ICDSST – PROMETHEE DAYS 2018 PROCEEDINGS – THE EWG-DSS 2018 INTERNATIONAL CONFERENCE ON DECISION SUPPORT SYSTEM TECHNOLOGY & PROMETHEE DAYS 2018:
Jason Papathanasiou, ???
(editors)
Heraklion, Greece, 22-25 May 2018

A smart campus design: data-driven and evidence-based decision support solution design

Uchitha Jayawickrama, Mohamed Sedky, Oumaima Ettahali
Staffordshire University
School of Computing and Digital Technologies, ST4 2DE United Kingdom
uchitha.jayawickrama@staffs.ac.uk, m.h.sedky@staffs.ac.uk
web-page: http://www.staffs.ac.uk/

ABSTRACT

The growth and the availability of the smart devices is becoming ubiquitous today and inter-networking of these devices make up what is commonly called the Internet of Things (IoT). IoT is being used to update, enhance, simplify and automate individual lives and communities. Most of the cities in general and universities in special are adopting IoT technologies in order to create a smart sustainable living and working environments. Based on the existing literature of smart campus domain, it can be observed that there is only a small number of models as such. This study attempts to bridge the following knowledge gaps of smart campus domain.

This project falls into the concept of Smart Campus and aims to design a Smart Campus solution for Staffordshire University. The primarily goal is to design a solution architecture able to collect data from remote sensor networks and analyse them with the support of data analytics and machine learning techniques for sound business decision making. The project has two stages. The first stage is the business side of the project where a business requirement study has been done to extract the exact business requirements and once this complete the second stage was the technical implementation of one or many requirements and evaluation of the solution. The scope of this paper limits to the first stage of the project.

A quantitative approach was chosen by considering the nature of this study. A self-administered online questionnaire was developed around several key challenges and directed especially to the staff members, in order to identify what are the expectations of university staff in relation to thematic topics. Subsequently, business requirements under each key challenge were ranked based on MoSCoW prioritisation method. Energy management, space utilisation and occupancy, cleanliness recognition, smarter car parking, internet enabled café, network and physical security and environment (temperature) control are the key business challenges identified. Moreover, intended system qualities and specific project benefits were also identified to scope the project well.

Keywords: Smart campus, Internet of things (IoT), Decision support, Data analytics, Machine learning, United Kingdom

INTRODUCTION

The Internet of Things (IoT) is becoming an increasingly growing topic of conversation both in the workspace and outside of it. It is a concept that not only has the potential to impact how we live but also how we work [1]. When talks about IoT it naturally means that data, big or small is in the center of IoT world of connected devices. As any organization or institution needs to collect meaningful and mirroring information about its internal environment [2,3]. The Internet of Things provides with lots of sensor data, these data are the output of some devices that detect and respond to some input from the physical environment. However, the data by themselves do not provide value unless convert them into actionable, contextualized information [4]. In this context, the amount of information flowing around and through systems at any given time is truly remarkable, and the intelligent machines/solutions being created to deal with it are becoming even more remarkable.

In the space of IoT, the concepts such as smart cities, smart homes and smart healthcare are dynamic and ever growing with the support of data analytics and machine learning [5]. This paper focuses on a fairly new concept called smart campus which largely attempts to improve the quality and performance of the university services, to reduce costs and resource consumption, and to engage more effectively and actively with its students, staff and other stakeholders. This paper presents the design of a novel smart campus solution in Staffordshire University, UK.

RELATED WORK

The Internet of Things (IoT) refers to the vast world of interconnected devices with embedded sensors which are capable of providing data, and in some cases, being controlled, across the internet [6,7]. Common examples include many home automation devices, like smart thermostats and remotely controllable lighting fixtures, but there are countless others, from traffic sensors to water quality meters to smart electric grid components to tracking manufactured goods and vehicle fleets worldwide [2,4]. Therefore, there is no exact definition to the Internet of Things, this concept was defined many times from different perspectives and points of view.

The idea of Smart Campus

Smart campus is a new idea in the development of ICT (Information and Communication Technology) within a University Campus to improve the quality and performance of the services, to reduce costs and resource consumption, and to engage more effectively and actively with its members. The university presents itself as the ideal space of experimentation, representing to a lesser extent the urban environment and its real needs [2,8]. The defining technologies that have brought Smart Campus concept to the forefront are IoT and Cloud computing.

Cloud Computing is the integration of various resources extensively, and the offer of supercomputing and storage capacity, which has three types of services: Infrastructure as a Service, Platform as a Service, and Software as a Service [1,5]. The internet of things which divides into sensing layer, network layer and application layer is the product of effective fusion of sensor networks, Internet, and mobile communication network, and its core is the sensory system [4,9]. The architecture of smart campus based on the cloud computing and the Internet of things consists of unified portal system, service support platform, data information convergence platform, network convergence platform, as well as information standard system and security maintenance [1,6]. The drive towards a smarter campus and its extension towards smart cities is inevitable.

Madrid Moncloa University Campus

The Campus of the University of Moncloa has around 150 buildings in an area of 5.5 square kilometers, including schools, research centers, and student housing, plus three sport areas and large green spaces. Tens of thousands of cars use the Campus roads every day. The Campus has a good public transport service with two subway lines and thirteen bus lines.

The platform proposed is Smart CEIM, it has a powerful cloud-based storage and computing infrastructure [10,11]. It complies with open standards in order to facilitate the deployment of new experiments and services. This infrastructure provides adequate capacity for the use of Big Data techniques, as well as interfaces for Open Data access [12]. The demonstration room houses the platform dashboard and offers several large screens for displaying experiment results. The platform offers an initial set of pilot services, which will be extended with additional services developed in the future. Currently deployed services include [10,13]:

- Environmental monitoring: By deploying a network of sensors distributed across the campus, this service allows monitoring various environmental parameters such as temperature, humidity, light intensity, noise, and air quality.

- Monitoring energy consumption: This service allows monitoring and analysis of electricity consumption in campus buildings by using sensors coupled to electrical boxes.
- Analysis of people flows and vehicle flows: This service allows the approximate count of people and vehicles in the campus, as well as the analysis of movement patterns, busiest places, times spent in points of interest, etc.

The implementation of these services has required the installation and configuration of several sensor networks throughout the campus, plus auxiliary power and communication network infrastructures.

University of Twente, Netherlands

There are two key aspects of the smart campus solution of University of Twente (UT); human movement aspect and CO2 reduction aspect.

Human movement in University of Twente, Netherlands

The University of Twente (UT) campus is a place where people can work, live and participate in leisure activities. All these functions were taken into account when the campus solution was designed. However, it is difficult to determine how the campus is actually being used. To this end, a measuring system that maps out the actual use and movements around the campus is required.

The technology to be used for this is Wi-Fi tracking, which entails using the Wi-Fi signals of mobile telephones to analyze visitor behavior. To this end, the UT will work together with BlueMark Innovations, which is a UT spin-off company. The technology UT have opted for will provide it with a lot of information as well as with challenges, such as incomplete data, disruptive signals, privacy issues, etc. Moreover, due to its extensive nature, it is difficult to contain it in a two-year project [14,15].

CO2 for life in the University of Twente, Netherlands

This project's goal is to complete the carbon cycle by combining the fully renewable resources. This entails combining CO2 from the air with water and renewable electricity to form methanol (CH3OH). This process can be realized for one or multiple buildings on campus, including the high-pressure laboratory. This makes it possible to store a temporary surplus in electricity generated by solar panels/wind turbines, thus actively reducing CO2 emissions. The CO2 produced can then be turned into electricity in fuel cells, but also into petrol and diesel replacements (DME) or into a resource for plastics back into synthesis gas. Furthermore, the collected CO2 could also be used for growing processes in greenhouses and for the cultivation of algae. This contributes to the creation of a society in which the carbon cycle is completed without creating an energy, food or resources deficit.

The project can fit in seamlessly with some current programs as well as with research projects at various faculties. The project will likely be an important, additional component in the development of major, newsworthy projects [14,15,16].

Research gaps

Based on the existing literature of smart campus domain, it can be observed that there is only a small number of models as such. This study attempts to bridge the following knowledge gaps of smart campus domain;

1. Lack of end-to-end smart campus solutions which look at all aspects of a smart building such as environment control, energy management, room utilisation, cleanliness recognition, smart carpark, security patrolling and internet enabled café.
2. Lack of usage of predictive and prescriptive analytics on real-time data feeds such as PIR sensors, air quality monitors, surveillance cameras and major university databases.
3. Lack of such smart campus solutions in the United Kingdom context.

RESEARCH APPROACH

Staffordshire University Smart Campus is a project that aims to bring many benefits in the short term as well as in the long term. It aims to develop both the human and the technical infrastructures of the University by offering smart solutions to some issues encountered inside the campus in order to make the life easier for students and staff and to produce some important optimizations including energy, human resources and so forth.

Therefore, the Smart Campus goal is to design an architecture able to collect data from remote sensor networks, to store them and to give access to them in an efficient way. The Smart Campus project has two stages. The first stage was the business side of the

project where a business requirement study has been conducted to extract the exact business requirements and once this complete the second stage was the technical implementation of one or many requirements and evaluation of the solution. The scope of this paper limits to the first stage of the project. The starting stage of turning Staffordshire University into a smart campus is converting Beacon building which is a new building that have been completed in September 2016 into an intelligent/smart building.

Considering the nature of the study, a quantitative approach was chosen [17,18]. The key challenges (building use, energy use, crewing guides, consumables and chemicals, response team, maintenance planning, security patrolling, positioning of retail offers and outlets, catering production planning, and student accommodation utilization) are the result of a number of comments and complaints received from the University students and staff directly or indirectly (social media pages, forums and student community). A questionnaire was developed around these challenges and directed especially to the staff members and student representatives, in order to identify what are the expectations of university staff and student representatives in relation to these topics. The reason for which the questionnaire was not directed to the students in general is that large numbers of student responses may lead the project requirements to a divergence in relation to the time and budget granted for this project.

Smart Campus questionnaire

The potential for and interest in developing the Staffordshire University as a Smart Campus, is considerable and growing. By Smart Campus, we mean a campus that is efficient, safe, sustainable, responsive and enjoyable place to study and work, underpinned and enhanced by digital/ internet based technologies. The objective of this questionnaire is to formulate and develop a clear idea about how a smart campus would improve the University business in order to be converted into a Smart Campus by targeting the users of university services.

There are different types of questionnaires depending on the targeted people and the scope of the study (such as internet mediated, postal, and delivery and collection questionnaires) [17]. Only the undertaken type will be justified as the other types do not cope with the project nature. The type of questionnaire used was the internet questionnaire classified as a self-administered type of questionnaires that are administered electronically and usually completed by the respondents [17]. The fact that the targeted people are University staff and student representatives means that they all have access to internet and obviously computers. The questionnaire was created using the online tool Survey Planet and could be previewed via a link in the tool's website - https://s.surveyplanet.com/593f53b2f09d543e1d4c5ed6

ANALYSIS AND FINDINGS

After determining the challenges faced by Staffordshire University's campus and the type of data required for each challenge, and after collecting the questionnaire results that have given a more clearer idea about the expectations of the University stakeholders related to these challenges, a detailed project specification was the output in order to determine the qualities or the benefits and the potential functionalities and requirements of the targeted system. This solution was broken down into a Smart Building and Smart car parking, each one has a number of qualities that should be fulfilled by the end of the Smart Campus project. Each system should respond to the security measures so that the data manipulated as well as the physical infrastructure that would turn into a smart infrastructure would be well protected and secured.

Business requirements

From the qualities previously defined for the Smart Campus solution, a set of functionalities were extracted from each one of them in order to have a clear idea about what the system need to do after its implementation. The requirements were ranked based on "MoSCoW" technique that uses four priority groups [19]: Must, should, could and will not and where the project stakeholders prioritize the requirements in a collaborative way. The list of requirements is presented below (other requirements related to key challenges were not listed due to page restrictions such as Space utilization and occupancy, Cleanliness recognition, Smarter car parking, and Internet enabled café):

Energy management

An overview of energy usage, providing readings for electricity, gas, and other relevant energy source usages for buildings.

MoSCoW	Solution Aspect
Must	▪ Collect & display data on: ▪ electricity usage per room per time ▪ gas consumption per unit per time – more electricity data ▪ water consumption

Should	▪ Switch off elevator light when not in use ▪ Switch off room light when not in use ▪ If devices are logged on and active for lengthy periods, email user – auto logout? ▪ Highlight/emphasise higher than usual usage
Could	▪ Collect & display data on electricity usage per room **per power outlet** per time ▪ Remote disabling of outlets in case of issue(s) or abuse(s)
Won't	

Smart Campus business plan

Several workshops have been conducted with the project stakeholders and coordinated by lead researchers in the project team in order to discuss different aspects of the project from various perspectives. One of the workshops was around studying the attractiveness factors of the project and prioritizing them based on the correlation between them and the elements that are going to be subject of the Smart Campus implementation. The project stakeholders participated in assigning to every correlation a number from one to ten [1-10] depending on whether it is high or low based on real examples. Then the total score was calculated for each challenge. This method was used in order to choose the three highest challenges that will be solved as part of the Smart Campus project which are the building use, the environmental monitoring, the crewing guides and the maintenance and planning, however, the implementation of the environmental monitoring is expensive and may lead to an over budget which will have negative effects on the university business.

Project benefits

The business benefit can be defined as an outcome of an action or decision that contributes towards meeting business objectives [9,20,21]. This serves well for many business planning and business analysis needs. Defining business benefits in terms of business objectives provides a practical basis for measuring, valuing, and comparing both financial and non-financial benefits [15,22]. The financial benefits are the defined and measured in financial terms, such as cost savings, sales revenues, or profits [23]. While the non-financial benefits are defined and measured first in non-financial terms [23]. These may include changes in key performance indicators, accident rate, or student satisfaction survey scores. The Smart Campus benefits where decomposed as well into financial benefits and non-financial benefits.

CONCLUSIONS

This paper focuses to determine the upcoming demonstrator design starting with the data sources available for this project until the visualizations that could come out from these data that will help the decision makers to make appropriate decisions. Figure 1 shows that the main technology that has been used during this project is Machine Learning. Many algorithms were created in order to implement Machine Learning that is subdivided into many fields but only one algorithm has been used for the project.

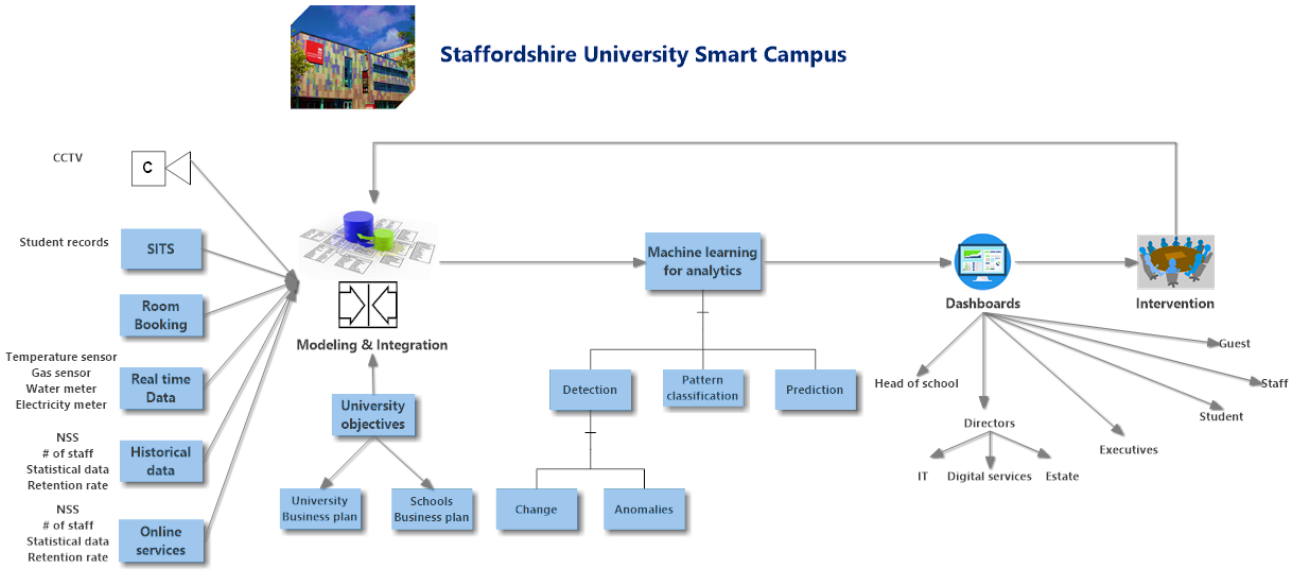

Figure 1: The Smart Campus design

The execution of this project as a whole requires data sources, these data sources vary between the University databases, historical data and online services, or they could be real time data generated by sensors. Based on the objectives set by the University that could result either from the University or the schools' business plans, data have been modeled and integrated in order to present in appropriate patterns and provide as input to Machine Learning for predictive and prescriptive analytics. Machine learning for analytics is divided into three components: detection that could be detection of a change or detection of anomalies, pattern classification is about classifying objects or events into some known classes, or it could be prediction for future actions, events or values [18,24,25]. The result of the Machine Learning will be used in providing dashboards and data visualizations intended to the heads of schools, the executives, the staff, the students and the guests for making the appropriate interventions and make the right decisions in order to improve the University's business results. These interventions could result in new ideas and needs for new data visualizations and new decisions [26].

All sections discussed in this paper constitutes different stages of the project; initial study of the Smart Campus project, that specifies all the work that was performed regarding this project, starting with the problems and challenges that were encountered by the University staff and students, then setting the targeted system qualities. Subsequently, the phase of requirements setting where for each challenge previously discovered, the business requirements were extracted based on priorities which were established based on questionnaire survey and MoSCoW prioritization method. Thus, the technical requirements and the material resources that will be required were externalized, and the benefits that would result from this project were presented. Finally, the design of this Smart Campus solution was developed.

In future, we expect to extend the works of this paper to another paper in order to present the implementation of this smart campus solution using machine learning intelligence and other technologies used to put the current project into action.

REFERENCES

1. Morgan, J. (2014). A Simple Explanation Of'The Internet Of Things'. In *The Little Black Book of Billionaire Secrets.*
2. Bates, O., & Friday, A. (2017). Beyond data in the smart city: learning from a case. 1.
3. Mashal, I., Alsaryrah, O., & Chung, T.-Y. (2015). Choices for interaction with things on Internet and underlying issues. *Elsevier, 28*, 68-90.
4. Pizurica, V., & Piet , V. (2015). *A Cloud-Based Bayesian Smart Agent Architecture for Internet-of-Things Applications.*
5. Ning, H., & Wang, Z. (2011). Future Internet of Things Architecture: Like Mankind Neural System or Social Organization Framework? *IEEE*, 461-463.
6. Jayavardhana, G., Rajkumar , B., Slaven , M., & Marimuthu , P. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Elsevier*, 1645-1660.
7. Khan, R., Khan, S., Zaheer, R., & Khan, S. (2012). Future internet: the internet of things architecture, possible applications and key challenges.
8. Alpaydin, E. (2014). *Introduction to machine learning.* London, England: The MIT Press.
9. Aazam, M., & Huh, E. (2014). Fog computing and smart gateway based communication for cloud of things., (pp. 464-470).
10. Ivan, S. (2014). The Fog Computing Paradigm: Scenarios and Security Issues. *IEEE*, 1-8.
11. SmarCitiesUK. (2017). *Smart Cities UK 2017 Conference, Expo and Awards*. Retrieved from smartcityuk: http://www.smartcityuk.com/
12. Yuwei, C., Subutai, A., & Hawkins, J. (2017). The HTM Spatial Pooler: a neocortical algorithm for online sparse distributed coding. *biorxiv*.
13. Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for Smart Cities. *IEEE*, 22-32.
14. University of TWENTE. (2016, March 16). *CO2 for life*. Retrieved from University of TWENTE: https://www.utwente.nl/en/organization/news-agenda/special/2016/living-smart-campus/projects/co2-for-life/
15. University of TWENTE. (2016, March 16). *Human Movement*. Retrieved from University of TWENTE: https://www.utwente.nl/en/organization/news-agenda/special/2016/living-smart-campus/projects/human-movement/
16. Weyrich, M., & Ebert, C. (2015). Reference Architectures for the Internet of Things. *IEEE*, 112-116.
17. Saunders, M., Lewis, P. & Thornhill, A. 2009. *Research methods for business students*, 5th ed. Harlow, England, FT Prentice Hall.
18. Wu, M., Lu, T.-J., Ling, F.-Y., Sun, J., & Du, H.-Y. (2010). Research on the architecture of Internet of Things.
19. Business Analyst Learnings. (2016, August 18). *A List of Requirements Prioritization Techniques You Should Know About*. Retrieved from Business Analyst Learnings: https://businessanalystlearnings.com/blog/2016/8/18/a-list-of-requirements-prioritization-techniques-you-should-know-about
20. EO, H., & Dj, C. (2003). Improving home automation by discovering regularly ocurring device usage patterns. *Third IEEE International conference on data mining* (pp. 537-540). Washington DC.: IEEE.
21. Geitgey, A. (2016, July 14). *Machine Learning is Fun! Part 4: Modern Face Recognition with Deep Learning*. Retrieved from medium: https://medium.com/@ageitgey/machine-learning-is-fun-part-4-modern-face-recognition-with-deep-learning-c3cffc121d78
22. *Internet of Things Network Campus Solution*. (2016). Retrieved from extremenetworks: http://www.extremenetworks.com/resources/internet-of-things-network-campus-solution/
23. Public Sector Executive. (2017, February 23). *Bristol: the booming smart city*. Retrieved from Public Sector Executive: http://www.publicsectorexecutive.com/Comment/bristol-the-booming-smart-city
24. Python. (2016). *Python*. Retrieved 4 2nd, 2016, from https://www.python.org/downloads/
25. Rawlinson, D. (2014, April 28). *TP 1/3: Temporal Pooler background*. Retrieved from Project AGI: http://blog.agi.io/2014/04/temporal-pooler-theory.html
26. *Staffordshire University*. (2017). (The complete University guide) Retrieved from https://www.thecompleteuniversityguide.co.uk/staffordshire/