Prioritized target tracking with active collaborative cameras

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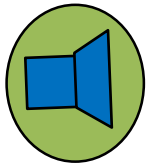
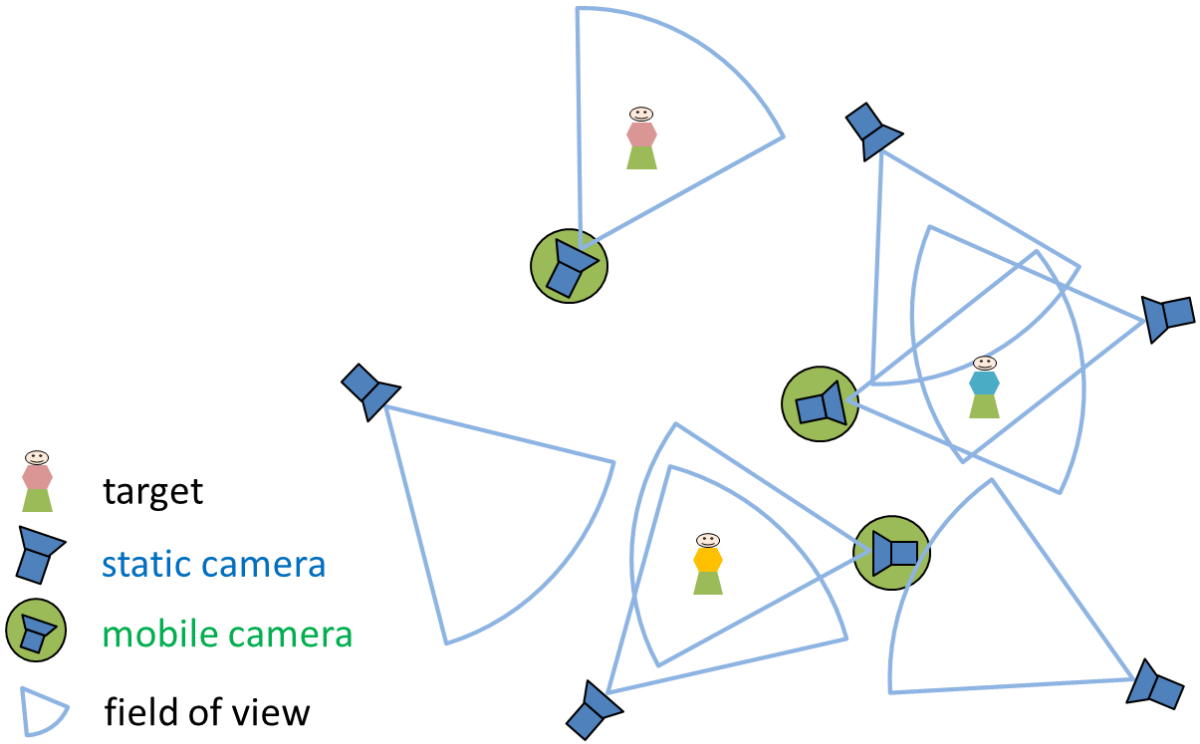


mobile camera
(top view)

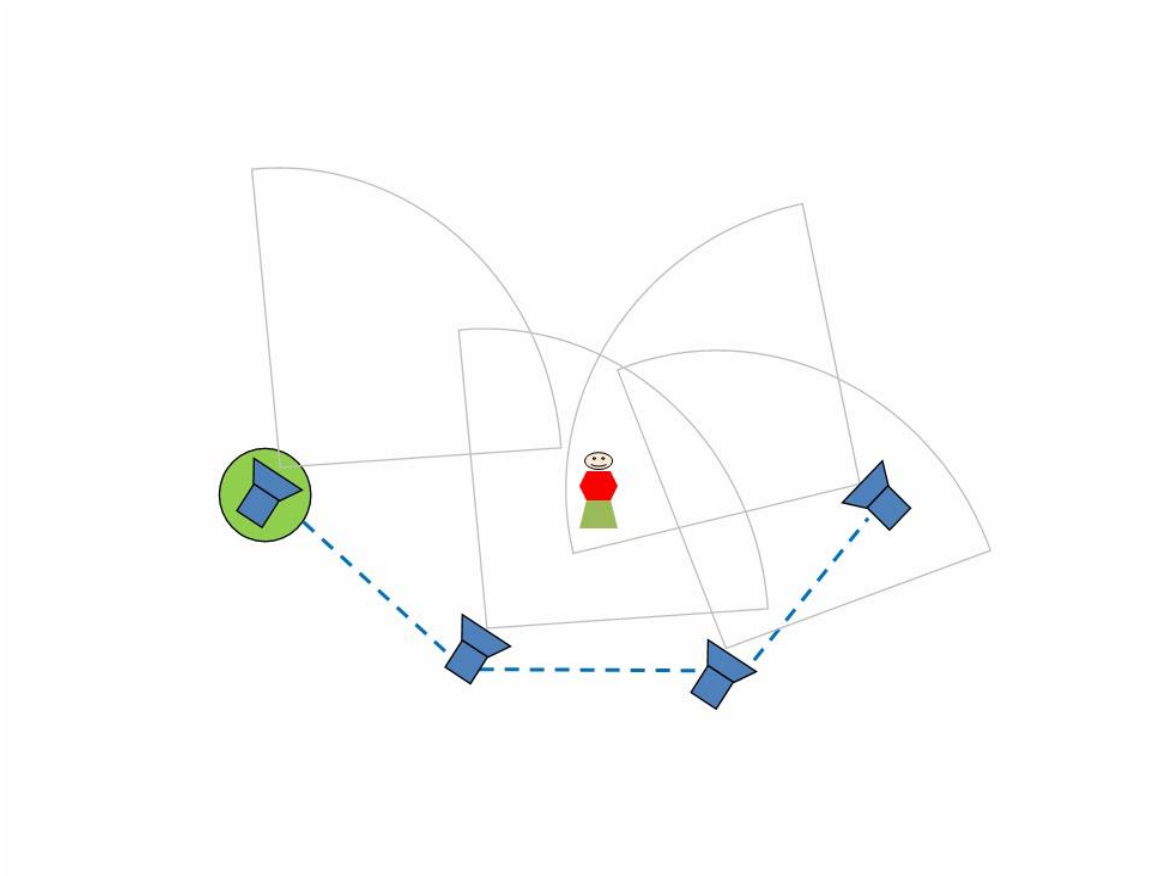
Mixed camera network

- Static cameras detect targets to track
- Mobile cameras move on demand



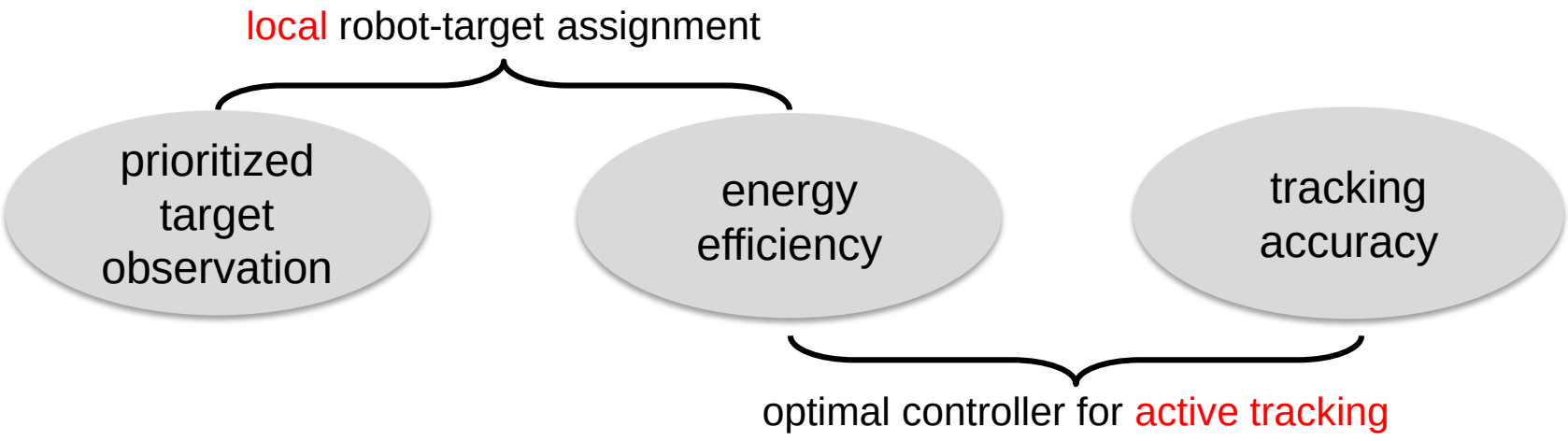
How does it work?

Static camera requests a mobile camera to help with tracking

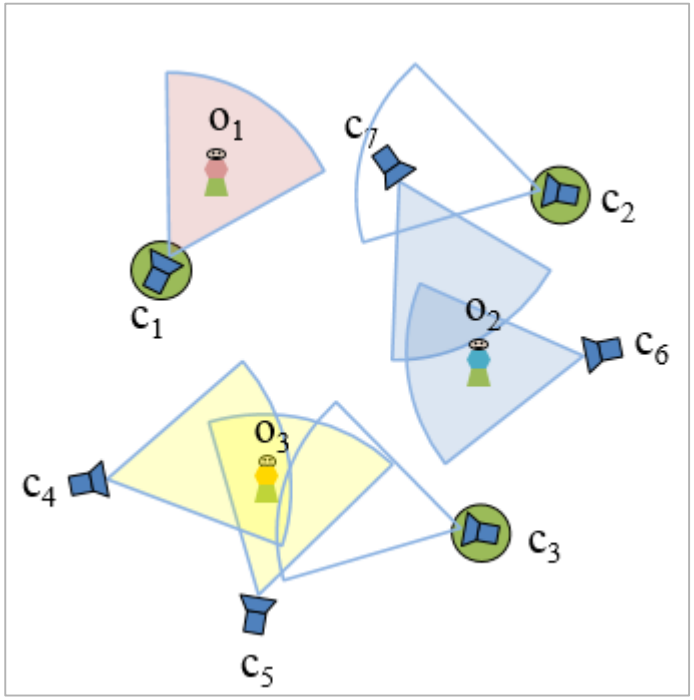


Objective

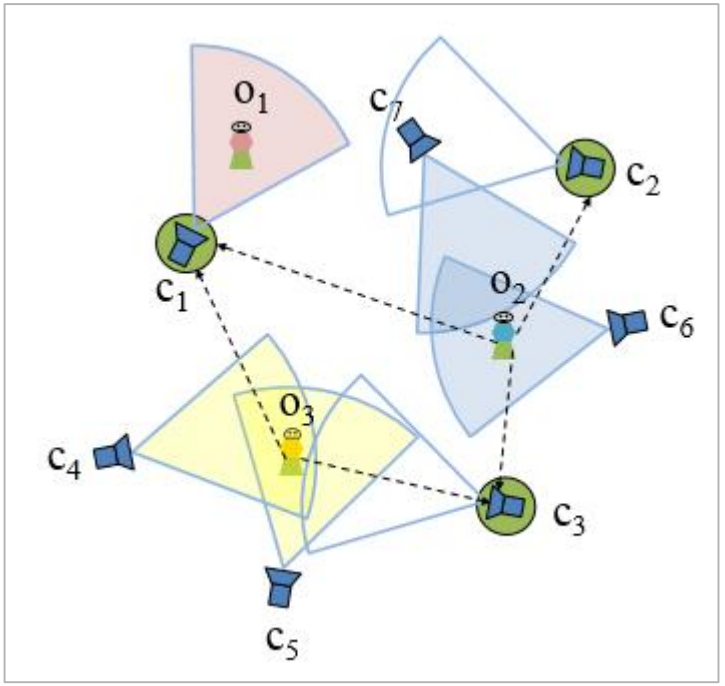
- Collaboration with ‘on-call’ mobile cameras for



Local target selection

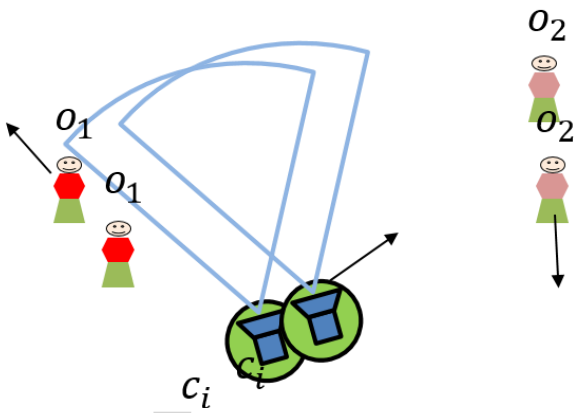


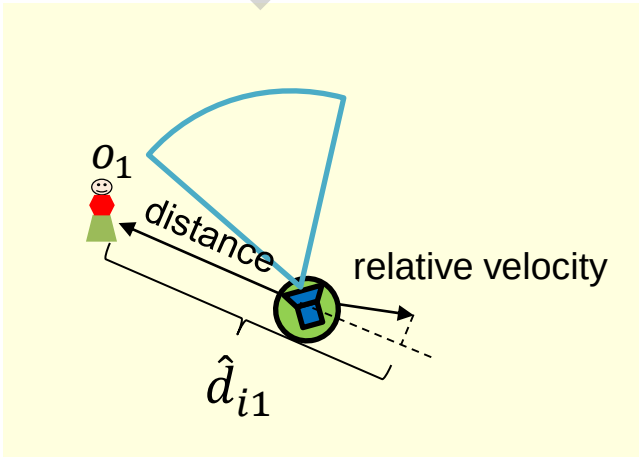
request to
mobile cameras



each robot selects a target to track after receiving requests

Local selection criteria





c_i receives requests to track o_1 and o_2

c_i calculates utility $a_{ij}(\mathrm{t})$ for each o_j

distance-related value

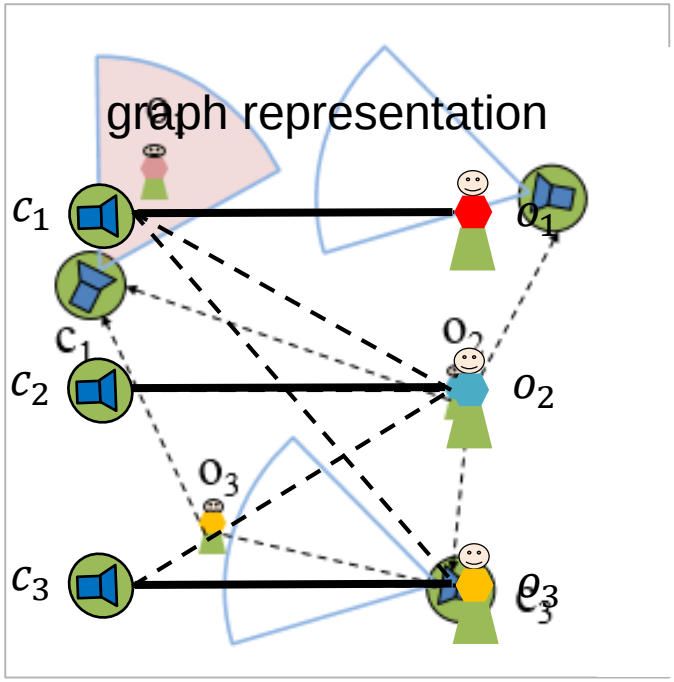
$$a_{ij}(\mathrm{t}) = w_j \; g_{ij}\,(t) \; k$$

target priority

penalty

Penalty k

Multiple mobile cameras could receive requests for the same target



k inversely proportional to the number of mobile cameras receiving the same request

k reduces the probability of multiple mobile cameras selecting the same target

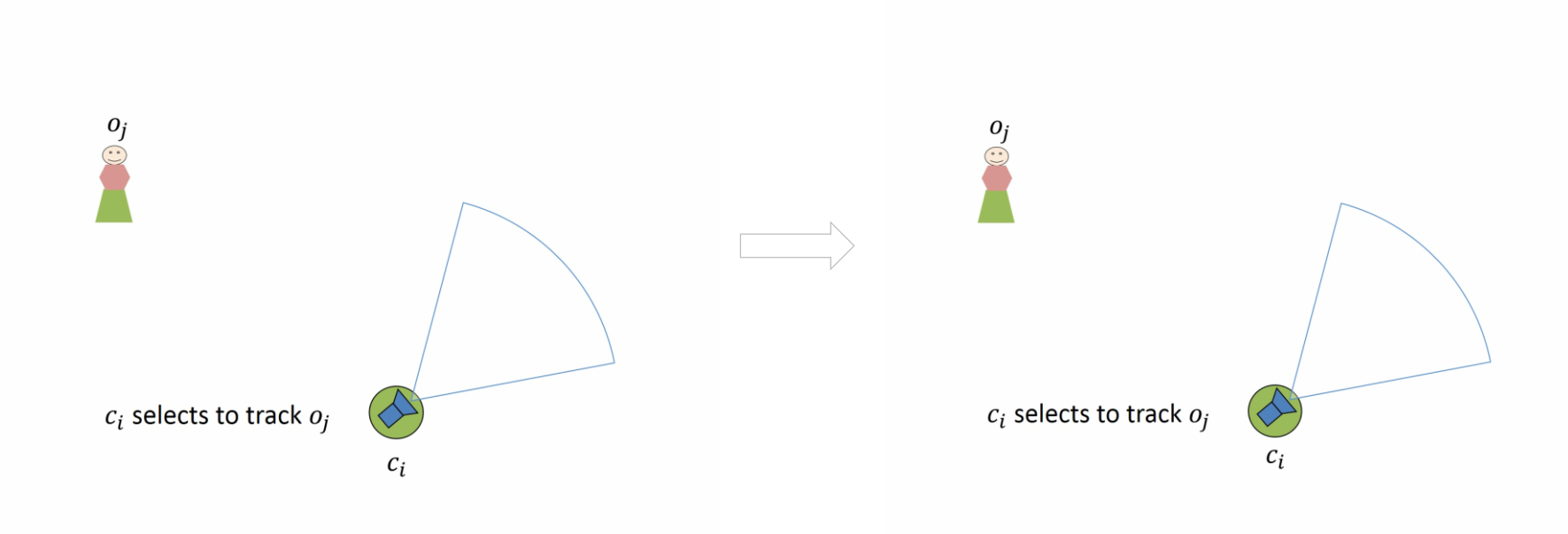
c_i selects the target with the highest utility

Motion planning

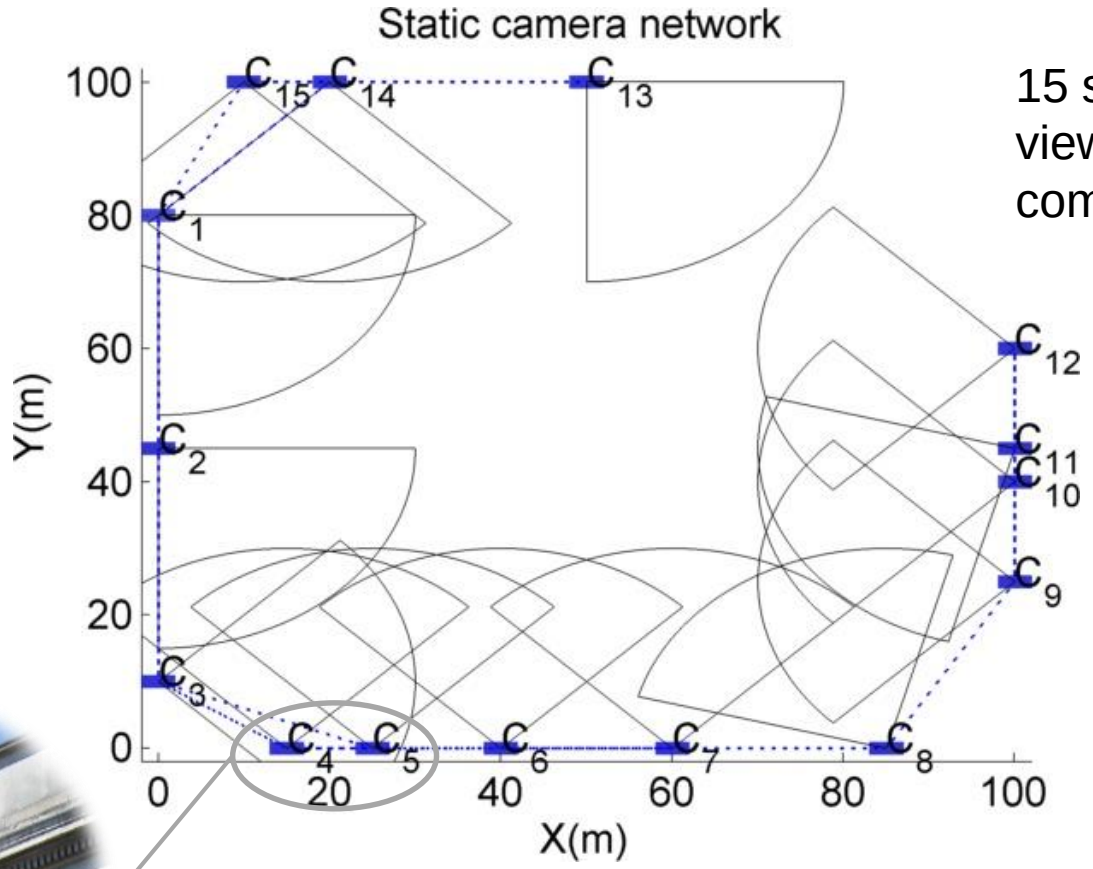
- Model Predictive Control (MPC) [Findeisen2002]
  - T^h: time horizon
  - compute next robot state using the predicted state at $t + T^h$
  - minimize a weighted sum of cost functions: J_1 and J_2

J_1 aims to center target in FoV

J_2 aims to reduce energy [Liu2014]



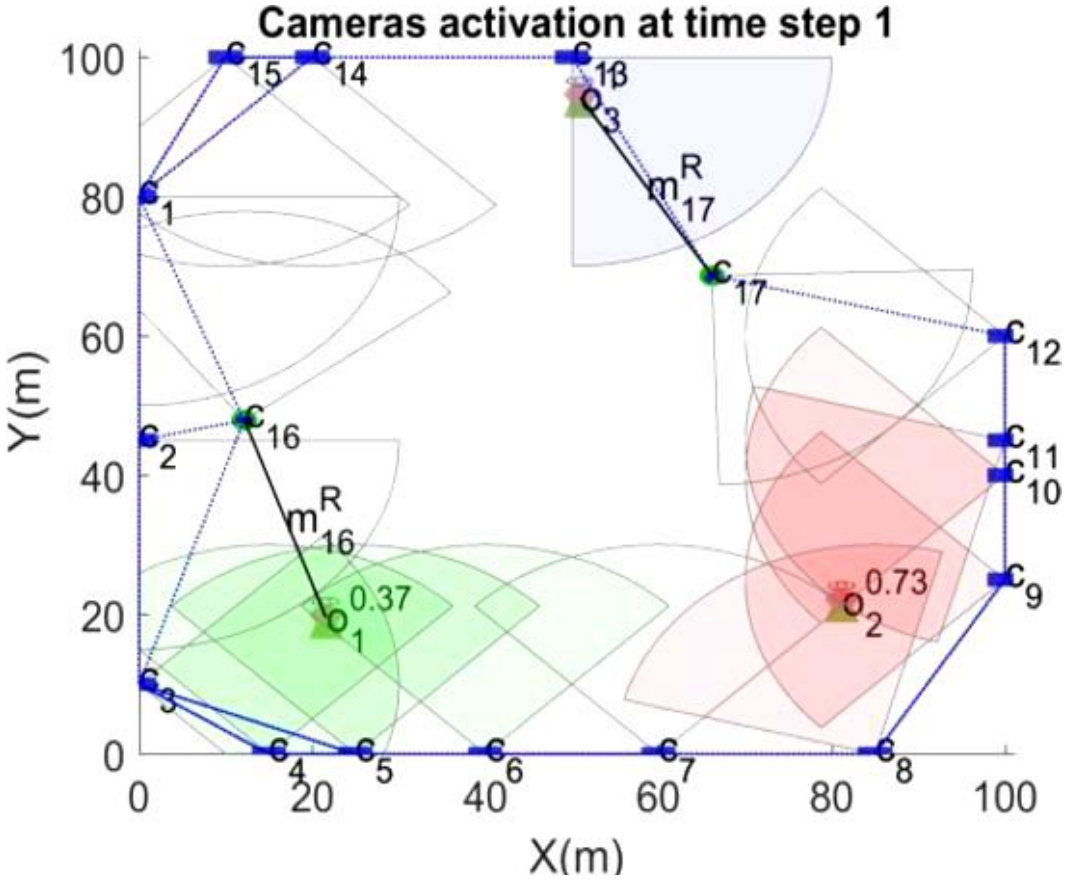
Testing scenario



15 static cameras
viewing range 30m
comm range 40m

----- connectivity among cameras

Example: 3 targets & 2 mobile cameras



$o_j^{w_j}$: target o_j with priority w_j

o_j —— m_i^R —— c_i

c_i receives a request to track target o_j

Performance measures

mean tracking error

$$\epsilon = \frac{1}{TN}\sum_{t=1}^{T}\sum_{j=1}^{N}\left\|\boldsymbol{s}_j(t) - \hat{\boldsymbol{s}}_j(t)\right\|$$

time steps (T); # targets (N); ground-truth state; estimated target state

prioritized target observation

$$\eta^M = \frac{1}{TW}\sum_{t=1}^{T}\sum_{j=1}^{N} B_j^M(t) w_j$$

$B_j^M(t)$: is target j being observed by a mobile camera? {0,1}

$$W = \sum_{j=1}^{N} w_j$$

normalized energy cost

$$e = \frac{1}{TN}\sum_{t=1}^{T}\sum_{i=1}^{N_M} E_{N,i}(t)$$

N_M: # mobile cameras

$E_{N,i}(t)$: normalized energy cost for a mobile camera

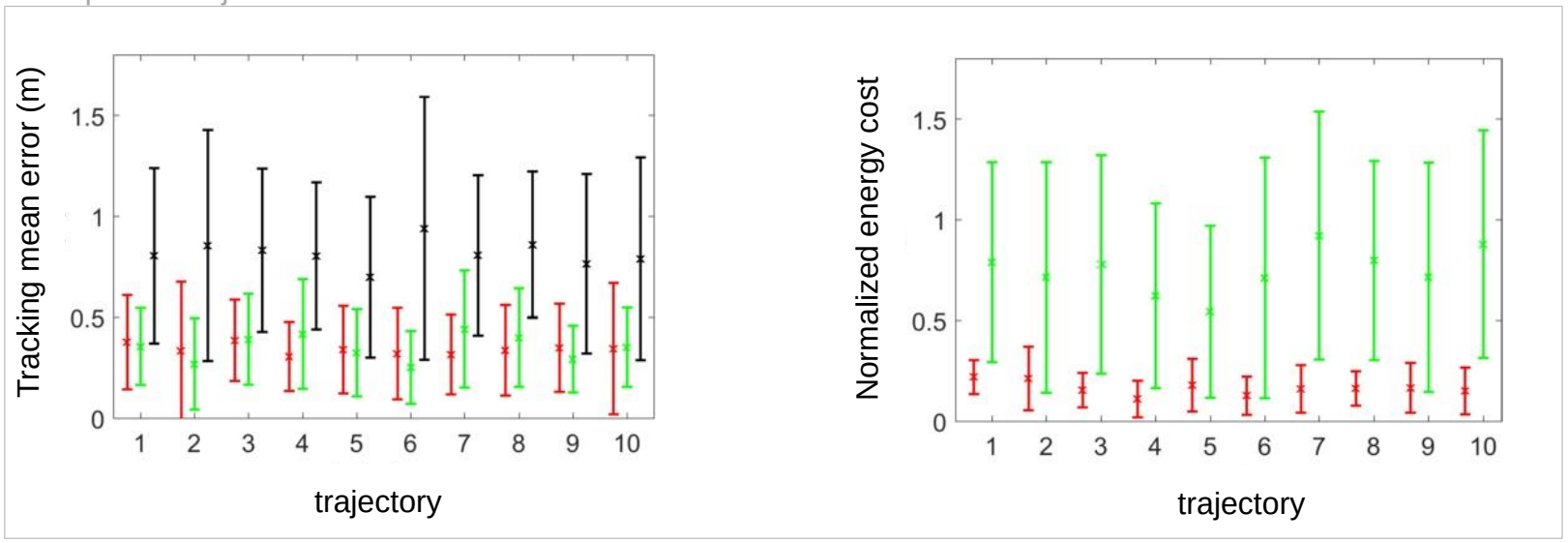
Tracking accuracy

X : static cameras + mobile cameras using MPC controller
X : static cameras + mobile cameras using one-step-ahead optimal controller [Wei2014]
X : only static cameras [Wang2015]

Average tracking error (m)
x : 0.34
x : 0.35
x : 0.73

Average normalized energy
x : 0.17
x : 0.75
x : n/a (no mobile cameras)

Example: 10 trajectories

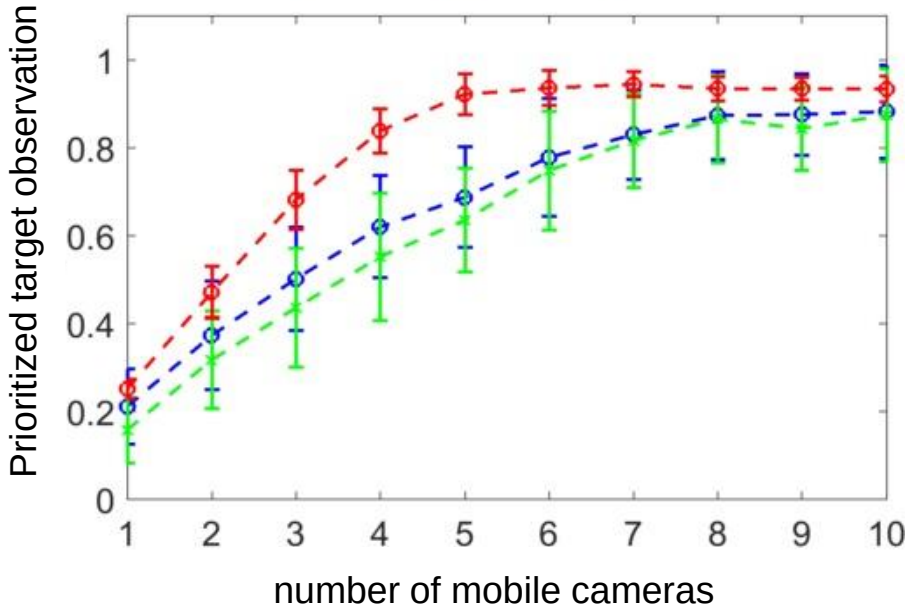


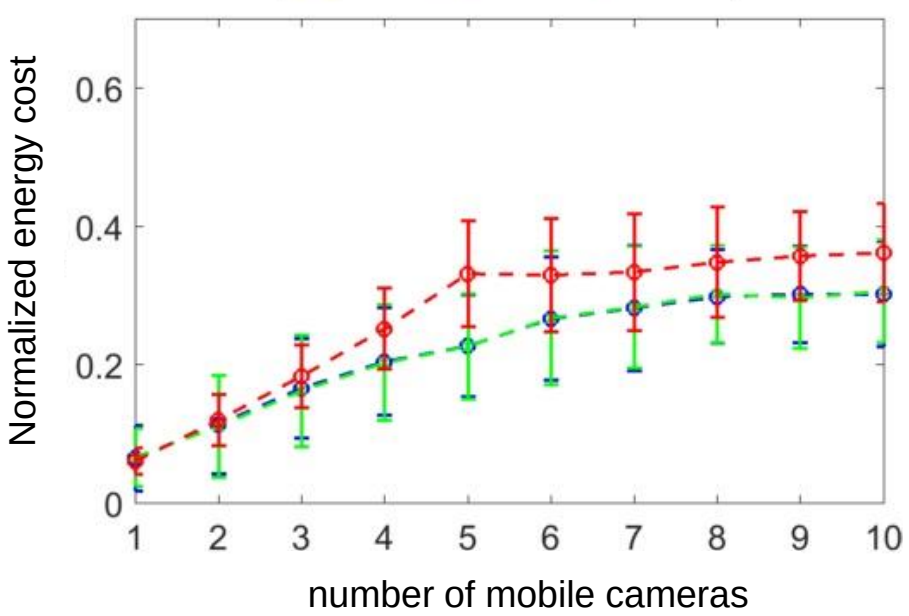
Prioritized target observation

distributed local target selection using proposed utility

distributed local target selection using robot-target distance [Yu2014]

centralized target-robot assignment with Hungarian algorithm [Kuhn1955]





Conclusion

- Collaborative framework for distributed target tracking with a mixed camera network
  - improved tracking accuracy
  - energy efficiency in robot assignment and motion planning

- Future work
  - to include collision avoidance
  - to model communication and detection errors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