TELECOM ParisTech

Institut Mines-Telecom

Autonomous Drones

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GDR Robotique

Work performed with:
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Jean-Luc Dugelay, Yves Roudier (EURECOM)
Benjamin Ranft (FZI Research Center)

Outline

LabSoC
- Presentation of our lab

Context and motivations

Contributions: Autonomous Drones

Conclusion

LabSoC

- Lab of Telecom ParisTech, Communications and Electronics Department
- Located in Sophia-Antipolis, France (South east)
  - "SophiaTech" campus

People

- 5 Researchers: Renaud Pacalet, Sophie Coudert, Ludovic Apvrille, Rabéa Ameur-boulifa, Tullio Tanzi
- 1 research engineer: Daniel Camara
- 5 Ph.D. students (Jérémie Brunel, Andrea Enrici, Florian Lugou, Adrien Canuel, Salaheddine Ouaarab)

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Our Lab

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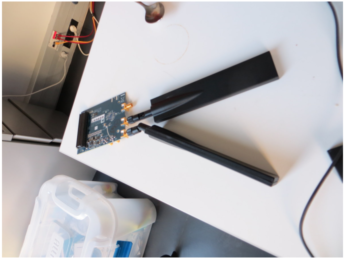
Our Lab (Cont.)

Our Lab (Cont.)


Innovate & foster
Entrepreneurship
in a Digital World


INNOVER ET
ENTREPRENDRE
DANS UN MONDE
NUMÉRIQUE

Our Lab (Cont.)

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ParisTech
ENRICI Andrea
Télécom ParisTech, COMELEC, LabSoC
CANUEL Adrien
Télécom ParisTech, COMELEC, LabSoC

Our Lab: Drone Fleet

Outline

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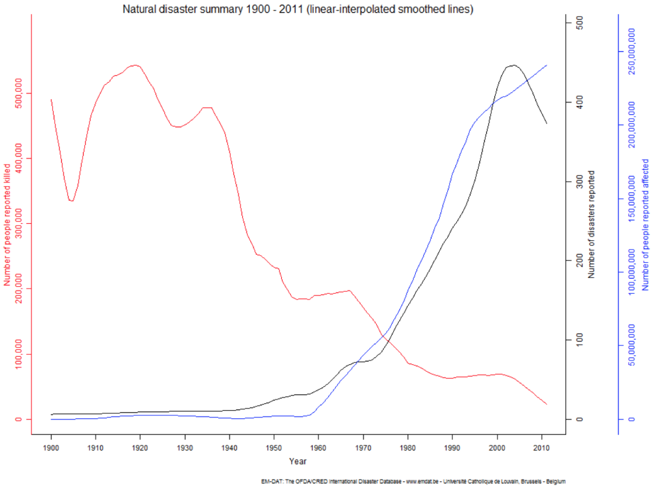
Natural Disasters

Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium);



(Mini) Drones (UAVS)

Since the Hewitt-Sperry automatic airplane (1917), Drone Ancestor.

Drones for Humanitarian Operations

Communication and coordination

- Handling communication blackout with alternative networks
- Secure data sharing

Source: South Asian Disaster Knowledge network

Terrain reconnaissance

- Efficiently exploring areas of interest

Search And Rescue (SAR) operations

- People detection, categorization and counting

Challenges

1. Autonomy

- Do not require specific skills for rescuers
- Do not induce additional work for rescuers
- Scattered and possibility fast moving victims
- Evolving terrain conditions

2. Reliability of the drone

- Prevent additional casualties
- May operate in hostile environment
- Adapted to a low level of maintenance
- Prevent drone hijacks

3. Strong ethical and deontological aspects

- Respect for disaster victims and relief team
  - Strict control of acquired data, . . .

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Outline

Drone Safety and Security

Safety

- Understanding of the environment (collision avoidance)
- Limitation of the impact in case of unexpected return to the ground
- Real time management (e.g., deadlines)
- Energy management

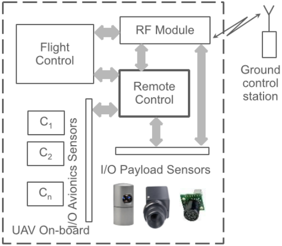
Security

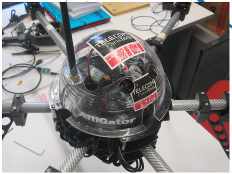
- Securing communications (authentication / encryption)
- Protection of acquired data

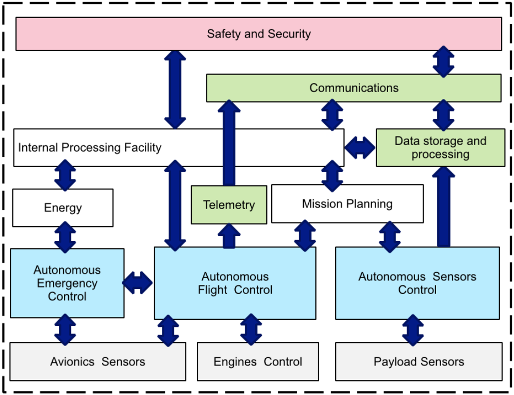
Our contribution:

Definition of a mini-drone architecture, validation of this architecture, implementation

Towards New Architectures

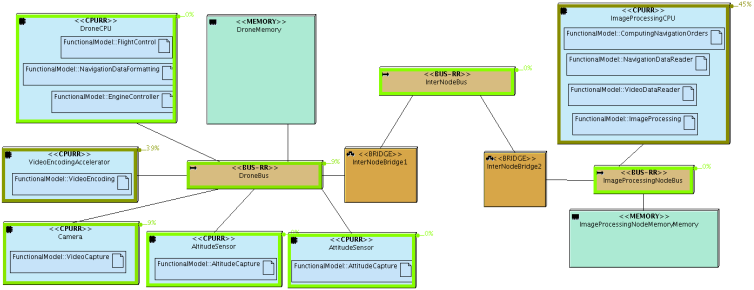




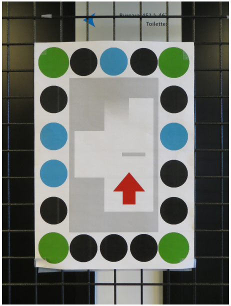


Architecture Validation

- Architecture is modeled with TTool/SysML-Sec
  - Explicitly takes into account Sw and Hw components
  - Simulation, formal verification
    - Performance, safety and security proofs
- Example: Image processing for 3D environment reconstruction with one 720p camera



Autonomous Navigation



Based on signs/landmarks recognition

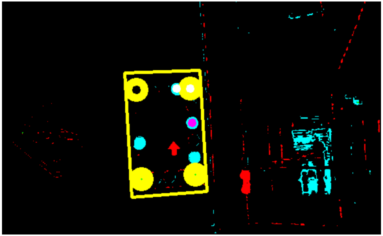
- Line of the path put on the ground
- Landmark on walls
  - Crossings, obstacles (stairs, sharp turns, ...)

Based on 3D reconstruction

- 3D Vision with a mono-vision camera
  - Dense reconstruction
  - Sparse reconstruction
- Require specific flight movements

Autonomous Navigation: Landmark Identification

Autonomous Navigation: Landmark Identification (Cont.)



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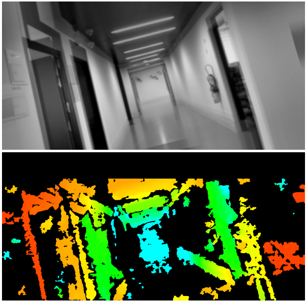
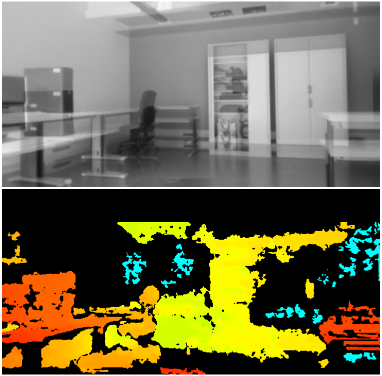
Autonomous Navigation: 3D Dense Reconstruction

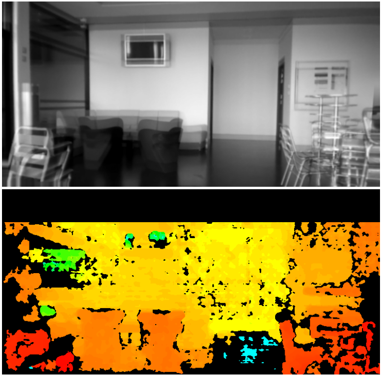
- Estimated distance for most pixels of images
- Exclusive flight control with change in altitude to create a 3D vision

- The overlayed rectified images before and after the height change illustrate the precision of the estimated camera motion
- Distance reconstruction



Autonomous Navigation: 3D Dense Reconstruction (Cont.)





Autonomous Navigation: 3D Sparse Reconstruction

- Spatial locations of a few hundreds of distinct image points
- Optical flow vector of points is obtained with a corkscrew flight

(red = 1m, cyan = 10m and above)

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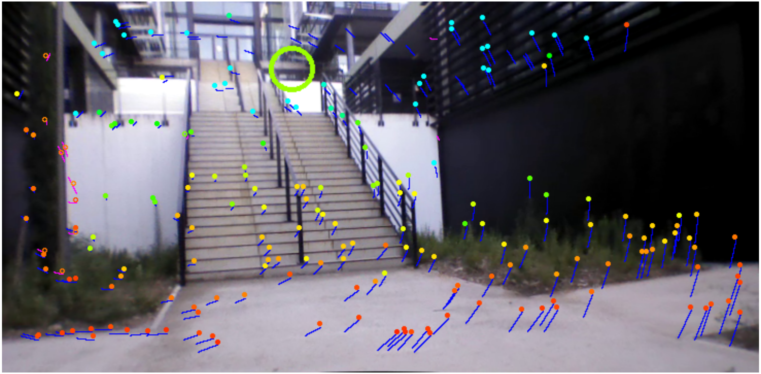
Autonomous Navigation: 3D Sparse Reconstruction (Cont.)

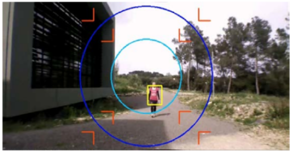


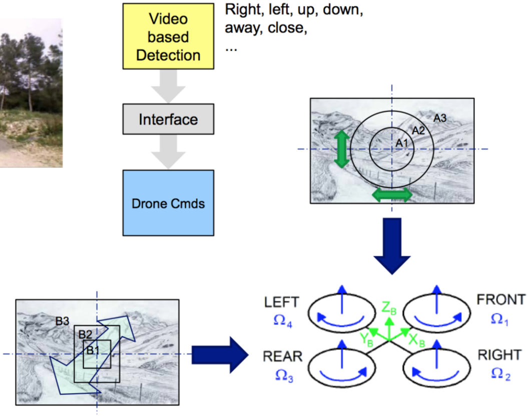
Autonomous Navigation: Movie

See https://www.youtube.com/watch?v=tamYpmGvzRw

People Following (Autonomously)

- Follow a person movement
- Based on two techniques: particle filter and color profile detection





People Following (Cont.)

People Following Movie

see https://www.youtube.com/watch?v=JNEZmV8yONQ

Outline

LabSoC

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Conclusion

- Conclusion, future work and references

Conclusion and Future Work

Achievements

- Autonomous drone navigation and people following
- Platform definition and validation

Future work

- Finishing the (new) platform
- Integrate more complex sensors (e.g., lidars, Groud Penetrating Radar, . . .)
- Settling collaborative projects

To Go Further ...

Web sites

- https://drone4u.telecom-paristech.fr
- https://ttool.telecom-paristech.fr

References

- Tullio Tanzi, Ludovic Apvrille, Jean-Luc Dugelay, Yves Roudier, "UAVs for Humanitarian Missions: Autonomy and Reliability". Proceedings of the IEEE Global Humanitarian Technology Conference (GHTC), Oct. 2014, California, USA.
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- Ludovic Apvrille, Jean-Luc Dugelay, Benjamin Ranft, "Indoor Autonomous Navigation of Low-Cost MAVs Using Landmarks and 3D Perception", Proceedings of OCOSS'2013, 28-31 Oct., 2013.
- Benjamin Ranft, Jean-Luc Dugelay, Ludovic Apvrille, "3D Perception for Autonomous Navigation of a Low-Cost MAV using Minimal Landmarks", Proceedings of the International Micro Air Vehicle Conference and Flight Competition (IMAV'2013), Toulouse, France, 17-20 Sept. 2013.