Data Mining on Spatial Data

In Focus of Positioning Accuracy in GIS Application

by

JUHAIDA BT ISMAIL

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Technology (Hons) Information Technology

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CERTIFICATION OF APPROVAL

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Approved by,

(Helmi Md.Rais)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

JUHAIDA BT ISMAIL

ABSTRACT

This project emphasizes on the concepts of Global Positioning System (GPS) in a broader perspective of research in GIS. The emphasis is placed on improving GPS positioning accuracy. The project is significant in terms of increasing the quality of the existing prototype by identifying and correcting the sources of errors. GPS is used in vehicles for both tracking and navigation. Tracking systems enable a base station to keep track of the vehicles without the intervention of the driver where, as navigation system helps the driver to reach the destination. GPS can be a powerful tool that assists researchers locates points of interest. While GPS provides an easy way to collect latitude and longitude, it is important to remember that there are errors inherent in any GPS collected point. In order to use GPS most effectively, users need to decide on a strategy for dealing with the errors. Although there are several approaches such as dead reckoning, real time kinematic, to improving position accuracy, *differential correction* (concept of DGPS) is common to most of researchers. Differential correction can remove most of the effects of S/A and other common sources of error in GPS computed positions. It is the most consistent and effective means of improving position accuracy.

This final year project will result in an enhanced version of existing vehicle-tracking prototype system. The enhancement is in the form of accuracy in tracking the truck in this system. This GPS-based vehicle tracking system will tell user where the truck is, who is the driver, the truck plat no and destinations. The project assesses the GPS accuracy issues; identify common sources of GPS position error and clarify some specific methods in reducing position error. Through this project, the author compares various techniques, analysts, interpreters to test, which is best. The targeted audience for this prototype is for employees working in companies involving in the field of transportation. The Rapid Application Development (RAD) model is used to decrease time needed to design and implement the enhanced system without sacrificing its quality.

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ABBREVIATIONS AND NOMENCLATURES

AVLS	: automatic vehicle locating system
CAD	: computer aided design
DGPS	: differential global positioning system
DR	: dead reckoning
GIS	: geographic information system
GPS	: global positioning system
INS	: inertial navigation system
MAMS	: mobile asset management system
PPS	: precise positioning services
PVT	: position, velocity, time
RAD	: rapid application development
RTCA	: radio technical commission for aeronautics
RTK	: real time kinematic
RTCM	: radio technical commission for maritime
SA	: selective availability
SPS	: standard positioning services
VTIS	: vehicle tracking and information system

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

Chapter 1 consists the basic information of the project, comprises of its background, its problem statement, its objectives and the scope involved. This section also described the integration of Geographical Information System (GIS) and Global Positioning System (GPS) in the collection of data in the vehicle tracking system and their relevance to the positioning accuracy.

1.1 Background Study

1.1.1 Geographical Information System (GIS)

Geographic

This term is used because GIS tend to deal primarily with `geographic' or `spatial' or 'graphical' features. These objects can be referenced or related to a specific location in space. The objects may be physical, cultural or economic in nature. Features on a map for instance are pictorial representations of spatial objects in the real world. Symbols, colors and line styles are used to represent the different spatial features on the two-dimensional map. Computer technology has been able to assist in this mapping process through the development of automated cartography (map making) and computer aided design (CAD). Computer programs can now accomplish in minutes and hours tasks, which previously took days or weeks for cartographers and draughtsman to complete.

Information

This represents the large volumes of data, which are usually handled within a GIS. Every graphical object has their particular set of data, which cannot be represented in full details in the map. So all these data have to be associated with corresponding spatial object so that the map can become intelligent. When these data are associated with respective graphical feature these data get turned to information that is now by click of a mouse on any object its corresponding data get highlighted. All information is data but all data are not information.

Systems

This term is used to represent the systems approach taken by GIS, whereby complex environments are broken down into their component parts for ease of understanding and handling but are considered to form an integrated whole. Computer technology has aided and even necessitated this approach so that most information systems are now computer based. Therefore, Geographic Information System (GIS) is a computer based information system used to digitally represent and analyze the geographic features present on the Earth surface and the events (non-spatial attributes linked to the geography under study) that taking place on it. Geographical information systems are not restricted to the conventional view of geography, i.e. that of people and places on the Earth's surface. Hidden geographies lie everywhere and a GIS is the perfect tool to take with you on voyages of discovery.

The role of GIS in vehicle tracking system project is to represent a new paradigm for the organization of information and design of information systems, the essential aspect of which is use of the concept of location as the basis for the structuring of information systems. The application of GIS has relevance to transportation due to the essentially spatially distributed nature of transportation related data, and the need for various types of network level analysis, statistical analysis and spatial analysis and manipulation. Most transportation impacts are spatial. At GIS platform, the transport network database is generally extended by integrating many sets of its attribute and spatial data through its linear referencing system. This linear reference system is frequently used to store information at points along highways: accident, speed limit, roadwork, road class, and lanes. Moreover, GIS will facilitate integration of all other socio-economic data with transport network database for wide variety of planning functions.

Global Positioning System (GPS), an integral component of GIS which is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these "man- made stars" as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

Of all the applications of GPS, vehicle tracking and navigational systems have brought this technology to the day-to-day life of the common man. Today GPS fitted cars; ambulances, fleets and police vehicles are common sights on the roads of developed countries. Known by many names such as Automatic Vehicle Locating System (AVLS), Vehicle Tracking and Information System (VTIS), Mobile Asset Management System (MAMS), these systems offer an effective tool for improving the operational efficiency and utilization of vehicles.

GPS is used in vehicles for both tracking and navigation. Tracking systems enable a base station to keep track of the vehicles without the intervention of the driver where, as navigation system helps the driver to reach the destination. Whether navigation system or tracking system, the architecture is more or less similar. The navigation system will have convenient, usually a graphic, display for the driver which is not needed for a tracking system

GIS provide the uniform environment in which the data for numerous planning purposes can be integrated. GIS technology provides the core framework for an integrated highway information system. The developed database can be further supplemented with new information as and when it is available. So, the database keeps on evolving, which is otherwise not possible to compile at one time. The topological information available in GIS database opens the new ways for analyzing the transportation related data for different purposes. Various GIS functionality, spatially the spatial analysis functions and querying capability, are very useful tools for the day-to-day management of the road network by the concerned organizations.

1.2 Problem Statement

Uncertainty is a significant problem in GIS because spatial data tend to be used for purposes for which they were never intended, and because the accuracy problems in GIS require considerations of both object oriented and field oriented views of geographic variations. GPS can be a powerful tool to assists researchers accurately locates points of interest. However it is important to remember it is like any other research tool, with its own set of limitations. The identified problem statements that urged for the development of this application are as follows: -

1.2.1 The GPS receiver measures the difference in time between when a GPS satellite emits a signal and when the receiver picks it up.

Remember that GPS receivers use timing signals from at least four satellites to establish a position. Each of those timing signals is going to have some error or delay depending on what sort of perils have befallen it on its trip down to the receivers. A GPS receiver antenna detects signals from several of the DOD's NAVSTAR satellites at the same time. The receiver uses precise time and satellite-position data, along with other information in the transmitted signals, to calculate position coordinates. The time that it takes the signal to travel from the satellite to the receiver is one of the critical values that the receiver must calculate. Uncontrollable atmospheric conditions that affect how fast the signals travel can cause small errors in the calculated coordinates. Under some conditions the receiver can confuse the signals from one or more satellites with reflections of the same signals from water surfaces or buildings that are nearby (multipart).

The clocks in the satellites are very sophisticated, very accurate atomic clocks while the clocks in most GPS receivers are not as accurate. This discrepancy in quality between the clocks can result in errors. There are also errors due to orbital variations of the satellites, interference from buildings or trees, as well as delays created by the signal passing through the atmosphere. All of these problems introduce an error of only approximately 6 meters to the location. While these types of errors are to be expected with any system as complex as GPS, the biggest source of error is selective availability and it is intentionally placed in the signal.

Most GPS equipment is designed for a particular type (or types) of positioning task. As long as a receiver is used on jobs that do not exceed its design limitations, position error will not be a problem, and it may not even be noticed. The significant of this project is to examine these issues analytically and identify all sources of GPS position error by using Differential Global Positioning System (DGPS) concept in reducing position error and improving position accuracy. Besides that this project is trying to employ error correction while the points are being collected.

1.3 Objectives and Scope of Study

This project will result in an enhanced version of existing vehicle-tracking prototype system. The enhancement is in the form of accuracy in the positioning system which involves 2 stages; (1) identify and analyze the common source of errors in GPS and (2) employ error correction while the points are being collected by using Differential Global Positioning System (DGPS) concept.

The objectives are as follow:

a) To do a research on the accuracy aspect in GIS
b) To improve and enhance the GPS accuracy of existing vehicle-tracking prototype system.
c) To identify the common sources of errors and imply appropriate error correction to it.
d) To understand the underlying concepts of Differential Global Positioning System. (DGPS)
e) To employ a new created methodology; combining Rapid Application Development and Prototyping model.

The scopes of the study are as follow:-

a) Focuses on the concepts of DGPS to improve the positioning accuracy of the system.
b) Concentrate on the development and enhancement of the application of vehicle tracking, which will enable the users to get points with greater accuracy.
c) In-depth coverage of accuracy characteristics of GPS.
d) Focuses on the methodology and model employed; the Rapid Application Development (RAD) model

CHAPTER 2

LITERATURE REVIEW AND THEORY

2 LITERATURE REVIEW AND THEORY

In GIS, users are combining data from many sources, using various scales, projections and data models; which is one of its major strengths. But the inevitable consequence of combining data sources and changing scales is a loss of sensitivity to each data set's idiosyncracies, particularly its accuracy. The papers and literatures in this section look at the factors influencing GPS accuracy (sources of GPS inaccuracy) and the solutions for error correction.

2.1 Factors Influencing GPS Accuracy

2.1.1 GPS Errors and Limitations for Vehicle Tracking

Claude Arpin in his white paper stated that GPS is the ultimate navigation and vehicle-tracking tool nowadays but in fact it is fragile, prone to error, easily disabled, and best-suited for navigation purposes only. In his paper, Arpin listed all the key factors to the position accuracy

Orbital Error

Arpin defines this error as the actual position of the satellite in space versus its predicted position. This occurs when the GPS receiver measures the difference in time between when a GPS satellite emits a signal and when the receiver picks it up.

Clock Errors

Both the satellite and the receiver require very precise clocks to function properly; the receiver clock is typically a weak link due to cost considerations. One billionth of a second (one nanosecond) of inaccuracy in a satellite clock results in about 30 centimeters (one foot) of error in measuring the distance to that satellite. For this reason, the satellites are equipped with very accurate (Cesium) atomic clocks. Even these very accurate clocks accumulate an error of 1 billionth of a second every three hours. To resolve the satellite clock drifts, they are continuously monitored by ground stations and compared with the master control clock systems that are combinations of more than 10 very accurate atomic clocks. The errors and drifts of the satellites' clock are calculated and included in the messages that are transmitted by the satellites. In computing the distance to the satellites, GPS receivers subtract the satellite clock errors from the reported transmit time to come up with the true signal travel time. Even with the best efforts of the control centers in monitoring the behavior of each satellite clock, their errors cannot be precisely determined. Any remaining satellite clock errors accumulate typically to about a few nanoseconds, which cause a distance error of about one meter.

Receiver Clock

Similar to satellite clock errors, any error in the receiver clock causes inaccuracy in distance measurements. However, it is not practical to equip receivers with very accurate atomic clocks. Atomic clocks weigh more than 20 kilograms, cost about US$50,000, and require extensive care in temperature control.

Assume that at a given time our receiver clock has an error of one millisecond, causing a distance error of about 300,000 meters. If the distances to all satellites are measured exactly at the same time, then they are all off by the same amount of 300,000 meters. We can, therefore, include the receiver clock error as one of the unknowns that we must solve for. We have three unknowns (X, Y, Z) for the position. Now we have four unknowns: three components of position and the new unknown of receiver clock error. We will need four equations in order to solve for the four unknown. Measuring distances to four satellites can provide us such four necessary equations. Instead of three satellites before, now we need four, but in return we can use inexpensive clocks in our GPS receivers.

Note that the concept of receiver clock being one of the unknowns is valid only if we take measurements to all satellites exactly at the same time. If distances to all satellites are not measured at the same time, then for each measurement we have a different clock.

Making simultaneous measurements to four satellites, we not only compute the three dimensions of our position, but we also find the error in our receiver clock with very good accuracy. A typical clock has a drift of about 1000 nanoseconds every second, but we can now adjust the receiver time to the accuracy of the GPS clock. This will make the inexpensive clock of the receiver as good as an atomic clock. Receivers correct their clock every second and provide a corrected tic signal for outside use for those who need accurate time. If we put a receiver in a precisely known location, then we need to track only one satellite to continuously calculate the receiver clock error and adjust it.

Atmospheric Errors

According to Arpin satellite signals travel over 20,000 km, including a trip to the Earth's ionosphere and troposphere, both regions of charged particles that distort the signal. Ionospheric signal propagation delay can vary from 40-60 meters 95% by day to 6-12 meters 95% at night. This is a particular problem with a single frequency user (i.e., a single frequency C/A code set). Dual frequency receivers can correct for ionospheric delays with a residual error of some 4.5 meters 95%. The satellite navigation message contains correction coefficients for the single frequency user to reduce the ionospheric delay by appropriate algorithm. Tropospheric delay may be up to 6 meters 95% in magnitude. Many receivers employ algorithms to minimize this troposphere delay error. An additional concern for Canadian users is that the further North you are, the greater this error becomes due to the longer signal path through these latitudes.

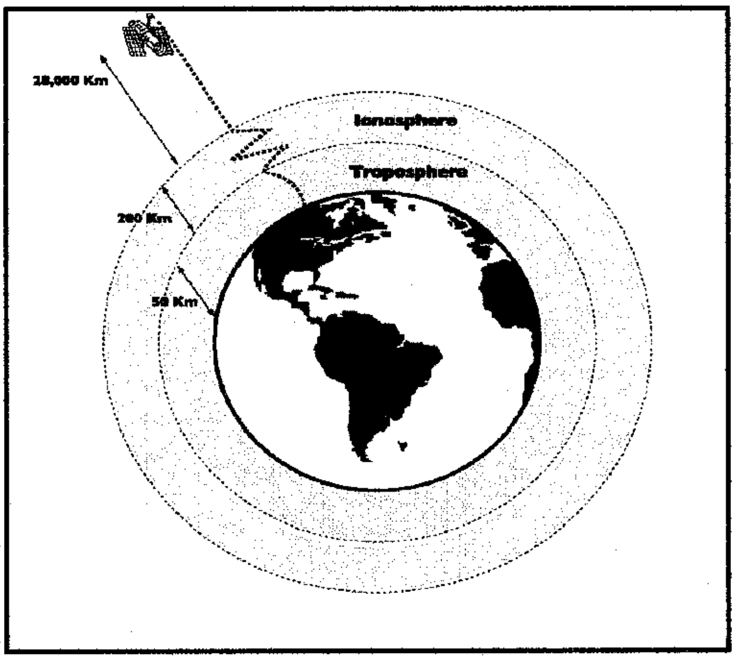

Figure 1: Atmospheric Errors

Multipath Errors

Multipath errors result when the satellite signal is reflected off some nearby object, like a person, a building, a roof, trees, defense foliage, a mountain, etc. Unless the GPS device has a clear sky view i.e. obstructed in all directions and a minimum of 4 satellites in view, multipath errors are very likely.

Receiver Noise

Arpin stated that this depends on the quality of the electronics employed in the GPS unit and translates into the cost of the unit. Consumer GPS units are lower cost, higher noise devices.

Relativistic Corrections

Arpin suggested that both of Einstein's theories of General Relativity and Special Relativity must be incorporated into the software/firmware built into receivers. These complex equations correct for the speeds of the satellites and their locations in the Earth's gravitational field very different from those of the receiver. Errors in the subtle relativistic corrections lead to errors of tens of meters or larger in positional accuracy.

Measurement errors and biases

Biases can be defined as being those systematic errors that cause the true measurements to be different from observed measurements by a "constant, predictable or systematic amount", such as, for example, all distances being measured too short, or too long. Biases must somehow be accounted for in the measurement model used for data processing if high accuracy is sought. There are several sources of biases with varying characteristics, such as magnitude, periodicity, satellite or receiver dependency, etc. Biases may have physical bases, such as the atmosphere effects on signal propagation, but may also enter at the data processing stage through imperfect knowledge of constants, for example any "fixed" parameters such as the satellite orbit, station coordinates, velocity of light, etc. A useful way of considering biases is as errors, which are correlated in space, or time Residual biases may therefore arise from incorrect or incomplete observation modelling and hence they will be treated as random errors.

Absolute or Differential Positioning Mode

For GPS, there are two positioning modes; absolute and differential positioning mode. The first is the absolute mode, the coordinates in relation to a well-defined global reference system. The coordinate system generally associated with GPS positioning is the earth-centered WGS84 Cartesian reference system. This coordinate system is *realized* via the coordinates of the monitor stations (of the Control Segment), and subsequently *transferred* to users via the (changing) coordinates of the GPS satellites. As the satellite coordinates are essential for the computation of user position, any error in these values, as well as the presence of other biases, will directly affect the quality of the position determination. The second mode is the differential positioning, which refers to coordinates in relation to some other fixed point. In GPS surveying this is referred to as baseline determination.

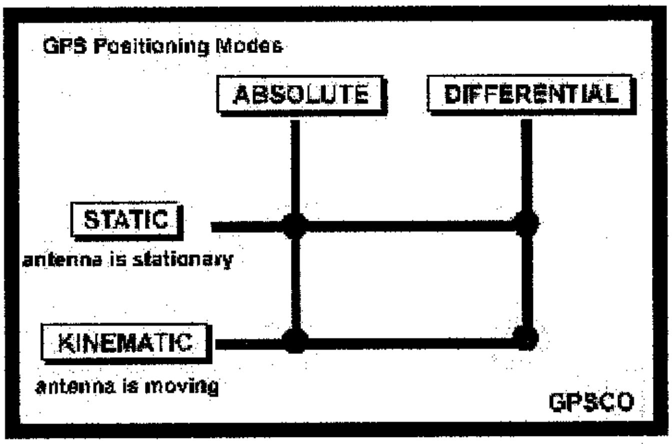

Figure 2: The basic GPS positioning modes

The most basic correlation between accuracy and positioning mode must also take into account the observation type used in the GPS positioning application. Hence accuracy versus positioning mode is a complex mosaic.

Higher accuracies are possible if the relative position of two GPS receivers, simultaneously tracking the same satellites, is derived. Because many errors will affect the absolute position of two or more GPS users to almost the same extent, these errors largely cancel when differential or relative positioning is carried out. There are different implementations of the differential positioning procedures, but all share the characteristic that the position of the GPS receiver of interest is derived relative to another fixed, or reference, receiver whose absolute coordinates in the satellite datum are assumed to be known. One of these implementations, based on combining the data from the two receivers before processing, is the standard mode for GPS surveying. GPS surveying is therefore essentially concerned with the measurement of the *baseline components* between simultaneously observing receivers. (The effect of satellite-receiver geometry in differential positioning is more complex than in the case for point positioning.)

Processing Algorithms, Operational Mode and Other Enhancements

The algorithms, operational mode and other enhancements will also play an important role in error/bias propagation into GPS positioning results. This is whether the user is moving or stationary. Clearly repeat observations at a stationary station would permit an improvement in precision due to the effect of averaging over time. A moving GPS receiver does not offer this possibility.

This is whether the results are required in real-time, or if post-processing of the data is possible. Real-time positioning requires a "robust" but less precise technique to be used. The luxury of post-processing the data permits more sophisticated modeling and processing of GPS data to minimize the magnitude of residual biases and errors.

The level of measurement noise has a considerable influence on the precision attainable with GPS. Low measurement noise would be expected to result in comparatively high accuracy. Hence carrier phase measurements are the basis for high accuracy techniques, while pseudo-range measurements are used for low accuracy applications.

The next factor is the degree of redundancy in the measurements. For example, the number of tracked satellites (dependent upon the elevation cutoff angle, the number of receiver tracking channels, satellites apart from GPS such as GLONASS and pseudolites, etc.), the number of observations (dual-frequency carrier phase, dual-frequency pseudo-range data).

The algorithm type may also impact on GPS accuracy. For example, "exotic" data combinations are possible (carrier phase plus pseudo-range), Kalman filter solution algorithms, more sophisticated phase processing algorithms. The Kalman filter algorithm recursively estimates the error state vector. It also calculates the uncertainty in its estimate as given by its covariance matrix. Define x k to be the estimate of the error state vector at time t k. The estimation error is the error in this estimate, or dx x- x. The covariance matrix of the estimation error at time tk gives a measure of the uncertainty in the estimated error state vector and is defined as

$$\boxed{P = E[x\,(x)\,] = E[(x - x)\,(x - x)\,]}$$

Techniques of data enhancements and aiding may be employed. For example, the use of carrier phase smoothed pseudo-range data, external data such as from Inertial Navigation Systems (and other such devices), additional constraints, etc.

Accuracy

Arpin concludes that all of the above-mentioned errors combine to provide an approximate position accuracy of 25 meters. This might be larger in some instances and smaller in others. Since the accurate determination of a position by GPS depends so much on the various types of errors inherent in the technology, any means of reducing these errors will naturally yield more accurate results. Orbital, multipath and atmospheric errors cannot be controlled for a given track. That leaves only clock errors and receiver noise as controllable variables. Unfortunately, the only way to achieve an improvement in these problem areas is through the use of much more sophisticated and costly equipment. In fact, whereas small commercial GPS receivers can be purchased for under US$500, equipment that would have accuracies better than 10 meters costs anywhere from US$5,000 to US$10,000 or more. These are primarily used for Global Mapping and Geographic Information Applications. Beyond this, there are “Survey Grade” receivers, costing tens of thousands of dollars, not readily available, and for specific land survey and military applications only.

2.1.2 Error in Digital GIS

Maffini, Arno and Wolfgang provide an overview of all the sources of error and uncertainty in geographic information. In this paper, they illustrate the size and range of some types of errors generated by GIS users in the digitizing process, explore ways in dealing with these errors in GIS products and make some observations and suggestions for research that may help to more comprehensively cope with the errors. Figure 2 shows a schematic of the sources that contribute to likely error. The likely error can be thought of as occurring due to three major causes.

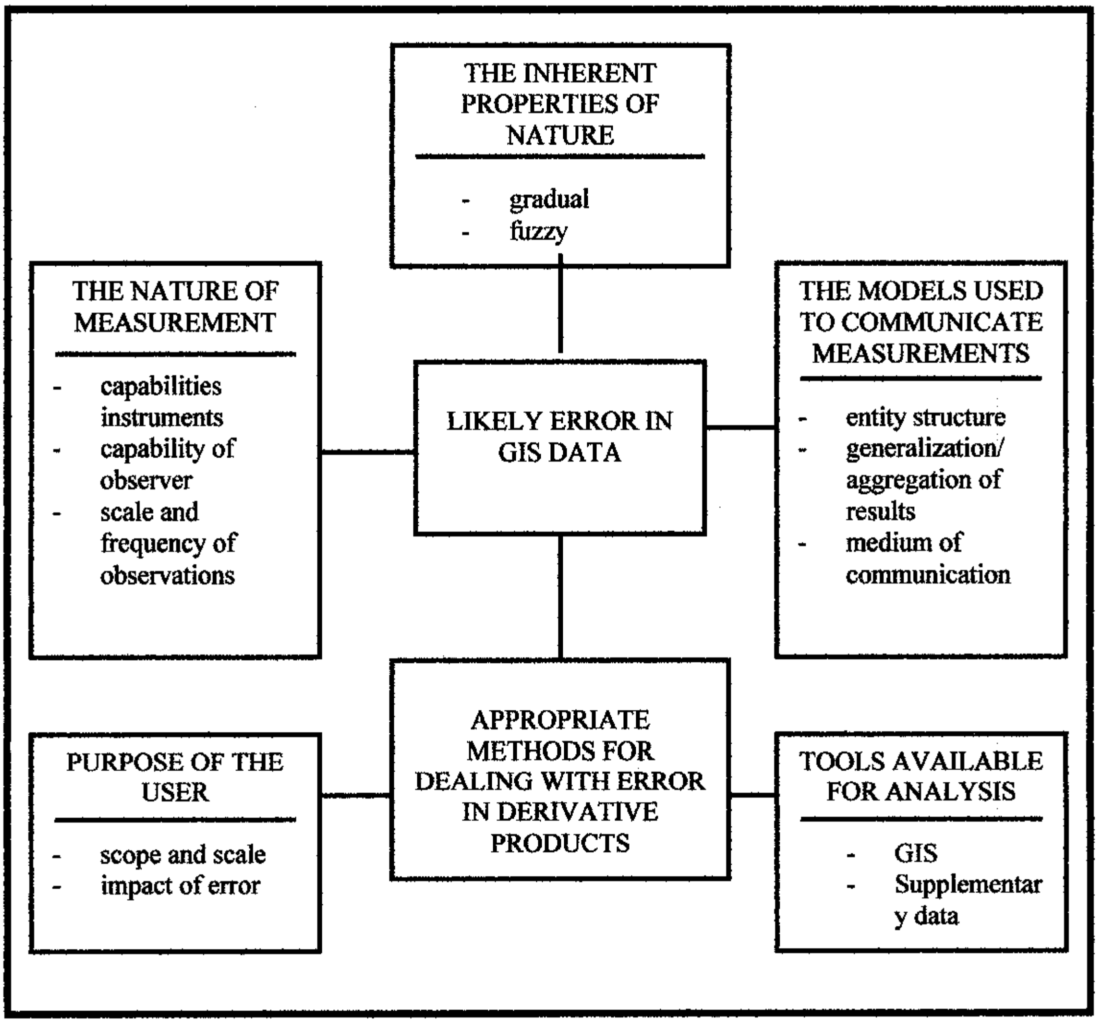

Figure 3: The error issue

Inherent properties of nature

Maffini, Arno and Bitterlich state that the first major cause of error is due to the inherent properties of nature. These researchers claimed that unlike geographic information data structures, the real world is not always distinct and clear, but is frequently gradual and fuzzy.

Nature of measurement in geography

The next major source of likely error stems from the nature of measurement in geography. Any measurements that are acquired with instruments inevitably introduce error. The researchers claim that the capability of the person handling the device can influence the amount of error introduced. The scale at the measuring device and the frequency of sampling will also lead to potential errors in geographic data.

Data models that we use to communicate our measurements

The geographic model structure is recognized as a source of error. In the case of vector, the representation of a line or an edge implies a level of certainty or precision that may not be discernable in the real world. Where else for raster case, the aggregation or averaging of conditions by imaginary cells is also susceptible to error. Lastly, it is stated that the medium used to communicate measurements may also introduce errors. When a satellite image is converted into a photograph or transparency, the error properties of this product may be different from those of the same information retained in the original digital form.

Data processing and transformation

It seems that more likely new errors or uncertainty will be introduced if more times a set of measurements are transformed through one process or another.

2.1.3 Sources of Inaccuracy and Imprecision

Foote and Huebner in their writings give definitions of accuracy and precision to distinguish between these two terms. Accuracy is the degree to which information on a map or in a digital database matches true or accepted values. Accuracy is an issue pertaining to the quality of data and the number of errors contained in a dataset or map. In discussing a GIS database, it is possible to consider horizontal and vertical accuracy with respect to geographic position, as well as attribute, conceptual, and logical accuracy. Precision refers to the level of measurement and exactness of description in a GIS database. Precise locational data may measure position to a fraction of a unit. Precise attribute information may specify the characteristics of features in great detail. It is important to realize, however, that precise data--no matter how carefully measured--may be inaccurate. Surveyors may make mistakes or data may be entered into the database incorrectly.

It has being identified that the quality of a GIS dataset may be affected by many sources of error. Few of these will be automatically identified by the GIS itself. It is the user's responsibility to prevent them. Particular care should be devoted to checking for errors because GIS are quite capable of lulling the user into a false sense of accuracy and precision unwarranted by the data available. For example, smooth changes in boundaries, contour lines, and the stepped changes of chloropleth maps are "elegant misrepresentations" of reality. In fact, these features are often "vague, gradual, or fuzzy" (Burrough 1986). There is an inherent imprecision in cartography that begins with the projection process and its necessary distortion of some of the data (Koeln and others 1994), an imprecision that may continue throughout the GIS process. Recognition of error and importantly what level of error is tolerable and affordable must be acknowledged and accounted for by GIS users. Burrough (1986) divides sources of error into two main categories:

1) Obvious Sources of Error

There are many sources of error that may affect the quality of a GIS dataset. Some are quite obvious, but others can be difficult to discern. The GIS will automatically identify few of these itself. It is the user's responsibility to prevent them. Particular care should be devoted to checking for errors because GIS are quite capable of lulling the user into a false sense of accuracy and precision unwarranted by the data available.

Age of data

Some of the data sources may be too old to be used for current GIS projects. Past collection standards may be unknown, non-existent, or not currently acceptable. For instance, John Wesley Powell's nineteenth century survey data of the Grand Canyon lacks the precision of data that can be developed and used today. Additionally, much of the information base may have subsequently changed through erosion, deposition, and other geomorphic processes. Reliance on old data may unknowingly skew, bias, or negate results.

Area cover

According to Foot and Huebner, there were cases where only partial levels of information available for use in a GIS project. For remote sensing, lack of data in certain parts of the world due to almost continuous cloud cover. Uniform, accurate coverage may not be available and the user must decide what level of generalization is necessary, or whether further collection of data is required.

Density of observations

For a data reliability guarantee, a map user should conduct a number of observations within an area. An insufficient number of observations may not provide the level of resolution required to adequately perform spatial analysis and determine the patterns GIS projects seek to resolve or define. A case in point, if the contour line interval on a map is 40 feet, resolution below this level is not accurately possible. Lines on a map are a generalization based on the interval of recorded data, thus the closer the sampling interval, the more accurate the portrayed data.

Accessibility

Foot and Huebner claim that accessibility to data is not equal. What is open and readily available in one country may be restricted, classified, or unobtainable in another. Prior to the break-up of the former Soviet Union, a common highway map that is taken for granted in this country was considered classified information and unobtainable to most people. Military restrictions, inter-agency rivalry, privacy laws, and economic factors may restrict data availability or the level of accuracy in the data.

Cost

True accuracy is expensive and unaffordable. Extensive and reliable data is often quite expensive to obtain or convert. Initiating new collection of data may be too expensive for the benefits gained in a particular GIS project and project managers must balance their desire for accuracy the cost of the information.

2) Errors Resulting from Natural Variation or from Original Measurements.

Careful checking on these error sources will reveal their influence on the project data.

Positional Accuracy

Positional accuracy is a measurement of the variance of map features and the true position of the attribute. It is dependent on the type of data being used or observed. This applies to both horizontal and vertical positions. Accuracy and precision are a function of the scale at which a map (paper or digital) was created. The mapping standards employed by the United States Geological Survey specify that:

"requirements for meeting horizontal accuracy as 90 per cent of all measurable points must be within 1/30th of an inch for maps at a scale of 1:20,000 or larger, and 1/50th of an inch for maps at scales smaller than 1:20,000."

Accuracy of content

Maps must be correct and free from bias. Qualitative accuracy refers to the correct labeling and presence of specific features. Other errors in quantitative accuracy may occur from faulty instrument calibration used to measure specific features such as altitude, soil or water pH, or atmospheric gases. Mistakes made in the field or laboratory may be undetectable in the GIS project unless the user has conflicting or corroborating information available.

2.2 GPS Solutions

2.2.1 Positioning techniques

In order to pinpoint a user's position, to refine that positioning information through a combination of GPS; several techniques have been developed. (Patrick Herron, Chuck Powers and Michael Solomon) Some of the popular techniques such as autonomous positioning, differential positioning and server-assisted positioning.

Autonomous GPS positioning

According to Herron, Powers and Solomon, autonomous GPS positioning is the technique that is commonly thought when a reference to using the GPS to determine the location of a person, object or address is made. They add that this technique is the practice of using a single GPS receiver to acquire and track all visible GPS satellites, and calculate a PVT (Position, Velocity, Time) solution. Depending upon the capabilities of the system being used and the number of satellites in view, a user's latitude, longitude, altitude, and velocity may be determined. The researchers claimed that with the discontinuation of Selective Availability this technique might now be used to determine a user's location with a degree of accuracy and precision that was previously available only to privileged users. Selective Availability (SA) is implemented by tethering the satellite clocks and reporting the orbit of the satellites inaccurately. Military receivers are equipped with special hardware and codes that can mitigate the effect of SA. SA can be turned ON or OFF through ground commands by the GPS system administrators.

Differential GPS Positioning

DGPS is used by GPS users to require accuracies not previously achievable with single-point positioning (autonomous GPS positioning). DGPS is said as effectively eliminated the intentional errors of Selective Availability, as well as introduced as the satellite broadcasts pass through the ionosphere and troposphere.

DGPS uses two GPS receivers to calculate PVT, one placed at the fixed point with known coordinate (known as the master site), and a second (referred to here as the mobile unit), which can be located anywhere in the vicinity of the master site where an accurate position is desired. By taking an example, the master site could be located on a hill or along the coastline, and the mobile unit could be a GPS receiver mounted in a moving vehicle. This would allow the master site to have a clear view of the maximum number of satellites possible, ensuring that pseudorange corrections for satellites being tracked by the mobile unit in the vicinity would be available.

In order to derive the difference between the positions calculated based on the SV broadcasts and the known position of the master site, the master site need to track as many as visible satellites as possible and processes that data. The error between the known position and the calculated position is translated into errors in the pseudorange for each tracked satellite, from which corrections to the measured distance to each satellite are derived. The mobile unit will then measure the applied pseudorange. This will then effectively eliminating the affects of SA and other timing errors in the received signals.

It is considered that the corrections to measured pseudorange at the master site are equally applicable to both receivers with minimum error as long as the mobile unit is less than 100 km from the master site.

To calculate a position using DGPS, a mobile unit must establish communication with a master site broadcasting DGPS correction information. It is also stated that a GPS receiver that has wireless communication capabilities, such as one that is integrated into an intelligent vehicle, may be able to access DGPS correction data on the Internet, or have it delivered on a subscription basis from a private differential correction service provider.

As long as the S/A is discontinued, DGPS positioning technique will still provide enhanced positioning accuracy, since other timing errors are inherent in the SV broadcasts that DGPS may help correct.

Server-assisted GPS positioning

According to Herron, Powers and Solomon, server-assisted GPS is a positioning technique that can be used to achieve highly accurate positioning in obstructed environments. It requires a special infrastructure which includes a location server, a reference receiver in the mobile unit, and a two- way communication link between the two, and best-suited for applications where location information needs to be available on demand, or only on an infrequent basis, and the processing power available in the mobile unit for calculating position is minimal.

For this technique, the location server transmits satellite information to the mobile unit, providing the reference receiver with a list of satellites that are currently in view. To collect a snapshot of transmitted data from the relevant satellites and from this calculates the pseudorange information, the mobile unit uses the satellite view information. This has been identified effectively eliminates the time and processing power required for satellite discovery and acquisition.

The researchers added that once the reference receiver has calculated the pseudoranges for the list of satellites provided by the location server, where the final PVT solution is calculated. The location server will then transmit this final position information back to the mobile device as needed. Because the final position data is calculated at the location server, some of the key benefits of DGPS can also be leveraged to improve the accuracy of the position calculation.

2.2.2 Error Correction

Since the inception of GPS, methods have been, and are still being, developed to reduce errors and enhance the accuracy, even with the implementation and presence of SA and partial availability of L2 (AS).

Differential Mode

For this technique, the receiver in the known location is called "base receiver" and the other receiver with unknown location is called "rover receiver". The function of the base receiver is to compute the instantaneous range to each satellite, based on its known position and the instantaneous location of each satellite. Then it compares each calculated value to its measured range for the corresponding satellite. The difference between the two is the range error (or correction value) for the corresponding satellite, which is reported to the rover receiver. The rover receiver subtracts the reported correction values from its measured ranges for all corresponding satellites and computes its own position with much better accuracy.

The correction values change due to the motion of the satellites and the changes in the satellite clock. Therefore the base receiver must quickly compute the range errors and transmit them to the rover.

The accurate knowledge of the position of the base directly impacts the accuracy of the position computed by the rover. If we enter a position for the base receiver that is off in some direction, then all range errors computed and transmitted by the base receiver will be off in such a way that the computed rover position will be off by the same amount and in the same direction as the base.

Baseline refers to the distance between the base and rover receivers. When the baseline is small, i.e. when the receivers are very close to each other, the range errors for the two receivers are nearly identical; therefore, we could use the range errors calculated by the base to correct for the rover position. As the baseline gets longer, the correlation between the range errors becomes weaker. In other words, there will be some residual errors in the computed position of the rover that depend on its proximity to base. As a rule of thumb, you can expect an additional one-millimeter of error or uncertainty for every kilometer of baseline when dual frequency receivers are used. This is abbreviated as 1 ppm (one part per million). For single frequency receivers this error increases to 2 ppm.

All the errors will be removed by the differential mode except the multipath and receivers errors. These errors are local to each receiver and will not be canceled by the differential mode.

The receiver error (or noise) is typically about 10 cm for the code phase and about 1 mm for the carrier phase. In high quality receivers these errors are even smaller by several times. The multipath error, on the other hand, could be as much as several meters for the code phase and several centimeters for the carrier phase. Therefore, if we somehow deal with the multipath errors, we can obtain millimeter level accuracy with carrier phase and decimeter accuracy with code phase.

Differential Global Positioning System (DGPS)

DGPS is based on measuring distances to satellites with code phase. Code phase is like a measuring tape that has tic marks and numbers only every meter. The meter-marks and numbers of this measuring tape appear instantly after we lock to satellites, therefore we can measure distances instantly but not accurately.

In DGPS, if range errors are transmitted from the base receiver to the rover receiver in real-time, (i.e. with a radio link) then the system is called real-time DGPS in which accurate results can be obtained in real time. This is desirable for applications in which some actions need to be performed in the field, such as placing markers or moving objects to exact locations. If real time results are not needed (e.g. for making accurate maps), the measurements are time tagged and recorded in the base and rover receivers and later transferred to a computer to calculate the accurate position of the rover at each instant. This is called post-processed DGPS.

According to Fenglin Guo, Yuesheng Ji and Guorong Hu, claimed that VINS belongs to a class of real time kinematic positioning whose precision is relatively low. So, in order to increase its precision, one method is to introduce differential GPS (DGPS) technique. DGPS can reduce or cancel error sources such as satellite clock bias, atmosphere delays, orbit bias. According to the different modes of operation, DGPS can be divided into three classes: position-based DGPS, pseudorange DGPS and carrier phase DGPS. The principles are basically the same but corrected sophistication and precision levels of each technique are quite different. In VINS, position-based DGPS and pseudorange DGPS are usually used.

Differential GPS (DGPS) was developed to meet the needs of positioning and distance-measuring applications that required higher accuracies than stand-alone

GPS could deliver. A typical differential GPS architecture (see Figure 4) consists of a reference receiver located at a surveyed, known location, and one or more DGPS user receivers. The user receivers are often called "mobile" receivers because they are not confined to a fixed location like the reference receiver. The Reference Receiver antenna, differential correction processing system, and data link equipment (if used) are collectively called the Reference Station. Both sets of receivers either collect and store the necessary data for later processing, or send them to the desired location in real time via the data link.

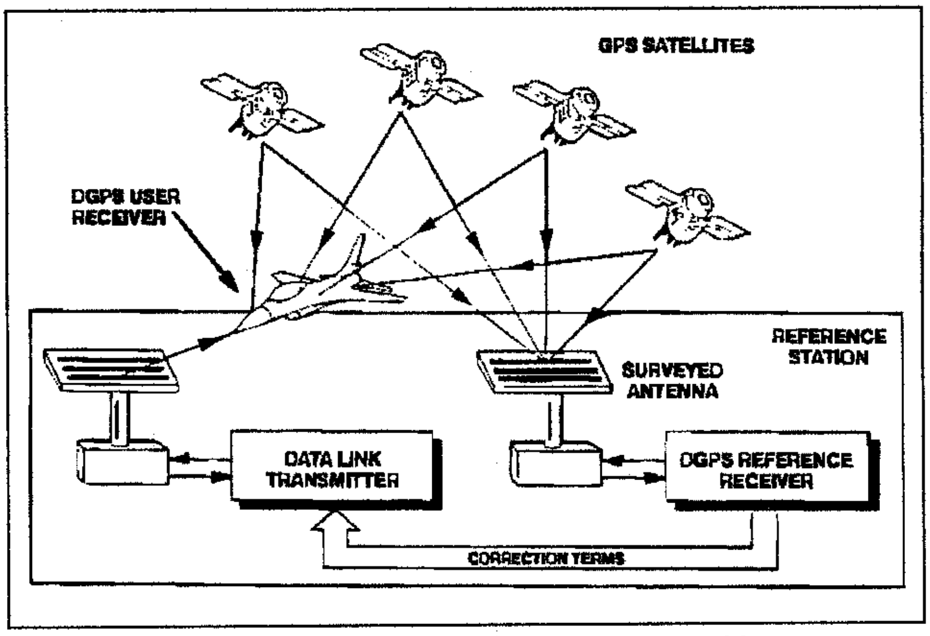

Figure 4: Typical Differential System Architecture

This overview outlines some of the fundamental issues of DGPS. Any user considering the need for a positioning system that can give accuracies better than the absolute PPS or SPS performance should consider these issues.

DGPS Concept

DGPS is based on the principle that receivers in the same vicinity will simultaneously experience common errors on a particular satellite ranging signal. In general, the user (mobile) receivers use measurements from the reference receiver to remove the common errors. In order to accomplish this, the user (mobile) receivers must simultaneously use a subset or the same set of satellites as the reference station. The DGPS positioning equations are formulated so that the common errors cancel. The common errors include signal path delays through the atmosphere, and satellite clock and ephemeris errors. For PPS users, the common satellite errors are residual system errors that are normally present in the PVT solution. For Standard Positioning Service (SPS) users, the common satellite errors also include the intentionally added errors from SA. Errors that are unique to each receiver, such as receiver measurement noise and multipath, cannot be removed without additional recursive processing (by the reference receiver, user receiver, or both) to provide an averaged, smoothed, or filtered solution. Various DGPS techniques are employed depending on the accuracy desired, where the data processing is to be performed, and whether real-time results are required. If real-time results are required then a data link is also required. For applications without a real-time requirement, the data can be collected and processed later. The accuracy requirements usually dictate which measurements are used and what algorithms are employed. Under normal conditions, DGPS accuracy is independent of whether SPS or Precise Positioning Service (PPS) is being used, although real-time PPS DGPS can have a lower data rate than SPS DGPS because the rate of change of the nominal system errors is slower than the rate of change of SA. However, the user and the Reference Station must be using the same service (either PPS or SPS). The clock and frequency biases for a particular satellite will appear the same to all users since these parameters are unaffected by signal propagation or distance from the satellite. The pseudorange and deltarange (Doppler) measurements will be different for different users, because they will be at different locations and have different relative velocities with respect to the satellite, but the satellite clock and frequency bias will be common error components of those measurements. The signal propagation delay is truly a common error for receivers in the same location, but as the distance between receivers increases, this error gradually decorrelates and becomes independent. The satellite ephemeris has errors in all three dimensions. Therefore, part of the error will appear as a common range error and part will remain a residual ephemeris error. The residual portion is normally small and its impact remains small for similar observation angles to the satellite. The Radio Technical developed the accepted standard for SPS DGPS Commission for Maritime Services (RTCM) Special Committee-104 (SC-104). The RTCM developed standards for the use of differential corrections, and defined the data format to be used between the reference station and the user. The standards are primarily intended for real time operational use and cover a wide range of DGPS measurement types. Most SPS DGPS receivers are compatible with the RTCM SC-104 differential message formats. DGPS standards have also been developed by the Radio Technical Commission for Aeronautics (RTCA) for special Category I precision approach using ranging-code differential. The standards are contained in RTCA document DO-217. This document is intended only for limited use until an international standard can be developed for precision approach.

DGPS Implementation Types

There are two primary variations of the differential measurements and equations. One is based on ranging-code measurements and the other based on carrier-phase measurements. There are also several ways to implement the data link function. DGPS systems can be designed to serve a limited area from a single reference station, or can use a network of reference stations and special algorithms to extend the validity of the DGPS technique over a wide area. The result is that there is a large variety of possible DGPS system implementations using combinations of these design features.

Ranging-Code Differential

The ranging-code differential technique uses the pseudorange measurements of the reference station to calculate pseudorange or position corrections for the user receivers. The reference station calculates pseudorange corrections for each visible satellite by subtracting the "true" range, determined by the surveyed position and the known orbit parameters, from the measured pseudorange. The user receiver then selects the appropriate correction for each satellite that it is tracking, and subtracts the correction from the pseudorange that it has measured. The mobile receiver must only use those satellites for which corrections have been received. If the reference station provides position corrections rather than pseudorange corrections, the corrections are simply determined by subtracting the measured position from the surveyed position. The advantage of using position corrections is obviously the simplicity of the calculations. The disadvantage is that the reference receiver and the user receiver must use the exact same set of satellites. This can be accomplished by coordinating the choice of satellites between the reference receiver and the user receiver, or by having the reference station compute a position correction for each possible combination of satellites. For these reasons, it is usually more flexible and efficient to provide pseudorange corrections rather than position corrections. The RTCM SC-104 and RTCA DO-217 formats are all based on pseudorange rather than position corrections. The pseudorange or position corrections are time tagged with the time that the measurements were taken. In real-time systems, the rate of change of the corrections is also calculated. This allows the user to propagate the corrections to the time that they are actually applied to the user position solution. This reduces the impact of data latency on the accuracy of the system but does not eliminate it entirely. SPS corrections become fully uncorrelated with the user measurements after about 2 minutes. Corrections used after two minutes may produce solutions, which are less accurate than stand-alone SPS GPS. PPS corrections can remain correlated with the user measurements for 10 minutes or more under benign (slowly changing) ionospheric conditions.

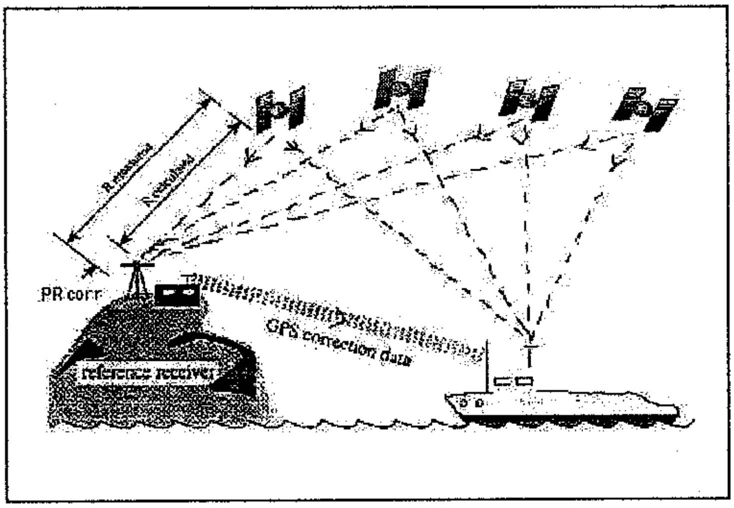

Figure 5: Ranging-Code Differential

Carrier-Phase Differential

The carrier-phase measurement technique uses the difference between the carrier phases measured at the reference receiver and user receiver. A double-differencing technique is used to remove the satellite and receiver clock errors. The first difference is the difference between the phase measurements at the user receiver and the reference receiver for a single satellite. This eliminates the satellite clock error, which is common to both measurements. This process is then repeated for a second satellite. A second difference is then formed by subtracting the first difference for the first satellite from the first difference for the second satellite. This eliminates both receiver clock errors, which are common to the first difference equations. This process is repeated for two other pairs of satellites resulting in three double-differenced measurements that can be solved for the difference between the reference station and user receiver locations. This is inherently a relative positioning technique; therefore the user receiver must know the reference station location to determine its absolute position. This same technique can be used to determine the attitude of a vehicle or platform. In this case the processing can be contained within one receiver using multiple fixed antennas. One antenna can be arbitrarily chosen as the "reference". Since fixed distances separate the antennas and since their relationship to the center-of-mass of the platform is known, it is possible to convert the carrier phase differences into angular differences between the antenna locations and the line-of-sight to a satellite. By using measurements from multiple satellites, or the position of the platform from a DGPS position fix, these angular differences can be transformed to represent the attitude of the platform with respect to the local vertical axis. The "raw" phase measurements are essentially a count of the number of carrier cycles between the satellite and receiver positions. The number of cycles times the carrier wavelength is a range measurement. The receivers can directly measure the fractional portion of the phase measurement and can track phase shifts including whole cycles, but they must calculate the initial whole number of cycles between the receiver and the satellite. This is referred to as the integer cycle ambiguity. For surveying applications, this integer ambiguity can be resolved by starting with the mobile receiver antenna within a wavelength of the reference receiver antenna. Both receivers start with the same integer ambiguity, so the difference is zero and drops out of the double-difference equations. Thereafter, the phase shift that the mobile receiver observes (whole cycles) is the integer phase difference between the two receivers. For other applications where it is not practical to bring the reference and mobile antennas together, the reference and mobile receivers can solve for the ambiguities independently as part of an initialization process. One way is to place the mobile receiver at a surveyed location. In this case the initial difference is not necessarily zero but it is an easily calculated value.

For some applications (such as aircraft precision approach), it is essential to be able to solve for the integer ambiguity at an unknown location or while in motion (or both). In this case, solving for the integer ambiguity usually consists of eliminating incorrect solutions until the correct solution is found. A good initial estimate of position (such as from ranging-code differential) helps to keep the initial number of candidate solutions small. Redundant measurements over time and/or from extra satellite signals are used to isolate the correct solution. These "search" techniques can take as little as a few seconds or up to several minutes to perform and can require significant computer processing power. This version of the carrier-phase DGPS technique is typically called kinematic differential GPS. If carrier track or phase lock on a satellite is interrupted and the integer count is lost, then the initialization process must be repeated for that satellite (known as cycle clip). Output data flow may also be interrupted if the receiver is not collecting redundant measurements from extra satellites to maintain the position solution. If a precise position solution is maintained, reinitialization for the "lost" satellite can be almost immediate. Developing a robust and rapid method of initialization and reinitialization is the primary challenge facing designers of real-time systems that have a safety critical application such as aircraft precision approach.

Real Time-Kinematic (RTK)

According to the author, RTK is another technique, which based on measuring distances to the satellites with carrier phase. Another analogy of carrier phase is that it is like a measuring tape that has meter-marks and millimeter-marks. But with this measuring tape, the meter-mark numbers do not appear instantly when we lock to satellites. We have to wait for the meter-mark numbers to appear and become clear (like a Polaroid picture) to be able to measure the distances. This is the time that we have to wait to determine the "initial unknown integers". The more we wait the meter-mark numbers become more clear (like a Polaroid picture). When meter-mark numbers become clear they remain clear and we can make instantaneous accurate measurements repeatedly until we lose lock to satellites in which case the meter-marks disappear again. When this happens, we have to wait for them to re-appear after we re-lock to satellites.

If you maintain tracking of at least five satellites, you can re-lock to satellites quickly and resolve their integer number immediately. When satellite interruptions are very brief, receiver may be able to continue based on the integer estimation that it had before.

Estimating the integer numbers incorrectly, or having cycle slips, is like reading the wrong number on the meter-mark. You can imagine examples when you measure something to be 3.874 meter while it actually was 4.874 meter. You read the millimeter-marks very accurately but misread the meter-mark number.

After the receiver resolves the ambiguities correctly, the accuracy of each position computation is between 0.5 to 2 cm horizontal and 1 to 3 cm vertical (depending on antenna multipath rejection capability) plus 1 ppm for double frequency and 2 ppm for single frequency. All RTK accuracy specifications from all manufacturers are within this range. They are all based on the assumption that the integers are estimated correctly.

Resolving the integers correctly is the key in RTK. The big question here is how long it will take to resolve the integers reliably after satellites are locked. If they are resolved incorrectly, it is like reading the meter-number wrong but continue to concentrate on reading the millimeter marks.

Dead Reckoning (DR) Method

Dead reckoning method determine a vehicle's position relative to an initial location by integrating measured distance increments and directions of travel (Hong, 1997). The distance increments are measured using a distance sensor. The directions can be derived through a course sensor. When the GPS signals are degraded, the position of a vehicle at ti epoch can be determined from the direction angle (α) and distance (D) components:

$$X_i = X_0 + \sum_{k=0}^{i-1} D_k \cos \alpha_k \qquad (1)$$

$$Y_i = Y_0 + \sum_{k=0}^{i-1} D_k \sin \alpha_k \qquad (2)$$

Figure 6: Dead Reckoning Method

(X_o, Y_o) the initial position at t_o

(Xi, Yi) the position at t_i

D_k, α_k distance and direction from (X_0, Y_0) at t_0 to (X_k, Y_k) at t_k epoch respectively.

The course sensor could be derived from geomagnetism, gyroscope or using information from the difference between the velocity of the left tyre and right tyre. The distance sensor may be tapped from the vehicle's odometer or from a velocity sensor. The navigation accuracy of DR is a function of the distance traveled. Longer distances tend to incur greater accumulated errors. Errors of DR are mainly caused by characteristics of the sensors and from environmental factors such as terrain and uneven tyre pressures.

Hence, DR per sec cannot be used over a long period. Navigation system which combines measurements from both DR and GPS system can mitigate the errors by continuously calibrating DR sensors by acquired GPS positions Another mode of DR system is INS (Inertial Navigation System) which can continuously provide direction and acceleration (Yuan, et al., 1993). Starting from a known position, INS uses the variations in positions to determine the trail of a vehicle. Errors of INS increase with the square of time. Hence, INS alone has its limitations. However, a combined GPS and INS solution could overcome shortcomings of each other and is an effective method for providing continuous and precise navigation for vehicles.

Map Matching Method

The positions of a vehicle determined by GPS/DR or DGPS/DR could be displayed in electronic map. Because errors exist in both positions acquired by GPS/DR and also in digital maps, it is not possible to ensure that the positions of the vehicle register properly on a digital map. The result of this is that a vehicle may be seen to be moving over a building or into the sea. To avoid this phenomenon, map-matching method can be used to improve the displayed precision of vehicle over an electronic map. The principle of map matching method is to ensure that a position is snapped or matched to the nearest street. However, a street network can be quite complicated especially when there are several crossroads. Determination of the correct street is not entirely straightforward. One such algorithm is proposed by Yi et al., (1998).

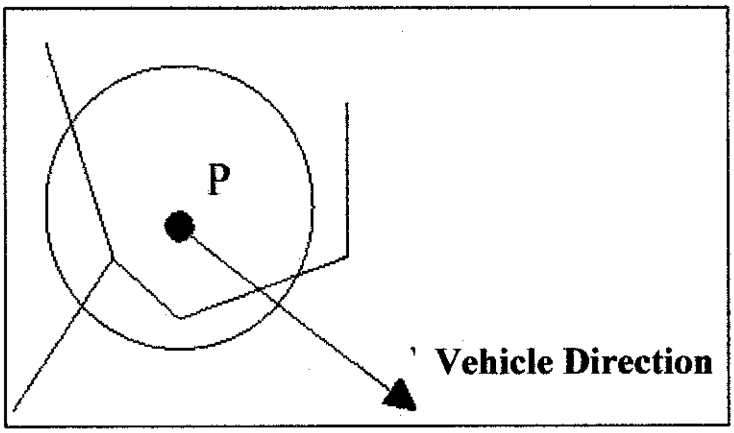

Figure 7: Search Area for Map Matching

Figure 7 presents a section of a network and one point (P (X, Y)) representing a vehicle's position. The position does not register correctly to a street. To find which street it belongs to, a circle with search radius R is drawn. With experience, a suitable value for R will be used. In this area, the objective is to find all streets that satisfy the following condition:

Distance between street and P point is shorter than R.

There exist two possible cases:

1. if vehicle is static, select the street whose D is the shortest;
2. if vehicle is moving, choose the street which has the smallest angle to the direction of vehicle movement.

After determining the street, the next stage is to display the projected point in the electronic map. R could be equal to the width of the widest street. If no street satisfies the search condition, it can be concluded that the vehicle is traveling outside the street and it is not necessary to match it. Furthermore, R may be variable to adapt to different environments.

CHAPTER 3

METHODOLOGY AND PROJECT WORK

3 METHODOLOGY AND PROJECT WORK

3.1 Rapid Application Development (RAD)

Throughout the enhancement of the application, Rapid Application Model (RAD) will be the framework for describing the phases involved in developing and maintaining this system. The RAD model will be used to decrease time needed to design and implement information system radically without sacrificing its quality. For this project, there are pressing reasons for speeding up the portion (accuracy consideration) of the existing application. This model is an object-oriented approach to systems development that includes a method of development as well as software tools. There are four broad phases to RAD:

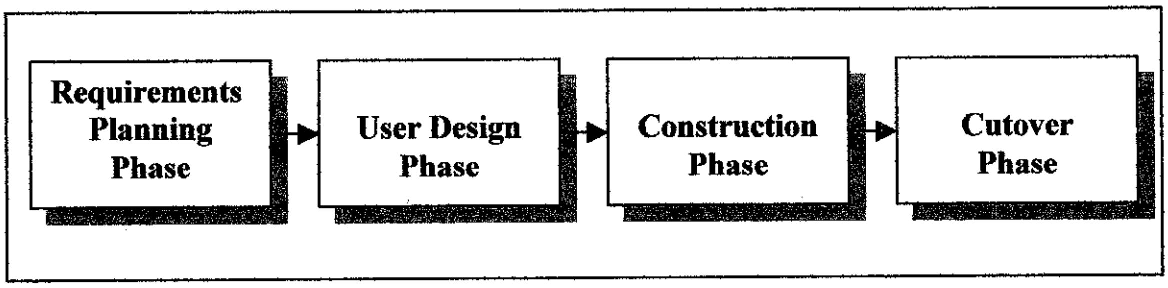

Figure 8: Phases in Rapid Application Development (RAD) Model

3.1.1 Significant of RAD Model

The RAD method has a task list and a work breakdown structure that is designed for speed. However the major difference in RAD is a set of management techniques that are optimized for speed. The Rapid Application Development methodology was developed to respond to the need to deliver systems very fast. The RAD approach is not appropriate to all projects - an air traffic control system based on RAD would not instill much confidence. Project scope, size and circumstances all determine the success of a RAD approach. The following categories indicates suitability for a RAD approach:

Project Scope

This enhanced truck tracking system project has a focused scope where the objectives are well defined and narrow. The enhancement is specifically in term of accuracy in the tracking system.

Project Data

Data for the project already exists (completely or in part). All the data gained from the features and functionalities of the existing prototype. The project largely comprises analysis or reporting of the data.

Project Decisions

Decisions can be made by a small number of people who are available and preferably co-located.

Project Technical Architecture

The technical architecture is defined and clear and the key technology components are in place and tested.

Project Technical Requirements

Technical requirements (response times, throughput, database sizes, etc.) are reasonable and well within the capabilities of the technology being used. In fact targeted performance should be less than 70% of the published limits of the technologies.

3.1.2 RAD Model Phases

Requirements Planning Phase

The first activity in the requirements planning phase is to identify objectives of the application or system and to identify information requirements arising from those objectives. So, for this enhanced system, the first development activity is to acquire requirements on the existing prototype. This stage involves the understanding of the content and nature of the requirements of the existing prototype developed by Miss Lo Tse Yi.

User Design Phase

This phase is a design and refine phase that can be characterized as a workshop. During this phase, the outcomes from the requirements planning phase; scope, objectives, data models and reports will be reviewed. During this analysis, the author should define and determine the functionality to be represented and added in the existing prototype. This functionality should focus upon the requirements that are unclear or fuzzy. It is undesirable and costly to prototype requirements that are fully understood. Besides determining its functionalities, this stage involved the improvisation of the existing prototype design. To construct and improvise the prototype, a suitable implementation approach must be used. This approach must offer features, which satisfy the general requirements of prototyping, such as rapidity and ease of modification. Obviously, an approach, which relies upon a complex and lengthy development cycle, is unsuitable. It can be argued that Microsoft's Visual Basic possesses many features, which the author can use to facilitate an effective prototyping process.

Construction Phase

During this phase, in the 'purest' form of RAD, detailed design is done using a design tool, and the design is 'translated' into code via a code generator.
Adjustments and enhancements of the system will be designed and tested during construction. It is desirable that any prototype construction activities be performed as quickly as possible. User interface construction using Visual Basic is indeed rapid, and has been simplified by the use of the 'drag-and-drop' style of interactive editing. User interface components, such as buttons and text-boxes, are placed upon a Visual Basic form and are then connected to appropriate functionality. The existing prototype is not that accurate in tracking the truck, so the enhancement in terms of its accuracy may seem useful and more effective.

Cutover

In this phase, conversion data and system will be developed. Besides that, fully test system will be conducted in terms of unit, system, and volume. Final documentation needs to be prepared during this phase. Technical people may be required for installation and acceptance testing.

3.2 RAD Model (Rapid Application Development)

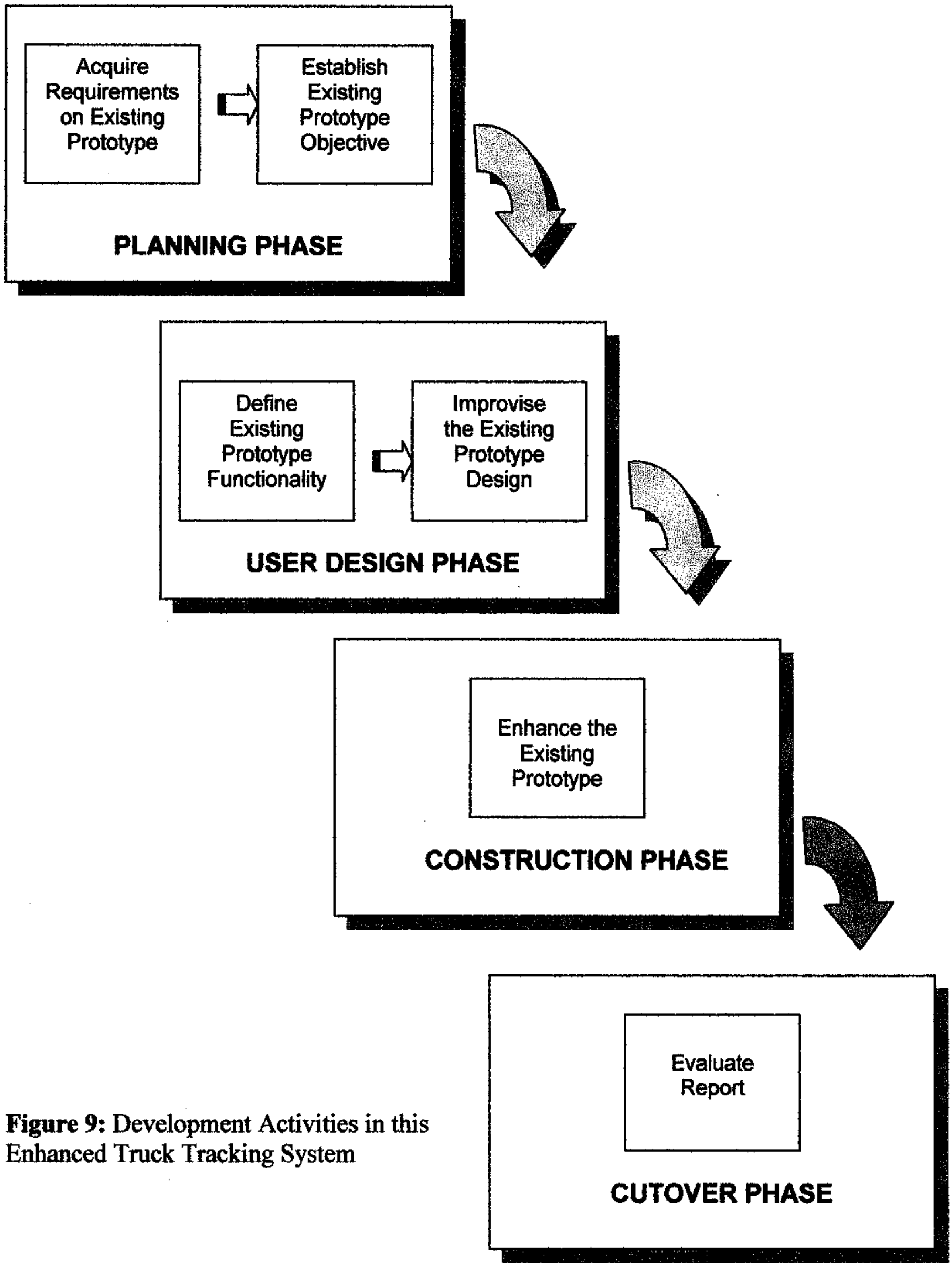

Figure 9: Development Activities in this Enhanced Truck Tracking System

3.3 Tools Required

This project is an enhanced version of existing vehicle tracking application in terms of its positioning accuracy. So, all the tools required in the development process of the existing application will be used in the enhancement process. Microsoft Visual Basic 6.0 is the platform for the prototype development and design purpose. As this is a GIS system, the application requires GIS packages, MapObjects v2.2 and ESRI's Arc View 3.2.

It has being finalized that in enhancing the existing prototype, MapObjects v2.2 will remain as the main tool. It is a powerful collection of embeddable mapping and GIS components. Some of the functionalities include providing dynamic live maps, generate spatial queries, display data using classifications, graduated symbols, label, pan and zoom through multiple map layers and get information on map features.

MapObjects, which is suitable to use to enhance existing application, build lightweight data viewing applications, or create new mapping and GIS programs that solve specific tasks. For this project, MapObjects v2.2 component is being integrated with Visual Basic helps in the development work.

CHAPTER 4

RESULTS AND DISCUSSION

4 RESULTS AND DISCUSSION

This chapter reports the product details and findings, which supports the project work. The main finding that is being highlighted is the area of enhancement from the existing prototype. There are also additional and relevant information obtained from journals and online resources.

4.1 Area of Enhancement

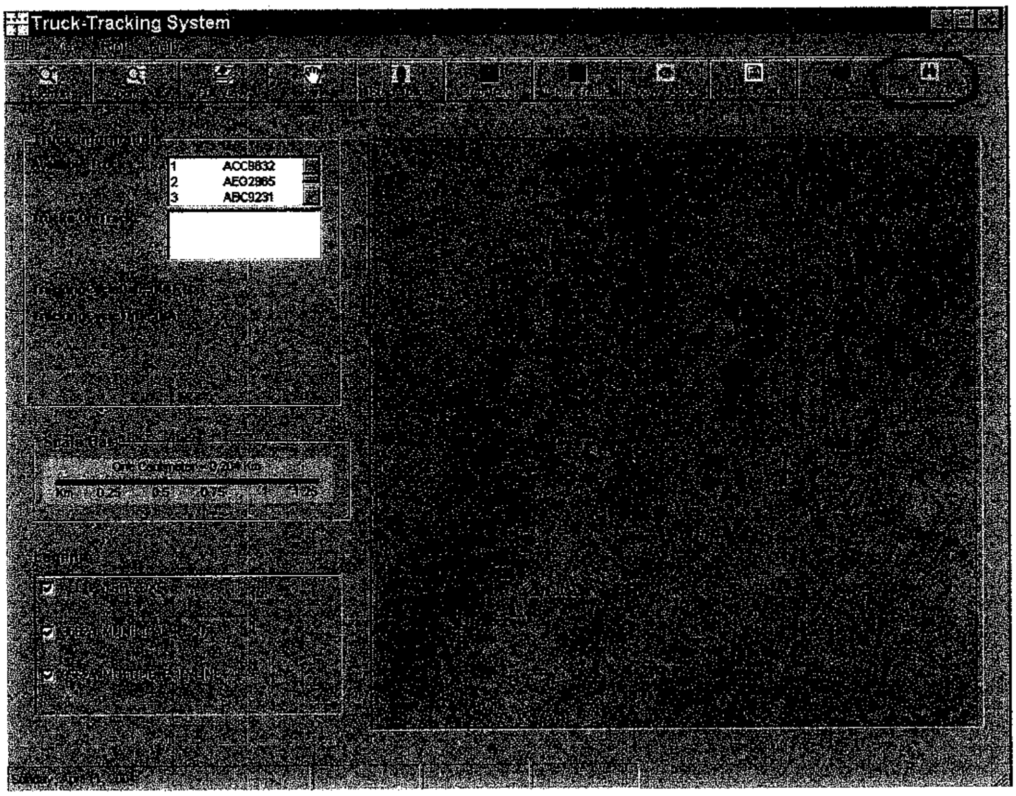

Figure 10: Existing Prototype User Interface

Figure 10 displays the main user interface for the existing prototype developed by Miss Lo Tse Yi. It consists of ten toolbar buttons at the top part of the screen, as to lead the users on where to find the buttons to carry out their job and which button is related for a particular task.

4.2 Dynamic Zooming

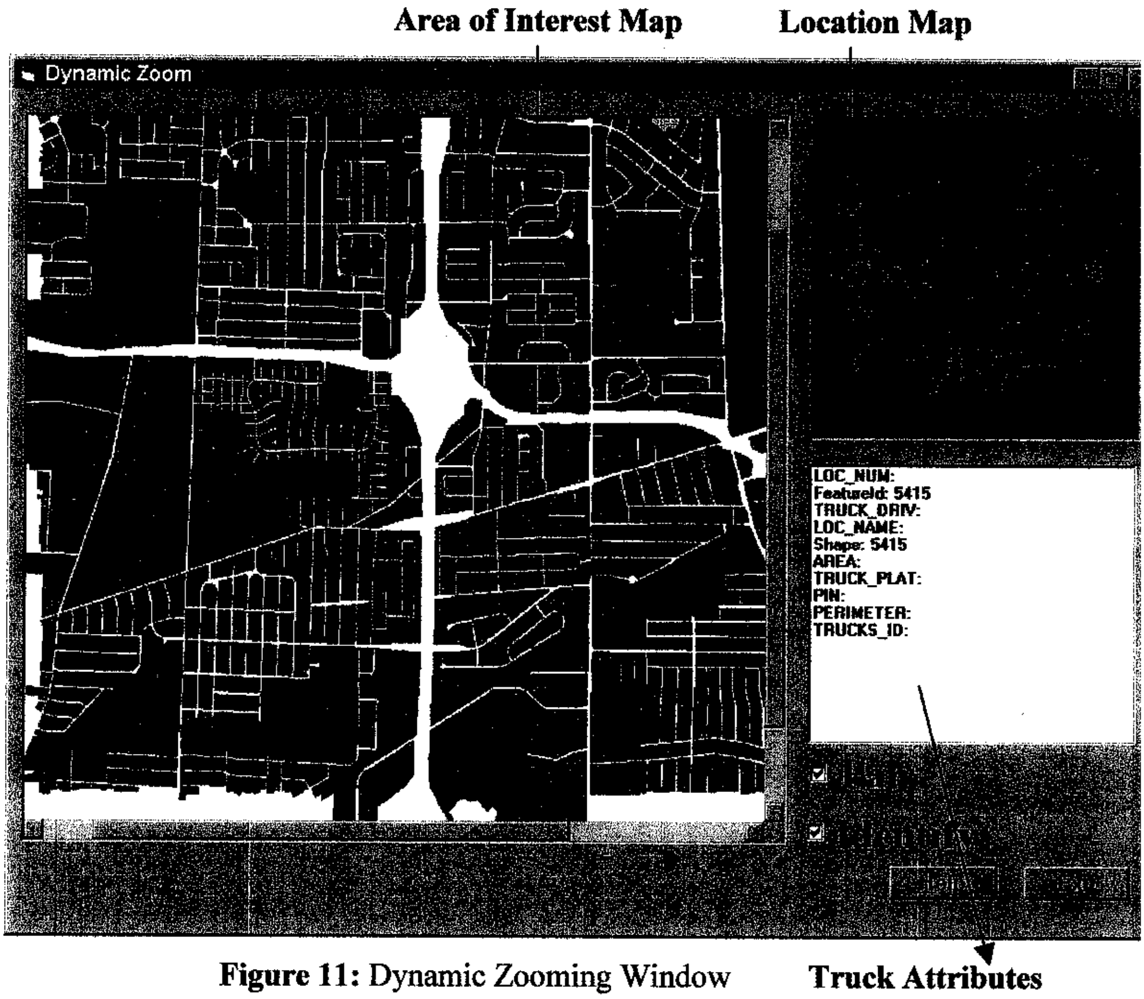

Figure 11: Dynamic Zooming Window

As shown in Figure 10, a new button/feature has being added into the interface of the existing prototype, which is called Dynamic Zoom. For the purpose of accuracy, the author will add the zoom features and capabilities, certain defined scale section, 360-degree rotational views, bearing identification and graphic user interface.

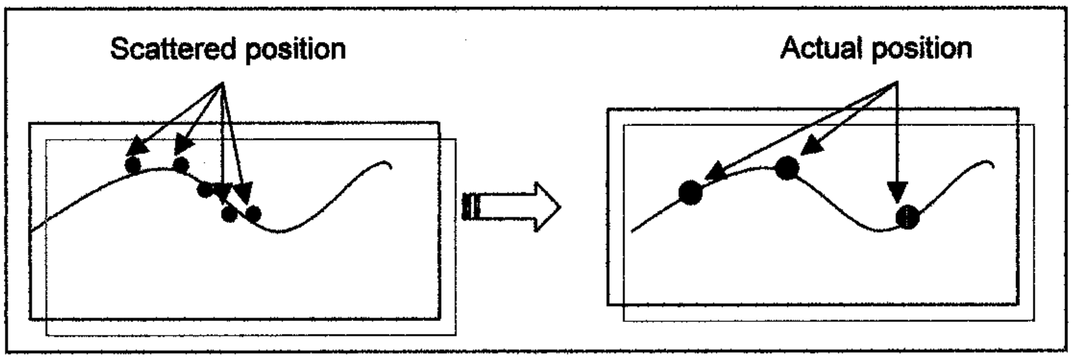

Figure 12: Zooming Features

This application, built in VB using MapObjects, allows the user to zoom in, zoom out, pan and at the same time accurately track and identify the location of the truck. The pan is a 'dynamic pan'; just push the mouse in the direction you would like to pan.

The application also shows scale dependent display and attribute retrieval. As shown in Figure 8, the user is presented with a form, which has 2 map controls, the larger one is the Area of Interest Map and the other is a Location Map. Other controls include a list box for attribute display, checkboxes for pan control and buttons for help and exit.

Zoom in by pressing the left mouse button anywhere in the Area of Interest Map. Zoom out by pressing the right mouse button anywhere in the Area of Interest Map. More detailed data will be displayed as zoom in, less detailed data as zoom out.

Panning is toggled on/off by either clicking the 'Pan' button on the form or pressing 'ALT A' on the keyboard. When 'Pan' is on, mouse cursor will be at the center of the 'Area of Interest' map. Simply push the mouse in the direction preferred to pan.

Truck attribute information (Loc_Num, Loc_Name, Area, Truck_ID, Truck_Driver, Truck_Plat) can be retrieved from the database by pressing the 'Identify' checkbox or pressing 'Alt D' while the cursor is anywhere in the 'Area of Interest Map'. Data will be displayed in the List Box below the Location Map. This option is available only when the trucks are detected on the map and the 'Pan' option is checked on. Notice that the information changes as you pan from one truck to another.

Simple instructions can be displayed by pressing the `Help' button. Exit the demo by pressing the `Exit' button.

4.3 Significant Interaction between Accuracy and Zooming Effect

Baecker and Small state that the outline zoom that accompanies the opening (and closing) of an icon orients the user to the location and origin of the new window that appears on the desktop. This is particularly helpful in a crowded environment. If the new window were to appear without the opening zoom, it would be more difficult for the user to determine that he had indeed opened the correct icon. The closing zoom assists in informing the user where he was working before he started the process that has just been completed. This type of animation is already in widespread use on the Macintosh, perhaps because of its relative ease of implementation and uncontroversial nature." (Baecker and Small, 1990, p.259)

As a measure of the accuracy of memory for location, we calculated the distance in ordinal location from the first folder opened after the subject had seen a match, to the folder, which actually contained the matching file. Hence, the minimum value of this statistic, given that a subject has perfect memory for location, is zero. If the subject selected a folder adjacent to the correct folder, than this statistic will be scored a one. It should be noted that this is not a direct spatial measure but an ordinal one.

Table 1. Ordinal distance to first response

	Zoom Enabled	Zoom Disabled
Mean	1.67	1.41
Standard Deviation	2.74	2.01

The difference is not in the hypothesized direction, but it is not significant ($F(1) = 0.32$, $p = 0.575$).

Post-trial memory

Users were given a sheet with the names of all the files, and were asked to write the numbers of the folder in which the files were located. We calculated the ordinal distance (as above) from reported location to the actual location of the folder visited immediately after the subject visited the first of the matching pair of folders.

Table 2. Ordinal distance error from first folder visited after match

	Zoom Enabled	Zoom Disabled
Mean	3.925	5.20
Standard Deviation	5.423	5.95

Subjects more accurately reported the location of the folder when zooming was enabled. Although not significant statistically ($F(1) = 1.51$, $p = 0.229$), the difference is in the hypothesized direction, indicating that subjects might have more accurate memory for location in the zooming condition.

An experiment was conducted to measure the effect of the zooming speed in a zoomable interface. The independent variable was the zooming speed. The dependent variables were performance time, retention accuracy and subjective preference.

The experiment hypothesized that there would exist a zooming speed at which the performance time is shortest. It also hypothesized that retention accuracy would improve as zooming speed decreased. The third hypothesis was that subjects would prefer the zooming speed at which the performance time was shortest.

In different point of view, Kenneth E. Foote and Donald J. Huebner warns to beware of the dangers of false accuracy and false precision, that is reading locational information from map to levels of accuracy and precision beyond which they were created. This is a very great danger in computer systems that allow users to pan and zoom at will to an infinite number of scales. Accuracy and precision are tied to the original map scale and do not change even if the user zooms in and out. Zooming in and out can however mislead the user into believing--falsely--that the accuracy and precision have improved.

Referring back to the real objective of this system, which is to improve and enhance the accuracy in the tracking system, it is relevant to have this dynamic zooming feature in the existing prototype, as this will assists in informing the user where the accurate location of the truck. This will be clearly shown in the list box, where all the truck attributes (location ID, location name, area, truck ID, truck driver and truck plat number) will be displayed.

According to what is being said by Baecker and Small, this new dynamic feature will particularly helpful in a crowded environment where it is quite difficult to track the truck in the main window as it is congested with other functions. But with the new dynamic zooming window, it is easy to pan and identify the location of a particular truck. So the location of the truck will be more accurately tracked.

CHAPTER 5

CONCLUSION

5 CONCLUSION

Geographic Information Systems permit a wide range of operations to be applied to spatial data in the production of both tabular and graphic output products. Too frequently, however, these operations are applied with little regard for the types and levels of error that may result. In numerous published articles detailing GIS applications, a critical examination of error sources is conspicuously absent and output products are presented without an associated estimate of their reliability. Unfortunately, in most cases these omissions do not imply that errors are of a sufficiently low magnitude that they may safely be ignored. Moreover, the fact that input data are themselves of relatively high quality is no guarantee that output products will be error-free.

GPS can be a powerful tool to assist researchers accurately locates features of interest to their study. However it is important to remember it is like any other research tool, with its own set of limitations. There are many factors that influence Global Positioning System accuracy, which may affect the quality of a GIS dataset. Some are quite obvious, but others can be difficult to discern. Few of these will be automatically identified by the GIS itself. It is the user's responsibility to prevent them. Particular care should be devoted to checking for errors because GIS are quite capable of lulling the user into a false sense of accuracy and precision unwarranted by the data available. Through this research, some of the sources of inaccuracy and imprecision have been identified. It consists GPS errors, error in digital GIS, and few other problems in GPS.

Although there are several approaches to improve position accuracy, differential correction (DGPS) is common to most of them. Differential correction can remove most of the effects of S/A and other common sources of error in GPS computed positions. It is the most consistent and effective means of improving position accuracy.

There are many reasons for performing an accuracy assessment in this project. Perhaps the simplest reason is curiosity – the desire to know how good something is. In addition to the satisfaction gained from this knowledge is to increase the quality of the existing vehicle-tracking prototype by identifying and correcting the sources of errors.

The additional feature, dynamic zooming is effective and relevant to the existing prototype in improving its accuracy in tracking the truck in the map. This enhanced system will be able to assist in informing the user where the accurate location of the truck.

For future enhancement, applying all the relevant algorithms such as Kalman filter solution algorithms or dead reckoning methods may further enhance and improve the accuracy aspect in this system. Due to time constraint, the author was unable to apply the algorithm in the system. In other words, it is the time that limits the author to integrate the algorithm throughout the system. Based on the research it shows that algorithms play an important role in error/bias propagation into GPS positioning results

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11 Singh A. K., Sikdar P. K. and Dhingra S. L., **"Geographic Information System: Information Technology for Planning and Management of Transport Infrastructure in Next Millennium, 59th Annual Session of the Indian Roads Congress"**, Hyderabad, 1999.

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13 Michael Chui, Andrew Dillon, **"Who's Zooming Whom? Attunement to Animation in the Interface"**

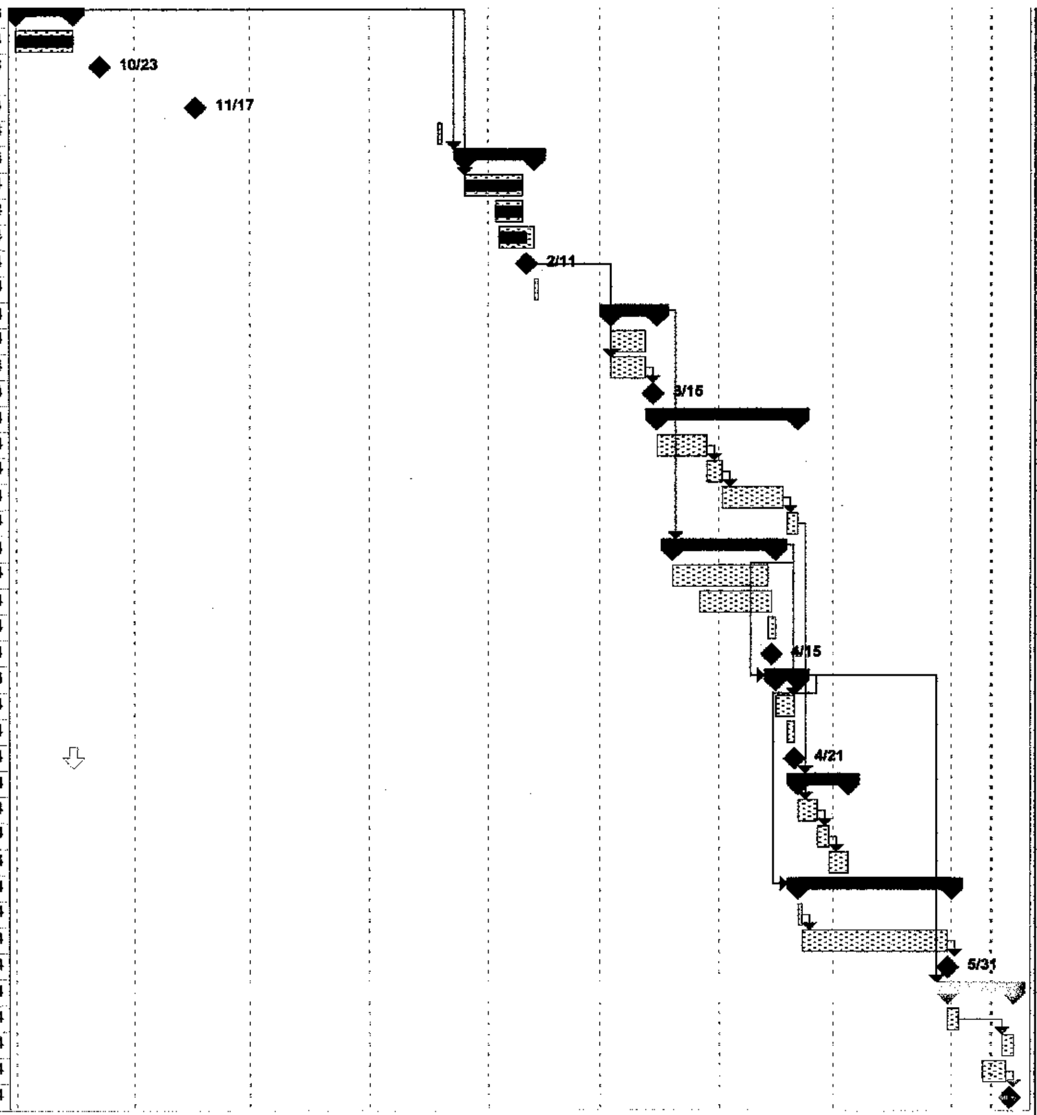
14 Huo Guo, Vivian Zhang, Jing Wu, **"The Effect of Zooming Speed in a Zoomable User Interface"**

15 Baecker R. & Small, **"The Art of Human-Computer Interface Design"**, 1990

APPENDICES

APPENDIX 1: FINAL YEAR PROJECT GANTT CHART

1	**1 Selection of Project Topic**	**13 days**	**Wed 10/1/03**	**Wed 10/15/03**
2	1.1 Consult Lecturers on interested areas	13 days	Wed 10/1/03	Wed 10/15/03
3	**2 Form 01 and 02 Submission (To FYP Coordinator)**	1 day	Thu 10/23/03	Thu 10/23/03
4	**3 Approval of Topic**	1 day	Mon 11/17/03	Mon 11/17/03
5	4 Form 03 Submission (To FYP Coordinator)	1 day	Mon 1/19/04	Mon 1/19/04
6	**5 Preliminary Information Gathering**	**16 days**	**Mon 1/26/04**	**Thu 2/12/04**
7	5.1 Information Gathering through Reference Books	13 days	Mon 1/26/04	Mon 2/9/04
8	5.2 Scope Definition	6 days	Tue 2/3/04	Mon 2/9/04
9	5.3 Requirement Specification	8 days	Wed 2/4/04	Thu 2/12/04
10	6 Submission of Requisition Form	3 days	Wed 2/11/04	Fri 2/13/04
11	7 Submission of Preliminary Report	1 day	Fri 2/13/04	Fri 2/13/04
12	**8 Progress Report**	**10 days**	**Thu 3/4/04**	**Mon 3/15/04**
13	8.1 Information Gathering for Progress Report	8 days	Thu 3/4/04	Fri 3/12/04
14	8.2 Progress Report Writing	8 days	Thu 3/4/04	Fri 3/12/04
15	8.3 Submission of Progress Report	1 day	Mon 3/15/04	Mon 3/15/04
16	**9 System Enhancement**	**32 days**	**Tue 3/16/04**	**Wed 4/21/04**
17	9.1 Work on 2nd Increment - Application Enhancement	11 days	Tue 3/16/04	Sun 3/28/04
18	9.2 User Approval	4 days	Mon 3/29/04	Thu 4/1/04
19	9.3 Work on 3rd Increment - Prototype Improvisation	14 days	Fri 4/2/04	Sat 4/17/04
20	9.4 User Approval	3 days	Mon 4/19/04	Wed 4/21/04
21	**10 Final Draft to Respective Supervisor and FYP Committee**	**23 days**	**Sat 3/20/04**	**Thu 4/15/04**
22	10.1 Information Gathering for Final Draft Report	21 days	Sat 3/20/04	Tue 4/13/04
23	10.2 Final Draft Writing	16 days	Sat 3/27/04	Wed 4/14/04
24	10.3 Printing and Compilation	2 days	Wed 4/14/04	Thu 4/15/04
25	10.4 Submission of Final Draft	1 day	Thu 4/15/04	Thu 4/15/04
26	**11 Final Draft to Supervisor and External Examiner**	**5 days**	**Fri 4/16/04**	**Wed 4/21/04**
27	11.1 Final Draft Amendments	4 days	Fri 4/16/04	Tue 4/20/04
28	11.2 Printing and Compilation	2 days	Mon 4/19/04	Tue 4/20/04
29	11.3 Submission of Final Draft	1 day	Wed 4/21/04	Wed 4/21/04
30	**12 System Testing**	**11 days**	**Thu 4/22/04**	**Tue 5/4/04**
31	12.1 System Integration and Testing	4 days	Thu 4/22/04	Mon 4/26/04
32	12.2 User Approval	3 days	Tue 4/27/04	Thu 4/29/04
33	12.3 Documentation	4 days	Fri 4/30/04	Tue 5/4/04
34	**13 IT IS Exhibition/Oral Presentation**	**34 days**	**Thu 4/22/04**	**Mon 5/31/04**
35	13.1 IT IS Exhibition	1 day	Thu 4/22/04	Thu 4/22/04
36	13.2 Preparation for Oral Presentation	32 days	Fri 4/23/04	Sun 5/30/04
37	13.3 Presentation Day	1 day	Mon 5/31/04	Mon 5/31/04
38	**14 Project Dissertation**	**15 days**	**Mon 5/31/04**	**Wed 6/16/04**
39	14.1 Dissertation Amendments	3 days	Mon 5/31/04	Wed 6/2/04
40	14.2 Seek of Supervisor's Official Approval on the Dissertation	3 days	Mon 6/14/04	Wed 6/16/04
41	14.3 Printing and Compilation	5 days	Wed 6/9/04	Mon 6/14/04
42	14.4 Submission of Hard Cover Copies of Report	1 day	Wed 6/16/04	Wed 6/16/04



Project: IT Final Year Project

Task · Progress · Summary · External Tasks · Deadline
Split · Milestone · Project Summary · External Milestone

Juhaida Ismail Information Technology

```
' APPENDIX 2: VISUAL BASIC SOURCE CODE
' ===========================================================
' Project
' ===========================================================
' Name        : Juhaida Ismail 1724
' Program     : Information Technology
' Supervisor  : Mr Helmi Md Rais
' Latest Date : 16 JUNE 2004
' Version     : 6.0.1
' ===========================================================

Option Explicit

Dim gZoomingIn As Boolean
Dim gZoomingOut As Boolean

Dim gSym As New Symbol
Dim gLineSym As New Symbol


Dim gFeedback As DragFeedback

Dim gCursor As New MapObjects2.Line

Dim gLastFID As Long

Private Declare Function SetCursorPos Lib "user32" (ByVal x As Long, ByVal y As
Long) As Long
```

```
Private Declare Function ClientToScreen Lib "user32" (ByVal hwnd As Long, lpPoint
As POINTAPI) As Long
Private Declare Function ShowCursor Lib "user32" (ByVal bShow As Long) As Long

Private Type POINTAPI
    x As Long
    y As Long
End Type

Private Sub CenterCursorOnMap()
  Dim pt As POINTAPI
  pt.x = ScaleX(Map1.width / 2, vbTwips, vbPixels)
  pt.y = ScaleY(Map1.Height / 2, vbTwips, vbPixels)
  ClientToScreen Map1.hwnd, pt
  SetCursorPos pt.x, pt.y
End Sub

Private Sub DoIdentify()
  Dim lyr As MapLayer
  Set lyr = Map1.Layers("lots")
  If Not lyr.Visible Then
    List1.Clear
    Exit Sub
  End If

  Dim rex As MapObjects2.Recordset
  Set rex = lyr.SearchShape(Map1.Extent.Center, moPointInPolygon, "")
  If rex.EOF Then
    List1.Clear
    Exit Sub
  End If
```

```
 If rex("trucks_id").Value = gLastFID Then Exit Sub

 List1.Clear

 Dim fld As MapObjects2.Field
 For Each fld In rex.Fields
  List1.AddItem fld.Name & ": " & fld.ValueAsString
 Next fld
End Sub

Private Sub LoadData()
 Dim dc As New MapObjects2.DataConnection
 dc.Database = App.Path & "\Data"
 If Not dc.Connect Then
  MsgBox "Data not found."
  End
 End If

 Dim lyr As New MapLayer
 Set lyr.GeoDataset = dc.FindGeoDataset("lots")
 Set lyr.Renderer = CreateTruckRenderer
 lyr.Symbol.Color = moNavy
 Map1.Layers.Add lyr
 lyr.Visible = True

 'Set lyr = New MapLayer
 'Set lyr.GeoDataset = dc.FindGeoDataset("lots")
 'lyr.Symbol.Color = moGreen
 'Map1.Layers.Add lyr
 'lyr.Visible = False
```

```
 'Set lyr = New MapLayer
 'Set lyr.GeoDataset = dc.FindGeoDataset("bldg")
 'lyr.Symbol.Color = moLightYellow
 'Map1.Layers.Add lyr
 'lyr.Visible = False

 'Set lyr = New MapLayer
 'Set lyr.GeoDataset = dc.FindGeoDataset("clines")
 'lyr.Symbol.Color = moLightGray
 'Map2.Layers.Add lyr
End Sub


Private Sub Check1_Click()
 If Check1.Value = 1 Then
  ShowCursor False
  CenterCursorOnMap
 Else
  ShowCursor True
 End If
End Sub


Private Sub Command1_Click()
 'Load frmHelpDZ
 frmHelpDZ.Show
End Sub
```

```
Private Sub Command2_Click()
 End
End Sub

Private Sub Form_Load()
 LoadData
ShowCursor True
 Dim r As Rectangle
 Set r = Map1.FullExtent
 r.ScaleRectangle 1.1
 Map1.FullExtent = r
 Map1.Extent = r

 Map2.FullExtent = r
 Map2.Extent = r

 gZoomingIn = False
 gZoomingOut = False

 gSym.OutlineColor = moRed
 gSym.Style = moTransparentFill

 gLineSym.SymbolType = moLineSymbol
 gLineSym.Color = moBlack
 gLineSym.Size = 3

 ' initialize the g_cursor with two points
 Dim p As New MapObjects2.Point
 Dim pts As New MapObjects2.Points
 p.x = 1
 p.y = 1
```

```
pts.Add p
p.x = 1
p.y = 1
pts.Add p
gCursor.Parts.Add pts


Map1.RefreshCount = 1000000

End Sub

Function CreateTruckRenderer() As Object
Dim r As New ClassBreaksRenderer
r.Field = "area"
r.BreakCount = 4
r.Break(0) = 22904.5268346446
r.Break(1) = 96490.0508795875
r.Break(2) = 170075.57492453
r.Break(3) = 243661.098969473

' create a color ramp
r.RampColors moLightYellow, moBlue

Set CreateTruckRenderer = r
End Function


Private Sub Map1_AfterLayerDraw(ByVal index As Integer, ByVal canceled As Boolean, ByVal hDC As OLE_HANDLE)
If index = 0 Then
  ' after drawing the first layer, refresh the locator map
```

```
  Map2.TrackingLayer.Refresh True
  If Check2.Value = 1 Then DoIdentify
 End If
 End Sub

Private Sub Map1_AfterTrackingLayerDraw(ByVal hDC As OLE_HANDLE)
 Dim ctr As MapObjects2.Point, p As New MapObjects2.Point
 Set ctr = Map1.Extent.Center
 Dim pts As MapObjects2.Points
 Dim pt As MapObjects2.Point
 Set pts = gCursor.Parts(0)

 Dim delta As Double
 delta = Map1.ToMapDistance(125)
 p.x = ctr.x - delta
 p.y = ctr.y - delta
 pts.Set 0, p
 p.x = ctr.x + delta
 p.y = ctr.y + delta
 pts.Set 1, p

 Map1.DrawShape gCursor, gLineSym

 p.x = ctr.x - delta
 p.y = ctr.y + delta
 pts.Set 0, p
 p.x = ctr.x + delta
 p.y = ctr.y - delta
 pts.Set 1, p

 Map1.DrawShape gCursor, gLineSym
```

```
End Sub


Private Sub Map1_BeforeLayerDraw(ByVal index As Integer, ByVal hDC As
OLE_HANDLE)
 If index = Map1.Layers.Count - 1 Then
  Dim width As Double
  width = Map1.Extent.width
  Map1.Layers("lots").Visible = width >= 3000
  'Map1.Layers("clines").Visible = width >= 3000
  'Map1.Layers("bldg").Visible = width < 3000
  'Map1.Layers("3562A_MOSQUE_polyline").Visible = width < 1500

 End If
End Sub


Private Sub Map1_MouseDown(Button As Integer, Shift As Integer, x As Single, y As
Single)
 If Button = 1 Then
  gZoomingIn = True
  Timer1.Interval = 50
 ElseIf Button = 2 Then
  gZoomingOut = True
  Timer1.Interval = 50
 Else
  Timer1.Interval = 0
 End If
End Sub
```

```
Private Sub Map1_MouseMove(Button As Integer, Shift As Integer, x As Single, y As
Single)

  If gZoomingIn Or gZoomingOut Or Check1.Value = 0 Then
    Exit Sub
  End If

  Dim jump As Integer, centerX As Single, centerY As Single
  jump = 25
  centerX = Map1.width / 2
  centerY = Map1.Height / 2

  If (Abs(centerX - x) > jump) Or (Abs(centerY - y) > jump) Then

    Dim dX As Double, dY As Double
    dX = Map1.ToMapDistance(x - centerX)
    dY = Map1.ToMapDistance(y - centerY)
    Dim r As Rectangle
    Set r = Map1.Extent
    r.Offset dX, -dY
    Map1.Extent = r

    CenterCursorOnMap
  End If

End Sub

Private Sub Map1_MouseUp(Button As Integer, Shift As Integer, x As Single, y As
Single)
  Timer1.Interval = 0
```

```
  gZoomingIn = False
  gZoomingOut = False
End Sub


Private Sub Map2_AfterTrackingLayerDraw(ByVal hDC As OLE_HANDLE)
  ' draw a rectangle indicating the current extent of Map1
  Map2.DrawShape Map1.Extent, gSym

End Sub

Private Sub Map2_MouseDown(Button As Integer, Shift As Integer, x As Single, y As
Single)
  ' convert to map point
  Dim p As Point
  Set p = Map2.ToMapPoint(x, y)

  ' if the click happened inside the indicator, then start dragging
  If Map1.Extent.IsPointIn(p) Then
    Set gFeedback = New DragFeedback
    gFeedback.DragStart Map1.Extent, Map2, x, y
  End If

End Sub


Private Sub Map2_MouseMove(Button As Integer, Shift As Integer, x As Single, y As
Single)
  If Not gFeedback Is Nothing Then
    Map1.Extent = gFeedback.DragMove(x, y)
  End If
```

```
End Sub


Private Sub Map2_MouseUp(Button As Integer, Shift As Integer, x As Single, y As
Single)
  If Not gFeedback Is Nothing Then
    gFeedback.DragFinish x, y
    Set gFeedback = Nothing
  End If
End Sub


Private Sub Timer1_Timer()
  If Not (gZoomingIn Or gZoomingOut) Then Exit Sub

  Dim r As Rectangle
  Set r = Map1.Extent
  Dim scaleFactor As Double
  scaleFactor = IIf(gZoomingIn, 0.75, 1.25)
  r.ScaleRectangle scaleFactor
  Map1.Extent = r
End Sub
```

```
' APPENDIX 2: VISUAL BASIC SOURCE CODE
'==========================================================================
' Project
'==========================================================================
' Name        : Juhaida Ismail 1724
' Program     : Information Technology
' Supervisor  : Mr Helmi Md Rais
' Latest Date : 16 JUNE 2004
' Version     : 6.0.1
'==========================================================================

' MODULES
Private Declare Function Rectangle Lib "gdi32" (ByVal hDC As Long, ByVal X1 As
Long, ByVal Y1 As Long, ByVal X2 As Long, ByVal Y2 As Long) As Long
Private Declare Function GetDC Lib "user32" (ByVal hwnd As Long) As Long
Private Declare Function ReleaseDC Lib "user32" (ByVal hwnd As Long, ByVal hDC
As Long) As Long
Private Declare Function SetROP2 Lib "gdi32" (ByVal hDC As Long, ByVal
nDrawMode As Long) As Long
Private Const R2_NOTXORPEN = 10

Dim m_map As Object

' variables that keep track of moving the indicator
Dim m_hDC As Long        ' a DC to draw into
Dim m_hWnd As Long       ' window handle
Dim m_xMin As Integer, m_yMin As Integer  ' drag indicator
Dim m_xMax As Integer, m_yMax As Integer  ' drag indicator

Dim m_xPrev As Integer     ' click location
Dim m_yPrev As Integer     ' click location

Function DragFinish(x As Single, y As Single) As Rectangle
  Rectangle m_hDC, m_xMin, m_yMin, m_xMax, m_yMax
  ReleaseDC m_hWnd, m_hDC

  ' return the rectangle
  Dim r As New Rectangle
  PixelsRectToMap m_xMin, m_yMin, m_xMax, m_yMax, r
  Set DragFinish = r
End Function


Function DragMove(x As Single, y As Single) As Rectangle
  ' current position
```

```
  xNext = x / 15 ' convert to pixels
  yNext = y / 15 ' convert to pixels

  Rectangle m_hDC, m_xMin, m_yMin, m_xMax, m_yMax
  m_xMin = m_xMin + (xNext - m_xPrev)
  m_xMax = m_xMax + (xNext - m_xPrev)
  m_yMin = m_yMin + (yNext - m_yPrev)
  m_yMax = m_yMax + (yNext - m_yPrev)

  Rectangle m_hDC, m_xMin, m_yMin, m_xMax, m_yMax
  m_xPrev = xNext
  m_yPrev = yNext


  ' return the rectangle
  Dim r As New Rectangle
  PixelsRectToMap m_xMin, m_yMin, m_xMax, m_yMax, r
  Set DragMove = r
End Function

Sub DragStart(rect As Rectangle, map As Object, x As Single, y As Single)
  Set m_map = map
   ' initialize the hwnd and hdc variables
  m_hWnd = m_map.hwnd
  m_hDC = GetDC(m_hWnd)
  SetROP2 m_hDC, R2_NOTXORPEN   ' raster op for inverting

  MapRectToPixels rect, m_xMin, m_yMin, m_xMax, m_yMax

  ' draw the rectangle
  Rectangle m_hDC, m_xMin, m_yMin, m_xMax, m_yMax

  ' remember the click position
  m_xPrev = x / 15 ' convert to pixels
  m_yPrev = y / 15 ' convert to pixels

End Sub
Private Sub MapRectToPixels(r As Rectangle, xMin As Integer, yMin As Integer,
xMax As Integer, yMax As Integer)
  Dim p As New Point
  Dim xc As Single, yc As Single

  p.x = r.Left
  p.y = r.Top
  m_map.FromMapPoint p, xc, yc
```

```
  xMin = xc / 15  ' convert to pixels
  yMin = yc / 15  ' convert to pixels

  p.x = r.Right
  p.y = r.Bottom
  m_map.FromMapPoint p, xc, yc

  xMax = xc / 15  ' convert to pixels
  yMax = yc / 15  ' convert to pixels

End Sub
Sub PixelsRectToMap(xMin As Integer, yMin As Integer, xMax As Integer, yMax As Integer, r As Rectangle)
  Dim xc As Single, yc As Single

  xc = 15 * xMin ' convert to twips
  yc = 15 * yMin ' convert to twips
  Set p = m_map.ToMapPoint(xc, yc)
  r.Left = p.x
  r.Top = p.y

  xc = 15 * xMax ' convert to twips
  yc = 15 * yMax ' convert to twips
  Set p = m_map.ToMapPoint(xc, yc)
  r.Right = p.x
  r.Bottom = p.y
End Sub
```