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Context aware ad hoc network for mitigation of crowd disasters

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ABSTRACT

Our research works focuses on the design and implementation of a novel ubiquitous multi context-aware mobile phone sensing network for mitigation of crowd disasters using machine-to-machine (M2M) communications. A mobile sensor network system integrated with wireless multimedia sensor networks (WMSNs) was designed for effective prediction of a stampede during crowd disasters. This proposed sensor network consists of mobile devices that are used as crowd monitoring participant nodes that employ light sensors, accelerometers, as well as audio and video sensors to collect the relevant data. Real-time crowd dynamics modeling and real-time activity modeling have been achieved by implementing the algorithms developed for Context Acquisition and multi-context fusion. Dynamic crowd monitoring was achieved by implementing the context based region identification and grouping of participants, distributed crowd behavior estimation, and stampede prediction based on distributed consensus. The implementation of the proposed architecture in Android smartphone provides light-weight, easy to deploy, context aware wireless services for effective crowd disaster mitigation and generation of an in time alert to take measures to avoid the occurrence of a stampede. The system has been tested and illustrated within a group of people for stampede prediction by using empirically collected data.

1. Introduction

Wireless Sensor Networks (WSNs) consists of large number of sensor nodes which are capable of linking the physical world with the digital world by capturing and revealing real-world phenomena and converting these occurrences into a format that can be processed, stored and acted upon [31]. These sensors are low power devices that can be used for a wide range of applications beneficial for society. The accurateness and the timeliness of this sensed information is extremely important to take critical action in various real world situations. Hence, the key consideration of our recent research work in WSN is to improve the quality and reliability of the sensed information by utilizing the potential of Context Aware Computing (CAC). This context awareness helps to configure the WSN to adapt and react according to the real time situation of the physical space in which the sensors are deployed. The key focus of our research work is to integrate the concept of CAC for WSN (CAC-WSN) to predict the onset of abnormality within a crowd.

Context aware computing is the key enabling technology for pervasive computing. The major classification of context includes computing context, user context and physical context [30]. Computing context includes network connectivity, communication costs, communication bandwidth and nearby resources such as printers, displays and workstations. User context specifies the user's profile, location, and people nearby, even the current social situation. Physical context includes lighting, noise levels, traffic conditions and temperature.

Design and deployment of context aware systems in open and dynamic environments is raising a new set of research challenges such as Sensor Data Acquisition, Context

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Data Fusion, Context Modeling and Reasoning, Service Discovery, and Execution of Services for the user. One of the crucial requirements of context-aware applications is real-time collection and aggregation of sensor data from sensors distributed in the environment.

The proposed Ubiquitous Multi-Context Model (UMM) consists of three major phases, namely the Context Acquisition phase, the Context Modeling and Inference phase, and the Context based Action Generation phase. The key problem under consideration of our model is to develop a distributed context aware architecture with key features such as reusability, non-redundancy and wide area coverage of context information.

The recent advancements in the field of WSN make use of mobile phones, specifically smartphones, to act as sensor nodes. The mobile phone penetration rate is increasing tremendously all over the world, and in India it is expected to reach up to 97% of the total population in the year 2014 [10]. The increased penetration rate of smartphones in everyday life has resulted in the development of many promising applications utilizing low cost embedded sensors such as accelerometers, microphone, camera, gyroscope, and light sensors. This new research area is referred to as mobile phone sensing.

The implementation of our UMM is performed on an Android framework using mobile phone sensing and CAC-WSN. The objective of our research work is to make use of UMM for applications suitable for both personal sensing (e.g. individual activity) and group sensing (e.g. crowd monitoring).

The demand for security and safety within public spaces is gaining attention nowadays due to the increase in crowd disasters. The brief history of crowd disasters in public gatherings for pilgrimage, sports events, etc. from 1989 to 2011 is reported in the reference paper [9]. India experiences more than 100 deaths per year due to crowd disasters. The major motivation for our research work is the stampede of pilgrims that occurred at the hilltop Sabarimala shrine in the state of Kerala in southern India, which took the life of 102 devotees [9]. The stampede was set off when a jeep drove into the crowd of pilgrims. The pilgrimage area was flooded with people and the situation went uncontrollable. The other causes of crowd disasters are terrorist activities that are focused on public gatherings resulting in the loss of life of many innocent people.

Integration of context aware computing with mobile phones makes the devices capable of sensing the physical world, process the current scenario, and adapt and react to dynamic changes of the environment. The proposed system uses the above-mentioned capability to develop an application suitable for crowd management, real-time monitoring of crowd behavior, and dissemination alerts and instructions for crowd control.

2. Context and context aware computing

Researchers defined the term context in a slightly different manner such as, Schmidt defined context as knowledge about the state of the user's IT devices, along with information on the surroundings, situation, and to a less extent, location [3], Chen and Kotz defined context as the set of environmental states and settings that either determined an application's behavior or in which an application event occurred and is interesting to the user [4], Dey et al. gave the definition of context as any information that is useful to highlight the interaction between a user and an application and also used to characterize the situation of an entity such as a person, place or object [5]. The knowledge of data along with its context will provide insights into the complex patterns hidden in those data. This understanding lead to the development of the new area of "context awareness" in ubiquitous computing.

The term "context-awareness" in ubiquitous computing was initially introduced by Schilit in 1994 [1,2]. According to Schilit [1], context awareness is the capability of a system to "adapt according to the location of the user, the collection of information about nearby people, hosts, accessible devices, as well as the changes to such things over time". Pascoe et al. [6] define context-awareness as the ability to detect, gather, interpret and react to context changes in the user's surrounding and changes in its device.

The research paper [6] discusses the importance of context-aware sensing and provides a general overview of acquiring context information and various context aware applications.

These context aware frameworks detailed several open research challenges such as:

- Context Acquisition Issues
  - Determination of appropriate sensors and the type of context to be acquired. Some of the sensors should initially be chosen for recognizing context because most of the applications do not require context data from all the available sensors. Use redundant sensors only in case of uncertainty. In this way, data transmission over the network decreases together with the processing demand.
  - Real time management of the sensors. Providing feedback to the sensors and dynamically managing them during the operational phase can improve the application's performance, improving the overall result.
  - Determination of who the context capturers will be and the number required. Assess the need for predetermined participants or new users of the application and determine how many smartphones are required for the best context inference. Develop automatic techniques to prevent redundant information capture due to close proximity of smartphones.
  - Determination of the most suitable time-period of monitoring with respect to the application.
- Context Modeling & Inference Issues
  - A distributed context aware inference formulating framework is required.
  - Since new contexts are continuously added in the sensor network, the requirement of continuous adaptive learning algorithm is an issue that draws attention.
  - Context inference is a complex task that requires a good mechanism for mapping simple captured context data to a higher level of data. This is not an easy