



# Multi-Drone Systems

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IEEE CNCS; Helsinki, September 19, 2017

# Ubiquitous Unmanned Aerial Vehicles

Unmanned aerial vehicles (UAVs) or  
drones are becoming ubiquitous

amazing functionality  
increasing commercial interest

Growing list of applications

Surveillance, transportation, security, farming,  
recreation, ...

„Top-11 technology of the decade“

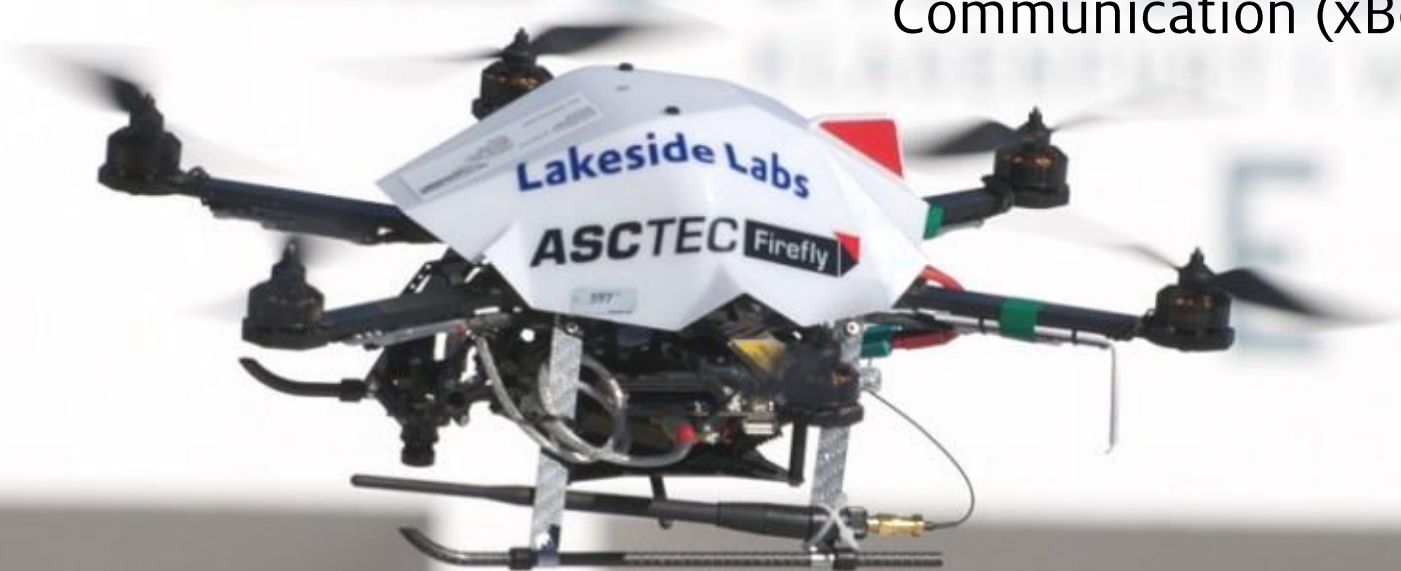
IEEE Spectrum in January 2011

Significant impact on society expected



# Small-scale Drones

- Battery-powered multi-copter
- Sophisticated control
- Onboard processing
- Camera & sensors as payload
- GPS & waypoint navigation
- Communication (xBee, WiFi, ...)



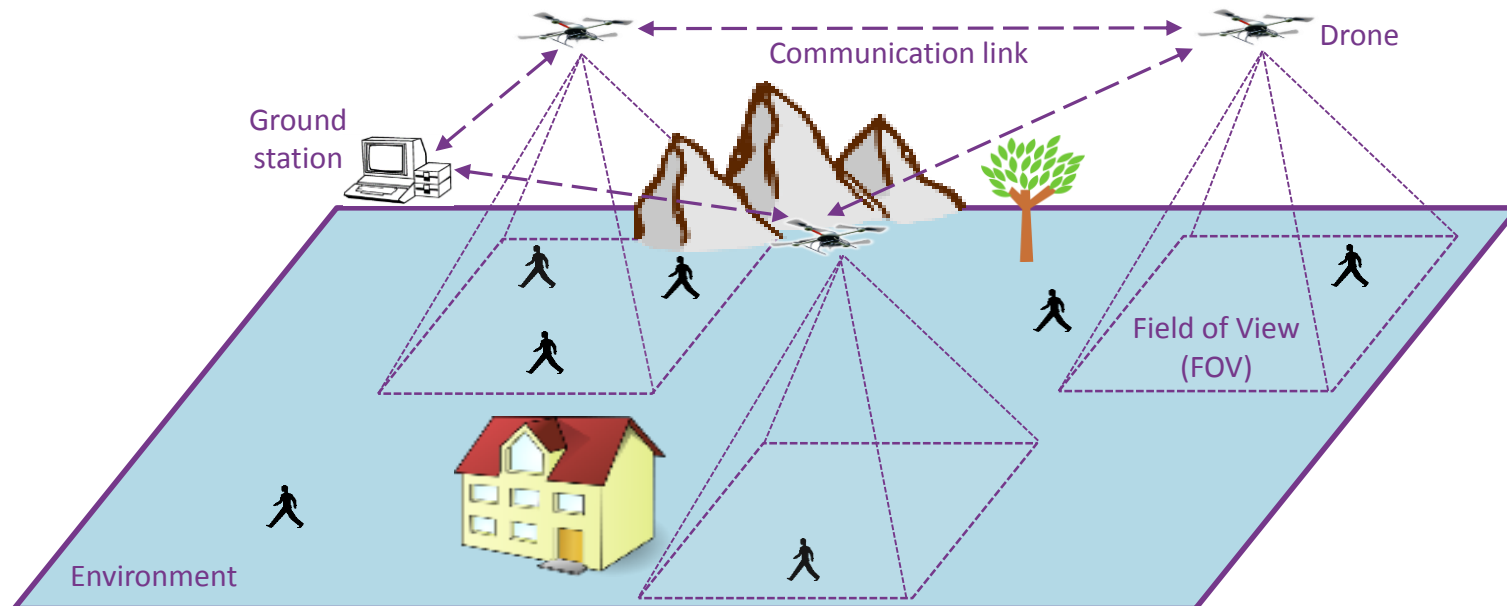
# From One to Many



# Multi-Drone Research at Klagenfurt

# Coordination with Uncertainties

- Plan **tasks and routes** of drones in unknown (dynamic) environments, e.g. for search and surveillance missions

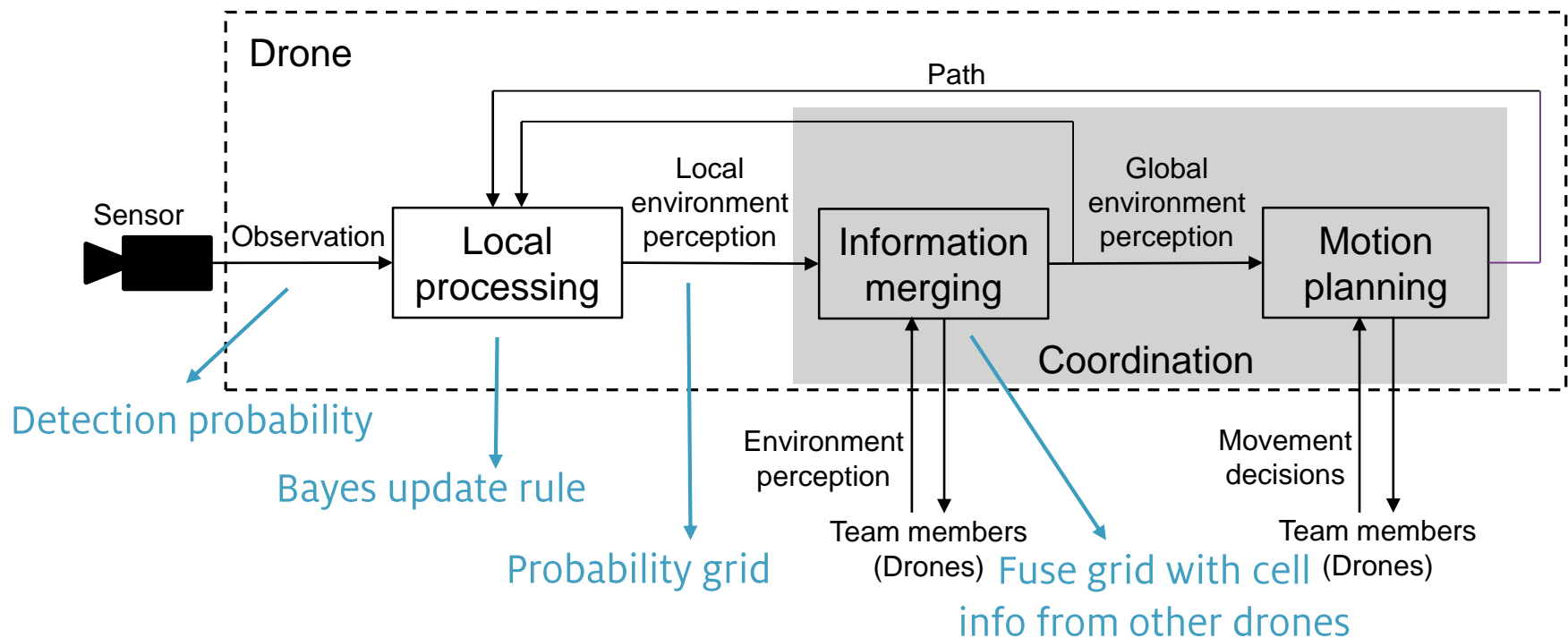


[Khan, Yanmaz, Rinner. [Information Exchange and Decision Making in Micro Aerial Vehicle Networks for Cooperative Search](#). IEEE Trans. Contr. Networked Systems 2015]

[Khan, Rinner, Cavallaro. [Cooperative Robots to Observe Moving Targets: A Review](#).

# Coordination: System Model

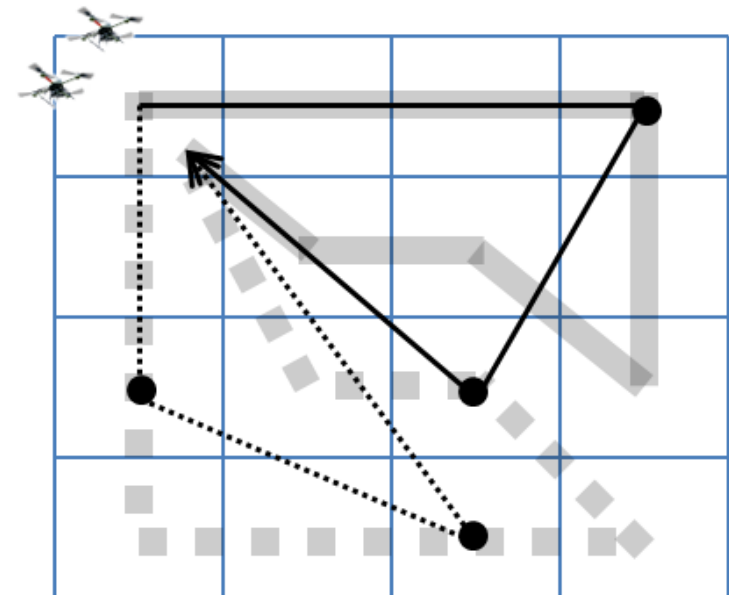
- Coordination of multiple drones for surveillance
  - Information merging (target existence)
  - Joint motion planning (next cells to visit)



- **Centralized** vs. **distributed** information merging and planning

# Motion Planning Approach

- Drones follow **individual routes** based on their probability grid
  - **Multiple observations** required for deciding whether grid cell is occupied or empty
  - For all **undecided cells** compute drone routes with multiple travelling salesman problems (MTSP)
  - Update probability grid based on **communication range**

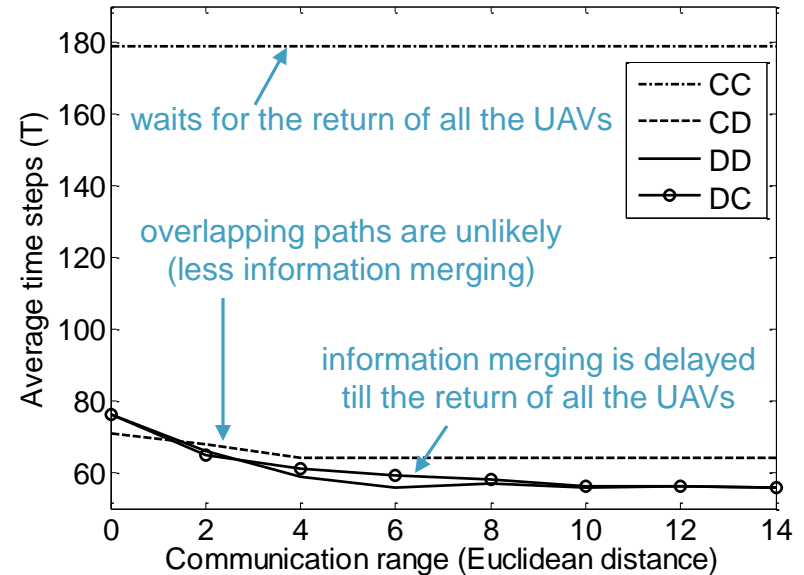


- UAV1 MTSP path, first round
- UAV1 MTSP path, second round
- - - UAV2 MTSP path, first round
- ..... UAV2 MTSP path, second round



# Motion Planning

- Distribution of autonomy reduces the search time
- DC and DD perform equally if communication range is unlimited

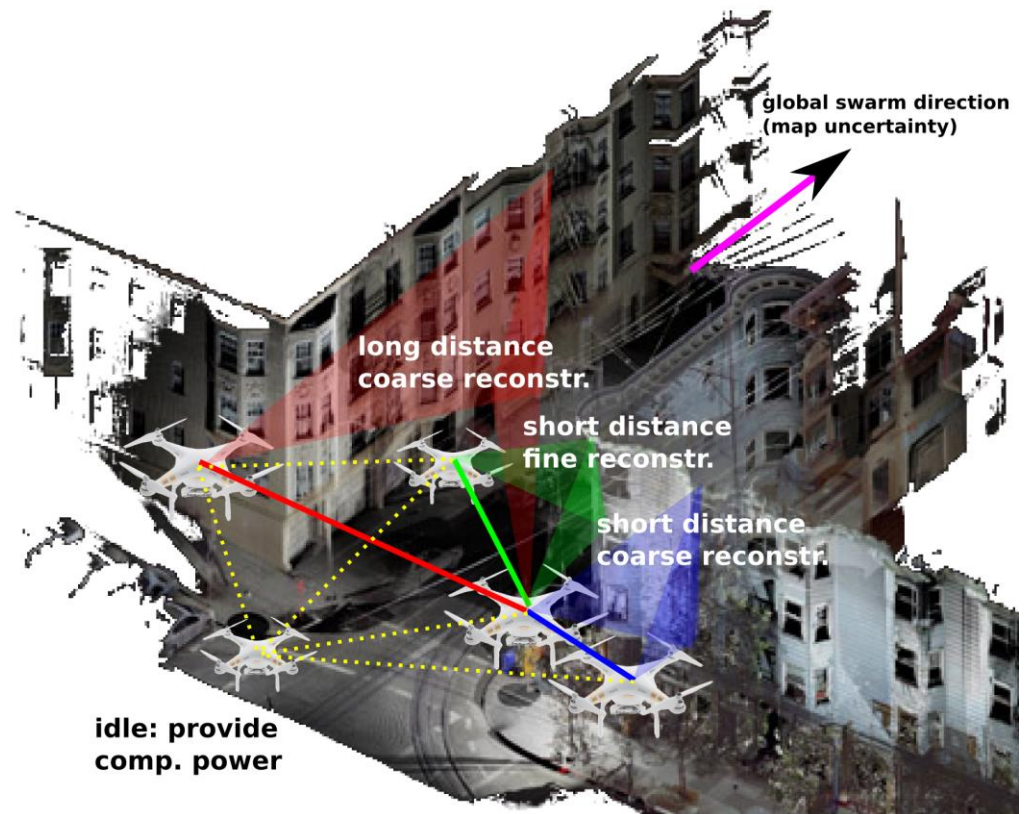


Grid of 10x10 cells, Number of UAVs (A) = 2, B = 1,  $p = 0.9$ ,  $q = 0.2$ ,  $\theta = 0.9$ ,  $P^0 = 0.5$ .

	Information merging	
Motion planning	CC	CD
	DC	DD

# Autonomous 3D Reconstruction

- Swarm autonomously explores and reconstructs environment
  - Long-distance exploration
  - Coarse reconstruction
  - Fine reconstruction
- Dynamic collaboration
- Real-time operation
- Strong requirements
  - Computation
  - Communication



# Research Challenges

- Positioning and Navigation
  - „GPS adverse“ environments
- Motion Control
  - Sensor fusion, collision avoidance
- Communication and Networking
  - 3D mobility, mixed traffic types, mesh/multi-hop
- Coordination and Mission Planning
  - Task assignment, swarm configuration, planning
- Computer Vision
  - Variable baseline stereo, 3D reconstruction
- (But also) safety, privacy and non-technical issues
- Highly dynamic environment with strong resource limitations

# Further Information

- Pervasive Computing group  
<http://nes.aau.at>  
<http://www.bernhardrinner.com>
- Our drone research web site  
(incl. papers and many videos)  
<http://uav.aau.at>
- Doctoral School on  
Networked Autonomous Aerial Systems  
starting in October 2017  
external support by NASA-JPL, DLR, Airbus

