FROM A PHYSICAL SYSTEM TO A PERVASIVE SOLUTION TO INCREASE PEOPLE PHYSICAL ACTIVITY:IS IT POSSIBLE?

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ABSTRACT

In the last few decades our lifestyle has deeply changed thanks to the advances in science and engineering: public transportation, escalators, elevators etc., have deeply reduced the physical activity that people usually make during the day. This, combined with an incorrect diet, has increased the number of overweighted people and people with cardiac problems. In this paper we present our preliminary study which shows the feasibility of a pervasive system to incentivize people to prefer the usage of stairs instead of escalators or elevators, transforming this strain into a funny moment.

***Index Terms*— ** Serious Games, Pervasive Computing, Mobile Applications.

1. INTRODUCTION

Modern technologies allow people to avoid simple strains of everyday life, like climbing the stairs. Several means of transport has been provided in the last few decades to help people in their daily movements. These services, that we call *movers*, can be divided into two different categories: *long distances movers*, e. g., trains, buses, metros etc., and *short or very short distances movers*, used inside a single building, e. g., elevators and escalators. The use of this *movers* brings several improvements in life quality, reducing the time necessary to move from one city to another or helping the elderly or people with motor disabilities to reach particular places or even to move inside a building, e. g., up and down several floors.

Despite all these positive aspects, the *movers* have led also to a problem, the abuse of them. Even if it is clear that *long distances movers* are indispensable nowadays, this is not always true for the second class of *movers*: every time people can choose between a *mover* and the pedestrian way for short distances, they tend to choose always the *mover*, thus reducing the amount of physical activities they do in everyday life. Let us think, for example, to the usage of buses or subway also for only one stop, or the usage of the elevator or escalators to move between very few floors instead of using stairs.

This choice, daily made by people, preferring the automatic *mover* instead of the pedestrian way, has drastically reduced their physical activity. Consider a typical day of a sedentary worker that does not practice any sport or physical activity in the evening: most of the time is spent in the office, sitting on a chair, without any physical activity. If his/her transfers are made using the *movers*, therefore without climbing stairs or without walking even for few meters, at the end of the day he/she will not have made any physical effort.

If we combine this lack of activity with an incorrect diet, the result is what medical researchers are claiming from several years: the number of overweighted people, either among adults and children, is dramatically increasing [1] [2]. The overweight condition creates several problems either for people themselves, i.e. they suffer a major probability of heart disease, strokes, diabetes or cancer, and even for the health system, i.e. medical costs much more higher to treat overweighted people [3] [4].

In this paper we present our preliminary study for a system that aims to incentivize people to choose the pedestrian way instead of the *movers*, in particular to choose stairs instead of escalators or elevators. The idea is to use a *serious game* in order to entertain and engage people while climbing stairs, because if they have fun while climbing stairs, probably the will take them more frequently, thus increasing the amount of physical activity they do in everyday life and, finally, their life quality.

Other solutions in literature address this problem, as discussed in Section 3. In the existing approaches, the authors usually equipped a dedicated space, e. g. a stair, to be used as a game. This kind of solution cannot be applied everywhere, e. g., consider an historical building, and can be very expensive. Our approach is completely different since we aim to equip the user to be able to play with *any* stair. For this reason, our game must be *portable*, in order to reach the majority of the people, *non-intrusive*, meaning that people will not have to buy new devices or tools to play, and do not have to stress people. For this reasons smartphones, in particular Apple devices and Android devices, commonly available on the pockets of most people, are the target devices for this kind of application, due to their diffusion all over the world and to their omnipresence, people usually take smartphones with them all the time. Smartphones give us the possibility to track people movements, in order to perform the game, without requiring any other devices, thus in a very cheap way.

This paper is organized as follows: Section 2 presents the main idea of the project and its motivation, Section 3 discusses related works and Section 4 provides our preliminary study on the architecture of the system and our test to demonstrate its feasibility. Finally, we conclude in Section 5.

2. THE IDEA AND MOTIVATION OF THE PROJECT

As already discussed, our aims is to build a system that helps people to increase their physical activity during their daily routine, in order to break their sedentary. In particular, we focus on convincing users to choose the use of stairs instead of escalators and elevators.

The biggest problem is how to define a system that try to convince people that stairs are better than escalators or elevators, without being too much intrusive. Non intrusiveness is extremely important, because if the application is too intrusive, it can stress its users, with the final result to convince them to immediately delete the application. An application is *extremely intrusive* if it requires the users to buy, and bring with them other, probably bulky, devices, if it requires too often the user attention, if it exceeds in power consumption thus prematurely exhausting the devices' battery and so on.

The *serious games*, i. e., applications developed not only for fun, but also to hide, under the games, a different purpose, are often used with the aims of changing people lifestyle into a better one. Actually there are a lot of different application of *serious games*, i.e. military field, educational field or governmental field [5]. One of the key idea of *serious games* is that if a person have fun performing a particular activity that he/she usually does not, there is a good probability that after several times that he/she repeats it with the game, he/she will do it again even without the help of the game. This is exactly what we want to do: a *serious game* that "teaches" people to choose stairs instead of elevators or escalators.

An experiment, which was part of "The Fun Theory" project provided by Volkswagen [6], shows that the use of *serious games* is the right way to incentivize people to use stairs. In particular, the installation named "Piano stairs" [7] tries to transform stairs into a piano, where each step is a key of the piano, that sounds every time a person climbs into. The authors experimented this idea by properly equipping the stairs of a subway station. As result more than 66% of the people preferred the "Piano stairs" to the escalators.

Despite its success, this solution has a big problem, i. e., its portability. In fact, this installation cannot be "moved" easily to another place, but requires the installation of many devices, sensors, actuators and speakers, together with related masonry and painting. Moreover, it is not always applicable, e. g. in an historical building, or the installation can be very expensive. For this reason, even if the principle is correct and evidences show the goodness of this approach, its widespread application is extremely difficult.

Starting from these good results in terms of people engagement, our idea is essentially to improve this system, in order to make it easier to be used everywhere. To do so, it is necessary to use something different from the modified stairs, and use something that has to be easy to access and use, not expensive and that does not require installation in the physical world. Therefore we need a system that could collect data about the activity of the user, analyze and process data in order to recognized his/her activity (i. e. to determine if the person is climbing the stairs or not).

Our goal is to switch from a physical installation to a *pervasive system* which follows the user during his/her movements. The principle of the *pervasive computing* is to use several non-intrusive sensors or devices to acquire data from the environment and elaborate it to provide services to the user based on the *context awareness* [8] [9]. One important aspect of a pervasive system is its invisibility or non-consciousness of the user, i. e., the user, in an ubiquitous system, could not be aware that devices are acquiring and computing data.

Starting from this principle, our application has to work in background, recognize if the person is climbing stairs or not, and present results to him/her in a non stressful way, to prevent people from deleting the application. This system requires a device or set of sensors that are able to analyze user activities, and in particular are able to determine if the user is climbing stairs, avoiding the necessity that the user has to tell in some way to the application that he/she is climbing stairs.

To determine the user current activity is the first goal of our system, the second, and probably more important is to provide fun, in order to engage him/her and incentivize him/her to make it again. This fun can be provided either with the environment, with some special effects like the "Piano stairs", or directly to the user, for example through his/her smartphone that could host a *serious game* that can use the amount of climbed stairs as a sort of "coins".

3. RELATED WORKS

Several tools, devices and gadget that try to incentivize people in their physical activity are available on the market. Probably, the simple (and first) tool used to keep track of movements are the pedometer, that are able to determine the number of steps made by a person during a day. This can be used simply to keep track of their own movements, in order to follow, for example, a specific exercise provided by a doctor, or simply to try to reach a particular goal defined by him/herself at the beginning of the day or of the walk.

A more complex example is the "Nike+ iPod" by Nike [10], a system that helps sportsmen/sportswomen to increase their performances, motivating them during their training. The system is based on a Nike+ pair of shoes, a wireless sensor for the shoes and a wireless receiver connected to the iPod or iPhone, and the corresponding application. This application, through the sensor, is able to keep track of the time, distance, speed and burned calories. In this way, the runner has a constant feedback about his/her training, and can try to increase his/her training level and performances based on the information received.

Another example is the "Nike+ FuelBand" bracelet [11], currently available only in the USA. This is a bracelet with an incorporated accelerometer, that is able to keep track of all day activities performed, in particular the number of steps made and the calories burned, giving the possibility to the user to define daily targets (the achievement of this targets is showed by some leds in the bracelet) and to keep track of daily energy consumption.

All this tools have essentially two characteristics: the first is that they are a separated tool, that mean that people have to spend money to get them, and sometime they could be expensive. Secondly, their are essentially dedicated to sportsmen/sportswomen, that starts alone their training, and simply want to check their performances and improvements, and not to all the people, in particular those that have a sedentary life and need to perform some physical exercises. Our application wants to eliminate this two problems, in particular it is thought for people that could have several difficulties to simply start walking or other simple physical activities.

Several studies have been made in the area of situations and activity recognition. In particular, two different approaches can be used: attaching different sensors to the human body and its surroundings to get information, or use simply a smartphone and its sensors.

Bao and Intille in[12] and Mantyjarvi, Hmberg and Seppanen in [13] performed several tests using wearable sensors to recognize activities made by a person. These experiments, that combine data coming from different accelerometers, have obtained very good results in activity recognition, with an estimated accuracies between 83% and 99%.

Lau and David studied the possibility to use only a single smartphone and its accelerometer to determine user activity [14]. In particular, they walk through an analysis of the different possible combination of settings that could be used to understand the different activities made by the user, in particular they try to understand which feature can be used to classify movements and what are the correct sampling rate and classification algorithms. As result, they showed that even a low sampling rate (10Hz and 20Hz) is sufficient to get good accuracy in classification (>90%), that can be much more higher with particular experiment settings (>96.5%).

An example of pedometer, realized using the sensors contained into smartphones, is described in [15]. It employs the smartphone's camera to capture images and measures the number of steps based on a time-series analysis of image features. The authors demonstrate the applicability of this visual pedometer through a four-seconds experiment. Compared with traditional inertial-sensor-based pedometers, this visual pedometer could be more user-friendly because of the extensive use of camera phones and digital cameras.

A pervasive use of smartphone is described in [16]. The authors realized a serious game that invisibly collect information about the accessibility of city roads. This information is then used to provide a Google Maps-like service to people with motor or visual disability, who can search for an accessible path between any two locations.

Another really important aspect mentioned before is the possibility to reach the largest number of people, i. e., we cannot limit the usage of our application to who owns a particular device. For this reason, and in order to build a non intrusive application, to attach several accelerometers to the body of people to determine their activity is not an acceptable solution. Therefore, the other promising possibility is to use only the smartphone and its accelerometer to determine user activity. However, even this approach bring a problem: the application must be installable on the multitude of different smartphones and different platforms, which are usually not compatible, require different operating systems and programming languages. For this reason, we need a cross-platform framework which allows to reach the largest number of devices, therefore the largest number of people.

Several studies have been made for cross-platform development in order to evaluate tools for the developer and further performances, e. g., [17] by Rahul Raj and Seshu Babu Tolety. There are essentially two possible solutions: to develop several native applications, one for each target device, or use frameworks like PhoneGap[18] or Titanuim[19] to develop one single application that is further converted into several application, one for each different platform. The first is the best choice in terms of performances, but is the most time consuming in term of development, due to the necessity to develop different applications from scratch, one for each different family of devices.

The second possibility may drastically reduce the developing time, due to the fact that it is necessary to develop only one single application that will be converted in several native applications. Problems may arise in terms of performances, due to the fact that most of this tools do not provide a conversion to a fully native application. As an example, PhoneGap wraps an HTML, CSS and Javascript application inside a webkit engine, in order to be able to execute the application without the browser. For this reason, it is necessary to evaluate, extremely well, application needs in terms of performances and user experience, in order to choose the right approach for each application.

4. SYSTEM DEFINITION

As already discussed, our goal is a pervasive system, non intrusive, that uses a smartphone to detect people movements, in particular it is able to detect when the user is climbing stairs. This pervasive system has one of its key point in the *serious* *game* that has to engage people and make fun while they are climbing stairs.

We have defined two different *game modes*, that can either work together or not: the *personal mode* and the *community mode*. The *personal mode* is simply a step counter, where the user is engaged with a series of different challenges, e. g., reach the moon, climb the Empire State Building etc. In particular, in order to increase the fun and the engagement of people making stairs, it is necessary to apply principles of *gamification*, meaning that the application has to introduce different level difficulties, bonus, rewards and so on to increase user's entertainment. This game mode can interact with the user with two different timings: an *online way* or an *offline way*. When using the system *online*, the user plays the game and has fun during the physical activity, i.e. when the user is climbing stairs, by reproducing the sound of a piano or other funny sounds. When the system is used *offline*, the user has the possibility to use the points/coins/rewards gained with the stairs to reach the different levels provided by the application. The *personal mode* does not require any physical installation and allows also to challenge friends through the Internet.

The *community mode* is the game mode that can be applied in public stairs, where the user wants to share experience with people in the same place. The main idea is that the smartphone detects the user activity and sends a message to a receiver installed near the stairs, that will make some fun with that information, for example reproducing the sound of a piano, counting people making that stairs to win a competition with other stairs of the tube and so on. Again, the main idea is to entertain people, engaging them in climbing the stairs. Different from other approaches, we do not required to install several sensors, but only actuators and some speakers.

The two different modes can work together, combining the *community* game, which may involve all the people to reach a common goal, with the *personal* game. If the *community* game is available, the users participate to the global goal with the points gained by their personal step counter. If the *community game* is not available, only a step counter and fun for the single user will be performed.

When used *offline* the system is similar to a step counter that entertain people while climbing stairs, something different appears when used *online*. In particular, the challenge in this case is how to implement and realize the system that can cooperate with the smartphone in a non intrusive way without the user intervention.

The main idea is to use a WiFi connection between the receiver and the smartphone. In this way, when the service is available, i. e., the smartphone is connected to the WiFi receiver, every time the smartphone reveals that the user climbs a step, it send a message to the receiver telling that the user, uniquely identified by an ID based on his/her smartphone in order to avoid multiple IDs, is climbing the stairs. With this information, the receiver can perform which operation is programmed for, with the objective to make fun for people, e. g., to play sounds from a piano, but also to make a global war between stairs of the tube, or cooperative levels (people have to help a character to reach the moon), etc.

4.1. Data acquisition tests

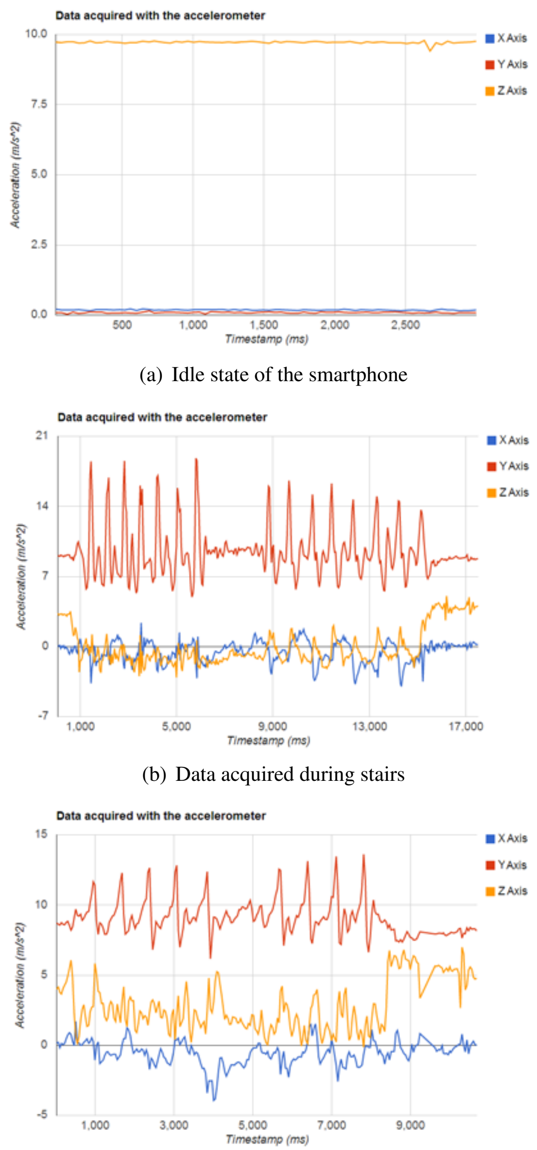
As shown by Lau and David in [14], with the accelerometer of a smartphone it is possible to achieve good results in activity recognition. The problem of this approach is that the analysis of acquired data is not made in a real-time way. In our system, when used *online*, real-time recognition is essentially to be able to provide the right information to the user and so to provide the right user experience.

We have made several tests in order to determine how different libraries work with the acquisition of data from sensors, in particular with data from the accelerometer. Using PhoneGap, it is possible to acquire data from the accelerometer between a frequency from every 40ms (25fps) to 1 second. As shown in [14], this frequency is sufficiently to achieve good accuracy in activities recognition. The experiments have been made on an Apple iPad and a Samsung Galaxy, and performing several different actions, in order to see the differences between the graphs of data acquired during different activities. We have made several tests, in order to determine if there is a particular pattern in the graph of data for every single activity, like walking, climbing stairs etc, or if the data is completely different every time even for the same activity. What we saw is that every activity build a particular graph, and it is very easy to distinguish one activity from another.

Figure 1 shows several examples of data acquired with an Apple iPad in different situations. Figure 1(a) shows data recorded when the smartphone is still on a table. Figure 1(b) shows data recorded when a user is climbing stairs and finally Figure 1 (c) reports data collected during a walk.

Analyzing the three figures, we can note that the different activities are easy distinguishable, since the pattern of the collected data for the three axes are different. If we compare the graphs which recorded data during a walk (Figure 1(c)) and when the user is climbing the stairs (Figure 1(b)), we can note that while in the first case, the values for the three axes vary inside different intervals but with quite the same distance between the maximum and the minimal values, in Figure 1(b), the values for axis y vary inside a larger range than values for the axes x and z.

Moreover, we changed the position of the devices during the tests, to check if this assumption is robust against the position in which the device can be carried on by the user, i. e., in his/her pocket or in his/her bag in case of the iPad. The results we get show that the general pattern described above is not influenced by the position of the devices. In particular what we can observe is that, despite of the position of the device, the values acquired from one axis vary inside a larger range than the values of the other two axis.



(a) Idle state of the smartphone

(b) Data acquired during stairs

(c) Data acquired during walking

Fig. 1. Examples of data acquired through the accelerometer of a smartphone

4.2. Energy consumption tests

Another key aspect of the system is energy consumption of the smartphone application. It is necessary that our application do not uses much energy, in order to avoid that the smartphone becomes useless for normal usage. In particular, a smartphone should have at least a day's operation time (with some daily phone conversation and text messages sent by the user) before a recharge is required. For this reason, it is necessary to find the correct data capture frequency that guarantees good recognition performances and low energy consumption. The problem is that, even in an idle state of the smartphone, that could be when it is posed on a table for several time, the accelerometer constantly acquires data.

This process of constantly acquisition of data causes a waste of energy, because from the accelerometer point of view, being in an idle state or moving along an axis is not different, it has to acquire data with a certain frequency. Moreover, there is not the possibility to throw an event when the smartphone start moving from an idle state, giving us the possibility to put in silence the data acquisition. For this reasons, it is necessary to adopt some strategy that gives the possibility to intelligently manage data acquisition and to avoid energy waste, i. e., the system lowers the acquisition frequency, when it recognizes an idle state, and increases the acquisition frequency when it recognizes the end of the idle state in order to get much more precise analysis.

We have made several tests in order to determine how data acquisition influences energy consumption. In particular, we have compared energy consumption of two different situations: with and without an application that acquires data (and do not elaborates it) at 25Hz.

Duration	App. active	Smart. mode	Consumption
7hh:30mm	No	Offline mode	2%
7hh:30mm	Yes	Offline mode	4%

Table 1. Results of energy consumption tests

Table 1 shows energy consumption for acquisition of data when the smartphone is in idle state. The application requires only 2% of energy consumption more than the normal usage, i. e. energy consumption is very low, due to the fact that the operation of reading data from the accelerometer do not requires particular computational capabilities from the smartphone (and so, do not requires much energy consumption).

Several tests have been made even during a normal business day, for several hours, with the application running in background and the smartphone used even for phone calls, text messages, 3G navigation, etc. Despite the fact that it was not possible to build a sufficiently exhaustive tests of this situation, due to the difficulties to recreate the same situation for several days to test the battery usage with or without the application running (the battery life is influenced not only by the number of calls or messages, but event from the network strength and other environmental characteristics that cannot be controlled), we can observe, on average, the same results of Table 1: the battery power is not drastically reduced, but remains the same as a user would expect after a day of usage, i. e., the use of the application is quite invisible.

5. CONCLUSIONS

In the last few decades our lifestyle has deeply changed thanks to the advances in science and engineering. In particular, the diffusion of cars, public transportation, escalators, elevators etc., has deeply reduced the physical activity that people usually make during the day, leading often to a too sedentary lifestyle. In this paper we have discussed a preliminary study for the feasibility of a system to incentivize people to prefer the usage of stairs instead of escalators or elevators, transforming this strain into a funny moment using the *serious games* paradigm.

Since the installation of new sensors and actuators is not always possible, due to the chosen environment, e. g., an historical building, or to a low budget, we propose a pervasive solution which uses the smartphones usually carried by the users as a set of sensors and, if necessary, actuators.

Our prototype has shown that is possible to recognize what the user is doing by analyzing the graph of data collected by the accelerometer, since particular patterns are recorded in each different situation. Moreover, these patterns are not affected by the position of the smartphone during the physical activity and by what kind of device is used.

Finally, we have performed some tests to explore issues related to energy consumption and we have shown that the operation of collecting data from accelerometer can be performed with a low energy consumption.

Unfortunately, these tests can be performed only on the Android platform, since Apple iOs does not allow to applications in background state to collect data from accelerometer. We plan to solve this problem in our future works which will be devoted to the realization of a pervasive serious game, realized as a mobile application available for all platforms, to improve the physical activity with the aim to provide fun for users climbing the stairs.

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