



ENHANCED WEIGHTED CENTROID LOCALIZATION BY FUZZY LOGIC AND SOM

By

Basant Reda El Samadony

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Computer Engineering

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Acknowledgment

Before any words I would like to thank God who give me ability, strength and will to complete this study.

Many sincere thanks for all the people who guide, organize, help and support me.

First, I wish to thank Dr. Rabie A. Ramdan, for his professional advice, experience sharing and patience along my thesis research.

Many thanks to Dr. Nevin M. Darwish for her support and guidance. I really appreciate their time and effort.

I would like to express my deepest appreciation to my family (father, mother and sister) for their great encouragement effort with me. They provide a constant source of motivation in my life.

Words can't describe how I am grateful to my husband Mohammed for his encouragement and understanding when I was busy too many days and weeks doing my thesis study. Without his continuous encouragement especially in depression time and patience, I would still be in my Masters dreams.

Finally thanks to my first, little and dearest daughter Roaa. Although she is very little, she has great favor on me for doing this thesis. She comes in a critical time and really changes my life.

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List of Acronyms:

AOA: Angle of Arrival

APIT: Approximate Point in Triangle

BMU: Best Matching Unit

DV-HOP: Distance Vector-HOP

FBT: Fuzzy Based Trilateration

FCS: Fuzzy Weighted Centroid Localization with Self Organizing Maps

FL: Fuzzy Logic

FLC: Fuzzy Logic Controller

GPS: Global Positioning System

LQI: link Quality Indicator

MDS-MAP: Multidimensional Scaling Map

PL: Power Level

RSSI: Received Signal strength Indicator

SOM: Self Organizing Map

SWCF: Smart Weighted Centroid Localization Based Fuzzy Logic

TDOA: Time Differential of Arrival

TOA: Time of Arrival

WC: Weighted Centroid

WSN: Wireless Sensor Networks

Abstract

Wireless Sensor Networks (WSNs) have an endless array of potential applications in many critical applications such as robotic land-mine detection, battlefield surveillance, target tracking, environmental monitoring, wildfire detection, and traffic regulation. Location in such applications is very important for decision makers to identify the event source. In some applications as fire detection, it is generally not sufficient to determine *if* a fire is present, but more importantly, *where* the fire is present.

Two of the famous localization methods are Trilateration and Centroid methods. Weighted Centroid Localization (WCL) algorithm is introduced to minimize the localization error of the pure Centroid algorithm.

In this thesis Fuzzy Based Trilateration (FBT) is introduced as an enhanced version of trilateration. In addition, FCS as an enhanced version of the Weighted Centroid is also introduced, where Fuzzy Logic (FL) and Self Organizing Map (SOM) intelligence are utilized. FBT and FCS use fuzzy logic to merge between three important parameters which are Received Signal Strength Indicator (RSSI), Link Quality Indicator (LQI), and Power Level (PL) in distance estimation. The usage of the three parameters in calculating the edge of the weighted centroid compensates for the uncertainty in their readings. Moreover FCS uses SOM algorithm in learning to enhance the nodes' locations.

Contributions of this work are therefore: First is adding new parameter as a distance estimator which is PL along with the traditional RSSI and LQI in the form of location estimation. Based on our knowledge, this is the first study that considers PL parameter to estimate the distance between two nodes. Second is using fuzzy logic controller with Centroid and Trilateration algorithms. The third contribution is using SOM as a learning algorithm along with the fuzzy controller to enhance the localization estimation of the nodes. The results show that merging between PL, RSSI and LQI as input parameters to fuzzy inference then using SOM learning reduces the error of the localization.

Chapter 1

Introduction

The next evolutionary development step in most environments and systems is smart environments. Smart Environments can be represented at building, utilities, industrial, home, shipboard, and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world. This data comes from many sensors of different modalities in distributed locations. The smart environment needs information about its surroundings besides its internal workings. The challenges in detecting the needed quantities, monitoring and collecting the data, assessing and evaluating the information, formulating meaningful user displays information, making decisions and alarming in dangerous situations are enormous. The information needed by smart environments is provided by distributed Wireless Sensor Networks (WSNs), which are responsible for sensing as well as for the first stages of the processing hierarchy.

WSNs are responsible for gathering the information needed by smart environments, as in buildings, utilities, industrial, home, transportation systems automation, or elsewhere. Many important sensing applications especially military applications require distributed networks of sensors that can be deployed using, e.g. aircraft, and have self-organizing capabilities. In these applications, running wires or cabling is not a practical solution. Rather than wires network, a sensor network is required that is fast and easy to install and maintain.

The WSN is built of nodes; nodes number varies from few to several hundreds and may reach to thousands, where each node is connected to one or several sensors. The cost of sensor nodes is variable, ranging from a few to hundreds of dollars, depending on the complexity of the nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth.

The basic components of a sensor node are sensor unit, ADC (Analog to Digital Converter), CPU (Central processing unit), power unit and communication unit. Sensor nodes are micro-electro-mechanical systems [1] (MEMS) that produce a measurable response to a change in some physical condition like temperature and pressure. The sensor unit senses or measures physical data of the monitored area. Then the ADC unit converts the sensed analog signal to digital and sends it to controllers for further processing.

The aim of wireless sensor network is connecting the physical environmental and internet worlds efficiently. Currently, wireless sensor networks are beginning to be deployed at an accelerated pace. It is expected that the world will be covered with wireless sensor networks with access to them via the Internet within few years to make life easier. This technology is exciting with unlimited important application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces.

1.1. Motivation

Smart wireless networked sensors will soon be all around us, collecting, processing vast amounts of previously unrecorded data to help run factories, optimize farming, monitor the weather and even detecting earthquakes. Many people think that wireless sensor networks can become as important as the Internet. As the Internet allows access to digital information anywhere, sensor networks will provide remote interaction with the physical world.

The main function of wireless sensor network is monitoring physical or environmental conditions, as pressure, temperature, sound, etc. then passing their data to a predetermined location through the network. WSNs were initially designed to facilitate military operations but its application has since been extended to health, traffic, and many other consumer and industrial areas. Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors to detect enemy intrusion [2]; a civilian example is the geo-fencing of gas or oil pipelines. Area monitoring is most important application.

Medical applications can be divided to two types: wearable and implanted [3]. Wearable devices are used on the human body surface or just close to the user. On the other hand, the implantable medical devices are inserted inside the human body. There are many other applications that can be used in medical cure e.g. body position measurement and location of the person, overall monitoring of ill patients in hospitals and at homes. Body-area networks can collect information about an individual's health, fitness, and energy expenditure. Consider a scenario where hospital patients could be equipped with wireless sensor nodes that monitor the patients' vital signs and track their location. Patients could move more freely while still being under constant supervision. In case of an accident - say the patient trips and falls - the sensor could alert hospital workers about the accident with the patient's location and condition. The closest doctor to the patient, also equipped with wireless sensor, could be automatically dispatched to respond to the emergency.

Glucose level monitoring [3] is a potential application suitable for wireless sensor network. Individuals with diabetes require constant monitoring of blood sugar levels to lead healthy, productive lives. Embedding a sensor that measures the glucose within a diabetes patient could allow the patient himself to monitor blood sugar levels trends and also alert the patient in critical cases or sharp change in blood sugar levels. Information could be sent wirelessly from the monitor to a wristwatch display. It would then be possible to take corrective measures to normalize blood sugar levels in a timely manner before they get to critical levels. This is of particular importance when the individual is asleep and may not be aware that his blood sugar level is abnormal.

Several cities use wireless sensor network to monitor the concentration of dangerous gases for citizens. It needs to be wireless rather than wired to make them more mobile for testing readings in different areas. An online GPRS-Sensors Array for air pollution monitoring system [4] consists of a Mobile Data-

Acquisition Unit (Mobile-DAQ) and a fixed Internet-Enabled Pollution Monitoring Server (Pollution-Server). The Mobile-DAQ function is to collect air pollutants levels (CO, NO₂, and SO₂), and packs them in a frame with the GPS physical location, time, and date. The Pollution-Server is interfaced to Google maps to display real-time pollutants levels and their locations in large area. The system is successfully tested in Sharjah, UAE. In [5] a wireless sensor network for monitoring Indoor air quality (IAQ) in buildings is presented. This network is capable of measuring IAQ levels at various locations within a building. Different indoor air pollutants such as CO, CO₂, VOCs, and airborne particles can be measured in places that may have potential sources of pollutant production. When the measured pollutant levels exceed the acceptable limits, the sensor network alarms the indoor occupants, triggers activation of the building's climate control equipment, exhausts polluted air, and brings in fresh air from the outside.

Wireless sensor networks can be used to prevent natural disasters consequences, like floods, volcanoes and earthquakes. Wireless network can be deployed in rivers to monitor changes in water level constantly. Wireless nodes have successfully been deployed at the top of volcano where changes of temperature, gases and lava levels can be monitored in real time. Now it is possible to know the occurrence of landslides before it actually happens to decrease its damage. A landslide detection system uses wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide.

A network of sensor nodes can be installed in a forest to detect when a fire has started. The nodes can be equipped with sensors to measure temperature, humidity and gases which are produced by fire in the trees or vegetation. Conceivably a fire starts in a forest. The WSN deployed in the forest could notify authorities at time before it begins to spread uncontrollably. Accurate fire location information is needed to be quickly deduced. Consequently, this time detection about fire and its location gives firefighters an unprecedented advantage, since they can arrive at the scene before the fire spreads uncontrollably. Thanks to WSN, we can now predict the natural disaster and huge accidents before they actually happen. This helps officials in avoiding or decreasing the huge damage which may lead to destroy a whole country.

1.2. WSN Projects and Systems

The concept of wireless sensor networks takes its importance from a simple equation:

$$\text{Sensing} + \text{CPU} + \text{Radio} = \text{Thousands of important applications}$$

As soon as people understand the capabilities of a wireless sensor network, many applications spring to mind. To demonstrate the capabilities of wireless sensor networks we present four examples of projects and associated systems for those applications.

The VigilNet system [2] is a military surveillance application. It is a long-lived real-time wireless sensor network. The VigilNet general objective is to monitor, alert and control units of occurrence of predefined events in hostile regions. Examples of events are the presence of people, people with weapons, and