Low Cost Methodology for Preliminary Road Maintenance Decision Support

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Abstract

This paper presents a low cost GIT based data collection technology that is similar and an input to the ROad Maintenance Data Acquisition System (ROMDAS). It is composed of a vehicle, two digital video cameras, 2 GPS receivers and a notebook computer. Two different camcorders used for comparison purposes (one real color and the other a modified consumer camera to register infrared) are mounted at the front of the vehicle using a homemade gyro mounting. The GPS receivers are placed at the dashboard of the vehicle. The notebook computer and GPS receivers are configured to record the position of the vehicle as it moves. The GPS log files maintain recordings of the latitude, longitude, time, speed and altitude of the vehicle position, as the researcher annotates a map document in the ArcGIS 9.3 software with location referencing details and various road attributes. This data collection technology is aimed at exposing the potential of Geographic Information Technologies (GITs) in performing inventory of the road condition. The captured data may be useful for a variety of applications relevant to road inventory and maintenance. It is basically recommended for preliminary road maintenance diagnosis for which in depth road analysis may proceed for the affected road sections. With this technology, it is possible to map road marks and other architecture along the road and provide a map immediately by the end of the survey. In conclusion, data mining of the spatial video databases to facilitate routine and periodic maintenance decisions and the possibility to modify consumer cameras for research purposes is recommended.

Keywords: Geographical Information Technologies (GIT), Low Cost, Road maintenance, Video-log, ROMDAS

1. Introduction

Various technologies are available to provide information to asset managers, policy makers and funding agencies concerning their road network (Fawcett et al., 2002). This information is intended to foster informed decision making. Besides knowledge of the mere network, i.e. inventory data, information relating but not restricted to, the spatial location of the roads, their condition, pavement type, traffic and features that are located along the road including bridges, sign posts and culverts are also quite relevant to the asset management departments. Therefore, numerous data types need to be collected to successfully apply a Road Asset Management System (RAMS). These are acquired through a comprehensive set of road surveys such as Location Reference Points (LRPs), Roughness (IRI- International Roughness Index), and Global Positioning Systems (GPS) surveys.
Often, data collection attempts for road maintenance requirements are spearhead in a big way. A team of road engineers is sent out to collect Information Quality Level 1 (IQL-1)* data on a whole road network of say 500km. In reality however, only sections of this network covering for example < 30% of the road is usually in need of immediate attention. The low cost GIT based methodology discussed in this paper is intended to introduce the concept of preliminary data collection of road condition on the whole length of the targeted road from which detailed data collection can proceed along the identified critical sections. The data levels recognized by the World Bank Paterson and Scullion (1990) were taken into account while collecting data with this technology. The data collected was only appropriate for the planned use, which as earlier mentioned was to preliminarily highlight maintenance required sections for further analysis. The methodology collected data at IQL-3, which data could then be used in preliminary screening studies for further road maintenance decision making. It is intended that in this screening study, sections that warrant more detailed investigation can be identified and analyzed more technically and at depth using the ROMDAS (see section 2.0). This is basically to avoid detailed data collection on the entire length of road, especially in financial stringent situations, which data eventually becomes useless for priority maintenance actions.

This technology is composed of a vehicle, two digital video cameras, 2 GPS receivers and a notebook computer. It involved video logging the road and storing GPS coordinates of the video-log. Video-log data collection technologies are quite popular of recent. This is partly because, the time spent in acquiring the video-logs and GPS signals in the field is very short. The unprocessed video is quite informative at onset as compared to cumbersome manual data collection techniques that obviously require processing before they can make sense to the decision maker. Even though augmenting the video captured is often a requirement which is obviously time consuming, this process happens in the office/ laboratory far from the uncertain field conditions (Silva et al., 2003). In Silva et al. (2003), a list of platforms for a couple of navigation and mapping sensors has been discussed. Vans and trucks are majorly used, but also, cars, trains and aircrafts, to develop the vast types of equipment for this navigation and mapping. Digital compasses, GPS, gyros, and odometers are used for navigation while, a number of CCD digital cameras, analogue cameras and digital camcorders are used for mapping. These mobile mapping systems have various names as decided upon by the various developers. Details can be obtained from Silva et al. (2003). This paper discusses a low cost methodology using GIT concepts to obtain an inventory of road

*Information Quality Level – 1 (IQL-1) data is the highest resolution and precision data. These information quality levels range from IQL-1 to IQL-5 in the order of reducing resolution and precision. The IQL is often agreed upon by relating the hierarchy of needs as well as the analysis methods for the data. It is a very fundamental consideration in data collection so as to collect just the right data that is actually required by the analysis.
condition data for preliminary road maintenance decision support. With this methodology, a road condition inventory base map of the road network is provided by the end of the survey. This development is part of an ongoing research targeting the accentuation of GIT use in the road infrastructure maintenance division of Kampala, Uganda.

2. The ROMDAS Technology

The most common video surveying technology in use to date is the well-known ROad Measurement and Data Acquisition System (ROMDAS). The ROMDAS was developed as a generic system for collecting data on road condition and travel time (Rashid and Tsunokawa, 2006). With ROMDAS, it is possible to conduct various surveys including: roughness, travel time, congestion, condition ratting, inventory, moving traffic, transverse profile/rutting and video logging surveys. Global Positioning Systems (GPS) data can be collected, the location of digital photographs recorded, and voice records which are associated with road attributes can be created (Sodikov et al., 2005, Hunter and Porter, 2005, Fawcett et al., 2002). ROMDAS is one of the few data collection systems that has been specifically designed for developing countries to be used by local road controlling agencies (Fawcett et al., 2002). In Uganda, the Project Management and Engineering Consultancy (PROME) is using ROMDAS to collect data to populate the national road databank and later design an asset management system. This data is to be used as a decision support tool for preparing annual and multi-annual maintenance and investment work plans and reporting in general. The system consists of a video camera and several measuring devices including a gyroscope, GPS receivers, odometer, bump integrator, etc, mounted on a vehicle, together with software that processes the measurements. As the vehicle moves, the visual road condition is recorded by the video camera. Meanwhile, the ROMDAS maintains synchronization between the video and the discrete data acquired by the several measuring devices on board (Dragan Ivetic et al., 2010). The ROMDAS is a flexible, easy to transport and well documented system that involves 3 modules (survey, record, and play back). Fawcett et al. (2002) provide an elaborate architecture of the ROMDAS.

Regardless of its obvious advantages, the ROMDAS collects so much data that in many situations remains useless besides creating storage and analysis problems for the road management departments. The Low cost GIT based methodology proposed in this paper suggests preliminary data collection for the entire road network at IQL-3. The results of this preliminary survey then lead to more detailed data collection with the ROMDAS along only the critical sections prior highlighted. These proceeding data collection and analysis phases should then be aimed at higher IQL-1 data.
3. Low cost GIT data collection methodology

This low cost GIT data collection methodology is similar to the ROMDAS technology. The methodology has been prototyped for selected roads in Jinja district of Uganda in East Africa. It is composed of a vehicle, two digital camcorders (a Canon HF 11 and a Sony HDR CX 520 VE), 2 GPS receivers (DG-100 GPS Data logger + receiver and BT-359S Bluetooth GPS receiver), and a notebook computer (Panasonic Toughbook CF-U1 running windows XP). The Sony camera was modified to record IR and the Canon was maintained with real color. The reason for the use of these 2 cameras was for comparison of real and infrared imagery of the captured road sections. The IR camera was mainly intended to capture the road shoulders besides the carriageway which ordinarily would not effectively be registered with a RGB camera because of the vegetation interference. This comparison is briefly discussed under the discussion section. The digital camcorders are mounted at the front guard rails of the vehicle, see Figure 1. The GPS receivers are placed at the dash board of the vehicle and they record the position of the vehicle, its time, speed and altitude. The visual road condition is recorded by the camcorders as the vehicle traverses the road. Meanwhile, the GPS loggers are synchronized with the GIS on the notebook computer to allow for tracking of the video path and making of annotations at LRPs and important road features & architecture along the road.

This technology is a position towards Intelligent Transportation Systems (ITS). ITS intend to use existing Information Communications Technologies (ICT) capacity more effectively by collecting detailed spatial and temporal data about the transportation network and using this information in transportation system management. The accomplishment made with this technology is also an awareness of the potential of GITs in the road infrastructure management sector. It is a pointer to the road maintenance organisations that preliminary data collection is a requirement before higher IQL data can be collected. Besides the expense of data collection, these high IQL data require technically involving analysis techniques that should not be unnecessarily performed on the whole length of a road.
3.1 Methodology

The network was prior divided into manageable sections that began and ended at known LRPs. The following hardware components were used; a vehicle pickup cabin with front guard rails, 2 GPS receivers (the 2nd handset was for backup purposes), two digital video cameras (Sony HDR CX 520 VE and Canon HF 11) and a notebook computer. The two cameras were mounted onto the guard rail of the vehicle using a homemade gyro mounting. The Canon HF 11 used visible light films that were recorded in full HD 1080p* (1920 * 1080). The Sony HDR CX 520 VE recorded in 1080i and was modified to Near Infrared (NIR).

3.1.1 Preparation

Initially, two (2) B+W 093 filters were placed in front of the lens of the Sony, to filter out the visible light (VIS). This was because light was so intense at the time of the survey and the automatic exposure measuring in the camera is only calibrated to VIS. An equivalent of a strong grey filter was placed outside the lens as light continued to be intense, see Figure 1. Fully charged cameras and GPS receivers were maintained with ready memory space.

*The p stands for progressive, meaning that every row of every frame is recorded in contrast to the 1080i, i standing for interlaced, where lines 1, 3, 5... of the first frame are recorded, lines 2, 4, 6... of the second frame, and lines 1, 3, 5... of the third frame and so on.
3.1.2 Location Referencing

At the start of the survey for a particular road section, link nodes and sections were predetermined for location referencing. No field signage was installed. Actual location referencing was performed during the course of the survey. The components qualifying linear referencing methods were professionally dealt with in the following manner;

1. Identification of a known point. These points comprised of KM posts, bridges and junctions and at such points, digital photos were taken. Their locations were annotated in the map document as GPS logging occurred.
2. Direction. For each video-log, a narration in the film was made about the current location of the survey vehicle and the direction that the vehicle was heading to. Sketches of this information were also made to the map document.
3. Distance measurement. The vehicle odometer was used to make distance measurements.

3.1.3 Data capture

This began from junction to junction and displacements were measured from 0 metres at the first node in the increasing direction of the moving vehicle. Sections then began and ended at more clearly defined junctions and roundabouts. The GPS receivers were placed at the dash board of the vehicle. The Panasonic Toughbook CF-U1 (with inbuilt GPS) running with windows XP and ArcGIS 9.3 was configured and synchronized together with the DG-100 GPS Data logger + receiver and BT-359S Bluetooth GPS receiver to record the position of the vehicle as it moved. On the notebook computer, the researcher maintained an annotated map document of the path taken by the vehicle with a Landsat ETM+ image at the background. At LRPs, the researcher made remarks in form of drawings and descriptions as annotations to the map document; see Figure 2. Features relating to roundabout locations, taxi parks, water falls (Bujagali falls), railway crossings, airfields and the golf course location to mention but a few, were demarcated on the shape file. Note that these are referred to as events when modeling transportation data in GIS and as such, are vital data requirements.
Figure 5: Field Base Map Document
3.2 Discussion

There are numerous providers of the state of the art data capture equipment for road network surveys (Fawcett et al., 2002). This particular low cost GIT based technology collects 2 basic categories of information; spatial coordinates using GPS and video logging for inventory and condition records. The software coming with Global sat GPS allows saving the GPS locations in different file formats. Figure 3 shows a snap shot of the GPS data in an excel sheet. The attributes to the captured records are Date, Time, Latitude, Longitude, Speed (Km/Hr) and Altitude in Meters. Figure 4 shows a snap shot of the Google Earth coverage from the KML file. The pegs along the road indicate the vehicle positions during the survey.

Two cameras were used and logging was done along both the from and to directions. An event point or detail on the road can therefore be seen from several positions of the
video-log. If analysis in one position was not effective, then successive positions would be used for more informative analysis. Figure 5 shows a snapshot of the video-log of the same position captured by the two different cameras at the same time instance. It is imperative to highlight the differences in the video-logs from the two different cameras and their causes. The cameras were mounted at the same side of the vehicle. In the forward direction of the vehicle, the canon was clamped on the left and the Sony on the right (further outward). This explains the difference in the portion of the road that is visible from each camera at the same time instance.

![KML plot of the GPS log](image)

**Figure 7: KML plot of the GPS log**

![Sections of Bujagali road captured at 10am](image)

**Figure 8a&b: Sections of Bujagali road captured at 10am**

When recording from inbuilt Bluetooth GPS, the user presets the rate at which recording should be made. This would naturally be inclined on the availability of satellites and the strength of the signals. Initially, the GPS locations were captured every second. This created a lag in the base map being annotated. The time was then reset to 5 seconds which proved exact in tracing the vehicle concurring to its speed. In harmony with the ROMDAS recommended speed of maximum 60km/hr, the average speed of the vehicle for the sample dataset in figure 3 is 56.535km/hr. This clearly shows that the methodology advocated for is still within the guidelines of the well
documented and recognized ROMDAS technology. A comparison of the ROMDAS and this low cost GIT technology is summarized in Table 1.

**Table 6: Comparison between the ROMDAS and the GIT Based Technology**

<table>
<thead>
<tr>
<th>Comparison parameter</th>
<th>ROMDAS</th>
<th>Low cost GIT based technology</th>
</tr>
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<tbody>
<tr>
<td>System components</td>
<td>Comprehensive ROMDAS system components comprising of both hardware &amp; software: Video camera, gyroscopes, bump integrator, odometer, DCP, GPS equipment, etc</td>
<td>Flexible and readily available equipment: GPS equipment, video camera, and laptop computer</td>
</tr>
<tr>
<td>Calibration</td>
<td>Demanding (time involving) calibration requirements for all system components</td>
<td>No calibration required. Preparations made include; fully charged battery, readily available memory space, filter placement for IR camera</td>
</tr>
<tr>
<td>Location Referencing</td>
<td>Location referencing procedures are involving. Performed and documented prior to the survey</td>
<td>Convenient location referencing performed during the survey</td>
</tr>
<tr>
<td>Speed</td>
<td>Maintained at &lt;= 60km</td>
<td>Managed by the driver depending on firmness of the digital cameras. Average for sample dataset is 56.535 Km/hr</td>
</tr>
<tr>
<td>Personnel</td>
<td>Requires skilled personnel for survey and analysis</td>
<td>Ordinary GIS professional required for survey and analysis</td>
</tr>
<tr>
<td>Survey results and data</td>
<td>• Time required to process measurements after the survey: IRI, GPS data, video-log, rut depth, distances, speed, transverse profile, etc.</td>
<td>• Results in form of a map document available at the end of the survey</td>
</tr>
</tbody>
</table>

All the comparison parameters above have cost implications. Some costs are directly incurred while others are indirect as implied in the time and involving procedures undertaken in surveying with the ROMDAS. The resolution and precision requirements attributed to IQL-1 data accrues additional expenses. The expertise required to interpret and process the ROMDAS data are equally expensive as compared to the ordinary GIS professionals performing works in the above described methodology. The calibration and location referencing procedures of the ROMDAS are likewise time consuming which relates to indirect costs.
3.2.1 Challenges and their effects

This low cost GIT technology is not without challenges. It is affected mainly by three issues; Rainfall—since the cameras are clamped outside the vehicle, no survey can be done during the rain, -extreme sunshine especially with the Sony modified camera. This was irrespective of the filters used. Moderation of speed was also of concern considering the fact that it is majorly done by the driver of the vehicle. The snap shot in figure 6 is of the same location as that of figure 5. The log of figure 5 was captured in the later morning with the sun high in the sky. That of figure 6 was captured on the same day but after some rain in the afternoon. Notice that videos from both cameras register better imagery with a sun free sky. The real color image however shows limited contrast. For the IR image, the log captured shortly after the rain is remarkably of better clarity than the one captured during high rise sunshine. This justifies the need for the extra grey filter especially at maximum sunshine. The spectral nature of light is known to influence imaging and image properties. It is therefore recommended that for the best video-log, the sun should not be high above the horizon, for when in that position, the sun lights directly into the potholes limiting contrasts in the captured video. Although the differences are sometimes negligible, better images are produced in the early mornings (before the high rising sunshine) or later in the evenings. Even if traffic counts are recommendable with this technology, it is advisable to survey at low traffic times to allow for more visibility of the road condition.

3.2.2 Sony HDR CX 520 VE and Canon HF 11 cameras compared

The major difference between the two camera products was as a result of the image stabilizing system. The Sony has a far better optical image stabilizing system. Both were mounted at the same holder, the Sony even further out, which would mean more movement in bumps. However, the vehicle bumping affected the canon camera much more than the Sony camera. Additionally, the Sony has an advantage of the inbuilt GPS showing the coordinates when played from the camera. Despite its poor image stability, the canon HF 11 has the best image quality available. This affirms that the sensitivity of a camera is inversely proportional to its image stability. It records on internal RAM 32 GigaByte, alternatively on a SD card which gives more hours of filming and quite long battery time. A recommendation for the image stability would be, to mount the cameras 1. at the rear of the vehicle or 2. at the wind shield, as much as possible towards the rotational centre of the vehicle to minimize the engine’s bumping effect.

In November 2010, Microsoft released the Kinect Xbox 360 video game console. Numerous developers are researching possible applications of Kinect that go beyond the system's intended purpose of playing games. The Kinect has 2 video recording devices, the RGB camera and 3D video sensors which is basically scanning the vicinity and producing depth models. The authors are currently investigating working with the kinect to capture visual road condition. With the kinect’s depth measurement
possibility, the size and extent of potholes can be calculated for purposes of estimating material required for pothole fixing. The suggestion is to mount it downward on the back of a car to register surface roughness of the road. This could even produce better results during the night as the irritating solar radiation together with the traffic is obviously eliminated.

![Real color image](image1.png) ![IR image](image2.png)

**Figure 9a&b:** The same section of Bujagali road as in figure 5a&b, captured after rainfall

## 4. Conclusion

The methodology described above provides both a practical and flexible solution for keeping up to date with road inventory and condition parameters. The captured video-log, GPS data and the map document prove that this low cost GIT based technology is an effective approach to inspecting road pavement condition and to mapping road street furniture and other important features along the roads. It provides for full visual and spatial referenced road condition. These details are quite important for decision making in the planning of road maintenance works. The main quality of the GIT methodology is the completeness, accuracy and effectiveness of acquiring the field data in a short time. Its major contribution is the ability to immediately, at the end of the survey, provide a map document of the route with annotations explaining the road parameters as observed during the survey. It is recommended that at the proceeding surveys from this preliminary level, there should be an increment in the IQL of the data captured. This is because for further analysis of the sections recommended for priority maintenance, more technical and in-depth data analysis is required. This research proposes data mining of spatial video databases to facilitate routine and periodic maintenance decisions. Additionally, there are advancements in camera models on the market which can be modified (e.g. Sony HDR CX 520 VE) and adopted for scientific studies. A modification of the varieties, beyond their intended purpose, should be considered for scientific research of this nature.

In several road management studies, data collection is considered expensive and time consuming. However, this technology, like all others video logging technologies, is
effective in managing this challenge. Since the platform (a vehicle in this case) carries all the hardware and software in just one route, then, in compliance with the appropriate sampling interval, and the IQL standards, all possible data that can be collected should be collected for each route. Whether to use the data will eventually depend on management requirements at that time. This is however in contrast with Bennett et al. (2007)’s advocate for collection of only the data that is needed for the present purpose.

References


