WEIGHTBIT: An advancement in wearable technology

Guida, D. and Basukoski, A.

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Dario Guida
Computer Science and Software Engineering
University of Westminster
London United Kingdom
dario.guida@my.westminster.ac.uk

Artie Basukoski (ORCID 2-2670-8598)
Computer Science
University of Westminster
London United Kingdom
a.basukoski@westminster.ac.uk

Abstract—**Wearable devices are becoming an important interface between users and fitness activities. Their capabilities are improving exponentially, and new strategies are being developed to track sports using sensors that are widely used in robotics. These wearable gadgets are normally created in conjunction with smartphone applications enabling the user to visualise the data and share it through social networks, or compete with other users. The technology behind these devices is often simple using sensors that can be found in a smartphone, such as GPS, accelerometer and gyroscope. However, there are currently no devices capable of measuring the gym activity of weight lifting. In this paper, we present WeightBit: a system consisting of technologically enhanced gym gloves, comprised of the aforementioned sensor's as well as an additional weight sensor to detect weight and arm movements. Using this data in combination with a smartphone application, it will be possible to monitor a new series of sports activities with specific focus on weight training. Furthermore, the data collected by the application will enable broader research by medical researchers or institutions. The goal is to keep users focused and keen to live a healthy life, providing them a great tool to track their progress, and to develop a system that will allow medical institutions access to this data for further study.**

I. INTRODUCTION

Health and fitness are increasingly becoming a part of people's everyday lives. With a greater awareness of the direct correlation between health, fitness and different medical conditions, it is no wonder that people are becoming more committed and invested in achieving their optimum health.

This greater focus on healthy living is in no small part due to the large quantity of information that is now available through the use of the internet and access to social media. In conjunction with the massive boom in wearable devices, which is supported by ACSM listing wearable technology as the No. 1 trend for 2016, there is no doubt that wearable devices have become a must have gadget for those tracking their fitness and training activities. A survey undertaken by GFK in 2016 across 16 countries shows that 33% of people currently track and monitor their fitness via an online app or device.

These wearable devices detect basic fitness activity through their inbuilt Global Positioning System (GPS), accelerometer, gyroscope and heartbeat sensor technologies, which are linked to a custom smart phone application providing the user with a visual display of the data. This wearable technology has effectively taken fitness out of the four walls of the gym and into people's everyday lives. They have handed ownership directly back to the individual user helping to maintain constant engagement with their personal fitness activity. They offer regular reminders and incentives to keep people motivated and invested in their own development.

However, further research and experimentation could provide a possible solution to evaluate performance and muscle gain for the upper arms that can be applied for both recreational activities in the gym as well as medical purposes such as physiotherapy.

In 2014 Apple Inc. announced the launch of their Health Kit Framework at their Worldwide Developers Conference (WWDC). The main purpose of this framework is to provide a platform that can collect meaningful data such as heart-rate, calories burned, blood pressure, blood sugar and cholesterol. The data can be automatically shared with medical institutions or hospitals using an iOS application, enabling them to monitor their patients remotely.

This Health Kit framework is still in its infancy, with a majority of the data collected still only being shared between users on social media or proprietary frameworks. This valuable data is rarely shared with medical institutions for further research and statistical analysis, and it is typically not platform independent. However, as these frameworks become more common in our medical establishments, it has the potential to revolutionise the way medical treatments are managed.

The use of wearable devices and performance tracking is commonplace in more cardio based fitness activities but the ability to track arm movements and weight lifted using wearable devices still remains a relatively unexplored area.

Strava, is an example of an existing application which records user's activities. It combines data retrieved from the GPS embedded in the phone to calculate distance run or cycled, and compares performances over time. It also has a social feature that allows the user to connect with Strava's

community and share results and data related to the user's activity. There is also the Apple Watch version for Strava which enhances the capabilities of the phone application allowing the user to retrieve the heart beat through the watch' embedded sensor.

Furthermore, Strava provides a set of API's to help software developers to include Strava user's data in their software.

The WeightBit App seeks to offer further functionality by providing an application that allows users to track their weight lifting activity through the use of a smart glove with inbuilt sensors. This App will create an interface between the user and the glove, allowing data to be retrieved via a Bluetooth connection. Once the user begins an activity session, the application will automatically start listening for incoming data and will store the data in the device database. When the user finishes the activity session, the application displays all the data collected giving the user a detailed report of the activity by displaying: weight lifted, type of exercise, repetitions, and heartbeat. The application will also synchronise this data with an external database where users' data will be stored and reused by a web application.

II. MOTIVATION

There are four key areas that the WeightBit Application intends to focus on. The first, is to help people stay focused and motivated in achieving their fitness goals. Leveraging their interest in tracking activity and rewarding users with virtual badges or encouragement to keep pushing their limits.

The second is to automate repetitive tasks such as inputting data into a fitness application (i.e. fitness app requires user to input the exercise, repetitions and possible weight lifted) that could discourage the user and act as a barrier to use.

The third is to create a reusable technology that is applicable in the medical sector (i.e. physiotherapy). The fourth is to create a standard, which could be adopted by different companies that produce wearable devices, to share these valuable data for medical research or medical statistics.

Weight lifting is increasingly becoming recognised as a fundamental element for success in the world of fitness, both in the professional arena and in everyday life. Weight lifting and resistance training are generally recommended as key components in any training program. Not only are they essential in the weight lifting arena but there is also the focus on building strength to improve performance in endurance sports such as running.

The benefits of weight training are also fundamental to ensuring optimum health. Inactive adults will typically see between a 3% and 8% loss of muscle mass per decade which can be easily avoided with a regular weight lifting program. Resistance training can also help increase metabolic rate by 7% which helps to minimize muscle loss.

Weight lifting can also help to preserve and advance muscle mass and bone mass which helps to reduce the risk of osteoporosis, by significantly slowing down if not completely halting bone deterioration. The regular activity of weight lifting also helps to decrease the risk of injury, by building muscle to protect joints helping to improve balance and enabling better co-ordination, which is crucial as people age to help guarantee they can maintain an active and independent lifestyle for as long as possible.

Resistance training can also help increase metabolic rate by 7% which helps to reduce body fat and burn calories more efficiently, resulting in healthy weight loss minimizing the risk of conditions such as heart disease, strokes and diabetes.

Tracking weight lifting in both fitness and health based activities is very important as it allows the user to remain engaged and focused on their own fitness and development.

It enables users to see their progress in real time and in doing so motivates the user to persevere, which is crucial to see the optimal benefits in all these fields.

Whilst tracking weight lifting and strength training can play a key role in improving fitness and health it can also be applied to physiotherapy and rehabilitation after injury. Rehabilitation requires regular activity, most of which will need to be undertaken outside the physiotherapy office. Therefore, having a way to accurately track progress both for the patient and the physiotherapist has many benefits. It allows the patient to remain motivated, which is one of the key advantage for people who use wearable devices. It could also help speed up treatment as it will help to ensure that the patient does not miss any sessions in their own time, as they know it will be tracked and reported to their doctor. It also allows both parties to monitor the activities remotely which allows the professional therapist to work efficiently, potentially reducing the number of visits required and in turn being able to treat more patients, whilst allowing the patient to fit their rehabilitation more readily into their lives with less trips to and from the physiotherapist office.

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III. THE GLOVE

To automatically collect data from individuals during their fitness activity without resorting to sophisticated tools, a simple technology must be applied to common tools used during the activity, in this case a gym glove.

Most people that attend the gym for weight and resistance training will usually use gloves to protect their hands against brush or excoriations. Therefore, applying sensors and a small circuit to the gloves will enable them to become the main entry point to collect data.

Detecting weight and type of movement requires three sensors to work together. The first is a weight sensor, which will measure the weight that is used. The second is an accelerometer to calculate the change in g-force in the three axes X, Y, Z and the angle that has been produced by the movement. The third sensor required is a gyroscope which will detect angular position around the three axes and in combination with the accelerometer, which detects the gravity vector, will allow the software to determine what type of exercise is in progress, constantly checking and comparing the angles and rotations produced.

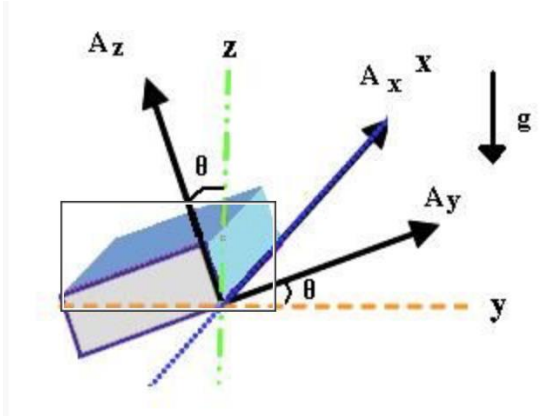
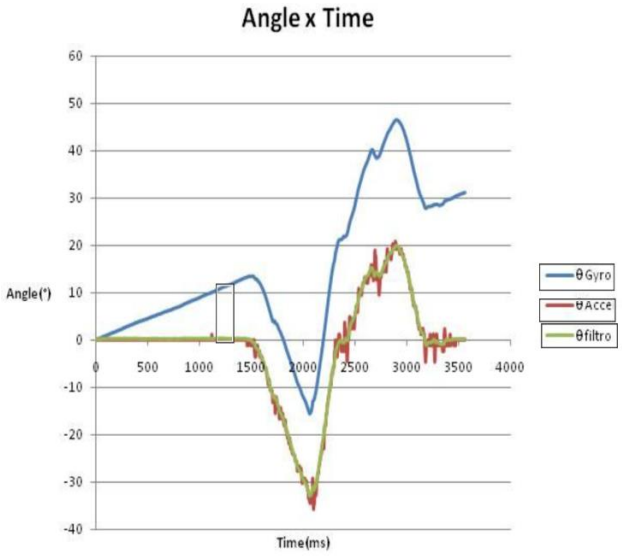


Fig. 1 Accelerometer 3 axis

Fig. 2 Differential measurements taken with gyroscope and accelerometer and complementary filter for the same angle



As shown in the figure 1, it is possible to calculate the angle, given 3 axes using this Eq. (1) :

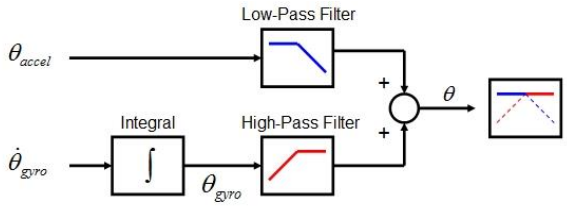
$$\theta = \tan^{-1}\left(\frac{y^2}{\sqrt{x^2 + z^2}}\right)$$

but as figure 2 shows the accelerometer is prone to interference due to its sensitivity to a force change. On the other hand the gyroscope is prone to another interference, called drifting, which makes the gyro to not return to a zero value when it goes back to its initial position.

Combining the signal of the gyroscope and the accelerometer, it is possible to achieve a complementary filter which gives a stable angle estimation.

As figure 3 shows the data coming from the accelerometer are processed with a low pass filter and the gyroscope data is processed with high pass filter, the combination of these two is called a complementary filter.

Fig. 3 Complementary filter



The mathematical formula behind the complementary filter applied to the accelerometer and gyroscope is

$$\text{angle} = 0.98 * (\text{angle} + \text{gyro} * dt) + 0.02 * \text{accelerometer}$$

The gyroscope data is integrated every 10 milliseconds (the sample rate) with the current angle value, and it is summed with the low-pass data from the accelerometer. The accelerometer data is just the angle in degrees calculated with the arctangent of the accelerometer value of x over the accelerometer value of y. The time constant (0.98 and 0.02) can be used as boundaries between gyroscope' s value , and the accelerometer' value.

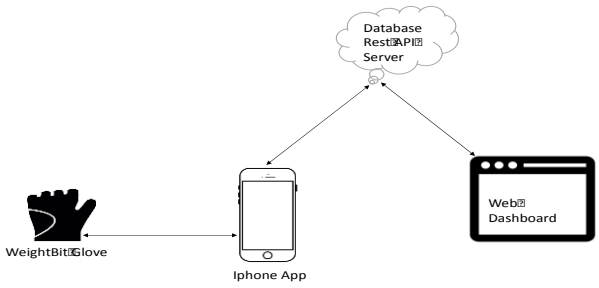
IV. THE APPLICATION

The glove needs to be connected to a device that can read, process, display, and share the collected data. The iPhone is the ideal candidate for this, providing a mature and efficient framework to work with.

All the inputs collected by the sensors are streamed via Bluetooth to an application that will interpret and store the data inside the iPhone database whilst also synchronizing and updating an external database to provide data to the web dashboard through an API.

Figure 4 shows the architecture of the WeightBit system and how all components are connected to each other.

Fig. 4 WeightBit System Architecture



The WeightBit application takes advantage of the Health-kit framework developed by Apple, helping the user to understand the progress made within a visual representation of the data in simple graphs. As an extra feature, it is also possible to connect the application to an Apple watch, to retrieve heartbeat data during the activity session and calculate calories burnt.

This technology is not only for use in a gym environment but can also be applied to the medical profession. Specifically, within physiotherapy, where the glove can be used to track the progress of a patient under rehabilitation after an arm injury. The application is a fundamental part of the ecosystem, providing a connection between the user and the glove and between the user and the doctor or medical practitioner who will observe and study the data. As previously mentioned, the data will be collected by the phone but will be anonymised and saved in an external database that will be available to medical institutions for further study or research, always guaranteeing anonymity for the users.

Fig. 5 WeightBit Ios Application Main GUI

V. How to Share Data

There are two ways of sharing and displaying data with via the http protocol. They are Json and Xml, both are widely used and both have advantages and disadvantages. Json is the most popular due to its clarity and simplicity, but for a doctor or a researcher it is not always easy to understand how to use the data in this format, or more importantly how to retrieve this data.

If every technology company that produces wearable devices decided to make data available in different formats and different standards, most of the data would go unutilized, due to the complexity in remembering how to retrieve and manipulate it. To overcome these problems a standard must be adopted to facilitate and help researchers and doctors use this data for their studies.

There are standards in web development that specify how data should be represented in order to make it available and consumed by developers and it works perfectly for those who work in software or web development. Usually to retrieve data from a service through the web an Application Program Interface (API) is used and it looks like

"https://domainname.com/api/service?serciseId=nameOfResource&secondService=nameOfSecondService".

It is essentially a Uniform Resource Locator (URL) with parameters to query the server. The more details that are needed, the longer and more complicated the query becomes.

People that need to retrieve and consume this data, shall be provided with an open on-line platform where data can be queried and sorted easily. WeightBit will provide a Rest API to make it easier for medical institutions to interface to this data, whilst ensuring security and anonymity for those sharing the data.

One of the key ways that WeightBit attempts to serve data is by providing basic or advanced filters on the server side to find data. By using meaningful and simple words in the Url, such as:

https://weightbit.uk/api/2016/man/25-45/heart

those searching through the data will be able to locate it easily. The example shows the Url uses simple words to describe a resource by filtering a set criteria for heartbeat data of all men between 25 and 45 years old during year 2016.

The Rest API will deliver raw data in Json format and despite the capabilities of filtering the data through a powerful API, the usage of the data is still limited in its raw state. The data must also provide meaningful information to an analyst using graphs or pie charts to allow quick and clearer understanding.

Taking advantage of Scalable Vector Graphic (SVG) combined with the data provided by the user using the Weightbit application, the web-dashboard will enhance visualisation of the data by providing a variety of graphs, to describe performance and progress over time.

Fig. 6 Web Dashboard WeightBit

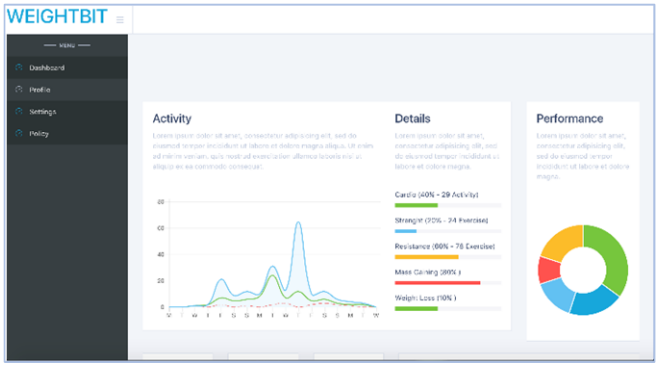


Figure 6 shows an example displaying a user's activities and performances using SVG graph and pie charts.

The dashboard will be a useful tool for professional physiotherapists and trainers providing them with meaningful ways to visualise the data. It will also allow them to filter tracked progress enabling them to provide immediate and more relevant advice to patients or athletes.

VI. Possible Usage of Machine Learning

When there is a high volume of data available, machine learning is one of the most useful tools to analyse this data and try to find a pattern that can be the key to both solving and spotting problems. If we think, for example, how hard it is to detect a type of exercise by just looking at the angular movement of the arm: people move in different ways and have different levels of strength, therefore a single hard coded algorithm is not enough to cover all these possible differences. Furthermore, with increased variables at play, bugs are more likely to impact the usability of this technology.

Machine learning in this context is the solution to solve this problem. It will be used to detect patterns in movement, which are unique to each individual user, and it will adapt and help to increase the types of exercises that are detectable by the glove. It could also provide analysis of possible physical improvements during a set timeframe, such as muscle loss/gain or possible cardio problems.

There are two possible approaches to implement machine learning. The first is using a cloud platform where the data stored or streamed into it is analysed by embedded machine learning tools (i.e. Microsoft Azure Platform). The second is to implement the machine learning within the iPhone application itself.

The first solution will allow for adjustments, improving the application generally and will be able to produce an accurate analysis of all users' data and enhance the algorithm's ability to detect different types of movements, but it will also be less accurate for each individual user. The second will improve the accuracy of measurement for individual users, and could allow for customization of the types of exercise that can be monitored.

VII. Strategy to Keep User's Using the App

1) Usage for in fitness/gym scenario

Key aspects to succeed in keeping the user using the applications over the time are:

- Provide readable and pleasant visualisation of data through simple graphs.
- Remind users to take a weekly challenge by offering reward such as a badge or points
- Avoid difficult setup or configuration to use the application
- Embrace its technological ecosystem (i.e. if the user uses an iPhone, chances are they also have an apple watch, hence provide an apple watch app that can be used instead of an iPhone).

2) Usage in a medical scenario

Key aspects to succeed in keeping the patient using/ understanding the applications during their rehabilitation:

- Daily remainders of the activity
- Direct communication with the doctor
- Automation of the process (the patient needs to perform the exercise routine prescribed by the doctor)
- Rewards and encouragement during and after the exercise
- Visible progress and notified countdown to the end of the treatment

VIII. Web Application

Most of the fitness apps, such as 'Runtastic', 'Runkeeper' or 'Strava' offer a web version of the iPhone app. These web apps provide the same data as is stored in the iPhone but take advantage of a wider screen size providing an overall better user experience in terms of visualizing and displaying the data. WeightBit will provide a dashboard-type web app that will help the users to understand, filter, sort and share data within a visual environment.

This dashboard concept could also be used as the interface between doctors and patients, where both can access, interact and monitor progress which is fundamental towards achieving physical rehabilitation. Furthermore, there will be less necessity for the patient to go to the hospital or clinics to check their status, hence decreasing the gap between the number of available doctors and the number of patients requiring appointments.

IX. Conclusion and further development

The Weightbit platform has been designed specifically to help people track their gym activity, automating the process of inputting data into a smartphone application, visualising progress over time, and sharing data with medical professionals or trainers. Weightbit also empowers people, giving them a tool to improve their fitness activity and keep them focused on a healthy lifestyle.

The future developments must primarily focus on the hardware part, the first iteration of the glove is a prototype made with an Arduino board, all the sensors used are separate modules connected within the main board and the sensitivity is poor. The base code that controls all the sensors must be rewritten to embrace efficiency in how component parts communicate between each other. Furthermore, all the sensors must be embedded in a miniaturised circuit designed to be resistant to sports activity.

One other important area which has to be improved is the algorithm to detect precisely which type of exercise the user has performed, possibly finding common patterns through the data that the glove will measure.

The final area which needs further development, is the dashboard, which can be incrementally improved to allow medical professional, physiotherapist or trainers to customise the displays for their needs. There is also the possibility to develop a desktop application.

With ongoing research to enhance the applications ability to recognise arm gestures, and by further development utilising improved hardware, WeightBit has the potential to combine medicine and sports, and put it in the hands of everybody.

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