System Architecture and self-configuration in Distributed Camera Networks

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Outline

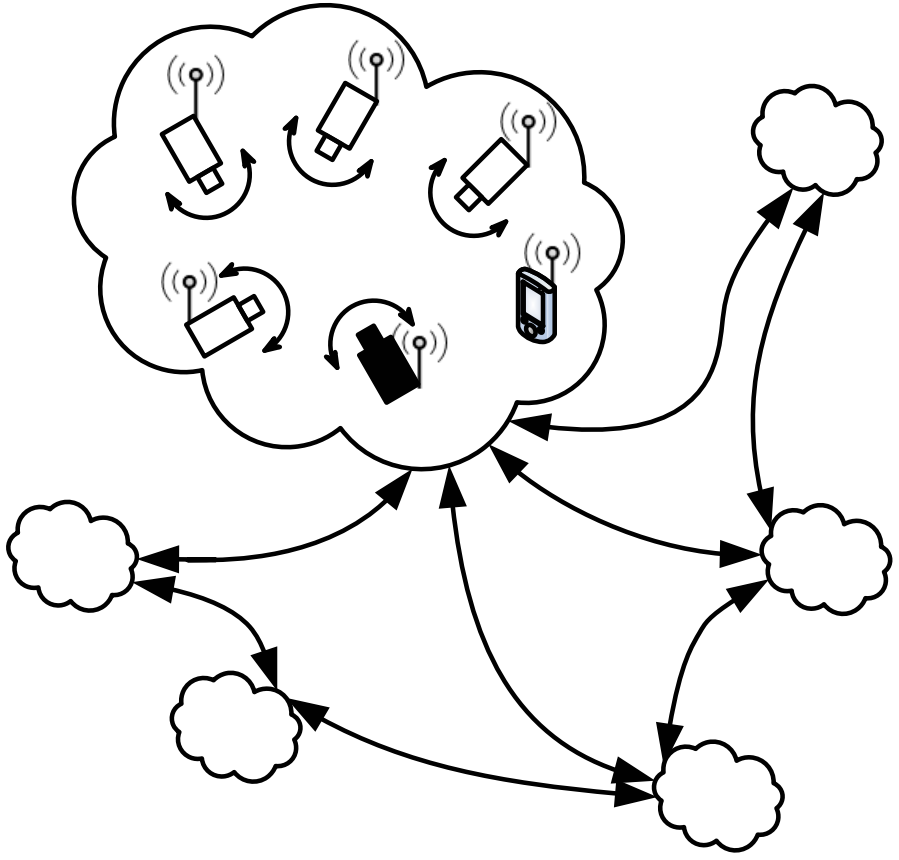
- Smart Cameras at a glance
- System Architecture
- Node Architecture
- Cooperative Tasks: Spatial partitioning problem
- Conclusion

Distributed Smart Camera System

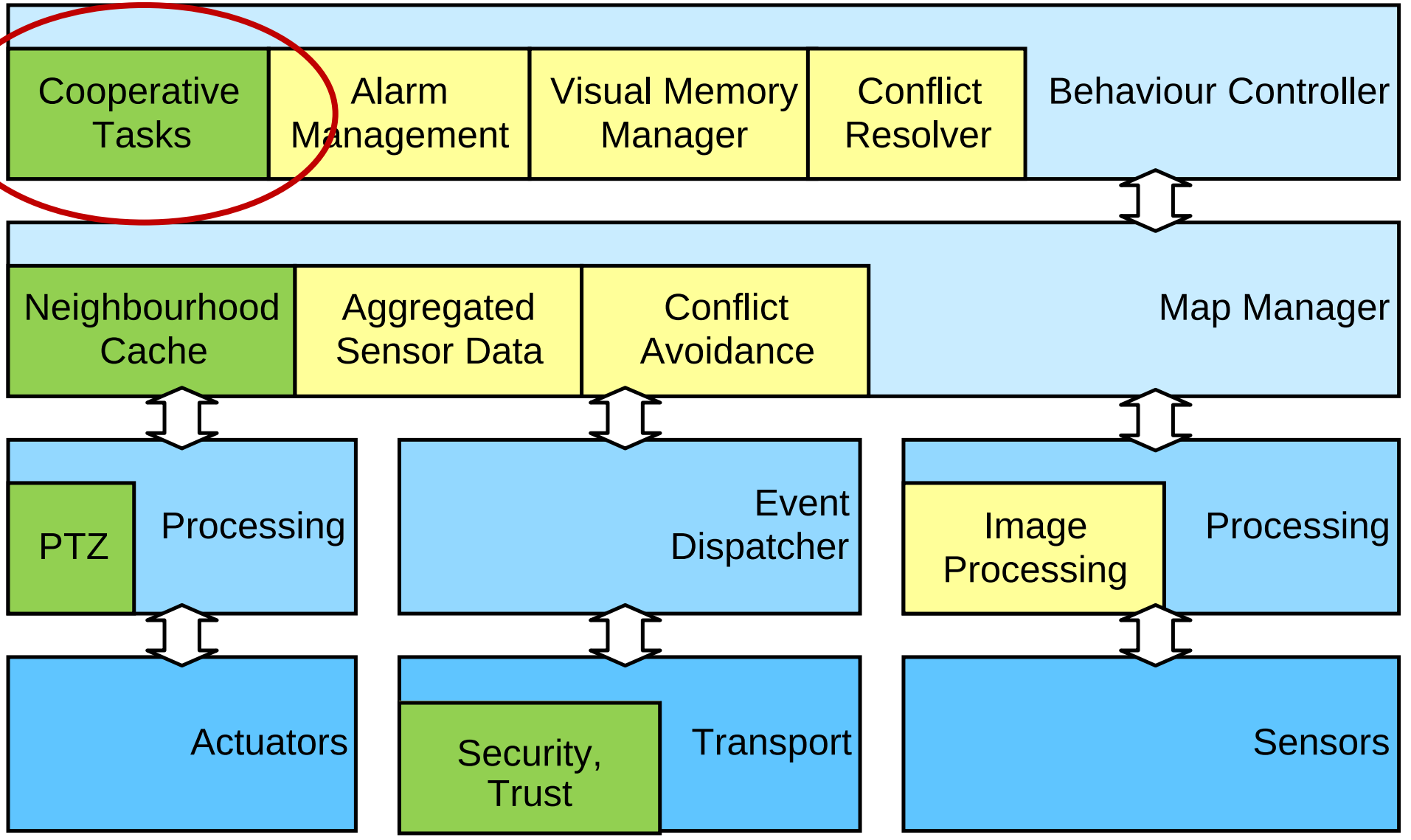
- What is it?
  - Each Smart Camera Node:
    - Obviously includes a (PTZ) camera
    - Local processing resources (CPU, memory, etc.)
    - Communication interface to exchange information with other Smart Camera Nodes (e.g. wireless ad-hoc or wired network)
  - Networked Smart Camera Nodes
    - Cameras can cooperatively solve surveillance tasks
    - Achieve goals that cannot be achieved with a single camera, e.g. wide-area object tracking, multi-view observation
    - Efficient and robust coordination and management of (possibly large number of) cameras required

Distributed Smart Camera System

- What is it good for?
  - Unburden human operators from trivial tasks
  - Help to preserve individuals privacy
  - Are superior to centralized surveillance systems
    - No single point of failure
- Where can it be used?
  - Possible application scenario: apron of an airport
    - safety critical, wide area
    - manual camera adjustment is time and cost intensive

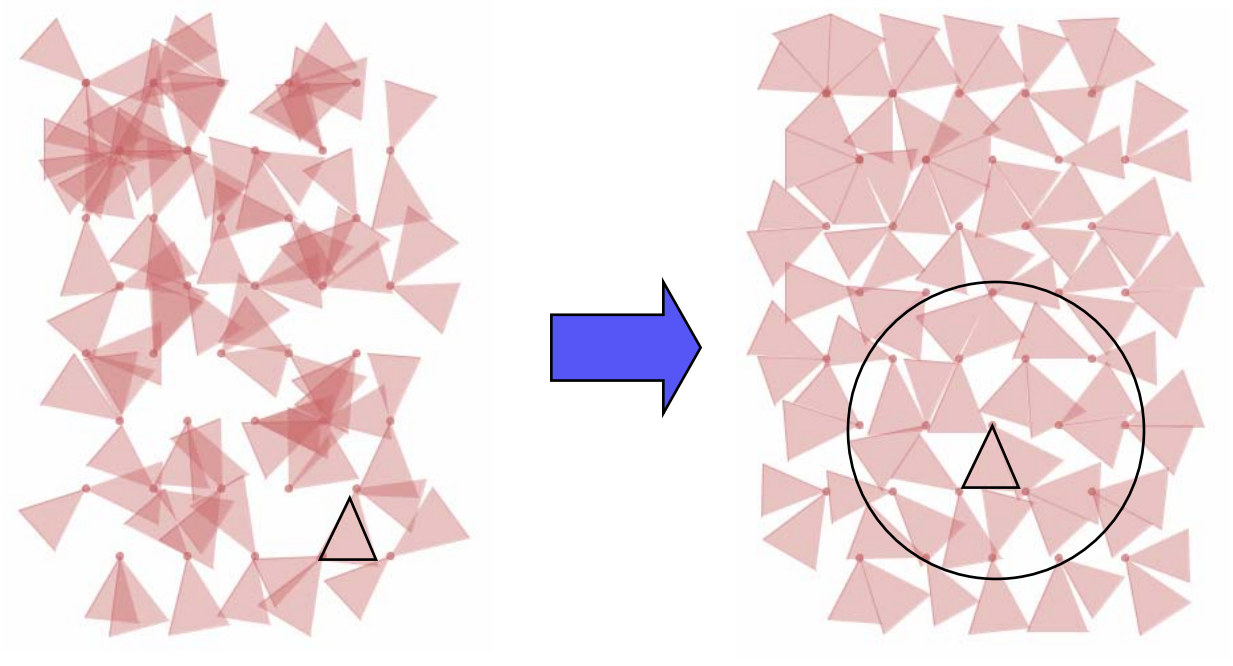


- Smart Camera Sub-system (SCSS): spatially adjacent cameras
- Gateways in SCSS: interconnect individual SCSS
- Mobile alarm management terminals (MAMT): deliver information to the operator



A distributed algorithm for spatial partitioning: ROCAS

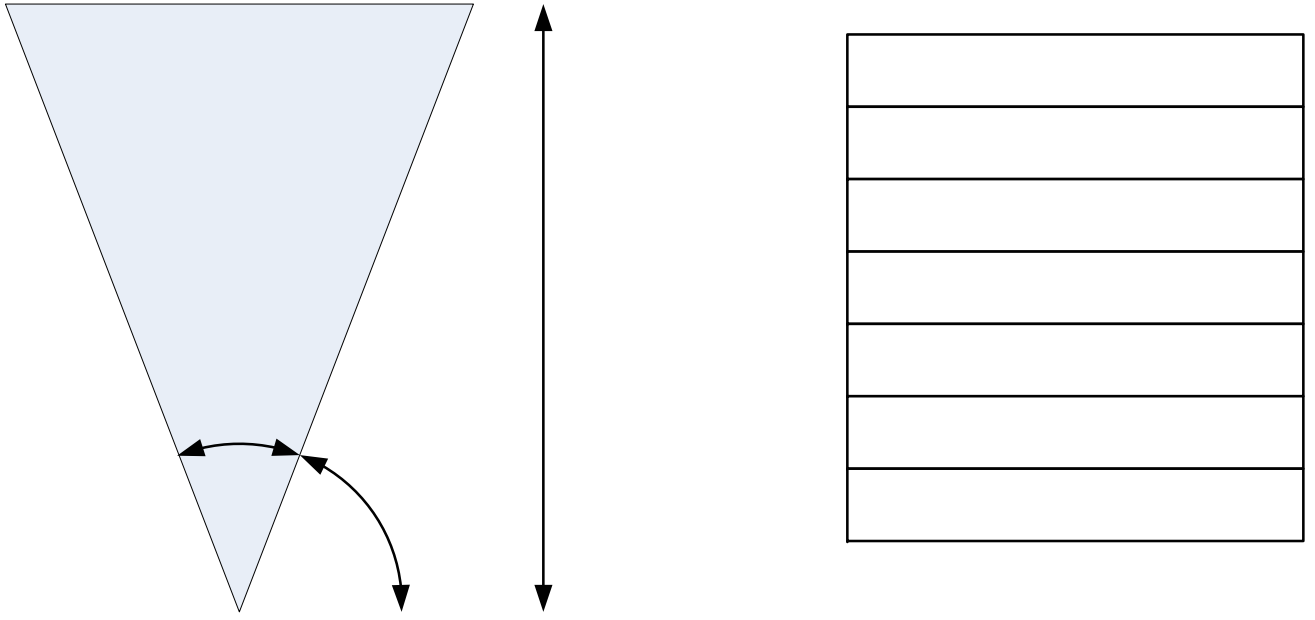
- Cooperative Task: Spatial Partitioning
- Robust Online Camera Alignment System (ROCAS)



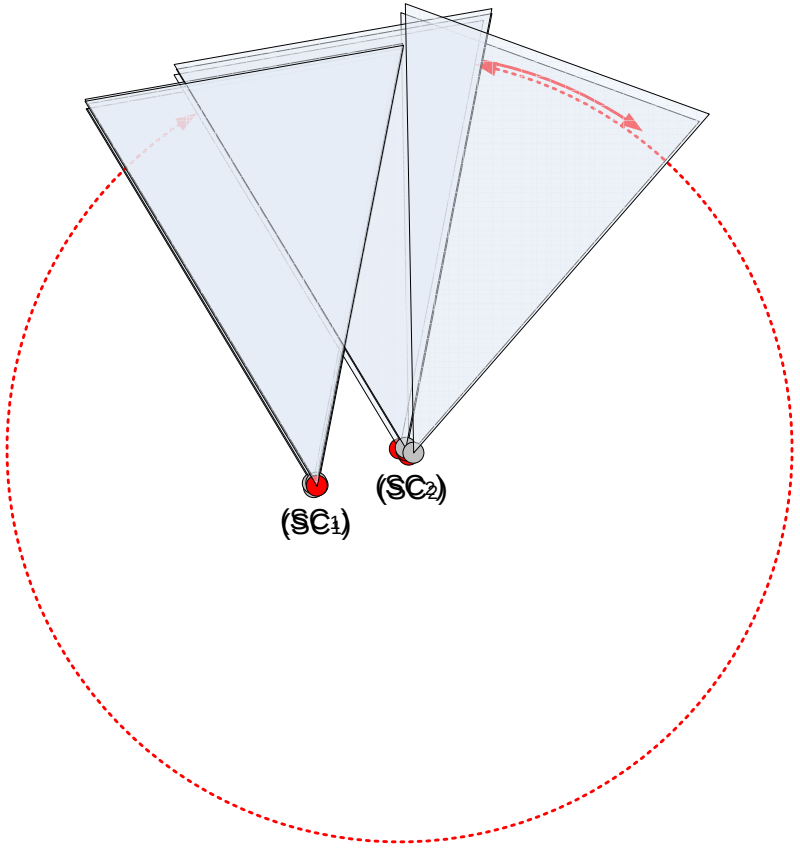
- Computational Geometry problem:
  - How many guards are needed to fully observe an n-walled room?
  - Goal: find an optimal positioning for the guards
  - NP hard problem (Aggarwal, 1984)
  - Art Gallery Theorems and Algorithms (O'Rourke, 1987)

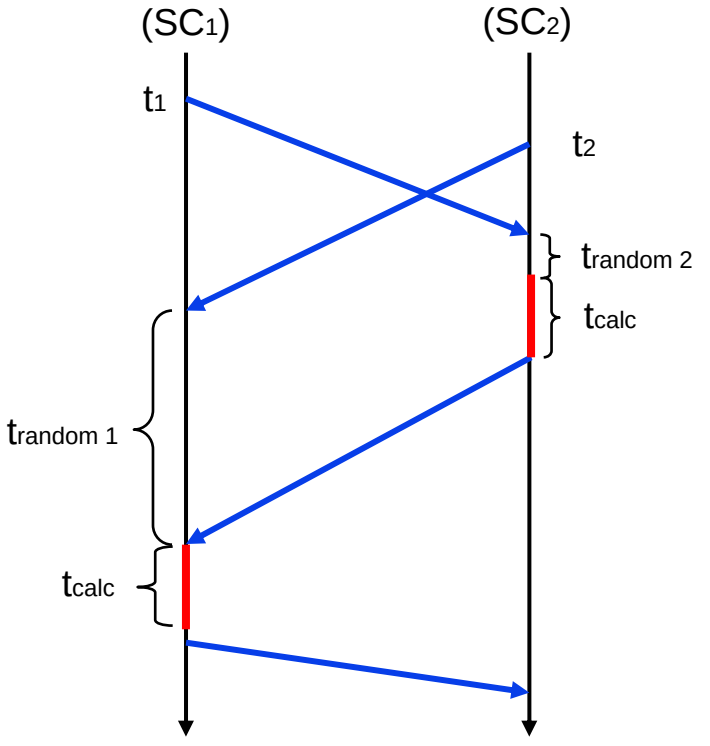
- SC partitioning problem is a derivative of the Art Gallery Problem
  - SCs have fixed positions (mobile nodes may be considered in future)
  - Degrees of freedom are limited to pan/tilt/zoom capabilities of SCs
  - Distributed, fault tolerant heuristics

ROCAS: Simplified field of view of a SC

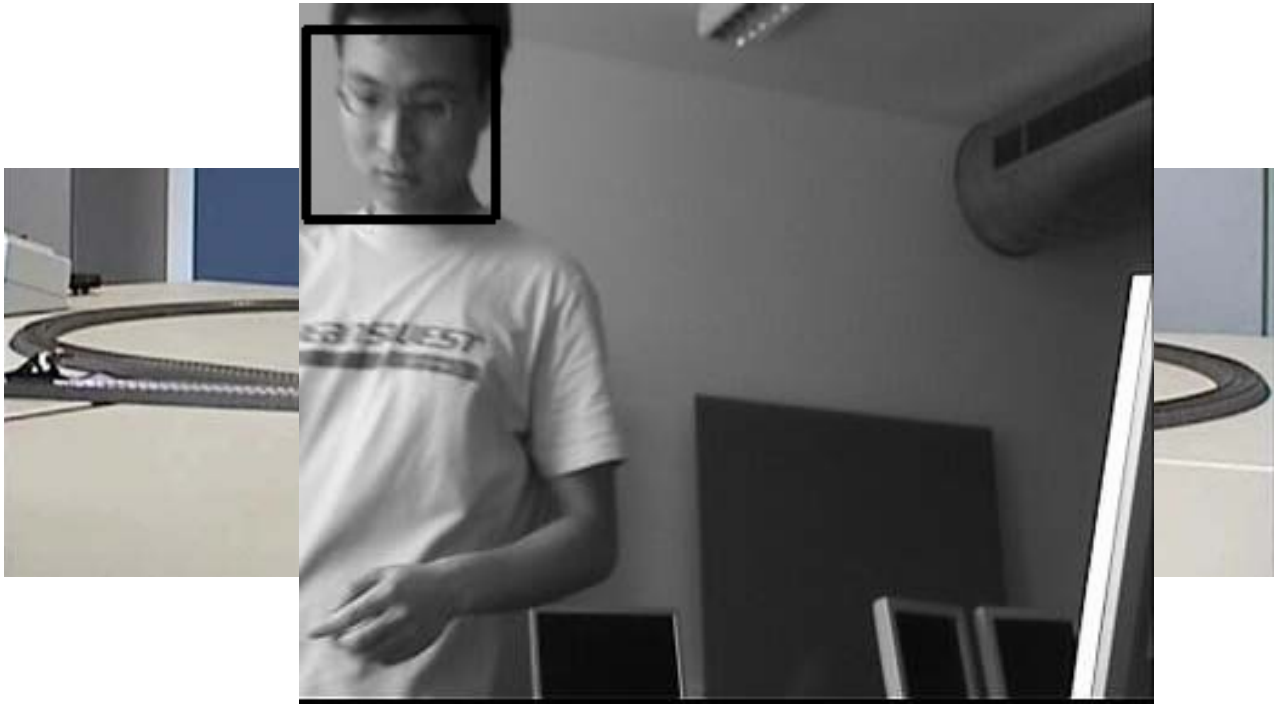


- A SC‘s field of view and ROCAS message format
  - each SC has a fixed position
  - ROCAS changes viewing angle to optimise surveillance coverage



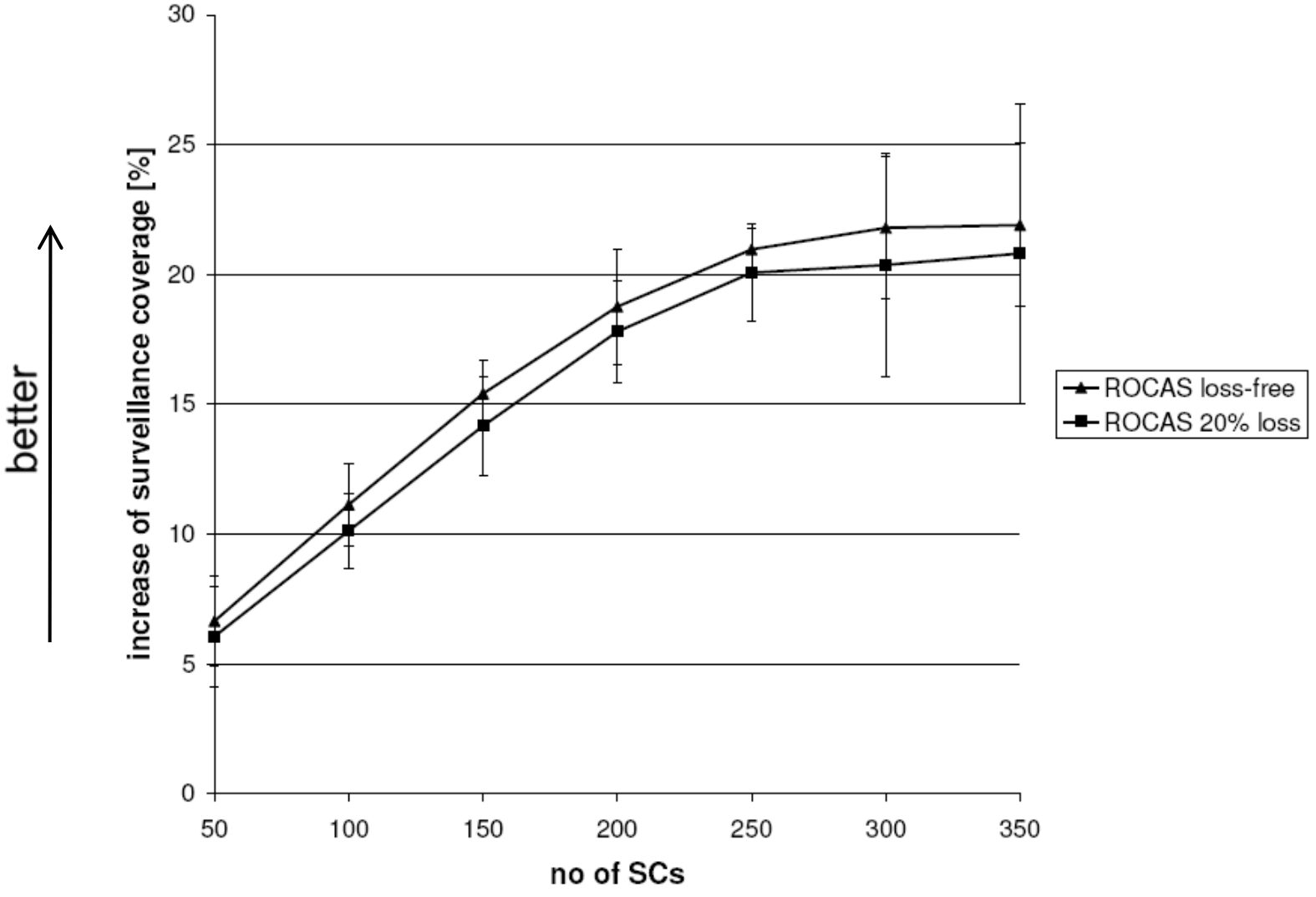


- PC based prototype
  - Use of well known computer vision library OpenCV
  - Motion detection
  - Face detection

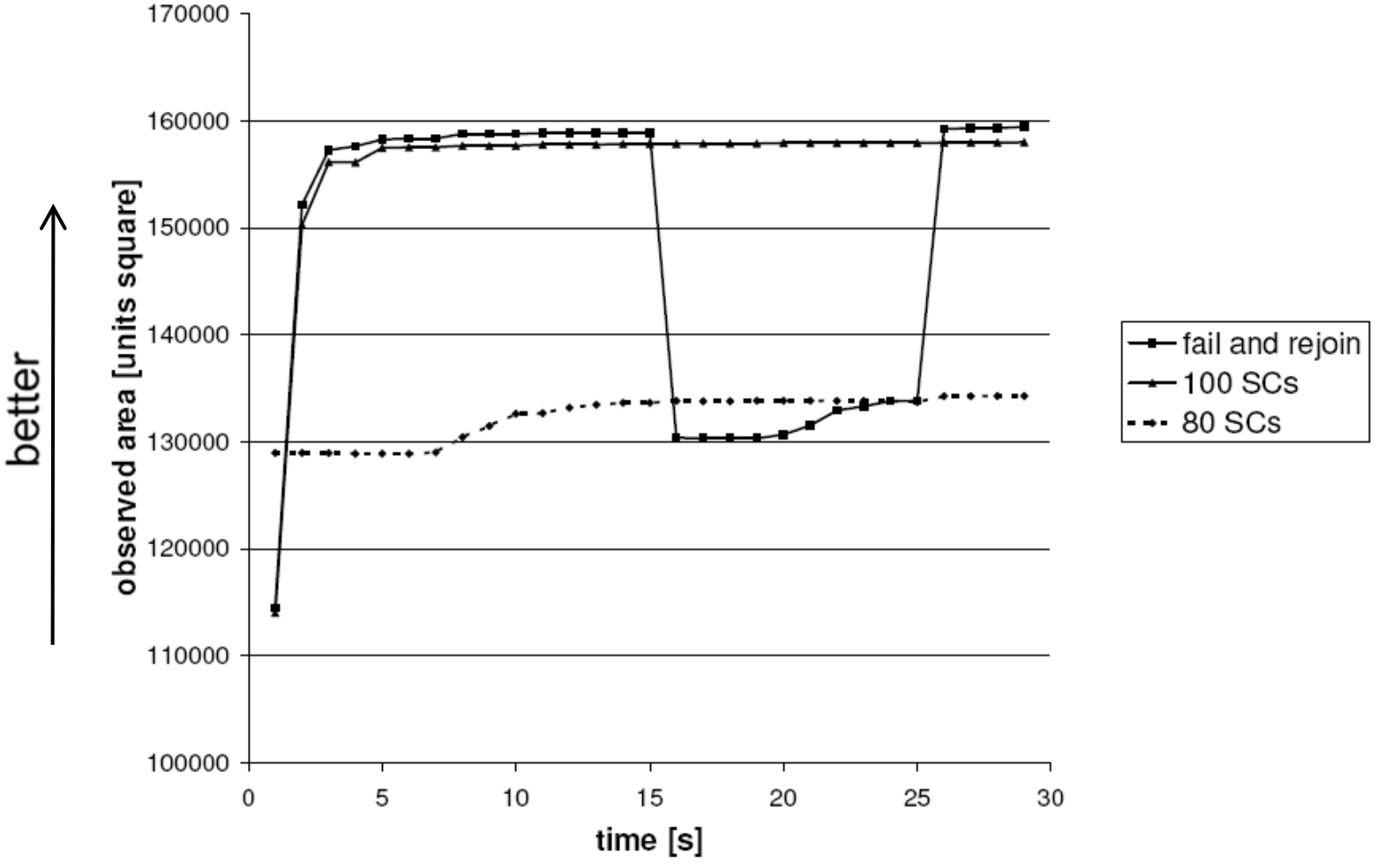


- Investigation of large-scale networks: simulation used
- Basis: Network simulator ns2 plus click modular router
- System parameters
  - 50 to 350 cameras
  - Area 600m x 600m
  - IEEE 802.11 ad-hoc (160m)
  - Field of view: angle 45 degrees, max. viewing distance: 50m
  - Deployed randomly or on a regular grid
- Performance metrics
  - Surveillance coverage
  - Message overhead
  - (Time to termination)

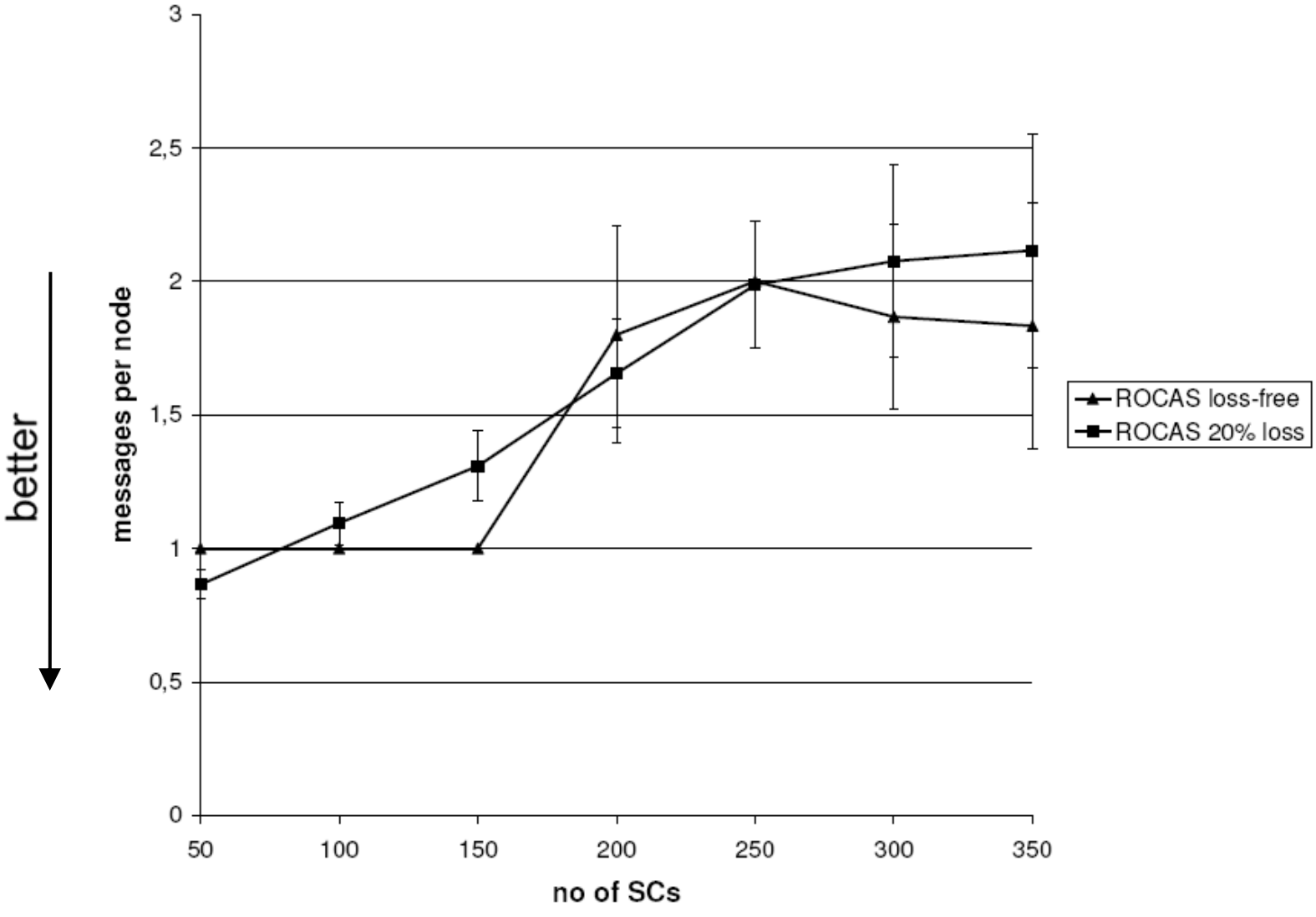
Experiment 1: Increase of Surveillance Coverage



Experiment 2: Fault Tolerance



Experiment 3: Message Complexity



- Distributed Smart Camera research includes
  - Computer vision, embedded systems, and system architecture
  - Requires the cooperation between (at least) these fields
- ROCAS enables SCs to partition an area under surveillance
  - Example for a distributed coordination algorithm in Smart Camera Systems
  - Scalable (up to 350 SCs per SCSS)
  - Lightweight (message complexity is low)
  - Robust and fault tolerant
- Future prospects
  - Object tracking
  - Demonstrator

Thank you for your attention!

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Something to read:

M. Hoffmann, J. Hähner: A Robust Online Algorithm for Spatial Partitioning in Distributed Smart Camera Systems. To appear in Proceedings of the 1st ACM/IEEE International Conference on Distributed Smart Cameras, 2007

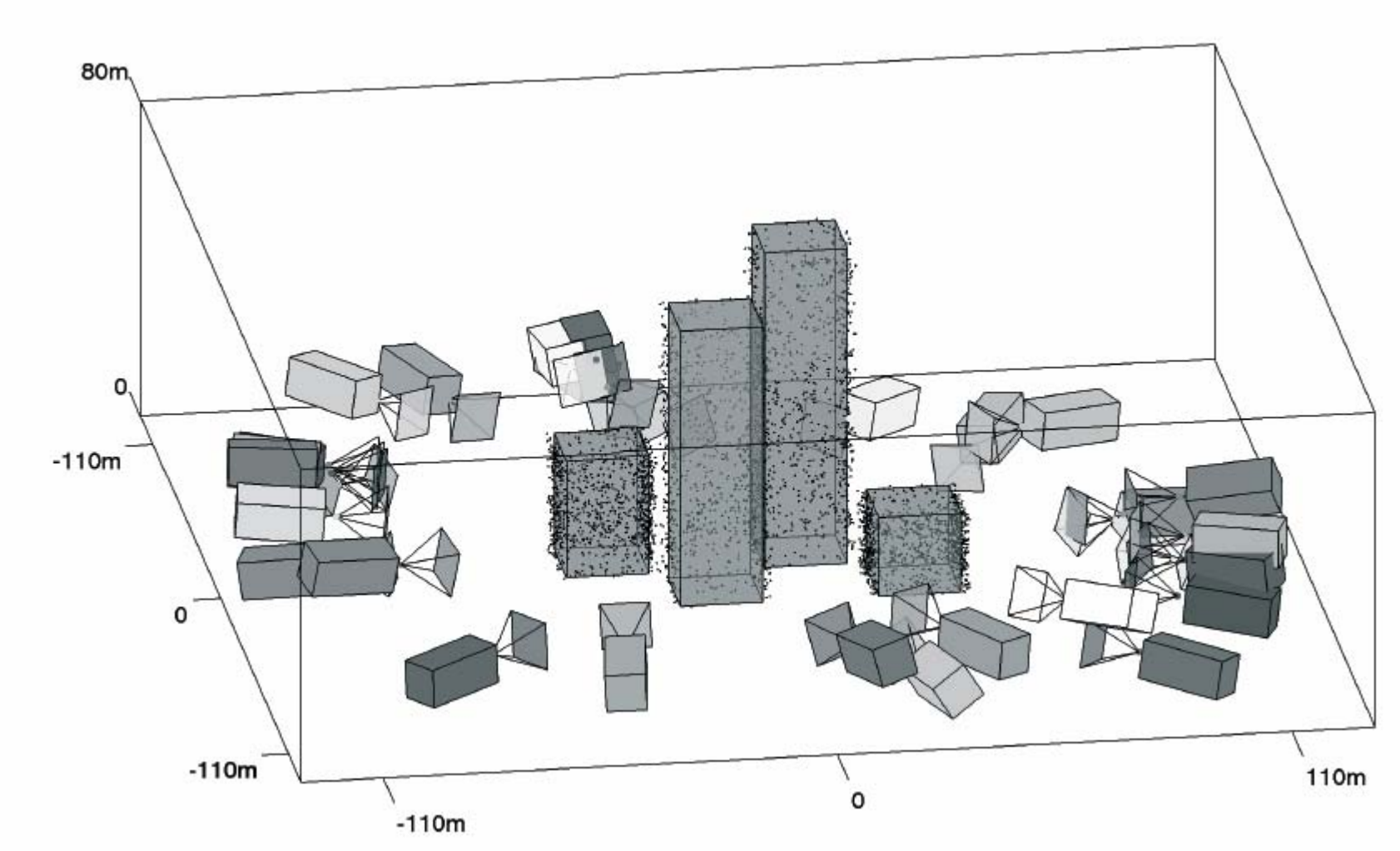
M. Hoffmann, J. Hähner, C. Müller-Schloer: Towards Self-Organising Smart Camera Systems. To appear in: Proceedings of the 21st International Conference on Architecture of Computing Systems (ARCS), 2008

Research disciplines involved

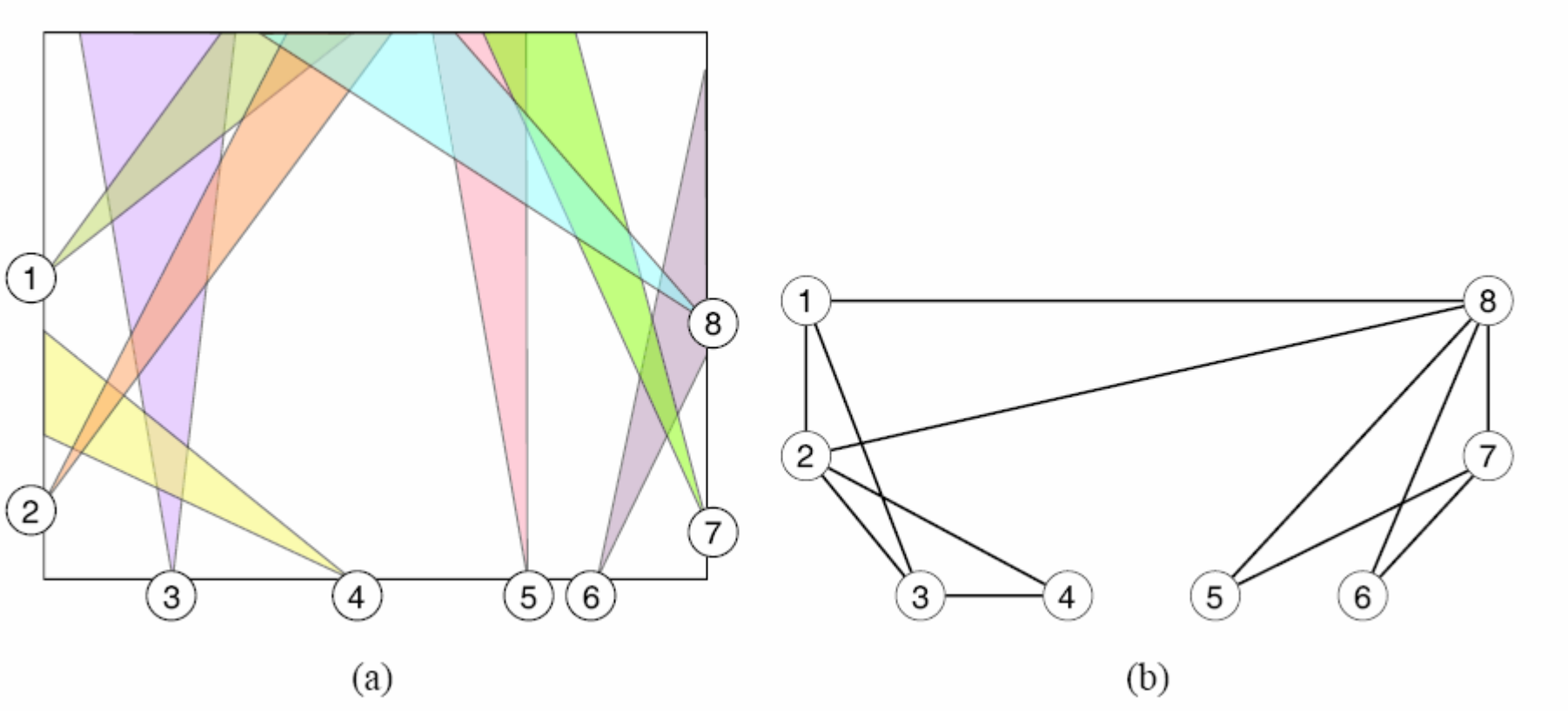
- Computer Vision
  - Identify and track objects
  - Detect events
  - Requires powerful computing units
- Embedded Systems
  - Small, capable, power-aware systems
  - Typically based on FPGA and DSP
- System Architecture
  - Self-organization in large Smart Camera Systems
  - Algorithms and protocols for coordination and management

Related Work II: Calibrating Distributed Camera Networks

- R. Radke, 2006



Related Work II: Calibrating Distributed Camera Networks



- (a) snapshot of camera network
- (b) vision graph