Towards Automatic Waistline Measurement with A Smartwatch

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Abstract To solve obesity which is one of the causes of lifestyle-related diseases, people first need to know the state of their bodies such as waistline. We have considered that a belt, which people wear every day, can be used for waistline measurement without a burden. Hence, we study a method of automatic waistline measurement in people's daily life using a belt and sensing technologies. In this paper, we propose an acoustic-based automatic waistline measurement method using *a common fashion belt* and *a widespread smartwatch's microphone*. Through the preliminary experiments, we discuss the feasibility and technical issues of the proposed method.

1 Introduction

Lifestyle diseases such as diabetes, heart disease, arteriosclerosis, and stroke, are regarded as an urgent issue in the world [12]. One of the significant factors of these lifestyle diseases is obesity. Jacob reported about 2 billion people are overweight and about 700 million people are classified to the obesity group all over the world [11]. The Japanese government (Ministry of Health, Labour and Welfare) also reported the survey that half of the adult men are patients or reserves of the metabolic syndrome, which is a complication of hyperglycemia, hypertension and dyslipidemia [9].

To diagnose metabolic syndrome, the measurement of the abdominal circumference (hereinafter, waistline) is required [4]. However, day-to-day waistline measurement might be a heavy burden for the user since a measuring tape is still a common method. Hence, most people have relied on periodic medical check-ups so far. This situation causes that there are only several times of opportunity a year that people can look back on his waistline, and it can be said that the motivation for changing

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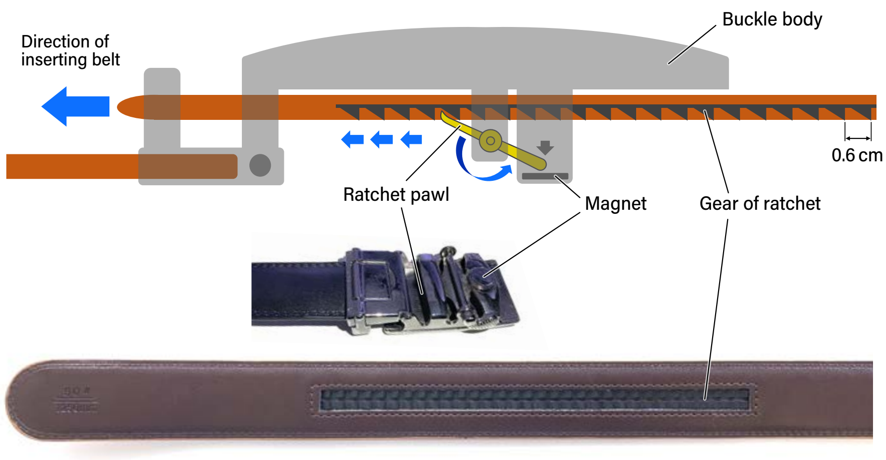

Fig. 1 Mechanism of ratchet belt.

his/her lifestyle is difficult to keep. The realization of a system that supports easy and customary measurement of the waistline is highly demanded.

In this study, we have focused on the belts people wear in daily life, and have studied the automatic waistline measurement method using a buckle-type wearable device [7, 6] and a dedicated device attachable to a common belt [10], so far. However, there is a problem that the dedicated device is also a factor that increases the burden on people, e.g., battery charging. Hence, in this paper, we propose a method for estimating the insertion length of a belt by collecting ticking sound when fastening a ratchet belt (Fig. 1) using a microphone of a common smartwatch. Due to the belt forms an annulus when worn, the circumferential length, i.e., the waistline length, can be derived if the insertion length could be estimated. As a feasibility study, we recorded the ticking sound of a ratchet belt using AppleWatch's *Voice Memos* app and analyzed data. As a result, we have confirmed the possibility of realizing the belt insertion length estimation by counting sound peaks, however, we also found that acoustic filtering is required for a noisy environment usage.

2 Related work

Spreading the popularity of wearable devices around the world, we can easily collect health-related data in daily life. Especially, wrist-worn wearable devices are widely used, e.g., *AppleWatch* [1], *Fitbit* [3]. Withings, Inc. provides *Withings Steel HR* [14]. It allow us to measure momentum data and physiological data such as maximal oxygen consumption (VO2 Max) and upload them to the cloud. In the cloud service, users can manage measured data, and analyze health conditions through combine with data measured by other health care devices e.g., body scale. Empatica, Inc. provides *Empatica E4 wristband* [2] for researchers. It have electrodermal activity (EDA) sensor, photoplethysmogram (PPG) sensor, and skin temperature sensor. The current state of the art in the wrist-worn wearable device is focusing on momentum, physiological data.

Automatic waist measurement methods have been proposed by several researchers and companies. Meyer et al. have proposed a system that automatically measures waistline by attaching a device with an automatic pulling back function to the measuring tape [8]. Since this is an idea of digitizing the measuring tape, there is a problem that it is difficult to maintain motivation for daily use. WELT Corp. has focused on the buckle belt, and released *WELT* [13] that automatically measures the waistline based on detecting the position of the belt's hole when the belt is tightened. It has employed a method of measuring the belt insertion length by reading a magnet embedded in the belt with a dedicated device built in the buckle of the belt. However, it has a restriction that both a dedicated belt and a dedicated buckle are required.

In the following part of this paper, we design a new waistline measurement methodology utilizing the widely-used wearable device.

3 Methodology

3.1 Approach and Preliminary work

In this study, we focused on a *belt* that people wear every day to incorporate waistline measurement into their daily lives. There are various fastening methods for belts such as *Buckle belt*, *Braided belt*, *Ring belt*, *Canvas belt*, and *Ratchet belt*. We particularly focus on the *Ratchet belt* [5], which has a mechanism that fastens the belt by gear and pawl as shown in Fig. 1, for the waistline measurement.

In our study so far, we have proposed a waistline measurement method using a dedicated device that can be mounted over a buckle of a ratchet belt [10]. This device is able to estimate the length of the waistline by measuring the pawl movement of the ratchet belt with a magnetic sensor and calculating the circumference formed by the belt. This method realizes daily measurement with a dedicated device, however, people should wear a new device, even they are surrounded by too many smart devices in daily life. The scattering of devices on the user's body is not a better idea from the viewpoint of battery charging etc.

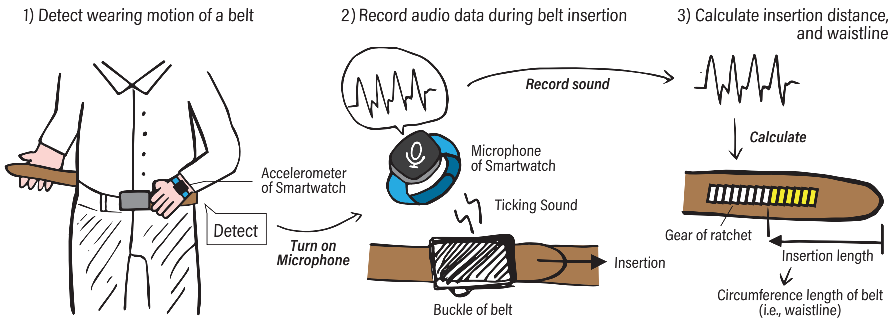

Fig. 2 Estimation steps of proposed method.

3.2 Waistline measurement method with smartwatch

The aim of this paper is to achieve automatic waistline measurement using common devices such as a smartwatch and a smartphone instead of a dedicated device. We noticed that the pawl of the ratchet belt produces not only a change in the magnetic field but also an acoustic signal (ticking sound). Hence, we propose a method of estimating the belt insertion length by measuring the acoustic signal using the microphone embedded on a smart device. In general, since audio data include various privacy-related information, it should not be collected continuously. Accordingly, by adopting the method of recognizing human activity such as inserting a belt or wearing pants using inertial sensors, audio data collected by the microphone might be minimized. As a common device that meets this requirement, we have employed a smartwatch in this paper.

The proposed method estimates the waistline in the three steps as shown in Fig. 2. The detail of each step is described as follows.

1. The smartwatch constantly monitors the inertial sensor (accelerometer, gyroscope) values and recognize the activity of the user. When motions of putting on the pants or the operation of fastening the belt are detected, it proceeds to Step 2.
2. Turn on the smartwatch's microphone and record the ticking sound of the ratchet belt. After a certain time, the microphone is switched off.
3. By analyzing the recorded acoustic signal, the operating noise of the ratchet pawl is extracted. Thereafter, the belt insertion distance is derived by counting the number of operating noise. The circumference length of the belt (i.e., waistline) is calculated by subtracting the belt insertion distance from the total belt length.

The minimum resolution of waistline measurement depends on the interval of ratchet gear (0.6 cm in case of Fig. 1), hence, that interval is needed as a parameter.

3.3 Substitutability of proposed method

In this paper, we have proposed to employ a smartwatch due to the requirement of the inertial sensor for activity recognition (detecting user's motion, e.g., wearing pants). However, the proposed method can be applied to other devices such as a smartphone, another wearable device, which has an embedded microphone.

4 Feasibility study

To verify the feasibility of the proposed method, we conducted a preliminary experiment of acquiring ticking sound with a microphone of the smartwatch. In this experiment, a commercially available ratchet belt and AppleWatch were used. The audio data during tightening the belt is recorded by using AppleWatch's default application, *Voice Memos*. Fig. 3 is a plot of the recorded data. During the user is wearing the belt, the position of the AppleWatch is close to the belt, hence, the ticking sound appears as a large noise. Each peak indicates that ratchet pawl has passed through one protrusion of the ratchet's gear. By counting this peak, the number of ratchet pawl movements can be acquired.

The estimation using acoustic data might be affected by environmental noise. Fig. 3 mentioned above was recorded at the place of approximately 30 dB (in a quiet room), so there is little environmental noise. However, when recording at the place of 70 dB (in a noisy room), much noise is mixed as shown in Fig. 4. The microphone of AppleWatch is close to the buckle of the belt at the beginning of inserting the belt, however, the ticking sound is decayed as that position moves farther. At the last part of insertion as highlighted with a green background, the noise makes it difficult to distinguish although there were two ticking sounds.

In such a condition, acoustic signal processing is required to accurately count ticking sound. As a simple solution, a method using an acoustic filter can be used. Fig. 5 and Fig. 6 are spectrograms of audio data recorded at 30 dB and 70 dB places, respectively. The blue triangles show the timing which ticking sounds are generated. Since ticking sound has a wide frequency band containing low to high frequency, it is considered possible to separate ticking sound and noise even in the case of 70 dB where a lot of noise is mixed.

As a reference, Fig. 7 shows the other recording samples collected in quiet/noisy places. Fig. 7 (a-1)–(a-6) are recorded in 30 dB place, and Fig. 7 (b-1)–(b-6) are recorded in 70 dB place.

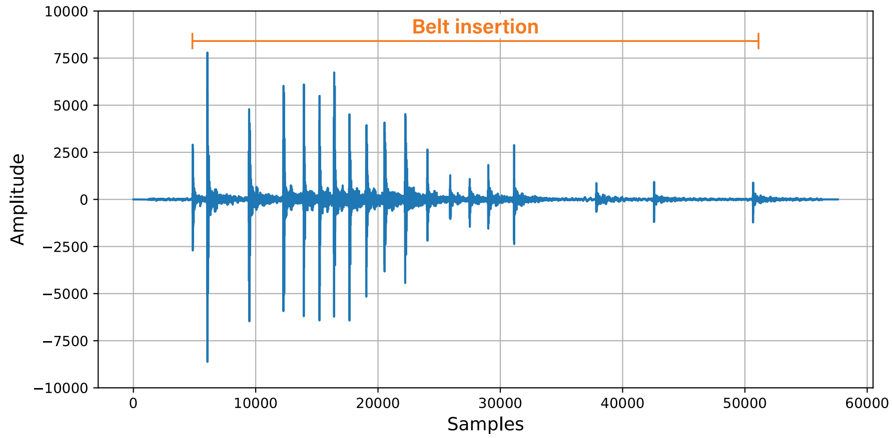

Fig. 3 Waveform of audio data recorded in a quiet room (30 dB).

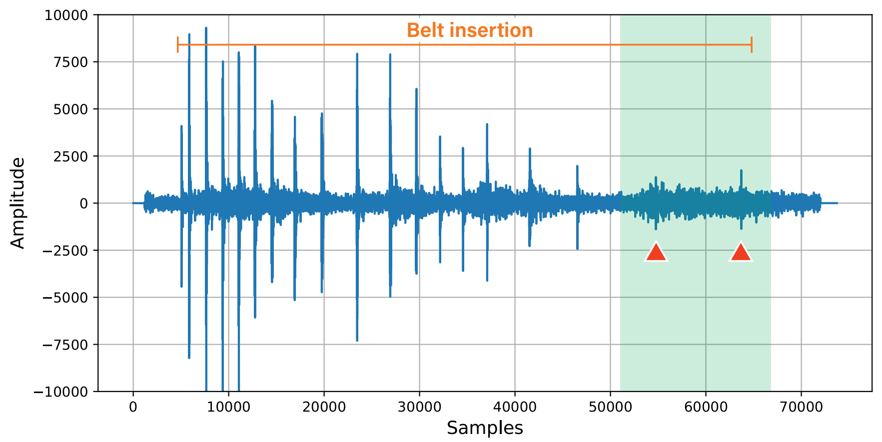

Fig. 4 Waveform of audio data recorded in a noisy room (70 dB).

5 Conclusion

The aim of this study is to automatically and naturally measure waistline in people's daily life. So far we have proposed a method that focuses on belts that people wear every day. However, the previous method requires the use of dedicated devices.

In this paper, we proposed an automatic waistline measurement method based on recording the ticking sound generated when tightening the ratchet belt, using the microphones of a smartwatch widely used by people. As a result of the feasibility

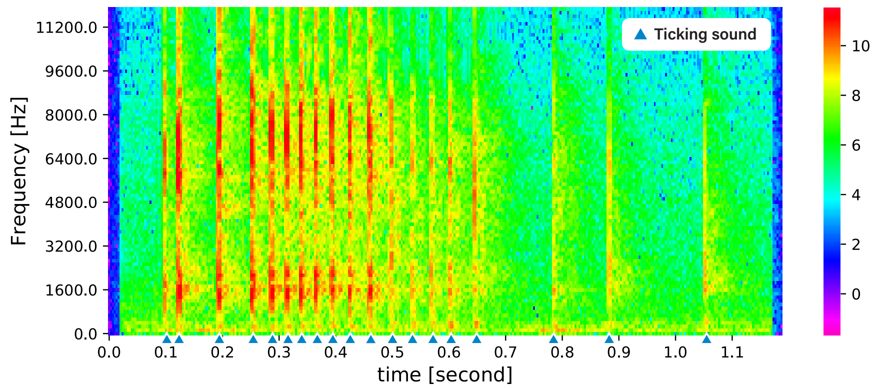

Fig. 5 Spectrogram of audio data recorded in a quiet room (30 dB).

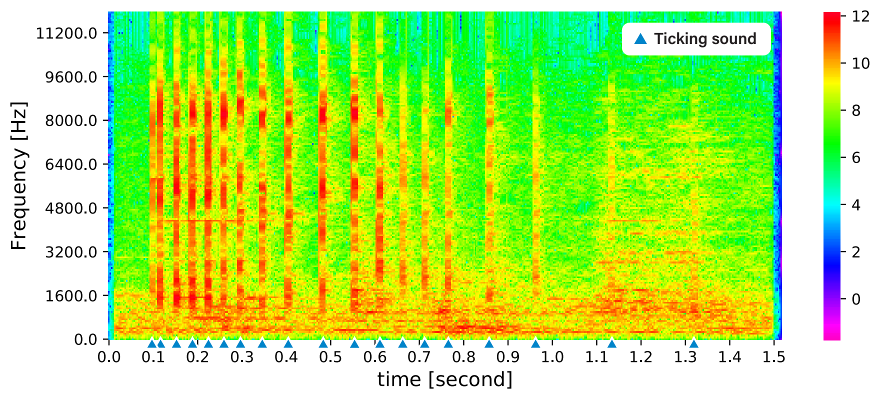

Fig. 6 Spectrogram of audio data recorded in a noisy room (70 dB).

study, we have confirmed the possibility of the belt insertion length estimation by the peak count of the recorded sound, however, we also found that acoustic filtering is required for a noisy environment usage.

As future work, we will build a waistline estimation method based on the counting of ticking sounds, and combine with activity recognition for controlling on/off of the microphone. Then, we finally realize automatic waistline measurement pipeline using the smartwatch in daily life.

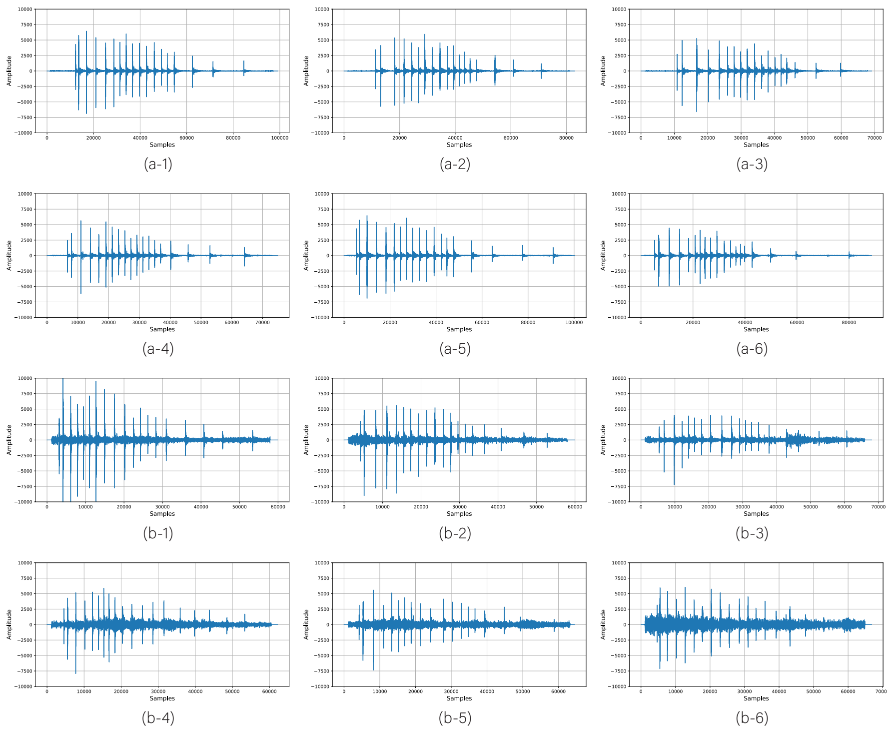

Fig. 7 Other recording samples in different noise level. (a-1)–(a-6): 30 dB, and (b-1)–(b-6): 70 dB.

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