Algorithms for Telerobotic Camera View Frame Placement Problem in the Presence of an Adversary and Distributional Ambiguity

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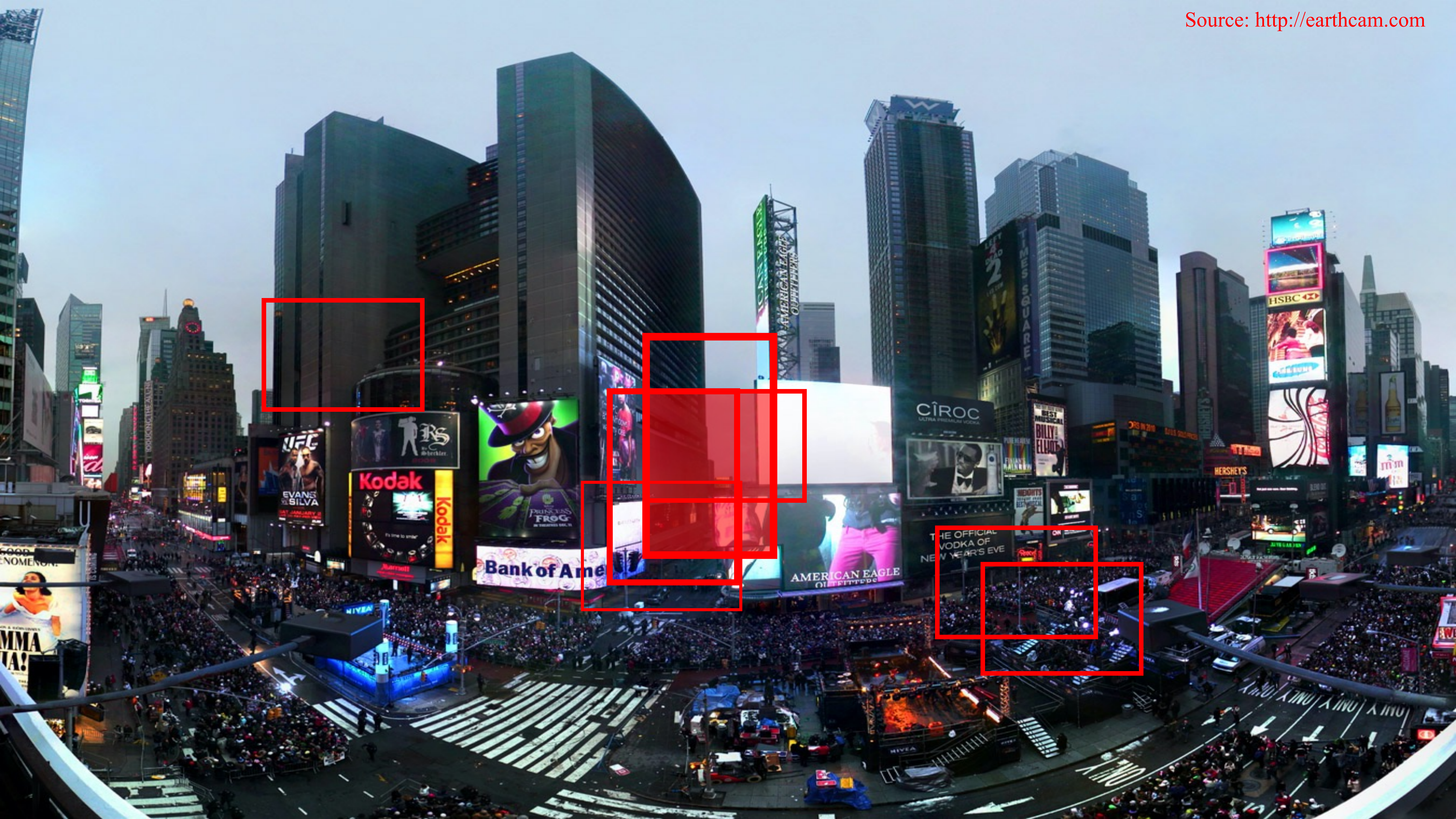

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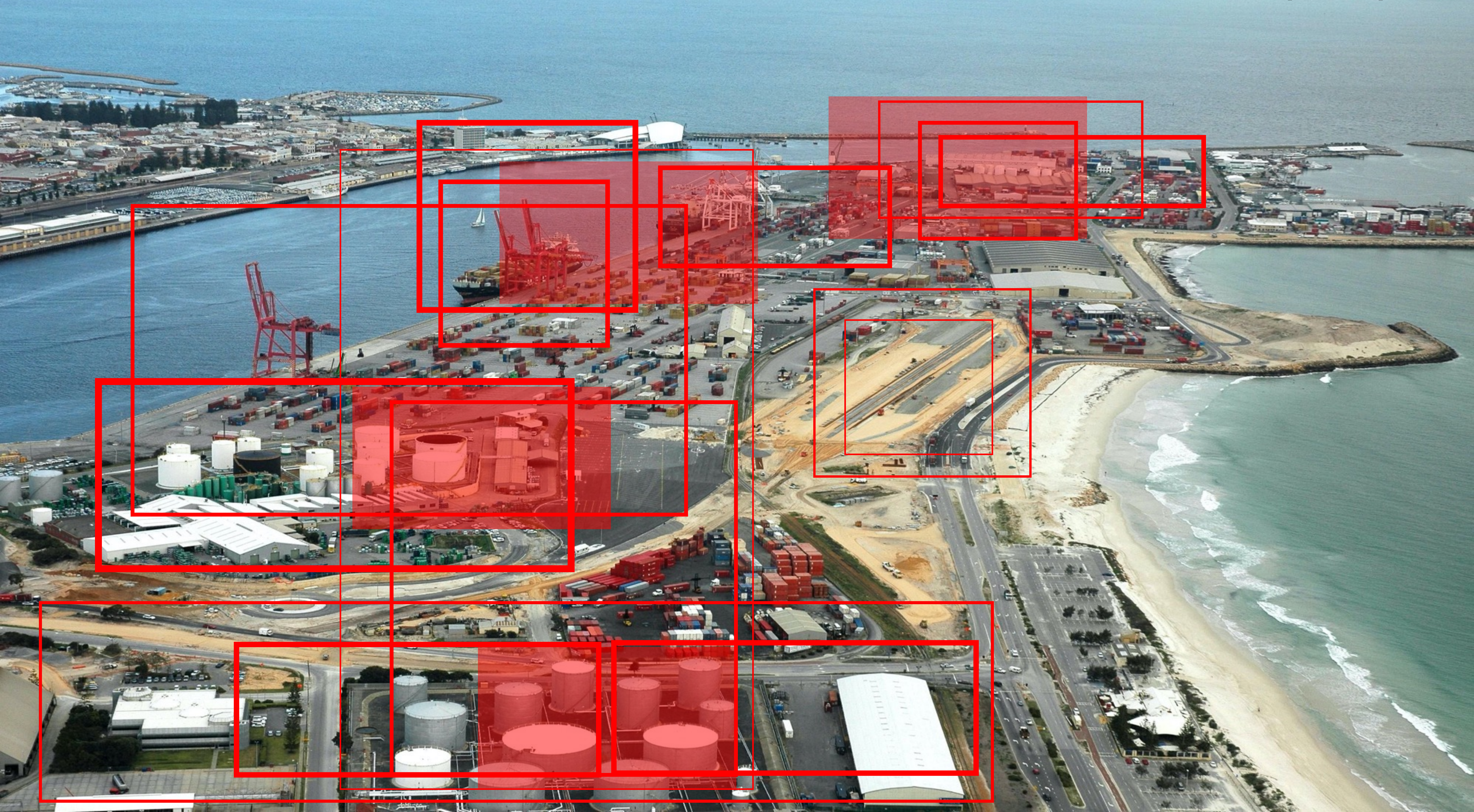
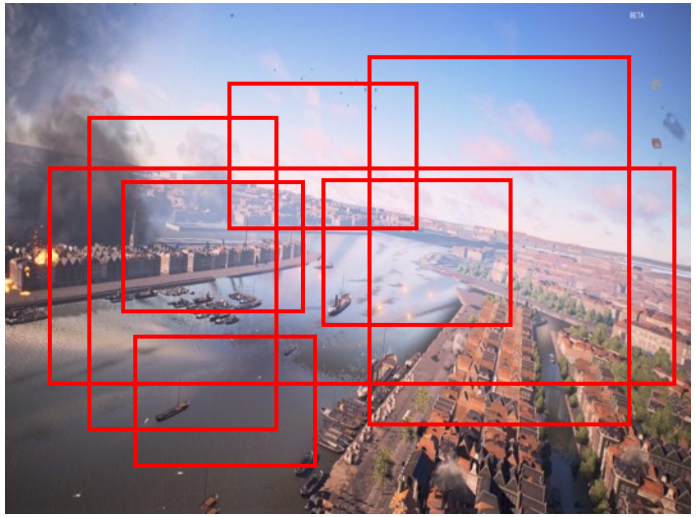


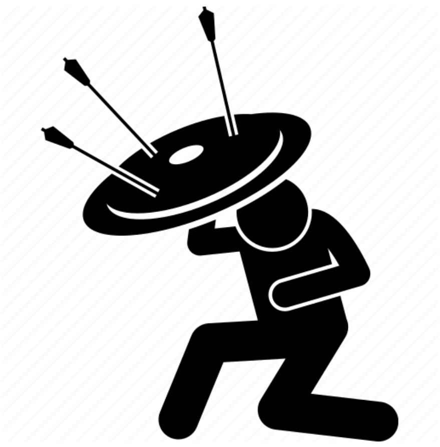
Adversarial Camera View Frame Placement Problem (ACFP)

❖ Motivation and Background

- In general, agents or telerobotic cameras are potentially vulnerable to adversarial attacks conducted by an adversary who aims to minimize the information acquisition for the decision maker.
- Defender place p camera view frames to capture the subregion with the maximum reward.

Attacker





Defender

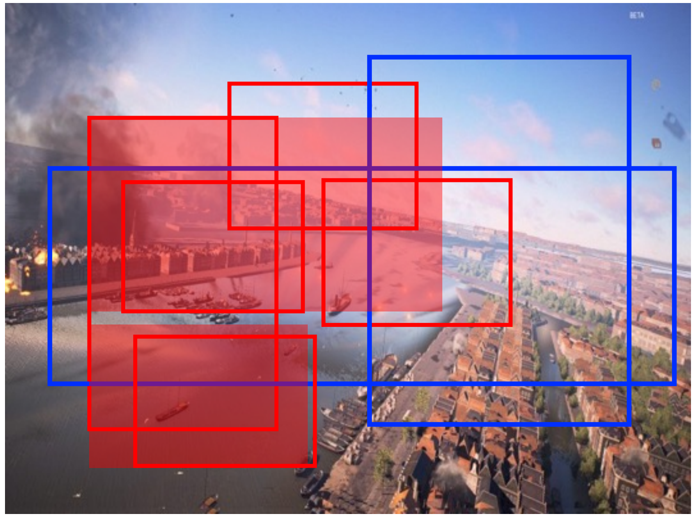
https://togetherintransit.nl/battlefield-5-rotterdam-map-comparison-to-real-life/

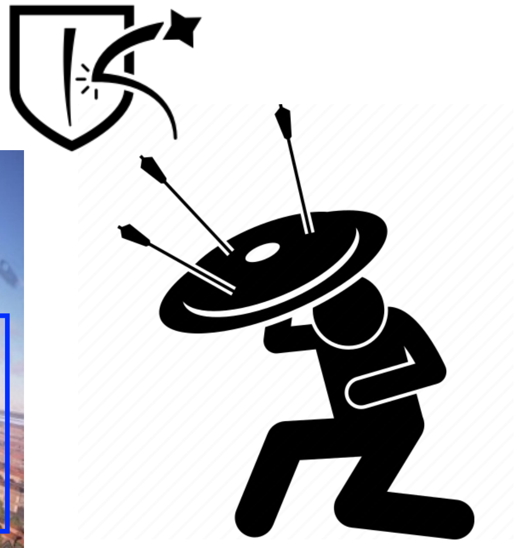
Adversarial Camera View Frame Placement Problem (ACFP)

❖ Motivation and Background

- In general, agents or telerobotic cameras are potentially vulnerable to adversarial attacks conducted by an adversary who aims to minimize the information acquisition for the decision maker.
- This leads to the game between two non-cooperating players: An attacker and a defender.

Attacker





Defender

Research Summary

Adversarial Camera View Frame Placement Problem (ACFP)

- Problem component
  - Uncertainty in the success of attacks.
  - Incomplete information of probability distribution associate with uncertain parameters.
- Solution Approach
  - Distributionally Robust Optimization.
  - Derived valid inequality to optimize objective function to the optimality.

Algorithms for Camera View Frame Placement Problem without an Adversary

- Single Camera View Frame Placement Problem (S-CFP)
  - Reduction in the original solution space considered in Song et al. (2006)
- Multi Camera View Frame Placement Problem (M-CFP)
  - Greedy algorithm and its approximation ratio
  - Branch-and-bound based heuristic method for M-CFP with fixed tilt of camera (M-CFP-F)
- Simulation Study (Search and Rescue)

Adversarial Camera View Frame Placement Problem (ACFP)

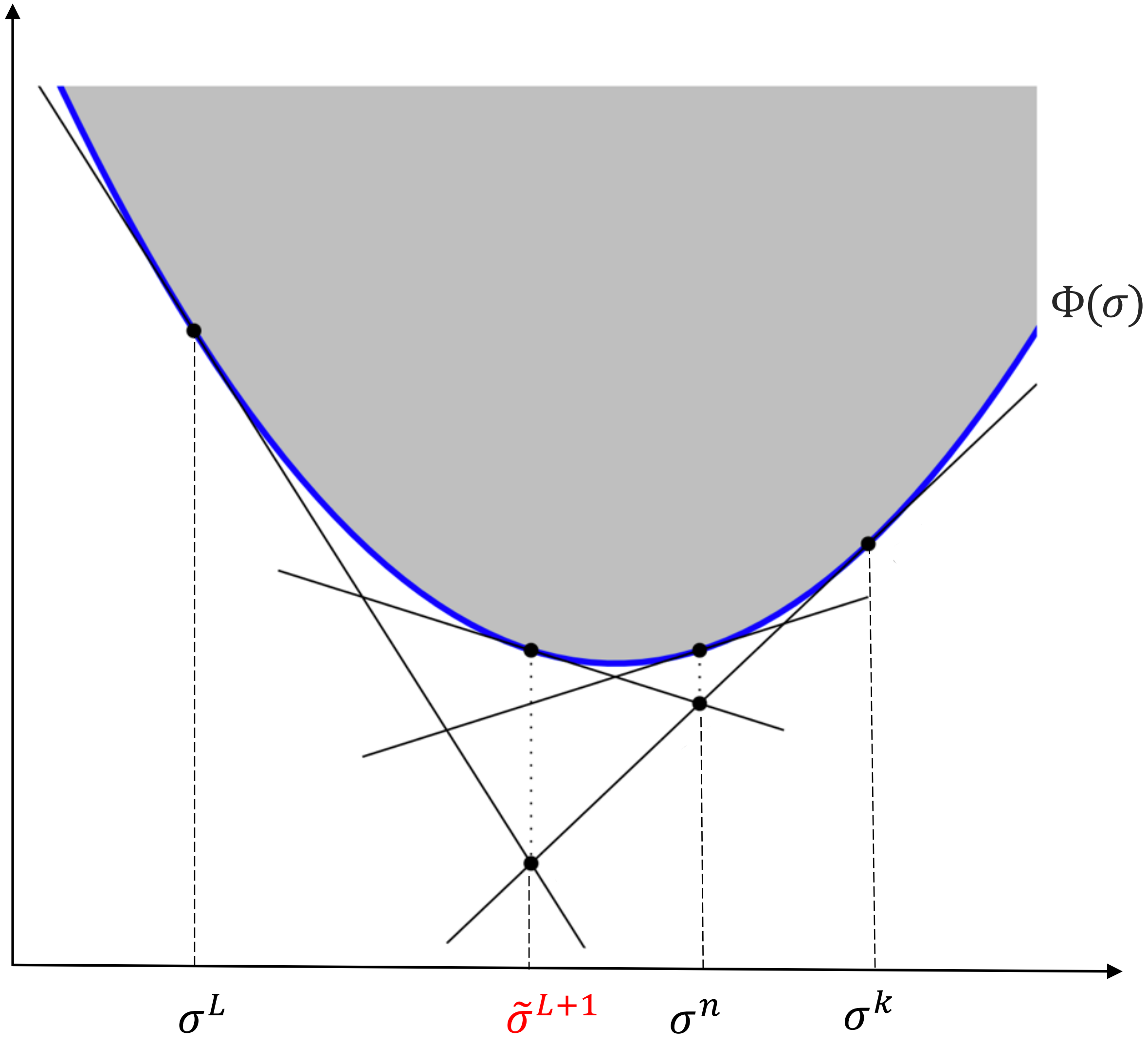
❖ **Solution Approach: Cutting plane method**

- We have derived a valid inequality that offers a lower bound approximation for our objective function, $\Phi(\sigma)$.
- By iteratively incorporating these approximations, we converge to the problem's optimal solution.

Mathematical Formulation

$$\min_{\sigma\in\{0,1\}^n}\left\{\Phi(\sigma) := \max_{P\in\mathcal{P}} \mathbb{E}_P[Q_\omega(\sigma,\xi)] \;\middle|\; \sum_{i\in N} c_i\sigma_i \le b\right\}$$

$$\text{where}\quad Q_\omega(\sigma,\xi) = \sum_{i\in N} \mu_i^\omega \qquad \forall\omega\in\Omega$$



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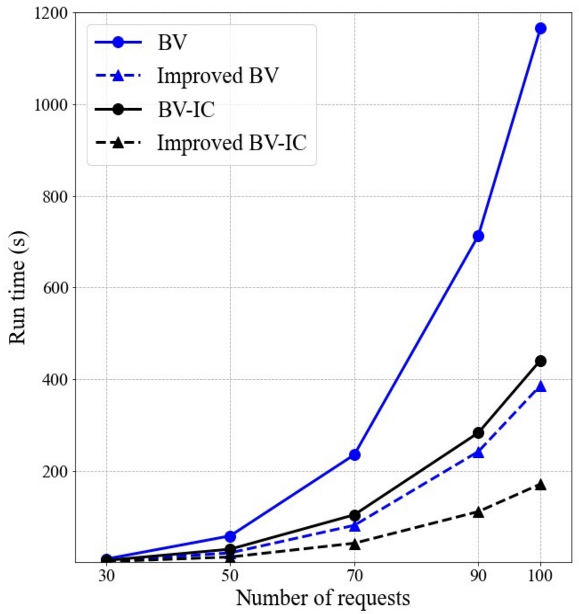
Computational Results

❖ Results for S-CFP

- When $n \leq 100$, the improved BV algorithm outperforms original BV-IC algorithm even though it is an upgraded version of BV algorithm.



❖ Results for M-CFP

- We prove that the approximation ratio of this approach is $1 - 1/e$ where e is the base of natural logarithm.

Theorem IV.1.

Let γ_g denotes the approximation ratio for the greedy algor ithm, i.e., ratio of the objective value of the greedy solution and optimal objective value of general M-CFP. Th en,

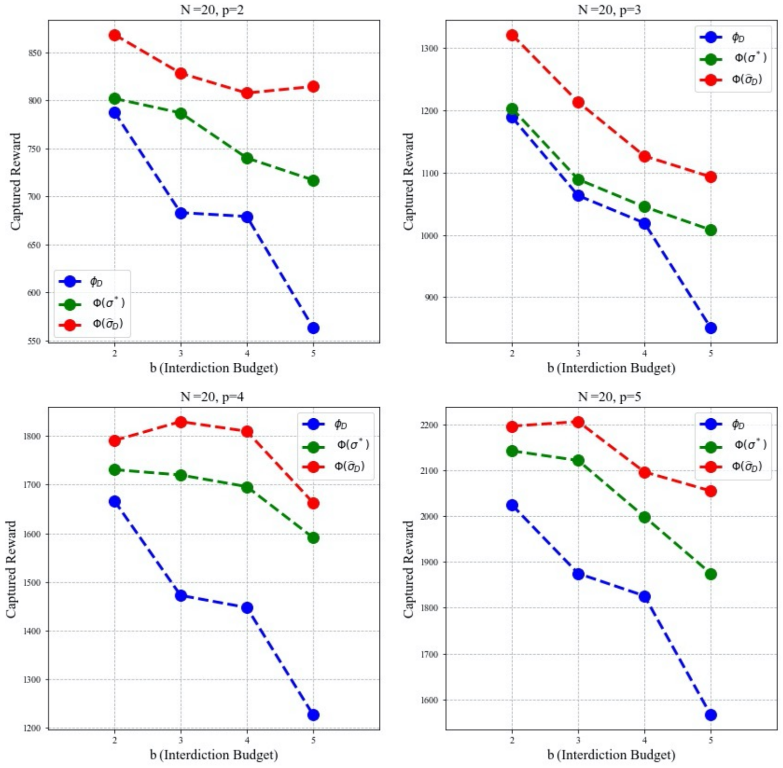
$$\gamma_g > 1 - \frac{1}{e},$$

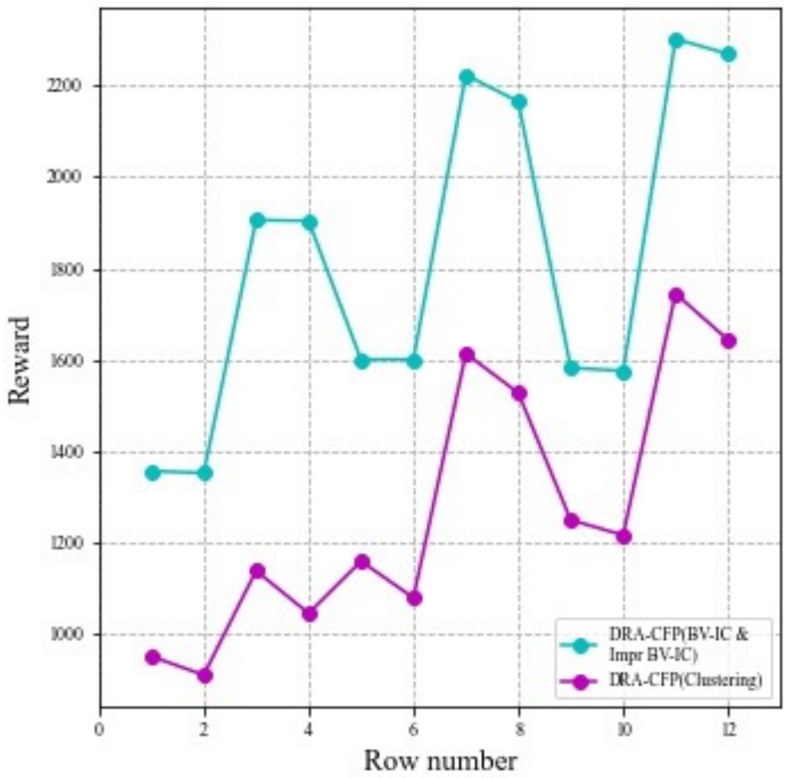
where e is the base of natural logarithm.

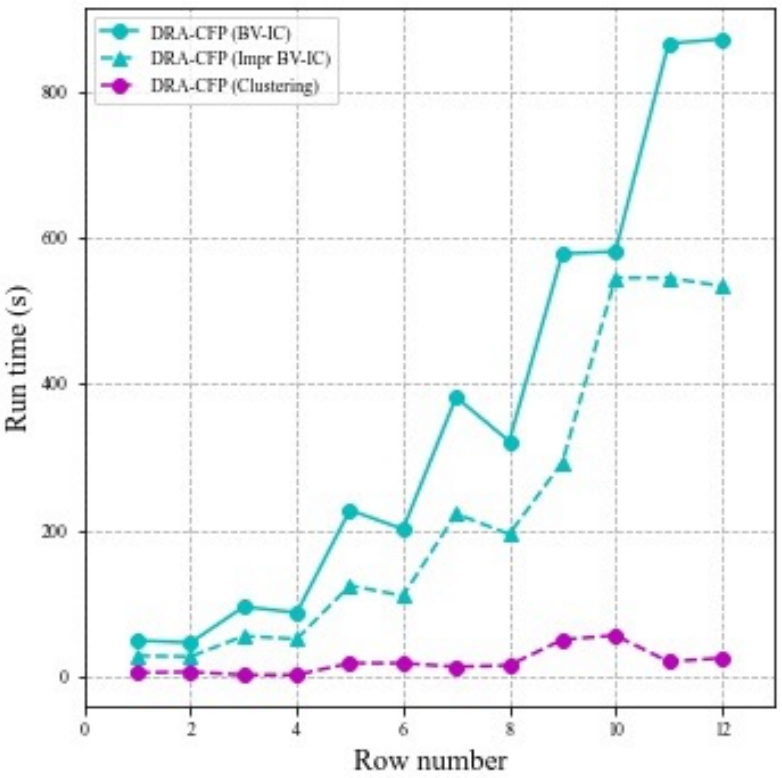
Computational Results

❖ Results for ACFP

- After we improve computational efficiency of algorithms for CFP, we have conducted experiments for ACFP.







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