A SPATIOTEMPORAL HELIX APPROACH TO GEOSPATIAL EXPLOITATION OF MOTION IMAGERY

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The transition from static to motion imagery enabled by UAVs, and distributed sensor networks introduces significant challenges – monitoring multiple video streams, indexing large amounts of video, and retrieving video segments with significant spatiotemporal events. Current analyst workflow systems support spatiotemporal analysis minimally: analysts roam through large image mosaics, revisit the same area, and make use of accompanying geographic information systems (GIS) databases to examine the evolution of a scene. However, the analyst still needs to decide whether the trajectory of a vehicle appears suspicious, whether a moving convoy resembles a formation of military vehicles, or whether the trajectory of a truck today resembles yesterday's pattern of movement of another vehicle. As data influx is increasing at substantially high rates, agencies are trying hard to keep up with tremendous amounts of incoming data, further exasperated during crises (e.g. military operations), where the rate of incoming information explode (e.g. as areas of interest are under heavy surveillance by fleets of UAVs).

What is needed is a geospatial exploitation of motion imagery (GEMI) system that automates monitoring, indexing, search and retrieval at a level of abstraction supporting the analyst workflow. Such a system should enable an analyst to query motion trajectory events such as:

- *Monitor or search* for video segments containing traffic similar to a specified pattern (e.g. a vehicle coming to a stop on the side of the highway, human activity near the stopped vehicle, and vehicle taking off after the stop)
- *Monitor or search* for video segments containing motion near a given highway (e.g. human activity in fields near the highway)
- *Monitor or search* for video segments containing unusual traffic activity deviating from the norm (e.g. deviations from temporal patterns, deviations from spatial patterns, etc)
- *Monitor or search* for video segments containing specific group patterns (e.g. crowd activity moving towards a convoy of vehicles)

In this paper, we present a motion pattern modeling, identification and indexing method based on our innovative model of spatiotemporal helixes (Agouris & Stefanidis, 2003)[i], and feasibility demonstration results for application to urban scenes using video imagery. Our research has shown the feasibility of modeling video motion trajectories with spatiotemporal helixes, and using this model as a monitoring and indexing mechanism for storage and query of spatiotemporal events. Our model captures the point-mass motion trajectory with an optimal number of nodes using self-optimizing neural networks. Similarly, our threshold-based approach captures motion dynamics (expansion or collapse of the object's outline) with an optimal set of prongs.

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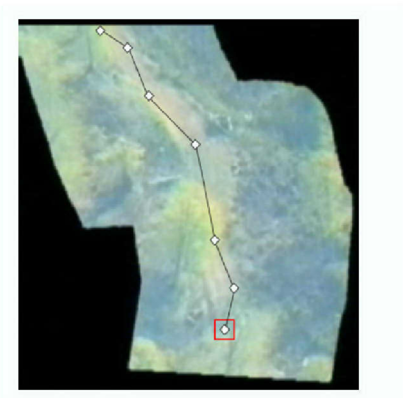
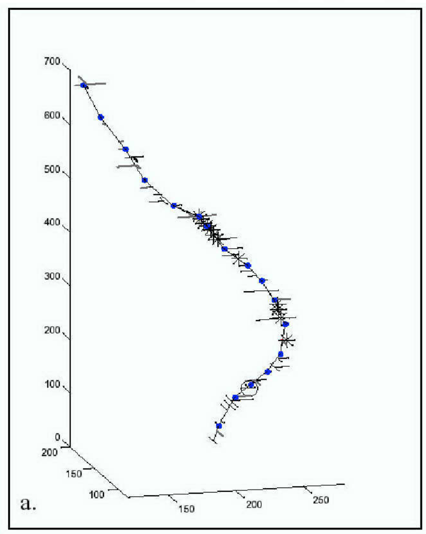
In order to compare helix motion models, we have developed similarity metrics to compare helixes using their node and prong information. Two helixes would be considered identical when their nodes and prongs follow similar patterns (displaying similar attributes at similar relative instances). Variations in these attributes would reduce the similarity of two helixes. The similarity metrics developed enable the comparison of trajectory models – at the coarse level - with mobility state transition metrics, and – at a granular level – with spatiotemporal distance metrics. Mobility state transition metrics perform abstract comparisons based on the high level attributes of node accelerations and decelerations; prong rotations, contractions and expansions. Similarity metrics compute the Euclidean distance for the same set of comparison variables.



The accompanying figure on the left shows the helix for an individual monitored by a UAV overlaid onto a virtual mosaic. The polygonic line linking 7 nodes (white boxes) depicts the helix, and the red box indicates the last tracked record of the person. The helix comprises only a spine in this case, as the person is represented as a point mass.

Prongs depicted in the accompanying figure on the right capture the expansion or contraction of the object (e.g. a convoy of vehicles, crowd demonstrating at a city square) Arrows pointing out of the helix spine denote expansion whereas arrows into the spine depict contraction of object outline.



In experiments with the spatiotemporal similarity metrics developed, distorting a helix through rotation and/or scaling has a nearly linear effect on the resulting quantitative similarity metrics (distance metrics), while abstract metrics (mobility state transition) behave very robustly, remaining almost unaffected as long as the distortions leave the nodes/prongs within the corresponding search windows.

In the full paper, we will present detailed empirical results obtained with the UAV data showing the representation efficiency and retrieval performance of our GEMI system. Our R&D will enable the DoD image analysts query motion trajectory events in multiple video streams or databases while using video registration software to integrate our query responses into virtual mosaics.

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[i] Agouris P. and A. Stefanidis. "Efficient Summarization of Spatiotemporal Events", *Communications of the ACM,* Vol. 46, No. 1, pp. 65-66, 2003.