Institut
Mines-Telecom

Autonomous Drones for Disasters Management:

Safety and Security Verifications

Ludovic Apvrille
ludovic.apvrille@telecom-paristech.fr
Yves Roudier, Tullio Tanzi

AT-RASC'2015

Our Lab: Drone Fleet

Outline

Context and motivations
- Disasters, UAVs

Contributions: Autonomous Drones

Conclusion

TELECOM ParisTech

(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, ...

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

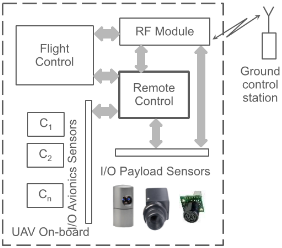
Security

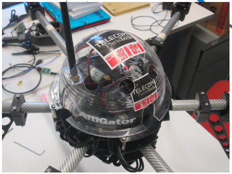
- Securing communications (authentication / encryption)
- Protection of acquired data

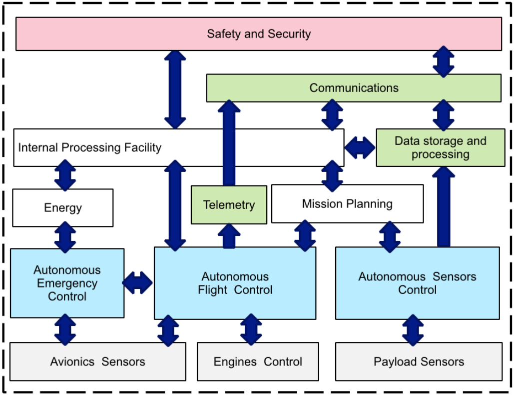
Our contribution:

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

Towards New Architectures

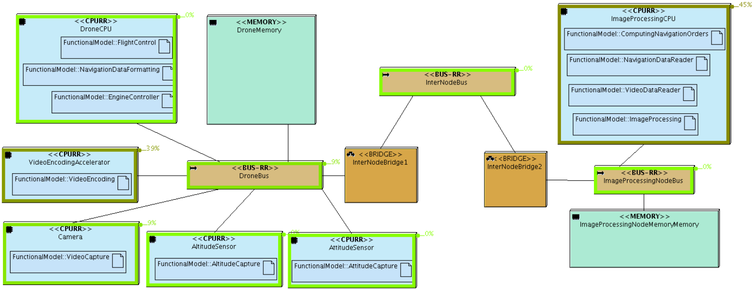




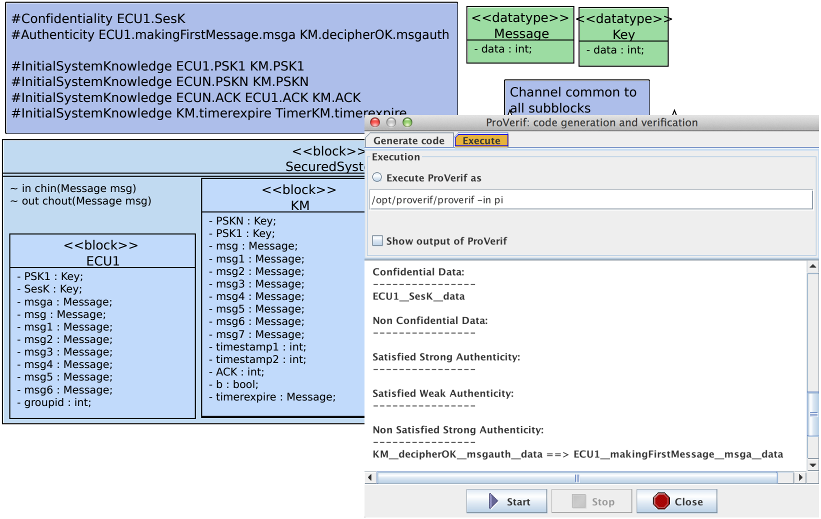


Architecture Validation: Performance and Safety

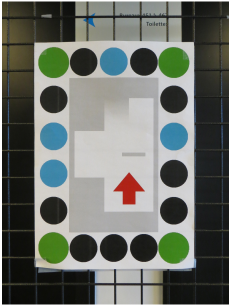
- Architecture is modeled with TTool/SysML-Sec
  - Explicitly takes into account Sw and Hw components
  - Simulation, formal verification
    - Performance, safety and security proofs
- Example: Image processing for 3D environment reconstruction with one 720p camera



Security Proofs



Autonomous Navigation



Based on signs/landmarks recognition

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

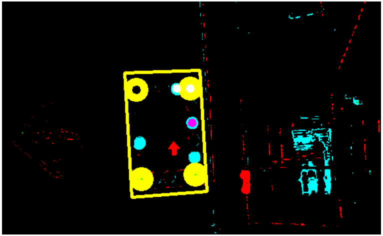
Based on 3D reconstruction

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

Autonomous Navigation: Landmark Identification

TELECOM ParisTech

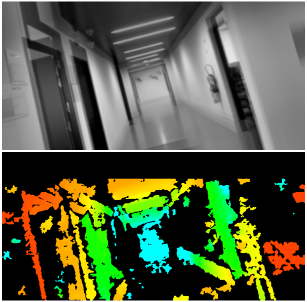
Autonomous Navigation: Landmark Identification (Cont.)



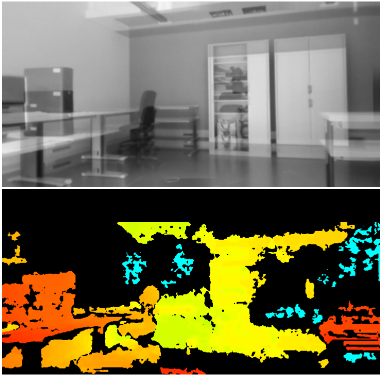
Autonomous Navigation: 3D Dense Reconstruction

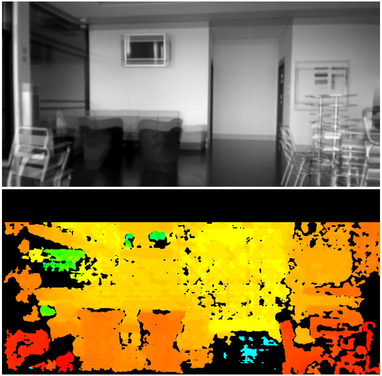
- Estimated distance for most pixels of images
- Exclusive flight control with change in altitude to create a 3D vision

- 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.)



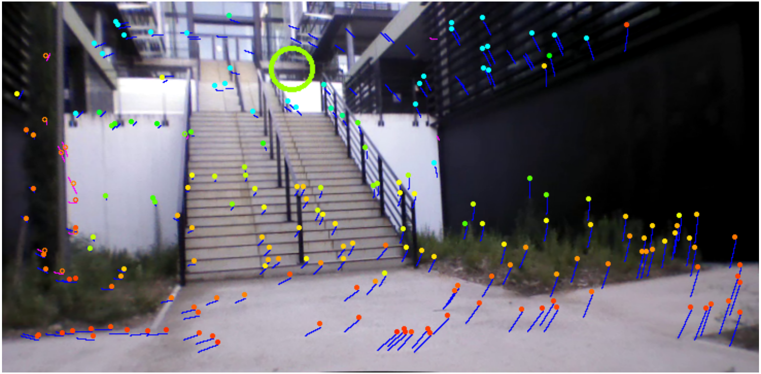


Autonomous Navigation: 3D Sparse Reconstruction

- 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)

Autonomous Navigation: 3D Sparse Reconstruction (Cont.)



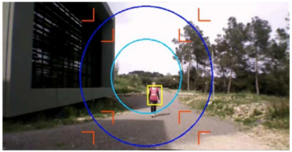
Autonomous Navigation: Movie

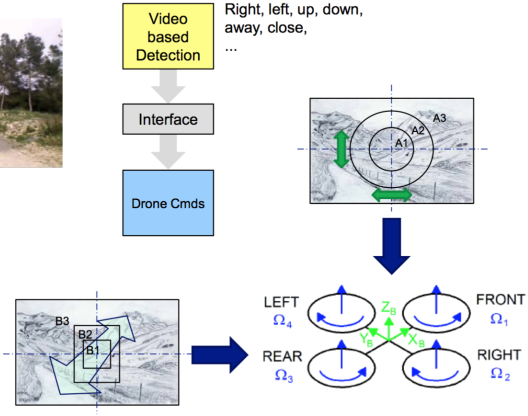
See https://www.youtube.com/watch?v=tamYpmGvzRw

TELECOM ParisTech

People Following (Autonomously)

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

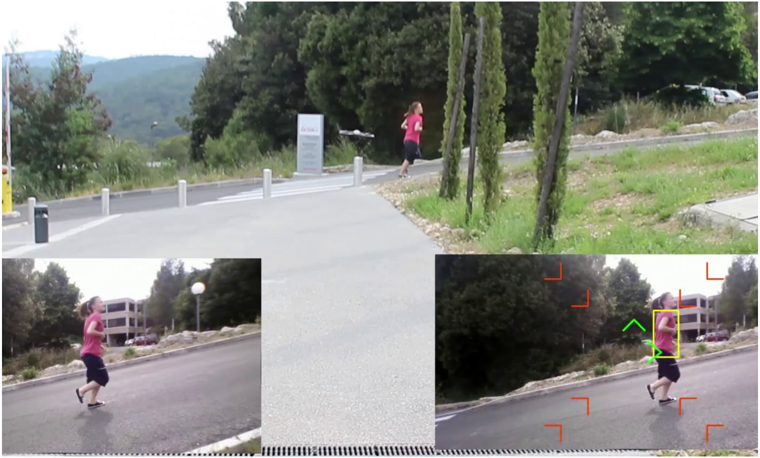




TELECOM ParisTech

People Following (Cont.)

People Following Movie



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

Outline

Conclusion and Future Work

Achievements

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

Future work

- Finishing the (new) platform
  - Integration into more powerful UAVs
- Integrate more complex sensors (e.g., lidars, Groud Penetrating Radar, . . .)

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.
- Ludovic Apvrille, Tullio J. Tanzi and Jean-Luc Dugelay, "Autonomous Drones for Assisting Rescue Services within the context of Natural Disasters". Proceedings of the XXXIst General Assembly and Scientific Symposium (GASS) of the International Union of Radio Science (Internation Union on Radio Science). August 17-23, 2014, Beijing, China.
- 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.