Multidisciplinary research as a contribution to the creation of a common European research and innovation area: the experience of the Institute of Automation, University of Bremen

Round Table Meeting “Some aspects of the improvement of higher education in Serbia”, Niš, 26 February 2014

Robotics in the focus of the presentation

- Because it is one of the main research areas of the Institute of Automation
- Because of the necessity for multidisciplinary and international robotics research to achieve European leader position
- Because of the necessity for tight interaction between research and innovation, research and industry
- Because of necessity for Serbian university research institutions to participate in international projects to cooperate with industry from developed industrial countries
Robots...
...in structured environment

- In industrial applications robots do what they are programmed to do – though they have no understanding of what they do or why

- In a structured environment this approach works well

Robots...
...in unstructured environment

- In real-world settings environments can be too nuanced, too complicated and too unpredictable to be summarized within a limited set of specifications

- Robots have to sense and understand environment and to adapt to sensed changes in environment
Human-robot interaction

- From industrial applications to all fields of human everyday life
- Person following robots
  - domestic robots
  - military robots
  - exploratory
- Symbiotic human-robot relationship
  - robot senses and understand behavior and intention of humans
  - robot reasons how to react so to adapt to sensed dynamical changes in human behaviour
- The solution is in Cognitive Robotics!

Cognitive robotics

- Multidisciplinary science with a tight integration between mechanics, electronics, control, and software development for its engineering aspects, and also includes cognitive and medical sciences.
Projects supported by European Commission

- ICT Challenge 2: Cognitive Systems and Robotics

EU FP7 ICT Cognitive Systems Large-Scale Integrating Project

- Area: Cognitive Systems and Robotics (ICT-2009.2.1)
- Project reference: 270219
- Total cost: 8.76 million euro; EU contribution: 6.1 million euro
- Project start: 1st February 2011; Duration: 48 months
- Consortium: 11 participants from 6 European countries
CORBYS - Objective

- To design, develop and validate an integrated cognitive robot control architecture to support robot-human co-working with high level cognitive capabilities such as situation-awareness, attention control and goal-setting prioritization.
- Specifically, capability for optimal time-critical control:
  - in take-over/hand-over of goal-setting initiative between robot and external agent
  - based on anticipation of purposeful behaviour of an external agent
- CORBYS control architecture will be validated within two challenging demonstrators:
  - a novel mobile robot-assisted gait rehabilitation system
  - an existing autonomous robotic system for investigation of hazardous environment

CORBYS Demonstrators

- Cognitive mobile robotic gait-rehabilitation system to be developed in CORBYS
  - Combination of a mobile platform and powered orthosis that is attached to the mobile platform
  - Integrates CORBYS cognitive modules
  - Advanced multi-sensor system
  - Adapts to requirements and abilities of the user

- Cognitive robotic follower
  - Follows human co-worker in investigation of environment
  - Preliminary integration of cognitive modules in CORBYS architecture
  - Here: empowerment based robotic (blue) following of human (green)
**Scientific and Technical Objectives**

CORBYS will extend State-of-the-Art in the following fields:

- Sensing systems for assessing dynamic robot environments including humans
- Self-awareness as a basis for adaptation of robot behaviour
- Anticipation in the context of a human-robot synergy
- Cognitive robot control
- Cognitive mobile robot-assisted gait rehabilitation

**CORBYS cognitive mobile gait rehabilitation system**

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Joint/Axis</th>
<th>Actuation</th>
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</thead>
<tbody>
<tr>
<td><strong>Mobile Platform</strong></td>
<td></td>
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<tr>
<td>Wheel 1..4</td>
<td>(x-axis)</td>
<td>Driving wheels</td>
</tr>
<tr>
<td>Steering 1..4</td>
<td></td>
<td>Wheel orientation</td>
</tr>
<tr>
<td><strong>Linear unit</strong></td>
<td>2-axis</td>
<td>Linear motion to lift or lower patients body</td>
</tr>
<tr>
<td></td>
<td>y-axis</td>
<td>Linear motion to move body sideways</td>
</tr>
<tr>
<td><strong>Powered orthosis</strong></td>
<td>Hip</td>
<td>Active extension and flexion</td>
</tr>
<tr>
<td>Left and right legs</td>
<td>Hip</td>
<td>Passive adduction/abduction</td>
</tr>
<tr>
<td></td>
<td>Hip</td>
<td>Passive i./e. rotation</td>
</tr>
<tr>
<td></td>
<td>Knee</td>
<td>Active extension and flexion</td>
</tr>
<tr>
<td></td>
<td>Ankle</td>
<td>Active plantarflexion and dorsiflexion</td>
</tr>
<tr>
<td></td>
<td>Ankle</td>
<td>Passive eversion and inversion</td>
</tr>
</tbody>
</table>

**CORBYS**
**CORBYS cognitive mobile gait rehabilitation system**

**Operating modes**

- **Learning**
  - treadmill-based walking
  - system learns native gait
  - system learns therapist assisted gait

- **Corrective (straight walk mode)**
  - over ground walking
  - system provides inputs for corrective actuation

- **Parameter based adaptation**
  (1st extension of straight walk mode)
  - Cognitive interaction between man and machine: detection of patient’s intention to stop or to speed up
  - system provides inputs for corrective pattern based on detection

- **Adaptive walking**
  (2nd extension of straight walk mode)
  - Cognitive interaction between man and machine: recognition of patient’s intended movement
  - system provides inputs for parameter-based, intra-cycle adaptation
CORBYS cognitive mobile gait rehabilitation system

Operating modes

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### Sensor supported gait learning

**Human body wearable sensors**: encoders, force sensors

**System sensors**: encoders, force sensors

- **SAWBB-situation assessment**
- **SOIAA (anticipation)-gait trajectory generation**
- **Gait pattern**
- **Assistance level**
- **Real-time robot control**

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<table>
<thead>
<tr>
<th>Partner</th>
<th>Role in the project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>University of Bremen</strong>, Germany</td>
<td>Project Coordinator, Cognitive robot control architecture, BCI detection of cognitive processes</td>
</tr>
<tr>
<td><strong>The University of Reading</strong>, United Kingdom</td>
<td>Situation Assessment Architecture, Evaluation methodology, benchmarking, metrics and procedures, Requirement engineering</td>
</tr>
<tr>
<td><strong>University Rehabilitation Institute</strong>, Slovenia</td>
<td>Evaluation, clinical tests of subsystems and components, System integration</td>
</tr>
<tr>
<td><strong>The University of Hertfordshire</strong>, United Kingdom</td>
<td>Self-Organizing Informational Anticipatory Architecture, anticipation of human behaviour and the creation of synergy with this behaviour</td>
</tr>
<tr>
<td><strong>Vrije University Brussels</strong>, Belgium</td>
<td>Low-level robot control, System integration</td>
</tr>
<tr>
<td><strong>Sintef</strong>, Norway</td>
<td>System integration and functional testing, Sensor network, Physiological monitoring</td>
</tr>
<tr>
<td><strong>Otto Bock Mobility Solutions</strong>, Germany</td>
<td>Demonstrator development, design and development of the mobile platform of the CORBYS robot-assisted gait rehabilitation system</td>
</tr>
<tr>
<td><strong>Neurological Rehabilitation Center</strong>, FriedeHors, Germany</td>
<td>Evaluation, End-user requirements and ethical aspects</td>
</tr>
<tr>
<td><strong>Bi&amp;Brain Technologies SL</strong>, Spain</td>
<td>Sensing systems for assessing dynamic system environments including humans, Brain computer softwares architecture</td>
</tr>
<tr>
<td><strong>SCHUNK</strong>, Germany</td>
<td>Design and integration of actuation system, smart and safe actuators, Sub-system conformance testing</td>
</tr>
<tr>
<td><strong>Otto Bock Healthcare</strong>, Germany</td>
<td>Design and development of the orthotic system of the CORBYS robot-assisted gait rehabilitation system, Demonstration, integration and evaluation</td>
</tr>
</tbody>
</table>
CORBYS project overview

Consortium:
- 11 partner institutions from 6 European countries
- 4 universities, 5 industrial partners and 2 rehabilitation institute

EU project CORBYS vs. BMBF project MOPASS

Cognitive mobile gait rehabilitation system
- EU contribution: 6.1 million euro
- Duration: 01.02.2011 - 31.01.2015
- Consortium: 11 participants from 6 European countries: 4 University, 5 industrial partners and 2 clinical partners

Adaptive mobile gait rehabilitation system
- Contribution of German Federal Ministry of Education and Research (BMBF): 754,895 EUR
- Duration: 01.02.2012 - 31.01.2015
- Consortium: 5 participants from Germany: 1 University, 2 industrial partners and 2 clinical partners
Want are the benefits of participating in EU projects?

- State-of-the-art research
- Transparency in robotics community
- Cooperation with experts Europe wide
- Funds for research infrastructure
- Funds for PhD positions

Robotics in FP7

Portfolio of >100 projects, ~500 M€ funding
Robotics in HORIZON 2020

- Develop strategic goals of European robotics and foster their implementation
- Improve industrial competitiveness of EU through innovative robotic technologies
- Position robotics as a key enabler for solving Europe’s societal challenges
- Strengthen networking activities of the European robotics community
- Promote European robotics
- Reach out to new users and markets
- Contribute to policy development and addressing ethical, legal and societal issues

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<table>
<thead>
<tr>
<th>LEIT CHALLENGE 5: ROBOTICS</th>
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<tbody>
<tr>
<td>Roadmap-based R&amp;D&amp;I in Robotics</td>
<td>€74m</td>
</tr>
<tr>
<td>Publication: 11 December 2013</td>
<td></td>
</tr>
<tr>
<td>Submission deadline: 23 April 2014</td>
<td></td>
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</tbody>
</table>

| ICT23.a - Research and Innovation Action | |
| PRIORITY: Market domains: manufacturing, commercial, civil, agriculture | €57m |
| RTD to advance key technologies relevant for industrial and service robotics, including shared resources and assessment | |

| ICT23.b - Technology transfer - Robotics use cases | |
| Industrial and service sectors | €12m |

<p>| ICT23.c - Pre-commercial procurement in robotics | |
| Public safety and monitoring of environment and infrastructure | €5m |</p>
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<tbody>
<tr>
<td>Roadmap-based R&amp;D&amp;I in Robotics - second Call</td>
<td>C83m</td>
</tr>
<tr>
<td>Publication: 15 October 2014 (TBC)</td>
<td></td>
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<tr>
<td>Deadline: 21 April 2015 (TBC)</td>
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<tr>
<td>ICT24.a - PRIORITY: healthcare, consumer, transport RTD to advance key technologies relevant for industrial and service robotics</td>
<td>C50m</td>
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<tr>
<td>ICT24.b - Technology transfer - Industry-academia cross-fertilisation</td>
<td>C12m</td>
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<tr>
<td>ICT24.c - Technology transfer - Robotics use cases</td>
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<td>ICT24.d - Pre-commercial procurement in robotics: healthcare</td>
<td>C5m</td>
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<tr>
<td>ICT24.e - Community building and Robotic competitions</td>
<td>C4m</td>
</tr>
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</table>

**Hvala na pažnji**
**CORBYS architecture overview**

- **Task Manager (TM):**
  - Based on state-machine
  - Coordinates transitions between working modes:
    - Verifies if preconditions are met
    - Takes care that modules start operating in the required order
    - Enables the desired working mode when all modules are ready
  - Changes system parameters based on user requests over GUI

- **Functionality Supervisor (FS):**
  - Observes the status of all modules, computers and the GPN:
    - Receives regularly heart-beats from all modules
    - Lack of heart-beat indicates problems with specific module or with the GPN
    - Observes if messages sent between modules are delivered properly and on time
    - Observes clock synchronization of computers
    - Measures transmission latencies between modules
  - Regularly sends brief status messages to TM
  - Triggers emergency stop if critical fault was detected

**CORBYS Module Template:**
- Communication API – responsible for general communication with other modules
- FS & TM – Responsible for sending heart-beats and receiving module configurations
- Node Logic – Implements the individual module-specific functionality

**Advantages:**
- Standardized module design
- Communication status can be easily observed
- Easy to add/improve common functionality

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**CORBYS software architecture design**

**Architecture overview-ROS based communication**

**CORBYS Module Template:**
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Test stand set-up for CORBYS control architecture – Learning mode

SOIAA Learning

gait dynamics

relationship between actuation and sensors

CORBYS cognitive control

- CORBYS cognitive modules will interpret the intention of the patient and his/her physical and psychological state and from these create appropriate commands for low-level robot control, **gait pattern and level of assistance**.

- The cognitive modules are supported by an advanced multi-sensor system consisting of physiological wearable sensors and EEG sensors for perception of the physical and psychological state of the patient.

- Through the cognitive robot control, the CORBYS gait rehabilitation system will be a **situationally-aware system capable of learning and reasoning to optimally match the requirements of the patient at different stages of rehabilitation in a range of gait disorders**.

Thank you for your attention!