INTELLIGENT TRAFFIC ANOMALY DIAGNOSIS THROUGH THE INTEGRATION OF DIVERSE INFORMATION SOURCES

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16. Abstract

While most transportation centers have the capability to collect and access various types of information such as planned and unplanned traffic incidents, and real-time and archived sensor data, many have not integrated this information in a coherent fashion. Information about anomalous highway situations can be collected from a variety of (currently) standalone sources and if integrated, would allow presentation of this data to transportation professionals and the traveling public, thereby enabling real-time and long term planning. The goal of this project was to simulate incoming data as it would be collected by a transportation agency from various sources such as inductive loop detectors, global positioning system devices, human reporters monitoring the system, emergency management personnel, and planned incident reports. In this project, a software prototype was developed that integrates incoming information about the roadway and uses this information in a centralized and intelligent computer algorithm that can provide transportation experts with accurate and timely diagnoses of traffic anomalies.

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SECTION 1.0   INTRODUCTION

While most transportation centers have the capability to collect and access various types of information such as planned and unplanned traffic incidents, as well as real-time and archived sensor data, many have not integrated this information in a coherent fashion. Information about anomalous highway situations can be collected from a variety of (currently) standalone sources and if integrated, would allow presentation of this data to transportation professionals and the traveling public, thereby enabling real-time and long term planning.

This project builds on previous work, and it made use of the results from those efforts. For the overall design, the team worked from the results of the first year URITC project [Peckham, 2001] that were developed through interviews with RIDOT. In the second year project [Peckham, 2002], the team developed software to report real-time traffic speeds using open source technologies [Liu, 2002], and investigated travel time collection and prediction strategies [Cannamela, 2001]. This was replicated and embedded in this project's prototype using commercial software.

Much of the work was predicated on examining the structure of data sources, developing an appropriate software system structure, and integrating various types of software. Data sources for this project included inductive loop detectors, GPS devices, human reporters, emergency management personnel, and planned incident reports. Developing an appropriate software system structure involved detailing the capabilities of various software modules and how they should provide information throughout the system. The integration involved development of an appropriate means of allowing each piece of software to interact with other software to finally demonstrate how data could flow from one location to another interactively.   The items are demonstrated in the following sections in further detail. Section 2 provides the methodology, while Section 3 provides the results. Sections 4 and 5 illustrate the capability of the prototype and conclusions with accompanying recommendations, respectively.

SECTION 2.0   METHODOLOGY

This section describes the efforts involved in the conducting the research effort. Included in this section is discussion about data sources, software system structure, system integration issues, traffic diagnosis algorithm development, as well as prototype development. The overall goal for the project was to simulate incoming data as it would be collected by RIDOT from sources such as GPS, loop detectors, human road watchers, emergency management systems, and planned incident systems. The ultimate outcome was to place the data on a web interface for travelers and transportation experts to access with a prototype for presentation of the data as the desired end product.

2.1   Data Sources

Various data sources such as inductive loop detectors (ILD), GPS devices, human reporters monitoring the system, emergency management personnel, and planned incident reports all provide information about traffic and the transportation system. Because the existing modes for monitoring or reporting about traffic and the transportation system were so diverse, it was important to understand and describe the format of the captured data, as well as the structures needed for data storage and presentation.

From previous work (Cannamela, 2001), information had been gathered about ILD data and GPS data. The information about human reporters, emergency management personnel, and planned incidents still needed to be understood, modeled, and formatted to provide a basis for database queries. Also needed was a procedure for feeding the data into the anomaly diagnosis algorithm. This information was important for the human-by-phone and for the utility and alteration permit processes. The human-by-phone process was designed to permit operators and safety and emergency personnel to enter information about existing or emerging situations that created or would create an anomalous situation in the transportation system. The planned incidents module was devised to replace RIDOT's paper-based process used by companies to apply for permits for highway alterations (inclusive of lane closures or shoulder work).

2.2   Software System Structure and Integration

Creating the software system structure was dependent on identification of the functionality desired in the system for the user and for transportation professionals. For the system user, the desire was to provide access to presentation of traffic performance data on roadways and any planned incidents or anomalies occurring in the system through a web-site. For the transportation professional, we wanted to be able to archive, mine, and give access to data and a presentation of performance historically or in real-time. To work toward this, it was determined that we needed the ability to integrate a database, GIS, and web-based technologies. See Figure 1 for the system architecture.
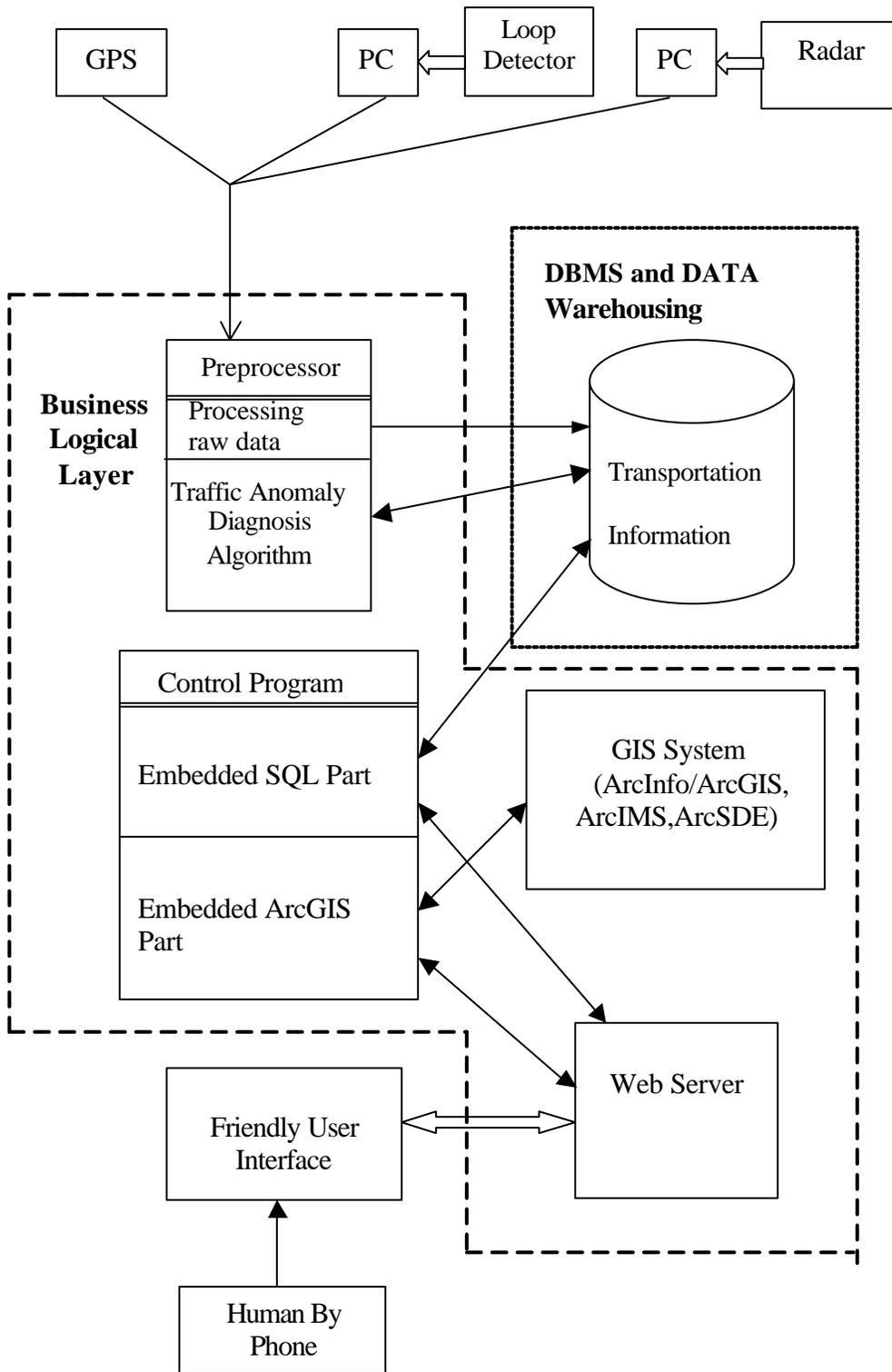
Figure 1. Software System Architecture

To accomplish the goals described in 2.1, various issues needed to be addressed, including the integration of various sources and types of information. This led to the development of an integrated interface and data management system. For example, sometimes the traveler wishes to know the speed of traffic on the highway, or information about unplanned incidents such as accidents at a given time. In this situation, real-time, up to date information is needed. Other times, the transportation system user may simply wish to query the database for information about planned incidents and disruptions of traffic, or get a sense of the historical highway performance at a certain time of day and week. In this case, archived information from various sources is needed. This includes information from sensors as well as the maintenance department, such as where permits for road disruptions are given, for example. This argues for easy access to archived data in different locations and databases. When executing procedures for incident detection, the system needs to access real-time and historical data at the same time. So for example, if a sensor reports slow speeds on a given highway segment, the system must then check the archived data to determine if this is expected due to commute traffic or a planned incident.

In a previous project [Peckham, 2000, & 2002], open source technology was used to implement a web-based interface to portray the flow of traffic on the highways. There were challenges as well as advantages of this technology. The same is true of the commercial technology that was employed for this project. Table 1 outlines the advantages and disadvantages of each.

Table 1. Comparison of Open-Source vs. Commercial Software Tools

	Open Source	**Commercial**
Training students on the technology	Students had access to professionals on the web through user groups. They did need to be trained to interact properly with these resources.	Training was available but too costly for a research project.
Software product support	Widely available on the internet	University had one license and access to support was through one university point of contact. Communication was very slow.
Software functionality	Missing needed functionality; team needed to code.	More robust set of needed functions
Ability to tailor to application	Able to tailor software to needed functionality and to add needed features.	When needed functionality was missing, was very difficult to modify or tailor to application domain.

Another challenging issue arose due to the type of application. The goal was to integrate GIS, database and web technologies. This meant that servers running these three different types of applications needed to cooperate to manage the data and to produce the results to the interface. This meant that the implementers had to work with different types of systems and a set of different servers. For example, the web interface needed to present data from the database in a spatially-oriented means (that is, a map on the interface) using the GIS system. The commercial software was more robust than it had been in earlier years. Now, there are software modules that can enable the systems to cooperate, but it was somewhat new technology at the time of the project. Since the project could not afford direct support from the company, and since the development team had to interact with the company through one point of contact at the university, this was a time-consuming process.

2.3   Traffic Anomaly Issues

To diagnose a traffic flow anomaly, it is essential to know the typical characteristics of the transportation system with respect to time and space. The time issue is important, since there are times of day when traffic volumes and lane occupancy are high and indicate traffic operations near or at capacity. This is not an anomaly; it is just a typical case for a certain time of day on a specific segment of the roadway system. Also, a system may be characterized as being at or near capacity when traffic volumes are high and when operating speeds are dramatically lower than the free-flow speed for a particular segment of roadway.

In the effort to present traffic conditions and to work toward understanding of the anomaly, it was important to gain a better understanding of the base data for segments along I-95, since the performance on this roadway was of interest. In earlier work (Peckham, Hunter, DiPippo, & Hervé, 2002), data were presented about volume, speed, and travel time along segments of I-95 in Rhode Island.

Without access to real-time data, it was decided to simulate the type of incoming data from an inductive loop sensor. The simulated data were produced using a random number generator along with multipliers to generate a range of expected speeds. This was in turn processed and assessed to make a judgment about the traffic conditions on the roadway, which would feed into the traffic anomaly diagnosis system. The speeds were in turn used as traffic performance measures that would be used in a database, which provides historical perspective of performance versus time and location within the system.

SECTION 3.0   RESULTS

In this section, the resulting aspects of this project, including the traffic anomaly detection algorithm, the computer platforms and software used, and the architecture along with the software system model are presented. The software prototype was addressed with a core project and various sub-projects. The core project included the integration of the web, database and GIS software to present real-time information for the potential traffic stakeholders. The sub-projects include the "human-by-phone" and the "utility and alteration permit" software.

Anomaly Detection Algorithm Development: The diagram for the anomaly detection below represents our model for how a system of roadway sensors in conjunction with archived historical data can be used to determine that an anomalous situation is underway.
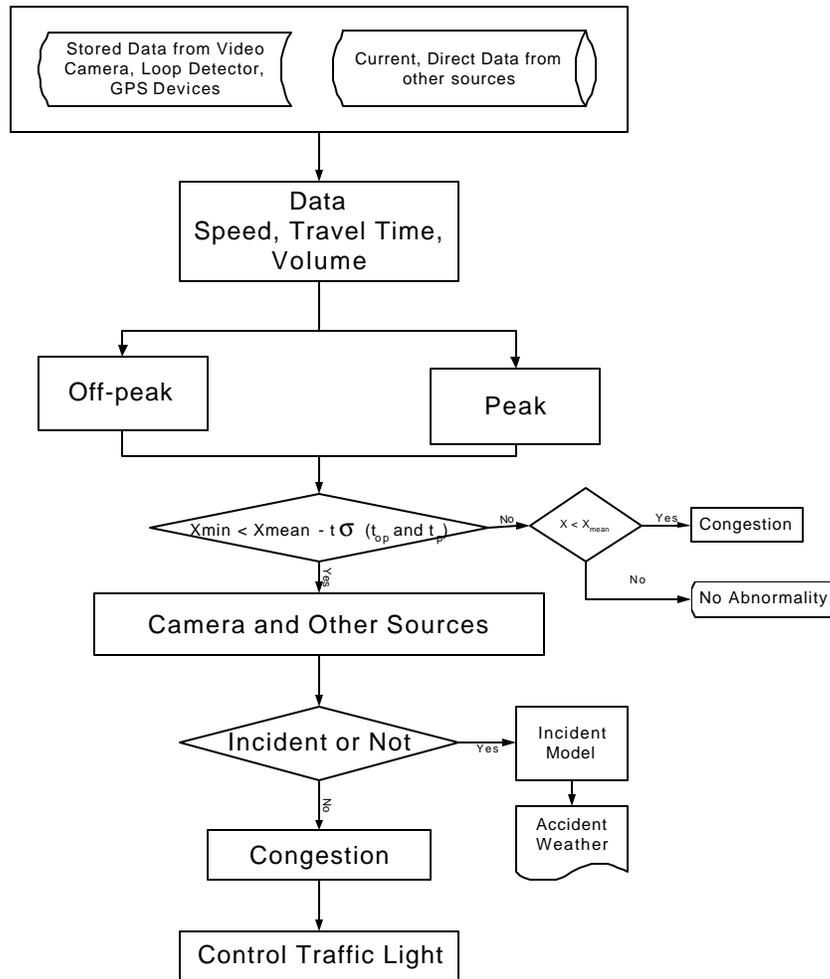
Figure 2. Traffic Diagnosis Algorithm Framework

In Figure 2, latitude is given for development of traffic signal control, although this was beyond the scope of this particular project.

Platforms and Software for Core Prototype: The client-server model for web applications was used for development. On the ***client side***, the system supports any platform running the following web browsers: ***Internet Explorer(4.0 and later), Netscape Navigator(4.0 and later)***. On the ***server side***, the developers used:

- ***OS: Windows 2000 Server***
- ***Web Server: Microsoft IIS 5.0***
- ***GIS System: Arc/Info 8.1, ArcIMS 3.1*** (used to connect the GIS system to the web interface)***, ArcSDE 8.1*** (used to connect the GIS system to the database)
- ***DBMS: Microsoft SQL Server 2000***

Software System Functionality: The main system use case diagram is given in Figure 3. This associates the user types and the modules they will use in the system. Here we see that there are expected to be two high level types of users: one that includes all "actors" such as the highway travelers and transportation (including safety and emergency) professionals, and another subset that includes safety and emergency professionals. Travelers and transportation professionals have access to travel situations on the roadways including planned and unplanned anomalies and emergency situations, but are unable to enter such events in to the system. Safety and emergency professionals will have access to all of the above and additionally will be able to modify and access information about anomalous and emergency situations on the highway. In fact, like the highway sensors, they are one source of real-time information, as they can enter this information into the system as it is conveyed to "the bridge" at RIDOT via word of mouth, phone messages, and through viewing the live camera feeds from various locations on the highways (http://www.tmc.state.ri.us/TrafficCams/LiveCams.asp). The prototype system as developed includes the following aspects:

- Integrates various types of real-time and archived information (from the database) to convey the current situation on the highway.
- Presents spatially oriented information (on a map) about flow of traffic on the highway
- Presents spatially oriented information about anomalous situations, including planned (such as construction sites) and unplanned (such as traffic jams and/or accidents).
- A web interface and database that permits a paper-free process that permits construction companies and utilities to apply for and be granted highway alteration permits. These alteration sites are considered planned anomalous situations and are reported on the web and map based interface.
- A Human-by-Phone interface that permits safety and emergency personnel to enter information about accidents on the highways.
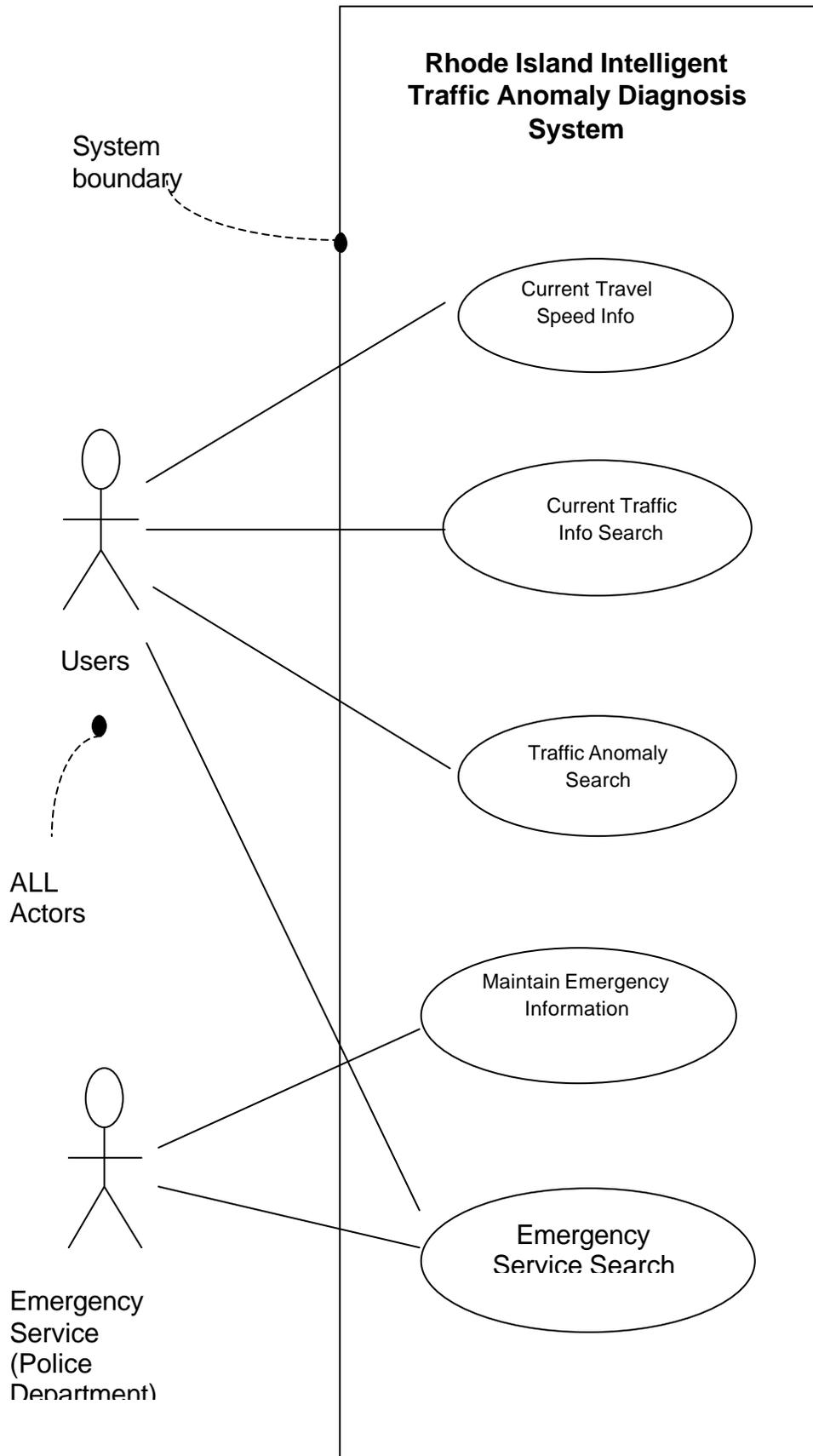
7

Rhode Island Intelligent Traffic Anomaly Diagnosis System

System boundary

Current Travel Speed Info

Current Traffic Info Search

Users

ALL Actors

Traffic Anomaly Search

Maintain Emergency Information

Emergency Service (Police Department)

Emergency Service Search

Figure 3. Use Case Diagram

Software System Model and Architecture: The system model and architecture are given in Figure 4. They show the primary conceptual and architectural features of the system including:
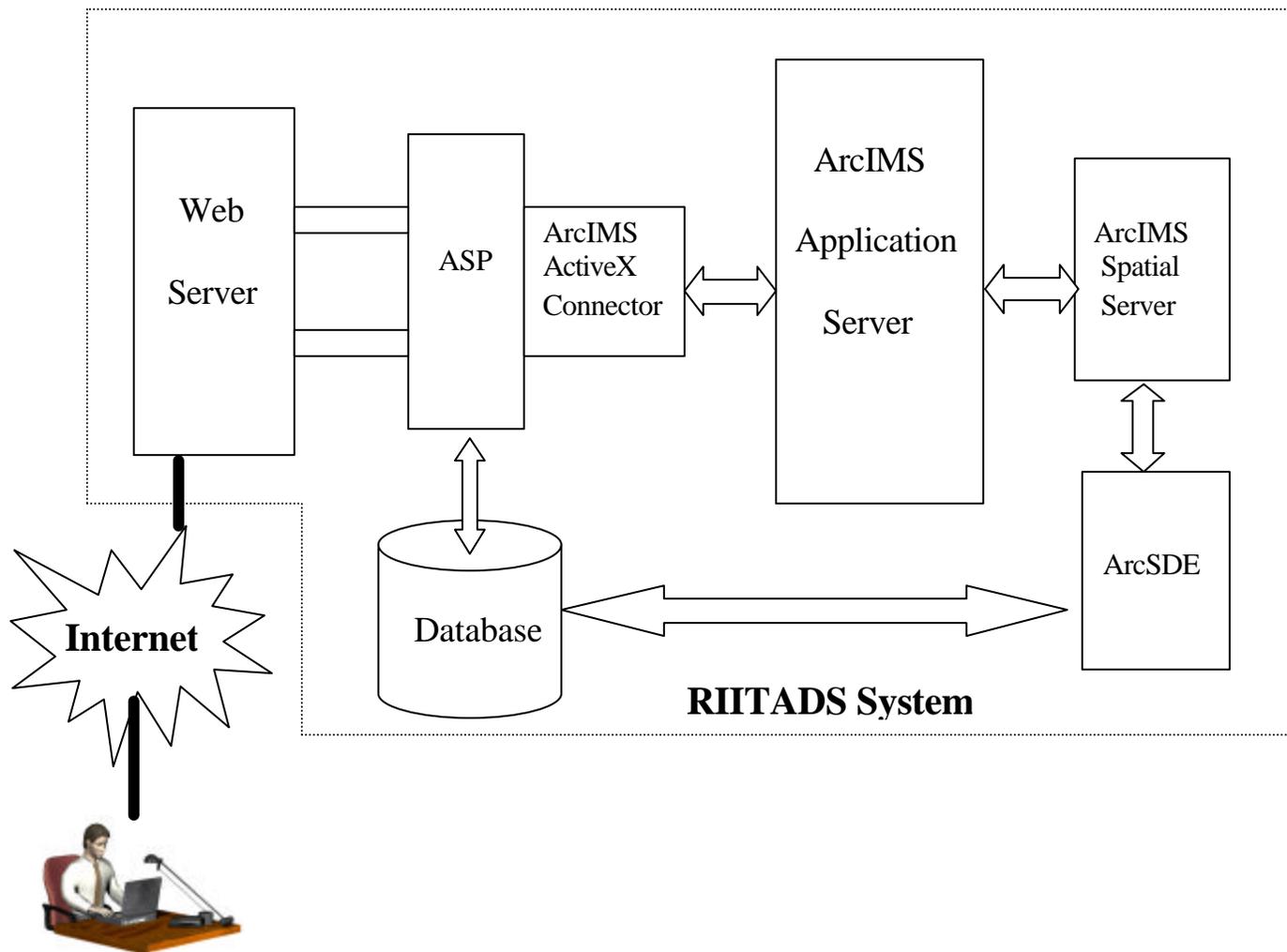

Figure 4. Software System Model

- An interface with various types of real-time inputs including the Human-by-Phone system, the sensors on the highways, and the web based utility and alteration permit system.
- Preprocessing software that receives the various types of information and prepares it for the GIS, database or web interface. Preparation includes formatting, aggregating, and cleaning the information (sensors, for example sometimes give data that does not make sense in the context of the highway sector from which the data is collected.)

- The business logic or control program that orchestrates the functionality of the integrated system. It is the software that notifies the GIS, database and web interface of the next processing steps.
- GIS system to spatially present the data using maps of the highways
- Database management system (DBMS) for archiving data about traffic incidents, highway modifications, and the traffic flows. The DBMS logically includes distinctly different databases that hold information about real-time and archived information about the sensor data, the Human-by-Phone information and the application for and granting of highway modification permits.
- Web interface(s) to permit entry for information as well as the dissemination of information.

Human by Phone: The Human by Phone system was developed to permit safety and emergency personnel to enter information about emerging anomalous situations on the highways. In the context of this integrated system it is one additional source of information for the detection of anomalies and for the web interface reporting about the highway. For the students[1] involved in this part of the project it provided a meaningful interaction between the developers and clients for the development of a software prototype. The diagram below shows the human-by-phone architecture:
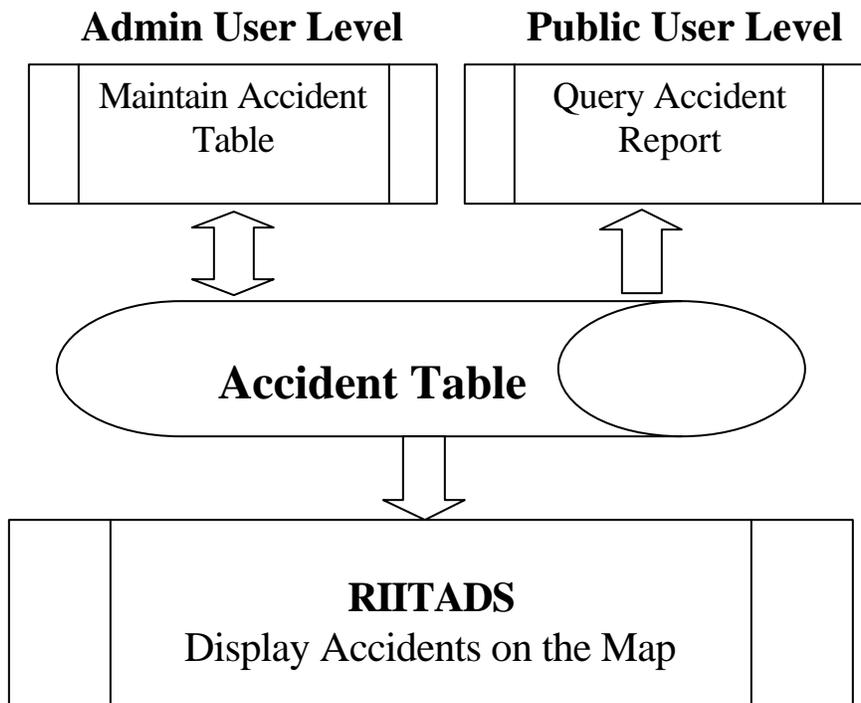

Figure 5. Human By Phone Software Architecture

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[1] Natayla Dymova, and Lucy Liu developed this part of the system. They were both computer science M.S. students at the time.

The software provides the following functionalities:

Primary function description:

- When traffic officials receive a report by phone about a condition or accident on the highway, they have a web-based interface into which they can enter information about the time, nature of, and location of an accident.
- The information is entered into an active incident database.
- The information is then automatically associated with an icon on the map within the centralized web interface. Users can click on the icon and get information about the incident.
- Once the incident is over, the information can be removed from the active incident database and archived into a historical database. The related icon on the real-time map is removed.

Other features include:
- An interface for administrators of the system to set passwords and authorize access to the system.
- An interface that permits users to logon with passwords to enter, edit, and delete information about an incident.
- An interface for users with passwords to view accident reports and to search by location or time.

Utility and Alteration Permit: [Wang 2003] RIDOT has a paper based process for utilities and other companies to apply for permits for highway alterations. The application is online, but must be printed out and filled out and then handed to RIDOT for processing. The developers worked with the RIDOT team to develop software that provides a paper free process. From a technical point of view, the computing team wanted to experiment with Microsoft's new .NET platform for web development and to perform a comparison with other pre-existing Windows platforms. This comparison and the design and development of the software for the specific transportation application (web interface to support the paper free application process) constituted the computing tasks of interest. The findings were that .NET is a robust and helpful environment for such development. The developers also found that the now legal use of digital signatures is key in providing a totally paper-free and electronic application process. The team used off the shelf digital signature technology and integrated this into the system.

With respect to other aspects of this project, the roadway alterations for which parties are applying using this software described above represent planned highway incidents. Thus, once a planned incident is approved and entered into a database in the RIDOT Maintenance Department, an icon appears on the web based map and users of the central integrated system need only to click on the icon to view information about the incident. So although the "human by phone" system database and the highway permit alteration database reside on different databases, in different locations, and on different machines, it is possible to provide a coherent integrated system that spatially displays all information

that represents ongoing planned or unplanned incidents on the highway. This is a very powerful paradigm that permits different departments at RIDOT to more easily work with each other. In addition, it provides an integrated means of portraying the active information for travelers and transportation professionals alike.

Other benefits of the web-based online permit application system include:

- Whole application process is web-based and paper free.
- The application process becomes streamlined and is faster from application to approval to availability of information for interested parties.
- The information is online, so applicants and involved parties at RIDOT can simply check for application progress and status online
- The use of .NET Microsoft technology sped up development
- Digital signatures and payment processes were also developed to be carried out online
- Applicants could get instant access to permit numbers (in a secure fashion) once assigned
- System is secure. A login is needed for both applicants and processors at RIDOT (with different but appropriate privileges for each)
- The application process involves a particular sequence of approvals and processes, many in different departments, so the interface was designed to support these procedures as outlined by RIDOT.

SECTION 4.0   APPLICATION

The end product from the prototype development is output to a website about the roadway system.   The website allows access to data detailed throughout the report from planned incidents to accident update capabilities to existing traffic speeds from a specific segment.   The prototype was named the Rhode Island Intelligent Traffic Anomaly Diagnosis System (RIITADS).   A screen-shot from the website is displayed in Figure 6. In the figure, you are able to view traffic conditions on segments and how a user can access other available data.
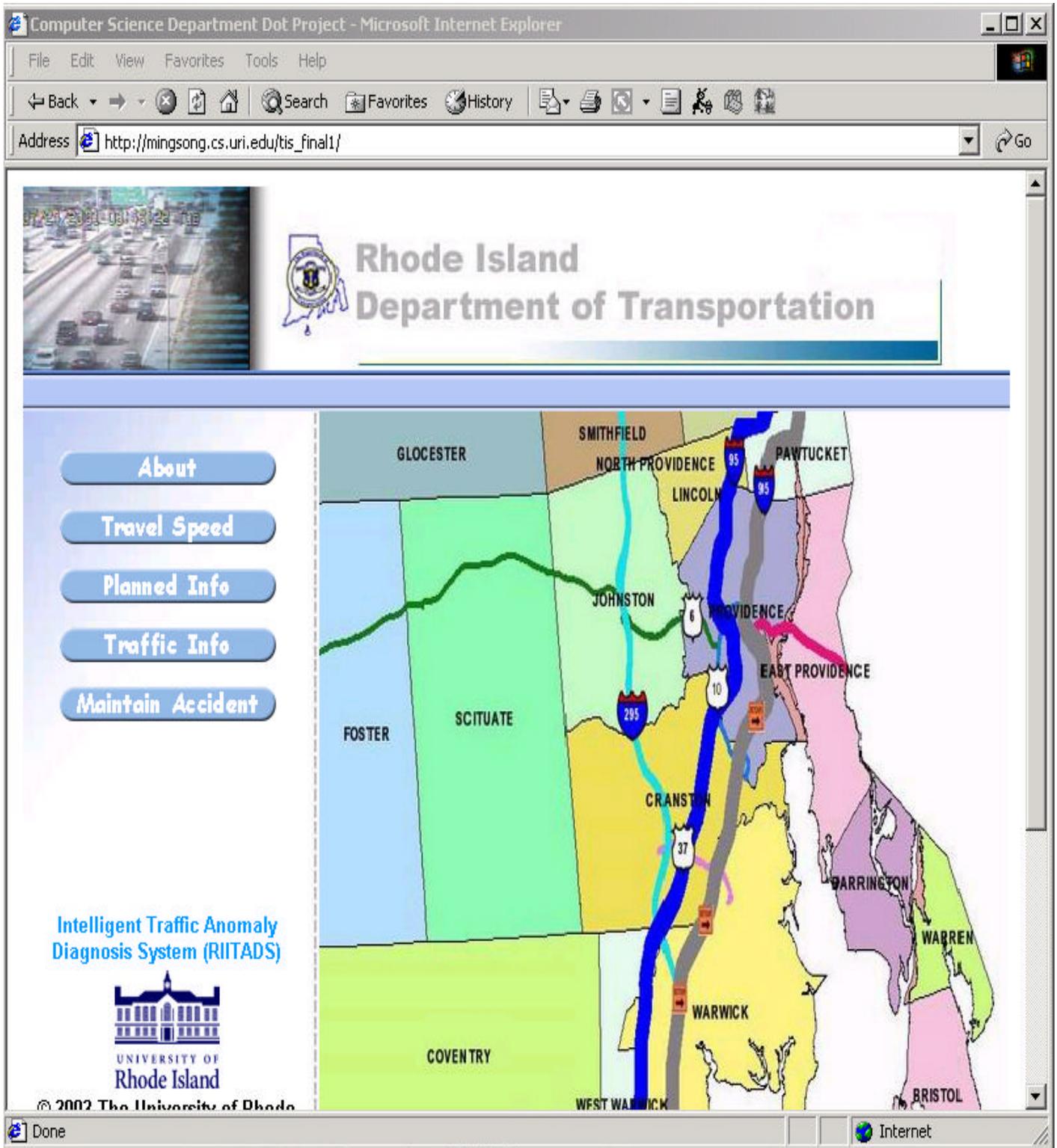
Figure 6. RIITADS System Screen-Shot

SECTION 5.0   CONCLUSIONS & RECOMMENDATIONS

5.1   Conclusions

The team successfully built upon the design and prototypes that were carried out in two previous years and made good progress in integrating various techniques for the detection of and presentation of information about anomalies on the highways. These accomplishments include:

- Built on year two data capture – The group has successfully built upon the capture of data that was carried out in year two of this project [Peckham 2000, & 2002]. Various techniques for the collection of data were developed and used in this project.
- Developed computer algorithms for diagnosis of traffic anomalies – One engineering graduate student[2], sketched an algorithm for the detection of anomalous situations on the highway using incoming various sources, including sensors and humans. For example, if the sensors detect the slowing or stopping of traffic in one location on the highway, the system checks both the planned and unplanned information in archived and real-time files to determine the situation on the highway. If it is a new anomalous situation, an icon is placed in the correct location and information is presented to the user about the situation.
- Integration of GIS, DBMS, and web technologies for a coherent and integrated analysis, data gathering and presentation system. Did not use CORBA as expected in the initial proposal; it was not needed due to new modules available from the GIS package to interconnect it with the DBMS and web interface.
- Due to the nature of the project, standards did not have as much of an impact on the system choices as expected at the proposal phase. Students were given the standards, but experimentation and the commercial modules employed in the project more strongly drove the architecture of the system.
- Open source to commercial software – As mentioned above, we moved from open source to commercial software and learned about the pros and cons of each environment.
- Extend model development – This project extended an integrated ITS (intelligent transportation system model that was previously developed by the team.)
- Planned incidents, anomalies, and predictions – Taken individually, the team gained expertise and developed prototypes for several different sub-domains such as the gathering and archival of information and development of web interfaces for safety personnel (Human-by-Phone system) as well as maintenance professionals (highway modification permits system)
- Multidisciplinary team experience – The PI's have since moved on to other funded project from other external sources. The lessons they learned about the strengths ad pitfalls of multidisciplinary teams have been invaluable and overall very positive. The team feels that this diversity of background lends strength to projects such as these in which computing and engineering techniques are needed.

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[2] This was computer science M.S. student, San Myint.

5.2   Recommendations for Further Work

This research team has now turned its attention to the issue of travel time prediction and ultimately that of alternative route selection. Predicting travel time is especially of interest during and after anomalous situations, thus this work will be used to help model and detect such situations. The software models for this project were developed to be extensible for the addition of new features, so the team will not have to carry out a completely new design if, for example, an alternative route module is desired.

Other areas that need attention in the software prototype are:

- Real real-time data processing – Currently the state of Rhode Island has installed more sensing equipment on the highways in the Providence area. As the volume of data increases, software developers must pay attention to possible bottlenecks in the data processing procedures. If frequent and timely update of the traffic situation is desired, this might become an issue for such traffic reporting systems.
- More data sources integration – As more equipment is placed on the highways, from a variety of sources, each data type must be seamlessly integrated into the system. This team developed an extensible prototype, but attention to the details of each new device is important.
- Dynamic icons display – There were some issues surrounding the dynamic placement of the icons on the screen. Due to the version of GIS software used, the solutions were not as elegant as desired for a robust and maintainable interface. It is hoped that newer versions of the commercial GIS product will permit better solutions in the future.

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