The “Hula Hoop” Scanner

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***Abstract*—In medicine, sports, bodybuilding, dressmaking etc, it is necessary to reliably measure human body. The device here presented can estimate without physical contact the perimeter of human body parts as waist, thigh, biceps etc. It can also measure the circumference of objects like tree trunks. The device actually scans the shape of the object’s cross section and the perimeter measure is a byproduct. We think that the shape of human body provides much more information than simple perimeter measure, and may have many applications.**

***Index Terms*—circumference measure, body measure, waist measure.**

I. Introduction

Measure of circumferences or cross-sections are used in many areas, like medicine, sports, clothing industry etc. A common example is the measure of waist circumference, a topic of intense study in medicine, linking larger waists with a higher risk of premature cardiovascular disease. The so-called “abdominal obesity” was strongly associated with an increased risk of diabetes, cardiovascular disease etc. [1], [2]. The prototype here described was developed having in mind waist measurement.

The device here presented is a system that can estimate the shape of convex or smoothly concave objects. The principle is basically the discrete measures of various segments from a circle to the object inside it (See Fig. 3).

The simplest way to measure such objects is with the help of a tape measure. The device here proposed have some desirable characteristics not present in the tape measure:

- Automation: It permits automatic measure and can guide the user to correctly position the device (correct height of measure, for instance). It allows to create profiles for various users, store history of measures etc.
- Precision: It performs hundreds of measures in a short time. Consequently, it can take into account, for instance, the breathing that changes the size of the body and make a decision based on all the measures.
- Contactless: It isolates the body from the sensation of the tape touching it, permitting a freer posture. A requirement of the ultra-sound measurement is that the person should use a tight clothing at the position being measured.

II. Device Description

The device is formed by a circular structure and very cheap HC-SR04 off-the-shelf ultrasonic range finders (i.e., sensors that measure distance between them and the frontal obstacle) are mounted in the inner side of this structure. Its shape resembles greatly a “hula hoop”. Any range finder can be used, being restricted only by design aspects – the principle remains the same. The object to be measured necessarily have to lie inside the scanner.

Fig. 1 shows the prototype where the distance measuring sensors were mounted at the inner side of a bicycle rim. This prototype uses 36 sensors and an Arduino Mega 2560 [3] controls the sensors, performs the readings and sends the measured results serially to a microcomputer, where the remaining processing takes place. A digital mockup (Fig. 2) was developed, where all the electronic parts are embedded and a display guides the user in the measurement process.

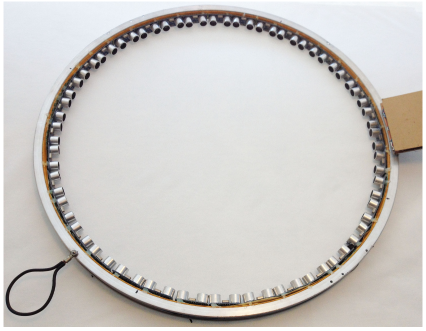

Fig. 1. Prototype of the “hula hoop” scanner. We mounted 36 ultra-sound distance measuring sensors at the inner side of a bicycle rim. At right, there is a board with auxiliary circuitry and connectors to the Arduino.

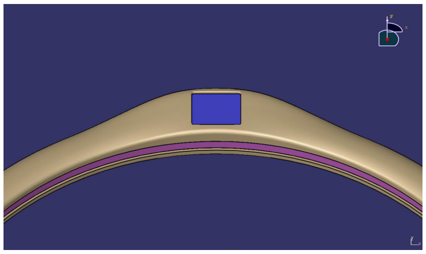

Fig. 2. Digital mockup of the device. The display can guide the user in the measurement process.

III. Calibration

There are some measurement inaccuracies that must be minimized, related to: (i) instability of the sensor itself; (ii) angle between the sensor and the object (incidence angle);

(iii) assembling of the device; (iv) movement of the device when measuring. We devised a calibration system to greatly reduce these problems. We use physical models of waists of real persons and other models like cylinders of several radii. We measure them with good precision and present them to the scanner in diverse positions. We train an artificial neural network with the models to produce corrected shapes by learning from the examples. After the calibration, we use a Kalman filter to estimate a constant value for the perimeter.

Many frames are acquired in a perimeter measuring session, until the software reaches a stable result. Fig. 3 shows a frame of a measure session (that consisted of 160 frames). The raw readings (red) do not correspond to the true shape of the waist being measured. The blue plot shows the corresponding calibrated measure.

Fig. 4 shows all the 160 perimeter measures of the session. The uncalibrated measures are depicted in red, the calibrated measures are depicted in blue and the final circumference estimates (obtained by Kalman filtering) is depicted in black.

The histogram of measures of the session (Fig. 5) makes it clear that the calibration and the Kalman filter increases the precision.

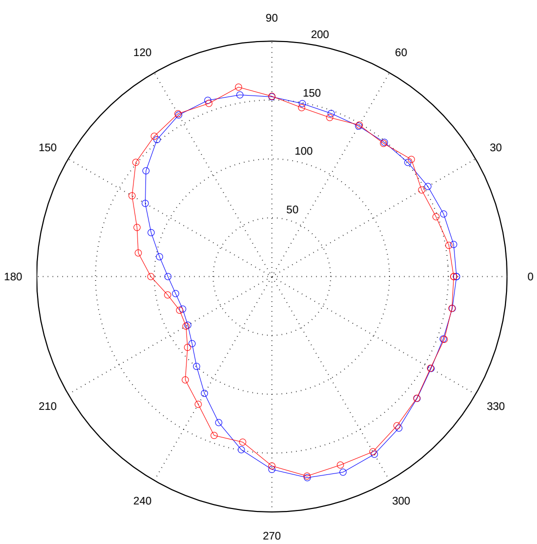

Fig. 3. Single frame of a waist perimeter measuring session. (Red) Raw readings from the sensors. (Blue) Calibrated readings.

IV. Acknowledgements

We would like to thank Alexandre de Souza Faria for the digital mockup design.

V. Conclusions and Future Researches

The method and device here presented can measure the circumference of objects and human body parts, like waist circumference. Actually, it can scan the shape of the object's cross section. Further research is necessary to relate the accuracy obtained using distinct models of sensors and to model the interference of clothing.

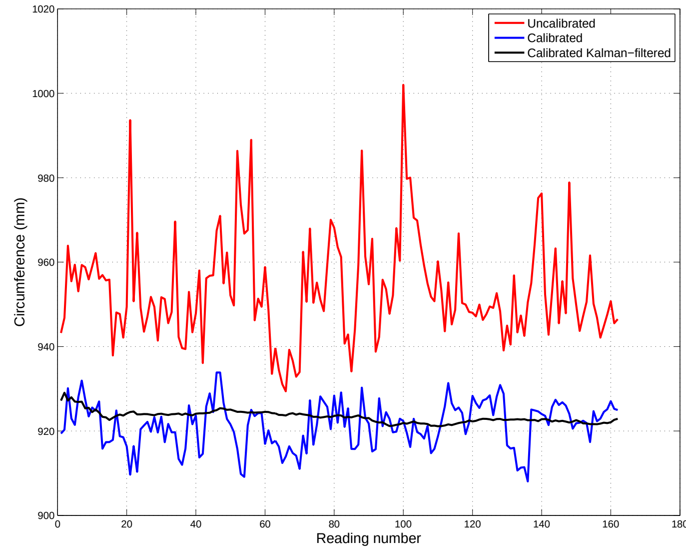

Fig. 4. All 160 measures of the session that measured the perimeter of a man's waist. Uncalibrated measures in red, calibrated measures in blue and Kalman-filtered measures in black.

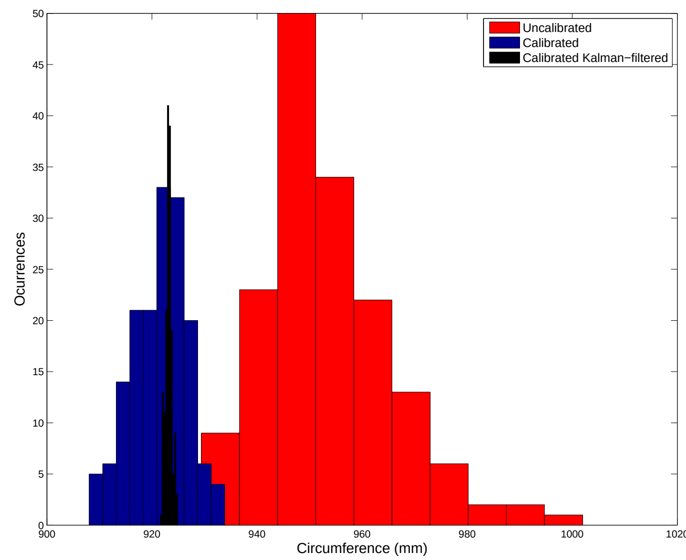

Fig. 5. Histograms of the measured perimeters. Raw readings in red, calibrated readings in blue and Kalman-filtered readings in black.

Appendix

This device has a patent deposited in INPI BR1020130194522, July 31, 2013.

References

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