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Positioning in Wireless Sensor Network for Human Sensing Problem

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Abstract

In this paper the possibility of utilization of wireless sensor network in application to human sensing problem is examined. With the emphasis on crowd dynamics monitoring, the most critical issues regarding this application are analyzed. Based on limitations and shortcomings of contemporary crowd monitoring approaches, as well as the specificity of the problem, modified positioning algorithm, combined with noisy data preprocessing technique is proposed. Moreover, physical principles of interaction between pedestrians and sensor network are analyzed. An experiment had been conducted to demonstrate the concept of data collection system aimed to obtain relevant information regarding pedestrian movements.

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Keywords: wireless sensor network; crowd disasters; human sensing; smart dust

1. Introduction

One of the major trends of 21st century is intensive urbanization process. This process is leading to increasing urban population all over the World. As a result cities are becoming more congested, therefore the probability of dangerous situations is increasing. Especially, public venues such as train stations, stadiums, airports etc. are highly vulnerable to so-called crowd disasters, such as stampede during mass events or emergency situations during rush hours. As an example, one can consider a deadly stampede during the Hajj in Saudi Arabia in 2015, where over 700 people died and nearly 900 were injured (Holly 2015). Notable that this tragedy occurred despite the fact that modern surveillance systems were being used and a lot of preparation work had been done in order to provide safety. Among many other reasons, the key challenge is the complexity of the problem. Crowd behavior is difficult to predict, describe and analyze, since people (especially during emergency situations) do not follow strict movement rules. More precisely, the milestone in the process of analyzing the crowd dynamics is complicated process of human sensing. Under the term "human sensing" we assume the process of extracting information regarding people's movement in some environment. Indeed, understanding of people's movement and behavioral pattern play crucial role in many applications.

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For instance, this information is essential for crowd management systems aimed to monitor crowd dynamics, detect dangerous situations and insure public safety (Jacques et al. 2010). Another application is urban planning. Here the analysis of movement pattern is used for provisioning the guidelines for the design of infrastructure and public venues.

However, despite the fact that modern surveillance systems are highly advanced, several major shortcomings are still exist. For instance, video surveillance systems have limited installation capabilities and experience difficulties during operating in crowded places. More precisely, it's very difficult to observe and identify individuals due to frequent occlusions. Another example is utilization of mobile devices. Recent advances in mobile computing and sensing provide a good opportunity to collect a wide range of new and rich data that can be used to detect pedestrian movement. Examples include GPS location information in participatory sensing (Wirz et al. 2012), Bluetooth identifier collected from sensors integrated on smartphones (Weppner et al. 2013), and social media data (Haghighi et al. 2013). The main disadvantage of these approaches is the availability of devices. These drawbacks, coupled with the complexity of the task itself, may lead to failure of these systems.

In order to overcome some of these limitations this study propose concept of the system based on Wireless Sensor Network (WSN) as a core component of human sensing system, with the application to the problem of crowd dynamics monitoring. Under the term WSN we assume spatially distributed autonomous sensors capable to monitor physical or environmental conditions, and cooperatively pass this data through the network. Need to mention, that a special case of sensor network is considered in this study, inspired by "smart dust" project, proposed by the researchers from the UC Berkeley. According to (Warneke et al. 2001), this is a "…system of many tiny microelectromechanical systems (MEMS) such as sensors, robots, or other devices, that can detect, for example, light, temperature, vibration, magnetism, or chemicals…". The intent is that these devices will eventually become the size of a grain of sand or a dust particle, hence the name smart dust.

The key difference from similar researches is that the concept of "smart dust" is considered in this study. This approach gives more flexibility in terms of monitoring pedestrians through the network, since denser network setup allows to obtain more precise positioning information. Moreover, nowadays devices are becoming smaller and cheaper, therefore there will be possible to realize this yet theoretical concept in near future. To meet this goal, modified positioning algorithm for sensor nodes localization had been developed, and several physical principles of "human sensing" were examined. In order to test and investigate the applicability of proposed solution, an experiment had been conducted.

2. Human sensing techniques

The need of advanced tools for understanding human behavior from sensory data is indeed emerging recently, since such applications as health monitoring, computer graphics, machine vision and human-machine interface are in a high need for this information. According to the proposed solution, WSN should be used for the purpose of crowd monitoring. However, sensors (ref. as MOTEs) have to interact with pedestrians in order to collect the information. Therefore, in this chapter the description and analysis of human-sensing techniques is provided. In other words, the description of different physical principles of interaction between MOTEs and pedestrians. According to researchers from MIT (Teixeira et al. 2011), different types of interactions can be caught by different types of sensors. On the picture above, taxonomy of measurable human traits is provided. Static traits stem from the physiological properties, and are produced whenever a person is present, irrespective of what he or she is doing. Common static traits are weight and shape. On the other hand, dynamic traits are those that arise from human activity. They are only present when people move, and are not detectable for reasonably stationary persons. The rest of this chapter is devoted to the description of wireless sensor based methods of human sensing.

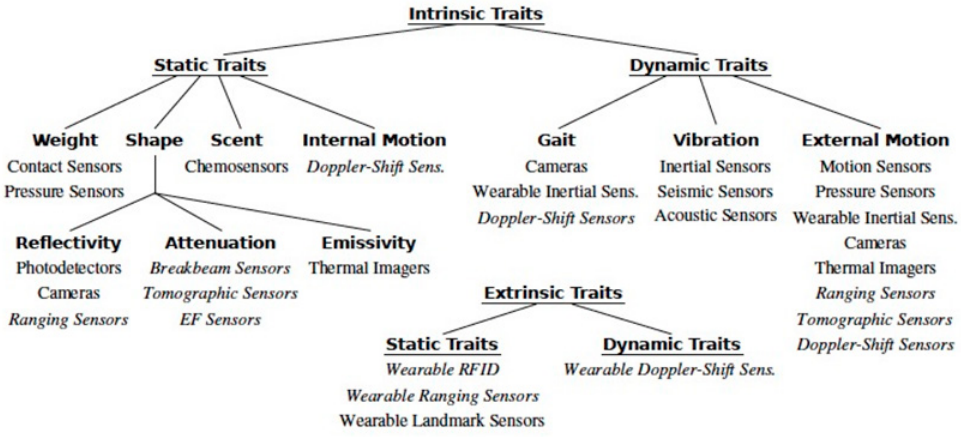

Fig. 1. Texonomy of measurable human traits (Teixeira al. 2001)