Ear Recognition for Young Children

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Abstract—Recognition of children using biometrics is a current and critical world issue that needs to be addressed, for the safety and wellbeing of our children. There has been extensive research with regards to adult biometric recognition. It is interesting to note that for children very little work has been done. This paper presents work that has been done on ear recognition for young children (individuals from age zero to 18 years). It comprises of the significance of using biometrics to recognize children, the advantages of using ear recognition and related work that has been done on ear recognition for children. In closure it seeks to unravel unanswered questions and looks to future prospects.

Keywords—children; identity; biometrics; ears; security

I. Introduction

In recent years, biometrics recognition has made great developments in security [1]. The developing usage of biometrics applies in various applications (i.e. identification in hospitals, usage of biometrics with Internet of Things, identification on borders or airports and tracking usage of services by an individual). Therefore, investigating the performance on recognition for young children is important [2]. Although investigation of biometric recognition for adults has been accomplished on a global basis, for children biometric recognition very little has been done [1], [3]. The challenge is that children still under-go mental and physical development. Therefore, most systems designed for adults do not perfectly work to identify children [4],[5]. It is through meticulous investigation and development of biometric systems for children that we can solve current identification complications. These complications to mention a few are incorrect identification in the hospitals of new-borns, difficulty in identifying missing and illegally adopted children.

There are different biometrics that are currently considered to recognise children, i.e. face, iris, fingerprints and footprint [5],[6]. However, very young children are often uncooperative and do not comprehend or follow instructions, among all biometric modalities ear images are the most viable for recognising children. This is mainly because the capturing of the ear image is easier, hygienic, convenient and inexpensive compared to other biometrics. It is practical to note that iris as a biometric recognition for children has its challenges. A child needs to stare directly towards the acquisition device to initiate iris capture. The use of the iris as a method for new-borns, e.g. the premature children hardly open their eyes, they do not have the ability of fixing their eye into a scanning device, and stressing their eyelids to collect an image it might hurt them. Moreover, it seems that the iris pattern only stabilizes after the child's second year [7].

It is worthy to note that with regards to footprints and fingerprints a child is required to touch or hold an acquisition device, in order to capture their fingerprints. This can be a labour intensive and unhygienic act for a new born. The face recognition systems also have difficulties, a child needs to remain still and maintain same emotions as the initial enrolment, which might be not possible as a child grows. The ear recognition as a solution allows for ear images to be captured even if a child is asleep, eating or even playing using a standalone digital camera or from the smart phone. In addition, the size of ear is bigger compared with other biometric trait like iris, fingerprints and footprints. This allows to capture images at a relative distance.

This paper comprises of an overview of the work that has been done on ear recognition for children. Introduction to ear recognition for children and assessment of the ear as a biometric on seven biometric characteristics is presented in section II. The literature review is resented in section III. At the end un-answered questions on ear recognition for children and future recommendations are presented in section IV.

II. Ear Recognition for Children

A. Permanence of the ear

The outer ear, shown in Fig. 1, is the visible part of the ear that is located outside the head. Ear shape can be used as a biometric to identify and/or verify a person using two- or three-dimensional features [8],[9]. The ear grows proportionally during the first four months of birth and increases slowly in size thereafter [10]. However, the earlobe may elongate in the vertical direction because of the effect of gravity. The rate of elongation is approximately five times greater during the period from the age of four months to eight years, and then it stops changing until around the age of 70 years when it starts to increase [11]. Similarly, in 2013, Purkait et al [12] performed a study to investigate progression of growth in the external ear from birth to maturity in a 2-year follow-up study [12]. Results presented shows that dimensions exhibited very rapid growth during the first 3–6 months of infancy and thereafter proceeded at a slow pace until adulthood. At birth, most of the dimensions were 52–76 % of their adult size. The width dimensions matured earlier, at 5.6–11 years, whereas the maturity age of lengths varied from 12 to 16 years [12].

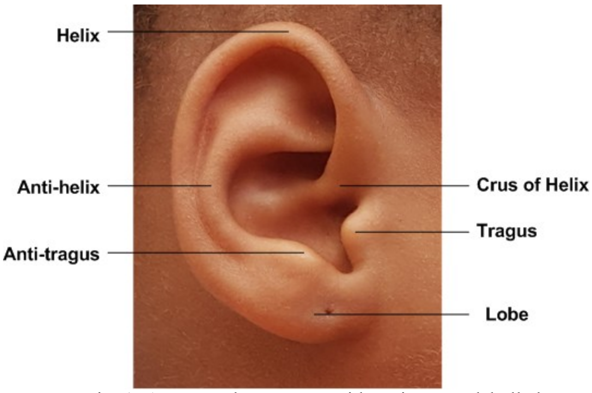

Fig. 1: An example outer ear with major parts labelled.

B. Assessment of the ear on seven biometric characteristics

In TABLE 1 below explained is the assessment of the ear on seven biometric characteristics. The ear scores high for universality because every human is born with ears [8]. It scores high for uniqueness because of its distinguishable features [13]. It scores high for permanence because once it is formed, according to the literature its shape does not significantly change [14]. With collectability and acceptability is cores high because it does not need a particular device for capturing and capturing process is hygienic. It score medium for performance because of well-known challenges such as uncontrolled environment during image acquisition, and other occlusions such as hair and accessories. Resistance to circumvention is medium because it is challenging to spoof the ear recognition system [8].

TABLE 1: ASSESSMENT OF THE EAR ON 7 BIOMETRIC CHARACTERISTICS

Biometric Characteristics	Rate	Explanation
Universality	High	Everyone is born with ears [8]
Uniqueness	High	Ears have unique features which can be used to distinguish between two people [13][15]
Permanence	High	Compared to face, are comparatively constant over a person's life and are not affected by facial expressions [14]
Collectability	High	Ear images can be easily collected using normal digital cameras and cooperativeness of a participant although the quality of the image can be affected by the environment such as illumination, and head direction towards the camera [16]
Acceptability	High	It convenient to most cultures and religions, and capturing process is hygienic sine its contactless [16]
Performance	Medium	Performance is increasing as ear recognition is currently highly studied. Although some performance methods get affected by the background information around the ear image [17]
Resistance to Circumvention	Medium	It can be challenging to spoof the system unless an attacker use three dimensional ear [8]

III. SYSTEMATIC LITERATURE REVIEW

Systematic literature review was performed from 2018 to 2019 using the Evidence for Policy and Practice Information Centre (EPPI-Centre) tool, which is available from https://eppi.ioe.ac.uk. Different search engines were used to find work related to the usage of ear recognition for children identification. The procedure followed is presented in Fig.5 and distribution of found work is presented in Fig.6.

A. List of used search engines

The list presented below are the electronic search engines that were used to conduct the literature review. These search engines were chosen because are the most used in the field of computer science, it is where most researchers and scientist publish.

- IEEE Xplore (www.ieeexplore.com.br)
- Springer (www.springerlink.com)
- Scopus (www.scopus.com)
- ScienceDirect (www.sciencedirect.com)

B. Work cited

According to literature reports, ear recognition for children was first introduced in 1960 by Fields et al. [13], who manually analysed ears of new-borns on a database of 206 participants. After identifying the problem of incorrect identification of children, authors investigated possible solutions to identify new-borns using their ears. Fields et al. [13] have concluded that visually ears can be used to distinguish amongst new-borns.

In 2011, Tiwari et al [16] performed the investigation if ear recognition of new-borns can be done. Their investigation was part of solving the problem of abduction, swapping and mix ups of infants while in hospital premises. This work is similar to the work presented by Fields et al [13], however the ear comparison methods are automated although ear region is manually segmented. Authors introduces the concept of using ear recognition for identification of new-born and presents automatic ear recognition algorithm. The main contribution of this research was the preparation of a new born ear database from 210 individuals. Ear images were captured by first acquiring side face images using a 12 Megapixel digital camera under different lighting conditions with illumination and pose changes. Both left and right ears were captured, at a 20-25 cm distance between the camera and the ear. Authors have tested different ear matching algorithms and concluded that ears can be used as a biometric to identify new-borns [16].

In 2012, again Tiwari et al [18] performed fusion of ear features and soft-biometrics for recognition of new-borns. Still attempting to solve the same challenge at hospitals, Tiwari et al [18] proposed an improvement of ear recognition for new-borns by fussing ear features and soft biometrics. The considered soft-biometric data is gender, blood group, height and weight to enhance the accuracy for identification. The main contributions of their research are the design and implementation for fusion of ear and soft biometric for recognition of 210 new-borns, and preparation of combined ear images and soft-biometric database of new-borns. Authors presented that the fusion of ear and soft-biometrics resulted in an improvement of approximately 5.59% over the identification system based only on ear recognition [18].

In 2013 Tiwari et al [19] gathered a multimodal database of new-borns only for biometric recognition with soft biometrics [19]. The database includes physiological characteristics like face, ear, head print and soft biometrics data like gender, height, weight and blood group of 280 new-borns. The database contributes provides identity characteristics that may be useful for authenticating the new-borns using unimodal and multimodal biometric systems development for new-borns.

In 2014 Berra et al [7] developed a research on biometric authentication of new-born identities by means of ear signatures. The aim of proposing their work was to solve the problem of new-borns swap, which is possible and actually happens, most of all in crowded maternity wards of big hospitals. Authors tested the viability of using ear recognition using a dataset of ear images of new-borns, and the obtained results showed that it is possible to decrease the probability of an error using this technique. With this work, multiple matching algorithms were used to test the accuracy of identification, authors concluded that ear images can be used to identify new-borns [7].

Again in 2015, Tiwari et al [20] proposed fully automated ear recognition for New-borns. The main problems they were solving are new-borns swapping, missing, mixing, and illegal adoption. In addition to automatically locate, segment and crop the ear region on the given ear image. Tiwari et al [20] investigated a unique approach for the automatic recognition of new-borns using 2D ear imaging. Authors presented that their investigation contributes a computationally effective and attractive solution to recognise new-borns automatically. The proposed algorithm yields identification accuracy of 89.28% on a database of 210 subjects [20].

In 2015, Bargal et al [21] developed a smart phone based ear recognition for the clinics. Authors presented work in progress of a computer vision application that would directly impact the delivery of healthcare in under-developed countries. They have described the development of an image-based smartphone application prototype for ear biometrics. The application targets the public health problem of managing medical records at on-site medical clinics in less developed countries where many individuals do not hold IDs. A pilot study was then conducted on the developed application to test feasibility in naturalistic settings. However, it was not specified if the pilot study involved any data acquisition from children under the age of 18 years. Their future works includes performing a longitudinal study on infants under the age of three, whose ears will be developing over time. This would follow the three stages of improving the app performance on adult recognition [21].

In 2016, Tiwari et al [5] presented a comparison of adult and infant ear images for biometric recognition. The aim of their work was to solve the global challenge of missing, swapping and mixing of infants. In addition to evaluate if current ear recognition algorithms developed for adult recognition can work on recognising new-borns. Tiwari et al [5] investigated adult and infant ear image for automated identification using 2D ear imaging. To demonstrate that ear can be used to recognize infant. The contributions of their work was the Implementation of seven algorithms on ear database of adult and infant and evaluation of ear recognition algorithms using database of new-borns' ears.

To the best of our knowledge, there has been no commercial automated system that perform ear recognition on children. However, the article released in October 2017 on the Intellectual Ventures News reported that the Matlab Health Research Centre in Bangladesh and the Angkor Hospital for Children in Cambodia, will partner to assess a range of biometric modalities such as fingerprints, irises, palm prints, ears and feet to determine which is most suitable for infants and young children [22].

Alternative ongoing work was reported in May 2017 that the Council for Scientific and Industrial Research (CSIR) in South Africa is in process of developing a biometric system that can determine or verify the identities of children from their infancy and throughout their childhood. CSIR researchers will assess three biometrics, namely: fingerprints, iris and ear shape and determine which of the three are best suited for the system [23]. As part of the CSIR work, Ntshangase et al [24] presented an evaluation of ear recognition algorithms on the effect of growth and illumination. The aim of their work was to determine the suitable ear recognition algorithm that is not tolerant to geometrical changes and still not tolerant to illumination changes.

C. *Summary of work cited*

Presented in TABLE 2 is the summary of the work done so far in ear recognition for children. It can be seen that there is little work done compared to other biometrics, such as fingerprints, face and iris [25], [26],[27], [28],[29].

IV. CHALLENGES AND FUTURE WORKS

The findings of little research available leads to the following work recommendations and un-answered questions:

1. Whether the changes in the shape and structure of the ear as children grow impact the ability of recognition systems to verify someone years after their initial enrolment as an infant. Such an example is shown in Fig. 2, a) shows the ear was captured few hours after birth and b) was captured after eight months. These images were collected from parents who had side face images of their children.
2. The change in size of the ear, does it really affect the recognition?
3. The present hair on some new-borns does it introduce false features that will not be present as hair fades away as children grow, as shown in Fig. 3.
4. Partial ear images, if some region of the ear is folded at birth, will that affect the ear recognition, as shown in Fig. 4.

TABLE 2: SUMMARY OF THE WORK DONE ON EAR RECOGNITION OF CHILDREN

Year	Author	Age of children considered	Number of images	Purpose of work
1960	Fields et al [13]	New-borns in the hospital	206	Identification of new-borns in hospital premises
2011	Tiwari et al [16]	New-borns in the hospital	210	Identification of new-borns in hospital premises
2012	Tiwari et al [18]	New-borns in the hospital	210	Identification of new-borns in hospital premises
2013	Tiwari et al [19]	New-borns in the hospital	280	Multimodal database
2014	Berra et al [7]	New-borns in the hospital	Not specified	Identification of new-borns in hospital premises
2015	Tiwari et al [20]	New-borns in the hospital	210	Automated detection of ear images for new-borns
2015	Bargal et al [21]	Everyone in the hospital	Not specified	Identification of patients in hospital premises
2016	Tiwari et al [5]	New-borns in the hospital	210	Evaluation of ear recognition algorithms on a database for new-borns' ears.
2017	Matlab Health Research Centre [22]	Not specified	Not specified	Ongoing work on identification of children
2017	Council for Scientific and Industrial Research [23]	Not specified	Not specified	Ongoing work on identification of children
2019	Ntshangase et al [24]	From new-borns to primary school	100	Evaluation of ear recognition algorithm on the effect of growth and illumination.

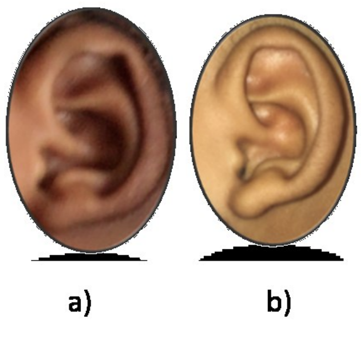

Fig. 2: Images of the same ear: a) captured few hours after birth and b) captured after 8 months

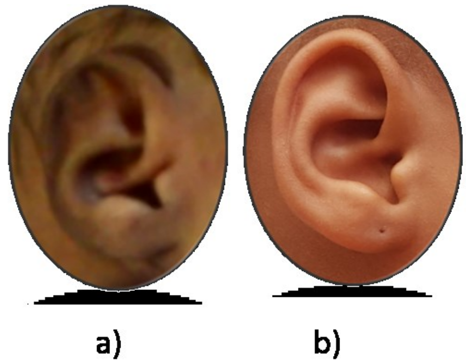

Fig. 3: Images of the same ear: a) captured hours after birth (with hair) and b) captured after 3 years and 6 months.

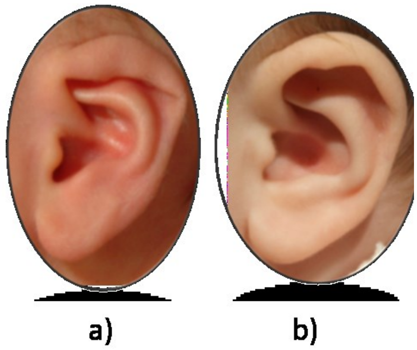

Fig. 4: Images of the same ear: a) captured soon after birth (folded) and b) captured few weeks after the ear has been stretched

5. After what age does the shape of the ear stop changing? Which features are stable, regardless of the change in size due to growth? How does this affect the recognition rate?
6. All children when born are lighter in complexion, does the colour change really affect the ear recognition as the ear is made up of skin colour region.
7. If spoofing is possible, what are spoofing methods and solutions for ear recognition? Is it possible to have automated system that detects liveness of the ear?
8. There is a need for a longitudinal study of ear recognition from infancy to adult.

V. Conclusion

The ear recognition is presented and the advantages of using ear recognition over other biometrics have been identified with the supporting assessment of the ear on seven biometric characteristics. The existing work done on ear recognition since 1960s up-to-date has been presented. The analysis of available work shows that there is still little effort that has been done on ear recognition for children. As a result, questions that have not been answered are presented. As part of our future prospects, there is need to perform a longitudinal study for ear recognition of children.

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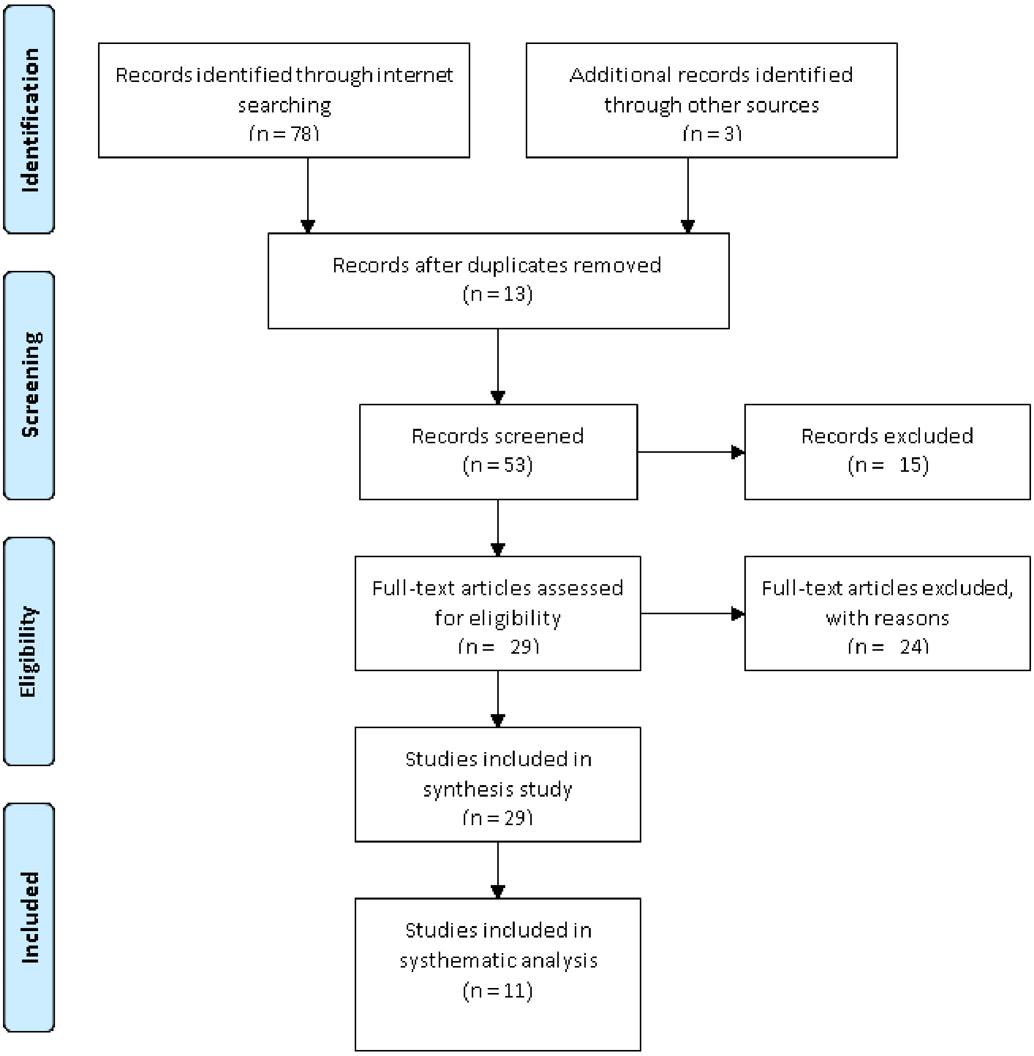

Fig. 5: Flow diagram for the systematic literature review

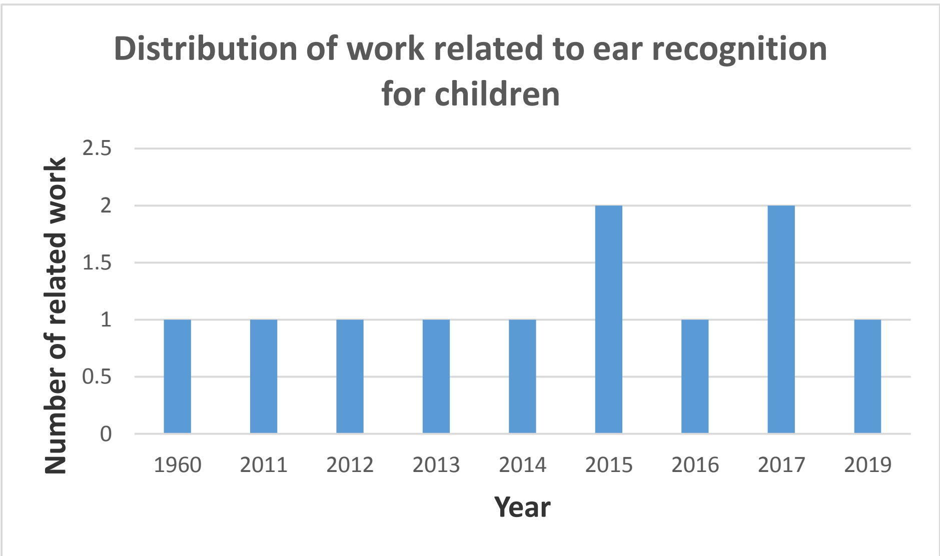

Fig. 6: Distribution of work related to ear recognition for children