Low Cost Road Condition Data Capture System for Sustainable Road Maintenance in Uganda

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Abstract. A low cost system to document and monitor road conditions in Uganda and comparable countries is presented. We used slightly modified Contour GPS and Micorsoft Kinect, both inexpensive devices that can be purchased off the shelf in most countries.

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1. Introduction

A well-functioning transport infrastructure is crucial for day to day life in a modern society. In most countries, travelling and gods transport is achieved by a combined network of road, rail, air and water transports. In an ideal case these services are coordinated, and give the best performance in terms of cost and travel time.

In the case of Uganda, a land locked country in sub-Saharan Africa, many parts of this desirable network are either initially missing (possible boat transport on Lake Victoria) or are not functioning due to lack of maintenance in postcolonial times (the rudimentary rail network). As air transport usually is more expensive, almost all transport is relying on the existing road network our study is dealing with. Apart from domestic traffic, Ugandan roads carry also a fast amount of transit gods from ports at the east coast of Africa with final destinations in Rwanda, Congo and South Sudan.

While the overall study, described elsewhere (Kayondo (2012), aims at several aspects of road maintenance, this paper focusses on a robust, low cost road condition documentation system that can easily be mounted on existing vehicles. The road network of Uganda comprises more than 70 000 km, of which 30 000 km are community access roads, 27 500 km district roads, and 10 800 km national roads (2700 paved, 8 100 gravel). At present there

are 112 districts, each of them responsible for roads under their legislation, which makes it even more difficult to have a common policy for estimation of road condition.

2. Methods

2.1. The Gadgets

There are numerous providers of the state of the art data capture equipment for road network surveys (Fawcett, Bennett et al.), and many of them are termed “low cost” systems. Nevertheless, many of these systems still cost in the order of several 10 000 US $ and spare parts for repairing and maintenance of the system are often hard to acquire.

Our proposed system consists of a Microsoft Kinect™, already sold worldwide in 20 million copies for less than 150 US $ and a setup of action cams (Contour GPS) available for some hundred US $.

In the following the utilized hard and software - available at the time of our study - is described, but we would rather put forward the overall approach outlined below under 2.2.

2.1.1 Depth Scanner - Microsoft Kinect™

The Microsoft Kinect™ used by us for depth scanning of road surfaces in urban areas of Jinja, Uganda, was of the first version released by Microsoft in November 2010. Initially, the Kinect was introduced as is a motion sensing input device by Microsoft for the Xbox 360 video game console. Its capability to sense depth made it however soon very popular in robotics and 3D scanning. In 2012 Microsoft released the Kinect for Windows™, an updated hard ware version, which even better suits the needs for 3D scanning of road surfaces. Alternatively the Kinect could be substituted by the Asus Xtion PRO™ that has a higher frame rate (60 instead of 30 frames /sec)

The scanning process (cf. Freedman et al. 2010) is achieved by an array consisting of an infrared laser emitter, an infrared camera and an RGB camera with a resolution of 640 x 480 (VGA). Depending on the used software to handle the data stream from the Kincet, data is stored as 16 bit depth maps and/or point clouds that can be further processed in proprietary or free software for volume estimation of the potholes. The same area on ground is simultaneously captured by the RGB camera in VGA resolution as 24 bit color images, which allows draping of these images over the archived road surface models for better illustration. Major drawback of the used Kinect version was the relative narrow view angle (45 degrees vertical FOV and 58 degrees horizontal FOV), which resulted in a high mounting

position in order to capture a broad portion of the road in nadir view. We tried to compensate with Nyko's Zoom for Kinect, but achieved vignetting issues. Our recommendation is to use several sensors mounted in line perpendicular to the driving direction.

Figure 1. Kinect mounted on vehicle scanning urban roads in Jinja, Uganda .

One major drawback of the IR-sensor used in outdoor conditions was the noise introduced by the IR-radiation of intense sunlight. Our solution was to register at dawn (with ancillary RGB) or night (with artificial visible light for RGB registration).

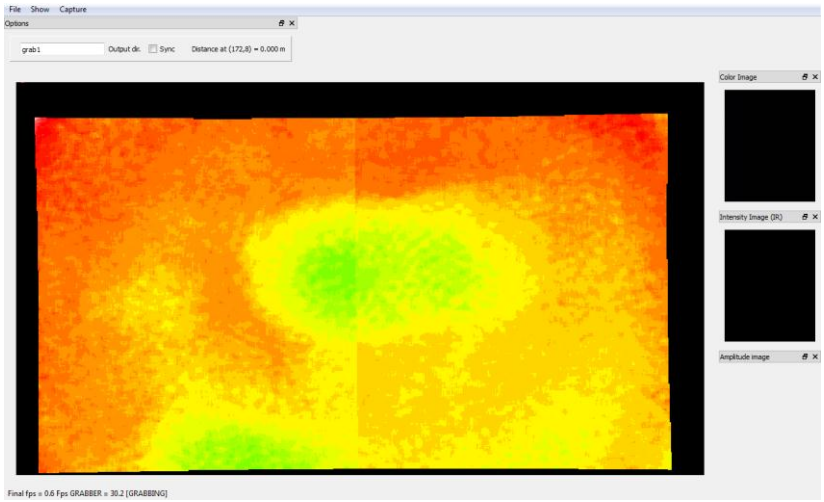

Figure 2. Depth map (screen dump) of a road pothole registered with the Kinect via software RGBDemo. Steep gradient line in the middle is an artefact.

2.1.2 Action Camera - Contour GPS

Our choice of video camera for documenting the full view of the road in heading direction was based mainly of the capability to geotag the video along track. Initially we used a Sony HD camera with built in GPS, but here the coordinates where not extractable frame by frame.

Figure 3. Two HD video cameras mounted at the front of the car. Left one modified to register NIR radiation only-

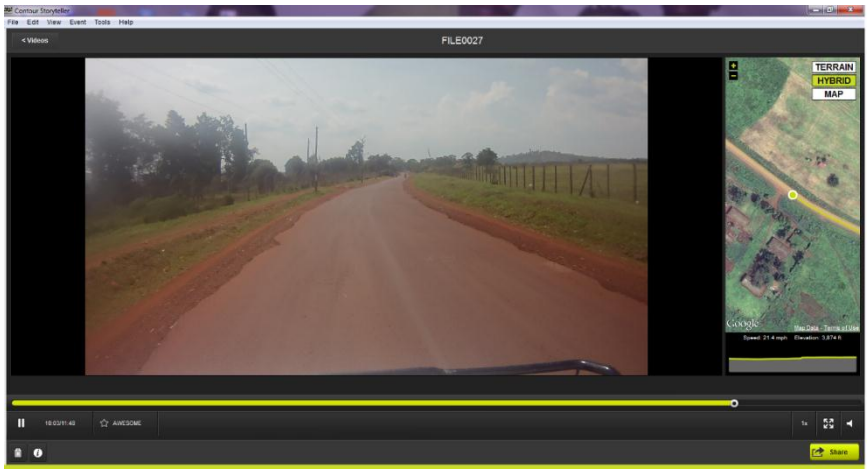

Figure 4. View in heading direction recorded with the Contour GPS™. The integrated GPS positioning is displayed by Storyteller™ software in the frame to the right together with a GPS derived elevation profile.

At present there is no common standard to geotag video, similar to the one found in exif data for still images. Countour released an action camera with integrated GPS together with the included Storyteller™ software capable of displaying the actual position overlaid on Google maps.

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 processed data before they can make sense to the decision maker. Even though augmenting the video captured is time consuming, this process happens in the office – laboratory far from the uncertain field conditions (Silva, Camargo et al. 2003). In (Silva, Camargo et al. 2003), a list of platforms for a couple of navigation and mapping sensors is given. Vans and trucks are majorly used, but also, cars, trains and aircrafts have been used to develop the vast types of equipment for this navigation and mapping. Digital compasses, GPS, gyros, and odometers were used for navigation while, a number of CCD digital cameras, analogue cameras and digital video cameras were used for mapping. These mobile mapping systems have various names as decided upon by the various developers. Details can be obtained from (Silva, Camargo et al. 2003).

2.2. The Concept

Our concept focusses on the overall method rather than the actual tools available at the time of our study. Documentation of road conditions in Uganda was previously done by visual, subjective inspection at place. The location of road damages was documented by driving distance to known landmarks like bridges or major crossings. The proposed concept introduces GPS positioning, video documentation, as well as volume estimates of individual potholes through depth scanning. Geolocation of the road damages is easily possible by implementing the GPS readings to the exif meta data of the depth maps.

All recorded information is therefore “GIS-ready” for visualization or further analysis. No advanced technical or GIS-knowledge is necessary for capturing the field data, and the affordability of the equipment makes it possible to arm every patrolling vehicle with a set up.

By replaying the geotagged video documentation a trained interpreter can easily estimate the need for repair measures in a more objective way than previously possible. Repeated registration of the same road segments enables time series studies to monitor potential degradation. Integration of these data in a dedicated GIS is necessary for road maintenance decision support.

3. Conclusion

This research proposes continuous accumulation of spatial video databases to facilitate routine and periodic maintenance decisions. The technology provides both a practical and flexible solution for keeping up to date with road inventory and condition parameters.

Our approach is sustainable as it utilizes low cost equipment that can be mounted on any vehicle and operated without special training of the patrolling personnel. All data is stored on small memory cards, making it easy to transfer and duplicate. Further examination is carried out by trained interpreters, implementing the findings in a GIS for combined analysis.

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