La robotique mobile au service du monitoring de l'environnement

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Research objectives at GeorgiaTech Lorraine

DREAM

Data-driven **R**obotics for **E**nvironment **A**ssessment and **M**apping (or **M**onitoring).

Key objectives

- Environment mapping and assessment where change happens over a wide spectrum of temporal scales: from seconds to months.
- From long-term autonomy towards autonomous monitoring.

Motivation: Applications

Industrial

- Industrial Inspection (e.g. bridges, power plants).
- Asset Monitoring (e.g. parking).
- Quality Control.

Environmental & Resource Management

- Capturing the spatiotemporal dynamic of ecosystems.
- Quality monitoring for resource management (water, forestry, ...).
- Autonomous Space Exploration

Challenges

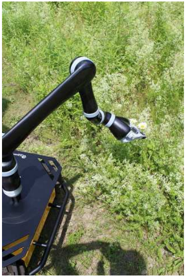
From mapping to spatiotemporal mapping

- How to merge, represent, exploit spatiotemporal maps?
- How to identify salient event?
- How to create summaries?
- How to learn from outliers?
- How to deal with the volume of data?

Exploiting robotics

- How to take best advantage of mobility?
- How to plan maximally informative path using spatiotemporal maps?
- How to realize scientifically significant observations?

Application: Precision Farming



From Husky & Jaco2 (R&D) to Bonirob (Bosch/DeepField)

- Supported by EU H2020 Project Flourish (Started April 1st, 2015).
- Mobile manipulation towards mechanical weeding
- Precise spraying

Application: Lake-shore Monitoring

Motivation

- Reliable ready-to-go, professional platform (PTZ camera & LRF).
- Simple, flat, closed environment for localization and navigation.
- Rich and challenging environment for perception.

Outline

Challenges

1 of 4: Moving sensor in a natural environment

From S. Eddins, Matlab Image Processing Toolbox

From Pattern Recognition and Image Processing Group, VUT

Challenges

2 of 4: Variation of Appearance in Natural Environments

From Churchill and Newman, 2013

Challenges

3 of 4: Navigation among other “intelligent” agents

Ducks

Swan

Challenges

4 of 4: Noise, uncertainty and incompleteness

Dirty Camera Dome ▶

Sun glare ▶

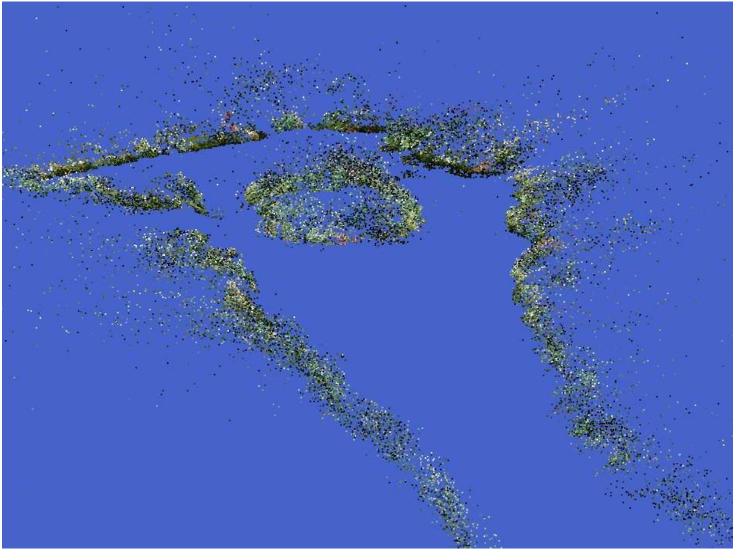
Non-smooth motion ▶

Seeds and pollen ▶

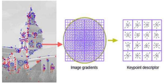
Initial Question

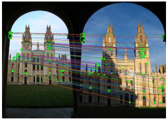
Is there a more stable characteristic of outdoor environment we can use as a starting place towards a full spatio-temporal model?

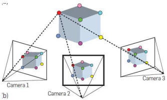
The Geometry of the Lakeshore

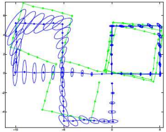


The Standard Visual SLAM Pipeline



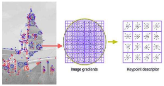


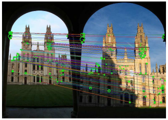


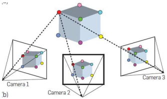


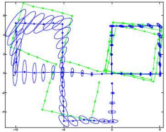
Feature Extraction →	Feature Matching →	Triangulation →	Optimization
SIFT	Epipolar constraints	Hartley & Sturm	iSAM2
SURF	RANSAC	Kneip *et al.*	iLBA
BRISK	...	...	Ceres
BRIEF			ASLAM

Our Visual SLAM Pipeline





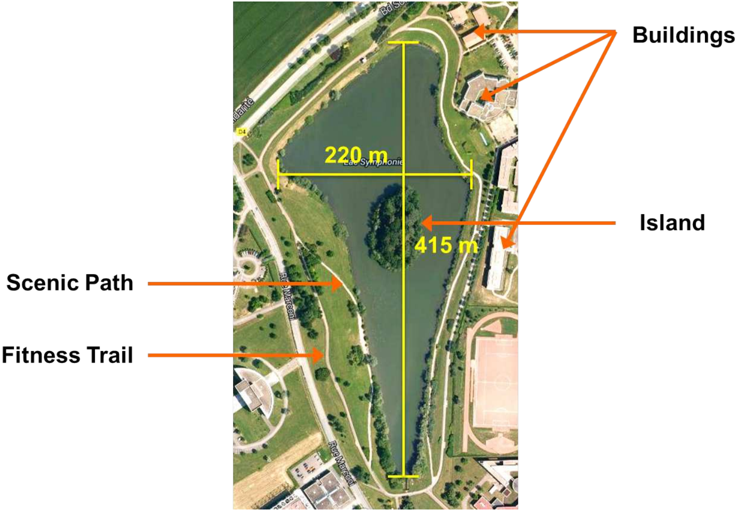




Feature Extraction → **Feature Matching** → **Triangulation** → **Optimization**

Feature Extraction	Feature Matching	Triangulation	Optimization
Lucas-Kanade	Epipolar constraints RANSAC	Hartley & Sturm	iSAM2 Smart Factors

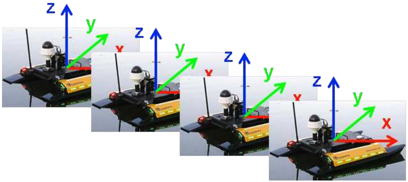
Lac Symphonie



Kingfisher from Clearpath-Robotics

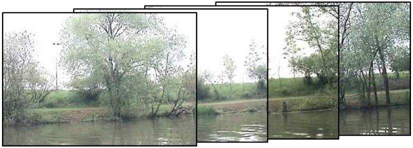
Data Collection

Boat Poses



- Position from GPS
- Orientation from IMU/Compass
- Approx. constant speed: 0.5m/s

Images



- 704 x 480 color images
- 10 FPS
- Light JPEG compression

Example of the autonomous monitoring route

Camera's Point of View

Natural Scene Variation Across Surveys

Natural Scene Variation Across Surveys

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Comprehensive Dataset

100 surveys collected since Aug. 18th, 2013
4,000,000+ images
Every second week in average

Optimized 3D feature positions

Based on the output of the KLT tracker & V-SLAM (iSAM2)

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Current work: inter-survey alignment

Examples of changes

Examples of changes

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Outline

Project Flourish

H2020 Project - ICT-2014

Aerial Data Collection and Analysis, and Automated Ground Intervention
for Precision Farming.
Started April 2015.

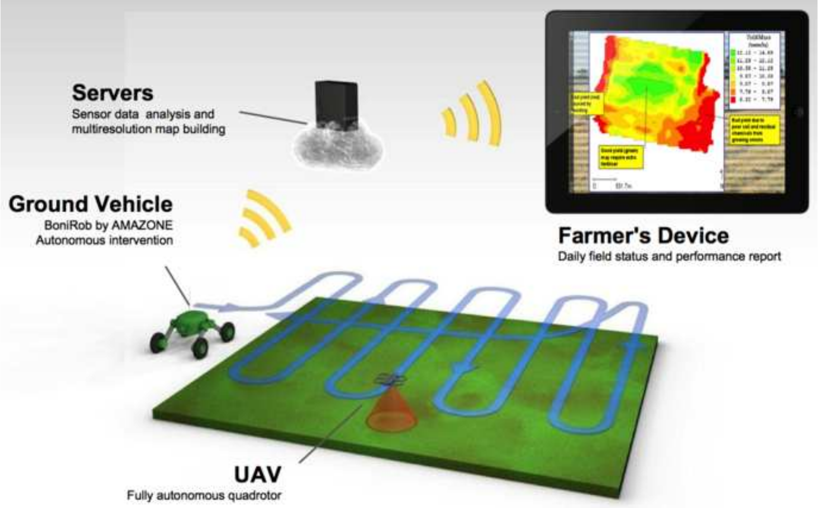
Project Flourish

H2020 Project - ICT-2014

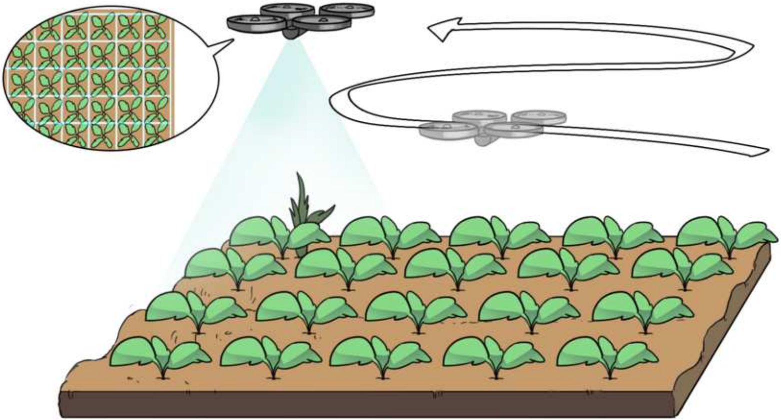
- Coordinator: ETH Zürich
- Acad. Partners: University of Bonn, Fribourg, La Sapienza (Roma), CNRS UMI 2958 GT-CNRS
- Industrial Partner: Robert Bosch GmbH, ASSAM (Agency for the Agriculture Sector of the Marche region, Italy)

Aerial Data Collection and Analysis, and Automated Ground Intervention for Precision Farming.
Started April 2015.

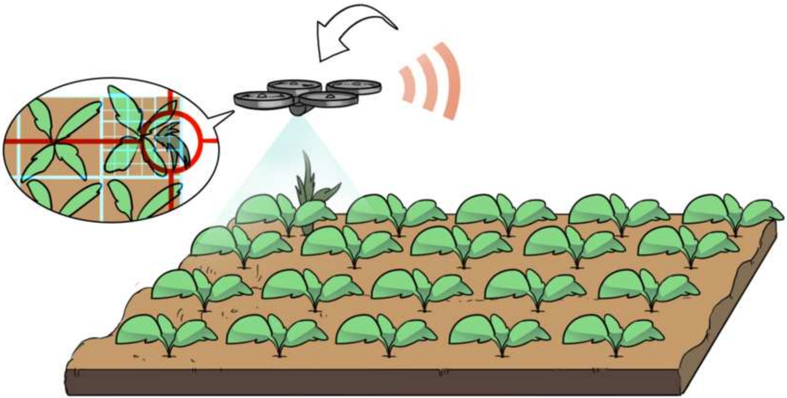
Concept


Servers
Sensor data analysis and multiresolution map building
Ground Vehicle
BoniRob by AMAZONE
Autonomous intervention
Farmer's Device
Daily field status and performance report
UAV
Fully autonomous quadrotor

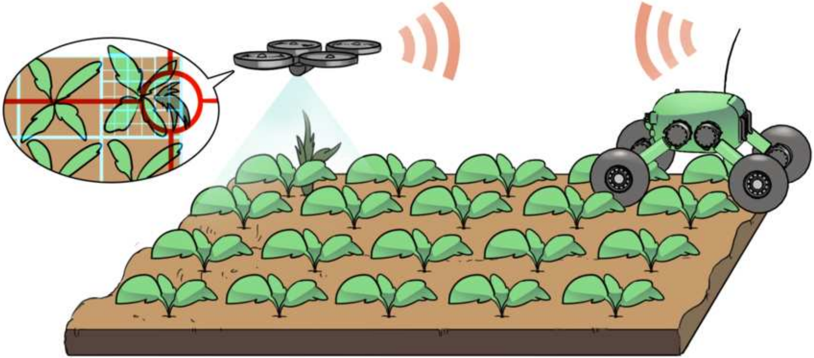
Scenario 1/6: large scale aerial observation



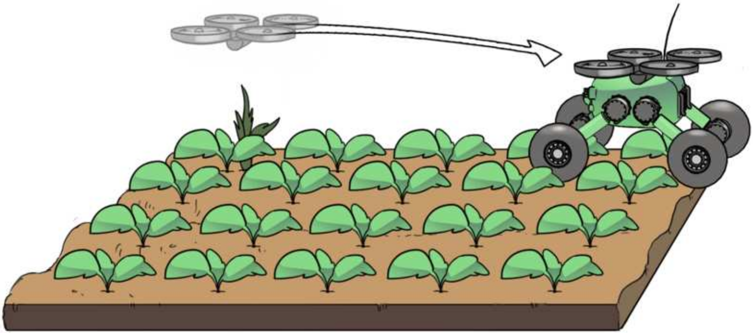
Scenario 2/6: detection of weeds or crop needs



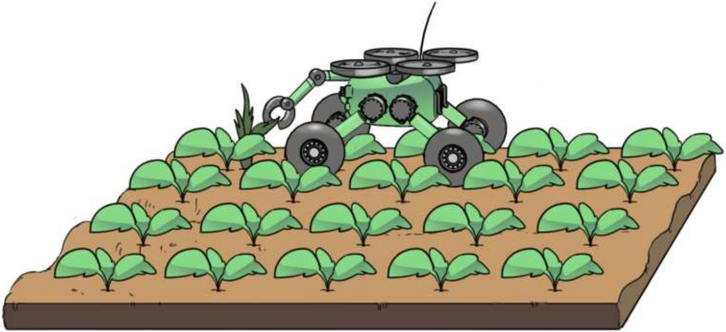
Scenario 3/6: communication of the target



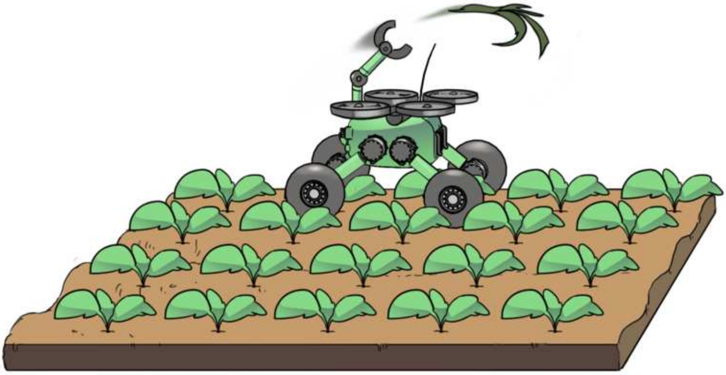
Scenario 4/6: Docking of the UAV on the UGV



Scenario 5/6: mechanical weed removal



Scenario 6/6: mechanical weed removal



Organic Weeding

Platform: DeepField Robotics (Bosch)

Platform: UMI 2958 GT-CNRS

Task: Precise Ground Intervention

Task Objective

- Develop the software tools required for the precise operation of the ground intervention while mobile platform is still driving.

Challenges

- Coordinate mobile platform and manipulator to achieve high precision motion
- Maintain high precision in off-road environment

Our work to date

- Coordinate the motion of mobile platform and manipulator to achieve high-precision high-reliability motion

System Modeling

Issues

- Dynamics v.s. Kinematics
- Separated or combined modeling

Kinematic Model of Mobile Manipulator [1]

$$\begin{aligned}\dot{r} = J(q)\dot{q} &= \begin{pmatrix} J_b(q) & J_a(q) \end{pmatrix} \begin{pmatrix} \dot{q}_b \\ \dot{q}_a \end{pmatrix} \\ &= \begin{pmatrix} J_b(q) & J_a(q) \end{pmatrix} \begin{pmatrix} G(q)\eta_b \\ \eta_a \end{pmatrix} \\ &= \begin{pmatrix} J_b(q)G(q) & J_a(q) \end{pmatrix} \begin{pmatrix} \eta_b \\ \eta_a \end{pmatrix} = J_n(q)\eta\end{aligned}$$

Kinematic Controller

Mathematical Expression

$$\eta = J_n(q)^{+}\dot{r}^{d} + (I - J_n(q)^{+}J_n(q))\eta_n$$

$$\eta_n = \sum_{i=1}^{n} \alpha_i \nabla_q H_i(q)$$

Explanation

- Task-space (Cartesian-space) controller
- Null-space (Optimization) controller

Redundancy Resolution

Advantages v.s Disadvantages

- (+) Avoid singularity
- (+) Deal with task constraints and requirements
- (−) Increase the system complexity and computational load

Online Multi-objective Optimization

- manipulability Index
- Joint limit avoidance, Turning constraint, ...
- Other task-oriented objective function

Platform: UMI 2958 GT-CNRS

Conclusion on Flourish

The next stages

- Integration of ML-based weed detection
- Real-time weed tracking while driving
- Predictive and integrated actuation

Role of Monitoring

- High-level field overview
- Scene interpretation
- Change detection
- Decision assistance

Outline

Robotics for Environment Monitoring

Robotics for Agriculture: the Flourish Project

Conclusion

Conclusion

Monitoring for Natural Environments

- Very hard perceptual challenges
- Vision alone is unlikely to be sufficient
- Surprisingly few academic works in natural environments

Integration with Mobility

- To date: mostly repetitive monitoring path
- Future: multi-robot multi-scale monitoring, reaction to changes, remediation...

Thank you for your attention

References

Alessandro De Luca, Giuseppe Oriolo, and Paolo Robuffo Giordano.
Kinematic modeling and redundancy resolution for nonholonomic mobile manipulators.
In *Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on*, pages 1867–1873. IEEE, 2006.