Offline Track association problem

Course Name:- Machine Learning

Group name:- ML Titans

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Problem Statement

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- Multi-object tracking (MOT) in UAV videos is a challenging task due to various factors such as occlusions, abrupt motion changes, missed detections, and false positives. These issues result in fragmented object trajectories, commonly referred to as tracklets, rather than continuous, accurate tracks.- In UAV-based MOT, fragmented tracklets degrade tracking performance and make it difficult to maintain consistent object identities across frames. The challenge lies in merging these tracklets into complete trajectories in an offline setting using machine learning-based approaches without deep learning or transformer models.

- Key Challenges:
  - Occlusions & Missed Detections: Objects disappearing and reappearing due to obstacles.
  - Abrupt Motion Changes: Unstable object movement due to UAV camera shifts.
  - False Positives: Incorrect object detections lead to incorrect track associations.
  - Scalability: Handling multiple objects efficiently in high-resolution UAV videos.

Literature Survey

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Paper	Method	Key Contributions	Limitations
V-Spline: A Velocity and Position-Based Spline Model for Motion Tracking	V-Spline	Smooths noisy motion data for better tracking.	Struggles in complex cases with occlusions.
STCMOT: Spatial-Temporal Correlation Multi-Object Tracking with Re-Identification	STCMOT	Uses ReID (Re-Identification) to improve object tracking.	Faces challenges with occlusions and cluttered backgrounds.
GMMCP: A Graph-based Global Data Association Method for Multi-Object Tracking	GMMCP	Uses global optimization for tracking despite occlusions.	High computational cost, making it slow for real-time tracking.
Detection-Based UAV Tracking: A Real-Time Multi-Object Tracking Framework	UAV Tracker	Optimized for UAV-based object tracking, even under moderate occlusions.	Limited effectiveness outside UAV environments.
Multiple Hypothesis Tracking: A Probabilistic Approach to Long-Term Object Tracking	MHT	Maintains multiple tracking hypotheses to reduce ID switches.	Computationally complex, requiring fine-tuning for different scenarios.

Table: Comparison of Tracking Methods

Dataset Discussion

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- The Visdrone dataset comprises two main folders: sequence and annotations.
  - Sequence folder – Contains imageframes used for object detection and tracking.
  - Annotations folder – Consists of multiple text files, each corresponding to a sequence file that serves as the ground truth label. Each annotation file includes key details such as frame ID, object ID, width, height, x, y, center x, center y, occlusion, etc. Using OpenCV (cv2), objects are detected, and bounding boxes are drawn around them frame by frame. Additionally, trajectory lines are plotted to visualize the tracklet or movement path of each object.

- To simulate object occlusion, the trajectory line is randomly segmented into 3 to 5 pieces. After occlusion, object annotations are updated for example, vehicle_0A before occlusion and vehicle_0B after occlusion to indicate that it is the same object.

- Finally, two CSV files are generated:
  - Ground Truth Label File – Stores all object annotations, including frame ID, object ID, and bounding box details.
  - Missing Trajectory CSV File – Represents occluded objects by assigning NaN values in the corresponding frame ID rows, indicating missing trajectory data.

Dataset Discussion [cont..]

Approach

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❖ **Approach for MHT(Multiple Hypothesis Tracking) Tracklet Association :-**

❑ Load Tracklets from CSV:

➢ The tracklet data is loaded from a CSV file into a dictionary, where each obj_id maps to a list of (frame_id, cx, cy) tuples. The data is sorted by frame_id for each obj_id to maintain the correct temporal sequence.

❑ MHT Association Pipeline:

➢ The MHT_TrackletAssociation class processes the tracklets by computing the association costs between pairs, constructing a hypothesis graph, solving the association using the Bayesian approach, and merging the tracklets into final trajectories with use of Hungarian algorithm.

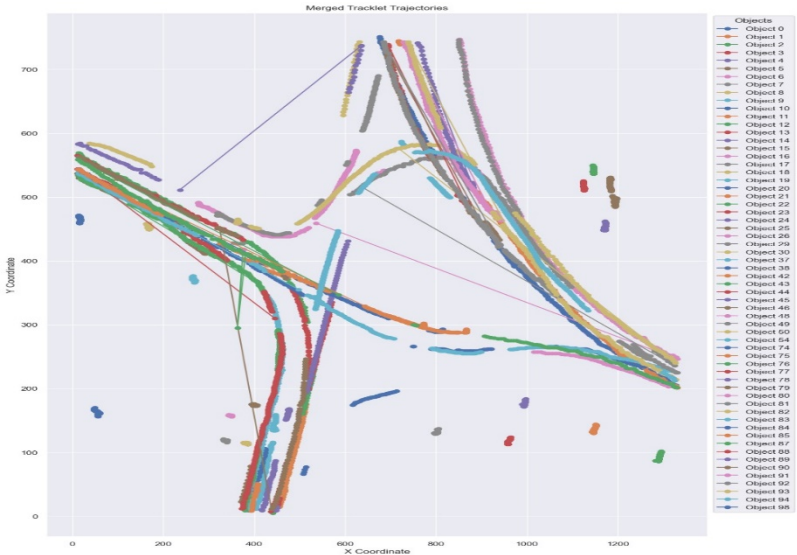
❑ Visualization:

➢ The visualize_trajectories function plots the trajectories of each object by connecting its cx and cy points across frames, displaying the motion paths over time.

❑ Main Execution:

➢ Tracklets are loaded from CSV, then passed through the MHT association pipeline to compute associations and merge tracklets, with the results saved and visualized for final output.

Approach



- Plot Type: Merged trajectories of tracked objects in 2D.
- Colors: Each object has a unique color.
- Patterns: Some paths are smooth, others have gaps or abrupt changes.
- Merging: Thin lines indicate tracklet merging.
- Use Case: Object tracking analysis(e.g.,vehicles, pedest rians).

Approach and Future Work

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- Future work on STCMOT and graph-based approaches will focus on integrating for spatio-temporal feature extraction, improving dynamic graph updates to handle occlusions and motion changes, and using Bayesian networks for robust tracklet association.

- It will explore multi-UAV collaborative tracking, real-time edge computing, and scalable graph structures for large environments. Additionally, advancements will include object interaction models, 3D tracking, and transfer learning for cross-domain adaptability, along with exploring hybrid models and probabilistic methods to enhance tracking accuracy and scalability.

References

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