Improving cardiovascular health and fitness levels by optimizing workout efficacy with a microprocessor controlled, cloud connected device

Alisha Saxena
Senior, Interlake High School, Bellevue, WA

1. INTRODUCTION

Whether the goal is to lose weight or to become an Olympian, people often carry a wide assortment of fitness tracking and motivational devices to help generate the best workout for their body. These devices are generally expensive, error prone, and do not work well with each other. There are devices that monitor fitness data such as distance traveled, calories burnt, heart rate, etc. but they are costly and offer fragmented capabilities. There is no one device that combines or analyzes multiple datasets to provide customized workout plans tailored to the unique needs of each individual.

Advancements in microprocessor and electronic sensor technologies, near ubiquitous connectivity to the Internet, and the availability of high computing power in the cloud open up many new opportunities to improve the workout experience. The goal for my research is to create a device that can combine the necessary health monitoring and motivational functions, as well as analyze and find patterns in workout logs to provide individualized recommendations that help users exercise at optimal intensity levels.

2. BACKGROUND AND RESEARCH

Since music is the most commonly used motivator during exercise, I found that the advantages of using music with exercise go far beyond just enjoyment. Most notably, I discovered two important facts:

- Research[1] has consistently shown that the synchronization of music with repetitive exercise is associated with **increased levels of work output**.[2]
- In addition, several studies[3] have shown that by listening to **high tempo music that is synchronized with the activity**, results such as the number of miles biked within a specific time period or the running speed improved by 16%.[4] [5]

3. APPROACH AND UNIQUENESS

My research revealed two encouraging facts

- Music is a great motivator and helps make exercise more efficient **especially when played in rhythm with the workout.**
- In my market research, I found that there is an emerging class of expensive, electronic devices that log specific workout data. However, the market is fragmented, with no standards for combining the daily activity logs and providing useful feedback to help individuals optimize their workout routine based on their health and fitness levels.

Most importantly, people need to carry multiple devices, and **there are no devices in the market that leverage the benefits of synchronizing music rhythm with activity levels to improve exercise effectiveness.**

3.1 Design goals

- Prototype an integrated microprocessor controlled device with built-in connectivity to the Internet
- Play music in tandem with the selected exercise program or vice versa. The prototype offers two distinct modes of operation:
  a) **Music drives workout intensity:** In this mode the user selects a preprogrammed workout routine e.g. “hill climbing”, and the device continuously monitors the user’s heart rate and selects an aptly paced song to help

[1] Reynolds, Gretchen. “Phys Ed: Does Music Make You Exercise Harder?"

[2] Harmon, Nicole M., and Len Kravitz. “The Effects of Music on Exercise”

[3] Sherwood, Chris. “How Can Music Affect Aerobic Exercise?”

[4] Karageorghis, Costas. "Music in Sport and Exercise: An Update on Research and Application."

[5] Harmon, Nicole M., and Len Kravitz. "The Effects of Music on Exercise”

increase, decrease, or maintain workout intensity levels and produce optimum results.

b) **Workout intensity drives selection of music:** This is an adaptive mode where the user controls the music type and tempo. As the person exercises faster the music changes to upbeat / high-tempo and as the user slows down the music switches to slower tempo music to match the desired intensity.

3.2 Development process

1. Combine functionality from multiple, separate devices used today into a single, integrated multi-purpose device which tracks steps taken using the accelerometer. The pulse during the activity will be measured using a pulse sensor, and music playback will be controlled using an mp3 decoder. Wi-Fi connectivity was implemented to upload activity logs to a website.
2. Program features using Arduino Sketch language on the Arduino microprocessor platform wired to the sensors. I developed a novel algorithm to program the accelerator to count the number of steps. The algorithm counts a step when the total vector displacement of the device was calculated to be greater than one. In mathematical terms, the algorithm assumes a step has been taken when $\sqrt{x^2 + y^2 + z^2} \geq 1$.
3. http://sensormonkey.com portal used to develop the website to track and share workout data.
4. To keep music synchronized with exercise rhythm, use the reading from the accelerometer to track activity intensity and combine it with Mp3 playback to switch music to higher / lower tempo based on mode of operation.

4. RESULTS AND CONTRIBUTIONS

4.1 Results

Overall, the prototype was able to meet all the design goals as demonstrated in this video: http://www.youtube.com/watch?v=NrTkFM5satQ

The fully-functional prototype validates my research goal that an affordable, yet more capable device can be developed using microprocessors to improve the effectiveness of the workout. The most significant and differentiating feature of my prototype is the effective use of the tempo of the music to increase motivation and enable exercising at higher intensity levels. This is a unique capability that is unmatched by the current market offerings.

To evaluate the effectiveness of this prototype, I conducted some user testing with emphasis on getting feedback on the design and features/functionality for the prototype. I use the device regularly myself and requested my friends to try it both outdoors and while using the treadmill. The feedback was unanimous:

1. **Design:** The spartan design with simple switches and LEDs instead of a display proved to be effective. People liked the switch-on-and-go design with the reliable reporting and the integrated capabilities in a compact package. They would like the device to be smaller, but that is understandable given that I used a breadboard instead of a PCB. If mass-produced, the device could be the size of a watch.
2. **Features/functionality:** The workout intensity monitoring features and easy upload to the web met the expectations of the users. More importantly, everybody loved working out in tandem with the beats of the music! I noticed that my run times improved by about 3% and some of my friends gave anecdotal feedback on the uplifting effects of the high tempo music on their workout routines. The music playing in concert with the activity levels was unanimously cited as the "best feature!"

Fig 1. Niki Waghani, a varsity cross country runner's 5K time improvement over 8 weeks of using my device

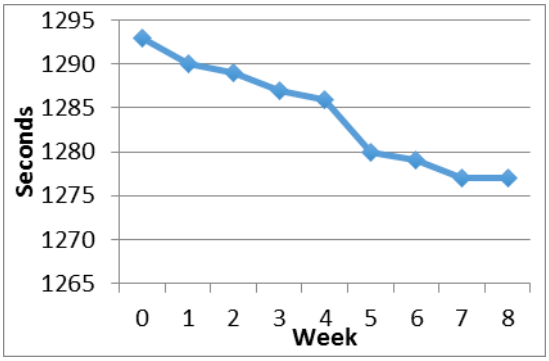
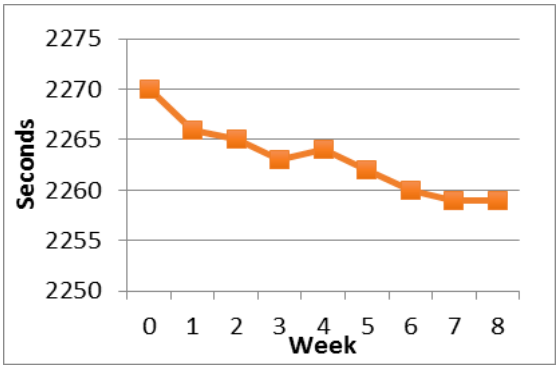


Fig. 2. Amrita Ballabh's 5K times while using my device to try and lose weight over a period of 8 weeks



4.2 Contributions

The contributions of my work are

- A compact, inexpensive device that helps users get more out of their workout and achieve their fitness goals faster.
- Opportunities to run big data analysis and machine learning algorithms to analyze exercise activity logs and find patterns to help improve workout efficacy for individuals.
- Incentivizes individuals to share their activity logs with health care professionals, friends and family. This could help health care professionals identify health related problems proactively. It could also help start a social network / community where individuals could share their workout playlists and music choices for exercise.

4.3 Future plans

Some improvements that can be made in the future are

- Port functionality to a smartphone. A smartphone application is already in development. It has most of the same functionalities as the original device, however it does not have the same level of simplicity as the device. The device instantly gives feedback at the flip of a switch, while the application requires a little more fiddling with the smartphone touch screen.
- Add additional sensors on the device. More sensors such as a blood pressure sensor, temperature sensor etc. will be added to offer the user a more complete picture of their vitals during the workout. All of this data will also be uploaded to the Internet so that it can be easily tracked.
- Switch from breadboard to PCB. The device is about the size of 2 iPod classics stacked, but it can be shrunk to the size of a watch if it were mass-produced on a printed circuit board.
- All of the data that will be uploaded when there are thousands or millions of this device out on the market can be analyzed for general trends. The big data analysis can help the device offer better, more personalized song and workout recommendations. The data can even be shared with friends or healthcare providers.

5. REFERENCES

Arduino. Arduino, n.d. Web. 31 Oct. 2012.

Bravata, Dena M. "Using Pedometers to Increase Physical Activity and Improve Health." *The Journal of the American Medical Association* 298.19 (2007): n. pag. *The JAMA Network*. American Medical Association, 21 Nov. 2007. Web. 13 Oct. 2012.

"Fitbit One." *Fitbit One Wireless Activity & Sleep Tracker*. N.p., 2012. Web. 15 Oct. 2012.

Harmon, Nicole M., and Len Kravitz. "The Effects of Music on Exercise." *Music and Exercise*. N.p., n.d. Web. 15 Oct. 2012.

"Health and Heart Rate Monitor for Wellness and Fitness." *Basis*. N.p., 2012. Web. 15 Oct. 2012.

"Heart Rate Monitor." *OMRON Webstore*. N.p., 2012. Web. 15 Oct. 2012.

Karageorghis, Costas. "Music in Sport and Exercise : An Update on Research and Application." *The Sport Journal* 11.3 (2008): n. pag. *The Sport Journal*. United States Sports Academy, 2008. Web. 15 Oct. 2012.

Marshall, Simon J. " Translating physical activity recommendations into a pedometer-based step goal: 3000 steps in 30 minutes." *American Journal of Preventive Medicine* (2009): 1-6. *National Center for Biotechnology Information*. U.S. National Library of Medicine, 17 Mar. 2009. Web. 13 Oct. 2012.

"Nike+ FuelBand." *Nike*. N.p., 2012. Web. 15 Oct. 2012.

Reynolds, Gretchen. "Phys Ed: Does Music Make You Exercise Harder?" Web log post. *Well*. New York Times, 25 Aug. 2012. Web. 15 Oct. 2012.

Scherz, Paul. *Practical Electronics for Inventors*. New York: McGraw-Hill, 2007. Print.

SensorMonkey. Vivid Spectru, 2012. Web. 15 Nov. 2012.

Sherwood, Chris. "How Can Music Affect Aerobic Exercise?" *LIVESTRONG.COM*. 29 Apr. 2012. Web. 15 Oct. 2012.

Sirkin, David. "Interactive Device Design." Electrical Engineering 47. Stanford University, Palo Alto. 2012. Lecture.

"Tractivity Products!" *Tractivity*. N.p., 2012. Web. 15 Oct. 2012.

"Tinké FAQ." *Tinké*. Zensorium, 2012. Web. 15 Oct. 2012.

Tudor-Locke, Catrine. "Taking Steps toward Increased Physical Activity: Using Pedometers to Measure and Motivate."*President's Council on Physical Fitness and Sports Research Digest* (2002): n. pag. June 2002. Web. 17 Oct. 2012.

"What Is Fitbug Air?" *Fitbug*. Fitbug, 2012. Web. 15 Oct. 2012.