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An intelligent healthcare system for detection and classification to discriminate vocal fold disorders

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HIGHLIGHTS

- An Intelligent Healthcare System for Voice Pathology Detection and Classification.
- Automatic screening system for the IoT-oriented detection of voice disorders.
- Voice samples which are sensed and transmitted through the Internet of Thing.
- Visualization of normal and pathological samples.

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ABSTRACT

The growing population of senior citizens around the world will appear as a big challenge in the future and they will engage a significant portion of the healthcare facilities. Therefore, it is necessary to develop intelligent healthcare systems so that they can be deployed in smart homes and cities for remote diagnosis. To overcome the problem, an intelligent healthcare system is proposed in this study. The proposed intelligent system is based on the human auditory mechanism and capable of detection and classification of various types of the vocal fold disorders. In the proposed system, critical bandwidth phenomena by using the bandpass filters spaced over Bark scale is implemented to simulate the human auditory mechanism. Therefore, the system acts like an expert clinician who can evaluate the voice of a patient by auditory perception. The experimental results show that the proposed system can detect the pathology with an accuracy of 99.72%. Moreover, the classification accuracy for vocal fold polyp, keratosis, vocal fold paralysis, vocal fold nodules, and adductor spasmodic dysphonia is 97.54%, 99.08%, 96.75%, 98.65%, 95.83%, and 95.83%, respectively. In addition, an experiment for paralysis versus all other disorders is also conducted, and an accuracy of 99.13% is achieved. The results show that the proposed system is accurate and reliable in vocal fold disorder assessment and can be deployed successfully for remote diagnosis. Moreover, the performance of the proposed system is better as compared to existing disorder assessment systems.

1. Introduction

Due to rapid growth in information and communication technologies, the building of smart homes and cities becomes a reality. Smart homes and cities take the home and living experience to the next level. One of the major reasons for the development of smart homes and cities is to provide the efficient and cost-effective healthcare [1] facilities. According to the American Association of Retired Persons [2], 85% of senior citizens want to stay at home for the treatment as long as the facilities are available. Of concern is that a large population around the world is aged 60 years or above. In the report of the United Nations on world population aging which was published in 2015 [3], it is mentioned that around 900 million people around the world are 60 years of age or above. This population will rise to 1402 million until 2030. Such a large population will occupy a significant portion of the health facilities in the hospitals. This situation can be avoided by building smart homes and cities, where automatic diagnosis systems will be a

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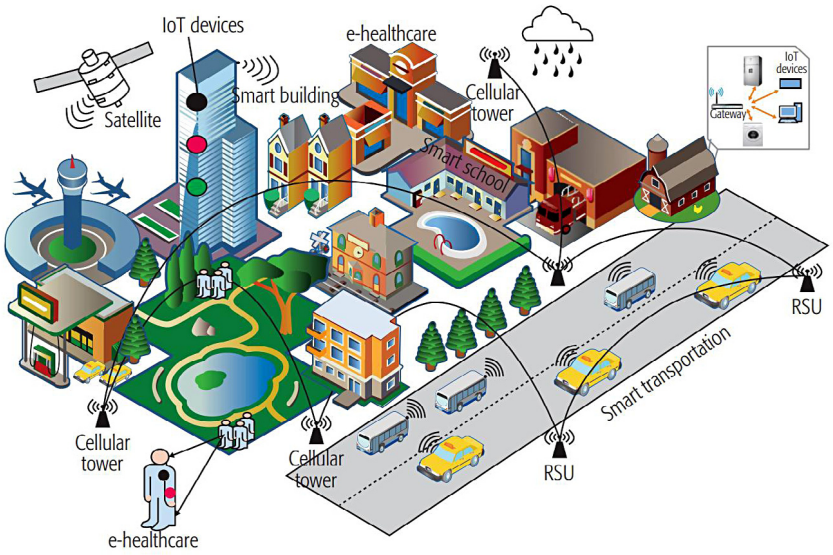

Fig. 1. An illustration of an IoT-based smart city [9].

critical component [4–8]. The automatic healthcare systems receive the data through the Internet of Things (IoT) and transmit it for the evaluation.

In smart cities, the IoT gathers a huge quantity of data and it can be processed by using automatic assessment systems [5]. A high-level illustration of an IoT-based smart city is depicted in Fig. 1. However, the increasing use of wireless transmission of health-related data raises the concern of data protection and authenticity. The medical data of an individual may be secured such that unauthorized access to the data could be denied. Only authorized healthcare staff may access the data to ensure the privacy of an individual's identity. A framework for a privacy-protected healthcare is shown in Fig. 2.

The main goal of this study is to develop a detection and classification system for vocal fold disorders which can be deployed in smart homes and cities for automatic diagnosis. A voice disorder affects the vocal folds and makes the vibration of the vocal folds abnormal. The characteristics of various voice disorders such as vocal fold nodules, cysts, and paralysis are presented in [10]. Due to irregular vibrations, the vocal folds exhibit incomplete closure or tight closure, which makes the voice breathy, weaker, strained, and harsh. The abnormal behavior of the vocal folds disturbs voice patterns and therefore the speech signal of a disordered person becomes more transient and noisy compared to that of a normal person [11]. A large number of populations around the world suffer from different kinds of voice disorders. According to the National Institute on Deafness and Other Communication Disorders, approximately 17.9 million people suffer from voice problems [12]. Around 700 cases of voice complications per year are observed in Riyadh, Saudi Arabia. More than 15% of the people visiting King Abdul Aziz University complain about voice problems [13]. Various types of voice disorders are described as follows.

Vocal fold polyps are fluid-filled lesions that appear on the free edge of the vocal folds, and the main reason for their occurrence is the abuse of the voice. Polyps resemble a blister; they are reddish in color. Polyps are associated with frequent breaks in singers, earlier vocal fatigue, and worsening dysphonia [14]. Several factors can contribute to the formation of vocal fold polyps, such as allergies, nicotine, and voice trauma [15]. Vocal fold polyps usually occur in adult men who use their voices excessively; these patients also have a high risk of vocal fold nodules and cysts [16].

Keratosis appears due to the presence of abnormal cells (white plaques) on the vocal folds [17]. This lesion is pre-cancerous but

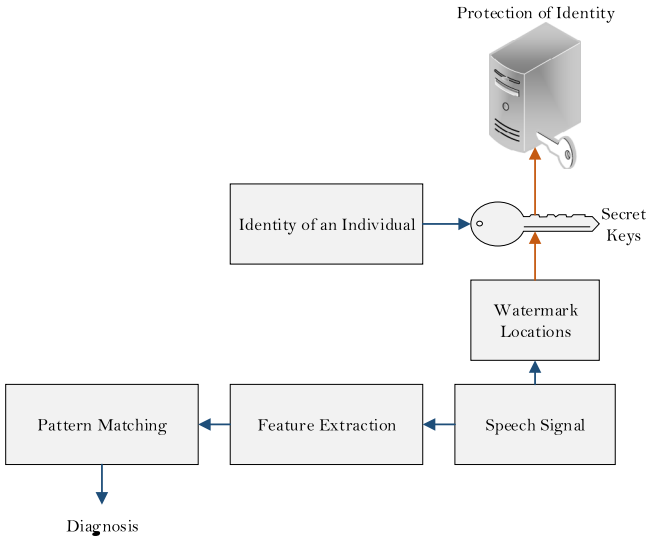

Fig. 2. A framework for the privacy protected healthcare system.

can turn into cancer in the case of negligence. Keratosis disturbs the normal vibration of the vocal folds and causes hoarseness. The main reason for the development of keratosis is smoking, the excessive use of the voice, and environmental pollutants. Gastroesophageal reflux disease may also be a reason to produce abnormal changes in cells [18]. Keratosis may be unilateral or bilateral and usually symmetric in nature. This lesion has more tendency to prevail in men than in women.

Vocal fold paralysis occurs due to the malfunctioning of one or both vocal folds when they open and close improperly. Unilateral vocal fold paralysis is a common disorder; however, bilateral vocal fold paralysis is rare and life-threatening. One of the main reasons for vocal fold paralysis is an injury to the recurrent laryngeal nerve [19]. This nerve controls the motion of the vocal folds. Vocal fold paralysis can also occur due to injury to the chest, neck, or head; thyroid or lung cancer; and tumors on the chest, neck, or skull base.

Vocal fold nodules [20] occur as bilateral symmetric swelling located at the junction of the anterior and mid-third part of the