Demo Abstract: A Smart Ring Monitoring Your Health using Hand-grip Strength

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ABSTRACT

Hand-grip strength is a widely recognized indicator of muscle strength and overall health of individuals, particularly among older adults. Hand-grip strength measurements are typically obtained using dynamometers or specifically tailored devices, limiting the context in which measurements can be taken to health checks and clinical settings. In this demo, we showcase a new smart ring, namely HIPPO. The smart ring implements an innovative approach that offers a non-intrusive and opportunistic way to extract hand-grip strength measurements from individuals. HIPPO re-purposes off-the-shelf light sensors available in existing wearable devices, e.g., smartwatches, and exploits the principle of light reflectivity, such that as an individual interacts with everyday objects, changes in their surfaces can be used to derive the hand-grip measurements.

KEYWORDS

Light reflectivity, Hand grip strength, Smart ring

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1 BACKGROUND

The human hand is an incredible natural engineering wonder that performs essential daily tasks and is a powerful indicator of our overall health. Hand-grip strength, measured by the force applied by hand muscles when squeezing an object, provides insight into the integrity of a complex network of muscles that extend beyond the hand itself. This seemingly straightforward measure goes beyond the hand, offering a valuable assessment of overall muscular strength and health. Research has shown that hand-grip strength is associated with several health conditions and diseases, including cardiovascular health, cognitive function, mortality and muscle loss to mention some [1].

Existing methods for assessing an individual's hand-grip strength pose usability challenges due to their limited applicability and their need for specialized equipment. For instance, the most common approach involves using a dynamometer, which provides a categorical assessment of hand-grip strength (e.g., weak, normal, strong) based on established reference tables derived from extensive clinical studies [1]. Using the dynamometer and other specialized devices limits the number of measurements taken over time as they require to be taken in a controlled (clinical) setting. In this demo, we showcase a new smart ring, namely HIPPO. The smart ring uses an innovative light-sensing approach to extract hand-grip measurements from individuals in a non-intrusive manner. Indeed, as people interact with various everyday objects, HIPPO leverages these interactions to obtain hand-grip measurements opportunistically. We demonstrate in this demo the performance of our smart ring to extract hand-grip measurements from different objects, including a disposable cardboard cup, plastic cup and washing sponge. Measurements are validated using a dynamometer baseline (ground truth).

2 THE HIPPO METHOD

The HIPPO [2] method to extract hand-grip measurements is illustrated in Figure 1. A light sensor (comprising a light source and a photoresistor) is worn on the user's hand (little finger), integrated into the exterior of a smart ring, and is used to measure changes in light reflectance as the user interacts with malleable objects (Figure 1(a)). When the object is held normally in the hand, its surface covers the light sensor, resulting in an approximately constant intensity of reflected light (Figure 1(b)). This constant value serves as the reference value to derive hand-grip strength. As the user applies grip on the object, the surface changes, influenced by the applied force and the object's material resistance (Figure 1(c)). These alterations in the object's surface impact the intensity of the reflected light, resulting in a fingerprint of reflection patterns on the object's surface. HIPPO monitors the changes in light reflectance and estimates the hand-grip strength from these changes.

3 SMART RING PROTOTYPE

Prototype: We have designed a prototype of a smart ring that incorporates light sensors consisting of a red laser diode (650nm, 5mW, 3-5V) and a photoresistor (5MΩ). These sensors are easily integrated into a flexible 3D printing ring design. The ring connects

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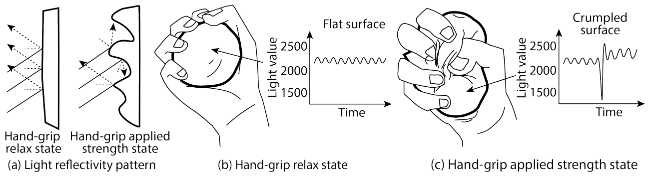

Figure 1: HIPPO overview.

to a computing board, which analyzes the incoming light data. We utilize the wireless M5StickC PLUS ESP32 development board for the computing board (Figure 3 (a)). This board controls the light sensor's sampling frequency (5Hz) and uploads the collected data to a centralized server in real-time. Changes in light are then read in analog voltage, and subsequently transformed to digital one. The M5StickC Plus has built-in Wi-Fi connectivity, a 120mAh battery (3.7V), and an LCD screen to display the board's activities.

Mobile application: We have developed an Android mobile application that receives and analyzes the data collected from the smart ring. The application provides a graphical interface that communicates to individuals its hand-grip strength (Figure 2). Besides this, the application also adopts the user-friendly and categorical standards used by the dynamometer, such that hand-grip strength measurements are fairly intuitive to understand.

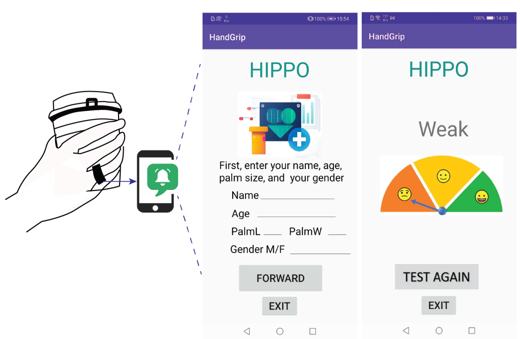

Figure 2: HIPPO smart ring and mobile application.

Demo procedure: Before starting the demonstration, hand dimensions are measured from the individuals wearing the ring. Following this, we gather essential participant information to enter the mobile application, including name, age (in years), gender (M/F), and hand dimensions (breadth and length in centimeters). Notice that this information is also collected when measuring hand-grip using the dynamometer in clinical settings, allowing better estimations of hand-grip strength. After this, a baseline of hand-grip strength is obtained from the participant using the dynamometer. To do this, the participant is instructed to maintain a seated position on a chair, ensuring both feet remain in contact with the floor while the back remains against the chair's backrest. The participant is also instructed to use its dominant hand and maintain its elbow to a precise 90-degree angle throughout the assessment. Once the measurements are obtained, the participant is instructed to wear the ring and perform the same procedure. This allows us to make our results comparable between approaches.

When providing hand-grip strength measurements using the smart ring, the participant needs to hold an object and initiate the measurement process by pressing the "START MEASURING" button on the app. Subsequently, the app acquires data from the smart ring and awaits stabilization, typically taking approximately 30 seconds. Once the app shows " ✓" symbol, the participant then needs to squeeze the selected household object with the maximum grip force for 2 to 3 seconds, then release the grip and push the "STOP MEASURING" button on the app. Following this procedure, participants can visualize their hand-grip strength displayed on the app interface and opt to save the data if desired.

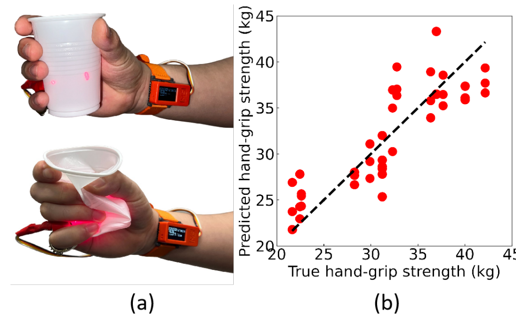

Figure 3: Smart ring prototype; a) HIPPO in action, b) HIPPO performance

4 DEMONSTRATION RESULTS

HIPPO prediction models: HIPPO prediction models are built using classical regression and classification machine learning algorithms. These models are trained with the data of 14 participants (equal genders) and considered three common household objects (disposable cup, plastic cup and kitchen sponge) for the experiments. Please refer to our paper to obtain more details and insights about the performance of our models [2].

Results: Figure 3 (a) shows hand-grip strength extracted from a plastic cup. Besides this, Figure 3 (b) shows that hand-grip strength measurements obtained by both, the dynamometer (True hand-grip) and the smart ring (Predicted hand-grip). From the figure, we can observe a fair linear relation between the two methods, suggesting that hand-grip estimations are correct even in different ambient light conditions and sources. Indeed, our experiments were performed in different scenarios, considering different ambient light and types of grip. Overall, the accuracy for the hand-grip strength prediction is around 91.9%. Lastly, measurements obtained by the smart ring are visualized through our mobile application for the convenience of the user.

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