Diplomarbeitspräsentation

Local Positioning System for Quadcopters

Masterstudium:
Technische Informatik

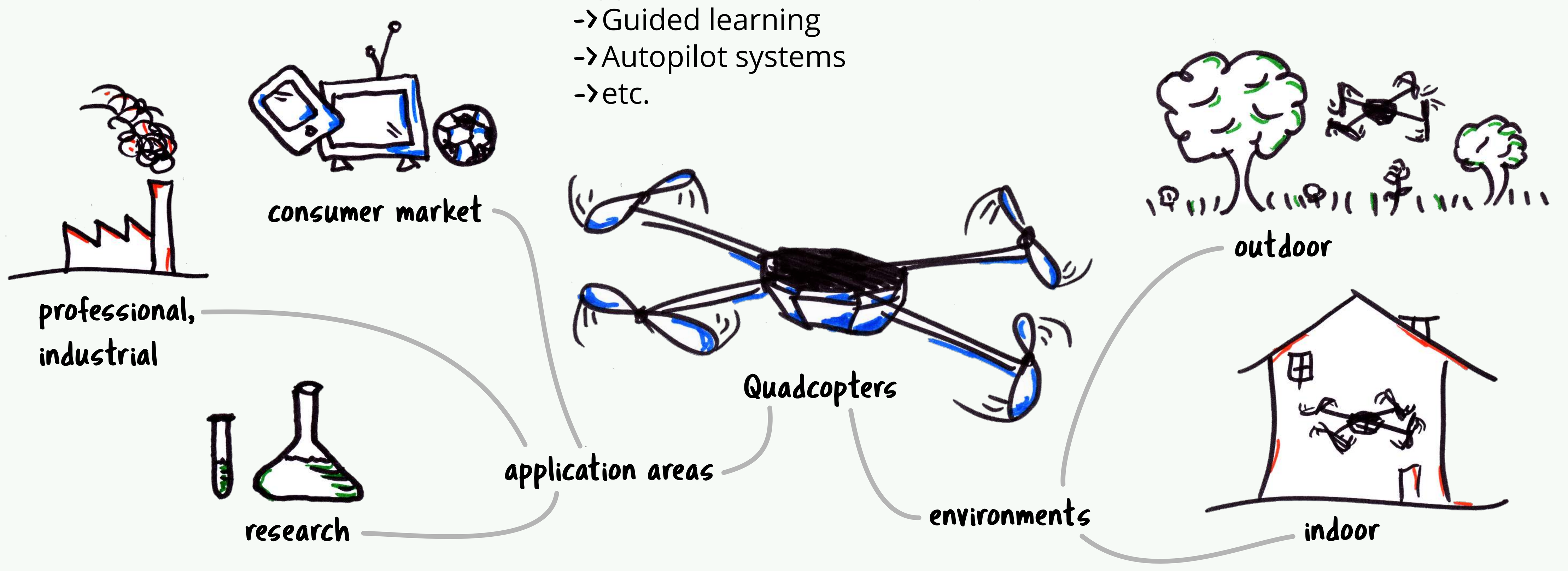
Andreas Brandstätter

Technische Universität Wien
Institut für Computer Engineering
Forschungsbereich: Cyber-Physical Systems
Betreuer: Univ.Prof. Dipl.-Ing. Dr.rer.nat. Radu Grosu
Mitwirkung: Univ.Ass. Dipl.-Ing. Bernhard Frömel, B.Sc.
Univ.Ass. Dipl.-Ing. Christian Hirsch, B.Sc.

Motivation

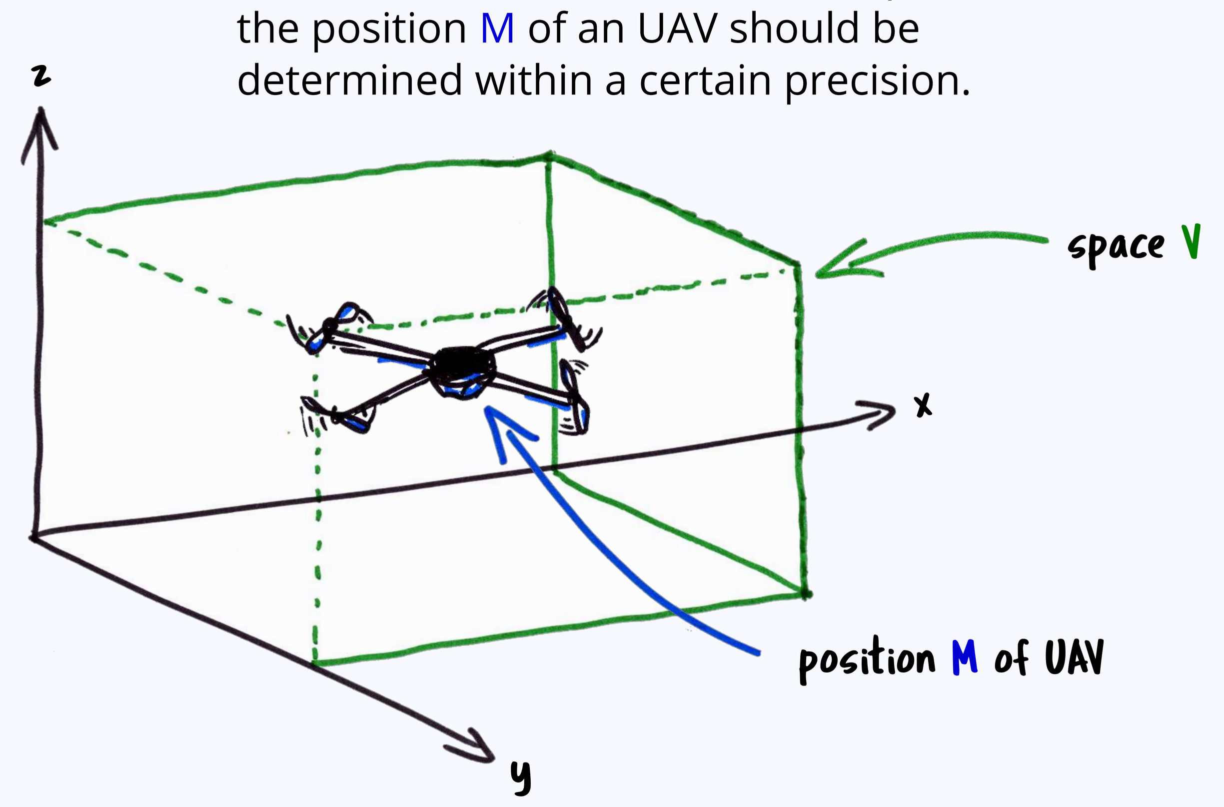
Unmanned aerial vehicles (UAVs), especially Quadcopters, are used for an increasing number of applications and environments.

Applications for localization systems:
->Guided learning
->Autopilot systems
->etc.

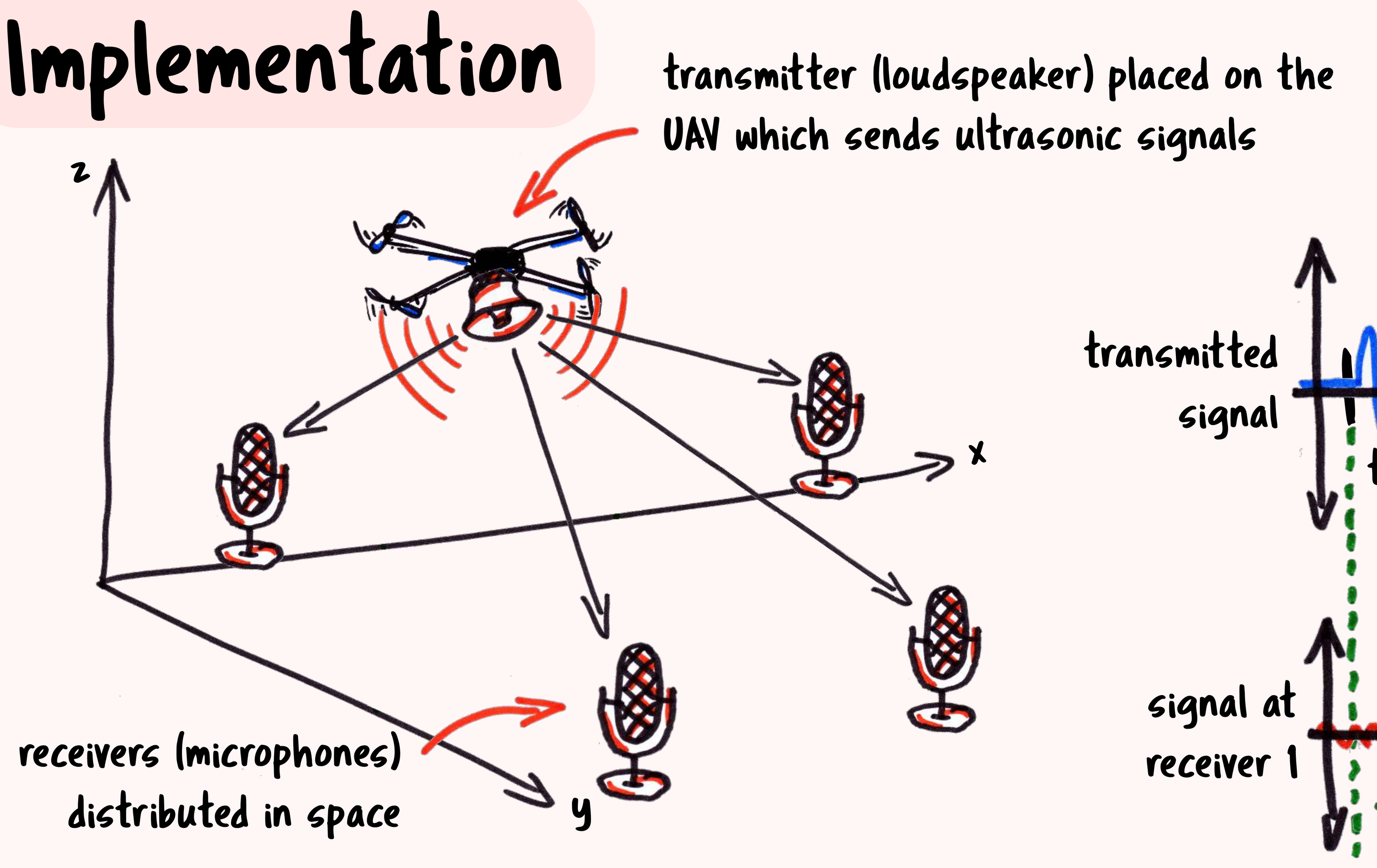


Problem Statement

Given a bounded 3-dimensional space V, the position M of an UAV should be determined within a certain precision.

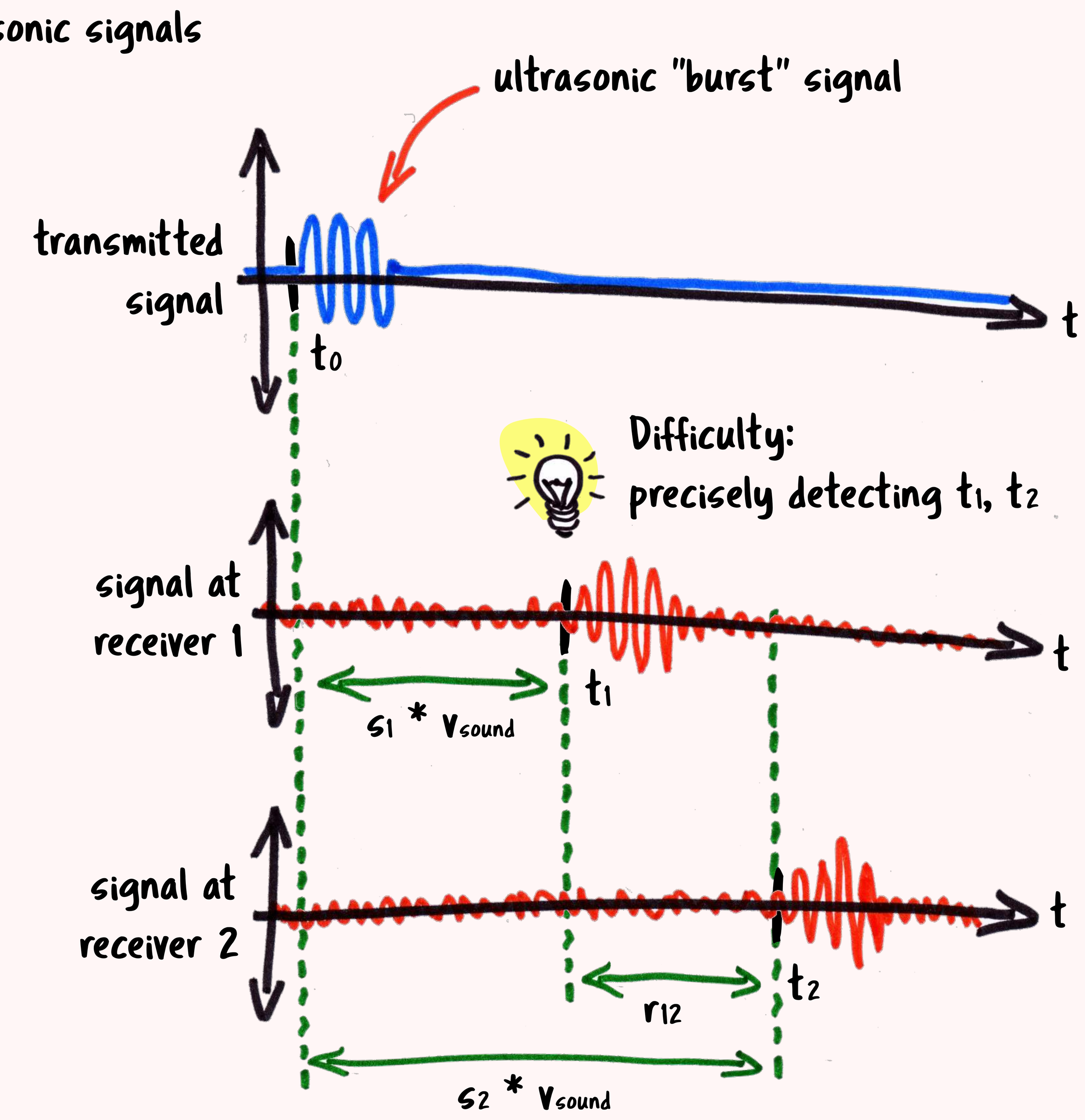


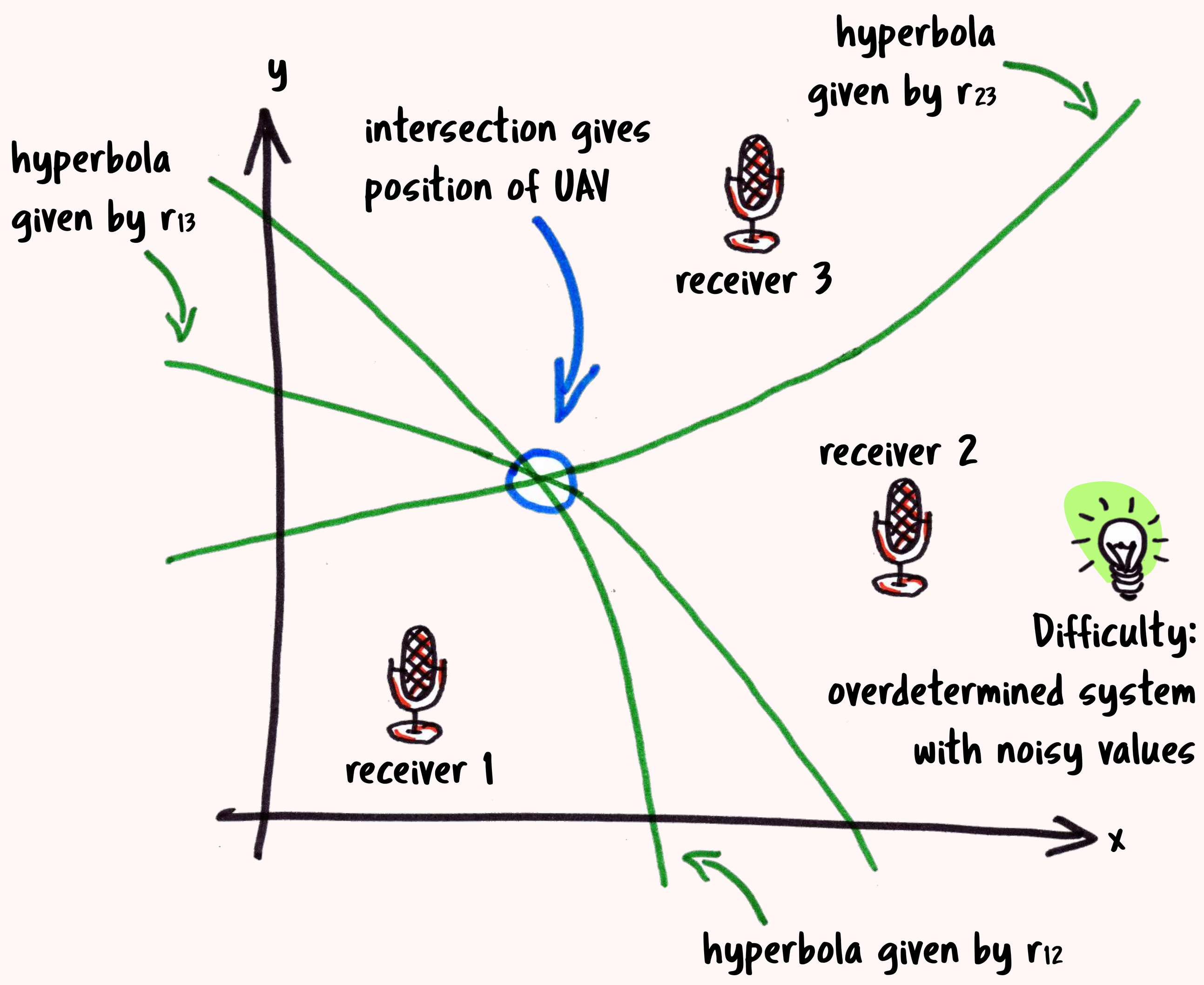
Implementation



Time Difference of Arrival (TDOA)

-> Ultrasonic burst signal transmitted at t_0
-> Received at $t_1 = t_0 + s_1 * v_{sound}$ by receiver 1
($t_2 = t_0 + s_2 * v_{sound}$ by receiver 2, ...)
-> Difference $r_{12} = t_1 - t_2$ can be measured by the system (similar for r_{23}, r_{13}, ...)
-> Position of the mobile object inferred by values r_{ij} and known position of receivers



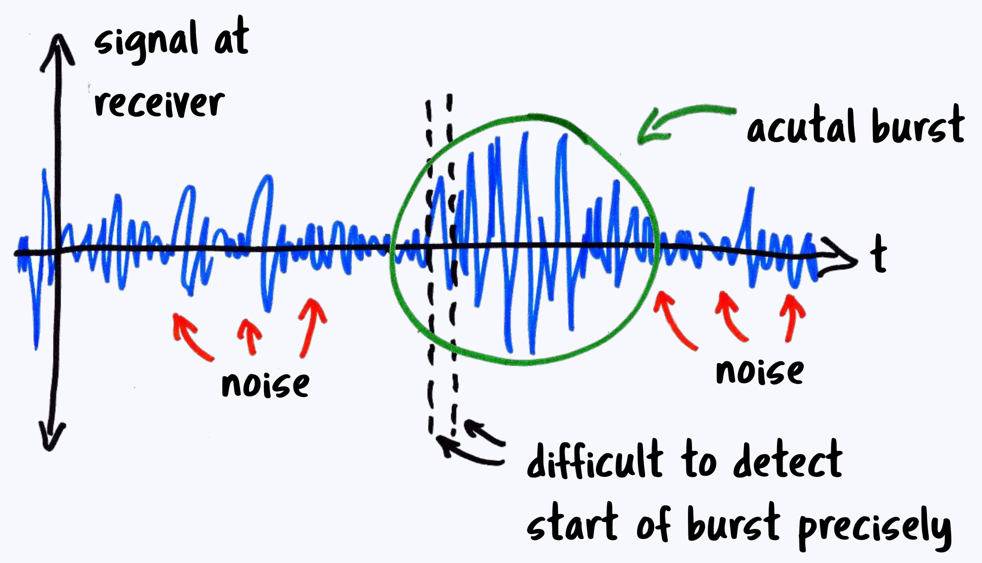


-> Time differences r_{ij} for each pair of receivers (i,j)
-> Values r_{ij} define hyperbolas with possible locations of UAV
-> Intersection of hyperbolas gives position of UAV

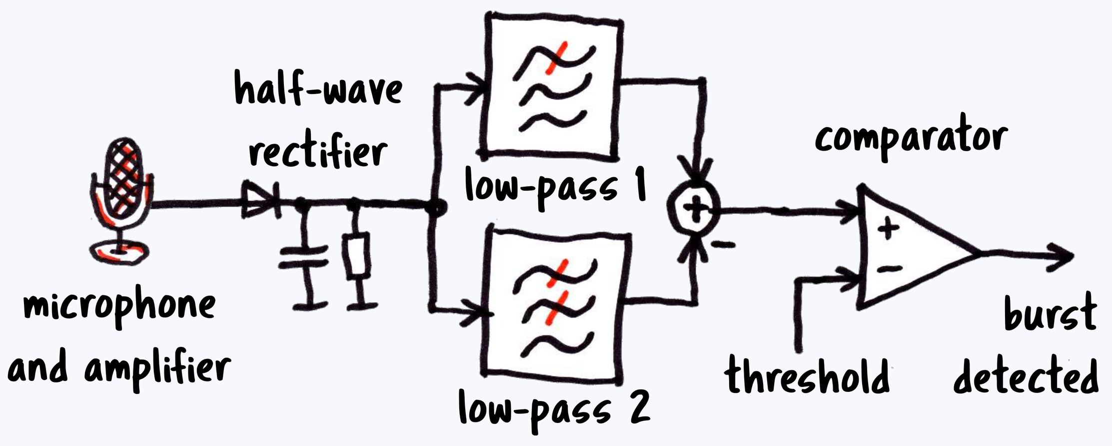
Solved Difficulties

Burst Detector

For TDOA calculation time measurements are crucial:
-> Burst signal must be detected reliably and precisely.

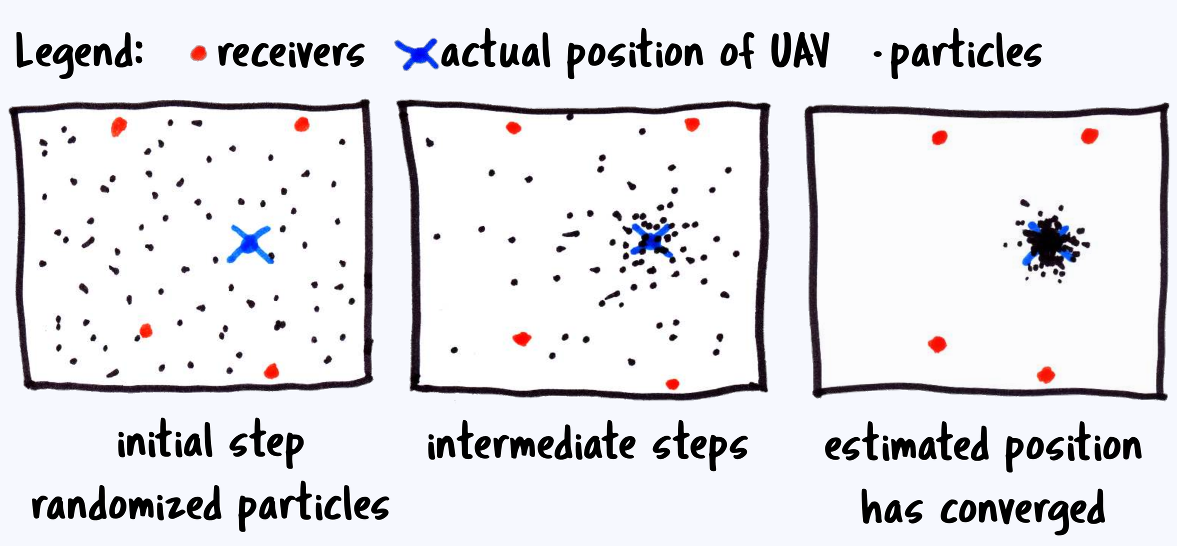


Burst detector implementation:
-> Half-wave rectifier
-> 2 low-pass filters (different cutoff-frequencies)
-> Comparator with threshold



TDOA Calculation: Particle Filter

Exact solution of the TDOA problem is not practical:
-> Overdetermined system: Large number of receivers.
-> Noisy values: Measurement errors influence accuracy of the determined position.
-> Outliers: Some of the receivers might not detect the burst signal properly.
Solution: using a particle filter for TDOA calculation.

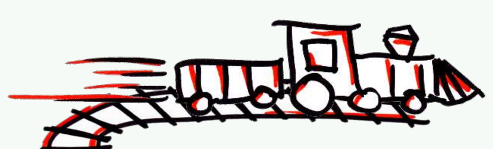


Computation steps:
Initialize particles (uniform distributed random locations)
Repeat:
  Calculate weights of particles (least mean square metric)
  Calculate estimated position as sum of weighted particles
  Resample particles for next step
  Add gaussian jittering noise to particles
Until estimated position converged or abort constant reached

Results

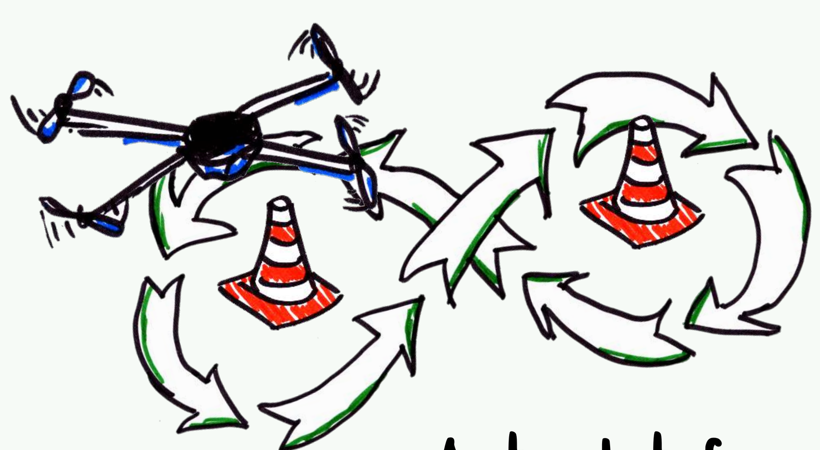
Static position tests

Transmitter placed on a tripod within space V.
Dimensions of V: x_{max} = 6m, y_{max} = 3m, z_{max} = 2m
Standard deviation: $\sigma_{x,y}$ = 1.9 to 4.9cm,
σ_z = 5.8 to 13.4cm



Mobile object tests

Transmitter placed on a model railway waggon on a oval shaped track.
Speed: $v_{railway}$ = 0.2m/s to 0.75m/s
Standard deviation: $\sigma_{x,y}$ = 6.0 to 7.3cm



Video online:

Autopilot for quadcopter

Demonstration of the implemented system to be used in an autopilot setup for a quadcopter:
-> Dimensions of V: x_{max} = 10m, y_{max} = 5m, z_{max} = 3m
-> Follow a path consisting of pre-defined waypoints.
-> Video: UAV performs several repetitions of an 8-figure.

Contact: abrandst932dap@lanthan.at