

A Survey of Recent Smart Space Context-Aware Systems for University Campus Environment

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Abstract

Background: *In the computing world, smart devices play a vital role in the modernization of smart spaces which include the environment where these devices act by sensing and control via sensors and actuators. In order to improve on existing smart space infrastructure in university campus environments, context aware computing has been recently proposed by many researchers. In this survey, the interested smart space researchers are provided with recent smart space literature of significant impact in the field of context-aware-computing including key algorithms/techniques used in the field and how it has been adapted to a campus environment. The implications of this study reveal the need to incorporate new techniques that leverage on hybrid or group processing coding to improve the overall functionality of smart space context aware computing systems.*

Keywords: *auto-regressive, context aware system, hierarchical search, k-Means-NN, real time, simple expert, smart space*

1. Introduction

Context aware computing systems (CAS) models are challenged with variety of multifaceted problems. First, there are sub-problems that relate to the formalization, expressiveness and generalization of processed information; these problems are a consequent of the domain dependency problem (ddp). Second is the device constrain problem (dcp). In this aspect, context aware devices for real time applications are constrained by space requirements and in turn hardware-specific memory requirements. An instance of this problem is in deployment of spy sensors where there is a requirement that devices themselves must be very tiny for a limited installation space and small hardware-specific memory foot print.

Although, there have been increased research in the CAS area, there is still a gap in the literature as to what CAS techniques are currently in use and their potential strengths or weaknesses. As it pertains the smart university, the campus wide applications of embedded smart devices are becoming common place. Thus, a knowledge of existing CAS models is essential if the smart space researcher must come up with better CAS solutions.

In this paper, we present the review of the current state-of-the-art in context aware computing systems (CACS) with a particular preference for smart space applications.

2. Related Works in the State-of-the-art for Smart Spaces

Smart devices and systems is almost everywhere with most organizations struggling to meet up with the rising trend in order to enhance business processes. On the flip side, consumers are really delighted that value added services are now included in modern day gadgets like

smart phones, pdas and tablets. Currently, it is projected that the number of internet connected devices will rise to as high as 50 billion; that would be roughly 7 times the expected human population (Sharma and Suryakanthi, 2015). In Atif *et al.* (2015), a framework for ubiquitous learning in a smart campus was proposed. The framework captures pervasive learning resources, semantic relations, multimodal learning and automatic generation of instructional paths in a smart campus environment. In Shen *et al.* (2014), investigations have been carried out on how Near Field Communication (NFC) devices can be applied in the Smart Classroom context for the intents of attendance management automation. The benefits of such system include real time student feedback, intelligent location, intelligent monitoring of learning progress, name visualization and remote course performance monitoring.

Sharma and Suryakanthi (2015) proposed a smart campus model system that has been deployed in a smart campus for performing real-time control and energy management of electrical and electronic devices. The system provides for situations where human interventions don't seem to work or function correctly by using a simple expert. Support for remote operation of smart devices within the smart campus is also provided using cloud computing principles. In Iqbal *et al.* (2015), a web based control scheme is proposed that employs HyperText Transfer Protocol (HTTP) and the Representational State Transfer (RESTful) framework for different control tasks including humidity and temperature regulator of exhaust fans, water pump, door control etc.

CUPUS - a community-based publish and subscribe IOT scheme for Mobile Crowd Sensing (MCS) has been proposed in Antonić *et al.* (2016). With CUPUS, the mobile end users are given special contribution access via wearable smart communication devices and coordinated by a mobile sensor broker.

Massana *et al.* (2017) proposed a smart campus application for predicting the consumption of electricity in 7 university buildings. Their model was based on a simple Auto-Regressive (AR) technique. Their results indicate the sensitivity of the AR technique to the profiling of the building and the quality of data obtained from the building smart space and the time of day or week the data is obtained.

In Lin *et al.* (2017), an Internet of Things (IoT) concept coined IoTtalk was developed for enhanced mobility management inside a university campus in Taiwan. IoTtalk uses a location dependent global positioning systems (GPS) for improved experiences within several applications such as campus dog tracking, emergency alerting, particulate matter 2.5microns (PM2.5) monitoring and environmental robotic monitoring of physical parameters.

Optimized microprocessor system including radio monitoring circuitry, two-lane traffic monitoring using infrared sensors, artificial neural network (ANN) based flash flood detection using ultrasonic sensors, water level sensors and a recovery circuitry for reliability enhancement is proposed in Jiang and Claudel (2017). The system has been applied in vehicle traffic monitoring established on the theory of temperature variance exhibited by presence-aware mechanisms and water level sensing in the KAUST campus in Saudi Arabia.

In Pagliaro *et al.* (2017), the performance evaluation of one of the winner strategies (the environment axis) which built on the notion of smart fields introduced earlier in (Mattoni *et al.*, 2015) was investigated in the Sapienza Campus in Rome Italy; the environment axis favors the use of trash compactors with recycling plans to remove waste from the Sapienza campus environment. Simulation studies using MATLAB-SIMULINK modeling software showed a more efficient way of displacing the trash compactors and renewal (renewed usage) of waste trucks. In Bakken *et al.* (2017), the benefits of a smart classroom based Natural Text-to-Voice and Voice-to-Text software systems for supporting learners with disabilities has been studied. The authors reported better learning and understanding positive ratings for

students with disabilities interacting with such natural smart sensing software compared to comparable Windows and Google Docs voice/text software.

Trilles *et al.* (2017) proposed embedded open sensorized hardware platforms for monitoring environmental phenomena such as meteorological data and air quality within a university campus. The system further described GIScience standards and solutions for ensuring interoperability between Internet of Things (IoT) and smart city solutions.

More recently, in Martín-Garín *et al.* (2018), a low cost but optimal environmental monitoring system was also proposed. The system used Open Source Platform (OSP) with Internet of Things (IoT) technology to calibrate and measure humidity, temperature and CO₂ gas emissions in a residential building. In Petrie *et al.* (2018), optimal smart control strategies for improving HVAC system performance has been developed for the Texas Tech University (TTU) campus. Here, their proposed solutions used Pattern Recognition Adaptive Controller (PRAC) and Model Predictive Controller (MPC) with online optimization algorithms for minimizing the errors within the Air Handler Unit (AHU) in the HVAC system; these methods gave better results than traditional control strategies used in the study campus. In da Cruz *et al.* (2018), qualitative and quantitative performance evaluation studies using open source middleware platforms were investigated for the Intel Smart Campus. Comparative studies were performed for 11 middleware platforms; qualitative performance indices for the middleware include the communication methods with the server, a quadruple security measure, their starter development kit (SDK) programming languages, and the number of releases in a year (year 2017 was considered). Quantitative studies were performed for only 5 middleware platforms - IntelPlat, Konker, Linksmart, OrionSTH, and Sitewhere. It was found that Sitewhere gave the best performance particularly for large number of concurrent users. Uzelac *et al.* (2018) proposed a smart classroom system that allows the classification of student's satisfaction against lecture quality based on certain physical parameters. In Toutouh *et al.* (2018), an evolution algorithm for prediction of vehicular road traffic mobility was developed for a smart campus application in University of Malaga, Spain. The system was intended to support real road traffic prediction in order to evaluate the situation of traffic from real sensors using a least feature set selection bi-level evolutionary optimization algorithm. A reduction of about 90% in data needed for learning mobility patterns was reported by the authors. Plageras *et al.* (2018) proposed a topology-architecture system for a smart campus building that allow for energy efficient solutions based on a well-managed sensor data collection process consideration several physical parameters such as temperature, movement, light and moisture. Trail-Care, a pragmatic context-aware/trail-aware scheme used for real-time support of wheelchair users has been proposed in (Barbosa *et al.*, 2018). The scheme enables the disabled users to store trails within an indoor/outdoor environment and later use the stored trails (trail recordings) to capture context for accessing locations. Carreira *et al.* (2018), proposed a vote consensus conditioning system that allows end users to play a contributory role in the smart space. The vote consensus is supported with a machine learning technique – k-Nearest Neighbors (kNN) for further coordination of Heating Ventilation and Air Conditioning (HVAC) system.

Kiziiikaya *et al.* (2019) developed algorithms for near field detection of car parking spots in a university campus. The algorithms used a hierarchical search procedure where a nearest car park is first found, and then the available (free) parking spot(s) is correspondingly searched. In Sutjaritham *et al.* (2019), a very interesting smart campus system application was developed for the prediction of classroom attendance and for optimally allocating classes so as to resolve the classroom underutilization problem. The system used several machine learning artificial intelligence (ML-AI) techniques including Multiple Regression, Support

Vector Regression for course attendance data prediction and a Constrained Programming (CP) optimization AI technique for optimal classroom allocation. Course attendance data was obtained in from over 250+ courses in real-time based on a variety of people detection sensors installed in 9 real classrooms. A prediction Root Mean Square Error (RMSE) of about 0.16 was obtained by the authors. Also, the authors report 10% savings in classroom costs with very low risk of classroom overflow occurring. In Aghniaey *et al.* (2019), a study on the user’s thermal sensation, acceptability and preferences in response to increased cooling temperature in some temporary occupied areas in a university campus in the United States was carried out. Actual Mean Votes (AMV) was computed in certain classes within the university campus with reference to relevant thermal standards.

In the context of secure monitoring, a framework for real time end to end monitoring and management of an open campus was proposed in (Celesti and Fazio, 2019); in this approach, Internet of Things (IoT) internetworking is used to interact with people and environment via context aware provisioning and physical parameter sensing.

3. Summary of Research Findings

A concise summary of some key contributions in the field of smart space context-aware computing has been critically examined and are provided in Table 1. In the reviewed literature (see Table 1) it is clearly evident that recent smart campus research in the area of machine learning/intelligence or statistical learning approach used simulation experiments and some key sense functionality – audio and video is not supported.

Table 1. Summary of Related Recent Smart Space Research Directions

S/N	Author / Year	Nature of Data Type			Feature Mining/ Control Technique			Validation Accuracy on Real Time Test Bed (UNIPORT Data)		
		Remote connectivity	Video /or Image Support	Audio Support	Monitored Physical	Explored Technique	Novelty	Simulation Control	Real Time	Accuracy (Simulation)
1.	Kiziikaya <i>et al.</i> (2019)	-	-	-	-	Hierarchical Search	Based on Binary Search Tree	√	-	-
2.	Carreira <i>et al.</i> (2018)	√	-	-	√	k-Means-NN	Consensus Voting	√	-	0.4946
3.	Martin-Garin <i>et al.</i> (2018)	√	-	-	√	-	-	-	-	-
4.	Massana <i>et al.</i> (2017)	-	-	-	√	AR	-	√	-	-
5.	Sharma and Suryakanthi (2015)	√	-	-	√	Simple Expert	-	√	-	-

Thus, this gave rise to smart campus feature mining solutions that are challenged by two main driving issues:

- The likelihood that smart campus research designs do not reflect current smart space environmental conditions.
- The likelihood that smart campus research designs do not capture impact of human-machine situation awareness in the smart space.

These two driving points suggest a need for a more contributive model that not only captures prevailing real time ambient conditions, but also one that fosters a marriage between human and machine contributions. This can be achievable if consensus-aware mechanisms are inherent in existing context-aware-computing (CAS) models. An important research in this direction is the study presented in Carreira et al (2018) which encourages group process coding rules and intelligence mining of real time information. Though this new feature of consensus voting or group coding in hybrid systems may be promising, it remains to be validated and tested by a great number of researchers in the smart space computing field.

4. Conclusion

A review of the recent state-of-the-art smart campus applications for deployment in university environments have been presented in this paper. The paper covers the researches that border on the use of real time sensing, simulations, machine learning etc., to unravel useful context in the rich smart data space available to university communities. The paper provides detailed survey of recent state-of-the-art techniques employed by various researchers including but not limited to kNN, Binary search, Auto-regression and Support vector regression etc. Thus, this paper provides a basis for the promotion of intelligent smart solutions in campus-wide applications. In future, consensus-aware systems can be integrated in existing models to improve the sense feature support, resiliency and accuracy in real time solutions.

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