Modern Applied Science
www.ccsenet.org/journal.html
Vol. 3, No. 6
June 2009

Visualization of Urban Transportation Data Generated by Wireless Sensor Network Using Modern Approaches

Manni Huang
Department of Computer Science, Trinity College Dublin
College Green, Dublin 2, Ireland
E-mail: huangm@tcd.ie

Abstract

Distributed wireless sensor networks are one of the first real world examples of pervasive computing, the notion that small, smart, and cheap sensing and computing devices will eventually permeate the environment. Nowadays, it has proved to be useful in various applications. In a large sensor network, no matter the sensors are large or small, the data are especially complicated and unintelligible. We should make it easy to understand with the help of technologies of existence. Certainly, data visualization, which is defined as the interactive graphical presentation of data, could present data in the forms of aesthetic layout rather than traditional tables, pie charts and bar graphs, making the data more beautiful, elegant and descriptive. Attempting to visualize the data generated by wireless sensor networks, the audience will not be simply restricted to experts, but also all the people.

This dissertation aims to demonstrate the technology of both wireless sensor network and data visualization with the basis for the critical problems, challenges and future goals of development and applications. And we propose a simulative model integrated the two above technologies, emphasis on the processing. The framework is based on Google Maps; thus it allows robust navigation and communications within several different spatial ontologies. Our approach factors the problem into the following sub goals: deploying the sensors in urban crossroad, acquiring and analyzing data, and representing the data with aesthetic forms.

Keywords: Wireless sensor network, Data visualization

Abstract

This chapter introduces the motives of this research; it addresses present situation and its derivative research questions. Furthermore, it concludes with an overview of the content of the dissertation.

1.1 Motives of This Research

Over the past ten years, true, the Construction of Urban Transportation Facilities developed rapidly, but due to outdated management style and unreasonable transport infrastructure, engineers (Jaesup Lee, Randall and Michael) indicated that congestion, safety and air pollution remain as serious challenges in urban transportation systems. Facing up to the problem of increased urbanization, industrialization and changes in population density, scientists in developed countries took up research and put forward the concept of ITS (Intelligent Transport Systems) in the 1960s. With the rapid development of Computer Science and Information Technology, today's ITS have been evolved into a synergy of new information technology for simulation, real-time control, and communications networks. The system could round-the-clock monitoring at the main roads, 24 hours a day, including a series of phenomenon (e.g. overspeed, retrogradation, running a red light, parking prohibition, floating car data and Latency time). Those images, data and information are used to transmit back to the Monitoring Center as evidence to punish drivers or reference materials. Take the case of motor vehicle inspection reporting system, it could analyses vehicle flow statistic at traffic crossing, including vehicle flow rate on a time basis (year/month/day), vehicle waiting time at a traffic lane, and then generates a bar chart or table to output so that traffic management can take measures to relief the problem of traffic congestion.

Despite the growing interest in Intelligent Transport System, most of the problems concerning it only exist due to low-stability, expensive cost, complex operation and low clarity. Scientists (Professor K Soga, Professor R Mair, Dr. CR Middleton, Dr. F Stajano and Dr. IJ Wassell, 2006) predict that future monitoring system will undoubtedly comprise Wireless Sensor Network (WSN) and will be designed around the capabilities of autonomous nodes. Each node in the network will integrate specific sensing capabilities with communication, data processing and power supply.

1.2 Research Questions

The guiding research question is: How to visualize urban transportation data generated by Wireless Sensor Network using modern approaches. This involves the following specific objectives:

- **To demonstrate how large number of sensors can be integrated into Intelligent Transport System using Wireless Sensor Network to improve performance**
- **To demonstrate how to visualize those sensing data using absolutely fascinating ways rather than using conventional ways like tables and bar charts.**

1.3 Overview of Contributions

The reminder of the dissertation comprises 5 chapters. The next two chapters overview key concepts and problems for wireless sensor network and data visualization. The 4th chapter focuses on the proposed model based on the existing technology.

Chapter 2 overviews fundamental concepts, critical problems, challenges and future trends of wireless sensor networks. It also illustrates applications widespread used in the field, and discusses its specific characters.

Chapter 3 presents an overview of fundamental concepts, critical problems, challenges and goals of data visualization. It also introduces applications widespread used in the field.

Chapter 4 reviews the current situations and focus on the process of deployment of sensor node and data visualization.

CHAPTER II: LITERATURE RIVIEW (i) - Wireless Sensor Network

Abstract

A wireless sensor network is wireless networks consisting of spatially distribute autonomous devices using sensors to cooperatively monitor physical or environmental conditions at different locations. This chapter introduces fundamental concepts and problems approached in the wireless sensor networks. The applications of wireless sensor network technology, which are from different areas briefly to demonstrate the most widespread used in the field, are presented. Characters of the wireless sensor networks are discussed.

2.1 Wireless Sensor Network: Introduction to Critical Problems, Challenges and Future Trends

With the vigorous development of world science and technology, and the advent of the Information Age, mankind now lives in an increasingly globalized and interconnected world. Once, as many people will agree, the achievement of the goal of seamless connection between people, objects and events were unachievable, but now this situation has been revolutionized. Due to the recent advances in sensor, computing and communication technologies, an interconnecting world is no longer confined to Internet use. Thus, it is fundamental to improve the understanding of how to integrate powerful mobile computing and wireless communication, which is complex, heterogeneous and geographically distributed.

Ubiquitous computing envisages everyday objects as being augmented with computation and communication capabilities. Date back to the 1970s, the rudiments of sensor network was composed of sensor control units interconnected through peer to peer transmission. Recent advances in embedded computing system have led to the emergence of the second generation sensor network which has the comprehensive process capability to achieve multiple information signals. Back around the end of the last Century, an intelligent sensor network system based on fieldbus technology was presented. (1) With the popularization of multifunctional sensors and the utilization of wireless connect technology, the wireless sensor network gradually developed. A wireless sensor network is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations.(2)(3) As originally motivated uses by military(4), Wireless Sensor Network have traditionally been approached as independent research area. So far wireless sensor network has placed emphasis on the deployment of sensors, protocol stack, the synchronization algorithm and the routing algorithm in order to maximize the lifetime of the network(5), and relatively little attention has been given to the integration of computing and communication technology.

Wireless sensor network is destined to see widespread adoption in large-scale commercial applications, but are limited to, certain aspects such as technology, yet to be adequately resolved. Over the past few years, however, a substantial collection of wireless sensor network has been put into operation. Among those applications, perhaps some perform conform to the planning, but a majority might encounter some particular barriers to the widespread deployment of sensor networks, including:

1) Communication Problem. When utilizing wireless sensor network to implement regular communication, signal disturbed by certain barrier or other electronic signals, might be influenced, therefore it is essential to provide a solution to communicate safely and effectively.

2) Cost Considerations. Each wireless sensor network is made of plenty of small sensors, and these sensors are currently too expensive for many applications and most massive rollouts, so in this case cost will restrict development. It needs to take technical improvements and volume orders, such as those expected from Wal-Mart Stores Inc. and its suppliers, to drive down pricing.

3) Energy Supply Problem. There is a need for energy supplies which could last for a long time. At present, some principal solutions includes the use of high-energy batteries, reduce sensor power, energy scavenging and energy efficient management besides. (6)

4) Efficient Wireless Sensor Network Structure. Each sensor node in the wireless network need to perform the functions of sensing, processing and communicating as the following figure 2.1 Architecture of a sensor node(7),

Hence a reasonable deployment of wireless sensor network could utilize the resources to its maximum. Besides, building a reliable wireless network to ensure network security probably based on a meshed topology, to transport data from sensors to server.

To achieve significant market adoption, wireless sensor network applications must overcome the present challenges which are addressed. In the meantime, developments lead traditional distributed sensor network to next generation wireless sensor network, and it is certainly a reflection of its far-reaching impacts on mankind.

Dipankar Raychaudhuri, director of WINLAB and professor of electrical and computer engineering at Rutgers University, North Brunswick, considered the five great changes happened in our daily life, which are:

Marching toward the ideal society, consumers could find the products and services through PDA while walking. Furthermore, they could directly purchase the expected products in the shop without the help of sales assistants.

Intelligent transportation system monitors factors that are at odds with each other in order to reduce traffic congestion and improve safety. And it could provide us with feedback on system's collision avoidance analysis. The most satisfaction is to assist people find their cars in the crowded parking lot.

Airport Transportation Security Administration ensures accessible boarding for passengers and retrieves data using devices called RFID tags to quickly get the lost luggage back, and even checks to see if there are special entrances or any explosive residue.

With respect to new smart house technology for elderly and disabled people, Smart House will play a very important role for in the future.

Office clerk in Smart Office could fast find the document and books in seconds, and they also could maintain the important log file based on location and dates.

Many developed countries such as America attach great importance to the development of wireless sensor network. Recently, the Boston University is leading the charge, forming a sensor network consortium to bring top academic, industry and venture-capital members together, expecting to promote sensor network industry growth. BusinessWeek Magazine predicted wireless sensor networks as one of the fourth new technology in the future, and MIT's Technology Review ranked it among 10 emerging technologies that most likely to change the way we live. (8)

In the following years, significant information and communication technology research and development will no doubt be needed to realize the potential of sensor networks. In addition, we could also express a bold forecast that the future view of wireless sensor network will become ubiquitous. Building on past success, early wireless sensor network have been used for various application areas, such as environmental and agriculture monitoring (9) (10), industry control (11), military operations (12) and medical care (13). Let us examine some of the emerging research trends in the sensor networks regime that are informed by experience with these deployments.

Multiple Applications. An important trend is the increased development of multiple applications in wireless sensor network. With the advances in Wireless Sensor Network, identical sensor network is headed for supporting multiple applications rather than single application. Since wireless sensor network is composed of large numbers of heterogeneous nodes, plenty of sensor data with different sensing attributes are emerged. For example, deploying a large-scale sensor network in a complex building, the wireless sensor network could provide quality services such as temperature and humidity sensors provide not only monitor temperature and humidity in different parts of the building at different times, but surpass conventional standards by also providing the foundation of air conditioning; movement detection sensor detect the distribution of all the workers inside the building in order to provide foundation of a distributed building air conditioning control; video sensor could ensure the security of the whole building. These sensors can be self-deployed in a purely decentralized and distributed monitoring area, or integrated different sensing functions into a single sensor. Rely on the different functions of sensor nodes, the variety of sensor data might not be the same, and even the speed of sensor data distribution due to the satisfactory of requirements of different service quality.

Heterogeneity. In heterogeneous sensor networks, typically, large numbers of inexpensive sensor nodes perform sensing, whereas a minority of expensive sensor nodes provides data filtering, fusion and transport. (14)The advantage of heterogeneity architecture is potential to increase network lifetime and reliability without significantly increasing the cost. It consists of three distinct types, computational heterogeneity, link heterogeneity and energy heterogeneity.

In a heterogeneous architecture, some nodes such as backhaul links have long-distance highly reliable links, some have unlimited energy resources or more capabilities the more demanding tasks, and the others have added computational power. For instance, resource-rich nodes can be better suited for localization, digital signal processing and long-term storage, nodes with more energy reserves for hierarchical coordination, whereas short-ranging sensing can be undertaken by the smaller nodes.

Another advantage of heterogeneity is some of the nodes could perform more complex tasks during the operation of the network. For example, vision provides an important, orthogonal sensing modality to traditional sensing applications but requires greater systems complexity. Cypress, which is the commercial sampling of a high-sensitivity, high-speed SXGA (Super Extended Graphics Array) resolution CMOS image sensor with color, offers a triggered and pipelined synchronous shutter with a high frame rate and windowing capability for undistorted images and fast readout. (15)

2.2 Wireless Sensor Network Applications

It is envisioned that large-scale, distributed sensor networks will eventually cover and instrument the entire world. They will continuously monitor and collect information on diverse phenomena, including endangered species, soil and air contaminants, patients, and man-made environment. The applications of wireless sensor network technology have been classified into four main categories: environmental monitoring, health care, security, and additional applications. (16) We will illustrate some application cases from different domains briefly to demonstrate the most widespread used of this field:

1) Environmental and habitat monitoring. Nowadays mankind attempts to highlight the environmental issues and concerns that have significant affect on all of us, therefore the required data collection becomes more and more important, as well as the amounts of the data. However, the emergence of wireless sensor networks provide convenience for those random research data, and also avoid, minimize or reduce unnecessary environmental damage by traditional methods of data collection. For example, in order to monitor the shy seabird's nest activity, researchers from University of California, Berkeley, and the Intel Research Berkeley laboratory installed a network of more than 20 miniaturized sensors, or motes which could beam back raw data about the conditions in the burrows and the island's microclimate to the Internet, on nearby Great Duck Island, and now they are able to monitor a popular breeding site in real time through the Internet while just sitting comfortably in front of their computers.(17)

Wireless sensor network could not only monitor the migration of migratory birds and insects, research on the effects of environmental changes on crop, but also monitor the basic components of ocean, air and soil, etc. For instance, MoistureMap, which is a system for sustainable land and water management, has been developed for Australia. To provide soil moisture information in different time periods, the system combine weather, climate and land surface model predictions with soil moisture data from satellite sensors.(18)Besides, wireless sensor network could apply to precision agriculture, monitoring pests within a crop cycle, soil acidity and fertilizer concentration.

2) Medical diagnostics and health care. Wireless sensor network technology has been explored to a range of medical applications. Researchers could make good use of wireless sensor network to implement remote medical monitoring. For example, deploying seventeen distributed sensor nodes in every room within a building; each sensor node contains five sensors: temperature, humidity, light, infrared and sound sensors, some of them even has ultrasonic sensors. Based on the data collected by these sensors, monitor interface in real-time will display the performance through people. Through the integration of information that obtained from multiple sensors, we could accurately identify the act of people, who is monitored, such as cooking, sleeping, watching television, taking a shower, etc, so that we could exactly determine the elderly' s physical health conditions. The smart medical home is an experimental deployment of wireless sensor network example in medical care (19) as shown in Figure 2.2 The Smart Medical Home Research Laboratory.

The researchers from University of Rochester built this intelligent medical room, using dust to measure patients' important symptoms, such as blood pressure, pulse rate and breathe, sleeping pose and 24 hours performance. The utilization of wireless communications not only efficiently transfers necessary information from each sensor networks, but also reduces the heavy burdens placed on carers. No wonder Eric Dishman, the director of Intel's proactive health research, said the wireless sensor networks are an extremely promising area for home health technology development. (20)

3) Military surveillance and industry security. Due to its intensive nature, distributed wireless sensor networks are suitable to apply to hazardous battlefield with the purpose of conducting reconnaissance, monitoring military strength, equipment and material. An example of network-centric warfare includes the cooperative engagement capability, a system that consists of multiple radars collecting data on air targets. (21) The U.S. Defense Advanced Research Projects Agency (DARPA) sponsored large amounts of money to assist the research of smart dust. The concept of the "Smart Dust" involved the use of loads of tiny wireless microelectromechanical sensors that could be spread over a large battlefield area, monitoring enemy movements and detecting everything from light to vibrations in a covert manner. (22)

Besides, wireless sensor networks enables security in some dangerous industry environments such as mine and nuclear power station. These wireless sensor networks could identify important information, like workers working in the field, what are they doing, and their safety guarantee. Deploying relevant wireless sensor nodes in each vent within the factory could monitor waste water discharged into water body and waste gas released into the atmosphere, collect, analysis and report of hydrometric sample data. Flammable, explosive and poisonous materials have provided a wide range of potential risks for workers working in mine and petrochemical industry, the high cost of monitoring is prohibitive. The widespread uses of wireless sensor networks benefit a few practitioners and also increase reactive speed and accuracy in dangerous situation.

2.3 Wireless Sensor Network Characteristics

As we mentioned before, wireless sensor networks could represent the common features as ad-hoc networks such us mobility and energy power limitation, and moreover, it is further characterized by the following features:

1) Large-scale network. Spatial and temporal scale concerns the sampling interval, the extent of overall system coverage, and the relative number of sensor nodes to input stimuli, and it is an important determinant of system design. (23) To be able to acquire accurate information, the combination of fine granularity sensing and large coverage area implies thousands of sensors, or even more, deploying in monitoring area. The spatial data attained from view-angles of different granularities contains larger signal-to-noise ratio (SNR) which is significant in the acquisition of high-quality digital images and applications requiring accurate light measurements. (24) In addition, using distribution management system methods to execute complex and large numbers of data could increase monitoring accuracy and decrease accuracy requirement of each nodes. The existence of the redundant node can improve the lifetime of the whole wireless sensor network and provides the system with strong capacity of fault tolerance. A high density of sensor nodes enables increase monitoring coverage and provides chances to eliminate caves or fade zone.

2) Self-organizing network. Under ordinary circumstances, sensor nodes will be placed in certain remote area without existing infrastructure. The geographic location of each node may not be possible to determine in advance, even the relationship between two physical neighbor nodes. For example, large numbers of sensor nodes are usually scattered in the spacious virgin forest or some places unreachable or dangerous for mankind. The communicating sensor nodes are abstracted into an easily controllable network infrastructure. That is, when triggered, nodes have the ability to deploy to locally self-configure among them to automatically interconnect to form a network. (25)

The lifetime of wireless sensor networks is an important issue. It is because some sensor nodes might run out of energy as a result of energy consumption or environmental factors. The wireless sensor networks are considered as a complex system, the fact that single node might fail will be ignored as long as the overall is fulfilled finally.(26) Yet new sensor nodes will be supplemented to network in order to make up invalid nodes and increase monitoring accuracy. Thus, dynamically increase or decrease the number of sensor nodes in wireless sensor network will also lead to the dynamic change of topology structure, which could prolong the networks' lifetime and greatly improve their performance.

3) Multi-hop routing. Since the communication distance between nodes is limited, usually in a maximum range of a few hundred meters, node could just communicate with its nearest neighbor. If majority of these nodes is expected to communicate with nodes outside of the radio frequency coverage, the intermediate node will represent its routing capacity, as the figure 2.3 The case of multi-hop routing below.

Node A can communicate with node B, and node B can communicate with node C. However, node A can not communicate with node C because of the range of radio frequency.(27) Suppose the implement of multi-hop routing in network is reliable on gateway and router, then typical multi-hop wireless sensor network architecture is formed by ordinary network nodes without any routing equipments. Thus, with routing protocols, each node plays a role as both the source node and destination node.

4) Dynamic network. Due to the presentation of the network capacity results under the node mobility**,** Wireless sensor network is a dynamic network. Some sensor nodes might quit the network as a result of energy consumption or other factors; whereas new sensor nodes will be supplemented to network, which depend upon the network requirements. Therefore, the topology architecture in wireless sensor network might be changed according to the following factors:

- Environmental factor or energy consumption, which leads to sensor nodes failure or invalidation;
- The elements in network, such as wireless sensors, awareness objects and observer, might be mobility;
- New sensor nodes joining the network;
- Reliable networks.

5) Data-centric network. Tasks and communications form a task network which performs monitoring tasks in wireless sensor network. Variability in system task determines the extent to which we can optimize the system for a single mode of operation. By no means can sensor nodes be separated from sensor network. Conventional sensor networks name every node with an identifier, the unification of node names depend on telecommunication network protocol design.

Because of the differential random deployment of sensor nodes, the relationship between sensors and identifiers is completely dynamic; there is no positive connection between node identifier and their current geographical location. Once in-network data processing is in place, we have to develop programming abstractions that allow users to program the entire sensor work rather than individual sensor nodes. (28) The idea of querying or transmitting clues based on data itself is much closer to natural language communication habits. That is why we always say that wireless sensor network is a network which is data-centric. For example, target tracking is an important application in wireless sensor network. The targets might appear anywhere in the network. However, users are concerned about nothing but location and time in which a target, often a spot, could appear. They don't particularly care which nodes that track the target.

6) Application-specific network. Mankind apperceives the objective world depending on multiple sensors, and even acquiring tremendous quantity of information in a physical world. For different applications we consider sensors is related to different quantity of information, when developing sensor systems, it should provide variety of requirements to meet the actual demands.

As we know, the differences in application context may lead to different sensor network requirements, and it differs greatly in hardware platform, software system and network protocols. According to it, sensor network is not like Internet that have uniform communication protocol platform. Due to the lack of the uniform protocol standard of sensor network, there is no universal architecture suitable for all types of different sensor networks.(28) Though there is still a lot of common problems existed in different sensor network applications, especially developing more effective target-specific sensor systems. But clearly directed against each exact application in sensor network design when researching sensor network technology remains a distinct feature that be different from conventional networks.

Wireless sensor networks are particularly well adapted for use in hazardous environment or some places unreachable for mankind. An outdoor, open wireless sensor network might be intentionally destroyed by irrelevant personnel or animals. Due to the environmental limitation of present monitoring area and significant amount of sensor nodes, manual configuration is not feasible. Furthermore, communication confidentiality and security in wireless sensor network are extremely necessary. Consequently, soft hardware in wireless sensor network has to possess the capacity of robustness and fault tolerance.

CHAPTER III: LITERATURE RIVIEW (ii) Data Visualization

Abstract

Data visualization is the study of the visual representation of data, defined as information which has been abstracted in some schematic form. This chapter introduces fundamental concepts and problems approached in the data visualization. The applications of data visualization technology, which are from different areas briefly to demonstrate the most succeeded in specific field, are presented.

3.1 Data Visualization: Introduction to Critical Problems, Goals and Challenges

In his early days, Hans Rosling, who is a professor of International Health at Karolinska Institute and Director of the Gapminder Foundation(29), made a searching enquiry to discover the imprint of starvation in Africa, then he came back to teach in Swedish university. Once in his global healthy lecture to top Swedish undergraduate students, he was sort of to expect them to know everything about the world. And then he gave them a pretest that which country, as he illustrated, has the highest child mortality in five pairs of different countries. However, the correct answer fill rate is far less than 50%. The result made Rosling fell that they did not correctly answer not because of their ignorance but deeply and firmly rooted erroneous preconceived ideas. Rosling asked his students how they view the world today, and their answer is it was still we and them, "we" means the western world which the people have long life and small family, and "them" refer s to the third world, they even thought the people from the third world, however, do not fill the traditional living standards and have a very short life span of the people. Having gone through that experience, Rosling has infinite faith in that the truth is not the same as what the students convinced. Since this, he realized there is really a need to communicate because the data and what happening in the world the child in every country could very well aware. Thus Rosling decided to using data to describe problems, as he considered, information could be interpreted from data, and data visualization is the most important step in data analysis.

When you go out for a walk, your vision system would immediately recognize various objects such as vehicle, buildings, human beings, trees and pets, etc. All these above have a coherent and meaningful organization scheme. Your brain attempts to overcome the problems associated with boundary, movement and distance, organize them in the form of multidimensional entirety to the effect that we could memorize their characters. The continuous process looks unnecessary but subconscious. Data visualization is powerful not just because human awareness is controlled by visual cortex but the rapid information transfer process. Besides displaying large amounts of information, data visualization could accelerate recognization of hidden wealth of data.

In the past few years, people used many different words to describe graphic representations of data, but the overall aim is always to visualize the information in the data and so the term "data visualization" has been emerged as a new specialism within the field of computer graphics. (30)(31) Now data visualization is the study of transforming data into some kind of visual representation. By means of graphical approach, data visualization could clearly and effectively communicate information. Yet it does not mean to achieve functions we have to visualize the data in a very dry and boring manner or make the graphs gorgeous but looks extremely complicated. Aesthetic form and functional needs have to go hand in hand for the sake of conception communication. Intuitively conveying important aspects and characters could lead to further observation of discrete and complex datasets.

Data visualization technology consists of the following basic concepts:

- Spatial data, a multidimensional information space which is made up of n-dimensional attributes and m elements;
- Data development, which covers the algorithm and tools for quantitative computation and deduction;
- Data analysis, slice or dice profile data, thereby could observe data from multi-angle.

With the popularization of network technology and electronic commerce, the decision making will depend on the implicit discipline found from large amounts of finance, communication and business data. In order to accommodate the recent development to hardware platform, operating system and network communication, visual software products get up to speed with those high-throughput technologies developments quickly, of which with AVS/Express developer edition, IDL(including VIP, ION) and PV-WAVE as their representatives. Take an example of AVS/Express developer edition; it provides multi-platform, component-based software development environment with interactive visualization and graphics features. (32)

How to analyze and explore large amounts of complicated and multidimensional data? The answer is to provide a visual environment like human eyes which is known to be more intuitive, interactive and quick-witted. Therefore the principal features of data visualization technologies are as follows:

1) Interactivity. Users could be more convenient to manage and develop data in a manner that is both interactive and enjoyable.

2) Multi-dimensions. It could allow users to view multi-attributes or variables that represent data on objects or events. According to the value of each dimension, the data could be classified, sequenced, integrated and displayed.

3) Visualization. A visualization technique for different kinds of data represent it as images, curves, two-dimensional graphics images, three-dimensional objects and animations, as well as for visual data analysis in examining data patterns and correlation. People's visual performance played a significant role in scientific discoveries, and this view has borne out by the history of evolution. Generally focused on aspects of visualization, the emergence of a new key technology is the preface to a great scientific discovery. The wonderful scientific effects of telescope and microscope in Astronomy and development of biology is the best proof of this. Our field of vision has been enlarged and extended far beyond our present ability via those tools. To the present day, there were many elements of truth in it. People's visual performance has the capacity to analyze the behavior of large amounts of abstract data. New data development tools could greatly extend our vision. A people's creativity not only depends on their logical thinking but also lies on their thinking in terms of images. Only visual representation of a mass of data into concrete terms can arouse people's thinking in terms of images. On the face of it, all of the data are jumbled up. But once you could find out the principle behind it, it will provide a basis for scientific discovery, engineering development, medical diagnosis and business decision. In addition, the generation of predictive models and the capacity to integrate multiple information resources are important to the development of system, and such data, knowledge and models are dependency relationship. Thus it is elementary to improve the understanding of their concepts. Data refer to a collection of facts, and information is useful data sorted from multiple resources, but it is not identical with knowledge, because not like knowledge, information can not reflect the internal relation between data. With regard to knowledge, there is no single agreed definition of it recently, nor any prospect of one(33), and someone presented a proposal that intended to separate it into two sections. One is the so-called tacit knowledge which can not be described as language and text, the other which is called explicit knowledge is completely opposite to it. Currently, information is one kind of explicit knowledge; it can be articulated, codified and readily transmitted to others. Looking ahead, based on the significant breakthrough in brain science, human beings will successfully develop a bio-computer that resembles human brains. It will consequently usher in a golden age in artificial intelligence. But even in that time, information can not fully express all the explicit knowledge. Only when focused on graphs and images to display numerical data and information, there is a possibility to set the stage for knowledge acquisition. In brief, data visualization could greatly accelerate data processing speed so as to make effective use of tremendous amounts of data that generated in every second. What's more, data visualization could implement image communication between people; thereby people could observe implicit phenomena from data and pave a way for discovering and understanding scientific laws. Besides, data visualization could implement guidance and control for computing and programming process.

Computer has been widely used in scientific computing and data processing for nearly 50 years. (34) But it have been a long time that data can be run to completion in a batch processing mode which is in contrast to interactive manipulation. Batch processing could not lead the intervention in computing process, and it has to passively wait for sets of output data files. And hand operation is the only way in which large numbers of output data manipulated. In this way, a user does neither get a visual global concept of relational data in time, nor be likely to lose vast quantities of information. In recent years, the data from communication equipment, such as super computer, communications satellite, advanced medical imaging equipment and geological prospecting, are growing with each passing day. Thus effectively visualize data constitutes increasingly the most urgent problem. On the other hand, with rapidly advancing increases in computing speed, and the constant expansion of memory capacity, network functions exist to continuously enhance and implementing many important pattern generation and image processing algorithm via hardware, there can be a possibility to visually display large amounts of data and information, as well as carry out interactive manipulation.

Let us take an example to illustrate the great significance of the development of visualization technology. Human beings have a long enough aspiration of recognizing human body structure. But it is only 1970s, with the emergence of computed tomography (CT), magnetic resonance imaging (MRI) and visualization technologies; the aspiration has become a reality. Under the direction of the US National Library of Medicine's (NLM) Board of Regents in 1989, the long term biological information repository project - Visual Human Project (VHP) came into effect. (35) The University of Colorado Health Sciences Center created a dataset of complete human male and female cadavers in anatomical modes. The researchers scanned a human male and a human female cadaver from the sole of the foot to the crown of the head in CT and MRI. The acquisitions of the anatomical cross-section images are at 1mm intervals and totally there are 1878 cross-sections. The anatomical cross-section images which are obtained from the female cadaver are at 0.33mm intervals but obtaining 5189 cross-section images that comprise the female dataset. After filling blue latex and wrapping in gelatin to the cadaver, the cadaver should be frozen as soon as possible. Similarly, to acquire the anatomical cross sectional images in the same interval as before, which contain a higher resolution of 2048×1216, the data produced are 56GB in all. (36) The emergence of Visible Human Project datasets announce the signing that digital three-dimensional reconstructed image and virtual reality technology are widely used for medical purposes.

In recent years, the question of information visualization has been raised. Generally speaking, visualization in scientific computation refers to spatial data visualization, but information visualization concern large-scale collections of non-numerical information which is non-spatial data. With the advanced society informatization and the popularization of web application, there existed a gigantic source of information. There is an urgent need to deal with the data storage, transmit, retrieval and classification, and realizing the close correlation and development tendency are an exception which is necessary to take into account most. As a matter of fact, a great many of important information are hidden behind the exploding data. People expect to analyze that information in a higher level as to make good use of the available data. The existing database system could efficiently implement certain functions such as inserting new data into existing data structure, querying existing data by end-users, but the only drawback is that it can not discover the existed data connection and regulation, as well it can not forecast the prospective trend in the development of in accordance with existing data. On the other hand, artificial intelligence has made significant progress since its birth in 1956. (37) Machine learning is a main focus these days. It is a technology that simulate of human-like aspects of learning via computers.(38) As our understanding of some mature algorithms continue to mature, neural networks and genetic algorithm have proven to be powerful and general technique for machine learning.(39) To store and retrieve data via database management system, and analyzing and mining the knowledge behind large amounts of data in the forms of machine learning, their combination result in the generation of Knowledge Discovery in Databases (KDD). Actually, knowledge discovery in databases including interdisciplinary topics in a variety of application fields such us machine learning, pattern recognition, statistics, intelligent database, knowledge acquisition, data visualization, high-performance computing and expert system.(40) And knowledge discovery in databases could widely use in area of information management, process control, query optimization, scientific research, decision support and data self-maintenance.

Data mining is the core technology of Knowledge discovery in databases, in which knowledge discovery actually takes place. It is an iterative process that aims at extracting previously unknown and hidden patterns from large numbers of incomplete, noisy, blear, random data. (41) People considered the original raw data as a source of knowledge, just like mining of minerals. The original raw data either could be fit structural equations models like data in relational database, or it could be semi-structured data such as text, graph, image data and even different configuration data distributed in network. The standard analytic methods for data mining could be either mathematical or non-mathematical, and it might as well be deductive or inductive. Data mining allow us to discover various kinds of data including extential forms of knowledge that reflect associative property of a group of things which are all of the same general type, characteristic-based knowledge that reflect every respect to the character of objects, knowledge that reflect different attributes between different objects, benefit-related knowledge that reflect dependent or associated relationship between one object and another, predictive knowledge that infer data in the future in accordance with present history and current data, and knowledge that reveal abnormal phenomena that object deviated. In order to discover the above different kinds of knowledge, we have to adopt multiple knowledge discovery tools. Furthermore, we must develop visualization methods for knowledge discovery for the sake of better understanding the process and result of knowledge discovery, as well as human-computer interaction in the knowledge discovery process. And falling back on visualization technology while attempts to understand the correlation and development tendency between data. Information visualization not only display multi-dimensional non-spatial data via images, leading users to get a deeper understanding of the meaning of data, it also point the way to data retrieving using visual graphs and accelerate retrieval rate. In visualization in scientific computing, displayed objects refer to different kinds of spatial data like scalar, vector and tensor, and the research focus on how to veritably and quickly display three-dimensional datasets. In recent information visualization, the displayed objects are mainly multi-dimensional scalar quantities; therefore, the key to the study is design and choose specific display modes so that it is convenient for users to understand enormous multi-dimensional data and their mutual relationship, and more emphasis on the problem of psychology and human-computer interaction.

Information visualization has a bright future for application in the field of commerce, finance and communication. On the one hand, the field of communication focuses on developing much more sophisticated and advanced network model for the sake of assistance of prospective planning process. But on the other hand, more complex transmission and exchange equipment provide greater degree of freedom and flexibility for current network reconfiguration, therefore, original raw data that operated in a single network element continuously increase. The optimization of entire network operation require necessarily employ the entire information source effectively, furthermore, it also need dynamic data exchange to exchange information and ideas between different conventional fields such as market, network plan and day-to-day management. Of course, the effective area of coverage of the physical network contains a wide range of fields such as sound, data and imaging services, and each of them has their own data management requirements. Besides, modern computer networks are specifically exempted from national boundaries, and it is an international organization covered many countries and carriers. Thus both its potential data size and complexity level increase progressively at a greater order of magnitude. Take the case of BT, one of the world’s leading providers of communications solutions and services, its network bring information visualization technology into exercise. The network has more than six thousand switching devices and nearly twenty-five million client threads. As a result, it produces network state and control data megabyte per minute. In BT’s network, running condition associated with local route which is connected to a digital switch, at an average of sixty thousand per five minutes, should report to central operations unit. And then central operations unit monitor and control these data in real time. By means of measurement of large amounts of operational parameter, the network produces more than two thousands megabyte data every day. The graphical output vividly describes the geographical distribution of chosen operational parameter and the animation you might be interested in within a specific time interval. Color bar pattern could be used to represent the maximum, minimum and average value of each local concentration parameter. Visualization is reflected a wide variety of interests in non-spatial data such us the applications in financial target or turnover statistics. A great many of visualization tools and technologies which are initially used in engineering and scientific applications could transfer rapidly to the fields of finance and statistics. The key to success of visualization applications is having the capacity of providing users with interactive research data and revealing the trend, circulation and pattern that difficult to repeal through other methods. A typical example of non-spatial data coverage application is network statistics, which each pattern is made up of plenty of attributes, such as the character, switch, and major distinct or physiographic division of single network element. (42)

In addition, using the Cityscape as a visualization tool is a potential useful technology in this respect as well. It is basically a generalization of three-dimensional bar charts. (43) The position in a scalar field represents blocks or buildings within a uniform grid. Visualization could describe statistical information which divided one year into twelve months and then using twelve geographical zones to represent them. BT Group has been employed cityscape application to offer investigation in statistics service and ride quality of transportation system by the month and area. These applications could apply to financial information very easily, such as income stock character for each region and specified period, or VisualMine based on geography and income to display total quantity in currency circulation, gross income and operating cash flows. (44) Take the case of bank of Italy. They employ the application which is developed by Artificial Intelligence Software Ltd, Italy to monitor unlawful activity through banking systems. Due to the real-time resolution of increasingly obvious “data overload”, information visualization will make a profound impact in the fields of commerce, finance and communications. It can be seen from this that the increasingly data and information are useful, but the crux lies in abstract helpful knowledge as soon as possible.

3.2 Data Visualization Applications

At present, data visualization applications have been widely used in various fields such as physical science, engineering technology, finance, communication and business etc. Take a closer look on some data visualization application examples that succeeded in specific fields.

1) Medical science. Medical data visualization is currently one of the most active and vital research areas in the field of data visualization. Due to the development of modern noninvasive diagnostic technology (CT, MRI etc.) and the progress in positron emission tomography (PET) technology, doctors could more easily obtain a set of two-dimensional cross-sections imaging of functional processes in the patients' body. Computer tomography (CT) technology breaks conventional sensitive film imaging mode, restructuring images of human organs and tissues via computer leads medical images moving towards from two-dimension to three-dimension era, and it enables the clinician to view and assess the human body from a functional biochemical perspective. PET combines nuclear technology and computer technology. Computer analysis reconstructs the images of tracer, called a positron-emitting radionuclide as well which is introduced into the body on a biologically active molecule, concentration in three-dimensional space within the body (45), it makes us possible to gain images of human metabolome and functions. On this basis, image fusion the images of diversified modes as mentioned above could accurately determine the pathogen's spatial location, size, geometry and spatial relationship between ambient biological tissue and it, thus efficiently diagnosing disease for patients in due course. A great deal of organizations have researched to translate and reconstruct the obtained two-dimensional cross-sectional images into three-dimensional images associated with human organs and tissues, including Advanced Diagnosis, Automation, and Control (ADAC) Laboratory at North State University (NCSU) (46), Medical Imaging Lab at Johns Hopkins University (47), Medicim, spin-off company of the Catholic University of Leuven (48), Technical University of Bialystok (49) etc. Now the software they developed have been widely used in a great many of hospitals. In addition, researchers in University of Washington utilize visualization software system and echocardiogram diagnostic technique to obtain three-dimensional images of human heart and provide proof for general inspection and diagnosis by means of monitor shape, size and movement of human heart. (50) Electron beam computed tomography (EBCT) substituted electron beam scanning for conventional X-ray tube and detector used in conjunction with mechanical scanning. As a result, scanning speed increased a hundred times, and clinician could indicate the presence of coronary atherosclerosis via clear images, it is a world-wide revolution in computed tomography technology. Cardiovascular Institute and Fuwai Hospital, Chinese Academy of Medical Sciences (CAMS) & Peking Union Medical College cardiovascular disease have been used EBCT three-dimensional image reconstruction technology in clinical diagnosis of aortic valve disease and display of blood vessel after Coronary Artery Bypass Graft (CABD).(51) Because of the high temporal resolution of EBCT angiography, it eliminates respiratory and motion artifact, and clarifies diagnosis of various aortic valve disease as well as reveals blood vessel anatomic structure of coronary artery bypass graft. Bringing to a conclusion with it, three-dimensional image reconstruction is propitious to integrally and visually display pathological changes and help clarify a diagnosis and provide operation guide. Therefore, EBCT is expected to replace conventional angiography in aortic valve disease diagnosis and postoperative blood vessel display of coronary artery bypass graft.

CHAPTER IIII: RESEARCH METHODOLOGY

Abstract

The process of visualize data are routinely to acquire and analyze vast amounts of data. This chapter focuses on introducing the process of visualization urban transportation data generated by wireless sensor network.

4.1 Research Design

The research plan will combine two disciplines, which are wireless sensor network and data visualization. Urban transportation monitoring system comprised Wireless Sensor Network (WSN) and assigned around the capabilities of autonomous nodes. Each node in the network could integrate specific sensing capabilities with communication, data processing and power supply. The system could round-the-clock monitoring at the main roads, 24 hours a day, including a series of phenomenon (e.g. overspeed, retrogradation, running a red light, parking prohibition, floating car data and Latency time). Those images, data and information are used to transmit back to the Monitoring Center. Obtained the complex data from monitoring center, using it to provide a meaningful solution to represent it to a visual form is another key part of the research plan, it requires insights from diverse fields: data acquisition, data analysis, data governance, data management, data mining, graphic design and information visualization.

Nowadays, the overwhelming majority of traffic map tools provide real-time traffic information, helping drivers make better decisions on choosing a correct traffic route on the basis of current traffic state. However, it is an unusual sight to view the full scenarios of vehicle flow statistic at traffic crossing, like vehicle flow rate on a time basis (year/month/day). It is the most regretful thing because it concerned with each citizen more than drivers.

A small quantity of existing map contained statistical information did not make data really and truly readable. For example, the website of Kansas Department of Transportation, America provides traffic and travel information as well as the road conditions map, they are all full and accurate data with beautiful design, and worth to consult, but the weakness or flaw existing in it is hard to understand. (52) Thus there is really a need to using a meaningful solution to represent data rather than generating a bar chart or table to output the information.

4.2 Research Methodology

As mentioned above, we must reconcile these fields as parts of a single process. The importance of computer science could be understood by Graphic designers for visualization, by the means of being aware of the principles for the visual design behind data representation, statisticians could communicate their data more effectively.(53) In this chapter, we use separated processes that bridges the individual disciplines, and form a path to the final question.

4.2.1 Data acquisition

Obtained the data from monitoring center, in which the data acquisition system reflect the data from sensors located in main roads. In this part we will describe the deploy of wireless sensor network and demonstrate how large number of sensors can be integrated into Intelligent Transport System using Wireless Sensor Network to improve performance.

As a core technology for traffic surveillance and control, a Real-time Vehicle License Plate Recognition (VLPR) applies broad technical knowledge in multiple sub-systems. Intelligent multimedia network license plate recognition system could be widely used in vehicle safety audits, pay tolls to drive on a turnpike, parking management, etc.

Considered we deploy large numbers of sensors in urban main roads, we make a number of assumptions regarding the capabilities of them.

The sensors detect and snapshot by means of real-time trigger, as well as automatic sensing, accurately recognize and check the plate number no matter the vehicle is under steam or power-off. Verifying the snapshot image by using database document for comparison, sensors could report to the monitoring system when and where they found the intercept vehicle. The system adopt advanced fuzzy image process technique, identifying plate numbers that human eyes are hard to distinguish by means of dealing with images with low spatial resolution(too small characters on the plate), blur, low contrast, bad light conditions(shadow and strong light) and high distortion.

To enable the real-time vehicle license plate recognition process, we divided it into four separate sections, including plate localization, plate pretreatment, character segmentation and character recognition. In order to improve the recognition performance, an algorithm on character recognition was proposed which use a Support Vector Machine (SVM) to train character samples and obtain the rules. (54) The main approach, which is called ‘one against one’, applies SVMs for multi-class classification. A series of classifiers are applicable to each class, furthermore, the system keep nothing but the label of the most prevalent computed class for each case. The utilization of such an approach requires $k\,(k-1)/2$ classifiers, once all $k\,(k-1)/2$ classifiers are undertaken, the max-win strategy is followed.

The approach algorithm can be described as below.

Given n training data

$\Omega = \{(x_1, y_1), (x_2, y_2), \ldots, (x_m, y_n) | x_i \in R^n, (i = 1,2,\ldots,n)\}$, and $y_i \in \{i = 1,2,\ldots,k\}$,

where k is the number of classes. The classification function is as:

$$\begin{cases} \min \quad {}^1\!/_2 \| w^i_j \|^2 + C\sum \S^i_j \\ s.t. \quad (w^i)^T \varnothing(x_i) + b^i >= 1 - \S^i_j\,,\ if\ y_j = i, \\ \qquad (w^i)^T \varnothing(x_i) + b^i <= 1 - \S^i_j\,,\ if\ y_j = i, \\ \qquad \S^i_j > = 0, j = 1,\ldots,n \end{cases}$$

where $K(x, x_i) = \varnothing(x)^T \varnothing(x_i)$

In APRN, k contains 10 for digits and 26 for letters. The above formula shows the following 36 decision functions for all 36digis and letters:

$(w^1)^T \varnothing(x) + b^1,$

…

$(w^{36})^T \varnothing(x) + b^{36}.$

An x is classified to be the digit or letter a if its decision function gives the maximum value in the SVM for a, i.e.,

Class of $x \equiv \arg\max_{i=1,\ldots,36} ((w^i)^T \varnothing(x) + b^i.$

Assumed that the sensors combine the capacity of vehicle flow statistic at as well, like vehicle flow rate on a time basis (year/month/day). The principle of this real-time system is to install sensors onto the main traffic lane, drawing power from the city’s infrastructure, and sensors adopt video trigger method to estimate the passing vehicle, and then transmit the digital video signals back to analyze. When discovering vehicle appear in monitoring area, the system startup vehicle flow rate detection module at once, once there is a car passing by, the arithmometer within the sensor automatic increase and make sure accomplish processing of vehicle flow rate detection, queue length, vehicle waiting time at a traffic lane, lane occupancy ratio, urban road information analysis and data retrieval in a short time.

Sensors are located throughout the crossroads in a consistent way in every district of the city. Some sensor locations are indicated as Figure 4-1. All of the observational sensing is built directly into the crossroads. Although the sensors are ubiquitous, they become part of the interior infrastructure.

We make the following assumption. The area of potential field is *S*, and the deployment position of sensor nodes satisfy uniform distribution model, as well as any two of the sensor nodes in the potential field does not locate in the same position. Furthermore, the sensing direction in [0, 2∏]of sensor nodes satisfy the uniform distribution model. Without regard to sensor nodes might be fall in edge area that leads to decrease the effective coverage (nodes that are unoccluded and within potential field are detected; nodes that are occluded or outside the range are undetected), because the monitoring area of each sensor nodes are aR^2, therefore the probability of monitoring whole potential field for each sensor node are $\alpha R^2/ S$. The initial probability p_0 formula of potential field which is covered by *N* sensor nodes as follows:

$$p_0 = 1 - (1 - aR^2/ S)^N$$

By the above formula, when the network coverage in the potential field reach at least p_0, the formula of deployment scale of sensor nodes are

$$N \geqq \ln(1- p_0)/(\ln(S- aR^2) - \ln S)$$

when network coverage are respectively p_0 and $p_0 + \triangle p$, the deployment scale of sensor nodes are respectively $\ln(1- p_0)/\tau$, $\ln(1- (p_0 + \triangle p))/\tau$, where $\tau = \ln(S- aR^2) - \ln S$. Therefore, the difference number of sensor nodes $\triangle N$ is

$$\triangle N = \ln((1- (p_0 + \triangle p))/(1- p_0)) / \tau$$

If the area of potential field, radius of sensing coverage and sensing included angle are all fixed, τ is a constant. By this time, when p_0 are a certain number, $\triangle N$ increase along with the increase of $\triangle p$; when Δp is a certain number, ΔN increase along with the increase of p_0, and the increasing rate become bigger. As a result, if increasing the coverage rate Δp, we should deploy ΔN sensor nodes(when p_0 is a big value, which is greater than *80%*, increasing Δp by *1%* will leadΔN increase ten or even hundred times).

In wireless sensor network, each sensor nodes located in the main road constitute a self-organizing multi-hop ad hoc mesh network infrastructure, terminal sensor nodes used for special traffic information acquisition and each neighboring nodes together compose star network to communicate, and ultimate data converge toward gateway nodes. Gateway nodes could be installed in the traffic signal controller as a module at crossroads, transmitting the collected data back to monitoring center via proprietary network of signal controller for processing purpose.

Data acquisition could be either complicated (obtaining data from large systems) or very simple (reading from a text file). In this particular case, data derived from sensors which contain various capacities, and it will update in an extremely short period. A copy of the vehicle flow rate list can be found on the IMD website, as it contains information of Madrid streets, it lists street statistics in alphabetical order, and measures data from each street. The listing is a freely available file, one for each of the code, a tiny portion of which is shown below in Figure 4-2. (55)

4.2.2 Data analysis

Data analysis is a process of precise and detailed studying and summarizing data to achieve a desired result of abstract useful information and come to a conclusion. Data analysis is directly bound up with data mining, but basically data mining tends to concern larger data sets, with less emphasis on reasoning. In the field of statistics, data analysis is divided into two basic forms of statistics, known as exploratory data analysis (or descriptive statistics) and confirmatory data analysis. (56) Exploratory data analysis tends to discover new features from data, whereas confirmatory data analysis emphasizes on existing hypothesis or falsification.

After acquiring data from monitoring center, we need to tag each part of the data with its intended use. For each line in the data file, we divide it into separate parts; in this case, it must be confine to each tag character. Therefore, each individual part of data will be converted into useful information format. The layout of each line of the vehicle flow rate data as has shown in the Figure 4-3 below, which we need to understand each of the prominent quantitative relationships and discover what we want.

With intent to handle in a conversion program later, we format each field as a data type:

Float. In computer programming, floating point numbers is representation of decimal fraction or more commonly, binary point. It could be places anywhere relative to the significant digits of the number. Here, the streets are assigned float data type, because the street name might be a large number of characters which requires tremendous memory space. But if we assign unique number to different streets, the name will be short for floating point.

String. Considered as a kind of data type in computer programming, it always used for represents an ordered sequence of characters. In this case, the scope is assigned string data type. Because the scope themselves are all composed of characters without any numbers. If there is number 0 existed in the beginning of a specific field like *0ARGANZUELA*, it would be stored as *ARGANZUELA* rather than *0ARGANZUELA*.

Index. Index is an associated pointer that mapping data to a location in another table of data. An index points to the associated table which could help you locate information faster than if there is no index. Here, the index maps numbered codes to the specific districts. The numbered code might be two or three bits which requires less memory space than the full name of the districts.

Integer. Integer data type is used to represent some finite subset of the mathematical integers. They are numbers without a fractional or decimal points.

After formatting each field as an individual data type, the data are completely tagged. Therefore, it would be more useful to manipulate or represent in some ways.

4.2.3 Data mining

Data mining, which is called knowledge discovery in database as well, is an extraordinary process that abstract effective, novel, potential useful and understandable module from large amounts of data.(57) In brief, data mining offers potential for extracting or mining knowledge from a great deal of data.

This step involves classification, estimation, prediction, affinity grouping or association rules, clustering and description. In this case, we simplify the handling process. The program must calculate the average of vehicle float rate during a specific time interval, such as per hour, per day or per week etc. Therefore, the data could be represented on a screen at a proper scale. But in most cases, the whole procedure would be far more complicated rather than simplex operation.

4.2.4 Data modeling

Data modeling is a process to structure a data model so it can be used easily by databases. The modeling process is shown as Figure 4-4. (58)

A physical data model is developed based on performance considerations for the application which is developed, perhaps in the context of technical environment. The physical data model generally constitute of tables, columns keys and triggers.

This step will determine the form of data representation. Some data sets are shown as line graphs, and some are presented as tabular charts. Different data sets might be represented in different forms. Here, each crossroad has the coverage and vehicle flow rate, so the codes can be mapped as a two-dimensional plot, with the average value for the coverage and vehicle flow rate used for the overall scale in each dimension. In our model, data presentation includes nodes where represent particular concepts or elements of the traffic condition.

This step makes me consider the forms of representation and making a most important decision in the project. It is extremely significant because it will affect what data I acquire and what particular pieces I should abstract.

Here, the system is composed mainly of two individual components which are the front end and background processing. Google maps APIs and AJAX together constitute the front end.

Google Maps API allows developers to integrate Google Maps into their websites with their own data points. It is reasonably possible to embed the full Google maps into external sites via Google Maps API. The advantage of Google maps is that it allows the maps to support as many detail levels as the satellite photography warrants. It allows us to retrieve the route information between arbitrary points on the map. Furthermore, to convert the string based location information of a sensor into estimated discrete latitude and longitude positions on the surface of the globe, it provides us some build-in JavaScript to carry out geocoding, and ready-to-use mapping information will be offered by its servers based on the search terms.

It allows users to interact with the layout by typing the specific name of the streets. In addition, users could make use of the “zoom in “or “zoom out” feature so that draws them closer to each subsequent digit, displaying more details around the area.

Based on the Google map, when we begin to visualize the data, we will probably have more in our project rather than just a map. Adding a small number of interactions could help display more attractive. Using the mouse, which is a kind of performance that interacts with the map, you might find yourself struggling to locate the pixel position of the various map objects on the screen. (59)

We should also take into account where we need to trigger events. In this case, when users zoom in and finally mouse clicks the specific crossroad, it will default display dense spot which the coverage depends on the value of the vehicle flow rate. In addition, we should also run into situations of other mouse-related events, such as mouse drag which the cursor did not touch the location, but we will indicate to the user the exact geographical position in means of two-dimensional representation.

CHAPTER V: CONCLUSION

Integrate mapping and information have been a new trend in the computing development. It allows users to search the information they expect, and display with high-quality pictures and written explanations, even those development tendency and business model that traditional table and graphs cannot represent.

Due to large amounts of factors we should consider in the deployment of wireless sensor network, the real system might be more complicated than what we expect, we will encounter lots of problems such as where we should deploy the sensor nodes, what capacity the sensor should have, the cost and the energy of the sensor nodes, what data we acquire from the database, how to improve the data analysis process, and the exact technology to represent the data, etc. Thus, we should research further to extend the goals and themes explored in this dissertation.

Based on the current applications widely used in the world, the combination of these two research fields will make fresh achievements in the coming future.

Acknowledgements

First and foremost, I would like to thank Marie Redmond for her guidance during my MSc period at the Department of Computer Science. (I know that she does not like to be called a 'supervisor' or anything or anybody, so I will refrain from doing so.) She created the freedom for me to do want I thought was best, while giving me ample opportunities to make the most out for my Trinity year. Her view – that focusing on teaching theory rather than on applications – was providing me solid academic foundation in Computer Science.

In addition, I would like to thank Linda Doyle for her suggestion of my dissertation topic selection and also for discussing various practical and interesting aspects of the problem in hand. Her extensive learning was inspiring me during my first encounters with dissertation writing.

Many people helped me during my scientific explorations. I feel privileged to thank the following researchers for both their insightful comments and the enjoyable discussions I had with them: Dr. Glenn Strong (Trinity College Dublin, Ireland), Prof. Edwin Hancock (University of York, UK), Dr. Andrew Vande Moere (University of Sydney, Australia), Dr. John Dingliana (Trinity College Dublin, Ireland), and Dr. Patrick Hiller (National University of Ireland, Galway).

Finally, my parents and friends are thanked for their love, understanding and friendship.

References

3rd Annual Conference on Arteriosclerosis, Thrombosis and Vascular Biology, at http://atvb.ahajournals.org/cgi/reprint/22/5/878-a.pdf?ck=nck

A. Dunkels, T. Voigt, J. Alonso, H. Ritter, and J. Schiller. (2004). Connecting Wireless Sensornets with TCP/IP Networks, in Proceeding of the 2nd International Conference on Wired/Wireless Internet Communications, February, 2004.

ADAC Laboratories to Provide Leading Pinnacle 3Radiation Therapy Planning Systems to The Johns Hopkins Hospital, Business Wire, 1999.

Alipio Jorge, Luis Torgo, Pavel Brazdil, Rui Camacho, Joao Gama. (2005). *Knowledge discovery in databases* – PKDD 2005: 9th European Conference on Principles and Practice of Knowledge Discovery in Databases, Porto, Portugal, October 3-7, 2005: proceedings, Birkhauser, 2005.

Ana-Bela(c)N Garca-A-Hernando, Ana-Belen Garcia-Hernando, Josa(c)-Fernan Marta-Nez-Ortega, Juan-Manuel La3pez-Navarro, Aggeliki Prayati, Luis Redondo-La3pex, *Problem Solving for Wireless Sensor Networks*, Springer, 208, p.177.

Antony Unwin, Martin Theus, Heike Hofmann. (2006). *Graphics of Large Datasets: Visualizing a Million*, Springer, 2006, p.4.

AVS/Express Agreement, at http://www.eduserv.org.uk/chest/agreements/software/existing/avs/overview.aspx

Ben Fry, *Visualizing data*, O'Reilly, 2008, p.5.

CCD Signal-To-Noise Ratio, at http://www.microscopyu.com/tutorials/java/digitalimaging/signaltonoise/

Computational Biomagnetics, at http://www.ee.washington.edu/research/compbe/

Cypress: Image sensors have snapshot shutter capability, at http://www.eetimes.eu/products/displays/212000600

Edgar H. Callaway, *Wireless Sensor Networks: Architectures and Protocols*, CRC Press, 2003, p.21

Falko Dressler. (2007). *Self-Organization in Sensor and Actor Networks,* John Wiley and Sons, 2007, p.96.

Francisco Sandoval, Alberto Prieto, Joan Cabestany, Manuel Grana. (2007). *Computational and Ambient Intelligence*: 9th International Work-Conference on Artificial Neural Networks, IWANN 2007, San Sebastian, Spain, June 20-22, 2007: Proceedings, Springer, 2007, p.891.

Frits H. Post, Gregory M. Nielson, Georges-Pierre Bonneau. (2003). *Data visualization: the state of the art,* Springer, 2003, p.ix.

Graham Wills, Daniel Keim. (1999). IEEE Computer Society, IEEE Computer Society Technical Committee on Visualization and Graphics, *1999 IEEE Symposium on Information Visualization(InfoVis '99)*: Proceedings, October 24-29, 1999, San Francisco, California, IEEE Computer Society, 1999, p.93.

Guang-Zhong Yang, Magdi Yacoub. (2006). *Body sensor networks, Birkhauser*, 2006, p.1.

Hans Rosling, at http://en.wikipedia.org/wiki/Hans_Rosling

Heinz U.Lemke. (2000). *CARS 2000: Computer Assisted Radiology and Surgery*: proceeding of the 14th international congress and exhibition, San Francisco, June 28-July 1, 2000, Elsevier, 2000, p.11.

Heng Tao Shen. (2006). *Advanced Web and Network Technologies, and Applications: APWeb 2006 International Workshops: XRA, IWSN, MEGA, and ICSE, Harbin, China, January 16-18, 2006: Proceedings*, Birkhauser, 2006, p.281.

Holger Karl, Andreas Willig, and Adam Wolisz. (2004). *Wireless Sensor Networks: First European Workshop, EWSN 2004, Berlin, Germany, January 19-21, 2004: Proceedings*, Springer, 2004, p.356.

IEEE 802.11 Layers, at http://www.cs.utexas.edu/~ypraveen/surveys/wlan_security/node3.html

Intel showcases innovative wireless sensor networks for in-home health care solutions, at http://www.intel.com/pressroom/archive/releases/2004/20040316corp.htm

Isaac Bankman. (2000). *Handbook of Medical Imaging: Processing and Analysis Management*, Elsevier Science & Technology Books, October 2000.

Jadwiga Indulska, Jianhua Ma, Laurence Tianruo Yang, Theo Ungerer and Jiannong Cao. (2007). *Ubiquitous Intelligence and Computing: 4th International Conference, UIC 2007, Hong Kong, China, July 11-13, 2007: Proceedings*, Springer, 2007, p.589.

Jie Wu. (2006). *Handbook on theoretical and algorithmic aspects of sensors, ad hoc wireless, and peer-to-peer networks*, CRC Press, 2006, p.370.

John Robert Anderson, Ryszard Stanislaw Michalski, Jerzy W. Bala, Gheorghe Tecuci, Jaime Guillermo Carbonell, (1994). *Machine Learning: a multi-strategy approach,* Morgan Kaufmann, 1994, p.405.

KANSAS Department of Transportation, at http://www.ksdot.org/

Kazem Sohraby, Daniel Minoli, Taieb F Znati. (2007). *Wireless Sensor Networks: Technology, Protocols, and Applications*, Wiley-Interscience, 2007, p.27.

Khan, A. and Jenkins, L. (2008). *Undersea wireless sensor network for ocean pollution prevention*, Communication System Software and Middleware and Workshops, 2008.

Knowledge, at http://en.wikipedia.org/wiki/Knowledge

Maneesha Singh. (2007). *Process in Pattern Recognition*, Springer, 2007, p.153.

Markus Kunze. (2000). *Non-smooth dynamical systems*, Springer, 2000, p.48.

Medicim, Medical Image Computing, the Catholic University of Leuven, at http://www.medicim.com/en/products

Michael Purvis, Jeffrey Sambells, Cameron Turner. (2006). *Beginning Google Maps Applications with PHP and Ajax: From Novice to Professional*, Apress, 2006, p.210.

Mohammad Llyas and Lmad Mahgoub, (2004). *Handbook of Sensor Network: Compact Wireless and Wired Sensing Systems*, CRC Press, 2004, 15-3.

Nirupama Bulusu, Sanjay Jha. (2005). *Wireless Sensor Networks,* Artech House, 2005, p.5, p.14.

Nitaigour Premchand Mahalik. (2003). *Fieldbus Technology: Industrial Network Standards for Real-Time Distributed Control*, Springer, 2003, p.152.

Nitaigour Premchand Mahalik. (2006). *Sensor Networks and Configuration: Fundamentals, Standards, Platforms, and Applications*, Springer, 2006, p.439.

Paul E. Ceruzzi. (2003). *A history of modern computing*, MIT Press, 2003, p.118.

Paul Martin, Patrick Bateson. (1993). *Measuring Behaviour: An Introductory Guide*, Cambridge University Press, 1993, p.126.

Peter Perner, Rudiger W. Brause, Hermann-Georg Holzhutter. (2003). *Medical Data Analysis*: 4th International

Symposium, ISMDA 2003, Berlin, Germany, October 2002: Proceedings, Springer, 2003, p.15.

Positron emission tomography, at http://en.wikipedia.org/wiki/Positron_emission_tomography

Robert Greenberger, Sandra Giddens. (2007). *Careers in Artificial Intelligence*, The Rosen Publishing Group, 2007, p.6.

Römer, Kay and Friedemann Mattern. (December 2004). "The design Space of Wireless Sensor Networks". *IEEE Wireless Communications* **11**(6):54-61.

Sankarasubramaniam, Y., Akyildiz, I.F., Su, W., Cayirci, E.. (2002). *Wireless Sensor Networks: A Survey*. Computer Networks. 393-422(2002).

Sholom M.Weiss, Nitin Indurkhya. *(1998). Predictive data mining: a practical guide*, Morgan Kaufmann, 1998, p.1.

Smart Medical Home Research Laboratory, at http://www.centerforfuturehealth.com/smart_home/

Special Report 10 Emerging Technologies 2008, Technology Review (n.d.). Retrieved from http://www.technologyreview.com/specialreports/specialreport.aspx?id=25/

Street data in different districts in Madrid 2006, at http://www.madridmovilidad.es/imd/resumen_data3.asp

The data modeling process, at http://en.wikipedia.org/wiki/Data_visualization#Data_mining

The Visible Human Project, at http://www.nlm.nih.gov/research/visible/visible_human.html

Thomas Haenselmann(2006-04-05). *Sensornetworks.* GFDL Wireless Sensor Network textbook.

VisualMine, at http://www.iunet.it/ais/vis1.htm

Walker J., Barrett D., Gurney R., Kalma J., Kerr Y., Kim E. and LeMarshall J., MoistureMap: *A soil moisture monitoring, prediction and reporting system for sustainable land and water management.*

Walter R. J. Baets. (2005). *Knowledge management and management learning: extending the horizons of knowledge-based management*, Springer, 2005, p.118.

Wireless Sensors Help Biologists Monitor Seabird in Maine, at http://www.universityofcalifornia.edu/news/article/4602

Yang Xiao, Yi Pan and Jie Li. (2006). *Ad hoc and sensor networks*, Nova Publishers, 2006, p.71.

Yarvis M., Kushalnagar N., Singh H., Rangarajan A., Liu Y., Singh S.. (2005). *Exploiting heterogeneity in sensor networks, INFOCOM 2005.24th Annual Joint Conference of the IEEE Computer and Communications Societies:Proceedings*, 2005.

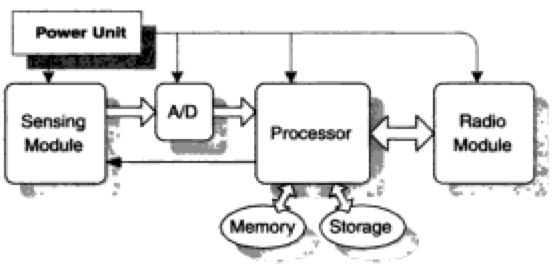

Figure 2.1 Architecture of a sensor node

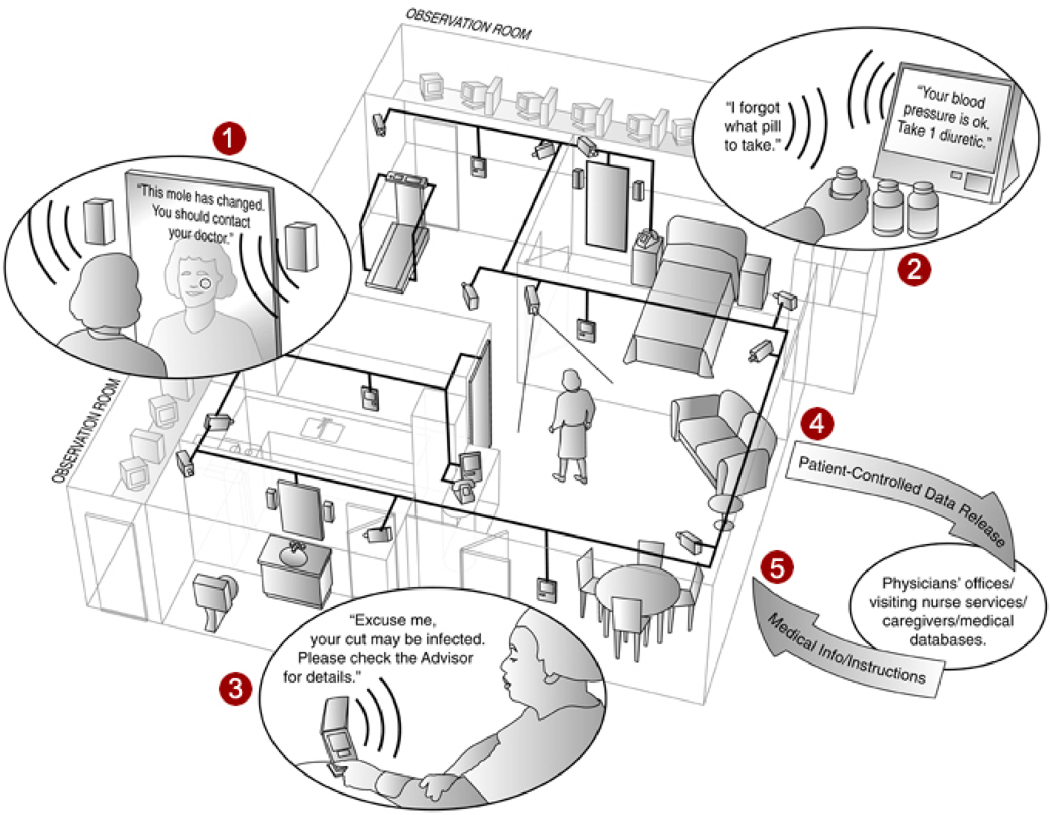

Figure 2.2 The Smart Medical Home Research Laboratory

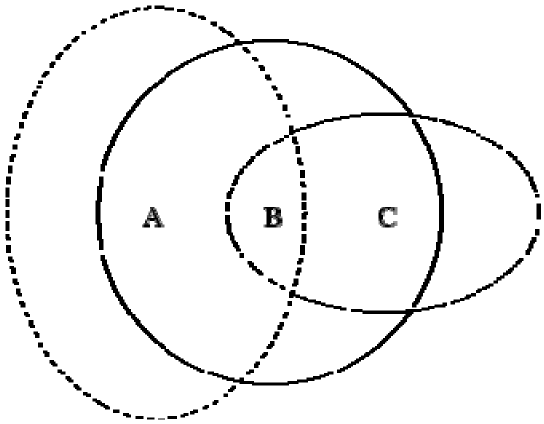

Figure 2.3 The case of multi-hop routing

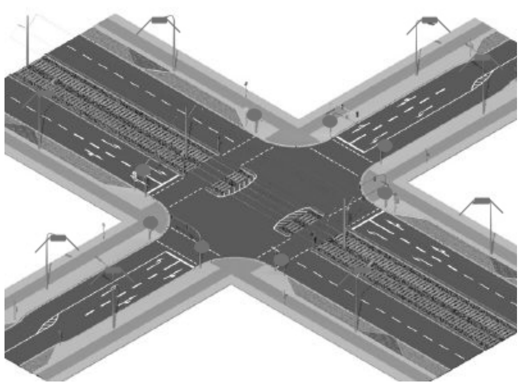

Figure 4.1 Sensor Deployment in crossroads

Número de:		Ambito	Ubicación		Datos		% de Participación	
Calles	Tramos		Zona	Distrito	Long.(Kms.)	VHS*Kms/día	Long.(Kms.)	VHS*Kms/día
	293	CENTRO		01	60.125	1.001.990	4.28%	
182	187	ARGANZUELA		02	60.555	1.535.763	4.31%	2.35%
97	157	RETIRO		03	47.550	1.536.893	3.38%	3.60%
70	278	SALAMANCA		04	76.330	1.821.063	5.43%	3.60%
88	369	CHAMARTIN		05	98.450	2.690.666	7.01%	4.27%
139	190	TETUAN		06	52.005	952.337	3.70%	6.31%
77	238	CHAMBERI		07	57.920	1.202.655	4.12%	2.23%
91	234	FUENCARRAL-EL PARDO	T	08	107.725	3.724.936	7.67%	2.82%
121	308	MONCLOA-ARAVACA		09	135.535	4.621.570	9.65%	8.73%
161	191	LATINA	O	10	81.850	2.305.262	5.83%	10.83%
101	199	CARABANCHEL		11	80.040	2.218.253	5.70%	5.40%
102	145	USERA	D	12	57.590	1.781.982	4.10%	5.20%
72	211	PUENTE VALLECAS		13	82.805	2.831.968	5.89%	4.18%
112	86	MORATALAZ		14	38.550	1.351.794	2.74%	6.64%
51	286	CIUDAD LINEAL	A	15	92.930	2.552.697	6.61%	3.17%
132	177	HORTALEZA		16	68.320	2.272.405	4.86%	5.98%
105	87	VILLAVERDE	S	17	48.280	1.575.617	3.44%	5.33%
58	42	VILLA DE VALLECAS		18	18.665	703.670	1.33%	3.69%
28	39	VICALVARO		19	20.740	907.087	1.48%	1.65%
27	177	SAN BLAS		20	77.480	2.963.870	5.51%	2.13%
92	63	BARAJAS		21	41.660	2.116.323	2.96%	6.95%
39	3.957	CONJUNTO			1.405.105	42.668.801	100.00%	4.96%
1.945								100.00%

Figure 4.2 Vehicle flow rate in the format provided by Department of Security and Mobility, Spain

182	187	ARGANZUELA	02	60.555	1.535.763	4.31%	2.35%
float TAB	String TAB	String TAB	Index TAB	float TAB	Float TAB	float TAB	float TAB

Figure 4.3 Structure of acquired data

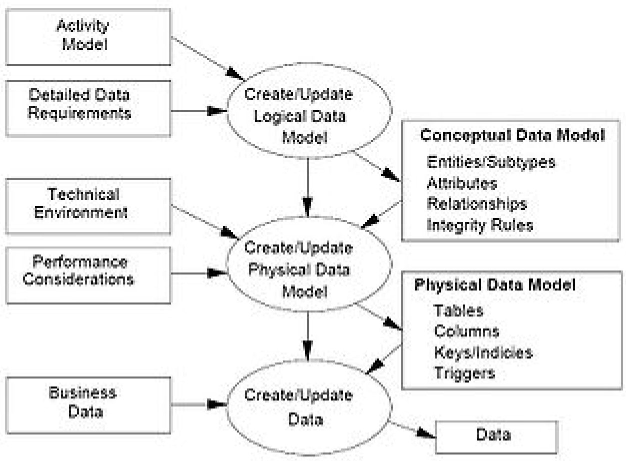

Figure 4.4 The data modeling process