Moving Video Mapper and City Recorder with Geo-Referenced Videos

Guangqiang Zhao(✉), Mingjin Zhang, Tao Li, Shu-Ching Chen, Ouri Wolfson, and Naphtali Rishe

School of Computing and Information Sciences,
Florida International University, Miami, FL 33199, USA
{gzhao002,zhangm,taoli,chens,wolfson,rishen}@cs.fiu.edu
http://terrafly.com/

Abstract. There has been growing interest in correlating co-visualizing a video stream to the dynamic geospatial attributes of the moving camera. Moving videos comes from various GPS-enabled video recording devices and can be uploaded to video-sharing websites. Such public website do not presently display dynamic spatial features correlated to a video player. Although some systems include map based playback products, there has been no unified platform for users to share geo-referenced videos that takes spatial characteristics into account. We present here Moving Video Mapper, which integrates both historical and live geo-referenced videos to give users an immersive experience in multidimensional perspectives. The platform has been evaluated using real data in an urban environment through several use cases.

Keywords: Geo-referenced video · Moving objects · Online map · Dashboard camera · Digital city

1 Introduction

A photograph is usually taken from a location. An action video, which can be seen as a series of photographs from different locations, usually reflects an object moving along a trajectory. In recent years, thanks to the price drop and miniaturization of Global Positioning System (GPS) chips, GPS-enabled video recording devices have proliferated. One remarkable example is the now widely used dashboard cameras (dashcam), which continuously record videos and GPS tracking while the users are driving [7]. Other examples include smartphones, unmanned

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aerial vehicles (UAVs), and sports (a.k.a. action) camcorders. Some devices with networking capabilities can even stream real-time video remotely. Videos taken by such devices comprise Big Data. However, the playback software modules are generally from different providers and they are often incompatible with each other. Integration is need to facilitate route preview, virtual sightseeing, crime monitoring, smart city applications [7] and data mining [13].

With the rapid development of online geographic information system (GIS) services, Web-based map applications have entered the everyday life. Many existing online map services include geo-tagged photos and videos, either uploaded by users or collected by the provider [6].

This paper proposes Moving Video Mapper, a framework to integrate geo-referenced videos from moving objects for immersive city observation through multidimensional perspective. Compared with the state of the art, our main contributions include:

- A smart data importing system able to recognize a wide variety of video and GPS track forms from devices of wide range of brands
- Supports real-time video streaming along with historical video archiving
- Geo-tagging service for video recording devices without GPS capabilities
- When possible, retrieve and display data from other sensors (e.g. accelerometer, gyroscope, and barometer)
- Automatically and intelligently classify related videos of specific locations by time of day, weather conditions, etc.
- Synchronous playback of both the video and the route, with cross-interactive capability

The rest of the paper is organized as follows. In Sect. 2, we introduce the related work. We then describe the architecture of our framework in Sect. 3. A prototype has been implemented and used to validate our system using volunteer collected data, which is discussed in Sect. 6. Finally, we conclude in Sect. 7.

2 Related Work

Displaying multimedia containing geographic information on a map is not a new idea. Many products on the market can display geo-tagged multimedia on a map [6,12], most of which are photo-based. For videos, they only reference them as points (markers on the map). It is difficult for users to understand how the videos were recorded by these scattered markers. Google developed a product named StreetView, based on GoogleMaps, which provides panoramic view-points along streets worldwide [1]. Although StreetView covers almost all sceneries along the road, it is still discrete photos. Some systems have been proposed to solve this problem by generating smooth videos or photos from panoramas along streets [2,5,8]. These methods depend on the intensity of the panoramas collected and therefore the quality of the videos or images generated from these panoramas can be compromised.

Recently, several platforms and frameworks have been proposed to utilize geo-referenced videos along with the map. These kinds of videos come with spatial and temporal information bound to frames of the video. PLOCAN [10] focuses on combining a Web-based video player and a map together to play dedicated videos with positions shown on the map. Citywatcher [7] lets users annotate dashcam videos and upload them to the City Manager. Chiang et al. [3] proposed a framework to share and search user-uploaded dashcam videos. However, it requires a specific application installed on the smartphone to record the video. Furthermore, there is no existing platform that integrates all kinds of geo-referenced videos.

The limitations of the aforementioned methods/systems have motivated us to find new ways of showing geo-referenced videos that provide the best user experience. Our proposed platform is based on our previous work named City Recorder [11]. We will introduce the architecture of Moving Object Mapper in the next section.

3 System Design

The Moving Object Mapper is an online GIS platform based on classic three-tier server-client. As shown in Fig. 1, the presentation tier resides on the client side while the logic tier and data tier run at the server side.

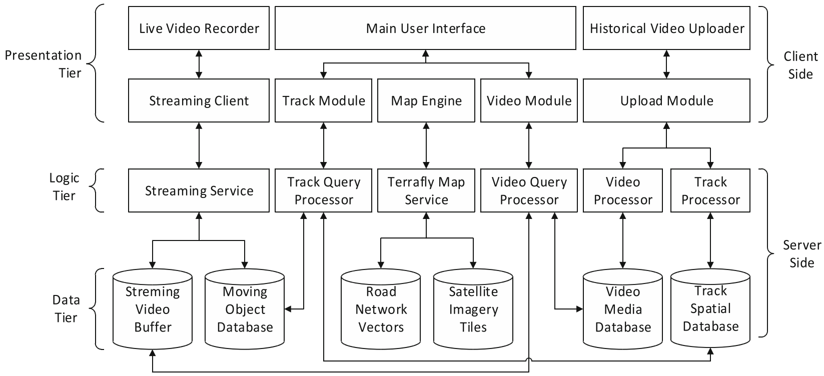


Fig. 1. System architecture

3.1 The Presentation Tier

The presentation tier collects data from users and respond with query results. The event-driven main user interface relies on three major modules. The track module and video module are core parts of the website to show tracks and videos to users, respectively. We use TerraFly [9] as our map engine to support the track visualization, and the video module utilizes the open-source jPlayer[1]. The historical uploader redirects users to the geo-referenced video uploading page and guides users through-out each step. Real-time videos will be transferred to the server by the streaming client.

3.2 The Logic Tier

The logic tier processes data between presentation tier and data tier. The historical data will be transferred to desired format and stored into the database, which covered in Sect. 4. In Sect. 5 we will show how to deal with data streaming. The track and video query processor mainly handles general queries from the main user interface. Section 6 will explain their visualization in depth.

3.3 The Data Tier

We use various types of databases to adapt different data in the data tier. The videos are stored in multi-media database. The tracks, road network vectors and satellite imagery tiles are stored in separate spatial databases. The recording locations of live videos are constantly updated into the MOD (Moving Object Database).

4 Historical Data Processing

Most GPS-enabled devices will store track files along with recorded videos in some kinds of storage media. Here the historical data specifically refers to the offline data that users uploaded manually.

4.1 Track Data Processor

The track data processor extracts tracks from the user-uploaded file and stores them into the track database. Since there are a variety of devices from different manufacturers on the market, the first step is converting these tracks to a device-independent format. The most common track file formats include: NMEA 0183[2], GPX, and KML. A track parse module inside this processor handles all the track extraction tasks.

For videos that recorded along streets (e.g. dashcam videos), we can align the track data based on the road network using a map matching algorithm (MMA). Regarding to the devices without GPS capabilities, there is also a geo-tagging tool for users to manually mark the track on the map.

1 http://jplayer.org/.
2 http://en.wikipedia.org/wiki/NMEA_0183.

4.2 Video Data Processor

Similar to track processings, we want a unified format for the videos which is suitable for Web-based players. The mp4 (MPEG-4 Part 14) is chosen considering its broad network compatibility. Another task is compression in order to reduce the video size. We utilize a free video processing tool FFmpeg[3] to perform video re-coding and compression tasks.

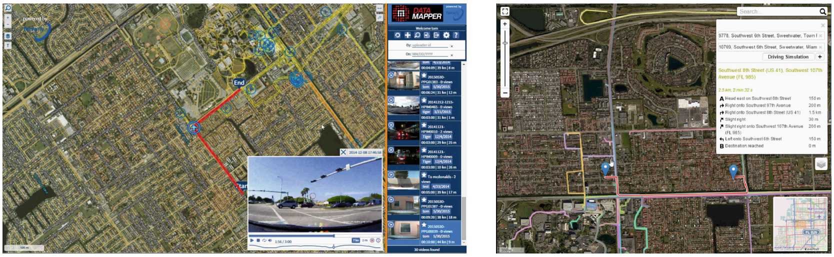
Then we utilize Support Vector Machines (SVM) to learn and classify the videos by different characteristics (e.g. weather, road condition, and time of day).

5 Live Video Streaming

We provide a mobile application for live video streaming purpose. After users correctly registered on the server, the application will notify the server whenever it is online. The video will be transferred to the server wirelessly along with current location from the GPS sensor. s The location of the moving object is updated in the MOD. Then the buffered video file on server is ready for responding to streaming requests from the users. The videos and tracks will be archived into the historical database in a certain time interval.

6 Use Case Study

In this section we demonstrate the effectiveness of our system and show how it is used in real life through a series of use cases.



(a) (b)

Fig. 2. (a) Street tracks. (b) Route query.

6.1 Street Network Based Videos

Most street network based videos come from dashboard cameras. Figure 2a shows that a car is turning right. The line graph below the video indicates the speed drop. It also can be switched to the altitude graph as needed. Figure 2b is a map with tracks rendered as polylines in different colors. We did a route query between two points. After clicking the simulator button, it will open the driving simulator shown in Sect. 6.3.

[3] https://www.ffmpeg.org/.

6.2 Free Moving Objects

Free moving objects (e.g. pedestrians, boats, and aircrafts) usually have unpredictable tracks. Figure 3 shows a live streaming video from a balloon. The polygon represents the field of vision projected on the ground.

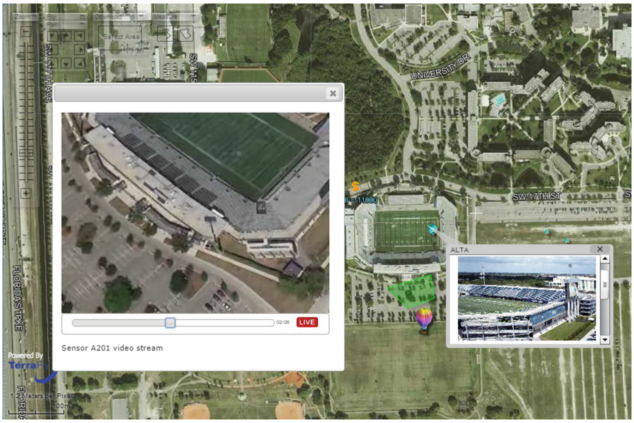
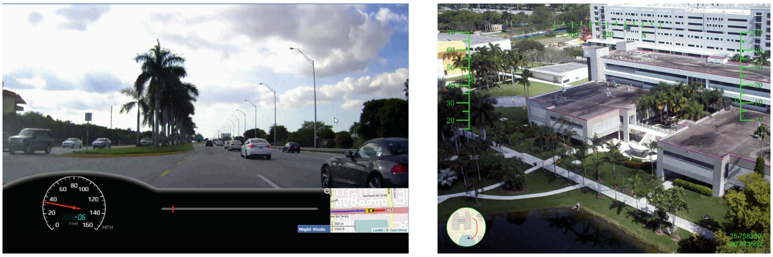


Fig. 3. Live video from UAV.



(a) (b)

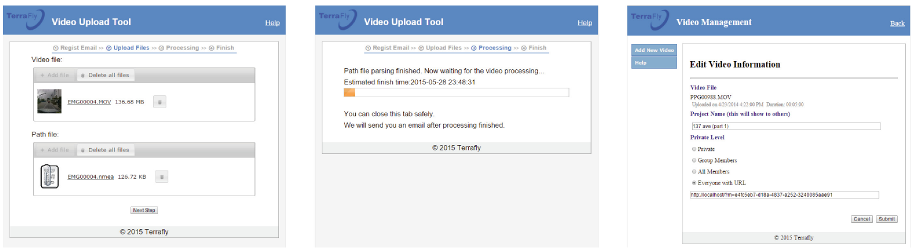
Fig. 4. (a) Car simulator. (b) Aircraft simulator.

6.3 Moving Video Simulator

The simulator is designed for providing the user an immersive experience. We have designed several different themes to simulate various life situations. Figure 4a simulate a car using the dashcam video. If other videos are found at the same location and have same directions, the application will notify users (See the blue "Night Mode" button). This allows users to preview a place under different time of day, season of year, weather conditions, etc. It will greatly improve the user experience. Figure 4b shows an aircraft simulator using the video from a hexacopter drone.

6.4 Data Management

Users can upload their geo-referenced videos to our system using a guided interface as shown in Fig. 5a. Then the data will be processed at the server side and the estimated time is displayed to users as shown in Fig. 5b. Users can choose between waiting online or getting a notification email. Users have the option to change privacy settings of videos as seen in Fig. 5c. They can also share a video with others using the system generated URLs, and the video will not available to public without this URL.



(a) (b) (c)

Fig. 5. (a) Data uploading. (b) Data processing. (c) Data management.

7 Discussion and Future Work

This study presented the Moving Object Mapper for geo-referenced video sharing. City Recorder is a public service that relies on contribution from and cooperation of voluntary users. This mode is proven to be successful in numerous geolocation-related domains in recent years (e.g. OpenStreetMap). However, it is difficult to ensure the quality of the videos or detect inappropriate contents. Another concern is privacy protection. We are working on utilizing some technologies like automatically blurring faces and license plates [4] to prevent publication of sensitive information. As we are entering an era of Virtual Reality (VR), we are also planning to deliver 3D contents via the Web.

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