.3333 %

The percentage error between the experimental and theoretical length:

Percentage error (P.e.) = | [(Practical - Theory) / Theory] | * 100 %

P.e. = [(0.9928 – 1)/ 1] * 100 %

= ±0.72 %

However, the width error is (1.33 %), while the length error is (0.72 %). The percentage of error appears as a reason for the presence of the hair and wax in the ear, so, laser could not irradiate all the human ear canal, so camera could not see all the points of human ear canal.

According to Ahmed and co-workers [9], the mean canal length was 2.7 cm. In this present work the length of ear canal appeared 0.9928 cm.

According to D. Groom and W. Chapman, average size of ear canal is 11.8 by 8.0 mm [10].

In this work, we consider the results as a proof-of-concept to measure the dimensions of human ear canal automatically for hearing aid production.

4. Conclusion

The device proposed can easily capture images of ear canal. This device has many advantages like low cost and easy to operate, i.e., easy to determine the dimensions of ear canal. The results are more accurate, and faster than classical method.

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