Teleoperated Visual Inspection and Surveillance with Unmanned Ground and Aerial Vehicles

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Outline

- Motivation
- Plattform
- Teleoperated Robot Control
- Vision System
  - Human visual attention
- Quadrotor
- Conclusion
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Research Questions

Finding a principle approach to building up and maintaining situation awareness including attention
(Spatio-temporal models, observation models)

Mobile Robots
- Computer Vision
- 6DoF (P)SLAM
- Robot Cognition
- .....
Applications benefiting from the research questions

- USAR (Urban Search and Rescue)
- Education
- Service Robots
- Entertainment
- Production
- …
Google street view
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Plattform (VolksBot® RT, ground vehicle)

- VolksBot is a robust construction-kit
- Scalable variants by use of common components (hardware and software)
- High payload (40kg)
- Extendable
- Several variants e.g. with a fuel cell or under water
- 2x150 W motors, VMC, 2 x MacMinis (2GHz)
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Tele-operated Robot Control (OCU)

- general purpose computer
- Always available
- High social acceptance and limited teaching
- Man pack able, light weight, small
- long runtime / operation time
- robust and substitutable

New: Configuration / and or control client loaded directly from the robot (Business Card)
Outline

- Motivation
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- Teleoperated Robot Control
- **Vision System**
  - Human visual attention
- Quadrotor
- Conclusion
Vision system, add on Sensors

- OmniVision, SphereCam
  - firewire: 1300x1000
  - 11xUSB 2.0: 1600x1200

- 3D laser scanner

- Control computer (MacMini)

- Motor Controller

- Docking Station

- Bumper, IR, Ultrasonic
Vision System

Alternative (real-time questionable):
- Sift
- Surf
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Simulation of human visual attention

Computermodell:

Research:

[Koch, Ullman: Human Neurobiology 1985]
[Tsotsos: Early Vision and Beyond, 1995]
[Itti, Koch, Niebur: PAMI 1998]
[Backer, Mertsching: PAMI 2001]
[Sun, Fisher: AI 2003]
[Navalpakkam, Rebesco, Itti: Vision Research 2005]
[Hamker: CVIU 2005]
Example: Vocus (Visual Object detection with a Computational attention System)

VOCUS
(New: separate Feature Maps, real-time implementation)

NVT combined Feature Maps)

Details in: Frintrop, Nüchter, Surmann: „Visual Attention for Object Recognition in Spatial 3D data“, in WAPCV' 04

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Mikrokopter (Aerial Vehicle)

VTOL construction kit:  Size: 650x650x220mm
Weight: 590g
Architecture of the Quadrotor

- 20MHz Atmel
- Payload 350g
- op.time 20 min.
- 2100 mAh battery
- WiFi, bluetooth radio link
- I²C bus
Saliency based Visual Attention for Tracking Unmaned Aerial Vehicles

D. Holz, S. May, H. Surmann, T. Linder, S. Blumenthal, P. Molitor and V. Tretyakov

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Most attentive object is marked with a red square.
Conclusion

- Ground Vehicle (VolksBot)
- Aerial Vehicle (Mikrokopter)
- Teleoperation
- Vision system (Vocus)
- Quadroter
www.volksbot.de

Thank you for your attention!

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Simulation of visual attention

VOCUS: Bottom-up Mode

Saliency map

Find max

Focus of Attention

Compute next focus

Input image

Intensity Color Orientation

Saliency based Visual Attention for Tracking Unmanned Aerial Vehicles

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Extended the work from om Itti et al:

Itti, Koch, Niebur: „A model of saliency-based visual attention for rapid scene analysis“, in PAMI ’98

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Top-down Attention

Goal object is marked with a red square.

Bottom-up saliency map

Most salient region in rectangle

Weights

Training image

Intensity  Color  Orientation

Int on-off: 0.0
Int off-on: 6.9

Ori 0°: 1.9
Ori 45°: 2.9
Ori 90°: 2.6
Ori 135°: 3.3

Col green: 0.6
Col blue: 8.0
Col red: 1.8
Col yellow: 0.1
Simulation of visual attention

Top down search

- **Compute next region**
- **Find max**
- **Global Saliency map $S$**

- **Excitation map $E$**
- **Inhibition map $I$**

- **Uniqueness weight $w$**

- **Intensity**
- **Color**
- **Orientation**

- **Bottom-up saliency map**
- **Top-down saliency map**

- **E: if ($w_i > 1$): Map * $w_i$**
- **I: if ($w_i < 1$): Map * ($1/w_i$)**

- **Focus of Attention**

- **Weights**

- **Test image**

- **Fraunhofer**
Simulation visueller Aufmerksamkeit

Bottom-up Mode

Top-down Mode:
Suche Schlüsselanhänger
Multisensorielle und multimodale Objekterkennung

- **Redundanz** durch Verwendung von 2D- und 3D-Daten: Kamerabild, Remissionsbild oder Tiefenbild
- **Komplementarität** durch Ausnutzung von Sensormodalitäten
- **Sehr schnelle** (20 ms) **Erkennung** mit adaptiertem Viola-Jones-Klassifikator (auch andere Klassifikatoren möglich, z.B. SIFT)
Docking station

• Infinit operation time

• Navigation based on leading light (2 LEDs and a camera)
More Sensors

- **Mini-3D-Scanner (Hokuyo) (CSEM)**
- **3D-Kamera Swiss Ranger**

- **Infrared camera (FLIR)**

Institute for the Analysis and Decision Support Systems (IAIS)
A module library for mobile robotics

- CAN Module
- ODE Simulator Module
- Generic Joystick Module
- Matlab Module
- Color-Vision Modules
- OpenCV Modules
- Tracking Modules
- DD-Behavior Modules
- CORBA Server Module
- Neuro-Controller Module
- RoboCup MSL Modules
- …
ProfiBot-Basismodell
ProfiBot-Module
Application of 3D sensor systems

- Environment recognition and Obstacle avoidance
- Mapping (2D, 3D)
- Surveying
- Object detection

Outlook:
- Recognition of Object function
- Mobile object manipulation
3D-Laserscanner

Voxel colored with Laser remission values
Publication (partly)

- S. Frintrop, E. Rome, A. Nüchter, & H. Surmann: A Bimodal Laser-Based Attention System. Computer Vision and Image Understanding (CVIU), vol. 100, no. 1-2, pp. 124–151. Special Issue on Attention and Performance in Computer Vision.
- K. Lingemann, H. Surmann, A. Nüchter, & J. Hertzberg. High-Speed Laser Localization for Mobile Robots, Robotics and Autonomous Systems, 4(51), pp. 229–316, June 2005
- A. Nüchter, K. Lingemann, J. Hertzberg, and H. Surmann. Accurate Object Localization in 3D Laser Range Scans, in Proc. 12th International Conference on Advanced Robotics (ICAR '05), pp. 665–672
- S. Mitri, S. Frintrop, K. Pervölz, H. Surmann, & A. Nüchter. Robust Object Detection at Regions of Interest with an Application in Ball Recognition, in Proc. IEEE 2005 Int'l Conf. Robotics and Automation (ICRA '05), pp. 126–131
- L. Paletta, E. Rome & H. Buxton. Attention Architectures for Machine Vision and Mobile Robots, In: Neurobiology of Attention (Encyclopedic Volume), L. Itti, G. Rees and J.K. Tsotsos (Eds), Academic Press/Elsevier, pp. 642–648, 2004
- A. Nüchter, K. Lingemann, J. Hertzberg, H. Surmann, K. Pervölz, M. Hennig, K. R. Tiruchinapalli, R. Worst, & Th. Christaller. Mapping of Rescue Environments with Kurt3D, in Proc. SSRR '05, pp. 158–163
- I. Stratmann & E. Solda. Omnidirectional Vision and Inertial Clues for Robot Navigation, Journal Robotic Systems, 1(21), January 2004, pp. 33–39
- S. Frintrop, Andreas Nüchter, H. Surmann, & J. Hertzberg. Saliency-based Object Recognition in 3D Data, in Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'04), pp. 2167–2172
- S. Frintrop, A. Nüchter & H. Surmann. Visual Attention for Object Recognition in Spatial 3D Data, in Proc. 2nd Int'l WS on Attention and Performance in Computational Vision (WAPCV 2004), Paletta, L., Tsotsos, J.K., Rome, E., & Humphreys, G. (Eds), Joanneum Research, Graz, pp. 75–82
- V. Becanovic, T. Günther and A. Bredenfeld, Modelling of Neuromorphic Vision Sensors in ODE, IEEE ICRA '05