Multi-Camera Multi-Object Tracking and Re-Identification

Research Project
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Declaration

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Place, Date

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Abstract

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Contents

1 Introduction

1.1 Lorem ipsum

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2 Structure

2.1 Citations

2.1.1 General

[1]: Current Trends in MCMOT. State of the Art. A lot of basic and advanced knowledge. Good for introduction. Analyzes 30 MCT algorithms.

[2]: General description of multi-camera tracking. State of the Art, Markov Process, graph partition theory, tracking by joint constraints.

[3]: Tracking people in multiple uncalibrated cameras. Discover spatial relationships between the camera FOVs. Tested on PETS 2001.

2.1.2 Beginning

[4]: First approaches of tracking humans in multi camera network. Already done in 1999 with real-time tracking. Automatic camera switching. Bayesian classification schema.

[5]: Bayesian modality fusion to track multiple people in an indoor environment. Tries to fix already known occlusion problem.

2.1.3 Real-time

[6]: Toward Real-Time. Only multi-object tracking. Introduces JDE (Joint learning of detection and embedding). Very important paper (first real-time MOT system). Single-shot detector

[7]: Indoor scene, multiple top-view **fisheye** cameras. Possible to cover large space, less occlusion among objects. People detection and tracking. Calibrate cameras, real time (FPS of about 10) without GPU support.

[8]: Real-time distributed MCMOT system. City-scale scenario. Keeping communication and computing costs of each device low. Installs smart stations on the roadside and connects them to maintain communication. Decentralized Tracking. Kalman filter and hungarian algorithm. YoloX and DeepSORT.

[9]: FairMOT, one-shot tracker (anchor-free style). Tackles issue of object detection against re-ID. Re-ID often threated as secondary task. Reasons behind failure: anchors, feature sharing, feature dimension.

[10]: Multiple non-overlapping cameras using fast-constrained dominant set clustering (FCDSC). Three-layer hierarchical approach. Orders of magnitudes faster than existing methods. Can be used in conjunction with re-id algorithms. Good graphics in paper.

2.1.4 VOT

[11]: VOT21 Challenge Results. Considers single-camera, single-target, model-free tracking. VOT-RT2021 focuses on real-time RGB tracking. Requires predicting bounding boxes. Top two trackers: TrasT_M and STARK_RT.

[12]: VOT22 Challenge Results. Considers single.camera, single-target. VOT-RT2022 focuses on real-time RGB tracking, VOT-RTs by segmentation, VOT-RTb by bounding boxes. Goes beyond previous challenges (updating datasets). Real-time tracking at 20fps. Top trackers: MS_AOT and OSTrackSTB.

[13] VOTS23 Challenge Results. First year considering multiple-target tracking challenge. Explores short- and long-term at once. Only one challenge for all. Does not distinguish between these scenarios. Success is measured in IoU, tracking Quality mathbfQ, Accuracy, Robustness, NRE, DRE, ADQ. Dataset with challenging situations, wide range and diverse set of objects, object which are a part of other objects. Also longer videos. 77 trackers submitted, 47 valid. Most trackers applied uniform dynamic model, utilized transformers, general segmentation network SAM. Top tracker: DMAOT built upon VOT22 winner AOT. Best segmentation-based trackers outperformed all bound.box trackers.

2.1.5 Dynamic Cameras

[14]: Tracking multiple vehicles in the front view of an onboard monocular camera. Siamese network with a spatial pyramid pooling. Markov decision process. Effective for real-time long-term tracking. Hungarian algorithm, reinforcement learning.

[15]: Single-Stage Global Association Approach. Dynamic MCMOT (moving cameras in vehicle). Solves fragment-tracking issues. Not relevant for static MCMOT.

2.1.6 Person Tracking

[16]: Non-overlapping cameras. Pedestrian Tracking. Fix ID-switching issues with long-term feature extraction. OC-SORT + feature extraction.

[17]: Soccer Players. Raw detection heat maps. Google Research Football Environment. Multi camera, multi targets. Cameras have fixed positions. Do not use bounding boxes, instead raw input with heat maps. Graph Neural Network. No visual cues, such as jersey numbers. Player movement trajectories and interaction between neighborhood players.

[18]: Optical-based Pose Association (OPA). Online data association algorithm. Solve the occlusion problem. Take also human pose (see [19]) and optical flow into account, not only visual and spatial information. OpenPose, Object Keypoint Similarity, PWC-Net, Kunh-Munkras algorithm.

2.1.7 Vehicle Tracking (AI City)

[20]: Multi-camera vehicle tracking. No real-time tracking. Improve single-camera tracklets. 4th place in 2022 AI City Challenge. Track refinement module. Yolov5 pre-trained on COCO. Using GAN to generate synthetic data. Background filtering. Hierarchical clustering, zones, two rounds of clustering (tracklets separately each possible transition between cameras, akk tracks fro adjacent cameras).

[21]: Inspired [20]. First place in 2021 AI City Challenge. Yolov5 pre-trained on COCO. Most important: Introduces two step clustering (inter-zone, inter-camera clustering).

[22]: Fourth place in 2021 AI City Challenge (Track 3). Occlusion-aware tracking system. Inspired by Stadler.

[23]: Second place in 2022 AI City Challenge (Track 1). No new innovations made on first glance.

[24]: First place in 2020 AI City Challenge (Track 3). Electricity. Efficient vehicle tracking system. Aggregation loss and fast multi-target cross-camera tracking strategy. Weighted inter-class non-maximum suppression.

[25]: Graph Auto-Encoder and Self-Supervised Camera Link Model. First implementation of GAE in MTMCT. Very interesting paper. Network topology is learned automatically.

2.1.8 Re-ID, Data Association and Tracklet Matching

[26]: Orientation-driven person re-id (ODPR). Leverages the orientation cuest and stable torso features to learn a discriminative representation. Also estimates camera topology.Entry/Exit zones are clustered with GMM.

[27]: Locality aware appearance metric (LAAM). Intra- and inter-camera metric for re-ID. Can be applied on top of globally learned re-ID features. Improves tracking accuracy.

[19]: State-aware Re-ID. Human pose information is adopted to infer the target state including occlusion status and orientation. State-of-the-art result on Duke-MTMCT.

[28]: Proposes Mutual Information Temporal Weight Aggregated Person Re-ID Model (MI-TWA). Person re-identification. New algorithm. Not so interesting.

[29]: Dynamic Graph Model with Link Prediction. Tackles problem of data association with a dynamic graph model. Better feature representations and able to recover from lost tracks during camera transitions. Works for person and vehicle tracking for overlapping and non-overlapping cameras. First time link prediction and dynamic graph are used together for MCMOT. Attention models.

[30]: Metadata-Aided Re-ID. Uses metadata information (car type, brand and color) for re-ID. Traffic-aware single-camera tracking. trajectory-based camera link model. Not so interesting.

[31]: Tracklet-to-Target Assignment. Solves cross-camera tracklet matching problem by TRACTA. Proposes the Restricted Non-negative Matrix Factorization (RNMF) algorithm. Estimates the number of targets in the whole network. Important paper.

2.1.9 Misc

[32]: Tracking framework for multiple interacting targets both overlapping and non-overlapping cameras, raw target trajectory with group state. SVMS, homography-based voting schema, networkflow problem, K-shortest paths algorithm.

[33]: Non-overlapping multiple cameras tracking based on similarity function. Data association method. Similarity based on color appearance and camera topology. Use superpixels for extracting color features generated by Simple Linear Iterative Clustering K-means camera topology learning.

[34]: Multiple hypothesis tracking (MHT) for multi-camera tracking. Track hypothesis trees. Disjoint views. Status: tracking, searching, end-of-track. Real-time online method (15 fps). Also uses pose of person.

[35]: Mathematical multi-camera tracking approach. Pre-clustering obtained from 3D geometry projections.

[36]: Utilizes information regarding spatial and temporal consistency. Reconfigurable graph model. Two step approach: Associate all objects across cameras spatially then reconfig into a temporal graph model. Matching object across different views.

[37]: Joint person re-id and camera network topology inference. First framework which jointly solves both problems. Minimal prior knowledge about environment. Multi-shot method implemented as random-forest.

[38]: Joint learning of feature, affinity and multi-dimensional assignment (FAMNet). Online MOT. One deep-network for all three tasks. End-to-end learning.

2.1.10 Datasets

[39]: Created MTMCT dataset in GTA V. No privacy issues. 6 cameras over 100 minutes per camera. Largest synthetic dataset for multi camera multi person tracking.

2.2 Approaches

Single vs Multi Camera Tracking

Static vs Dynamic MCMOT

Single-Stage vs Multi-Stage Tracking

Intra camera vs Inter camera tracking

Local and Global tracklets

Cross-camera tracklet matching problem

Graph Neural Networks, Self-Attention, Transformers

Hierarchical Clustering

Tracking by detections (Multi-shot) vs One-shot (Single-shot)

Challenges: Occlusion, perspective changes, changes in lighting, changes in appearances, unknown number of targets in the whole network, unknown number of cameras in which a certain target appears.

Common Pipeline:

- Detection
- Feature Extraction
- Single Camera Tracking
- Cross Camera Association
- Multi Camera Tracking

2.3 Die Beschics

Single Object Detection (SOD)

Multi Object Detection (MOD)

Object Re-Identification (ReID)

Single Camera Tracking (SCT)

Multi Camera Tracking (MCT)

Camera Link Model (CLM)

Trajectories and Tracklets

Fisheye vs Normal Cameras

Online vs Offline Tracking (Online: real-time and frame-by-frame, Offline: post-processing)

Local neighborhood: Single-camera tracking: Consecutive frames. Multi-camera tracking: Neighboring cameras.

Different cameras have different technical characteristics.

Appearance features vs Motion features

Datasets:

- DukeMTMC
- MOTChallenge
- AI City Challenge
- PETS
- CityFlow

2.4 Composition

- Introduction
- Motivation
- Technical Background
- Problem Statement
- State of the Art
- Approaches

- Challenges
- Papers
- Further Research
- Conclusion

2.5 Research

2.6 Mentioned Papers

mentioned in [22]:

D. Stadler and J. Beyerer. Improving multiple pedestrian tracking by track management and occlusion handling. In IEEE Conf. Comput. Vis. Pattern Recog., 2021.

mentioned in [34]:

Ristani, E., Tomasi, C.: Tracking multiple people online and in real time. Proc. Asian Conf. Computer Vision, Singapore, 2014, pp. 444-459

Wei, S.-E., Ramakrishna, V., Kanade, T., et al.: Convolutional pose machines. Proc. IEEE Conf. Computer Vision and Pattern Recognition, Las Vegas, USA, 2016, pp. 4724-4732

2.6.1 Arising Questions

Online Tracking?

Hungarian algorithm?

Multi Object vs Multi Target (definitions)

Detection Frameworks:

- YOLO
- Faster R-CNN
- R-CNN

Tracking Frameworks:

- OpenCV
- DeepSORT

- SORT
- MOTSA

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