Monitoring Road maintenance using video-geotagging in geographical information system: an innovative approach

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Abstract: Maintenance of roads is a key concern for smooth flow of traffic and goods for any economy to thrive. The maintenance part has been limited in GIS to information collected through ground-based surveys, GPS location of affected road area, uploading geo-tagged photos shared by public through mobile app on GIS data. The present work focuses on one such innovative approach using geo-tagging of videos of road surface with Road layer in GIS. Stretches of road in and around Ludhiana city of Punjab to reflect different scenarios such as roads located in open village area, highways, and broad and congested city roads have been used for understanding condition of surface of road in a contiguous fashion.

Keywords: GIS, Video Geotagging, Infrastructure, Road Maintenance

1. Introduction

Transportation System is the key to economic growth of any country. India is no exception and is constructing roads at a record speed 37 km/day to cater to its industrial and socio-economic development. In general, the developed countries are spanned by a very dense transport network, which has driven their economies example abounds such as USA, UK, and China.

GIS has been extensively used in conjunction with remote sensing data such as satellite images and drone data for optimal route planning (Mondal et. al., 2021) design processes, store survey details based on GPS data, field survey, satellite images, monitoring the construction and operational issues (Yunus & Hassan, 2010). In general, road alignment has been mapped in GIS using remote sensing data as base layer generally in all GIS based projects. However, a critical component related to maintenance of the roads has not found many GIS driven applications.

Maintenance of roads is a key concern for smooth flow of traffic and goods for any economy to thrive. The maintenance part has been limited in GIS to information collected through ground-based surveys, GPS location of affected road area, uploading geotagged photos shared by public through mobile app on GIS data or using bump integrator (Dattani et. al., 2018) to check for the unevenness of the roads. Dedicated vehicles equipped with high definition cameras and laser scanners can also be used but the limitation of these vehicles is the high cost of purchase/make and high operating cost (Radopoulou et. al. 2016; Werro, 2013). Other methods for monitoring road condition and road maintenance includes using Laser based system (LiDAR, Mobile Laser Scanning (MLS)) (Li et. al. 2020) but these are too complex, costly and are prone to various errors. AI and machine learning has proven to be quite useful in identifying the road condition but most of these algorithm focus on 2D images (Radopoulou and Brilakis 2015; Jog et. al. 2012; Tsai et. al. 2009; Battiato et al. 2006) and might not be able to give proper road condition. Some AI and ML techniques do focus on videos (Koch et. al. 2012) however, they do not contain the telemetry and geolocation data which are important for road condition assessment. Moreover, some method using AI and ML on phone sensor data (Basavaraju et. al. 2020) but it depends on vehicle moving directly over the damages across the roads.

Gleave (2014) mentioned the effects of untimely maintenance of roads on environment such as increased CO2 emissions, fuel consumption, and pollution from difficult rehabilitation works, other impacts can be seen in the increased maintenance cost of the road, increased vehicle operating cost, even including less safety and adverse health impacts. Light vehicles (mostly private users) see 34% increase in fuel consumption, while 12% fuel increase is noted in heavy vehicles, furthermore poor road condition can increase maintenance cost for heavy and light vehicles by 129% and 185% respectively (Chatterjee et. al. 2018, Gleave 2014). This brings out the urgency of maintenance of road and the approach in the present work helps in monitoring the condition of the road and in verifying if the said road has been repaired or not after maintenance work has been carried and thus, brings in the transparency factor.

Accurate, timely and cost-effective information about road condition is a key for repair and maintenance of road infrastructure (Nodrat et. al., 2018). The present paper focuses on one such innovative approach using geotagging of videos of road surface with Road layer in GIS with a case study devoted to a small stretch of Ludhiana city in Punjab. Geotagging is the process of adding geographical identification metadata to various media such as a photograph or video and is a form of geospatial metadata (Luo et. al., 2011).

2. Objectives

One of the concerns of the govt. is to bring transparency in maintenance of road and also to aid the engineers involved in identifying the stretches of road which needs to be fixed.

The above twin objectives can be met very efficiently by making use of geotagged videos of road surface (videos of road surface linked with location of road on Earth) which provides details of road condition in a contiguous fashion

unlike geotagged photos, which are linked only to a particular point in the long stretch of the road.
The geotagged videos provides information of inventory of road surface in a visual format along with date and time – a big evidence of road surface condition unlike the current trend of paper record which may be prepared for vested interest. Likewise, geotagged videos of road surface condition after said repairs would be evidence enough if the road has been repaired or not. Thus, the objectives of the present work are:

- Make use of Geo-Tagged Videos showing road condition in conjunction with GIS road layer or on top of satellite image in GIS.
- Make database of status of road condition before and after repairs for inventory of repair works.
- Make use of free ware/open-source software for limiting expenses for database generation.

3. Study area

Stretches of road in and around Ludhiana city of Punjab to reflect different scenarios such as roads located in open village area, highway, broad and congested roads in the city.

4. Methodology

The work involves (Figure 1) taking videos of road surface in a vehicle along with GPS readings. The GPS readings can be taken using a GPS device or equally accurate available mobile apps now-a-days such as GPS tracker, Avenza or many other apps which can be downloaded free of cost on any smartphone generally available with public. This in turn saves on finances for procuring any GPS device. The videos can also be taken through another mobile rather than investing in acquiring costly video camera. Both video and GPS activity should begin at the same time for proper geotagging as common thing to marry both datasets (video and GPS readings) called as video geotagging is the time.

Video geotagging in general sense is the video having location data in its metadata, but in the present work it has been utilized to next level where each frame is associated with location data (taken from GPS track). Since, the location data cannot be put into metadata, therefore, another file format can be created (as UAV tracker of QGIS). For this type of geotagging, it is imperative that the video length and GPS track length (in terms of time) are equal. Speed of vehicle plays an important role in assessing road condition as the general mobile camera can only capture videos at 60 frames per second (FPS), moving too fast would result in some smaller potholes to be missed or video to be blurry. Therefore, the vehicle speed should be kept around 40Kmph (11.11mps, meaning 60 frames are assigned for 11meters), or slower. For present study, the camera settings were 1080p at 60 FPS, with 48MP resolution (mobile camera). GPS track points were taken at every second. Once, the data (video and GPS tracks) are synchronized, the frame at the beginning of the video will have the first GPS coordinate and after video runs for a second, the second GPS coordinate is assigned and so on resulting in geotagged video.

The twin data of video focused on road surface and its accompanying GPS coordinates can be geotagged in Commercial of the shelf (COTS) software or using free and open source software such as QGIS. However, in the present work video UAV tracker of QGIS, a free option was exercised. Thus, expenses are generally limited to vehicle and manual cost.

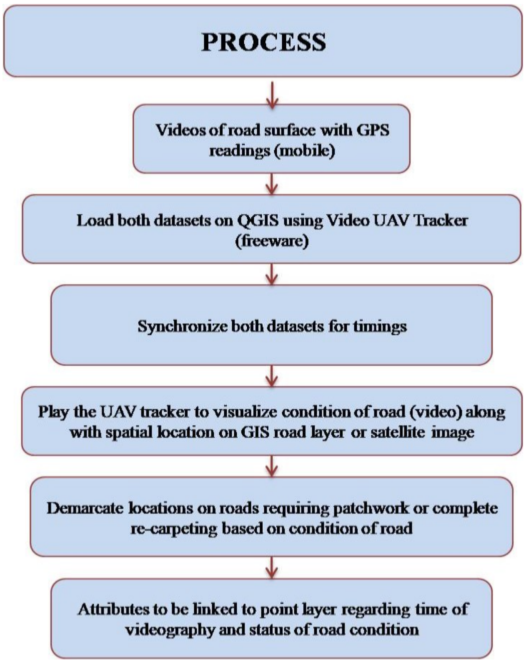

Figure 1. Methodology Flowchart

The workflow (Figure 1) involves loading video and corresponding GPS file in the video UAV tracker of QGIS with GIS vector file of roads if available otherwise Web Map Services available free of cost can be called in the background in QGIS requiring only internet connection, a facility available under "Base Map" option of QGIS. At times, the road layer generated may not be accurate or updated but satellite image would be accurate in terms of geolocation and updated as well. Thus, satellite image available free of cost may be the proper choice.

Both video and GPS must be synchronized in the module. Once synchronized GPS track layer is made available with a pointer. The pointer moves on road GIS layer or georeferenced satellite image in sync with video of the same location on the road. The GIS analyst can then run the video with the pointer highlighting the location of the road. The GIS analyst can infer from video the type of maintenance required (patchwork or complete road to be carpeted) based on condition of road surface made apparent from video. Based on observation of the video geotagged, GIS analyst can demarcate on the GIS layer, the condition of road and suggest the type of maintenance required, such as patchwork or complete road carpeting. The Video part also gives the date and time of acquisition which can be added as attribute at the specified locations where road requires maintenance. If road is repaired, details of repair carried can also be part of attributes giving complete information of road maintenance which can come handy in future maintenance work also.

5. Results and discussions

5.1 Scenario: Urban road (pre-repair)

The video clip (Figure 2) taken on an urban road in Ludhiana on 06 October 2021shows that there are broken patches.

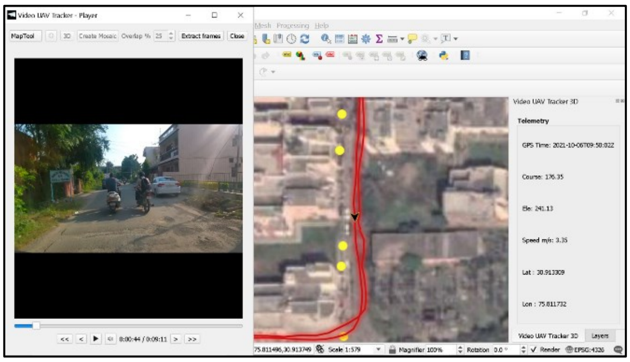

Figure 2. Urban Road (Pre-Repair)

The red line is the GPS track, which helps to relate location of Earth with video of road surface.

Figure 3. Locations of potholes in Urban Road

On closer inspection, Figure 3 shows the locations of the potholes that were identified using video geotagging. Over 20 potholes as highlighted by yellow points in Figure 3 with extreme damages were identified on less than 500m length of road as such complete carpeting of road is suggested over patchwork

5.2 Scenario: Urban road (post-repair)

The video clip (Figure 4) taken on 09 December 2021 shows that the road as shown in Figure 2 has been repaired.

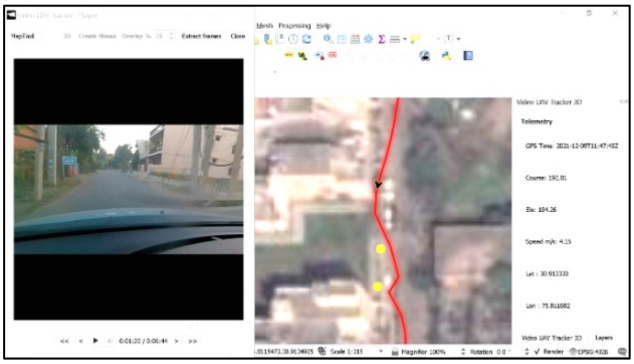

Figure 4. Urban Road (Post-Repair)

The red line is the GPS track helps to relate location of Earth with video of road surface. Thus, the process helps to understand condition of road at various times, before and after repair.

Figure 5 shows that the whole stretch of road has been carpeted; the damage of road visible in Figure 3 has been fixed. In addition, the telemetry data (Figure 4) reflects date and time of video acquisition and helps in verifying if the road has been repaired or not as on date thus providing transparency to the work.

Figure 5. Location of Potholes and road condition after repairs (complete carpeting)

5.3 Scenario: Village road

The video clip (Figure 6) taken on 07 December 2021 of a village road which is exposed to sky and therefore, GPS readings are accurate as the red line in Figure 4 showing GPS track is almost straight and located on road itself.

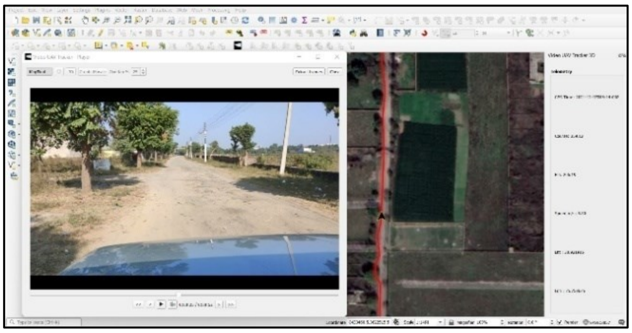

Figure 6. Village Road

The road connecting the village to the highway/city was remarkably well maintained however, once inside the village it was clear that the road condition was not up to the mark.

In the 500m (village road) stretch undertaken in the study 90m road required complete carpeting, and in 120m 4 major potholes were present. The two points labeled '5' and '6' in Figure 7 shows the extent up to which carpeting is required

Figure 7. Location of potholes on Village Roads

5.4 Scenario: State highway

The video clip (Figure 8) taken on 07 December 2021 of state highway called as Humbran road in Ludhiana which is broad and therefore, exposed to sky results in accurate GPS readings as the red line (GPS track) in Figure 8 is straight representing GPS track is almost straight and located on road itself. The video snap of road surface shows a very smooth road surface devoid of any potholes and, therefore, needs no repair.

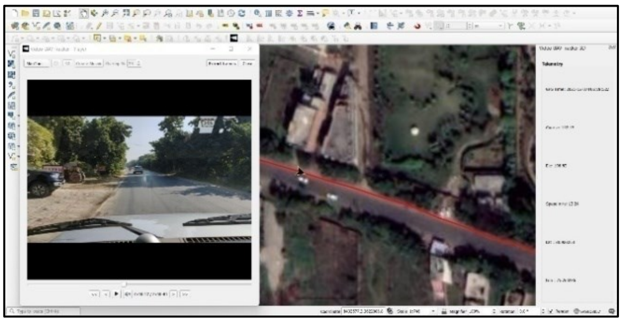

Figure 8. State Highway

5.5 Scenario: Urban Road (Congested)

The video clip (Figure 9) taken on 03 December 2021 a very congested part of Ludhiana city and therefore, not very exposed to sky results in inaccurate GPS readings as the red line (GPS track) in Figure 9 is not located on the road but crosses over the nearby buildings and therefore, would be difficult to relate video (ground condition of road surface from video) with location on ground as GPS track is in error. Thus, in congested areas such methodology may not work efficiently as getting accurate GPS readings may not be possible. However, Figure 10, a zoomed version of the road surface highlighted in Figure 9 with some intelligence can aid to interpret various stretches of road which shows mixed road surface conditions such as pot holes around point 1,2,3 and 4 which needs patchwork but around pt 0, there is continuous distressed road and needs complete carpeting.

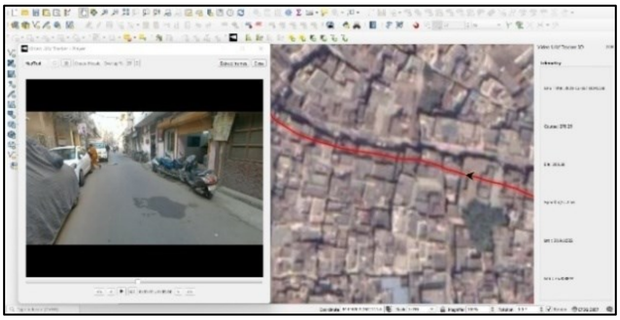

Figure 9. Urban Road (Congested)

Figure 10. Location of potholes in Urban Congested Road

6. Conclusions

It can be concluded from the work that the condition of the road can be had in a contiguous fashion using videos, which can be geotagged with GIS road layer, or georeferenced satellite image for quick assessment of road surface to help relevant authorities plan for repair work as needed. In addition, the process is economical, based on free and open source GIS software, free GPS apps and mobile for videos over costly video cameras. Limitations of the technique may be due to ground conditions such as flooding, traffic jams, or public unrest, which may not permit the vehicle mounted with cameras to record videos, and other limitations may be due to weather problems, or high electrical/magnetic disturbances affecting the functioning of GPS. In addition, the approach can be used where roads are broad and GPS readings can be obtained accurately. The work is likely to bring transparency and help many departments.

The present work gives a visual technique for understanding road conditions by geotagging videos of roads with corresponding road GIS layers. However, to aid the various officials involved in maintenance of road, in interpreting the road conditions such as potholes or completely distressed road, AI classification techniques should be tried in future to classify the video to highlight potholes or distressed parts of the road. This will not only help in automation and fast work, but it might also help in creation of a decentralized system which can provide road condition over regular period using public/private vehicles, which will further cut down costs and increase transparency significantly.

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