Autonomous Navigation for Flying Robots

Lecture 1.4: Brief History on Quadrotor Research

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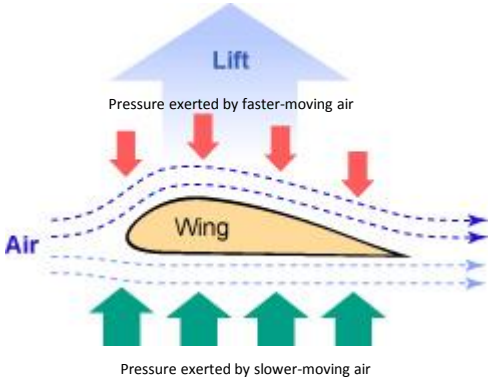
Fixed-Wing Airplanes

- First motorized flight: 1903 (Wright brothers)
- Generate lift through forward airspeed and the shape of the wings
- Attitude controlled by flaps

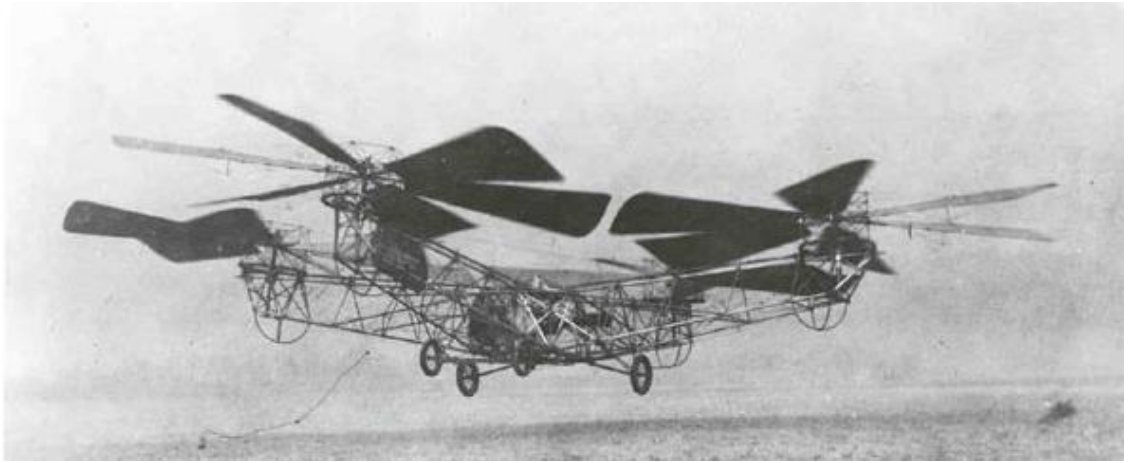
http://www.loc.gov/pictures/item/00652085/



CC-BY-SA CJ Kazilek http://askabiologist.asu.edu/how-do-birds-fly

Quadrotors

- First successful flight: 1924
- Vertical take-off and landing (VTOL)
- Problems: stability, control



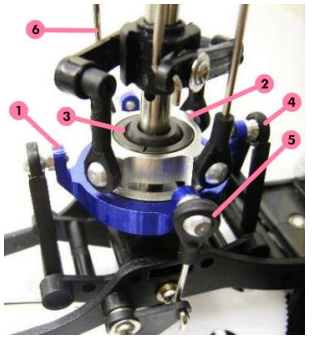
http://en.wikipedia.org/wiki/File:De_Bothezat_Quadrotor.jpg

Helicopters

- First successful flight: 1936
- Swash plate adjusts pitch of propeller cyclically, controls pitch and roll
- Torque is compensated by tail rotor

cc licensed (BY) flickr photo by Tony Hisgett:
http://flickr.com/photos/hisgett/349272553/

CC-BY-SA-3.0 Richard Wheeler (Zephyris)
http://en.wikipedia.org/wiki/File:HelicopterSwashPlate_Flat.gif



CC-BY-SA-3.0 Bernd vdB
http://en.wikipedia.org/wiki/File:Taumel_142_b.png

Micro-Aerial Vehicles (MAVs)

- Attitude stabilization using MEMS sensors
- Remote-controlled quadrotors
- Renaissance in the early 2000's

Remote Controlled Flight (2001-)

Team BlackSheep, http://www.team-blacksheep.com, http://youtu.be/M9cSxEqKQ78

First Person View (FPV)

Intuitive Aerial, http://intuitiveaerial.com/, http://youtu.be/IoXSfpkUEm0

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Autonomous Quadrotors

- How can we achieve autonomous flight?
- Initially with external positioning aids
- GPS
  - 2 Hz
  - 3-5 m accuracy
- Motion capture (indoor)
  - 200-500 Hz
  - 1 mm accuracy

Learning of Flight Parameters

[Schoellig et al., ETH, 2011]

The Flying Machine Arena, ETH Zürich: http://www.youtube.com/watch?v=goVuP5TJlUU

Angela P. Schoellig, Fabian L. Muller, and Raffaello D'Andrea, "Optimization-Based Iterative Learning for Precise Quadrocopter Trajectory Tracking", Autonomous Robots, Volume 33, Number 1-2, pp.103–127, 2012.

Aggressive Flight Maneuvers
[Mellinger et al., UPenn, 2010]

GRASP Lab, University of Pennsylvania, http://youtu.be/YQIMGV5vtd4

N. Michael, D. Mellinger, Q. Lindsey, and V. Kumar. The GRASP multiple micro UAV testbed. IEEE Robotics and Automation Magazine, Vol. 17, No. 3. 2010.

Daniel Mellinger, Nathan Michael, and Vijay Kumar. Trajectory Generation and Control for Precise Aggressive Maneuvers with Quadrotors. International Journal of Robotics Research, Apr. 2012.

Quadrotor Ball Juggling

[Müller et al., ETH, 2011]

The Flying Machine Arena, ETH Zürich: http://www.youtube.com/watch?v=3CR5y8qZf0Y

Mark Muller, Sergei Lupashin, and Raffaello D'Andrea, "Quadrocopter Ball Juggling", IEEE/RSJ International Conference on Intelligent Robots and Systems, pp.5113–5120, 2011.

Aerial Construction

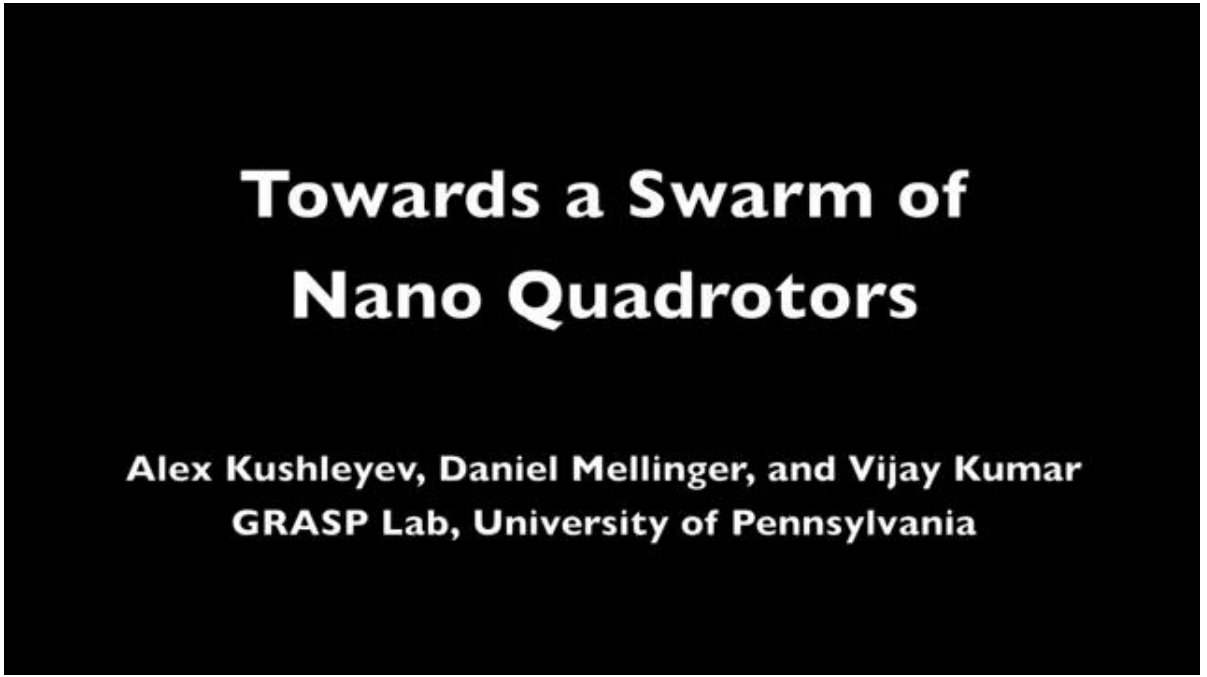
[Lindsey et al., UPenn, 2011]

GRASP Lab, University of Pennsylvania, http://youtu.be/W18Z3UnnS_0

Quentin Lindsey, Daniel Mellinger and Vijay Kumar, "Construction with quadrotor teams," Autonomous Robots, 33, (3), 2012.

Miniaturization

[Kushleyev et al., UPenn, 2012]



GRASP Lab, University of Pennsylvania, http://youtu.be/YQIMGV5vtd4

Alex Kushleyev, Daniel Mellinger, and Vijay Kumar. Towards A Swarm of Agile Micro Quadrotors. Robotics: Science and Systems, July 2012.

Interaction using a Kinect

[Ambühl, ETH, 2011]

The Flying Machine Arena, ETH Zürich: http://www.youtube.com/watch?v=A52FqfOi0Ek

Navigation with Onboard Sensors

- Very cool results, but external motion capture systems are unpractical
- Is this also possible with onboard sensors?
  - GPS
  - Laser scanner
  - Cameras
  - Kinect

Our Goal

- **Enable flying robots to operate autonomously in 3D environments using onboard cameras as the main sensor**
- Cameras are light weight and provide rich data
- Subproblems: Navigation, localization, 3D reconstruction, exploration, people following, …

http://www.seeedstudio.com/depot/Crazyflie-Nano-Quadcopter-Kit-6DOF-with-Crazyradio-BCCFK01B-p-1364.html

https://www.mikrocontroller.com/

Course Instructors


Jürgen Sturm


Daniel Cremers

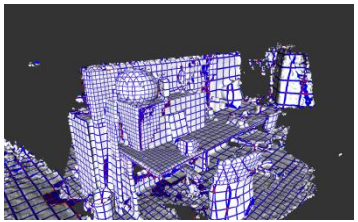

Christian Kerl

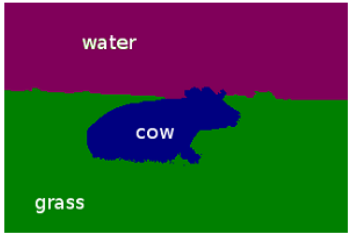

Julian Tatsch

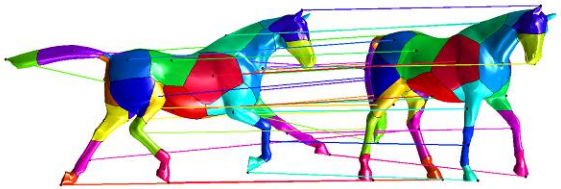

Jonas Jelten

Computer Vision Group

- 1 professor, 3 postdocs, 11 PhD students
- Our research topics:
  - Quadrotors
  - Depth cameras, RGB-D
  - Visual SLAM, 3D reconstruction
  - Image segmentation
  - Shape matching
  - Convex optimization







Camera-based Navigation

[Engel, Sturm, Cremers; IROS 2012]

J. Engel, J. Sturm, D. Cremers : Camera-Based Navigation of a Low-Cost Quadrocopter, In Proc. of the International Conference on Intelligent Robot Systems (IROS), 2012.

Computer Vision Group, Technical University of Munich;, http://youtu.be/tZxlDly7lno

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[Engel, Sturm, Cremers; IROS 2012]

J. Engel, J. Sturm, D. Cremers : Camera-Based Navigation of a Low-Cost Quadrocopter, In Proc. of the International Conference on Intelligent Robot Systems (IROS), 2012.

Computer Vision Group, Technical University of Munich; http://youtu.be/eznMokFQmpc

3D Reconstruction with a Quadrotor

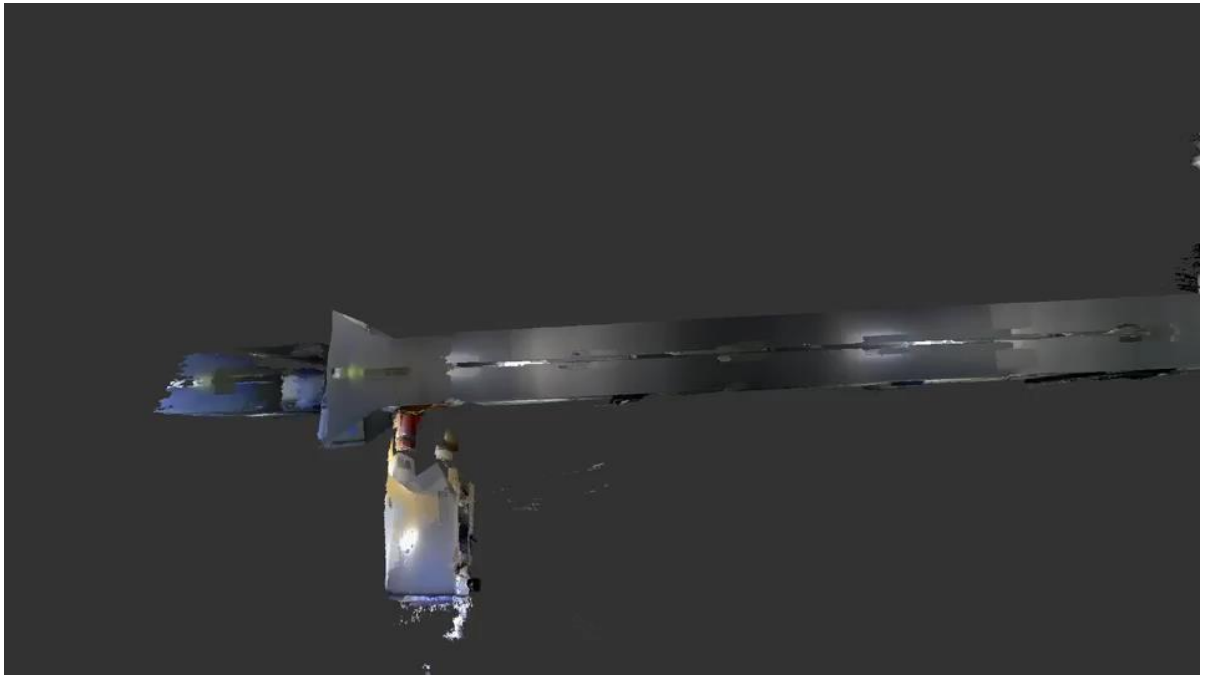
[Bylow, Sturm, Kahl, Cremers; RSS 2013]

E. Bylow, J. Sturm, C. Kerl, F. Kahl, D. Cremers : Real-Time Camera Tracking and 3D Reconstruction Using Signed Distance Functions, In Robotics: Science and Systems Conference (RSS), 2013.

Computer Vision Group, Technical University of Munich; http://youtu.be/MzLdRFSrtuI

Large-Scale 3D Reconstruction

[Steinbrücker, Kerl, Sturm, Cremers; ICCV 2013]



F. Steinbruecker, C. Kerl, J. Sturm, D. Cremers : Large-Scale Multi-Resolution Surface Reconstruction from RGB-D Sequences, In IEEE International Conference on Computer Vision (ICCV), 2013.

Computer Vision Group, Technical University of Munich, http://youtu.be/RZckDPvGmyI

More Information About Our Research

- Website (Papers, code, …)
  http://vision.in.tum.de/
- YouTube Channel (Lecture and research videos)
  http://www.youtube.com/user/cvprtum/videos?view=1
- Facebook page
  https://www.facebook.com/vision.in.tum.de
- Scientific conferences and workshops
  ICRA, IROS, RSS, ICCV, CVPR, ECCV, GCPR