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Implementation, Operation and Suport of the Multimedia-Based Highway Information System

Kelvin C. P. Wang, Xuyang Li, Robert P. Elliott

Final Report

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Multimedia-based Highway Information System (MMHIS)

Submitted to

Arkansas State Highway and Transportation Department

Principal Investigator: Kelvin C. P. Wang

Co-Principal Investigator: Xuyang Li

Co-Principal Investigator: Robert P. Elliott

Department of Civil Engineering

University of Arkansas, Fayetteville

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Project Abstract

The primary goal of the project was to implement the Multimedia based Highway Information System, MMHIS, which was developed under a previous AHTD project, TRC 9606, "Development of A Pavement Management System". The end product from this project would provide AHTD with a usable system allowing synchronous data and video viewing for approximately 3600 directional miles composing the Interstate and National Highway System (NHS). In this project, MMHIS as in the form from TRC 9606 has been substantially revised and improved to accommodate the daily needs of AHTD. Specifically, actual data sets from AHTD's log book and other data archives have been incorporated into MMHIS. In addition, the vast majority of videotapes for Interstate highways and a large portion of National Highway Systems have been digitized into the MPEG-2 format. A complete Redundant Array of Inexpensive Disks (RAID) at the capacity of 150 Gigabytes and a video authoring system have been integrated into the MMHIS. New authoring software tailored to accurately synchronize video locations with bridge locations was also developed and tested. A revised user interface in the Windows NT environment allows users to view accident data, bridge information, job status, roadway inventory and other items that were not present in the previous MMHIS, but are databases used by AHTD personnel on a daily basis. Furthermore, the new MMHIS can accommodate roadway sections that have identical log miles, so that users can query any roadway location based on route number, direction, section number, and log mile. The investigators also provide recommendations regarding the potential incorporation of several new technologies into the new MMHIS, including a geo-referenced mapping utility, higher resolution video log video and imagery, tighter integration with AHTD databases such as accident database and job status database, and direct data collection with digital video devices for the MMHIS. The investigators also studied the in-house resource needs of AHTD to manage MMHIS versus using external contracts to maintain the MMHIS for the AHTD.

Acknowledgement

The principle investigators are grateful for the support provided by the research staff of AHTD. Specifically, Mr. Alan Meadors, Staff Research Engineer of AHTD, provided much needed technical advice. Mr. Bobby Bradshaw took countless trips to meet with the research team to probe, answer and solve problems associated with the implementation of MMHIS. Mr. Mark Evans helped provide needed data for the implementation. The investigators also appreciate the foresight of Mr. Steve Teague, assistance chief engineer of AHTD, who supported the initialization of MMHIS research nearly six years ago. Lastly, without the help of two diligent assistants, Mr. Kofi Addo Nyarko and Mr. Wei Yih Tee, the multimedia database would not have been completed in time to meet the deadlines.

Introduction

In 1995, the Arkansas State Highway and Transportation Department (AHTD) contracted with the University of Arkansas to develop a pavement management system (TRC 9606). As a result of this project (TRC 9606), a Multimedia-Based Highway Information System (MMHIS) was developed. MMHIS allows the end-user to view a digital video of a highway section on the computer screen with corresponding site data for this location on the same computer screen. Additional features of the MMHIS include the display of the corresponding roughness and rutting data as collected by AHTD's ARAN data vehicle, and a prototype of a graphical display of pavement distress and its analysis. Lab based geo-referencing techniques were also developed in the MMHIS to link any location related data, including digital video, into a relational database and to a digital map.

A number of pieces of computer hardware were purchased under TRC 9606, including a Symmetrical-Processing (SMP) based video server, 90 GB of hard drive storage, and a state-of-the-art MPEG-2 encoder at one-half D1 resolution. MMHIS has the potential for providing AHTD with a system that can greatly enhance the ability of a designer or planner to quickly resolve questions regarding a roadway feature without conducting a field inspection.

However, implementation of MMHIS at AHTD headquarters will require additional research in the areas of computer networking, MPEG-2 encoding, and possibly DVD-R (Digital Versatile Disk – Recordable) technology, and issues relating to system performance when in operation.

MMHIS is not being used in a production environment and exists only on a small, dedicated Lab network. In order for AHTD to use it in a production environment, MMHIS must be integrated into the current computer network. Additional research is needed to determine the most efficient way for AHTD to maintain its investment in the current network and at the same time, upgrade to handle the additional load created by MMHIS.

Objectives of this new study on MMHIS include:

(1) The implementation of MMHIS will provide AHTD with a usable system allowing synchronous data and video viewing for approximately 3600 directional miles composing the Interstate and National Highway System (NHS).

(2) The project will provide necessary hardware required to support the 3600 miles of the Interstate and National Highway System.

(3) The project will provide a software system capable of supporting the State's highway system consisting of 16,000 plus miles.

(4) The system to be implemented should support simultaneous access by 12 users.

(5) The multimedia database can be easily modified to incorporate data identified during and after the project completion into MMHIS.

(6) The system to be implemented will have a provision to allow the incorporation of a pavement surface view with identified cracking superimposed over the image.

(7) The digital video in MMHIS will have full MPEG-2 D1 resolution.

(8) The project will procure an authoring workstation capable of capturing and converting S-VHS video from the ARAN into MPEG-2 digital motion video and composing the multimedia databases with the video streams and site data records.

(9) The project will determine the proper format of DVD-R technology for AHTD districts to use MMHIS and procure a DVD recorder or writer that is capable of producing DVD disks for districts.

(10) The project will integrate MMHIS into AHTD network.

(11) Digitize the Interstate and NHS video and compose the video with the databases provided by AHTD.

(12) The project team will deliver and install the video server and authoring workstation at AHTD headquarters. AHTD will be responsible for the end-user workstations and all network switch and cable installations.

(13) Project team will provide (a) training to AHTD personnel to operate MMHIS, (b) technical support addressing operational issues or problems during the period of the research project, and (c) recommendations to AHTD for operation, maintenance, and support of MMHIS.

(14) The research team will make continuing refinements to the existing MMHIS and may add additional necessary features in MMHIS to make MMHIS complete and fully operational.

(15) A common reference system is needed to synchronize the data and video. As AHTD's Highway Log provides the official beginning and ending log miles of a route along with other features, such as bridges, intersection, etc. This information will be used to set key frames during the database composing stage to ensure the accuracy of data synchronization.

Background

Visual information is frequently used in highway departments for traffic engineering and infrastructure management. Another type of information is tabulated site data organized in traditional engineering databases on pavement history and layer information, pavement width/type, average daily traffic (ADT), accident history, and signing and marking inventory, and others. These two types of information (roadway images and traditional engineering database) can be of daily benefit to the needs of various divisions in state highway departments. In order to improve data accessibility in a highway department, it will be very beneficial to combine these two information sources into one comprehensive database that can be accessed simultaneously.

However, most existing photo logging systems used by various highway departments are analog based and located at specific location(s) within the department. Simultaneous multiple accesses to the video data are not possible. Searching for site data is cumbersome. Traditional engineering site data are contained separately from the video databases. There were a few studies in an effort to exploit new technologies to improve the accessibility and usability of video information collected from the photo logging process. Wang et al. presented general concepts and design issues for the development of a distributed multimedia based highway information system (MMHIS) and discussed the economic and technical feasibility of using digital video and new networking technologies for such a system. It was concluded in that study that the latest technology allows such a system to be developed cost-effectively. This report summarizes the studies in the areas of high-speed networking, video server technology, and data synchronization that are essential for the implementation of an MMHIS. It is demonstrated that a future digital video-based highway information system will be efficient and productive through use of technologies such as Asynchronous Transfer Mode (ATM) and state-of-the-art video server devices.

A working system has already been developed for the Arkansas State Highway and Transportation Department (AHTD). The system has a user intuitive interface. A guide on how to use this system is also given in this document.

History of Photo-logging System and Basic Features of MMHIS

Problems with Existing Photo-logging Systems

Current existing photo-logging systems use data collection vehicles to collect data on pavements and roadside structures and to take videos of the right-of-way. The video information used by highway agencies is stored in analog format and located at specific locations. The storage media include tapes, films, and laser disks. Engineering site data are stored in separate databases. Video playing devises are used to play the highway videos. This is shown in Figure 1. Special-purpose software is used in some existing systems to retrieve and present site data tables to the user. The data in the database, however, are not well organized. Some systems require the user to use general-purpose DBMS software to open the table and query information. Others use file processing instead of database management. The limitations of existing systems are exhibited in the areas of accessibility, search capability of the video library, and synchronization of video data with traditional engineering site data. Users who are interested in a section of a road when viewing the video have to go to another location to look for the corresponding site data. The existing systems also lack multiple-user access capability. Due to the analog nature of the video signals, it is difficult to integrate the visual information with computer databases. It is a time consuming process to look up and reassemble the video and site data in different formats and from various sources.

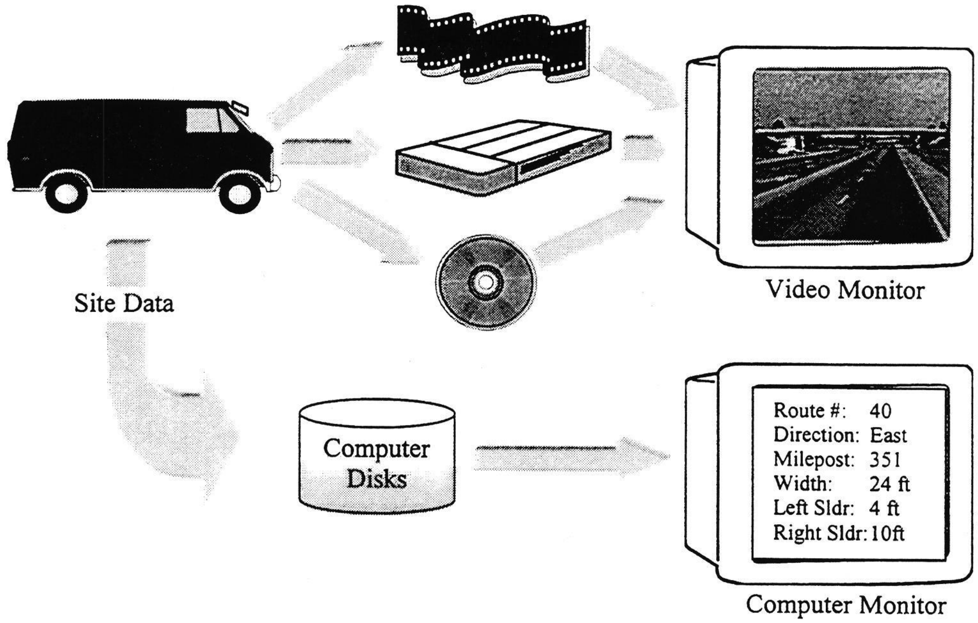

Figure 1 – The Existing Photo-logging System Data Flow

Basic Features of MMHIS

A new system – Multimedia-based Highway Information System (MMHIS) – was developed in the previous project, TRC-9606, to solve the problems in existing photo-logging systems. Technologies used in the new system include digital video, high-speed video server, ATM networking, relational database management system, and 3D-map rendering. MMHIS also uses a data synchronization algorithm to synchronize the highway motion video with the display of other data – engineering site data, roughness and rutting graphs, and location on the 3D-map. A high-speed network links workstations with the MMHIS server so users can look at the photo-logging video and the synchronized data sets without leaving their offices. Because the engineering site data are stored in computer databases, MMHIS can be easily customized to fit the need of different departments.

Apart from easy data accessibility, data presentation in MMHIS is more flexible than the old systems. An integrated environment hosts various views that are used to display data from various sources. The views can be customized to display a certain collection of fields in the data set. It can display the data in either categorized or user-defined format. Users can choose whether to use metric or imperial units in the data display. When using the user-defined format, the order of the data fields can also be customized.

The Querying database in MMHIS is object-oriented. There are several different ways to conduct a query in MMHIS. It does not require users to be familiar with any general-purpose DBMS products. Users need only to specify the location on a road by specifying the route number, direction, and milepost, or by clicking on the map offered by MMHIS. MMHIS provides highway engineers an efficient and effective tool in analyzing road and roadside structures with instant accessibility to the multimedia databases. This tool is not available to any highway department in the United States at this time. The core technologies developed for this system can be used in future generations of highway information systems in any highway department. The mapping technique was developed in a Lab environment and cannot be directly used for AHTD needs at this time.

New Technologies of Digital Video

Digital Video for MMHIS

The video quality associated with consumer TV and videotapes, including video from Super VHS and laser disks, is determined by the analog video standards set by the National Television Standard Committee (NTSC) in the early 1950s. Even though an analog video signal can be transmitted and copied through narrow bandwidth, it is difficult to manipulate, copy, and distribute without introducing electronic noise into the original signal, resulting in the deterioration of image quality. Without the use of high-end video production equipment, the integration of analog video with other types of data, such as text and graphics, is very difficult.

Additionally, in the MMHIS, multiple users need simultaneous and random access to video data. For data stored in an analog system, multiple and unsynchronized access to video data is a problem. For instance, it is difficult to view two different sections of the same videotape simultaneously, and then decide to freeze one while running the other. Routing of multiple analog video data to users is also complicated. If the video signal is presented in digital format, like the digital sound in compact disks, it can provide much better image quality, can be easily duplicated and can be incorporated into other media without introducing as much artifacts or losing as much fidelity as analog media would. Because digital video data is stored in disk files, it is possible to allow simultaneous multiple accesses to the same digital video files through computer networks. Digital video is necessary when high fidelity, fast and multiple user accesses are required of the MMHIS.

Data Collection, Compression and Decompression (CODEC)

Presently the visual data is collected in a vehicle, such as a van, with video capturing equipment. Normally, the visual data is recorded onto a Y/C signal based tape (S-VHS or Hi-8mm) or laser disk. The video signal is analog based with luminance and chrominance information separated. The perceivable vertical resolution of the video data is about 400 lines. The recorded media are then categorized for viewing in the office. To prepare the video for the MMHIS, the analog based video data is digitized and becomes digital data sets that are directly manageable with computers. The digital video is generated through a process called encoding from source video data, such as tapes. One full color (8-bit for each of red, green, and blue) digital image with a NTSC TV resolution (640 x 480) requires approximately 0.92 megabyte of data storage, resulting in about 27 megabytes of storage space for one second of motion video. In addition, the input and output bandwidth of modern microcomputers are not generally capable of processing this amount of data per second. Therefore, data compression is needed to reduce data storage requirements on the one hand, and to improve the data flow rate on the other.

The amount of compression ranges from 2:1 to 200:1, depending on the type of algorithm, the implementation of the algorithm, the level of video quality, and the presence of hardware assistance. Most compression algorithms are "lossy", meaning that some information is lost during the compression of the data, due to the fact that the compression ratio based on lossless encoding algorithms is low, around 2:1. The objective for most applications is to retain visually faithful representations of the original images and discard any visually insignificant information. The process of compression and decompression (for playback) is called CODEC for encoding and decoding. Some approaches require more operations to be performed in encoding than in decoding. This type of CODEC is referred to as asymmetrical. If both processes require the same amount of processing, it is called symmetrical CODEC.

Motion JPEG (Joint Photographic Experts Group) and MPEG (Motion Picture Experts Group) are the two dominant types of digital video CODECs, both of which are used in this MMHIS research. The Joint Photographic Experts Group (JPEG) developed the JPEG compression algorithm for still images based on Discrete Cosine Transformation (DCT), the quantization approach and Huffman encoding. The standard was then widely adopted as Motion JPEG for video sequences, each frame of which is compressed based on the JPEG standard. Motion JPEG allows easy random access to any frame in a digitized sequence. Compression for Motion JPEG is conducted exclusively on redundant data in individual frames without condensing any data between frames. Hardware based JPEG CODEC's can capture full-screen, 30 frame per second video in real time. When a high compression ratio (over 20:1) is not required, this symmetrical CODEC is very effective in preserving the details and fidelity of single video frames.

Unlike JPEG, which condenses information only within each frame, the standard developed by the Motion Picture Experts Group, MPEG, compresses information based on data within a frame and frame-to-frame motion. It should be noted that the compression within frames in MPEG is also based on DCT and related algorithms.

MPEG allows compression ratios over 100:1 while still retaining good visual quality. Due to its high compression ratio, MPEG is a desirable delivery format for applications that require narrow bandwidth transmission, such as CD-ROM and video networks. However, due to the asymmetric nature of MPEG, the encoding process requires very high computing power. For example, a state-of-the-art MPEG encoding device can consist of over a dozen RISC based compression processors. The decoding process of MPEG needs relatively less computing power. At similar levels of video quality, a Motion JPEG stream will require a much higher data rate than an MPEG compressed stream. Current available MPEG systems are classified into the categories of MPEG1 and MPEG2 with MPEG1 being used for CD storage and the Internet, and MPEG2 being used for studio quality video and satellite digital TV systems.

Location Synchronization with Video and Site Data

When a query is on-going, a location indicator (a small flashing red dot) is displayed on the map to show the current vehicle location. The location indicator goes along the highway on the map as the video plays. The synchronization timer handler queries the current vehicle location from the fixed data table and passes the query result to the 3D-map sub-module. The map module then finds the screen coordinates of the current vehicle location. MMHIS maintains a 3D position in window coordinates. (This is handled internally by the OpenGL engine.) This position, called the *raster position*, is used to position pixel and bitmap write operations. It is maintained with sub-pixel accuracy. The current raster position consists of three window coordinates (x, y, z), a clip coordinate value (w), an eye coordinate distance, a valid bit, and associated color data and texture coordinates. The w coordinate is a clip coordinate, because w is not projected to window coordinates. MMHIS converts world coordinates to window coordinates by calling appropriate API functions. The converted window coordinates are used to display the location indicator on the map.

Data Synchronization Algorithms and Their Implementations

The Preparation of Video Frame Index

Video frame indexes were created with the MMHIS Index Building module. The index building process is divided into the following steps.

- Obtaining information. In this step, necessary information is collected in the *Building Index* dialog box. The fields are listed in Table 1.

Field	Explanation
Video File Name	The name of the video file for which frames will be indexed
Video Start Frame	Frame number corresponding to the beginning milepost
Video End Frame	Frame number corresponding to the ending milepost
Route Number	Route number of this section
Direction	Direction of this section
Start Milepost	Starting point of this section
End Milepost	End point of this section
Key points	Mileposts of points that corresponds to known frame numbers
Turning points	Destination route numbers, directions and mileposts of turning points

Table 1 – Index Building Module Input

- The key points specified by the user are used to define subsections of the highway section covered by the current video. Each subsection begins at one key point and ends at the next key point. That is, in each subsection only the first milepost and the last milepost have corresponding video frame numbers specified. Video frame numbers corresponding to the rest of mileposts are calculated by using the linear interpolation method. The speeds of the vehicle when it took the video are recorded into the main data table. The speed data are used as the determining factors.

The above method guarantees that key points are exactly indexed with the frame number specified. This is especially useful when the speed data is not accurate enough to be used as the sole factor to interpolate values. If the total accuracy is guaranteed, only the starting point and end point of the whole section need to be defined as key points.

To describe the above algorithm mathematically, suppose for a subsection the starting milepost is s, which corresponds to frame number *fs*, and the end milepost is e, which corresponds to frame number *fe*. The number of mileposts in this subsection n can be calculated as

$$n = \frac{e-s}{step} + 1,$$

in which *step* is the distance between consecutive mileposts. In the current database, the value of step is 25 meters. Suppose the speed value for milepost i (i is $1 - n\text{-}1$) is *speed(i)*. The corresponding frame number is *frame(i)*. The traveling time for the video to cover this subsection T is calculated as

$$T = \sum_{j=1}^{n-1} \frac{step}{speed(j)}.$$

The frame numbers for the rest of mileposts are calculated as

$$frame(i) = \frac{(fe - fs)}{T} \sum_{j=1}^{i} \frac{step}{speed(j)} + fs.$$

Database updates are involved in the index-building module. Because the Microsoft Access ODBC driver supports database updates, it is just a simple matter of calling the appropriate update functions with proper SQL commands to finish building the index. The index building process is shown in Figure 2.

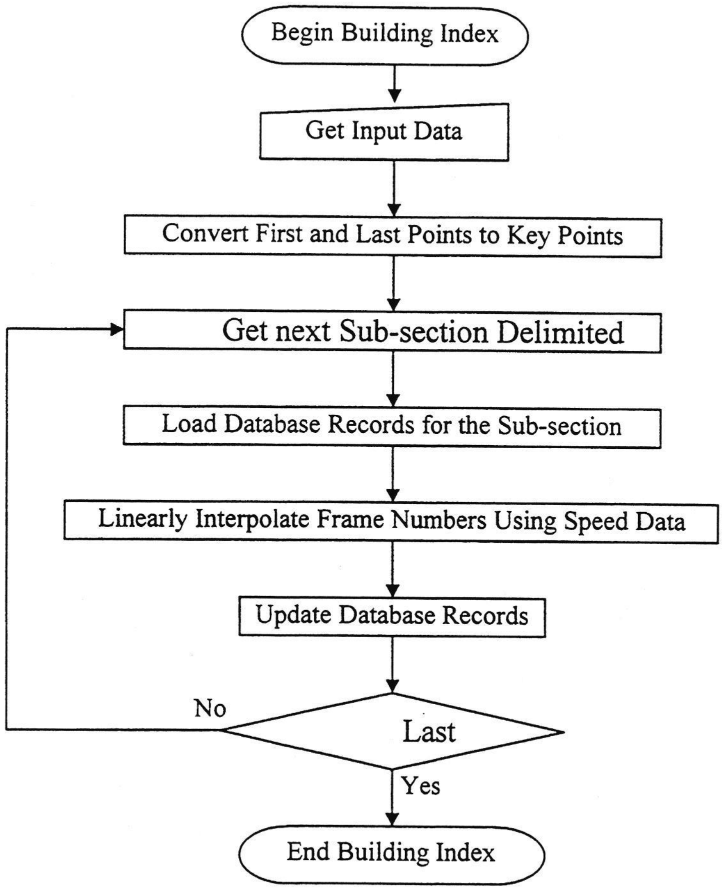

Figure 2 – Index Building Flowchart

The Synchronization of Video and Site Data Display

When MMHIS is started with a query, the information displayed is all synchronized. That is, when the video is playing, data displayed in the various windows changes dynamically with the video frames. The view window of the MMHIS control module has a timer that is set up at creation time. This timer, called the *synchronization timer*, is used to synchronize the display of site data with the video. The synchronization timer handler in the MMHIS control module does not actually find the correct data and display them. Instead, it acts as a director to orchestrate all sub-modules of MMHIS.

The synchronization process uses a frame range to check if the current frame of the video is still in the range for the current milepost. The range is updated when the site data and the video frame are synchronized. The first time a query is started, this range is set to an impossible range to guarantee that the synchronization operation is applied upon initialization. The synchronization process is shown in Figure 3.

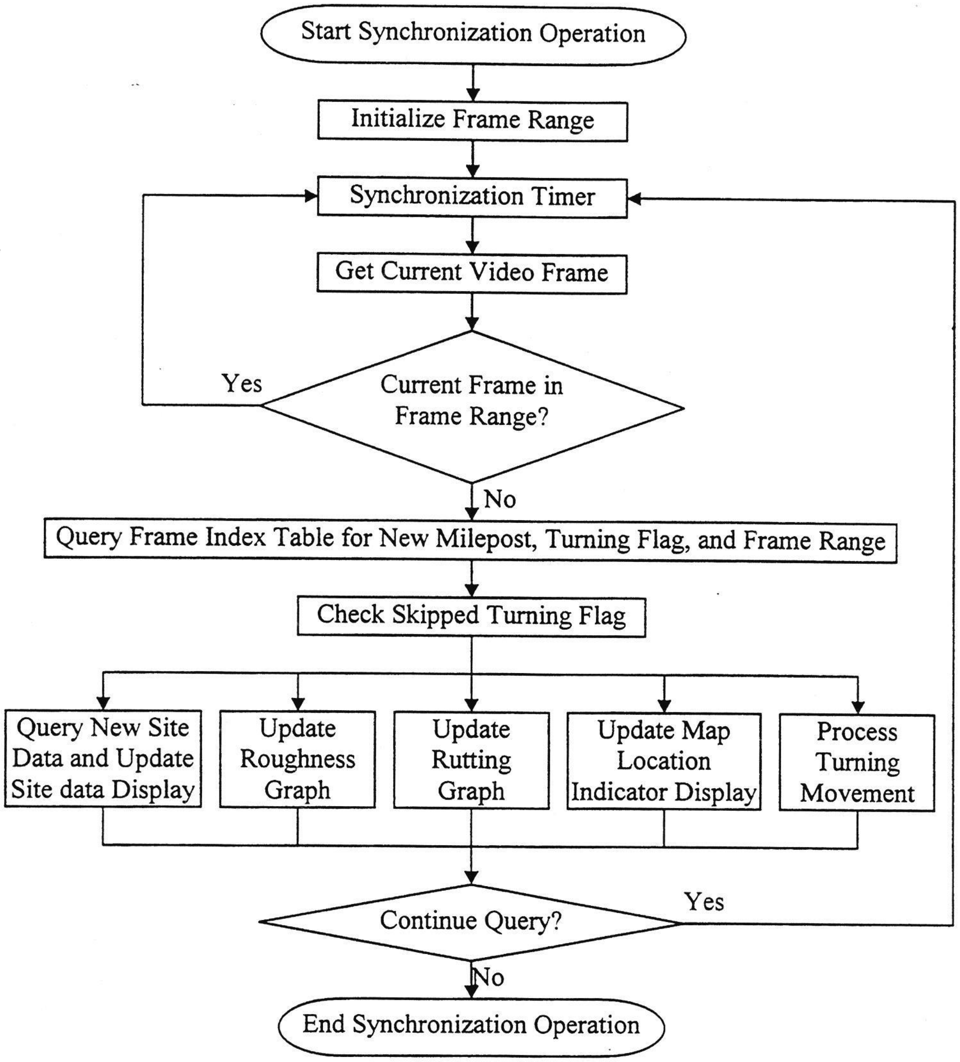

Figure 3 – The Synchronization Process Flow Chart

MMHIS Database Authoring for Operation and Implementation

ODBC Data Source Configuration

The MMHIS uses MS Access databases. The only database that needs to be registered in the ODBC settings is the main database. The file name of this database can be anything. The ODBC data source should be named MMHISMain. Figure 4 shows a typical screen of the ODBC Data Source Administrator. In this figure, the data source MMHISMain belongs to the User DSN category. By putting the data source to user DSN group, different users are allowed to have different settings.

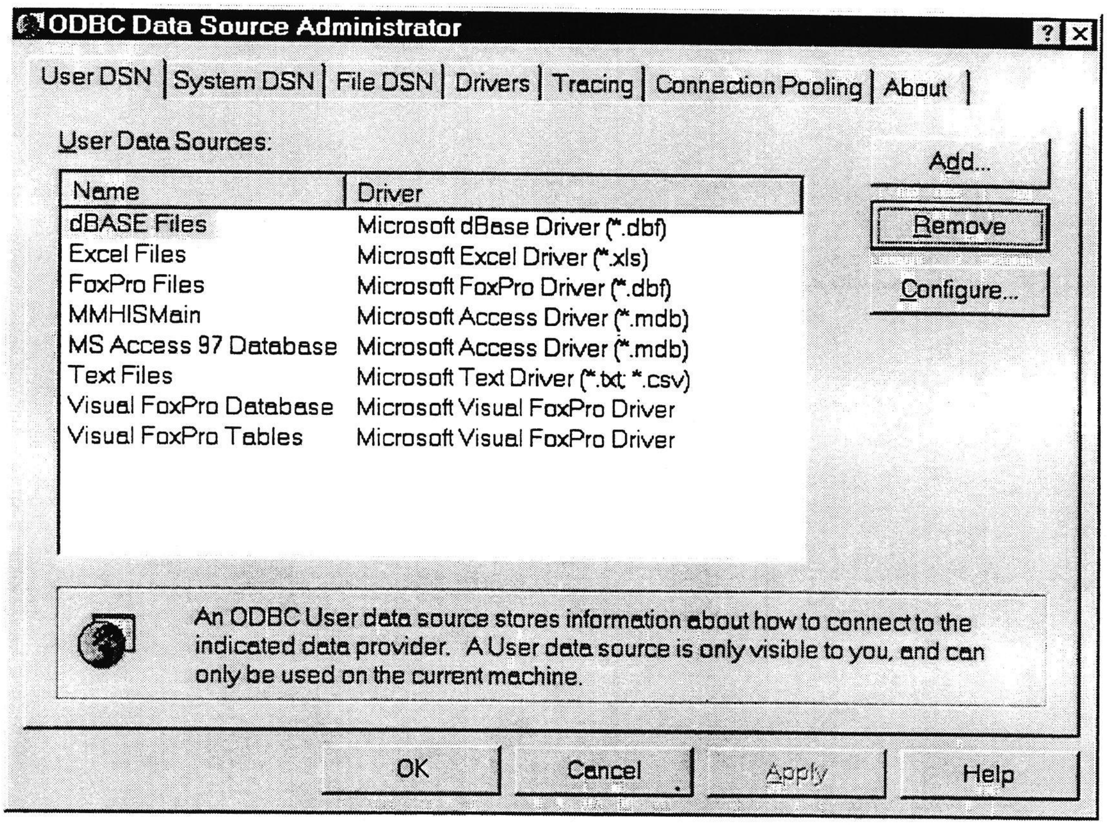

Figure 4 – ODBC Data Source Administrator

The data source MMHISMain should point to the main database file, as shown in Figure 5. In this figure, it is assumed that the main database is in a file named AHTDMMHISMain.mdb.

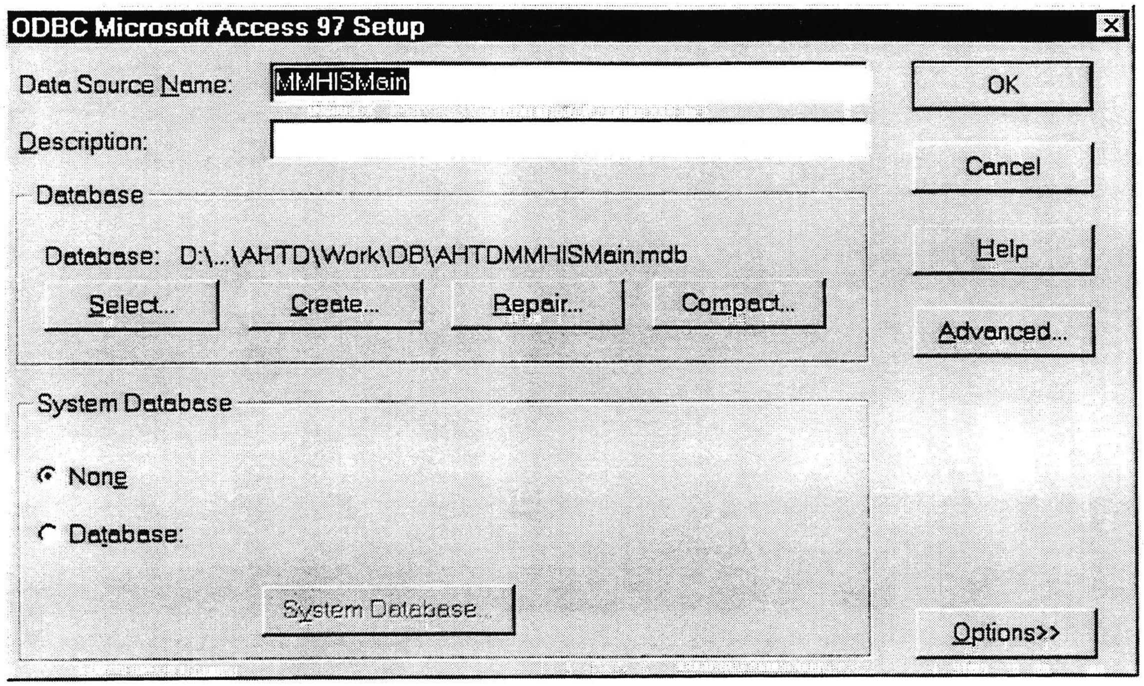

Figure 5 – MMHISMain Data Source Setup

Another group of database files used by the MMHIS stores site data for all the routes. The database files in this group are registered in the main database and are configured in the ODBC data source manager dynamically during program execution.

Database Structure

Currently the main database contains tables shown in Figure 6.

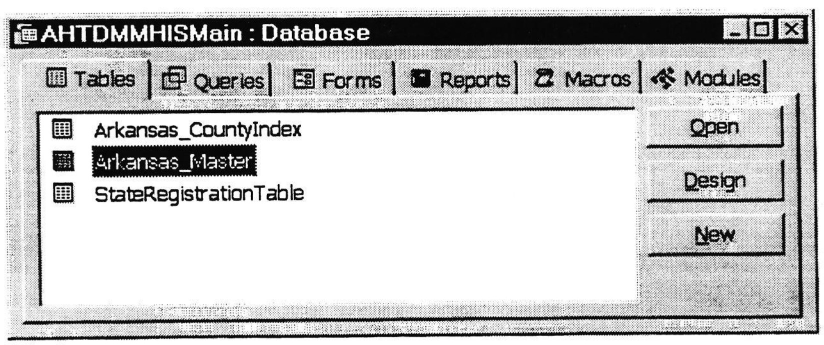

Figure 6 – MMHIS Main Database Tables

The tables "Arkansas_CountyIndex" and "StateRegistrationTable" do not need to be changed in data entry operations. The table "Arkansas_Master" has the structure shown in Figure 7.

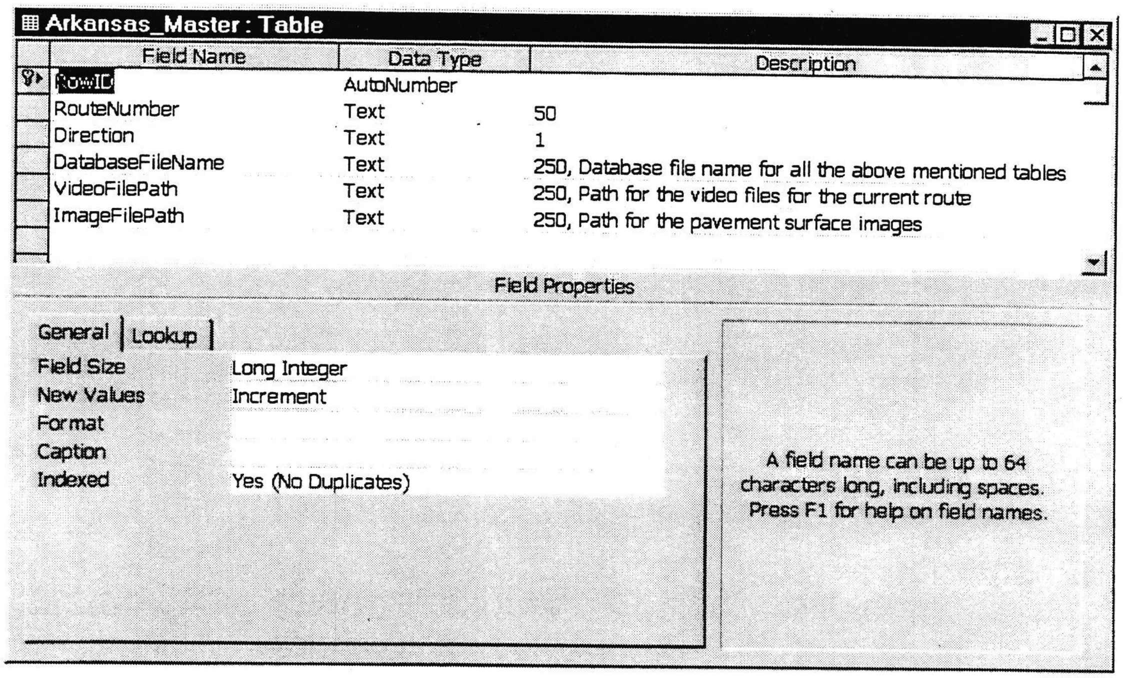

Figure 7 – The Master Table Structure

Whenever a new route is added to MMHIS, the route needs to be registered in this table. The process is addressed in following sections.

The site data database contains tables for each route. The Figure 8 shows an example on what kind of tables it contains.

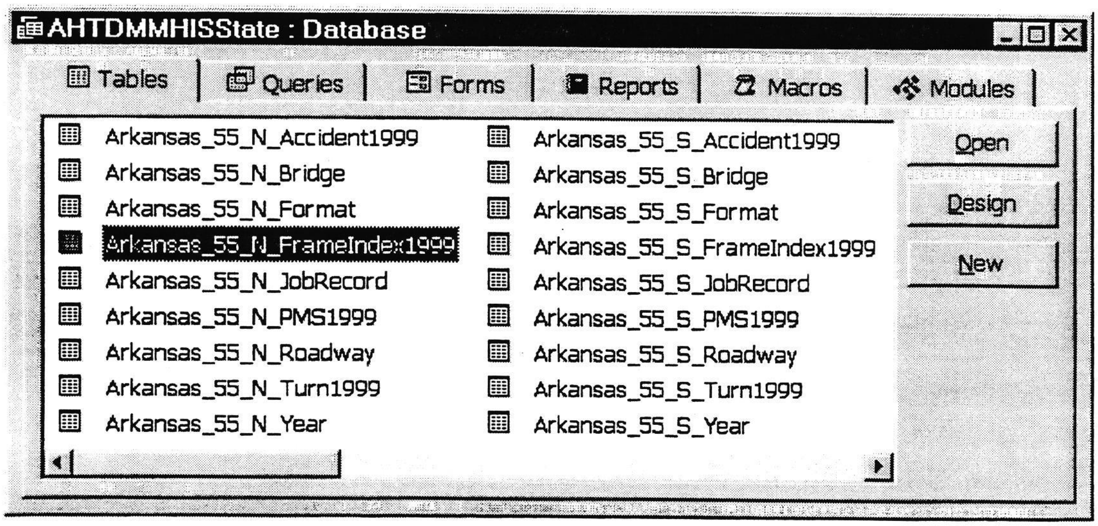

Figure 8 – Database Tables For Each Route

In Figure 8, the database file name is AHTDMMHISState.mdb. Site data of a certain route and direction are put into nine tables. Some of the table names have a year number as their suffix. For this kind of data, multiple years' data can be put into different tables. Therefore the total number of tables may exceed nine.

Following is a brief introduction to the structure of the database tables. For detailed information on the data types of the fields, please open the database in MS Access and open the tables in design mode.

The ***accident table*** contains data on accidents. The Figure 9 shows the structure of this table.

Arkansas_55_N_Accident1999 : Table

Field Name	Data Type	Description
DateUpdated	Text	
CrashNumber	Number	
LogMile	Number	
Section	Text	
NumberOfFatalities	Number	
NumberOfInjuries	Number	
CrashInConstructionZone	Number	
IntersectionType	Number	
NHSCode	Text	
RoadSystem	Number	

Figure 9 – The Accident Table Structure

Figure 10 shows the structure of the ***bridge table***.

Arkansas_55_N_Bridge : Table

Field Name	Data Type	Description
ID	AutoNumber	
LogMile	Number	
BeginningLogMile	Number	
EndingLogMile	Number	
Section	Text	
DateUpdated	Text	
StructureNumber	Text	
FacilityOnStructure	Text	Route carried by structure
HighestMinimumVerticalClearai	Text	
HighestMinimumVerticalClearai	Text	
YearBuilt	Text	
MainSpanType	Text	Main structure type
ApproachSpanType	Text	Approach structure type
NumberOfApproachSpans	Text	
MaximumSpanLength	Text	Length of maximum span
StructureLength	Text	
CurbToCurbWidth	Text	Bridge width curb to curb
OutToOutDeckWidth	Text	Deck width out to out
DeckCondition	Text	
SubstructureCondition	Text	
OperatingRating	Text	in Tons
BridgePosting	Text	
RoutineInspectionDate	Text	
DesignatedInspectionFrequenc	Text	
YearReconstructed	Text	
DeckType	Text	
SurfaceType	Text	Type of wearing surface
SufficiencyRating	Text	
ReplacementFundingCode	Text	

Figure 10 – The Bridge Table Structure

Figure 11 shows the structure of the ***format table***. This table is used to format the display of the site data in a specific window. It is also used to store the conversion factors for different unit systems. Currently Metric and Imperial systems are supported.

Arkansas_55_N_Format : Table

Field Name	Data Type	Description
FieldName	Text	field name in the database tables
Caption	Text	text shown in the site data view
Type	Text	't' for text, 'i' for integer, 'f' for float
Unitless	Yes/No	'Yes' if this item has no unit. Otherw
MetricsUnitName	Text	'Km', 'Meter', etc.
MetricsConverter	Number	multiplier to convert the number int
ImperialUnitName	Text	'Mile', 'Ft', etc.
ImperialConverter	Number	multiplier to convert the number int
Format	Text	'%s', '%d', '%8.3f', etc. used to forr
GroupName	Text	name of the group this field belongs
DefaultDisplayOrder	Number	default order for site data display
SourceTable	Text	'fixed' or 'year'

Figure 11 – The Format Table Structure

Figure 12 shows the structure of the ***frame index table***. The frame index table is used to locate site data based on the current frame number of the video. In this way, the video playing is synchronized with the site data display.

Arkansas_55_N_FrameIndex1999 : Table

Field Name	Data Type	Description
LogMile	Number	
Section	Text	
VideoFileName	Text	
StartFrameNumber	Number	
EndFrameNumber	Number	
TurningMovementFlag	Number	

Figure 12 – The Frame Index Table Structure

Figure 13 shows the structure of the ***job record table***.

Arkansas_55_N_JobRecord : Table

Field Name	Data Type	Description
DateUpdated	Text	
BeginningLogMile	Number	
Section	Text	
JobNumber	Text	
ProjectLength	Number	
MinuteOrderNumber	Text	
MinuteOrderDate	Date/Time	
LetDate	Date/Time	
CompletionDate	Date/Time	
TotalCost	Number	
Location	Text	
TypeWork	Number	
HIPTypeWork	Text	
IncludedInHIP91	Text	

Figure 13 – The Job Record Table Structure

Figure 14 shows the structure of the ***PMS table***.

Arkansas_55_N_PMS1999 : Table

Field Name	Data Type	Description
LogMile	Number	Milepost
Section	Text	
IRILeftWheelPath	Number	
IRIRightWheelPath	Number	
RuttingLeftWheelPath	Number	
RuttingRightWheelPath	Number	
Grade	Number	
FaultCount	Number	
AverageFault	Number	
MaximumFault	Number	
Latitude	Number	
Longitude	Number	
Speed	Number	

Figure 14 – The PMS Table Structure

Figure 15 shows the structure of the ***roadway inventory table.***

Arkansas_55_N_Roadway : Table

Field Name	Data Type	Description
ID	AutoNumber	
DateUpdated	Text	
District	Text	
County	Text	
Section	Text	
BeginningLogMile	Number	
EndingLogMile	Number	
Length	Number	
RuralUrbanCode	Text	
FunctionalClassification	Text	
NHSSystemClassification	Text	
SurfaceTypeCode	Text	
SurfaceWidth	Number	
LaneWidth	Number	
MedianWidth	Number	
RightShoulderSurfaceType	Text	
LeftShoulderSurfaceType	Text	
RightShoulderWidth	Number	
LeftShoulderWidth	Number	
JobNumber	Text	
YearBuilt	Text	
AverageDailyTraffic	Number	
YearADTCollected	Text	Not present in Bobby's table.

Figure 15 – The Roadway Inventory Table Structure

Figure 16 shows the structure of the ***turn table***. The turn table is used to chain sections of the same route together.

Arkansas_55_N_Turn1999 : Table

Field Name	Data Type	Description
LogMile	Number	
Section	Text	
LeftState	Text	
LeftRowID	Number	
LeftLogMile	Number	
LeftSection	Text	
ThroughState	Text	
ThroughRowID	Number	
ThroughLogMile	Number	
ThroughSection	Text	
RightState	Text	
RightRowID	Number	
RightLogMile	Number	
RightSection	Text	

Figure 16 – The Turn Table Structure

Figure 17 shows the structure of the ***year table***. The year table is used to register year numbers that the database has data on.

Arkansas_55_N_Year : Table

Field Name	Data Type	Description
Year	Text	

Figure 17 – The Year Table Structure

Database Composition

The master table

For all of the routes, the route number, direction, database file name, and video file path should be stored in this table. The "ImageFilePath" field is not used in the current version of MMHIS. The table is named "Arkansas_Master" and is stored in the main database file.

The accident table

The "Date Updated" field should reflect the date of the data the table contains. All other fields should be copied directly from AHTD's "Accident Data" table, which contains accident data for all routes and sections. The accident table should be named as Arkansas_<route number>_<direction>_Accident<year number>. For example, the accident table for the 1999 data of route 55 north should be named as "Arkansas_55_N_Accident1999."

The bridge table

The " Date Updated" field of the bridge table ("the new table") should reflect the date of the data the table contains. All other fields should be copied from AHTD's bridge table, which contains data about NHS bridges on or over NHS routes ("the original table"), and bridge data for all routes and sections. One exception is the "minvu" field of the original table. It needs to be split to two parts and put into two corresponding fields. For example, a value 1602 is split to 16 and 2. They are put into the fields " HighestMinimumVerticalClearanceFeet" and " HighestMinimumVerticalClearanceInches" respectively. The bridge table should be named as Arkansas_<route number>_<direction>_Bridge. For example, the bridge table for route 55 north should be named as "Arkansas_55_N_Bridge."

The format table

Normally the format table need not be changed. When new routes are added to the database, the format table for any other route can be copied and renamed for the new route. The format table should be named as Arkansas_<route number>_<direction>_Format. For example, the format table for route 55 North should be named as "Arkansas_55_N_Format."

The "Caption" field stores the text that is displayed in the site data window's "item" column. The "Type" field stores the data type of the item. The "Unitless" field stores a flag indicating if the item has a unit or not. The table treats the item with two unit systems: the metric and the imperial. The metric unit name for the item is stored in the field "MetricsUnitName." The imperial unit name for the item is stored in the field "ImperialUnitName." The field "MetricsConverter" saves the conversion factor for metric unit. The field "ImperialConverter" saves the conversion factor for imperial unit. Data stored in the database are multiplied by the corresponding conversion factors to yield the final number to be displayed in the site data window. The "Format" field stores the C format string to be used by the program to format the data for display. The "GroupName" field stores the text string to be used as the category name in the site data display. Items will be displayed in the order specified by the field "DefaultDisplayOrder". The "SourceTable" field specifies which table the item's data is from.

The frame index table

The "LogMile" field stores the log meters collected by the ARAN vehicle. Because the log meters collected by the ARAN vehicle do not match the roadway inventory data, some adjustment should be made before the data is entered into the table. This will be addressed in later sections. The field "Section" stores the section for the corresponding "LogMile." The "VideoFileName" field stores the video file name of the video for this LogMile. The "StartFrameNumber" field and the "EndFrameNumber" field store the frame range for the log meter of the current record. The "TurningMovementFlag" field stores a flag signaling a turning point. This is currently used to achieve section continuation. All the fields except "LogMile" and "Section" are maintained by a utility offered by MMHIS. The information on how this is done can be found in the section entitled "Building the Index." The frame index table should be named as Arkansas_<route number>_<direction>_FrameIndex<year number>. For example, the frame index table for the 1999 data of route 55 North should be named as "Arkansas_55_N_FrameIndex1999."

The job record table

The "Date Updated" field should reflect the date of the data the table contains. Other than that, the fields are copied from AHTD's "Job Status" table. When copying, the "MinuteOrderDate" field's value should be obtained by combining the fields "MINUTE ORDER MONTH" and "MINUTE ORDER YEAR" of the AHTD's "Job Status" table. The "LetDate" field's value should be obtained by combining the fields "LET MONTH" and "LET YEAR" of the AHTD's table on job status. The "CompletionDate" field's value should be obtained by combining the fields "MONTH COMPLETED" and "YEAR COMPLETED" from the AHTD's "Job Status" table. The job record table should be named as Arkansas_<route number>_<direction>_JobRecord. For example, the job record table for route 55 North should be named as "Arkansas_55_N_JobRecord."

The PMS table

The "LogMile" field stores the log meters collected by the ARAN vehicle. It should be exactly the same as those stored in the "LogMile" field of the frame index table. The field "Section" stores the section for the corresponding "LogMile." All other fields except the "Latitude" and "Longitude" fields are copied directly from ARAN vehicle collected data files. Currently the "Latitude" and "Longitude" fields should be left blank. The PMS table should be named as Arkansas_<route number>_<direction>_PMS<year number>. For example, the PMS table for the 1999 data of route 55 North should be named as "Arkansas_55_N_PMS1999."

The roadway inventory table

The "Date Updated" field should reflect the date of the data the table contains. All other fields are directly copied from the corresponding fields of AHTD's roadway inventory table for Interstate - NHS Routes. The roadway inventory table should be named as Arkansas_<route number>_<direction>_Roadway. For example, the roadway inventory table for route 55 North should be named as "Arkansas_55_N_Roadway."

The turn table

This table does not need manual maintenance. It only needs to be created. The turn table should be named as Arkansas_<route number>_<direction>_Turn<year number>. For example, the turn table for the 1999 data of route 55 North should be named as "Arkansas_55_N_Turn1999."

The year table

Whenever a new year's data is added to the database, a new record should be added to this table. The year table should be named as Arkansas_<route

number>_<direction>_Year. For example, the year table for route 55 North should be named as "Arkansas_55_N_Year."

Matching the PMS Log Meters With the Roadway Inventory Data

The roadway inventory data's log mile should be used as the absolute log mile standard. If the length of a section in the PMS data does not match the roadway inventory data's length for the same section, the PMS data's records are evenly stretched or compressed to meet the roadway inventory data's length. This can be done with an Access Basic program or an Access Update Query. It can also be done with some other utilities like the MS Excel.

Building the Index

The frame index table is maintained by a utility offered by MMHIS. From the MMHIS's main window, choose `Tools | Build Index`, a window shown in Figure 18 will appear on the screen.

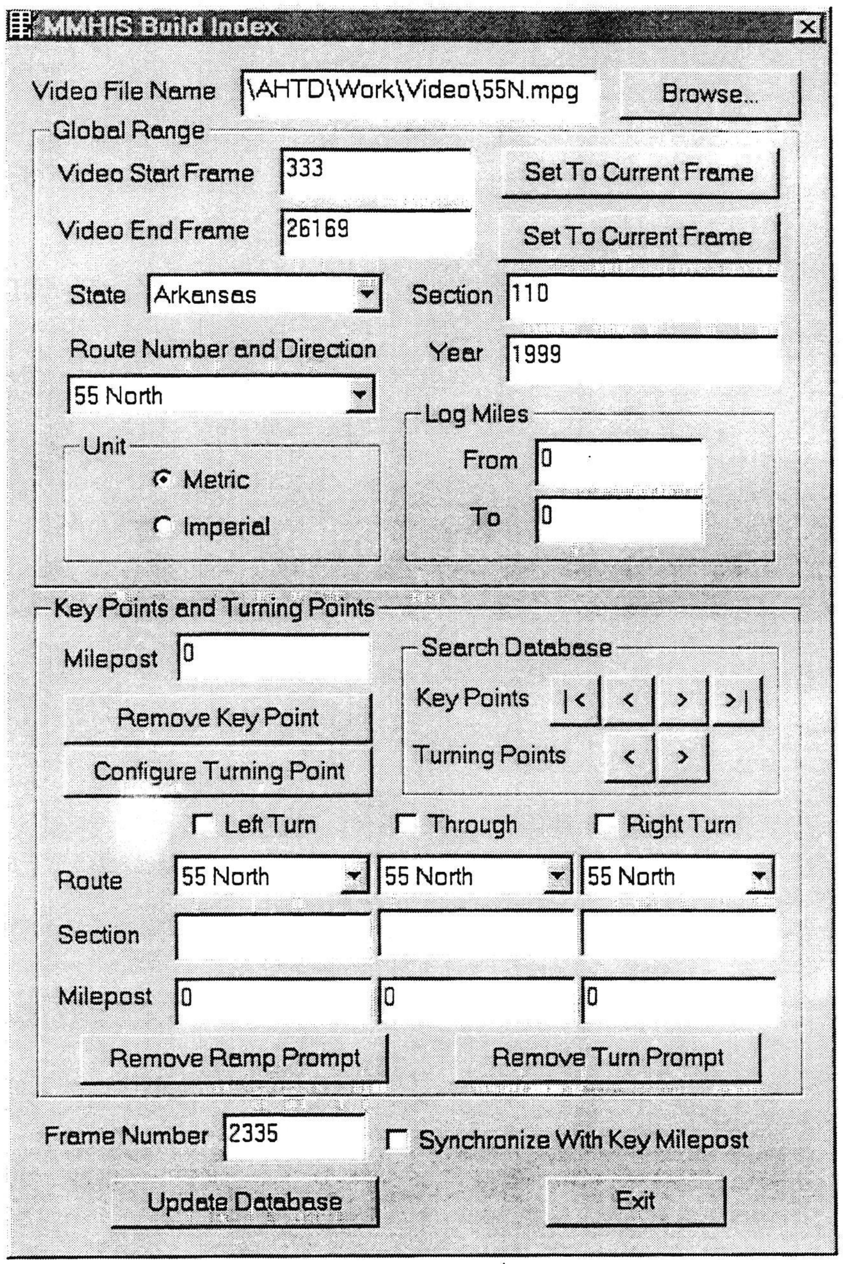

Figure 18 – The Index Building Window

When building the index, first fill out the Video File Name field (this should include path) and all the fields in the Global Range group. The From and To fields in the Log Miles group should be filled out according to the video's coverage of the section of the road. This normally is the same as the section's full length. All the bridges in the section are used as key points. To define a key point, run the video to the point (e.g., the beginning of a bridge) and input the milepost of the bridge to the Milepost field. Then click the Add Key Point button. Existing key points in the section can be found by using the buttons in the Search Database group. After all the key points are defined, use the Update Database button to calculate the frame range for all the records. To remove a key point, input the key point's milepost and click the Remove Key Point button. To remove all the key points in a section, click the Remove Key Point button while holding the control key.

Note that for anti-log direction, the section's log mile range should start with a bigger number and end with a smaller number. That is the number in the From field should be the log mile corresponding to the beginning of the video, and the To field should be the log mile corresponding to the ending of the video. The program uses this information to decide if it is log or anti-log direction.

Chaining Sections

Different sections of a route can be linked together so that when the video reaches the end of one section, it goes to the next section automatically. To do this, use the build index tool and input the ending log mile of the section to the key point log mile field. Then check the Through check box and supply the next section's information (section and beginning log mile). Then click the Configure Turning Point button. This will add a turning flag in the frame index table and update the turn table.

MMHIS User's Guide for AHTD

Launching MMHIS

Logon to the workstation as user AHTD with no password. Double click on the MMHIS icon on the desktop to launch MMHIS. The program shows its main window as in Figure 19.

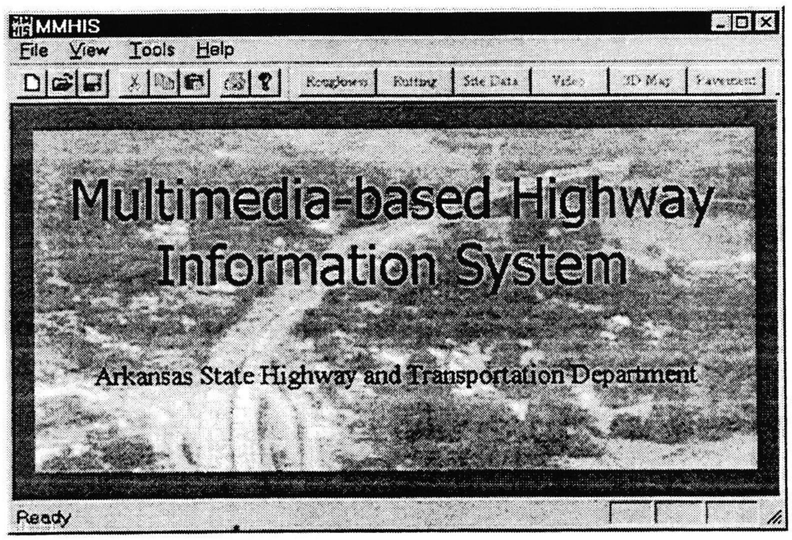

Figure 19 – The MMHIS Main Window

Conducting A Query

To query data for a site using the MMHIS, follow these steps:

1. Opening a new query.

Select from menu *File* | *New*. The MMHIS Query Location window (shown in Figure 20) will appear on the screen.

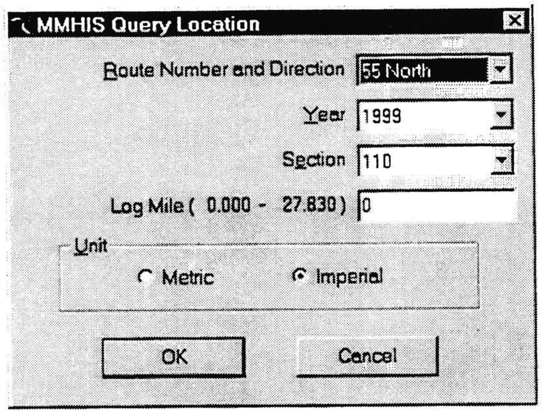

Figure 20 – The MMHIS Query Location Window

Select the route number, direction, year, and section from the corresponding drop-down lists, then enter the log mile of the site in the appropriate box. The log mile will be in the unit specified by the unit selector shown at the lower part of the window. The entered log mile must be within the range shown to the left of the entry. The data available in the drop-down boxes is determined by the engineering data sets that are currently in the database. These data sets were constructed through an authoring process by a system operator who has received training on how to build MMHIS databases. Click OK after everything is specified. The system will open the database and the corresponding video file if the data for the specified location can be queried. If the location does not have complete data sets saved in the database, specifically, if the pavement management system data and the roadway inventory data are missing, the query will not continue. A message (see Figure 21) is shown instead.

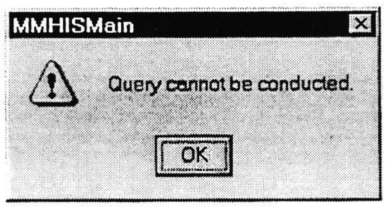

Figure 21 – Message Indicating an Invalid Query

Hitting OK will return you to the main window of the MMHIS.

__Note__: The first button on the toolbar  can be used as a shortcut of the above menu selection to conduct a new query. If the toolbar is not shown in the window, use the menu item *View* | *Toolbar* to show it.

A successfully opened query shows the site data in one window and the video in another window. Two additional windows show roughness and rutting data of a stretch of road in graphics mode. Figure 22 shows a query screen.

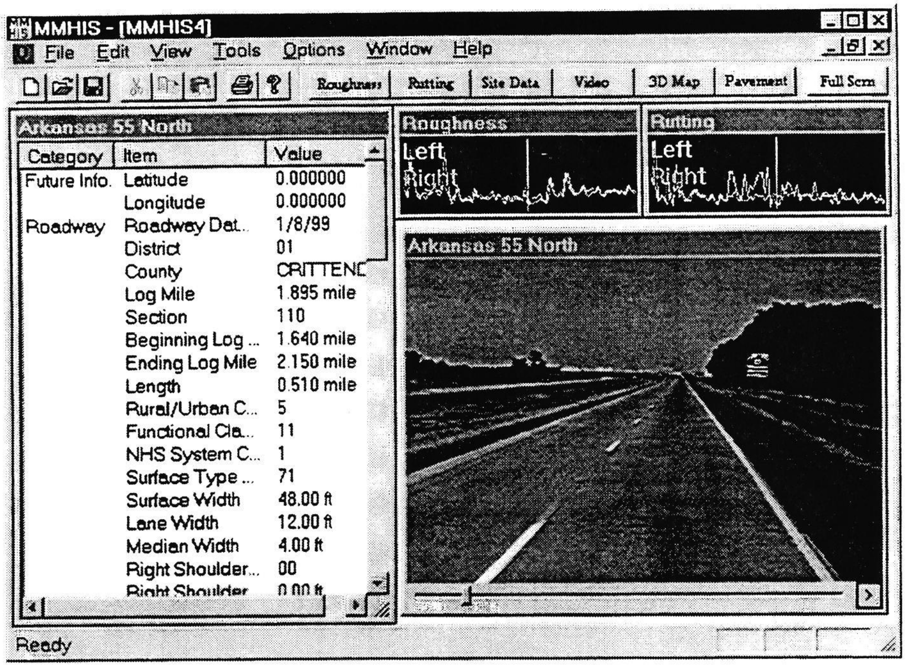

Figure 22 – An MMHIS Query Screen

2. Changing location.

This can be done by selecting the menu item *Tools* | *Specify* Location. The same dialog box that was opened when you requested a new query will appear to allow the user specify a new location.

The vertical bar shown in the graphing windows represents the current location in a stretch of road. It can be dragged to a different position. Everything shown in all the other windows will be synchronized to show data for the new position.

The slider thumb in the video window can be also used to change location. Fine-tuning the location can be achieved by ***double-clicking on the title bar of the video window***. Left button double-clicking causes the video to backup about 100 meters. Right button double-clicking causes the video to advance about 100 meters.

3. Changing site data display format.

The site data are grouped by categories. The groups can be opened and closed by double-clicks on the category title. If a free-style format is preferred, it can be defined and shown by using the context menu of the site data window. Just right click on the window and choose from the context menu *Change Format* to do so.

The font used to display site data can be changed by using the command *Options* | *Choose Font...* or the context menu command *Choose Font....* The unit used in the site data display can be changed by using the command *Options* | *Units* | *Metric* or *Options* | *Units* | *Imperial*. The graphs shown in the two graphing window can be individually zoomed by using the commands *Options* | *Zoom Roughness Graph* and *Options* | *Zoom Rutting Graph*. The same functionalities are also offered through the context menu of the two graphing windows.

The program can run in full-screen mode. Use *View* | *Full Screen* to toggle between normal mode and full-screen mode.

4. Saving and reopening a query.

A query can be saved by using the standard *File* | *Save* or *File* | *Save As* command. The route, direction, log mile, window location, window arrangement settings, format, unit, zooming factors, etc. are all saved into the query file. The file can be reopened with the standard command *File* | *Open...* later to continue the same query.

A query can be closed by using the command *File* | *Close*. The system will offer the user a chance to save an unsaved query when it is being closed.

MMHIS was designed to be able to query more than one site at the same time. Due to the limitations of current hardware and software, however, the current system can only query one site at a time. If a query is opened, it must be closed before another new query is created. Otherwise the second query's video will show a blank window. Also the video window may not always go away when a query is being closed, especially after many queries were opened and closed. This is not a normal behavior. In case this happens, use the Windows NT Task Manager (available by pressing Ctrl+Shift+Esc key combination) to end the process of MMHISVideo.exe. We are planning to provide multiple video-window support in the next version of the MMHIS.

Recommendations on MMHIS Operation and AHTD's Future Highway Information System

Using high quality digital video and integrated databases in field operations through a computer network is the first of its kind for highway management. The operation will require dedicated personnel to manage and conduct the authoring of the database. In the past few years, technologies associated with MMHIS and highway data collection were developed at the University of Arkansas through a number of research grants from the Arkansas State Highway and Transportation Department (AHTD) and others. A key portion of these technologies are used in the present MMHIS, which is planned to be implemented at AHTD, while others may have potential to be used in conjunction with the MMHIS to have a streamlined data process from collection to delivery.

Resource and Logistic Needs for MMHIS Operation at AHTD

There are several tasks associated with the operation of MMHIS at AHTD headquarters. The tasks are not necessarily in sequential order in time nor in importance.

Task 1: Digitization of Tapes into MPEG-2 Video

There is a total of 3,600 miles for Interstates and NHS in Arkansas. Assuming the average taping speed is 50 MPH, the videotapes in one cycle of data collection would total 72 hours in length. Based on our experience in digitizing tapes at the university Lab for the MMHIS, there will be a minimum 100% overhead in the time required for digitization. That is there should be 144 hours for the digitization process for the tapes in one data collection cycle. The time overhead is large due the fact that there will be time used to prepare tapes and equipment, naming video files, and re-digitizing due to errors or video quality issues. Therefore, it would take one-month of time for one dedicated person to digitize the tapes of the Interstate and NHS. The skill needed for this task is a technician at entry level with a background of basic computer operation.

Task 2: Database Preparation

This process may take most of the time, as databases at AHTD that could be useful for MMHIS are currently located at various computers, managed by different personnel, and of different formats. It is also anticipated that as the MMHIS is being used at the AHTD, more data sets will be put into the MMHIS database. It is estimated that a full-time staff will be needed to fulfill the requirements of this task. Skill needed for this task is a technician at an advanced level and who is intimately familiar with database software, Microsoft Access and the Microsoft Windows operating system.

Task 3: System Management, Maintenance, and Logistical Operation between AHTD and the Research Team at the University

The RAID system and the MMHIS authoring workstation will need maintenance as additional data and video is collected and brought into the office. In addition, the RAID system should be linked to the internal computer network at the AHTD headquarters. There exists a need for a person who will be responsible for the management of the hardware systems for the MMHIS, the network connection of the MMHIS, and technical support for the MMHIS users. In addition, the university team may continue to work on the MMHIS. This person will also act as a liaison between the AHTD and the university and handle the logistics such as transferring videotapes and digital video files. It is estimated that a half-time person will be needed to carry out this task. Skill needed for this task: computer information staff with strong background in both hardware and software, and highway databases.

As MMHIS is still being refined to fit the needs of AHTD, the university research team can be responsible for Tasks 1 and 2 in the near future if needed. When the features of MMHIS are frozen and the MMHIS is in full operation, AHTD can take over these two tasks. During this transition period, data transfer can be conducted through two 50-GB external SCSI drives between Little Rock and Fayetteville.

Further Integration with Data Collection and Future Directions for MMHIS

Traditionally, highway data collection and application are independent processes predominantly involving analog-based visual information. Currently, AHTD is preparing to use a digital information system, which is still based on analog tapes through the use of a data vehicle. As the collected data can be used in various divisions in a highway department, the need to establish an integrated, department-wide information system is apparent. This is even more evident when information technology itself is progressing at a rapid rate. Figure 23 illustrates a designed enterprise system with the entire data flow paths. The development is based on Intranet for the internal information system, and the Internet for the general public will fulfill the need of an open and portable system that can be easily deployed in any highway agency.

In this enterprise information system shown in Figure 23, the data vehicle is a digital device that directly collects both right-of-way and pavement surface images, and composes the multimedia database while the data sets are being acquired and archived in a computer system in the data vehicle. The data sets include images and positioning information from a Global Positioning System receiver and from other sensors. The research team using the university data vehicle has largely completed the basic development of the digital device for both right-of-way and pavement surface imaging. The multimedia databases can be immediately downloaded into the server for viewing without the process of digitizing tapes.

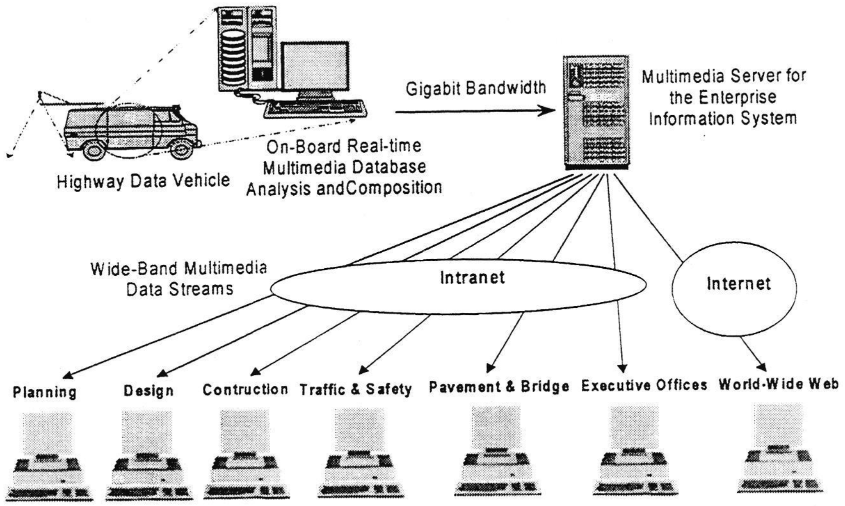

Figure 23 An Enterprise Information System

For right-of-way video, we developed the technique of using MPEG-2 encoding for motion video at standard resolution (current MMHIS quality) and high-resolution color image acquisition at fixed distances at the resolution of 1300 by 1024. Both MPEG-2 motion video and high-resolution still images are acquired simultaneously, and also can be viewed through the synchronization module, such that motion video is synchronized with the still images. However, the developed technology would allow AHTD to use either MPEG-2 motion video, or high-resolution still images, or a combination of both.

In addition, a mapping utility developed in a Lab environment can be used with MMHIS so that query can be conducted on a highway shown in the map. As collected images and sensor data already have GPS positioning information, the relevant data can be geo-referenced, as long as there are also positioning data for the highway network on the digital map of the state of Arkansas.

A major advantage for AHTD to apply the direct digital acquisition of multimedia data sets is the elimination of the process to digitize videotapes and author the multimedia database. The manual process of tying video frames to physical highway location is not only tedious, but also prone to errors. In the even that AHTD chooses to use the direct digital acquisition approach, there would be no need for AHTD to conduct Task 1 and a large portion of Task 2, resulting in substantial savings.

Furthermore, AHTD may want to incorporate additional database features into MMHIS. For instance, current MMHIS only displays summary of accidents in each section. A new feature would be to display accident data at roadway locations where they occurred. In addition, the display of Job Status in current MMHIS only shows the most recent job on the roadway section. The user may want to view the major construction job done at the section, not necessarily the most recent one.

Conclusion

MMHIS represents a major step in the process of applying digital technology for highway management. This implementation project has reflected the needs of AHTD staff in using their current analog video data and site engineering data sets. Several key changes and improvements of MMHIS were made over the previous MMHIS developed in TRC 9606, including tighter integration with AHTD databases, synchronization based on bridge information, query based on sections, and several other software improvements. It is hoped that through this implementation, further improvements will be made to MMHIS, such as integration of more data sets into MMHIS database, directly using digital devices to collect visual information, therefore eliminating several manual steps in composing MMHIS databases.