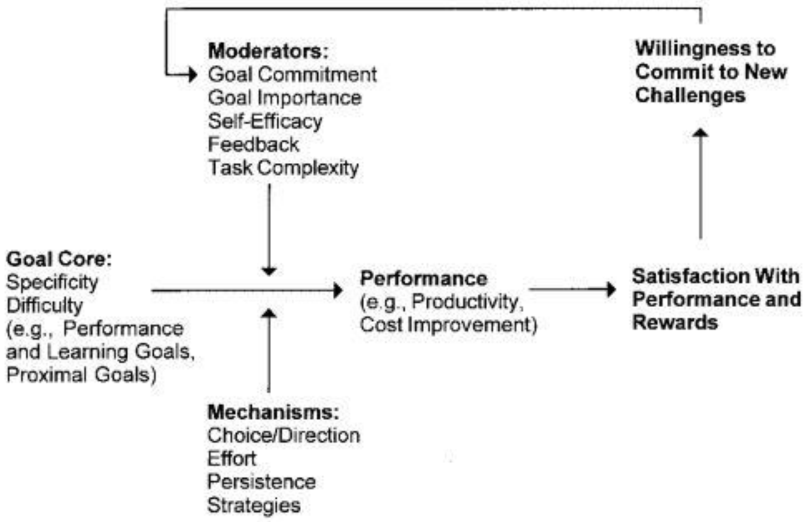
1.1 . Detailed research question/problem

How can Human Activity Recognition be implemented on a mobile device in order to help inactive people self-manage sedentary behaviour?

The aim of this project is to develop an application that will support inactive people change their behaviour and become more active. The application will facilitate behaviour change by providing the users with a self-management framework such as the one Locke and Latham (2002) suggested – (see figure 1). They (ibid.) showed that goal setting, monitoring and giving feedback are very important elements when it comes to motivating one's behaviour change. In this project the goals will be set by the user but informed by medical guidelines, the monitoring will be achieved by accelerometer sensor in a smartphone and real-time feedback of achievement via phone notifications will be shown to the user. In order to answer the research question, the following has to be undertaken: -

- Literature review to investigate current mobile device behaviour change approaches and further find out the current state-of-the-art in Human Activity Recognition (HAR)
- Design and build a system that will:
  - Gather accelerometer sensor data, extract features of the data, and classify and log user's activity as "active" or "static" over time – HAR component implementation.
  - Implement self-management component
  - Ensure usability by allowing the user to set goals and show notifications to the user when prolonged inactivity intervals are detected and show achievement accomplishments.
- Evaluate the approach by testing the proposed mobile application under real circumstances (e.g., the system will be evaluated by volunteers, and a questionnaire will be conducted to gather information about the effectiveness of the application).

Figure 1. Essential Elements of Goal-setting (Locke and Latham, 2002)



1.2 Keywords

Human Activity Recognition; machine learning; data mining; self-care; self-management

1.3 Project title

A Mobile Application that applies a Self-Managing Approach to Reducing Sedentary Behaviour

1.4 Client, Audience and Motivation:

Nowadays, with the rapid advance of technology people spend a lot of their time in a static position. In a statistical report Townsend et al. (2015) concluded that people in England spend their leisure time sitting- on average 4.9 hours and 4.7 hours per weekend day for men and women respectively. The majority of the adults in Great Britain, for example, spend a lot of their time watching TV, browsing the Internet or playing video games (Lader, Short, and Gershuny, 2005). The current shift of technology and work becoming more sedentary will potentially cause many health problems. According to Wilmot et al. (2012) spending prolonged periods of sedentary time increases the chances of all-cause mortality by 49%. In addition, people who lead non-active lifestyle are 112% more likely to get diabetes, 147% more likely to experience cardiovascular events, and 90% more likely to die due to cardiovascular events (ibid.). In order for a person to reduce the chances of developing the above diseases they should to follow the recommended levels of activity per day. According to the Department of Health (2011) and Townsend et al. (2015) the guidelines of activity per day is that adults (19-64 years) should do 30 minutes on at least five days a week. Parkinson (2016) and Siddique (2016) claim that an hour of activity per day would be ideal. Furthermore, lead scientist Professor Ulf Ekelund, from Cambridge University and the Norwegian School of Sports Sciences, cited in Siddique (2016) said that every hour spent sitting should be broken by a five-minute break.

This project will develop a smartphone application that will help inactive people reduce sedentary behaviour by monitoring their inactivity during the day, notifying the user when extensive inactivity times are detected. What is more, the application will give feedback upon goal achievements when the user has accomplished the previously set goals in order to motivate and encourage activity. As part of the self-management logic of the application, the user would be able to set an exercise goal (e.g., 30 minutes of activity and maximum inactivity period of one hour per day) – thus trying to prevent or minimise the occurrences of diseases associated with sedentary lifestyle. The primary audience for the above application is the general public - anyone who is spending most of their time in a static position and being inactive in general.

1.5 Project Plan

Project plan for the project includes six stages – Literature review and application analysis, Gathering application requirements, Application design, Implementation, User Evaluation and Report preparation (see also Project Plan as a Gantt Chart in **figure 2**). As for the implementation stage, I have decided to follow the waterfall software development modal (see figure 3) since I do not have a particular client to exchange information/feedback. The waterfall software development modal perfectly fits the linear execution of my project (see the six stages bellow) as well as it is simple to understand. (S. L. Osmani et.al. 2013).

1. **Literature review and application analysis** – it includes researching:
   1.1 Self-management in the health care sector
   1.2 Human activity recognition
   1.3 Analysing existing mobile applications.
2. **Gathering application requirements** – includes:
   2.1 Identifying what the application will do in terms of functional and non-functional requirements.
3. **Application design** – includes:
   3.1 Defining use case scenarios to allow design of prototype user interface
   3.2 Defining the data storage and the application logic
4. **Implementation** – includes the following:
   4.1. Implementing HAR system
      4.1.1 Preparing documents such as participant's consent forms
      4.1.2 Collecting user data
      4.1.3 Training and exporting classifier
   4.2 Implementing self-management logic (e.g. recommended activity amounts according to health guidelines)
   4.3 Implementing application User Interface (UI)
5. **User evaluation** – the proposed application will be evaluated by real users. They will use the application for a whole day and will give feedback regarding how effective (if successfully recognised if they were active or not as well as if it reminded them when being static for a long time) the application has been throughout the day. The feedback will be gathered in the form of a questionnaire
6. **Report preparation –** gathering and summarising findings and results.
7. **Demo presentation** – prepare a demo version of the mobile application

ID		Task Mode	Task Name	Duration	Start	Finish
1			**Honours Project**	**154 days**	**September 30, 2016**	**May 3, 2017**
2			**Literature review and application analysis**	**1 mon**	**September 30, 2016**	**October 27, 2016**
3			Self-management in health care sector	1 wk	September 30, 2016	October 6, 2016
4			Human Activity Recognition	2 wks	October 7, 2016	October 20, 2016
5			Analysing existing mobile applications	1 wk	September 30, 2016	October 6, 2016
6			**Gathering Application Requirements**	**3 days**	**October 28, 2016**	**November 1, 2016**
7			Identifying what the application will do - functional and non-functional requirements	3 days	October 28, 2016	November 1, 2016
8			**Application Design**	**7 days**	**November 2, 2016**	**November 10, 2016**
9			Defining use case scenarios to allow design of prototype user interface	3 days	November 2, 2016	November 4, 2016
10			Defining the data storage and the application logic	3 days	November 7, 2016	November 9, 2016
11			**Implementation**	**40 days**	**November 13, 2016**	**January 5, 2017**
12			**Implementing HAR system**	**7 days**	**November 13, 2016**	**November 22, 2016**
13			Preparing documents such as participant's consent forms	1 day	November 13, 2016	November 13, 2016
14			Collecting user data	6 days	November 14, 2016	November 21, 2016
15			Training and exporting classifier	1 day	November 22, 2016	November 22, 2016
16			Implementing self-management logic	15 days	November 23, 2016	December 13, 2016
17			Implementing application User Interface (UI)	1 wk	December 14, 2016	December 20, 2016
18			User evaluation	1 wk	January 6, 2017	January 12, 2017
19			**Report preparation**	**2 wks**	**January 12, 2017**	**January 25, 2017**
20			Gathering and summarising findings and resul	2 wks	January 12, 2017	January 25, 2017

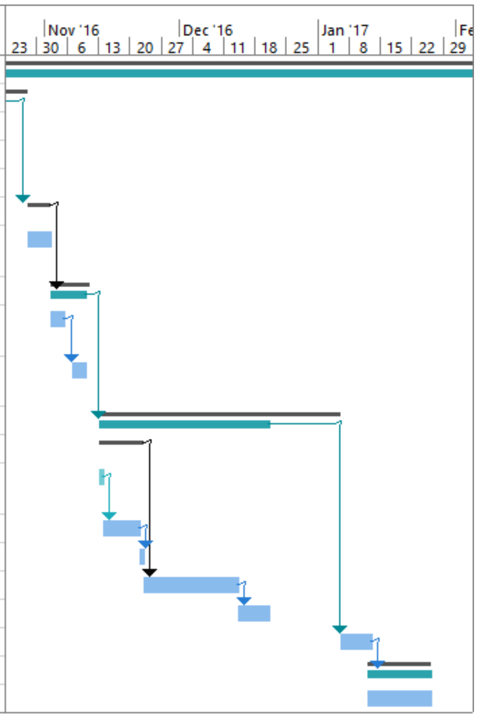


Figure 2. Gantt chart of the project plan.

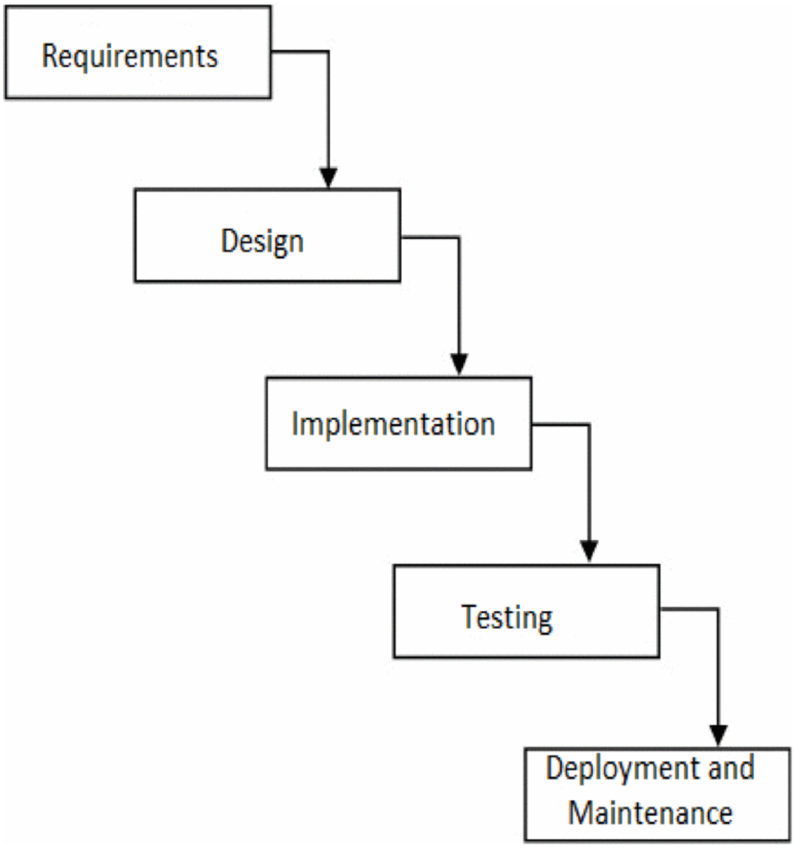


Figure 3. Waterfall Software development modal (S. L. Osmani et.al., 2013)

This is the end of section one.

2.1 Abstract

It is known that many people nowadays spend most of their time in front of a computer screen, both at work and in their leisure time. It is evident that a lot of time is spent in a static position (e.g., writing an article on a PC or watching TV). This means that if people do not follow the recommended physical activities guidelines they can easily develop health issues such as lower back pain, diabetes and cardiovascular diseases, in addition to having an increased chance of early age mortality. The aim of this project is to develop an application on the Android platform to help inactive people reduce the time they spend in a static position. The main objective of the project is to change user behaviour via 3 step process - (i) set goal (the user sets a goal – e.g., being active for 30 minutes per day), (ii) tracking and (iii) analysing goal achievements. Furthermore, the application will be designed so that when a prolonged inactivity interval is detected, it will notify the user via a notification in order for them to take action such as going for a walk. Another objective of the project is to design logic for personalising the classifier (previously trained from the accelerometer sensor data on the mobile device) to adapt to the user's movement patterns. The application will detect when the user is sleeping to prevent unnecessary notifications. The application's effectiveness will be evaluated by a small number of research participants. The evaluation will consist of research participants using the application for a certain amount of time and giving feedback via a questionnaire.

2.2 Initial/Mini Literature Review

One of the main challenges in this work is to develop an effective Human Activity Recognition (HAR) component that will support self-management logic for reducing sedentary behaviour. HAR has been and still is a hot research topic due to its many existing and potential application areas across a wide range of health and fitness applications (e.g. Google fit. no date, Apple Inc., 2016). There are many good examples of HAR systems implemented on mobile devices, for example Shoaib et al. (2015) proposed a HAR system that used both smartphone and smartwatch sensors to detect 'bad habits' such as smoking or not eating on time. This information could be used to gain insight into how people addicted to smoking progress over time.

One of the most important characteristics of a HAR system is to be accurate, unobtrusive and energy efficient. As far as accuracy is concerned, "*Vigilante*", a mobile application that implements HAR (Ó D. Lara and M. A. Labrador) achieves overall accuracy of 96.8% by utilising a C.45 decision tree classifier. The application uses a sensor strap attached on the user's chest to collect sensor data such as acceleration, heart rate and skin temperature. *ActiServ* (Berchtold et al., 2010) uses only the accelerometer sensor on a mobile device (NEO FreeRunner) to recognise activities with high accuracy. Compared to the system that Ó D. Lara et.al proposed, it achieves a slightly better recognition accuracy of 98%.

Another important characteristic of a HAR system is being unobtrusive to the user or not requiring too much interaction with the application (Labrador and Lara Yejas, 2013). "*Vigilante*" could be improved by eliminating the need for the user to wear a sensor strap on their chest and using only the smartphones sensors – thus minimising its obtrusiveness. As for ActiServ, it is less obtrusive, compared to "*Vigilante*" due to the fact that it uses the built-in accelerometer sensor on the mobile device. On the other hand, it requires the user to complete several activities in order for the application to personalise its classifier which could introduce human error when the classifier is being personalised (e.g. incorrectly labelling of the data).

Least but not last a HAR system should be battery friendly, Kalic et.al. (no date) showed the Bluetooth communication consumes a considerable amount of energy - 10% per hour (for constant Bluetooth download) which means that "*Vigilante*" is spending valuable energy to send the raw data from the sensor strap to the phone. What is more, Parkka et. al. (2010) showed that when data is transferred wirelessly (e.g. via Bluetooth) there is a known percentage of samples that is lost - 0.01% to 2.02% (depending on the sampling rate). As for *ActiServ*, additional energy is spent making network calls to the application's server to select the best Activity Classification Module Set (ACMS). Kalic et. al. (no date) showed that Wi-Fi upload data transmissions could use a lot of smartphone's battery - about 4.2 hours (with constant Wi-Fi communication).

The system proposed in this paper will use only the accelerometer sensor on smartphone and does not require any external sensors (*Vigilante*) - thus its level of obtrusiveness is low. In addition, a personalised classifier will be trained without the requirement of the user to perform any necessary activities. This is done via selectively gathering newly labelled data and training a new classifier based on the new data. This autonomous process allows for minimising human error. The main purpose of the application proposed with this work is to identify prolonged inactivity intervals and to remind the user when those occur.

2.3 Relevant professional, social, ethical, security and legal issues to the project

The project has considered the following issues:

Professional

As a student studying CGA (Computing for Graphics and Animations) – a course that is accredited by the British Computer Society (BCS) I intend to comply with the BCS Code of Conduct. Specifically point 4 (d) (BCS Code of Conduct, 2016) - "act with integrity and respect in your professional relationships with all members of BCS…" I intend to give credits to the authors of any third party software I use in this project.

Social

The proposed application will try to avoid promoting any body image stereotypes by focusing more on encouraging the users to be more active rather than on their body characteristics such as weight and height or BMI (Body Mass Index). In addition, the application will only show what the recommended activity intervals per day are and will not force the users of the application to follow those strictly (some jobs do require seating for extended intervals of time – e.g. Pilots).

Ethical

The data collected during the project development such as names of the project participants and their accelerometer sensor data will be stored on disk only for the development purposes of the project.

Security

The mobile application, proposed in this work, will offer an authorization component to prevent other people accessing personal data such as total minutes of activity/inactivity collected daily. What is more, any relevant or valuable user data will be anonymised in order to protect individual's identity.

Legal

To prevent any harm done to the user, the mobile application will show a disclaimer (warning) dialog message to inform the user that they should be in a good physical condition (not suffering from diseases that could lead to worsening the condition of the user) before they use the application. In addition, I intend to fully comply with the terms of conditions of any third party software that I intend to use (my main goal is to use primarily Open Source software). As far as the project participant's data is concerned, I intend to keep the data only for the purposes of this project, and the data will not be used for any commercial purpose.

2.4 Bibliography (key texts for your literature review)

Apple Inc. (2016) *IOS - health*. Available at: http://www.apple.com/uk/ios/health/ (Accessed: 14 October 2016).

Berchtold, M., Budde, M., Gordon, D. and Beigl, M. (2010) 'ActiServ: Activity Recognition Service for mobile phones', Seoul, Korea: Karlsruhe Institute of Technology. pp. 1–8.

BCS Code of Conduct (2016) Available at: http://www.bcs.org/category/6030#profession (Accessed: 18 October 2016).

Shoaib, M., Bosch, S., Scholten, H., Havinga, P.J.M. and Incel, O.D. (2015) 'Towards detection of bad habits by fusing smartphone and smartwatch sensors', *2015 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops)*, . doi: 10.1109/percomw.2015.7134104.

Siddique, H. (2016) *One hour of activity needed to offset harmful effects of sitting at a desk*. Available at: https://www.theguardian.com/lifeandstyle/2016/jul/27/health-risk-one-hour-activity-offset-eight-hours-sitting-desk (Accessed: 17 October 2016).

S. L. Osmani, G. Arifi and F. Idrizi, "Choosing the Most Suitable Model for Developing a Software," *Computational Intelligence, Communication Systems and Networks (CICSyN), 2014 Sixth International Conference on*, Tetova, 2014, pp. 83-88

Google fit (no date) Available at: https://www.google.com/fit/ (Accessed: 14 October 2016).

Kalic, G., Bojic, I. and Kusek, M. (no date) *Energy consumption in Android phones when using wireless communication technologies*. Available at: http://ieeexplore.ieee.org.ezproxy.rgu.ac.uk/document/6240745/ (Accessed: 14 October (Accessed: 14 October 2016).

Labrador, M. and Lara Yejas, O. (2013) ‘Human Activity Recognition’, in *Human activity recognition: Using wearable sensors and smartphones*. Boca Raton: Taylor & Francis Group, pp. 14–14.

Lader, D., Short, S. and Gershuny, J. (2005) *The time use survey, 2005 how we spend our time A report on research using the ONS omnibus survey produced on behalf of the economic and social research council (ESRC), department of culture, media and sport (DCMS), department for education and skills*. Available at: http://www.timeuse.org/sites/ctur/files/public/ctur_report/1905/lader_short_and_gershuny_2005_kight_diary.pdf (Accessed: 10 October 2016).

Locke, E.A. and Latham, G.P. (2002) ‘Building a practically useful theory of goal setting and task motivation: A 35-year odyssey’, *American Psychologist*, 57(9), pp. 705–717. doi: 10.1037//0003-066x.57.9.705.

Parkinson, C. (2016) *Hour’s activity ‘offsets sedentary day’*. Available at: http://www.bbc.co.uk/news/health-36895789 (Accessed: 17 October 2016).

Pärkkä, J., Cluitmans, L. and Ermes, M. (2010) ‘Personalization algorithm for real-time activity recognition using PDA, wireless motion bands, and binary decision tree’, IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society., 14(5), pp. 1211–1215.

Ó D. Lara and M. A. Labrador, "A mobile platform for real-time human activity recognition," *2012 IEEE Consumer Communications and Networking Conference (CCNC)*, Las Vegas, NV, 2012, pp. 667-671.

The Department of Health (2011) *Start active, stay active A report on physical activity for health from the four home countries’ chief medical officers*. Available at: http://www.bhfactive.org.uk/userfiles/Documents/startactivestayactive.pdf (Accessed: 10 October 2016).

Townsend, N., Wickramasinghe, K., Williams, J., Bhatnagar, P. and Rayner, M. (2015) Physical Activity Statistics 2015. London: British Heart Foundation.

Wilmot, E.G., Edwardson, C.L., Achana, F.A., Davies, M.J., Gorely, T., Gray, L.J., Khunti, K., Yates, T. and Biddle, S.J.H. (2012) ‘Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis’, 55(11), pp. 2895–2905. doi: 10.1007/s00125-012-2677-z.