Tracking Problems: Combinatorial Aspects

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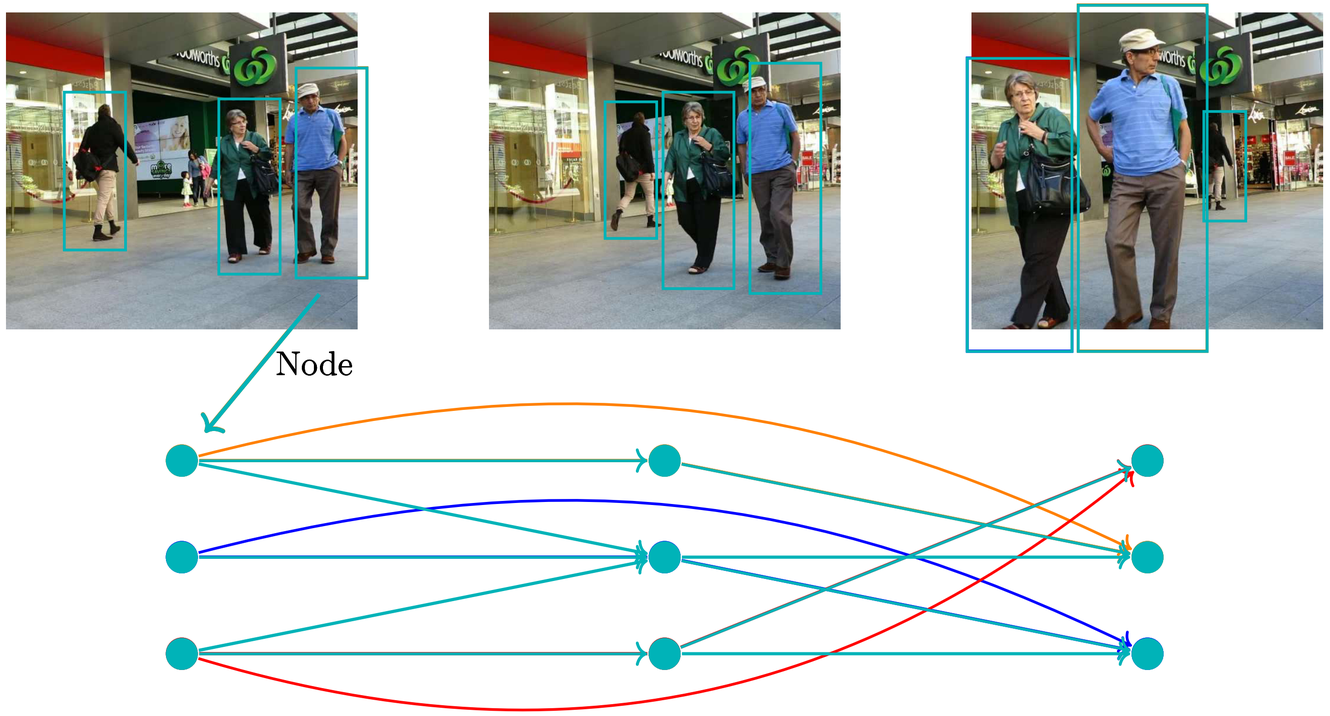
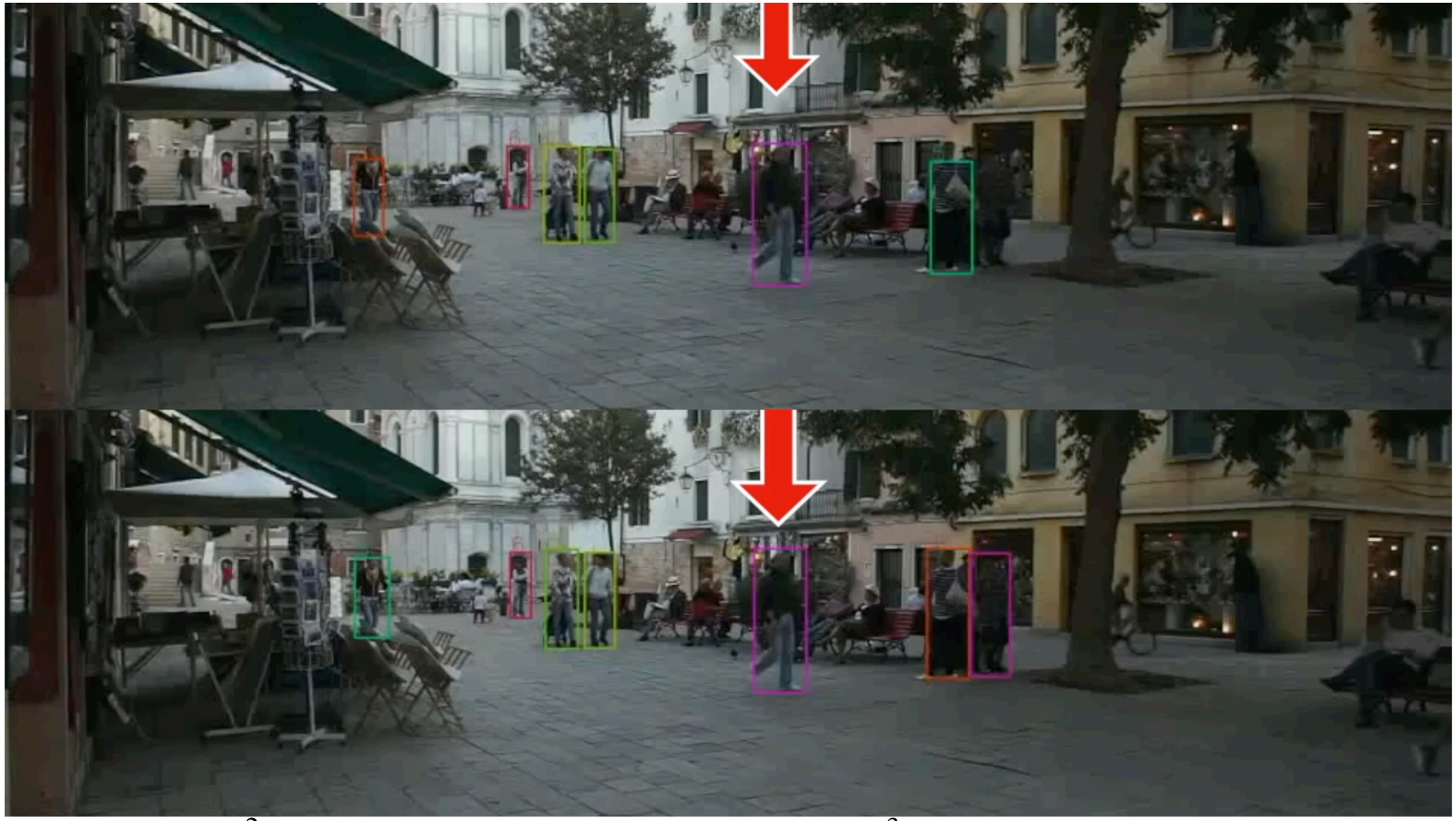
Multiple Object Tracking[1,2]

- **Base model:** disjoint paths
  - Constraints on output ✔
  - Multiple timescales. (Markov assumption) ✘
- **Better model:** Lifted disjoint paths
  - Predictors in multiple timescales contribute to finding solution ✔



[1]: Hornakova, Swoboda et al, ICML 2020 [2]: Hornakova, Swoboda et al, ICCV 2021

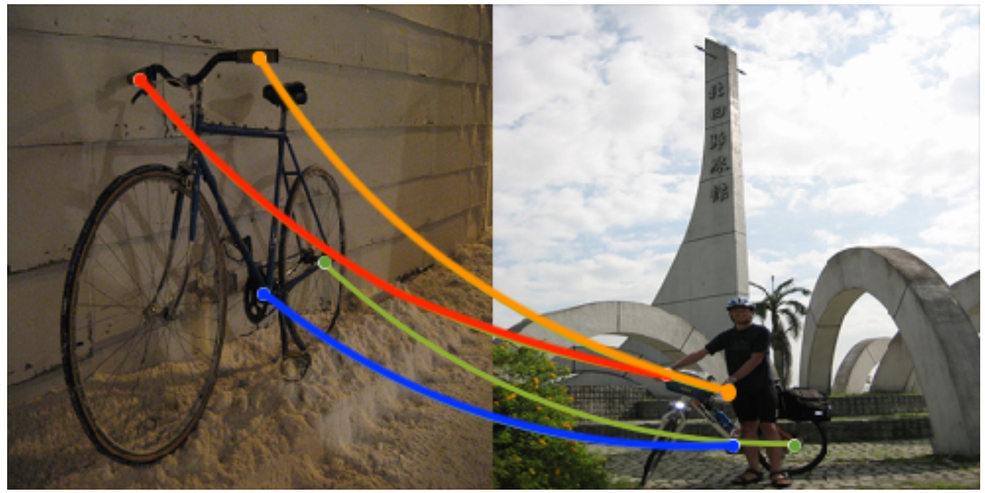
Tracktor[1] vs. Lifted Disjoint Paths[2,3] on MOT Challenge ’17

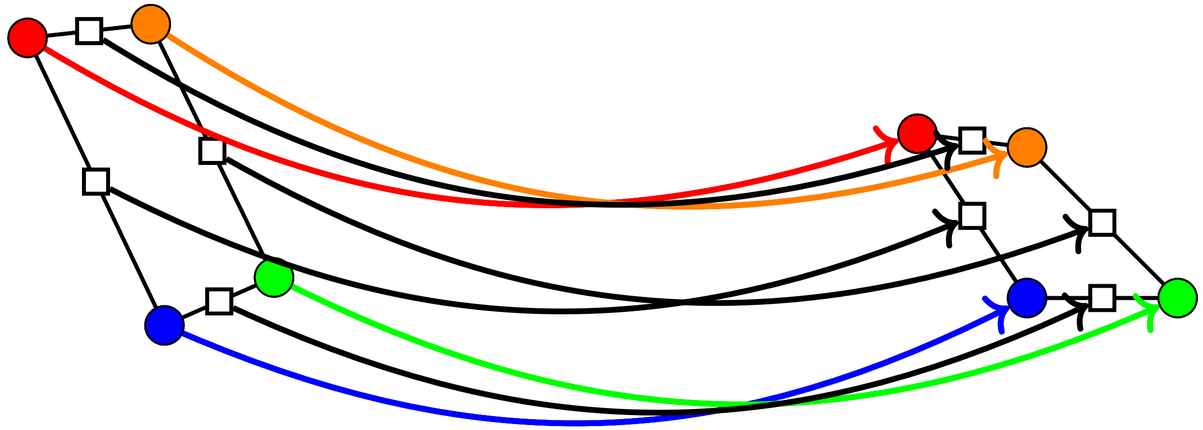


[1]: Bergmann et al, ICCV 2019 [2]: Hornakova, Swoboda et al, ICML 2020 [3]: Hornakova, Swoboda et al, ICCV 2021

Key point matching[1,2]

- **Base model:** Linear assignment problem
  - Affinity between key points
- **Better model:** Quadratic Assignment Problem
  - Affinity between pairs of key points
  - Geometric consistency
- **Can be integrated in Tracking Pipelines**





[1]: Rolinek, Swoboda et al, ECCV 2020 [2]: Swoboda et al, CVPR 2017

End-to-End Training[1,2]

Backpropagate through energy

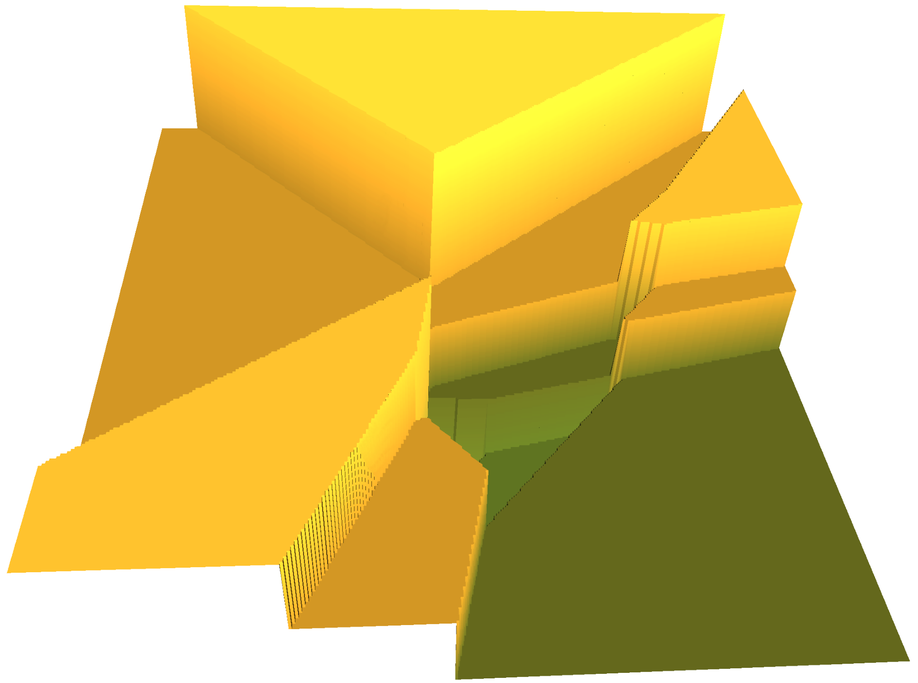
- **Problem:**
  - Algorithms for solving the energy typically not differentiable

$$s : \mathbb{R} \to \mathcal{Y} \subset \{0,1\}^n,$$

  - $c \mapsto \arg\min_{y \in \mathcal{Y}} \langle c, y \rangle$
    - Not even continuous!
- **Solution:**
  - (Multiscale) Finite difference schemes

- Loss $L : \mathbb{R}^n \to \mathbb{R}$
- Gradient through solver w.r.t. loss:

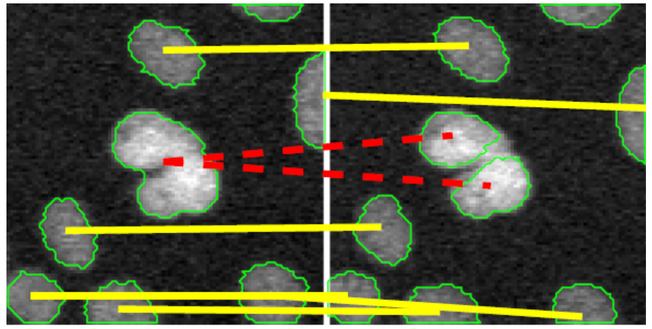
$$\frac{\partial L}{\partial c} \stackrel{?}{=} \lim_{\lambda \to 0} \frac{s(c) - s\left(c + \lambda \frac{\partial L}{\partial s(c)}\right)}{\lambda}$$

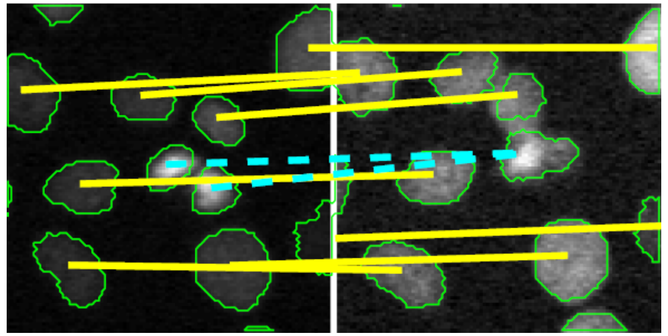


[1]: Rolinek, Swoboda et al, ECCV 2020. [2]: Abbas, Swoboda, NeurIPS 2021

Other Tracking/Clustering

- **Biomedical Imaging:** Cell Lineage Tracing[1]
- **Clustering Problems:** Multicut Solver on GPU[2]
- **General Purpose Optimization Solver:** Arbitrary constraints, GPU enabled





[1]: Haller, Swoboda et al, AISTATS 2020 [2]: Abbas, Swoboda, CVPR 2022 [3]: Abbas, Swoboda, CVPR 2022

Tracking: Deep Learning

- **Talk of Adrian Kosmala**