MINDWALKER:
A Brain Controlled Lower Limbs Exoskeleton for Rehabilitation.
Potential Applications to Space.

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MINDWALKER Overview

• 3 years long (2010-2012) research project funded by the European Union (FP7 Accessible and Inclusive ICT)

• 2.75 MEUR funding

• 7 partners: Space Applications Services (Coordinator), Univ. Libre de Bruxelles, Santa Lucia Foundation, Univ. of Twente, Technical Univ. of Delft, eemagine, Ossur

• Addresses the lack of mobility of people having Spinal Cord Injury (SCI) condition
Research Topics and Work Plan

- BNCI technologies
  - EMG
  - EEG

- DRNN

- Orthosis commands

- Virtual Reality Simulation for Training

- Exoskeleton Structure and Control
Research Topics and Work Plan

• Large User Requirements baseline, with early involvement of:
  1. Over 40 Spinal Cord Injured (SCI) patients
  2. Over 15 medical staff in rehabilitation: MD, therapists, care givers, etc.

• Multiple steps integration: M12, M18, M24, M27, M33

• Clinical evaluation with SCI patients and medical staff
  • Will take place from M27 to M36, to Santa Lucia Foundation, Rome, Italy
  • After formal ethical review and acknowledgment by Italian “Istituto Superiore di Sanita”.
Subsystems Challenges and Approach
Objective: developing a convenient EEG cap that patients could wear in their every day life.
Dry EEG Cap

• **Challenge**: most usual EEG caps are not convenient for every day use…

Up to 256 channels…
Dry EEG Cap

- **Approach**: dry electrodes, lightweight EEG cap
  - No need for wet gel – multipin electrodes, trying different types of alloys and coating (gold, titanium, etc.)
  - Embedded signal amplification stage

Early prototype
BNCl Processing Chain

Objective: mapping brain signal to lower limbs kinematic control signal – non invasive manner…
BNCI Processing Chain

• **Challenge**: BNCI traditional approaches rely on Evoked Potentials (EP), e.g. “P300” approach:

(speed 2x)

Credit: N. Waytowich and G. Johnson, Old Dominion University
BNCl Processing Chain

• **Challenge**: mapping brain signals to kinematic control signal?
  => demonstrated with invasive interfaces so far:

Credit: Motorlab, Pittsburgh University
BNCl Processing Chain

• **Approach:**
  - Non-invasive, EEG based
  - Mathematical tools for spatial and temporal filtering (EEG signal is very noisy…)
  - Identifying promising patterns in EEG of walking subjects (number of neuroscience related experiments)
  - Development of a “translation engine”: Dynamic Recurrent Neural Network (DRNN).
  - Returns hips + knees + ankles angles from (filtered) EEG fed signal

• **Arms EMG:** backup option investigated in parallel (as a feed to the DRNN)
Objective: to develop a prototype of a lower limbs exoskeleton (and its controller) allowing dynamical balance while walking
Lower Limbs Exoskeleton

- **Challenge:** safe, crutch-less mobile structure supporting the weight of an adult being
Lower Limbs Exoskeleton

• **Approach:**
  - Novel lower limbs exoskeleton mechanical structure and actuators
  - Low level controller
    - limit cycle walking approach +
    - model predictive control
    - ensures dynamic balance of the system (exo + human being)
  - High level controller
    - “supervisory” controller
    - local environment digital elevation map (exteroceptive sensors)
    - navigation model

Early prototype CAD
VR Training Environment

Objective: develop VR based tools that are effective at stimulating and training patients
VR Training Environment

**Challenge:** what VR stimuli / combination of stimuli may effectively trick a patient in generating brain signals similar to those produced for walking…?

**Approach:**
- Supporting BNCI scientists experiments with VR setups, to identify relevant stimuli types and protocols
- Baseline setup:
  - 3D visual feedback,
  - Kinect based torso / head / arm tracking,
  - Complementary vestibular stimulation with actuated seat
Project Status

• Lower limbs exoskeleton hardware procurement and assembly ongoing – assembled prototype to be ready by June 2011.

• Control software experimented with the Univ. Twente LOPES setup

• Experiments for EEG-to-kinematics control on their way – integration of related outcomes by the fall 2011.

• Dry EEG cap early prototype to be made available in the project by June.

• VR training environment and setup under development – early prototype to be released by June 2011.

Next milestone: M18 integration step (end of June): “early integrated prototype”
Potential Applications to Space
Although primarily for rehabilitation oriented applications, MINDWALKER technologies are relevant in other domains, including in particular space:

=> Astronauts health condition mitigation

=> Robotic platforms control
Astronauts Health Condition Mitigation

Return to Earth / after-landing condition mitigation
• Health condition: difficulty to stand up, loss of balance, risk of fainting.

MINDWALKER technologies:
• Lower limbs exoskeleton for walk with safe balance keeping
• + possibly EEG-BNCI (though EMG may be considered instead)
Astronauts Health Condition Mitigation

Microgravity related health deconditioning countermeasure

• Health condition: bones deconditioning, muscles atrophy

MINDWALKER technologies:

• Lower limbs exoskeleton as a mean to exercise bones and muscles (simulating gravity conditions)
• Immersive VR environment with visual feedback and (possibly) vestibular feedback
Robotic Platforms Control

EEG based dexterous manipulation

• Setup: on-orbit astronaut operation of a robotic arm (EVA or IVA)

MINDWALKER technologies

• EEG-BNCI to kinematics control
• Dry EEG cap
• Immersive 3D visual feedback
Mobile robotic planetary exploration with telepresence

- Setup: Teleoperation of a mobile planetary robotic platform (rover or bi-pedal platform), from e.g. an orbiting spacecraft or a planetary outpost.

MINDWALKER technologies

- EEG-BNCI to locomotion and manipulation control,
- Dry EEG cap
- Immersive VR (telepresence feeling)
Conclusion

• MINDWALKER is a FP7 EU funded project that investigates the use of BNCI technologies for lower limbs exoskeleton control

• Lower limbs exoskeleton for rehabilitation is a hot research topic (competition)

• EEG BNCI control for robotic devices is a hot research topic too… Promising and is worth being fully considered as a user interface modality

• Immersive VR is anticipated to be a powerful stimulation approach in addition to being effective training tool

• Those technologies may have potentially interesting applications in space…
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https://www.mindwalker-project.eu/

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