# Role of Spatial Video in GIS

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## 1. Introduction

GIS elemental units are often defined in terms of points, lines and areas. However, another type of spatial data that is becoming frequently captured, but as yet, GIS largely ignores, is that of spatial video. Here we consider the implementation of spatial video data within GIS.

Digital video recording is a commonly encountered medium in modern society and encompasses many forms, from simple personal camcorders through to sophisticated surveillance systems. In the majority of cases the video footage is usually captured while the device and/or the objects being viewed are in motion. What is of particular interest is when video streams can be, or have been, associated with spatial data such as location, orientation, etc; to create geographically referenced videographic data. For simplicity, these combined data sources will be defined as spatial video. Fundamentally, the nature of video is to record space, so when spatial properties can be accurately acquired and associated with this footage, an important geographical element can be considered for integration within a GIS.

Existing spatial video systems, both commercial and research, are predominantly used in survey or LBS roles and are usually bespoke and application specific, (Kyong-Ho et al., 2003B, RouteMapper, 2007, Red Hen, 2005). These systems do not model Spatial Video in a generalised way that is both data and platform independent. They do not support GIS integration and/or analysis from a purely spatial content perspective. A video-image centric approach prevails where usage options range from simple visualisation interfaces to interactive computer vision systems. What has been largely overlooked is a spatial approach where the inherent geographical extent recorded in each video frame is modelled. While this modelling approach has not been fully realised, it does exist in a GIS form, where the spatial context of video is defined in a structure called a ViewCone, (OGC OWS-3, 2005, Lewis, 2006). This is the only standardised implementation of spatial video to date. However, ViewCones only define a 2D model with the geographical extent of each frame being restricted to a three or five sided polygon representation.

To extend and investigate the potentials of this approach, the ViewCone data structure is here replaced by a more complex Viewpoint model. A Viewpoint is defined from the spatial data and video camera calibration parameters and enables a higher dimensionality and structure extensibility than that of the ViewCone. Implementing a spatial database from Viewpoints, which have been constructed from a number of terrestrial spatial video surveys, it is demonstrated here how a GIS-based geospatial analysis approach to video can be developed. Thus, the following sections briefly define the Viewpoints data structure and some results of selected geospatial analysis operations that have been tested using this model.

## 2. Spatial Video Viewpoint Structure

The Viewpoint data structure is an extension of existing methodologies for modelling viewable regions that include isovist, viewshed and frustum forms. Theoretically, it is a 3D viewshed approach that has been defined where a viewing frustum represents each frames geographical space; figure 1 shows the principle elements that define the basic structure.

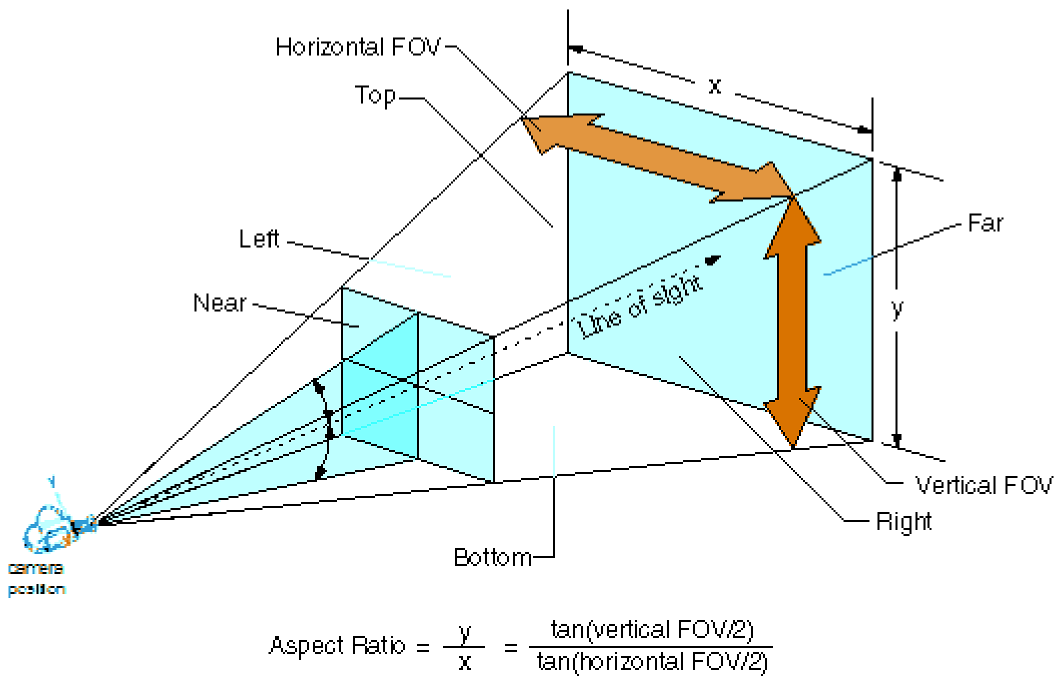


Figure 1. Principle elements that represent a spatial video viewpoint. The bounding geographical extent limits are shown as the camera-displaced polyhedron shape. This is contained by the near, far, left, right, top and bottom field-of-view planes. Image taken from http://wwweic.eri.u-tokyo.ac.jp .

This structure can be developed to approximate an images geographical extent by using a minimal set of spatial and camera parameters, which includes the location and orientation spatial data, and the angle-of-view and depth-of-field camera properties. This methodology has been applied on 46 minutes of oblique terrestrial spatial video. Approximately 75,000 Viewpoints were generated which are stored in a PostGIS spatial database. From this database numerous spatial video geospatial analysis operations can be performed. These operations, two examples of which are demonstrated here, are spatial data operations where the video is either described in terms of its spatial content or composed into spatially-logical streams of imagery. Figure 2 shows a simple example of a single-frame Viewpoint.

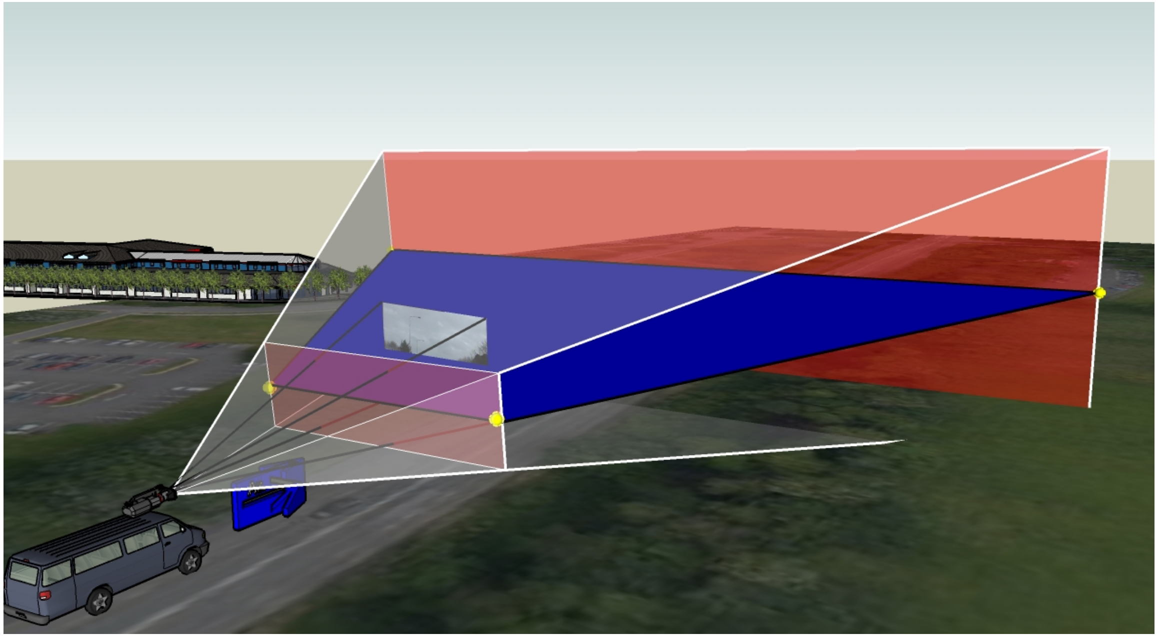

Figure 2. 3D spatial video single-frame Viewpoint representation. This image also highlights the 2D visualisation polygon as the central bisecting plane (blue polygon) which is used in the section 3 examples.

## 3. Video Geospatial Analysis

These examples are based on a plan-view 2D visualisation and the simplest spatial extent form of each Viewpoint. This provides a sufficiently accurate proof of concept platform towards further work in a 3D context, which is currently ongoing. Significantly, in this case the Viewpoint spatial extent form defines the maximum possible geographical coverage regardless of occlusions that may exist in the image space. A higher accuracy Viewpoint structure is possible through many alternative methodologies, but currently represents a different research direction.

Common to both examples in this section is a non-video spatial data set used as the query context. It is a polygon data set, relevant to the survey area, and defines census small area districts. Each area is assigned a simulated land-use coverage as the query objectives for example one. Figure 3 shows the study area, some of the spatial video road network capture points and the non-video spatial data.

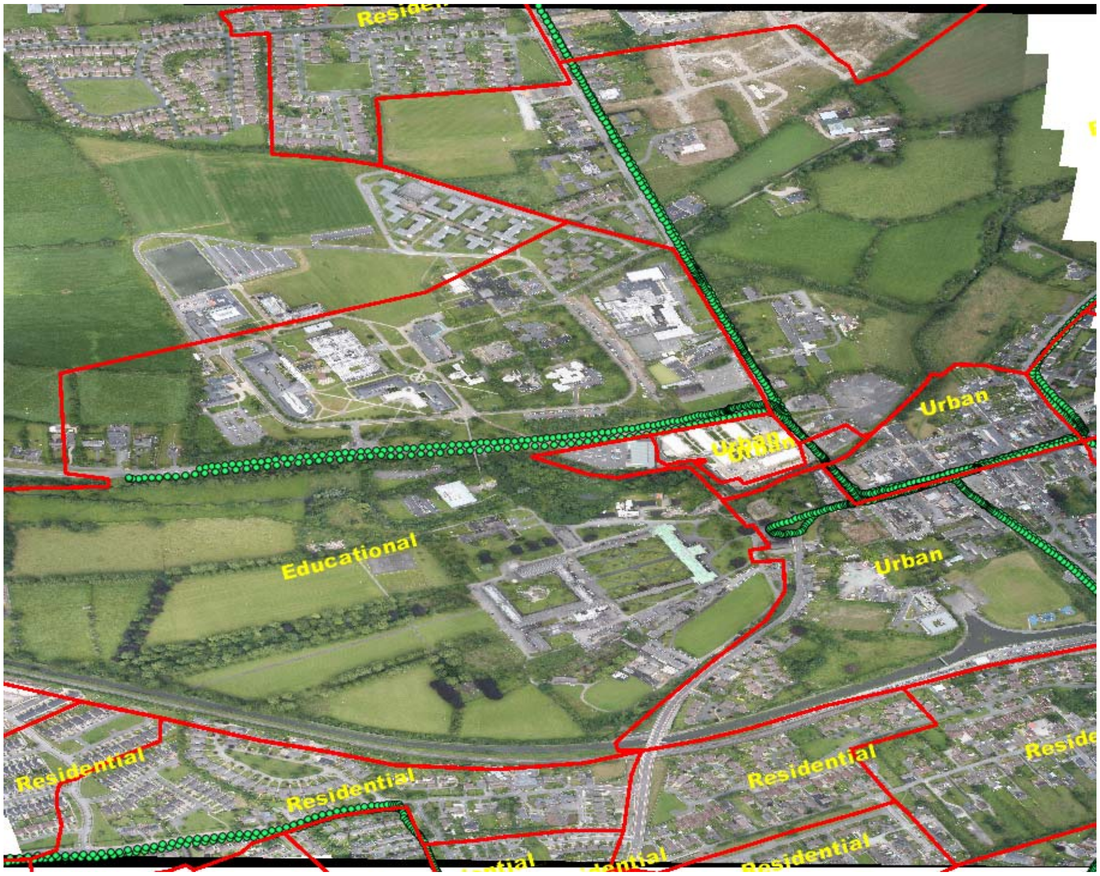


Figure 3. Overview image of the data sets used in the analysis examples. Shown here is an orthophoto of the study area, some of the spatial video route tracks, the green points, and the non-video census small area districts, the red polygons with the land-use assignment.

### 3.1 Analysis Example One

This example investigates the geographical content in the survey video, based on queries intersecting the Viewpoints coverages with the land-use polygons. Table 1 defines the percentage of video footage geographical area that records each land-use type.

| **Coverage Type** | **Area $m^2$ Total** | **% of total Spatial Video** |
|---|---|---|
| Residential | 40,489.03$m^2$ | 5.0 |
| Urban | 65,683.27$m^2$ | 8.1 |
| Educational | 38,803.22$m^2$ | 4.8 |
| Rural | 40,365.74$m^2$ | 5.0 |
| Undefined | 625,137.21$m^2$ | 77.1 |

Table 1. Aggregate results of the Viewpoints database, where the video content is determined to contain various percentages of thematic geographical content based on the polygon data sets metadata. The undefined element involves spatial video recorded outside the highlighted study area.

These results could be composed from many alternative perspectives that include temporal, spatial and visual questions. In this case the spatial coverage of the video is used, but many more relevant analysis approaches could be applied based on a user defined query approach.

### 3.2 Analysis Example Two

Using the same external spatial data, this example queries and returns a spatial video sequence that records geographical space within a single polygon. Essentially, this query can be likened to a point-in-polygon search; however there is an important semantic context that has to be included. The context is what is in and what is not; video that records the query region can be captured within, on or outside the polygon boundaries. Thus, frame-capture location points cannot fully satisfy a standard point-in-polygon approach as frames captured inside the region may not be recording region space. Also, frames captured outside the region may record region space that should be included. Therefore, the Viewpoint spatial extent can be used to control whether the video frame is relevant to the search space or not. Figure 4, shows the results of this approach.


Figure 4. Viewpoint controlled polygon-in-view operation where the Clane Road query polygon is the search space. The result Viewpoints are shown as the green points with transparent red polygons. The geographical extent of each Viewpoint is either completely or more than 60% contained within the query region.

## 4. Conclusions

This approach to modelling video's spatial content has been largely ignored in GIS; however it does represent a novel methodology that offers many opportunities for both the study of video and also for improving the methods of spatial definition. These examples represent only a small portion of many similar demonstration approaches that investigate how video can be analysed in a Viewpoints context. They have all been integrated into bespoke systems that visualise the results, be it planar maps or bespoke video sequences composed from multiple file formats, from different storage locations, containing only partial segments of complete streams.

## 5. Acknowledgements

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## 6. References

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