International Journal of Distributed Systems and Technologies
Volume 7 • Issue 1 • January-March 2016

City Data Fusion:
Sensor Data Fusion in the Internet of Things

Meisong Wang, Research School of Computer Science, Australian National University, Canberra, Australia
Charith Perera, The Open University, Milton Keynes, UK
Prem Prakash Jayaraman, RMIT University, Melbourne, Australia
Miranda Zhang, Research School of Computer Science, Australian National University, Canberra, Australia
Peter Strazdins, Research School of Computer Science, Australian National University, Canberra, Australia
R.K. Shyamsundar, School of Technology & Computer Science, Tata Institute of Fundamental Research, Navy Nagar, India
Rajiv Ranjan, CSIRO, Canberra, Australia and Newcastle University, Newcastle, UK

ABSTRACT

Internet of Things (IoT) has gained substantial attention recently and play a significant role in smart city application deployments. A number of such smart city applications depend on sensor fusion capabilities in the cloud from diverse data sources. The authors introduce the concept of IoT and present in detail ten different parameters that govern our sensor data fusion evaluation framework. They then evaluate the current state-of-the art in sensor data fusion against our sensor data fusion framework. The authors' main goal is to examine and survey different sensor data fusion research efforts based on our evaluation framework. The major open research issues related to sensor data fusion are also presented.

KEYWORDS

Context Awareness, Data Fusion, Internet of Things (IoT), Sensor Data Fusion, Smart City

1. INTRODUCTION

During the past decade, the Internet of Things (IoT) has gained significant attention in academia as well as industry. The main reason behind this is the capabilities that IoT promises to offer. It promises to create a smart world where all the objects around us are connected to the Internet and communicate with each other with minimum human intervention (Sundmaeker, Guillemin, Friess, & Woelffl´e, 2010). This survey paper will address sensor data fusion in IoT from different perspectives. Hence, we first present the most commonly used IoT definitions from the literature. Tan and Wang (Lu & Neng, n.d.) have defined IoT in a fairly comprehensive manner as "Things have identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environment, and user contexts (Lu & Neng, n.d.). Some other definitions are presented in (Atzori, Iera, & Morabito, 2010). The papers (Atzori et al., 2010; Yang, Liu, & Liang, n.d.) have surveyed the definition of IoT in three different perspectives: things, the Internet and semantics.

IoT enables the vision "*from anytime, anyplace connectivity for anyone, we will now have the connectivity for anything (Union, 2005)*". Further expanding this idea, the European Union has defined the above vision as "The IoT allows people and things to be connected Anytime, Anyplace, with Anything and Anyone, ideally using Any network and Any service (Guillemin & Friess, 2009)".

DOI: 10.4018/IJDST.2016010102

The term Internet of Things was firstly coined by Kevin Ashton (Ashton, 2009) in a presentation in 1998. He has also mentioned "*The IoT has the potential to change the world, just as the Internet did. Maybe even more so. (Sundmaeker et al., 2010)*". Then, MIT presented their IoT vision in 1999. Later, IoT was formally introduced by the International Telecommunication Union (ITU) by ITU Internet report in 2005 (Union, 2005).

2. MOTIVATION: SENSOR DATA FUSION FOR SMART CITY APPLICATION

Data from citizens, systems, and general things flow through our cities thanks to the wide spread adoption of smart phones, sensor networks, social media and growing open release of datasets (Antonelli et al., March 19-20, Athens, Greece, 2014). The data from Smart cities present a grand challenge to researchers and smart cities promoters, as we need to take advantage of these streams of information to build new services and define a clear return of investment for the benefit of the society (Jara, Genoud, & Bocchi, 2014).

The challenge in smart city is not to build a single generic model e.g. weather model based on temperature and humidity, complex models about noise pollution, traffic etc., but to combine all these together to build a good predictive contextually rich model. This model will help understand the dynamics of the society, and most importantly provide vital knowledge back to the citizens in order to enhance their quality of life.

A recent work from a group of researchers from MIT (Sobolevsky et al., 2015) demonstrate the potential of fusing data from disparate data sources in smart city to understand a city's attractiveness. The work focuses on cities in Spain and shows how the fusion of big data sets can provide insights into the way people visit cities. Such a correlation of data from a variety of data sources play a vital role in delivering services successfully in smart cities of the future.

In smart cities, ability to fuse sensor data enables context awareness which has a huge potential for IoT. Understanding the context of the city and its citizen can help develop and provide a new world of services based on what an individual user is doing, what the infrastructure is doing, what nature is doing or all the above in various combinations (Karimi, Accessed on: May 2015). The variety of services that can be developed is only limited to one's imagination. An example scenario could be a bridge experiencing a structural issue due to adverse environmental conditions can alert the city administrators and alert all cars travelling towards the bridge to stay away and seek alternative routes. For such a scenario to be feasible, it is important, smart city applications built on IoT have the ability to fuse data from diverse data sources to enable context-aware decision making and support (Deng et.al., 2015).

3. CONTRIBUTIONS

In this survey paper, we highlight the importance of sensor data fusion for IoT application in particular smart city applications. To this end, we conduct an elaborate examination of different sensor data fusion research efforts related to IoT stemming from wireless sensor networks. Based on this examination, we propose an evaluation framework by carefully selecting ten different metrics. We believe these ten metrics are open challenges in the field. Some of these challenges are addressed by the researchers significantly and some are in its infancy. One of the major goals of this article is to highlight the opportunities for improvements and research gaps in the field.

The rest of the paper is organised as follows. Section 4, sensor data fusion is defined and techniques are discussed. We also outline the possible extensions to improve sensor data fusion. Section 5 presents the evaluation framework that we used to evaluate different research efforts. We survey various sensor data fusion efforts and its importance towards IoT in the Section 6. Section 7 presents an evaluation summary of current state-of-the art in sensor data fusion against the developed evaluation framework. Section 8 concludes the survey by highlighting the survey results and research gaps.