The SmartPT

Wearble sensor integration and tracking in training equipment

Teddy Falsen Hiis
Westerdals Oslo ACT
Faculty of Technology,
Oslo, Norway
hiited14@student.westerdals.no

Tor-Morten Grønli
Westerdals Oslo ACT
Faculty of Technology,
Mobile Technology Lab
Oslo, Norway
tmg@westerdals.no

Gheorghita Ghinea
Brunel University
London, UK &
Westerdals Oslo ACT
Faculty of Technology
george.ghinea@brunel.ac.uk

***Abstract*—This paper describes the use of Internet of Things as a solution for personal training, based on NFC wearable sensors mounted on garment like gym t-shirts and smart training units. Instead of sowing in wearable technology to every possible body part in motion, our solution builds on a sensory system applied to the object in training — such as a training mat, a barbell or a rod. The described study is underpinned by a research gap of-which a prototype solution (SmartPT) is developed to fill. Furthermore, the planning-, design- and development processes are described. Lastly, novel lessons learned and challenges faced when developing SmartPT are discussed, as well as possibilities for future research.**

Keywords—wearable; smart clothing; IOT; internet of things; training; exercise

I. Introduction

Dedicated fitness trackers, heart-monitoring systems, GPS-tracking devices and activity bands are already available within the IoT (Internet of Things) application domain topics ‘health’ and ‘personal training’. The problem is that they are usually limited to exercise methods such as running and biking, which excludes people who are doing strengthening and muscle enduring training. To better train and motivate this group of people, this article presents and follows an application-led structure and contributes to the area through a prototype development and test.

Sensor networking technologies are increasingly used within the IoT application domain ‘health' but as research show, most use-cases are related to collecting medical data or patient-monitoring activities [10]. Within the subdomain ‘personal training’ though, the contributed services are mostly designed for tracking aerobic related training, which often are defined by elements such as speed or distance [12]. These kind of activities are usually measured though a single heart-rate and/or sensor GPS receiver. There is a clear research gap regarding muscle enduring training through non-GPS reliant data, such as muscle-strengthening exercises at a gym location. Both regarding training done on dedicated workout equipment, and regarding muscle enduring exercise done on a simple exercise mat in the gym, such as push-ups or sit-ups.

As mentioned, most services available are designed for GPS-activity related exercises. At the same time there is a trending spike in gym and personal training which is costly and little relatable to your digitalized, fitness tracking. Much of personal training activity takes place on the ground, on dedicated training mats or on exercise equipment inside a gym. These kind of training exercises involve coordinated motions of different body parts, exceeding how we are able to track motion and activity though services like FitBit and other similar technologies. The study is motivated by two main factors: (1) An increasing trend of spending dollars on personal training and (2) the fact that there is a research gap of how to measure training beyond speed and distance. The purposed solution is a wearable sensor, where the user simply can replace his/her normal gym t-shirt with the smart garment, which allows the monitoring to happen without any other sensors involved. The purposed solution is therefore a contribution to the expanding research area of personal training in IoT.

II. Background

A. The IOT paradigm

As we are moving towards a world of ubiquitous computing of such IoT solutions deliver, we are also able to predict a rapidly paced growth of sensor deployments in our dependent environments. Cisco estimates that our everyday life will consist of 50 billion devices connected to the Internet by 2020 [5]. Perera et.al. [4] refer to this as ‘the Internet of Things paradigm’ and explain how the IoT paradigm hold elements of multiple technologies and combine them in a communicational mix. This technology mix could contain components such as different kind of sensors, cloud technologies, hardware, network protocols and application layers. It is simply the requirements of the IoT solution in question, that defines the mix of technologies applied. When visualizing the evolution of Internet, starting with two computers interacting, we find some distinct phases before we hit the IoT paradigm, which is about interconnected objects rather than machines only. Furthermore, it is important to stress that IoT does not necessarily revolutionize our lives but allows us to interact with technology in an evolving way [4].

B. Architectural elements of IoT solutions

If we all are becoming connected, to anyone, anywhere and at any time, there are to be identified new application challenges when designing architectures for IoT solutions. The number of interconnected devices are increasing but the demand of providing connectivity is just one of the domains of- which architectural challenges are identified. In their paper ‘Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges’ Kahn et. al. [15] discusses key challenges related to IoT, with information privacy, scalability and identity management as examples. Related to architectural elements though, it's relevant to mention interoperability and standardization as key challenges. We find ourselves at the beginning of a new interconnected era, and for us to be able to achieve sustainable system interoperability and product quality we need to manage how most manufacturers are pushing their own technologies, without standardization strategies, which is limiting interconnectivity possibilities with other sensors or smart objects [9].

Because of the challenges that IoT brings regarding technology interaction and stack, we demand more of a generic IoT architecture than with any other developed solution. Kahn et al. [15] purposes a basic IoT model of-which include five layers, to grasp the essence of a system architecture. These are:

Perception Layer: often referred to as the 'device layer'. It holds information on the physical objects, sensors and corresponding measurement elements such as temperature, pressure or location. *Network Layer*: which manages how to transmit information from the device to a processing system. Elements could be communication protocols such as Wi-Fi, BLE or cellular networking technologies. *Middleware Layer*: it is the perception layer which builds the foundation of the IoT solution middleware architectural elements. Each objects communicational need is based on its ability to connect to other services, which makes the middleware layers' main task to manage the services and storing data. It can also be trained to make automatic decisions based on information processing. *Application Layer*: holds the global management of the IoT solution though objects information processed in the middleware layer. Applications could be oriented around domains such as health, homes, transportation etc. *Business Layer*: An IoT solution is also very much defined by the business layer. Models, analysis and results are managed though this layer.

C. *Applying wearable solutions to physical environments*

As mentioned, sensors are becoming smaller, even to the stage where they are not visible to the human eye. Within IoT research 'wearable technology' is a term that ranges between manufacturing clothing with micro technology to lesser high-tech garments, such as a smart-umbrella [1]. The common idea is that lightweight devices, wireless networks and information processing are elements of- which detect the state of its user and act accordingly [11].

Within the IoT application domain 'health', wearable solutions are mostly used to improve health monitoring systems with correlating sensor elements such a heart-rate and activity related parameters [17]. Although most wearable solutions found in literature are developed for medicinal purposes, there are some contributed studies showing how wearable technology can be used within personal training. One example is found in the paper 'MOPET: A context-aware and user-adaptive wearable system for fitness training'. Here Buttussi and Chittaro [7] present a wearable personal trainer platform of-which real-time data, coming from sensors, help monitor out-door physical fitness activities.

III. PROTOTYPING THE ARTEFACT

Prototyping SmartPT included the following phases: Research and scope, architecture and design, technology and development. A further developed version of SmartPT could bring some more of the desired features to life. This is the reason for including extended architectural elements to the paper, as well as information about the technology stack for future development. The following paragraphs include a presentation of the mentioned phases, to demonstrate demands and approaches in a IoT-driven solution. Based on personal interest as well as an identified research gap, the application domain 'Health', with the correlating subdomain 'Personal Training'. A literature search was done based on keywords such as health, internet of things, wearables, personal training, NFC, Sport tracking, activity recognition and pressure sensors. When defining a user scenario, the approach was to identify a problem definition, gather data on this problem, define business possibilities and lastly develop the actual scenarios.

A. *2.2 Architecture and design*

It is the previously developed user-scenarios that build the foundation an IoT architecture stands upon. In the case of SmartPT the following architectural components were created (Figure 1).

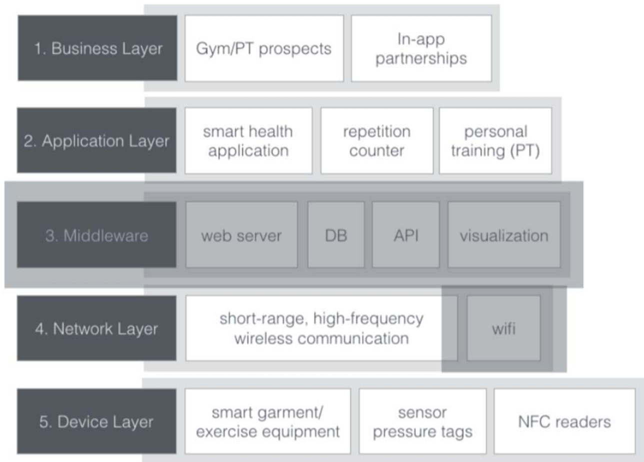

Figure 1 SmartPT system architecture

The identified user feature requirements of-which was developed was (1a) whether the solution is a low-price version of the service our user currently get through his/her personal trainer and (2a) whether the solution is easy to use. In addition to this, the solution architecture was motivated by two main factors: (1b) That there is an increasing trend of spending dollars on a personal training session of-which rarely brings value beyond those in-training minutes you share with the trainer him/herself. And (2b) the research gap of how to measure training beyond speed and distance, with a requirement of body-meet-equipment motions.

Based on the architectural model of Kahn. et.al [15] the following high-leveled architecture was developed (see Figure 1). Layers represent multiple elements such as devices or objects. The third layer (3. Middleware) is in this illustration disabled because of the prototype built. See more information regarding technology choices in the discussion below. Regarding NFC, the basic way of how an NFC dispatch system works is that the tag dispatch system defines three intents, which are run in order of highest to lowest priority; ACTION_NDEF/TECH/TAG_DISCOVERED (Priority 1, 2, 3), illustrated in Figure 2.

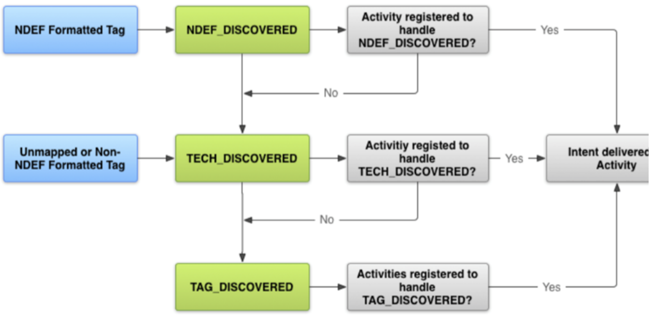

Figure 2 NFC dispatch system architecture (How NFC Tags are Dispatched to Applications, 06 April 2016)

B. UI sketches and design

Graphical design of the solution UI is a key element in the development of SmartPT. The reason is that for the prototyped version of SmartPT an Android-powered phone serves as the NFC reader and solution UI. The phone itself is actually faced down when the application is run, making audio a more relevant component to use for indicating change, than visuals. If developed further, there is relevancy in doing a complete re-design of the UI as the reader will no longer be a phone. UI of the solution will at this stage be more focused at enhancing workout progress and visualizing repetition data. The actual UI design of the SmartPT mobile application is presented in Figure 3. The initiated design sketches were followed in a large sense with current design trends of having a simple UI and very few focus-points to draw attention to the options the user has.

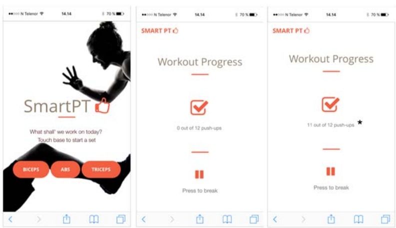

Figure 3 Mobile application design

C. Technological set-up

The prototype includes a set of double NFC sensors; A passive device (tag), more specifically, the tag series of NTAG21x, and an active device (in this case an Android powered phone). The tag holds enough memory for writing simple NFC record actions, and do not need battery functionality as they are provided with battery through NFC reader scans. The tags are programmable to have written any data from any Android powered smartphone or tablet device. The chosen software approach for this project was 'Bootstrap', a framework for quickly developing responsive, mobile first, applications. (Bootstrap, 05 April 16) Plugins needed, such as animations and audio were available with the use of jQuery JavaScript based libraries, and icons was made available through the Ionic-based font library 'Font Awesome' [8]. Data is stored using HTML5 localStorage, without affecting web application performance. Instead of sowing in wearable technology to every possible body part in motion, SmartPT is a sensory system of which applied to the object in training, such as a training mat, a barbell or a rod. In addition to this, the user simply can replace his/her normal gym t-shirt with the smart garment, which allows the monitoring to happen without any other sensors involved.

IV. RESULT AND DISCUSSION

Newest releases of NFC tags hold the '24-bit counters' feature which stores the number of times a tag has been scanned into a counter and can mirror this count dynamically back into the URL/output data [14]. This would mean reading the current NDEF message, increment the counter value and store the complete NDEF message back to the tag to save new information. As mentioned above, data is stored using HTML5 localStorage. For the reason being it solves the temporary task of counting workout repetitions. During the exercise, the NFC reader is counting NFC sensor usage meaning that every contact between the NFC reader (phone) and NFC sensor is counted (gym t-shirt). Although, the calculations did not include the fact that an NFC tag forces a new website tab to open with each touch. This caused complications regarding counting each set, though a sessionStorage element. A workaround here was to reset localStorage each time the repetition hit a specified set number, in this case 12. But this was not a pretty solution, and having done this again the option of using the 24-bit counters feature makes much more sense. The code-snippet in Figure 4 illustrates this workaround.

Figure 4 Code snippet highlighting local storage

Regarding storage, it is also worth mentioning is that information is never transferred to a server. An ideal approach is to set up a web-server using Node.js or similar, for visualization progress user-data through a service like Plotly or Tableau. This would allow the user to have better PT planning, execution and improvement of training results.

As mentioned above, the prototype was executed using an NFC readable Android powered smartphone. But this also calls for some issues regarding demanding the user to include his/her phone into the workout space, and also to develop a ubiquitous experience for the user. As a prototype, the Adafruit NFC Controller Shield for Arduino (or similar for Raspberry Pi) could be used to read tags [2]. In this case there is be a need for an IoT gate for communication and a networking setup, likely through a Wi-Fi shield.

Development of the purposed solution (SmartPT) was a successful despite the limited scope of the solution itself. The main reason for considering it a successful approach was seeing how SmartPT contribute to the literature reviewed and research gap found there. SmartPT is a wearable sensor system where the user simply can put on a gym t-skirt with the smart garment, which allows the monitoring to happen without any other sensors involved. This, including the lack of IoT based measurement systems for muscle endorsement training, is what makes the purposed solution a contribution to the ever expanding research area of personal training in IoT.

Results show great deal of value in utilizing on a trending hype of personal fitness. Regarding business prospect possibilities this could be as simple as personal trainers selling follow-up sessions through in-app digital services, a gym selling NFC enabled gym clothes, mats and other wearable supporting smart objects or even partnership with food appliers or training facilities. As the prototyping process of SmartPT happened, there was soon a realization of great potential in more features than executed on. Some examples are to provide usable training statistics. When analyzing these statistics, the user can create better personal training plans. SmartPT can integrate with activity tracking tools, such as Fitbit, Endomondo, Strava and gym specific applications for a combined training tracking experience [16]. The solution could suggest training programs and include videos for supporting new exercises. And lastly, the solution could have iBeacon BLE technology auto-detect the exercise or training units being used. In addition to adding weight enabled sensors, not only track repetitions but also kilos, for each repetition, inspired by Timofeev [13] and their study on tracking weighted training machines.

Market gap analysis show a need for this specific solution. But, there are some fundamental IoT challenges to comprehend; How to make these sensors discoverable, how to optimize the flow of information, how to standardize IoT environments on a large scale and how to manage the growing amount of monitoring data that is available. Developing SmartPT further could potentially take lead in answering some of these questions. Also, it could inhale great potential and commercial opportunities. In the case of doing so though, there is a need for re-designing the communication flow between NFC reader and the user itself. Beneficially the smartphone would be taken out of the equation and alternative technology would be used for middleware architectural layers, to suggestively store data in a web-server for usage and training progress visualization.

V. Conclusion

This paper describes our research project and the development process of the IoT solution 'SmartPT' — a personal training (PT) system based on NFC wearable sensors mounted on garment like gym t-shirts and smart training units. It is a sensory system of which applied to the object in training — such as a training mat, a barbell or a rod. Technologies are mostly of light-weight web frameworks and data is stored locally in a browser. Literature review and market gap analysis show that there is potential in moving the application from the prototype stage of-which it is today. Doing so would include re-designing the middleware architectural layer, for improved communicational methods and data storage. Business related potentials are many, motivated by the fact that there is an increasing trend in spending money on personal training services and results from the research of wearable training sensor can advance our use of IoT in everyday life.

VI. References

[1] A. McEwen and H. Cassimally, *Designing the Internet of Things*, Wiley: West Sussex, UK, 2014.

[2] Adafruit. *PN532 NFC/RFID controller breakout board.* [ONLINE] Available at: https://rapidnfc.com/nxp_ntag21x [Accessed 05 April 16].

[3] Boostrap. *About Bootstrap*. [ONLINE] Available at: http://getbootstrap.com [Accessed 05 April 16].

[4] C. Perera, A. Zaslavsky, P. Christen D. Georgakopoulos, *"Context aware computing for the internet of things: a survey"*, IEEE Communication Survey and Tutorials, 2014.

[5] Cisco. *Internet of Things*. [ONLINE] Available at: http://www.cisco.com/c/en/us/solutions/internet-of-things/overview.html? [Accessed 02 April 16].

[6] Developers Android. *How NFC Tags are Dispatched to Applications.* [ONLINE] Available at: https://developer.android.com/guide/topics/connectivity/nfc/nfc.html#dispatching [Accessed 06 April 16].

[7] F. Buttussi and L. Chittaro, "MOPET:A context-aware and user-adaptive wearable system for fitness training," Artif. Intell. Med., vol. 42, no. 2, pp. 153–163, 2008.

[8] Font Awesome. *About.* [ONLINE] Available at: https://fortawesome.github.io/Font-Awesome/ [Accessed 07 April 16].

[9] H. Chaouchi, "The Internet of Things — connecting Objects to the web", Wiley-ISTE, UK/USA, 2010.

[10] H. Zhang and J. Li, "NFC in Medical Applications with Wireless Sensors", Electrical and Control Engineering (ICECE), pp. 718-721, 2011.

[11] J.A. Fraile, J. Bajo, J.A. Corchado and A. Abraham, *"Applying Wearable Solutions in Dependent Environments"*, IEEE Transactions on Information Technology in Biomedicine, Vol. 14, No. 6, Nov. 2010.

[12] M, Sundholm, J. Cheng, B. Zhou, A. Sethi and P. Lukowicz, *"Smart-Mat: Recognizing and Counting Gym Exercises with Low-cost Resistive Pressure Sensing Matrix*", Ubicomp '14, September 13 - 17, 2014.

[13] N. Timofeev, A. Vasilyev, I. Timofeev and S. Lobarev, "Architecture of Automatic Training Data Gathering *System - Training Assistant",* Proceedings of the 17th Conference of Fruct Association, 2015

[14] Rapid NFC. *The NTAG21x Series Explained*. [ONLINE] Available at: https://rapidnfc.com/nxp_ntag21x [Accessed 05 April 16].

[15] R. Kahn, S. U. Khan, R. Zaheer, S. Khan, *"Future Internet: The Internet of Things Architecture, Possible Applications and Key Challenges",* 10th International Conference on Frontiers of Information Technology, 2012.

[16] Wareable. *Best fitness trackers 2016.* [ONLINE] Available at: http://www.wareable.com/fitness-trackers/the- best-fitness-tracker [Accessed 06 April 16].

[17] Y. Hsu, C. Yang, T. Tsai, C. Cheng, and C. Wu, "Development of a decentralized home telehealth monitoring system," Telemed. e-Health, vol. 13, no. 1, pp. 69–78, 2007.