Development of smart inner city recreational facilities to encourage active living

FOSTER, Leon <http://orcid.org/0000-0002-1551-0316>, HELLER, Ben <http://orcid.org/0000-0003-0805-8170>, WILLIAMS, Alan, DUNN, Marcus <http://orcid.org/0000-0003-3368-8131>, CURTIS, David <http://orcid.org/0000-0002-2244-3318> and GOODWILL, Simon <http://orcid.org/0000-0003-0638-911X>

Published version

FOSTER, Leon, HELLER, Ben, WILLIAMS, Alan, DUNN, Marcus, CURTIS, David and GOODWILL, Simon (2016). Development of smart inner city recreational facilities to encourage active living. In: GARCIA, Carmelo R., CABALLERO-GIL, Pino, BURMESTER, Mike and QUESADA-ARENCIBIA, Alexis, (eds.) Ubiquitous computing and ambient intelligence : 10th International Conference, UCAmI 2016, San Bartolomé de Tirajana, Gran Canaria, Spain, November 29 – December 2, 2016,. Lecture Notes in Computer Science, II (10070). Springer, 458-468.

Copyright and re-use policy

Development of smart inner city recreational facilities to encourage active living

Leon Foster[1*], Ben Heller[1] Alan Williams[2], Marcus Dunn[1], David Curtis[1] and Simon Goodwill[1]

[1]Sheffield Hallam University, Centre for Sports Engineering Research, Broomgrove Teaching Block, 11 Broomgrove Road, Sheffield, S10 2LX, UK
[2]The Parks and Countryside Service, Moorfoot, Level 3, West Wing, Sheffield, S1 4PL, UK

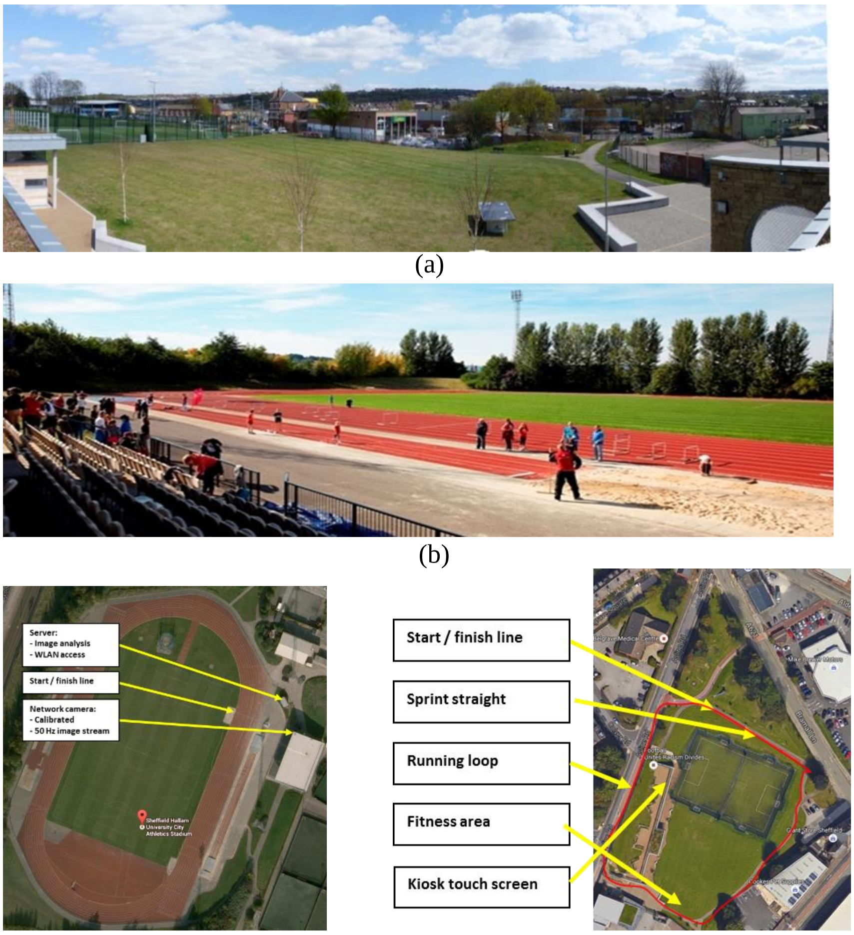
{l.i.foster, s.r.goodwill, b.heller, m.dunn, d.curtis}@shu.ac.uk, alan.williams@sheffield.gob.uk

Abstract. Lowfield Park in Sheffield, UK is a green recreational space maintained by the City Council. Lowfield Park was selected as the primary Sheffield FieldLab for the ProFit project which ended in 2015. The ProFit project was European Interreg IVbNWE funded with the aim of encouraging physical activity through innovations in products, services and ICT systems. In 2014 the Sheffield Hallam University City Athletics Stadium (SHUCAS) was introduced as a secondary FieldLab. A number of innovative systems have been installed into the FieldLabs, these include: Pan Tilt Zoom cameras, automatically timed sprint and running tracks, outdoor displays/touchscreen and a gait analyser. This paper describes the hardware, software and cloud infrastructure created to enable these systems. Pilot testing has been carried out over the last year and has found a positive effect on both sites. The systems created will be taken forward to Sheffield's Olympic Legacy Park, which is currently under development.

Keywords: Smart public monitoring • Participant tracking • RFID running lap • ProFit FieldLab • SHUCAS • Smart Park

1 Introduction

ProFit was a collaborative European Union Interreg IVbNWE funded project that aimed to support product innovation and novel ICT system development in sport, exercise and play. Public recreational spaces in five European cities are now hosts to FieldLabs, which serve as end-user locations for research and development of product and ICT innovations. The cities that currently host FieldLabs are: Sheffield and Ulster in the UK, Delft and Eindhoven in the Netherlands and Kortrijk in Belgium [1]. Sheffield's first FieldLab is located in a City Council controlled recreational green space called Lowfield Park [2] and houses a children's playground, 3G football pitch, fitness zone and a community building called the U-MIX Centre run by the charity, Football Unites Racism Divides (FURD). An overview of the Lowfield site is shown in Fig. 1a/1d. As a spin off from the ProFit project a second Sheffield FieldLab was created within the Sheffield Hallam University City Athletics Stadium (SHUCAS) on Woodburn Road [3] shown in Fig. 1b/1c.



(a) (b) (c) (d)

Fig. 1. Overview of the Sheffield's FieldLabs: a) Lowfield Park b) Sheffield Hallam University City Athletic Stadium SHUCAS and aerial view of c) Lowfield park and d) SHUCAS.

Over the lifetime of the ProFit project a number of innovative ICT systems were installed at both Sheffield FieldLab sites, creating a "Smart park" and a "Smart track". These recreational spaces were utilized by the Centre for Sports Engineering Research to under-take various research and development projects for these systems. Both sites act as demonstrator and prototyping hubs for the research centre and external partners.

2 Related work – Smart Cities

Smart Cities are cities which use modern information and communication technology (ICT) as well as the Internet of Things (IoT) to function more efficiently and provide an improved quality of life for residents and visitors. Smart Cities aim to manage and integrate various city services such as transportation, water supplies, waste management law enforcement and other community services in order to function more efficiently. As part of the Smart City concept, and falling under the category of community services, smart recreational facilities or parks could play an important role in improving the quality of life of residents by providing smart spaces for recreational activities. Increasing recreational and physical activity of a city's population is linked to improvements in health and well-being, and a potential reduction in health care costs, due to a healthier population [4,5].

The use of persuasive technology to encourage physical activity as part of a preventative healthcare model is a new field of research and the most effective ways to use technology to motivate healthier living is not fully known [6, 7]. One effective method could be to use of persuasive technology combined with the application of the IoT to create smart recreation facilities and open spaces or "Smart Parks". The creation of Smart Parks" has not been as abundant as other Smart City concepts and is potentially due to the benefits of smart not being fully documented as yet. One example of persuasive technology being used to encourage people to be more active is the Move More App for smartphones deployed in Sheffield, UK [8]. As part of the National Centre for Sport and Exercise Medicine, NCSEM [9] the Move More App was created and released to the general public in Sheffield in August 2016. The app intention is to encourage the city's population to be active through the logging daily activity and the creation of competitions between individuals and groups of people. The effectiveness and competitive nature of the app is currently undergoing evaluation.

The use of IoT within Smart cities has been used widely in other applications such as traffic monitoring, lamppost systems, smartphone detection, patient monitoring and waste management systems [10, 11]. All systems have in common sensor systems which are interconnected through the latest standards in Bluetooth, the internet, LAN/WAN as well as Wi-Fi. These sensor units usually communicate to a central server where data is stored and processed to produce reports. Some of these sensors units are stationary such as traffic monitoring sensors mounted on traffic signs [12] and other are mobile such as air pollution sensors mounted on refuse vehicles and have other issues such as power provision [13-14].

The use of a variety of sensor systems and other IoT technologies have been deployed in the two Sheffield FieldLabs as a novel "Smart park" concept, for on-going evaluation as to the effectiveness of these technologies in promoting physical activity. As the most effective method to encourage physical activity through technology is not fully understood the concept of monitoring and reporting activity performance was considered, following on from the Move More App. For the benefit of future Smart Park and FieldLab sites, this paper gives an overview of the IoT systems installed at both Sheffield field labs, the benefits of the systems and pitfalls of creating and running Smart Park sites.

3 Technology systems overview

3.1 Server, centralised SQL research database and cloud database

Given the collaborative nature of FieldLab sites, an agent software model was considered to be appropriate. An agent model allows the separate development of software applications that communicate with each other through a central data storage medium. This enables software to be developed independently at different sites by developers using any development environment. Within the ProFit project all software created for use on FieldLab sites followed a standardised database structure. In this way each FieldLab site has its own individual database based on this standard structure.

A Microsoft™ SQL database was created on a central high specification Windows based server and managed through Microsoft™ SQL Server Management Studio 2012. Microsoft™ SQL was chosen as this is widely used, and universal connection strings can be used by most agent applications. The database is accessible by any device or agent software, providing that the correct permissions have been granted and a local area network link has been obtained. For applications that are used by the public an additional layer of security was implemented, whereby web services were used to communicate with the database. Additionally, the server hosting the database was encrypted with Microsoft BitLocker.

A cloud database was created to store public accessible data which was later utilised in a running lap system. This was initially hosted in a Parse backend, but has been moved to the Microsoft Azure hosting services. The Parse backend system was initially used because it was free platform system which was envisaged to be sustainable with little operating costs. However, the system had to be migrated to an SQL database on the Microsoft Azure cloud platform due to cost constraints and available IT resources provided by the Sheffield Hallam University IT team.

3.2 Connectivity of the server and technology systems

The Sheffield FieldLabs central server was connected to a local area network, and local Wi-Fi. This allowed for the interconnection of other devices at the site and communication to the central SQL database. The main server had an internet connection to allow remote access of the server system for maintenance and monitoring. Additionally, this allowed for a connection to a cloud database. A schematic of the LAN system is shown in Fig. 2.

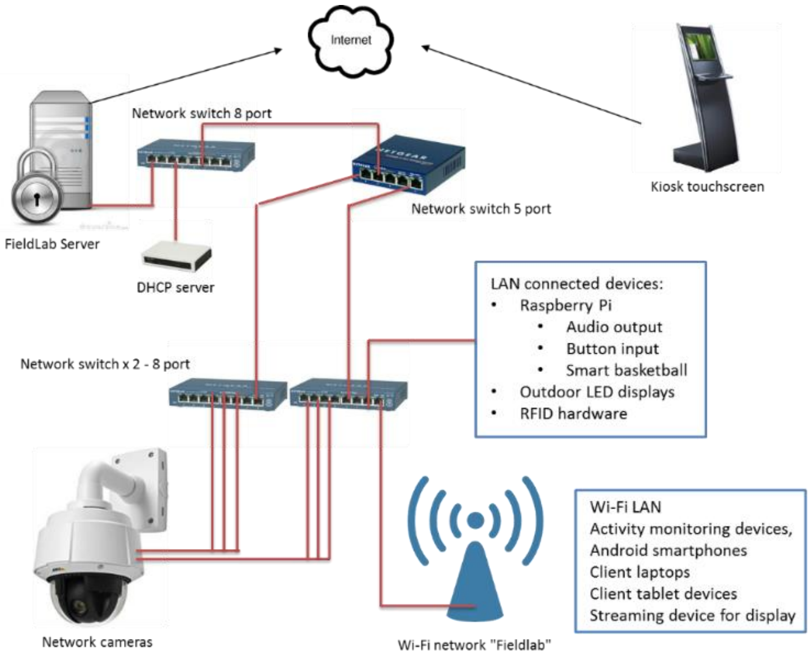


Fig. 2. Overview of the basic local area network infrastructure at each FieldLab site.

3.3 Pan-tilt-zoom and fixed camera system

At all FieldLabs a number of high definition pan-tilt-zoom and fixed camera systems were installed. These systems were used to gain quantitative/qualitative information about participants using the sites. Additionally, these cameras are used to directly measure the interaction of participants within the FieldLab. All cameras communicate via the LAN and were accessible from the central server. The camera systems were not directly accessible remotely due to security concerns.

3.4 LED display and outdoor screen systems

To feedback information to park and track users, two outdoor screens were created. At Lowfield a permanent LED display Fig.3a was installed that feedback lap and sprint times to participants. Communication with the LED screen was over a serial port emulator on the Ethernet network. A 42” outdoor display screen system was implemented for the SHUCAS site, Fig.3b. This was a standard screen with multiple HDMI inputs. A Chromecast device was used to stream a second screen from the server PC which allowed the use displaying of information from software applications around the track. This system could be wire-less through the use of a battery.

(a) (b)

Fig. 3. Outdoor displays at the field lab sites (a) SHUCAS (b) Lowfield

3.5 Kiosk feedback system

Touch-screen kiosk PCs were installed at the Lowfield and Delft FieldLab. These consisted of internet connected low power PC with a large touchscreen. A high screen was created for adults and a lower screen for children and wheelchair users. These kiosks were used to give out information of the FieldLab site but also capture verbal/visual feedback from users through a webcam and microphone. The kiosk is also used as a platform for results from the RFID lap timing system to be presented.

3.6 Smartphone activity monitoring system and tracking

An activity monitoring system was created to enable live monitoring of participants for research studies investigating participant interaction with pieces of installed equipment [15]. This system includes: Android smartphones with a custom application, Wi-Fi access points for beacons and various server based applications. An overview of this system is shown in Fig. 4.

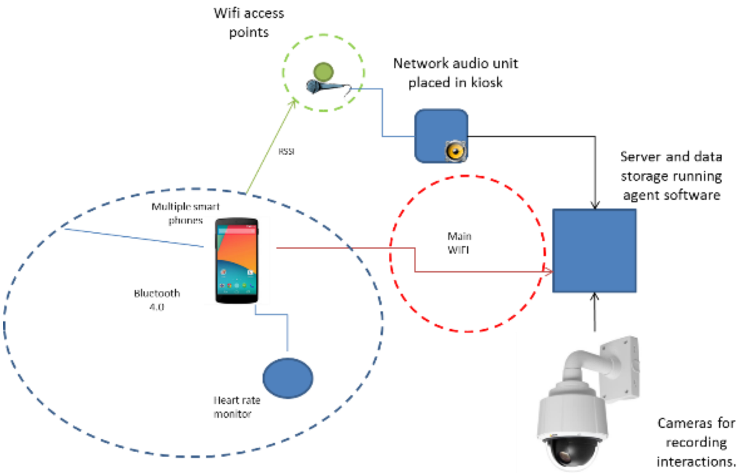


Fig. 4. Overview of the sprint track system components and agents

3.7 Interactive sprint track system

An automatically timed interactive sprint track was created on a perimeter footpath at Lowfield Park FieldLab. The system is started by a participant pressing a button at the start of a 50 m marked out running track. The button is linked to a Raspberry Pi model A running a script to monitor button-push. The system then outputs a start sound through a speaker and sends a signal to image processing software running on the main server. The software on the main server uses on of the pan-tilt-zoom camera pointed at the finish line to monitor two participants crossing the finish line in two lanes. A time is calculated based on the start trigger and the crossing of the participants over the line. When a time is calculated, these are posted to an LED display. An overview of this system is shown in Fig. 5.

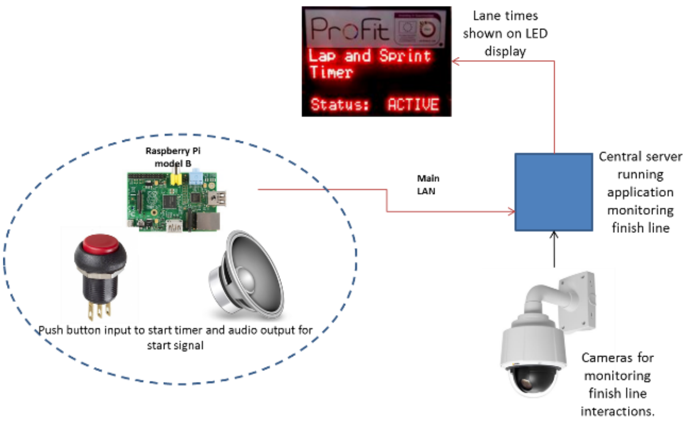


Fig. 5. Overview of the sprint track system components and agents

3.8 Radio frequency identification (RFID) running lap timing system

Within the footpath at the finish of the sprint straight at Lowfield park is a Radio frequency identification (RFID) system. Antennas are directly mounted underneath composite non-metal drainage covers to allow the passing of radio signals. The system is based on an ultra-high-frequency UHF system, and the RFID tags are passive. Tags are worn by participants and registered on a cloud database. The tag-user registration process takes place on an internet connected PC with a USB RFID reader within the U-Mix. When a tag worn by a runner passes over the start finish straight it is registered on the system and time/lap logging is initiated. Times/distance/laps are posted to the outdoor display system. A similar system is available at the SHUCAS FieldLab, but this system is portable and needs to be setup each time it is used and has the option of using a split timing system whereby distance run can be specified. To make this second system portable it was connected via a Wi-Fi link.

3.9 Gait Analyser

The Gait Analyser is an example of an agent application which has been deployed at the SHUCAS FieldLab site. The software analyses the gait of a participant in view on the running track. To perform analyses, users need only identify the running lane and capture duration (typically 3 seconds); no markers or sensors are applied to the athlete or running track. Software is operated using a graphical user-interface (shown in Fig. 6 on Wi-Fi enabled devices, minimising restrictions to the system's use (i.e. portability).

When performing live running analyses, a fixed network camera, viewing the final 10 m of the 100 m straight (perpendicular to running direction), streams RGB colour images (1280 × 720 pixels) to a server computer at 50 Hz. The Gait Analyser – developed using the .NET framework (C#) – automatically analyses images to identify foot contacts observed during running; multithreading allows parallel image capture and processing. Camera calibration parameters are retrieved from a database, allowing the calculation of real-world, spatio-temporal gait parameters. It has been reported that the system identified 100% of foot contacts (optimised setup) during sprint running; root-mean-square error was 108.9 mm and 0.03 s for foot contact position and time respectively [16]. Further, numeric and video results were provided to athletes within 2-3 s of capture.

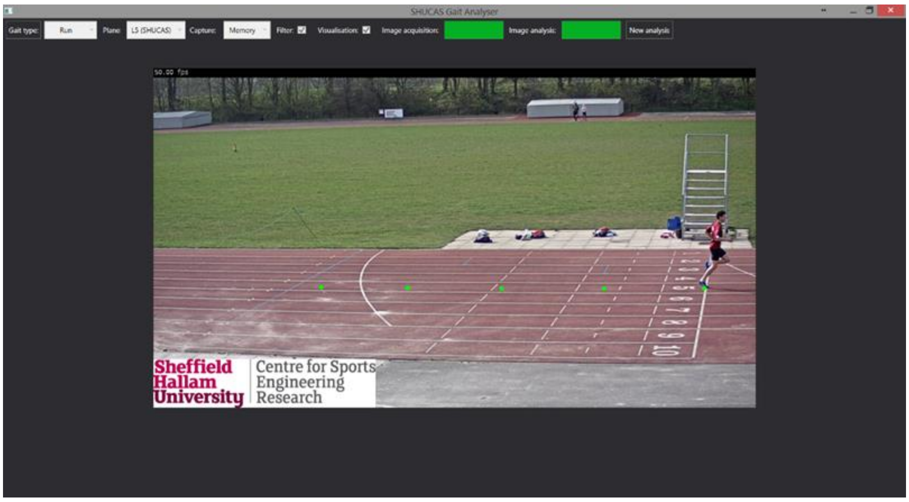


Fig. 6. Graphical-user-interface for the Gait Anlyser agent software

3.10 Justification for the selection of IoT technology systems

An overview of the IoT systems used, alternatives and the justification behind each of the choices for the FieldLab Smart Park systems are shown in table 1.

Table 1. IoT system deployed in both the Sheffield FieldLab Smart Parks, their alternatives and justification for their use.

System type	System used	Alternatives	Original justification
Central Database	MicrosoftTM SQL	MYSQL or NoSQL alternatives	Widespread use of Microsoft SQL, in existing systems and data validation could be undertaken.
Cloud database	Parse™	Microsoft Azure, AWS + other cloud providers	Parse™ free to setup and had a host of featured to help development. Moved to Microsoft Azure due to Parse shutting down in Jan 2017.
LAN cameras	Axis Network cameras	Various other network camera systems	Development team had experience with Axis products
Health care sensors for live streaming of data	Smartphone with bespoke software	No available at the time of development	No cost effective alternatives at the time
Input system, network enabled switch	Raspberry Pi	Off the shelf solutions such as the Axis P88221 input output module	Raspberry Pi, low cost and quick to develop. Provided option for customization and includes audio output
Identification system	RFID, UHF passive system	Near field RFID, active RFID	RFID UHF tags are cheaper and do require battery power. Range can be greater for UHF system over alternative frequency ranges. Range gained by an active system not required.
Permanent display	Bright LED 4 line	Outdoor HD display	LED display less likely to be stolen and vandalised compared to the alternatives.
Portable display	Weatherproof outdoor display	Bright LED display	Flexibility to show video and custom display information
Interactive kiosk system	Windows based website touchscreen	Tablet based	Off-the-shelf outdoor system were available and website development could be outsourced easily.

4 Conclusions and future work

Overall the creation of the Smart Parks or FieldLabs in Sheffield and the other European cities was deemed a success. The technology systems developed and deployed at both sites in Sheffield have generated a lot of interest from the general public and researchers. The technology has also been welcomed by elite athletes and coaches who use the video capture system and gait analyser at the SHUCAS site. The running lap system and sprint track at the Lowfield site has been well received and the user base is growing daily. The running lap has now been included as one of the official ‘Run Route’ which are being promoted around the city of Sheffield. The number of users of the Lowfield site has been monitored and qualitative feedback has been collected from the Kiosk touchscreen PCs, which have been positive. The majority of systems deployed at the SHUCAS site have also been utilized in school events where events have been automatically timed and results displayed on the outdoor screen.

There have been some issues with implementing the IoT systems at both the FieldLab sites. The first issue is that both sites are remote which meant that general maintenance and upkeep of the technology was difficult. Remote access was carried out with Teamviewer^{TM}, but supporting users of the system proved difficult remotely. Additionally, simple things such as a reliable internet connection was difficult to secure at both sites. This meant the stability of the RFID running lap system which used a cloud database was affected when the internet connection was down. One of the problems of the Lowfield site specifically was environmental issues, where some of the systems were affected by water ingress and extreme cold temperatures. This meant some of the hardware on the site had to be replaced and some of the systems have been down for periods of time since the end of the ProFit project. Finally, it has been found that some of the systems at the SHUCAS site have suffered from reduced usage due to the potential complexity of the system and lack of training of staff at each site to use the systems to their full potential.

In conclusion the prototype systems showed that people will utilize the IoT systems to enhance their experience in using the facilities and the numbers of users at the Sheffield Smart Parks are increasing. If there are any technical issues users will get frustrated and cease to use the system. Therefore, any system being deployed needs to be simple and robust. Longitudinal data is currently being collated to see whether these systems can sustain their usage in the long term.

The systems developed in the Sheffield FieldLabs are going to be transferred to the Olympic Legacy Park [17] which encompasses the Advance Well-being Research Centre (AWRC) [18]. The systems will be developed to fit in with the new recreation space available within this park and incorporate new features to make the systems more user-friendly, robust and easy to deploy. This will hopefully increase the usability of the systems and increase numbers using the systems.

The vision of the AWRC is to encourage healthy living through increases in physical activity levels in the general population. Technology and systems like that explained in this paper allow for the creation of “smart” recreational facilities which could help facility the AWRCs goals in the future.

References

1. ProFit 2013. FieldLAB: An opportunity for internation cooperation in sports innovation [online]. Last accessed on 01/11/2013 at URL: http://www.fieldlabs.eu/
2. Lowfield Park [online]. Last accessed on 01/06/2016 at URL: https://www.sheffield.gov.uk/out--about/parks-woodlands--countryside/parks/city-district-local-parks/lowfield-park.html
3. Sheffield Hallam University City Athletics Stadium [online]. Last access 01/06/2016 at URL: https://www.shu.ac.uk/shucas
4. Godbey, G. (2009). Outdoor recreation, health, and wellness: Understanding and enhancing the relationship.
5. Lachowycz, K., & Jones, A. P. (2013). Towards a better understanding of the relationship between greenspace and health: development of a theoretical framework. Landscape and Urban Planning, 118, 62-69.
6. Arnrich, B., Mayora, O., Bardram, J., & Tröster, G. (2010). Pervasive Healthcare. Methods of Information in Medicine, 49(1), 67-73.
7. Intille, S. S. (2004). A new research challenge: persuasive technology to motivate healthy aging. IEEE Transactions on information technology in Biomedicine, 8(3), 235-237.
8. Move More App #EveryMinuteCounts [online]. Last accessed on 31/08/2016 at URL: https://www.movemoresheffield.com/app
9. Sheffield NCSEM up and running [online]. Last accessed on 31/08/2016 at URL: http://www.iseh.co.uk/news/latest-news/sheffield-ncsem-up-and-running
10. Gluhak, A., Krco, S., Nati, M., Pfisterer, D., Mitton, N., & Razafindralambo, T. (2011). A survey on facilities for experimental internet of things research. IEEE Communications Magazine, 49(11), 58-67.
11. Nati, M., Gluhak, A., Abangar, H., & Headley, W. (2013, June). Smartcampus: A user-centric testbed for internet of things experimentation. In Wireless Personal Multimedia Communications (WPMC), 2013 16th International Symposium on (pp. 1-6). IEEE.
12. Sánchez, L., Gutiérrez, V., Galache, J. A., Sotres, P., Santana, J. R., Casanueva, J., & Muñoz, L. (2013, June). SmartSantander: Experimentation and service provision in the smart city. In Wireless Personal Multimedia Communications (WPMC), 2013 16th International Symposium on (pp. 1-6). IEEE.
13. Perera, C., Zaslavsky, A., Christen, P., & Georgakopoulos, D. (2014). Sensing as a service model for smart cities supported by internet of things. Transactions on Emerging Telecommunications Technologies, 25(1), 81-93.
14. Kotsev, A., Schade, S., Craglia, M., Gerboles, M., Spinelle, L., & Signorini, M. (2016). Next Generation Air Quality Platform: Openness and Interoperability for the Internet of Things. Sensors, 16(3), 403.
15. Foster, L., Gielen, M., Beattie, M., & Goodwill, S. (2014). Real-time monitoring of user physical activity and position in an outdoor public space. In Ubiquitous Computing and Ambient Intelligence. Personalisation and User Adapted Services (pp. 100-107). Springer International Publishing.
16. Dunn, Marcus and Kelley, John (2015). Non-invasive, spatio-temporal gait analysis for sprint running using a single camera. Procedia Engineering, 112, 528-533
17. Olympic Legacy Park [online]. Last access on the 01/06/2016 at URL: http://olympiclegacypark.co.uk/
18. Advanced Wellbeing Research Centre (AWRC) [online]. Last accessed on 01/06/2016 at URL: www.shu.ac.uk/research/awrc