Drohnen – wohin führt die Entwicklung

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www.asl.ethz.ch
www.wysszurich.ch

NGW Naturwissenschaftliche Gesellschaft Winterthur

Winterthur, 3. März, 2017

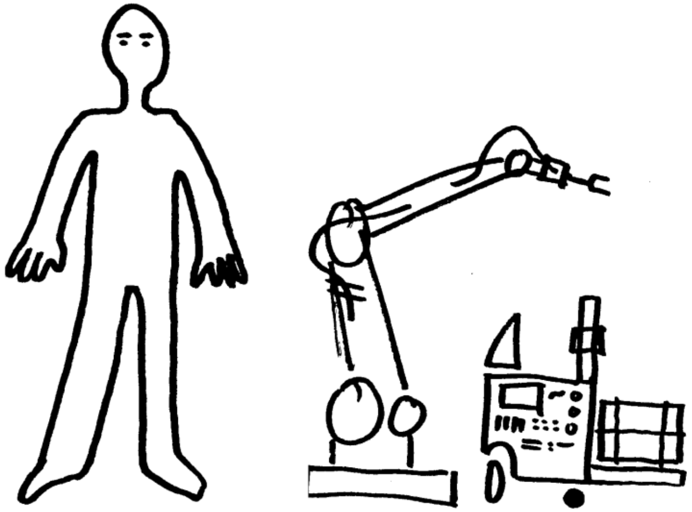
Robotics today (Changan-Ford China)

248’000 industrial robots sold in 2015
68’000 in China

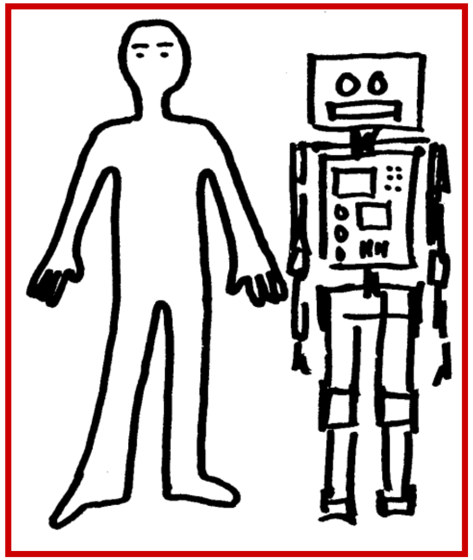
https://www.youtube.com/watch?v=SeIoQy0oXjI

Die nächste Generation von Robotern

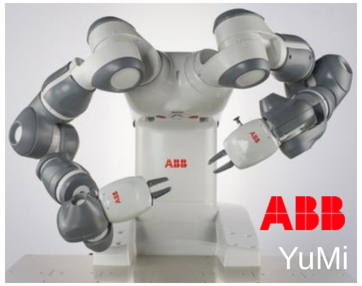
| mobil, intelligent, vernetzt, adaptive und interaktiv

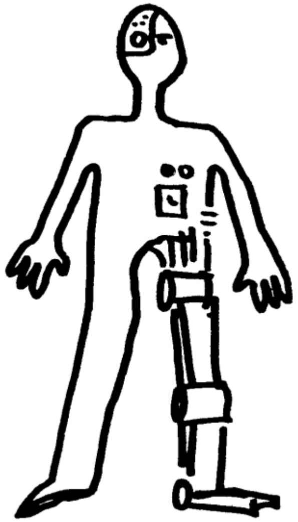


Industrieroboter



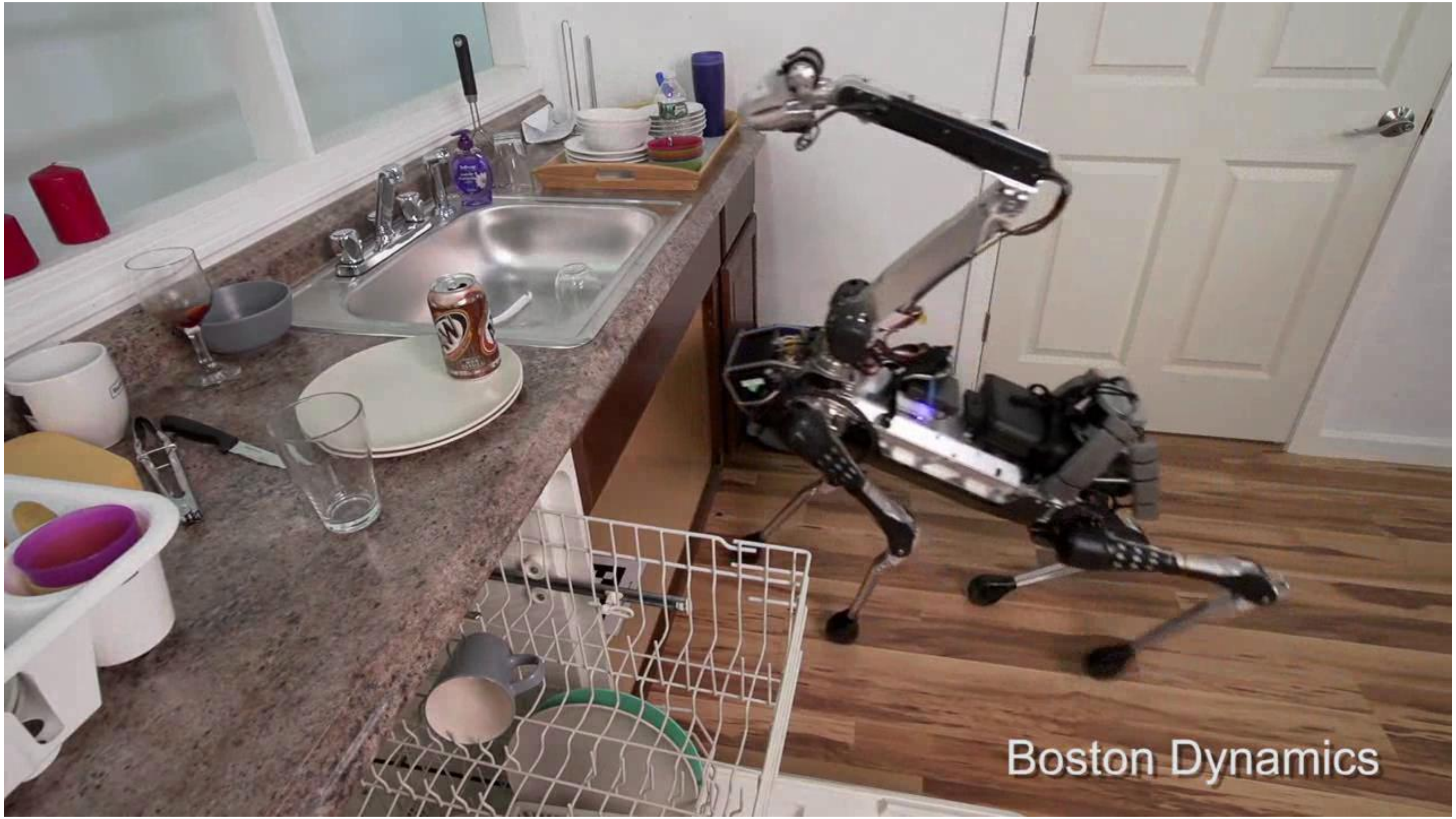
Serviceroboter





Cyborgs

Fascinating Robots

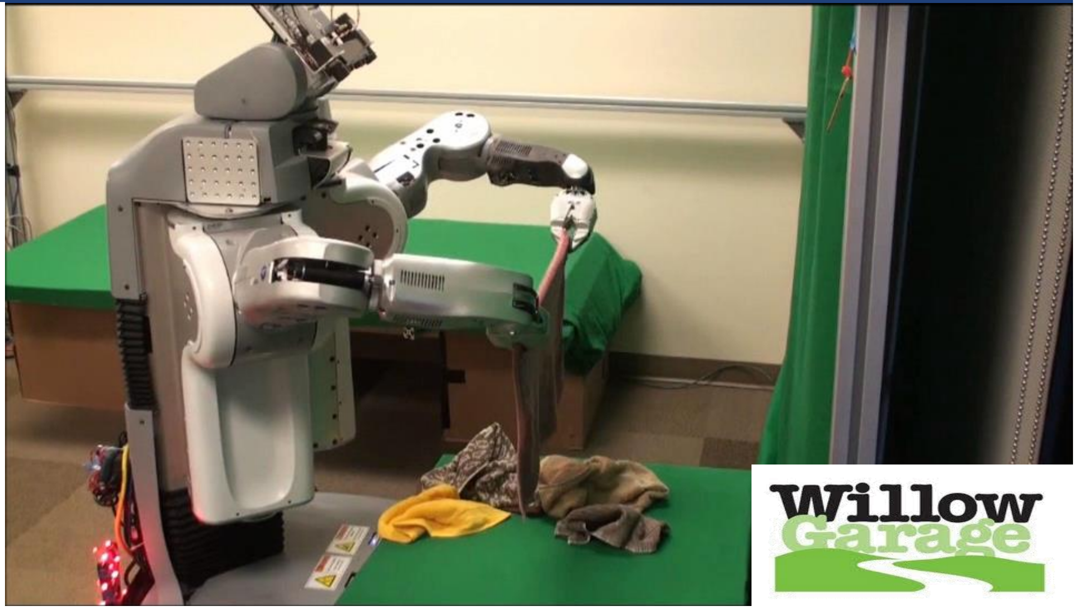


SpotMini | electic quadruped, Boston Dynamics

https://www.youtube.com/watch?v=tf7IEVTDjng

Serviceroboter | die Herausforderungen

- Roboter müssen mit ***unsicherer*** und nur ***teilweise verfügbarer Information*** umgehen können.



50x speed
https://www.youtube.com/watch?v=gy5g33S0Gzo

- Roboter müssen ***sehen***, ***spüren*** und ***verstehen*** können.

- Roboter müssen taktil mit der Umgebung interagieren können -> («soft robots» mit Kraftreglung)

- Roboter müssen ***intuitive programmierbar*** sein

- Roboter ***lern-*** und ***anpassungsfähig*** sein

Autonomous Systems Lab @ ETH

Institute of Robotics and Intelligent Systems
Prof. Dr. Roland Siegwart

- ## Unere Mission
  - Kreation von intelligenten Robotern die in unserem täglichen Umfeld selbständig Aufgaben erfüllen können.

- ## Forschungsschwerpunkte
  - Neue Roboterkonzepte die optimal für Anwendungen auf dem Boden, in der Luft oder im Wasser angepasst sind.
  - Neue Algorithmen für die Wahrnehmung, Lokalisierung und Planung die den Robotern eine autonomen Einsatz in komplexen Umgebungen ermöglicht.

Körper Design

Geist Navigation





Robotik startet mit dem Design (Körper)

Fahren, Schwimmen, Laufen und Fliegen

Service Robots – designed for challenging tasks

Vertigo
| the ultimate wall climber

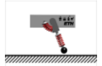
https://www.youtube.com/watch?v=KRYT2kYbgo4

AnyMal
| the ultimate quadruped

RSL Robotic Systems Lab

Prof. Marco Hutter

https://www.youtube.com/watch?v=EI1zBTYpXW0

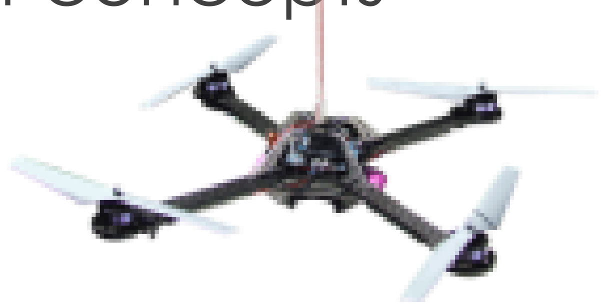


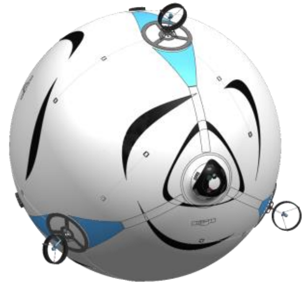
Scalevo
| the stair-climbing wheelchair

https://www.youtube.com/watch?v=3lb_8nmy90c

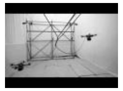
Drones / UAV (Unmanned Aerial Vehicles) | flight concepts

- Helicopters: (video Prof. D'Andrea ETH)
  - < 20 minutes
  - Highly dynamic and agility
- Fixed Wing Airplanes:
  - > some hours; continuous flights possible
  - Non-holonomic constraints
- Blimp: lighter-than-air
  - > some hours (dependent on wind conditions);
  - Sensitive to wind
  - Large size (dependent on payload)
- Flapping wings
  - < 20 minutes; gliding mode possible
  - Non-holonomic constraints
  - Very complex mechanics





Festo BionicOpter



Flying Robots | new ways of flying

OS4 (2003)
| pioneering quadrotors

https://www.youtube.com/watch?v=vSvte6_74tU&index=34&list=PLJol3sa8g75RNJ0vALyl0BBfTNuhwWe1g

Reely (2009 – with Disney)
| the flying reel

https://www.youtube.com/watch?v=RF6OyKKmrX8

Skye (2012 – with Disney)
| the omnidirectional blimp

AEROTAIN

https://www.youtube.com/watch?v=qXvI3anK3w0

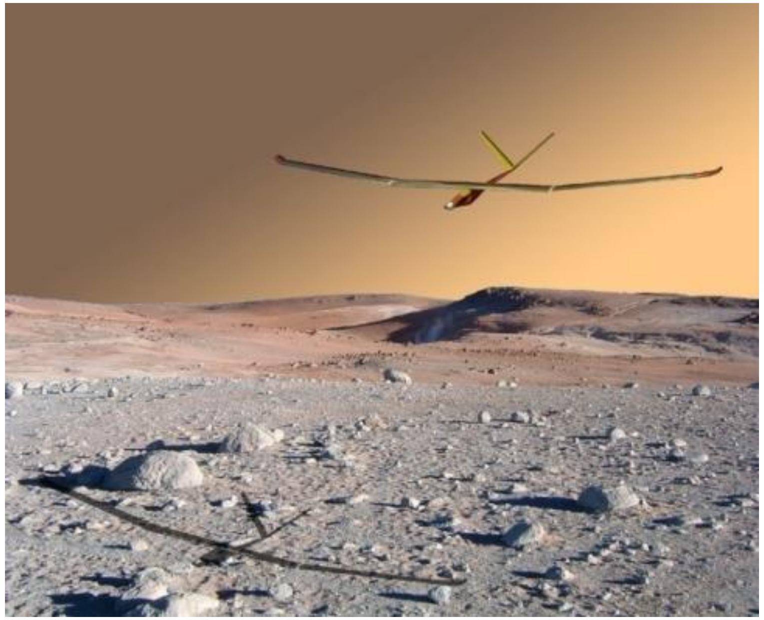
PacFlyer/wingtra (2013)
| the VTOL UAV

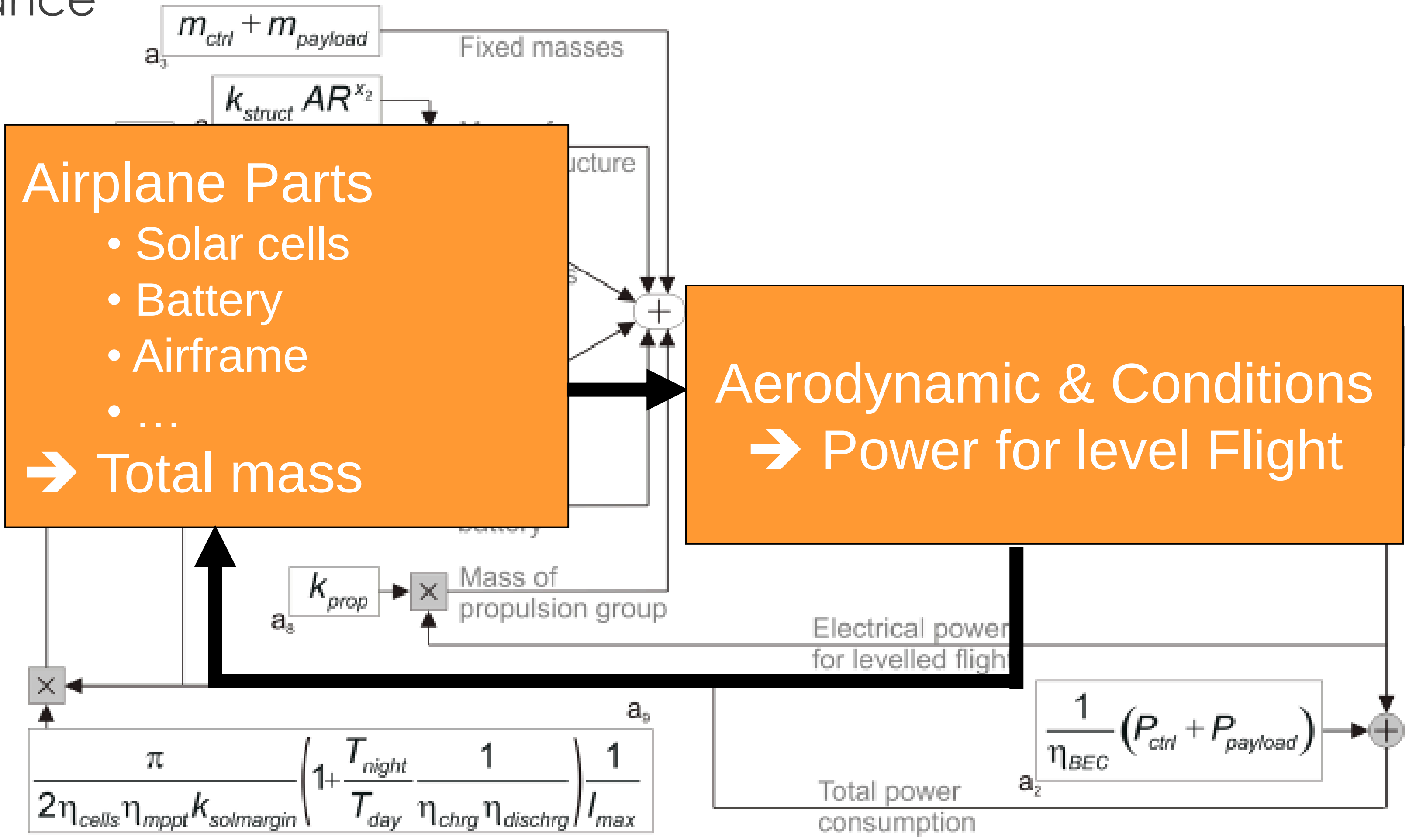
wingtra

https://www.youtube.com/watch?v=QADvPDWtgFU

Solar Airplane |
design methodology for continuous flights

- Based on Mass & Power Balance
  - Need for precise scaling laws (mass models)





Flying Robots – fixed wing

Skysailor (2008)

| pioneering continuous flights

| 3.2 m, 2.3 kg

https://www.youtube.com/watch?v=IU4BoEFOEKI

senseSoar (2012)

| robust and versatile solar plane

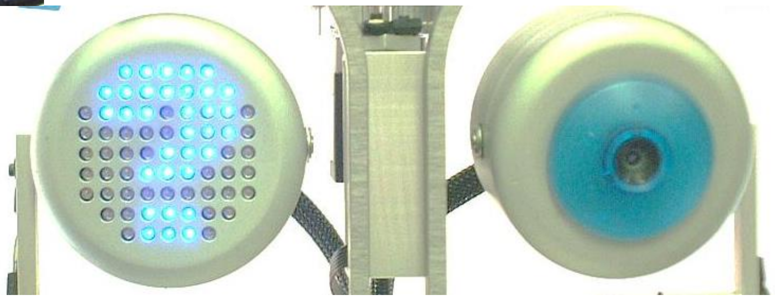
| 3 m, 3.8 kg

AtlantikSolar (2015)

| 81 hours non-stop in summer 2015

| 5.64 m, 6.2 kg

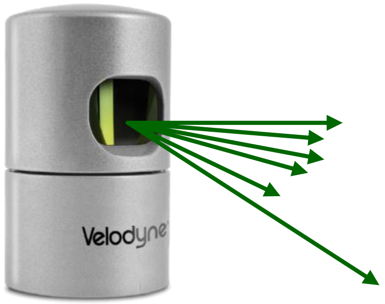
https://www.youtube.com/watch?v=8m4_NpTQn0E

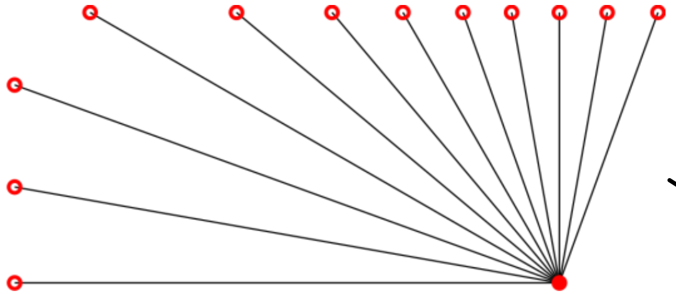


Roboternavigation (Geist)

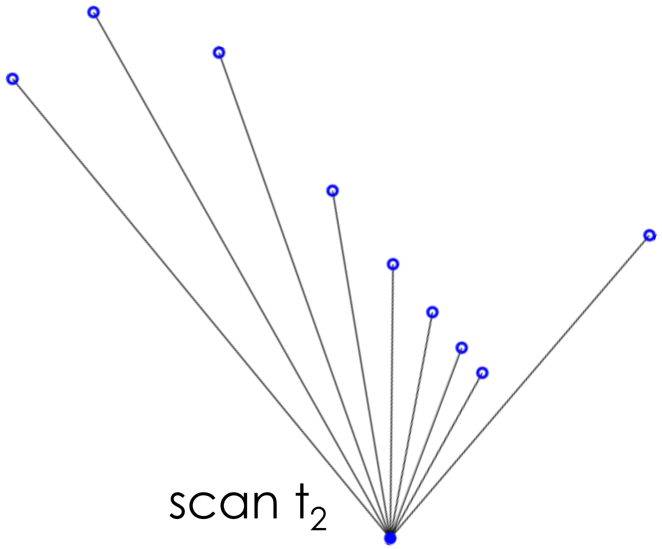
Lokalisierung und Wegplanung

"Seeing" | Laser-based 3D mapping





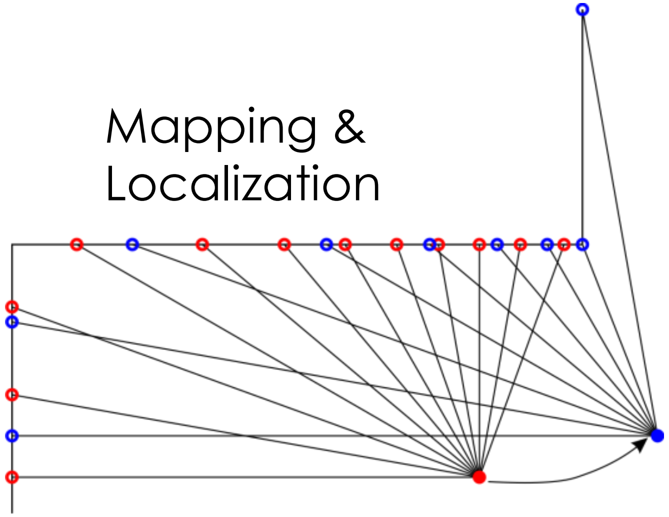
scan t_1



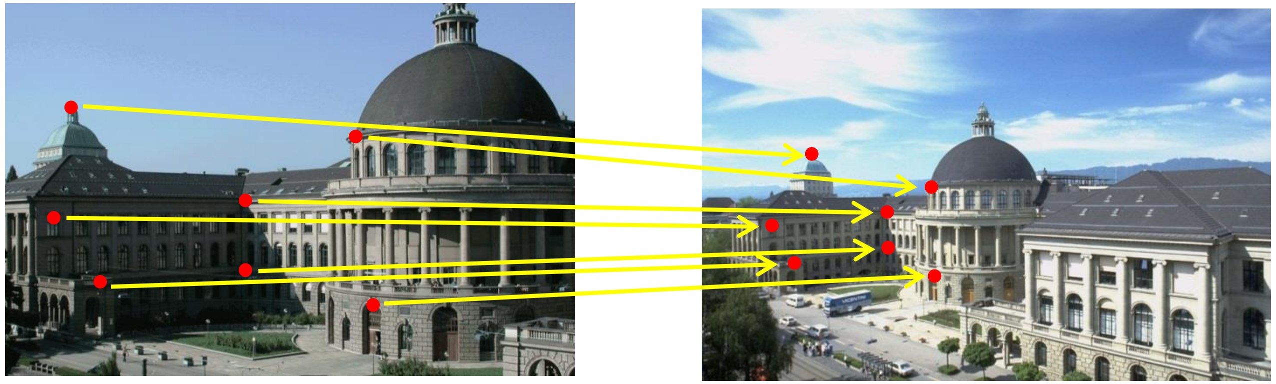
scan t_2

scan matching

Mapping & Localization



"Seeing" | Visual-Inertial Motion Estimation



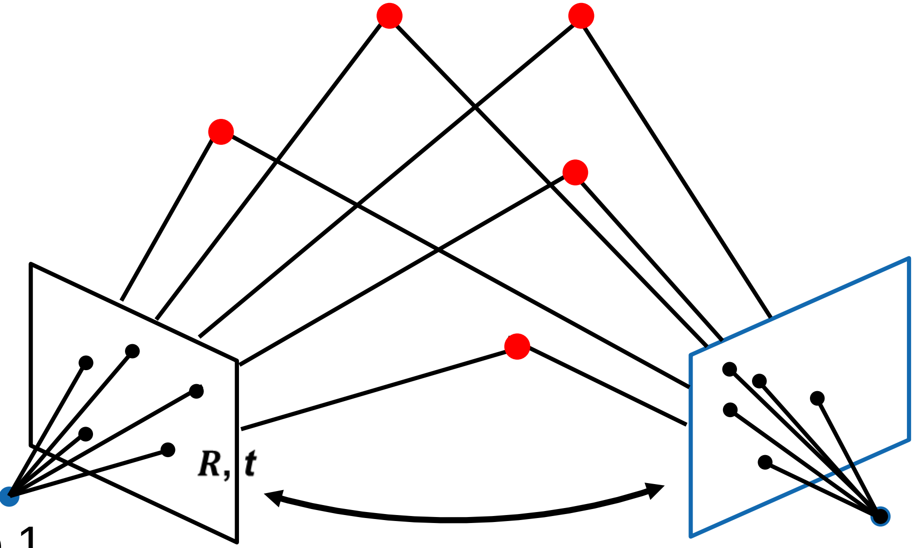
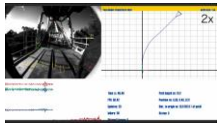


Image 1

Image 2

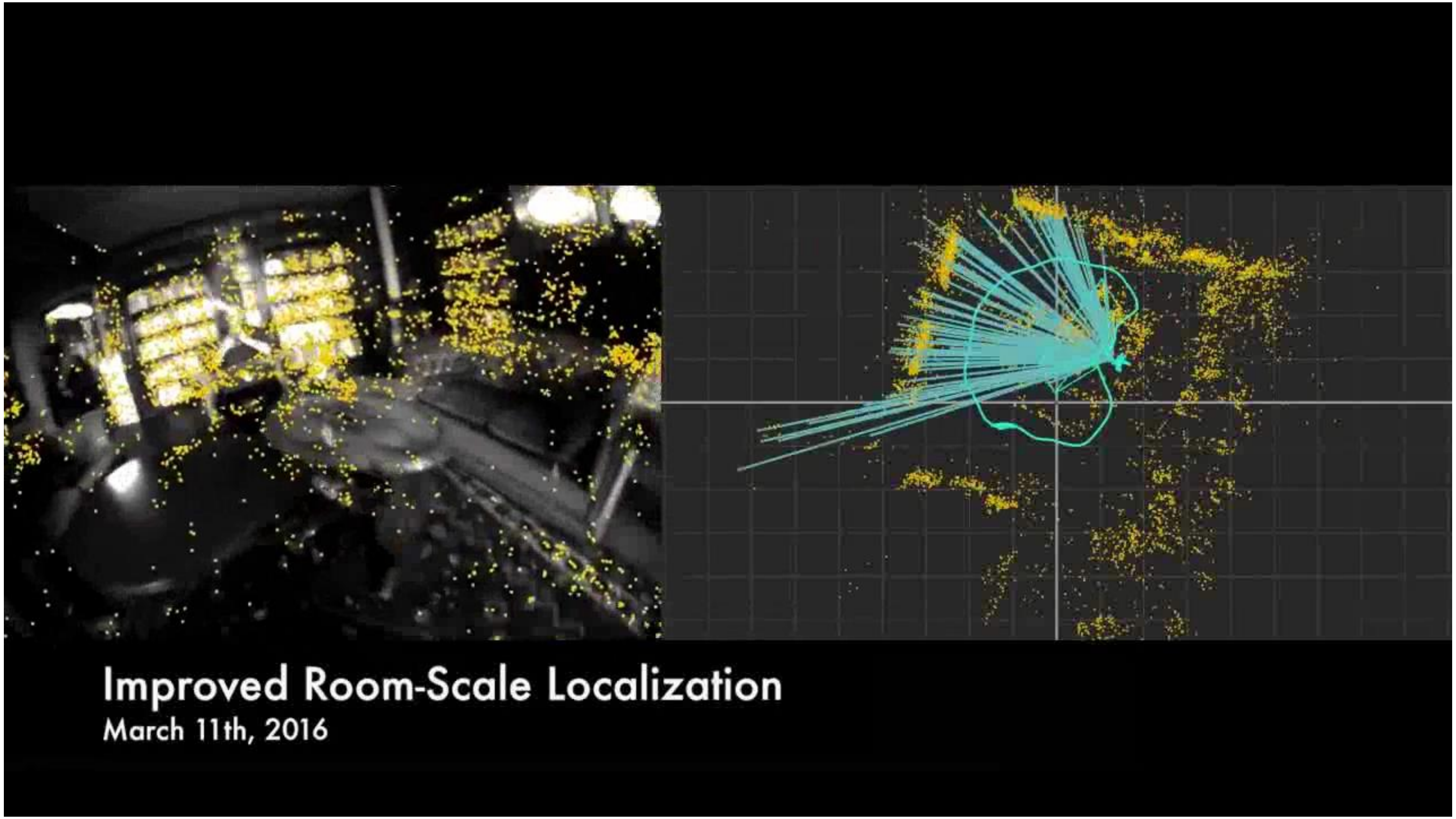
Google

Project Tango



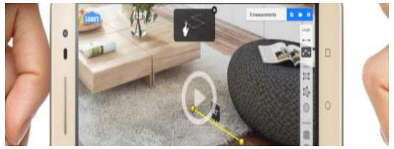
https://www.youtube.com/watch?v=yvgPrZNp4So

Intelligent Smartphone | perceiving the environment



https://www.youtube.com/watch?v=yvgPrZNp4So

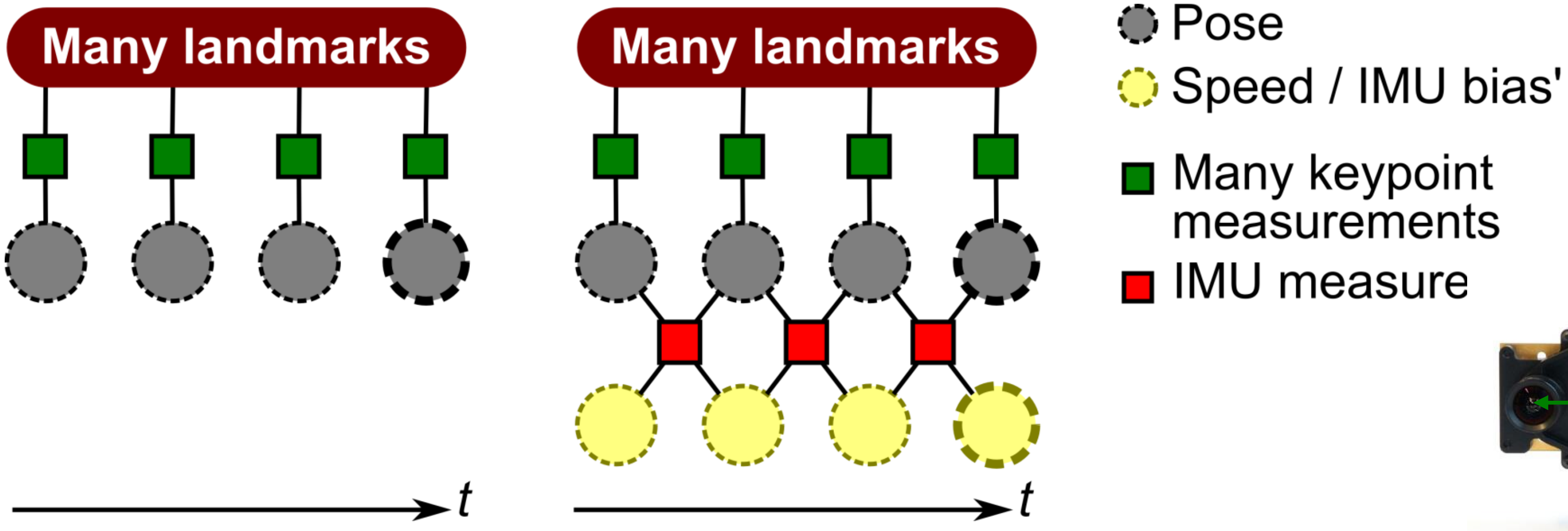
Google Project Tango

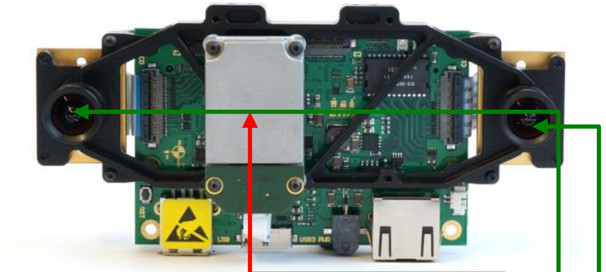


phab2pro
Lenovo

OKVIS | Open Keyframe-based Visual-Inertial SLAM

(tight coupling of vision and IMU)



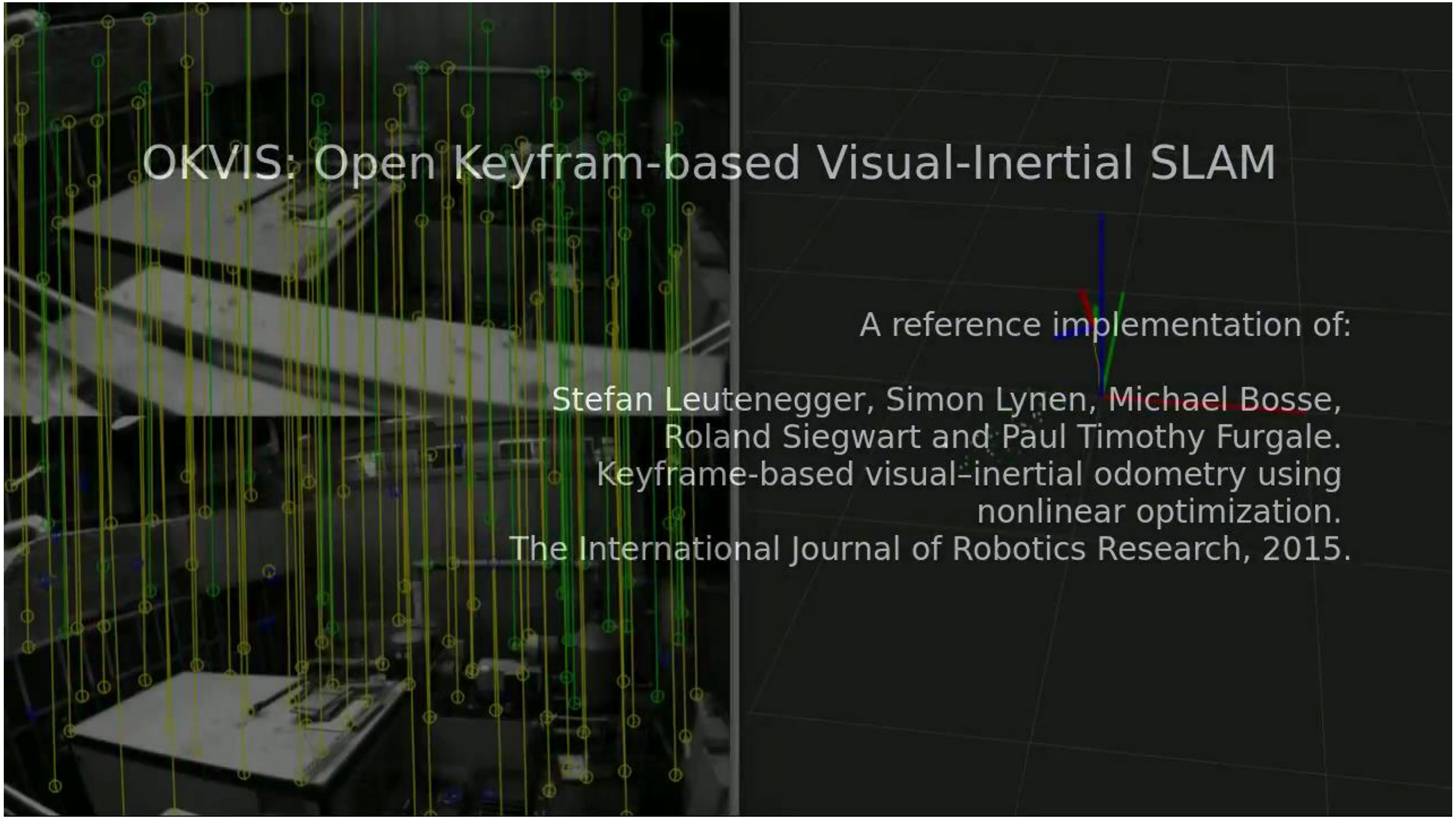


$$J(\mathbf{x}) := \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{j\in\mathcal{J}(i,k)} {\mathbf{e}_{\mathrm{r}}^{i,j,k}}^{T}\mathbf{W}_{\mathrm{r}}^{i,j,k}\mathbf{e}_{\mathrm{r}}^{i,j,k} + \sum_{k=1}^{K-1} {\mathbf{e}_{\mathrm{s}}^{k}}^{T}\mathbf{W}_{\mathrm{s}}^{k}\mathbf{e}_{\mathrm{s}}^{k}.$$

Cost — Reprojection errors (weighted) — IMU terms

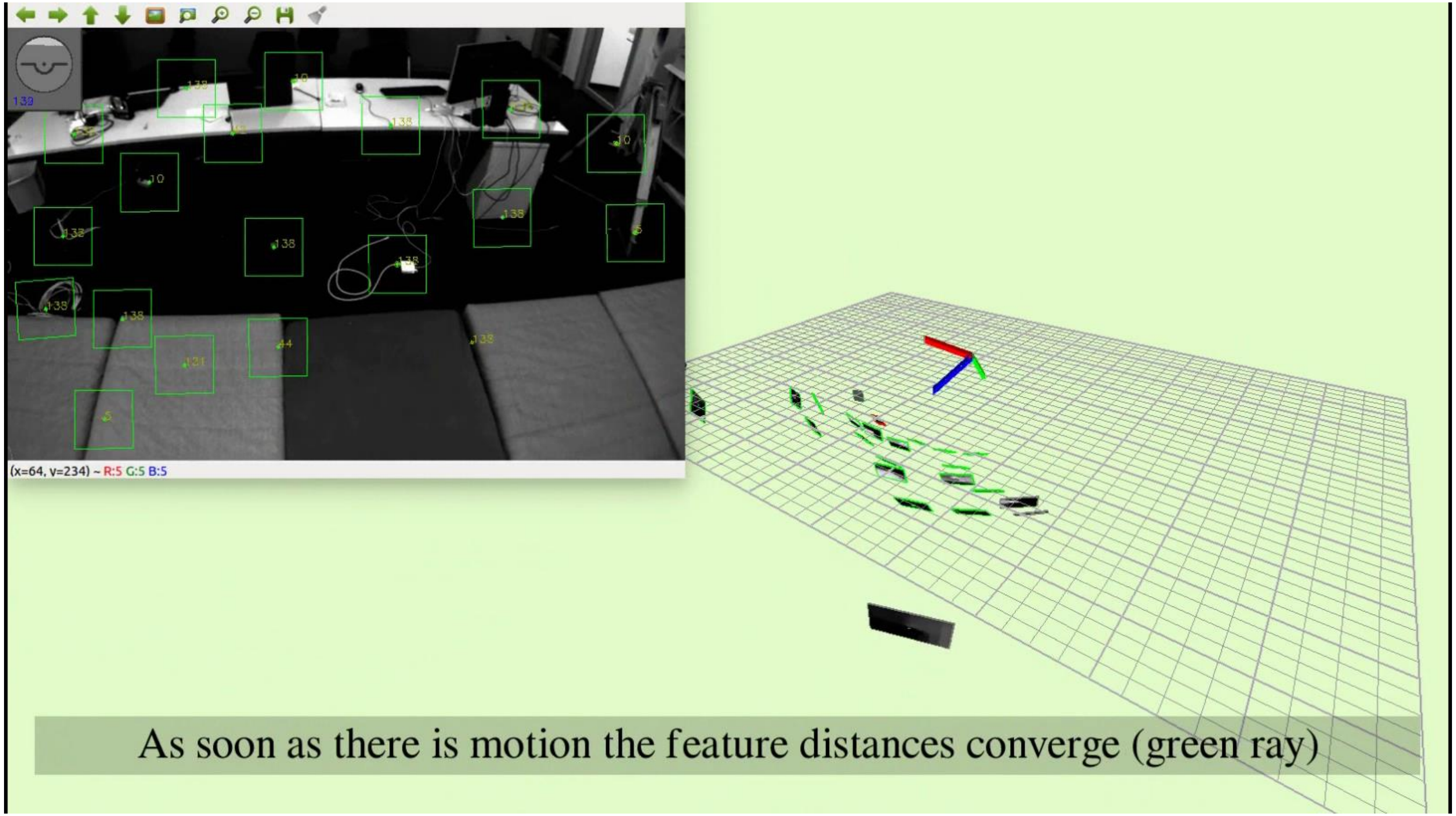
i: camera index; *k:* camera frame index; *j:* landmark index.

OKVIS in Action



ROVIO | Robust Visual Inertial Odometry

https://www.youtube.com/watch?v=ZMAISVy-6ao&list=PLJoI3sa8g75RNJ0vALyI0BBfTNuhwWe1g&index=2



[M. Bloesch et al (2015). Robust Visual Inertial Odometry Using a Direct EKF-Based Approach, IROS]

Flying Robots | navigation

- Appropriate robot concept
  - Power autonomy
  - Agility
  - Robustness
- Navigation with on-board sensing and processing
  - Robustness against communication and GPS loss
  - "home" button
- Simple and intuitive operation
  - Stable on "hands-off"
  - Collision avoidance and localization / SLAM
  - …

Courtesy of Ascending technologies

Flying Robots | navigation

- Appropriate robot concept
  - Power autonomy
  - Agility
  - Robustness
- Navigation with on-board sensin… processing
  - Robustness against commun… loss
  - “home” button
- Simple and intuiti…
  - Stable on “ho…
  - Collision a… ocalization / SLAM
  - …

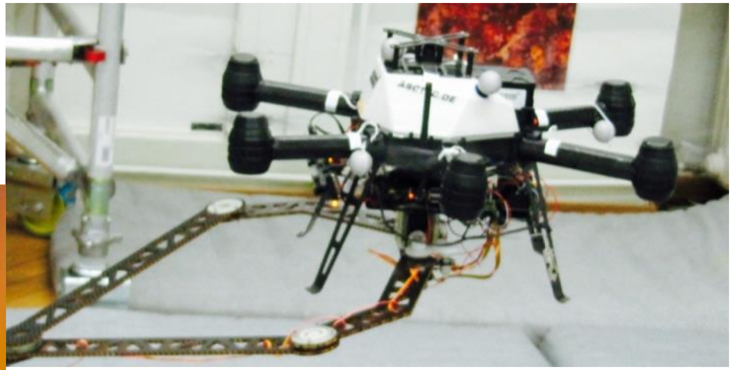
Teleoperation or GPS only navigation will, for most applications, not do the job

Courtesy of Ascending technologies

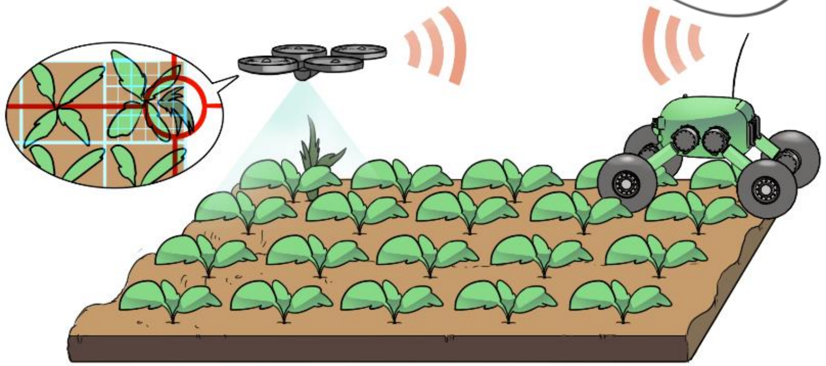
Flying Robots | EU-Projects

European Robotics Challenges

AERO WORKS



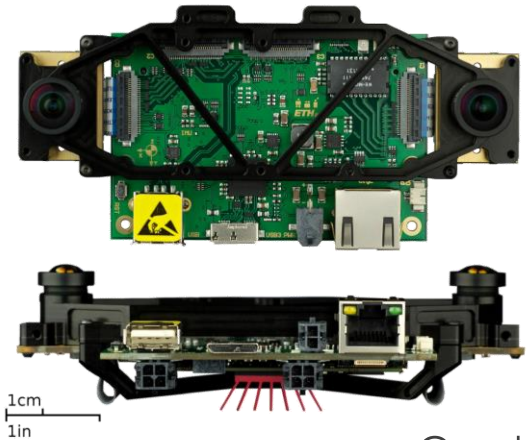
Flourish



SHERPA

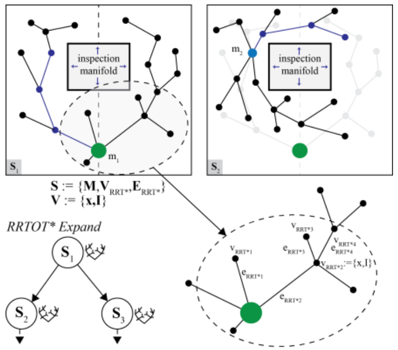
Autonomous Flying Robots

- Visual-Inertial Sensor



- Combined High- and Low-level Control and processing power
- Versatile algorithm deployment

- Motion Estimation
- SLAM
- Dense 3D reconstruction
- Path-planning algorithms
- Obstacle Avoidance



- Robotic arm

www.sfly.ethz.ch/

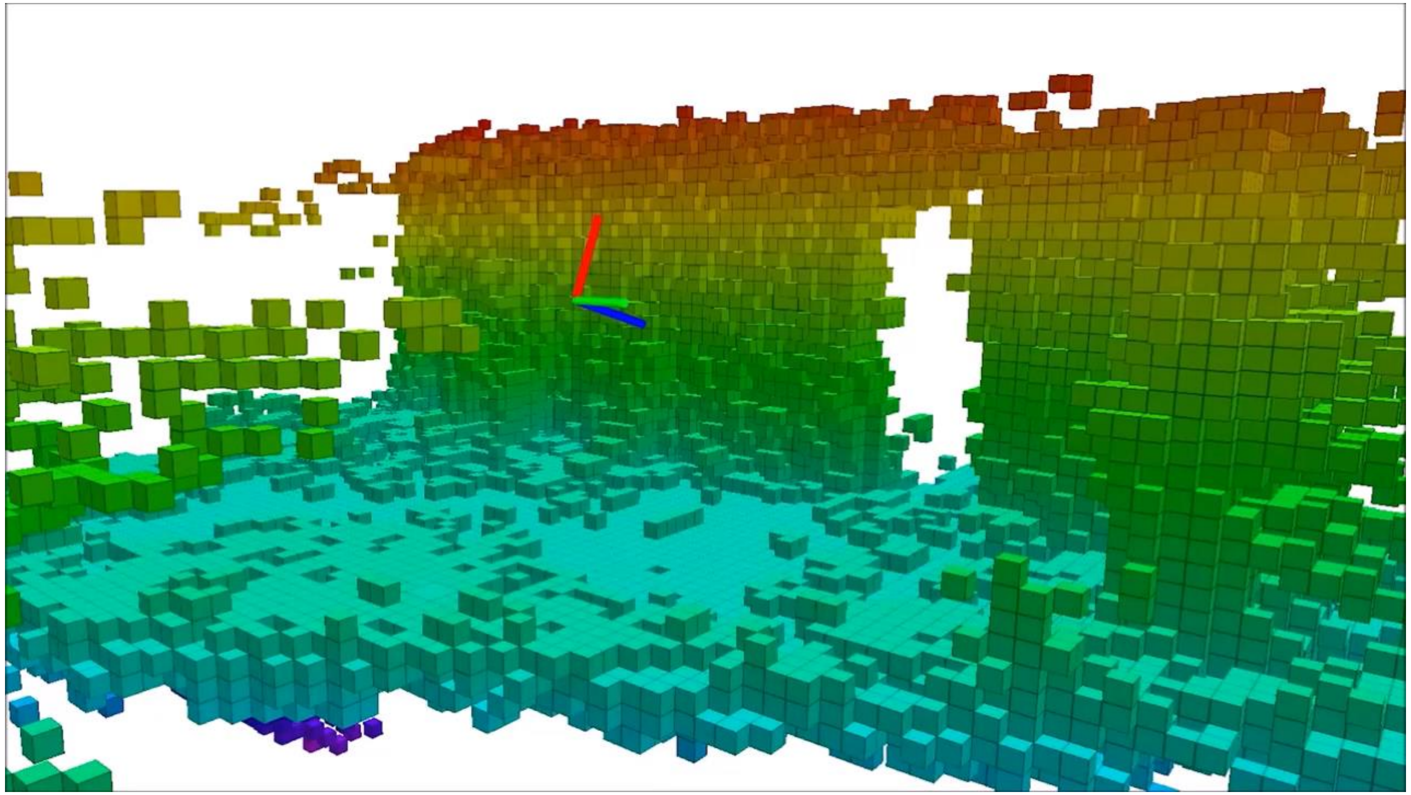
UAV | vision only navigation

- Vision-inertial navigation (one camera and IMU, **GPS denied**)
- Fully autonomous with on-board computing
- Scale estimation
- Feature-based visual SLAM
  - robust against lighting changes and large scale changes

https://www.youtube.com/watch?v=vHpw8zc7-JQ

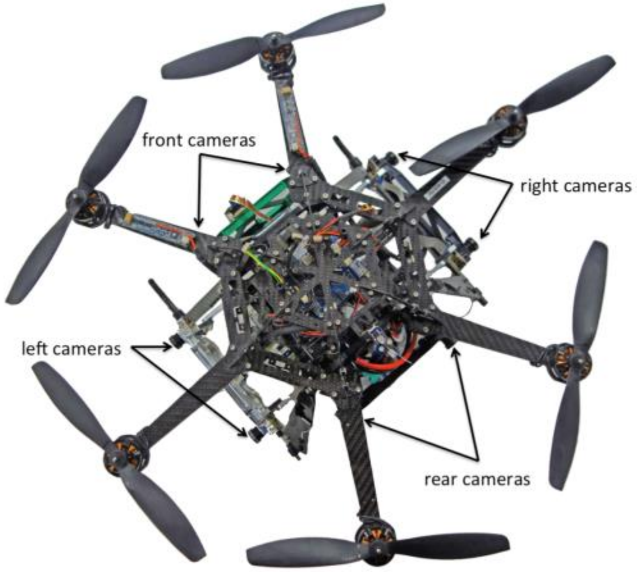
UAV | collision avoidance and path planning

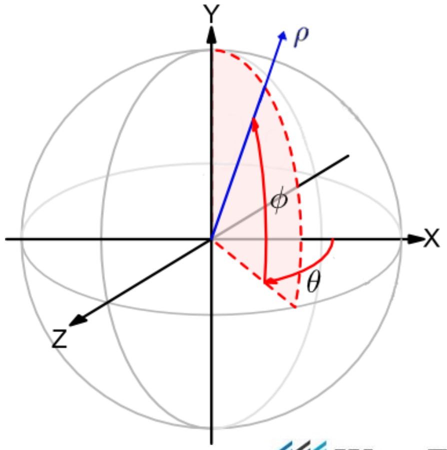
- Real time 3D mapping (on-board)
- optimal path planning considering localization uncertainties

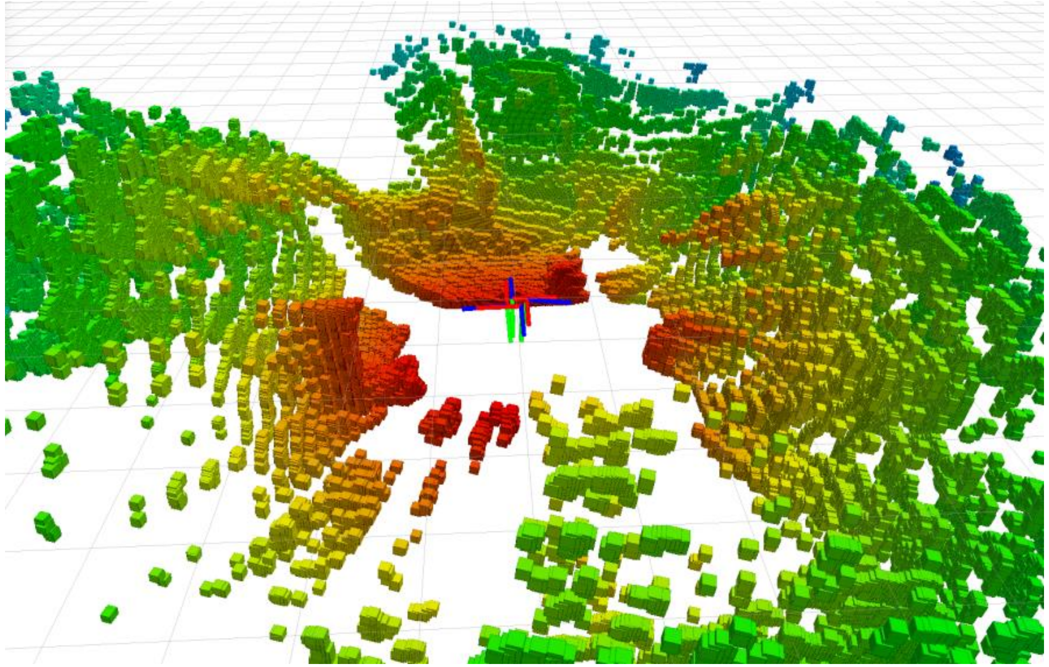


https://www.youtube.com/watch?v=95XGvEs9iTs
https://www.youtube.com/watch?v=D6uVejyMea4
https://www.youtube.com/watch?v=-cm-HkTI8vw

Omnidirectional 3D | visual obstacle detection and avoidance







https://www.youtube.com/watch?v=0qeDc2mWlfI

Requirements for an Intelligent MAV

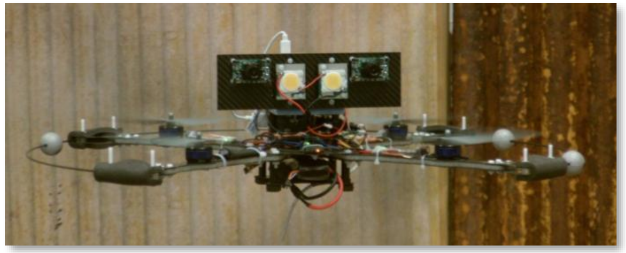
- Control
  - Agile

Flying Manipulation | tree cavity inspection

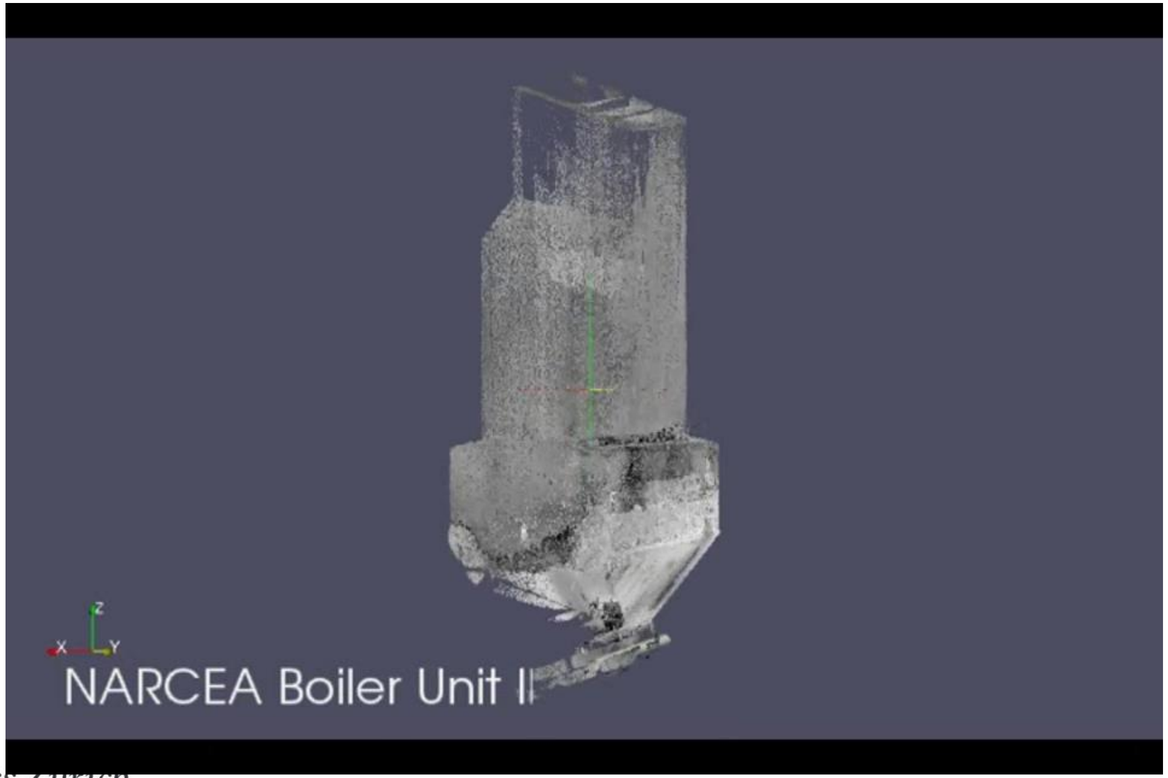
- 3DOF
  robot arm

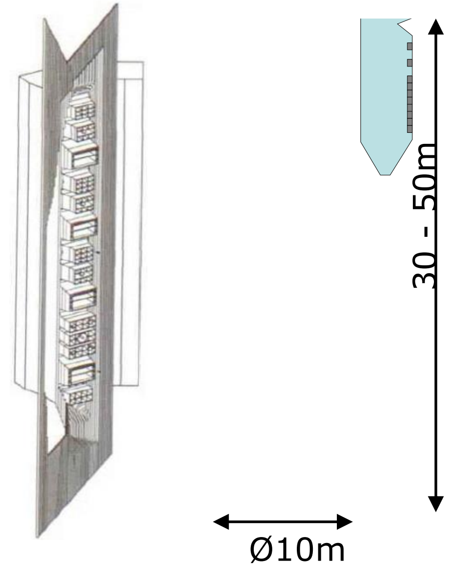
Stereo Vision-based Navigation for Industrial Inspection

http://airobots.ing.unibo.it/



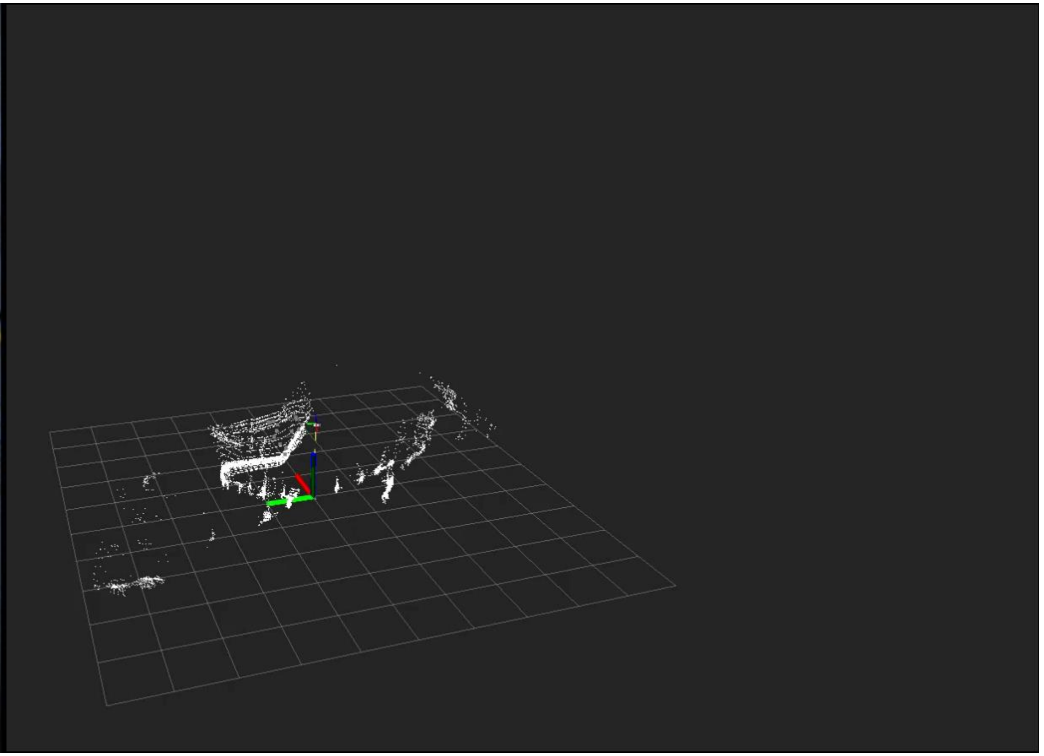
- Robust vision based control using stereo images and enhanced features
- Features: BRIEF / BRISK



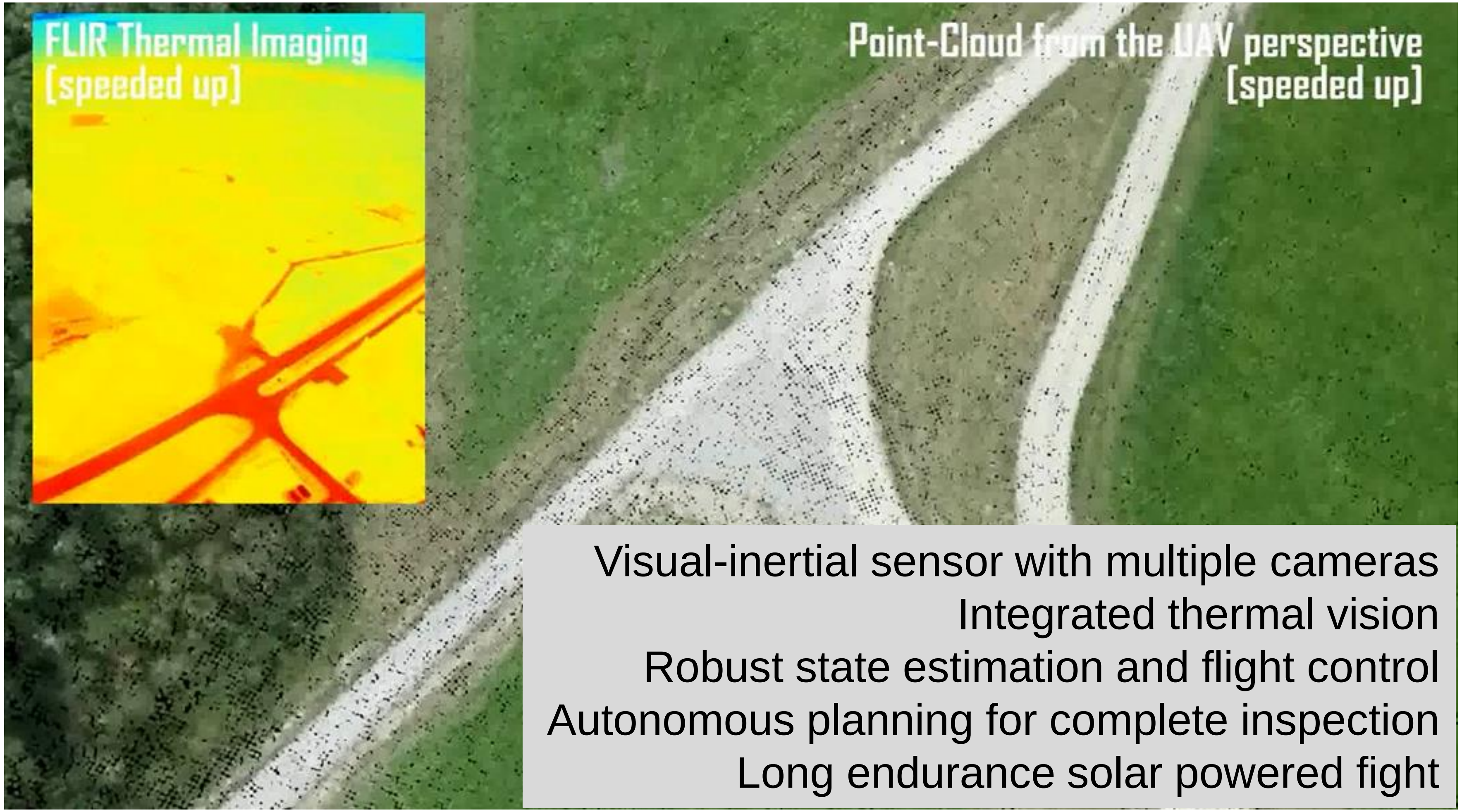


UAV | 3D mapping in mines

- Vision-based localization and SLAM
- Laser-based 3D mapping



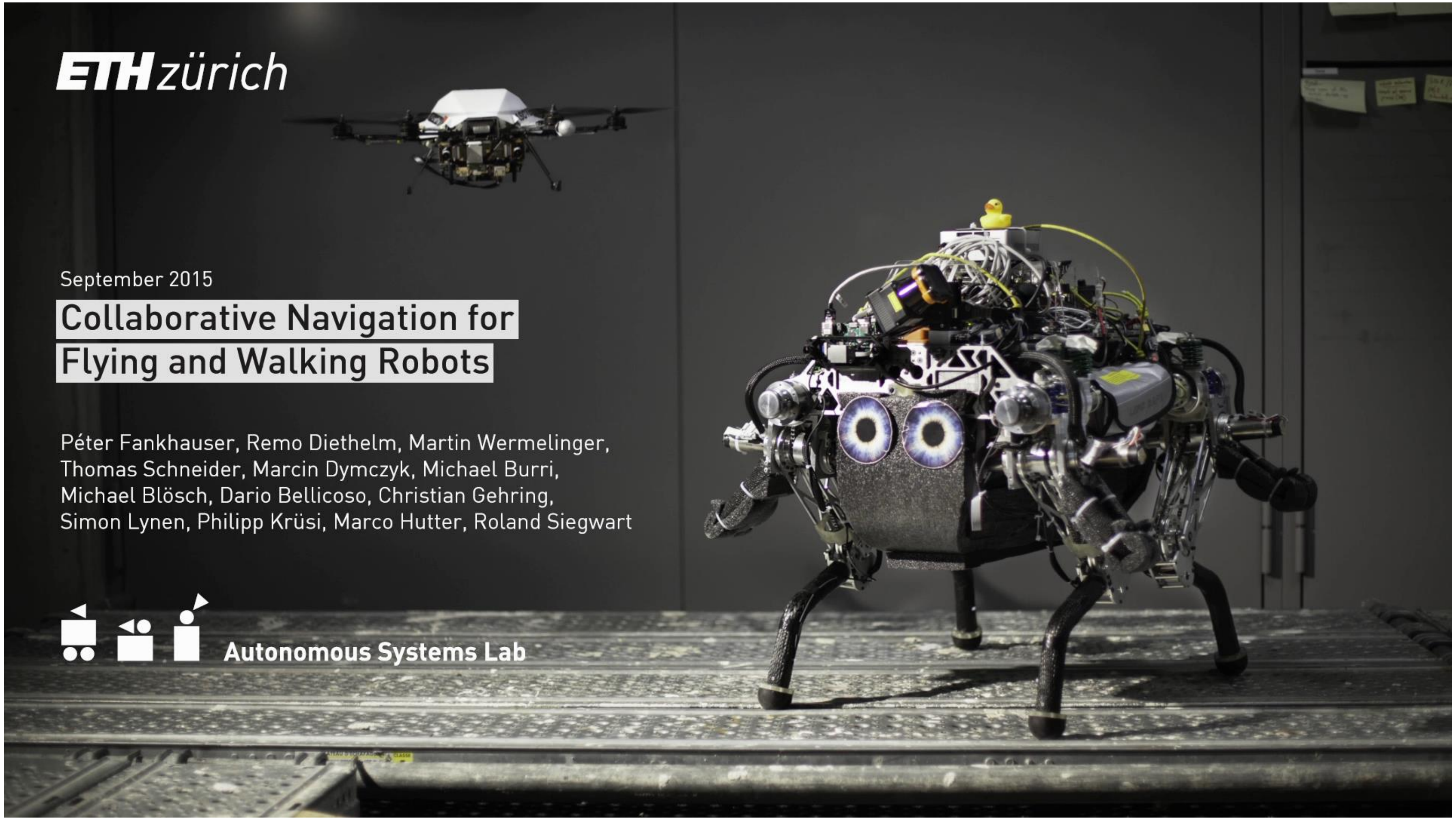
Solar Airplane | visual navigation



Collaborative Visual-Inertial Navigation

in collaboration with

Prof. Marco Hutter



https://www.youtube.com/watch?v=9PprNdIKRaw

Examples **ETH / EPFL Startups in Flying Robotics**

More in the pipeline

- Fotorkite http://fotokite.com/
  aerial filming made simple
- SenseFly https://www.sensefly.com/
  - aerial imaging drones for professional applications
- Verity Studios http://veritystudios.com/
  - The magic of flying robots
- Pix4D https://www.pix4d.com/
  - Generate your own 2D and 3D content, purely from images
- Flyability http://www.flyability.com/
  - collision-tolerant flying robot
- Aerotainment Labs http://www.aerotainmentlabs.com/
  - blimp aerial entertainment
- Wingra https://wingtra.com/about/
  - Fly like an airplane, take-off and land like a helicopter

Zusammenfassung

- Entwicklung von Drohnen geht sehr schnell voran
  - Neue Technologien (Inertialsensoren, Kameras, Motoren, Batterien …)
  - Neue Navigationsalgorithmen
- Volle Autonomie ist aber immer noch eine grosse Herausforderung
  - Wahrnehmen und verstehen
  - Lernen
  - Systemintegration
- Die Schweiz ist weltführend in Drohnentechnology
  - Top Forschung an Universitäten
  - Grosse Anzahl von Startup-Firmen

Tanks to: ASL Team – Industrial Partners – Funding Agencies

- Current and former ASL Members (2016)