Global Challenges Showcase: Translation & Innovation Hub (I-HUB)
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Robotics for Neurosurgery: The EDEN2020 Case Study

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Key Facts about Brain Cancer

- Glioblastoma affects 6 per 100,000 people
- Treatment cost in Europe: 5.2 Billion euros
- Average Survival Time: 12-18 months
- Average estimated cost for a new pharmaceutical agent: 1 Billion euros

DATA: Cancer Research UK and EU reports
Motivation

- Conventional Keyhole Surgery:
  - Straight rigid needles
  - Inflexible/limited use
  - Restricted access

- How to improve targeting accuracy and account for tissue deformation?
  - Vessels and structures
  - Tool tissue interactions
A Biologically Inspired Approach

Wasp inserting the ovipositor into the wood

Eggs pass through here

Reciprocating Mechanism

Mechanism of Motion

Wood

Electron microscope view
The STING concept
2D Steering in Action
3D Steering in Action

3D Curvature Tracking

Adaptive Low-Level Control

Secoli et al., IEEE TRO 2016 (under submission)
Secoli et al., BioRob 2016
How we Reduce Tissue Invasiveness

- One laser
- Two cameras
- Galvoscanner
- Seeded gelatine box, needle & actuation system
Reciprocal Motion in Action

Insertion experiments into a gelatine phantom: **DIRECT PUSH**

Insertion experiments into a gelatine phantom: **RECIPROCAL MOTION**

*Oldfield et al., JMBBM 2014*
Reducing Target Motion

Direct Push

Reciprocal Motion

> 20% reduction in tissue deformation

Leibinger et al., Interface Focus 2016

Needle Insertion Direction

Needle Insertion Direction
A Europe Wide Effort

- €8.3M H2020, started on 1st April 2016
- 8 partners: 2 companies, 2 hospitals, 4 engineering departments
- AIM: To create a neurosurgical robotic-assisted technology platform for minimally invasive surgical delivery for:
  - Therapy
  - In Situ Diagnostics and Progress Monitoring
EDEN2020 at a Glance

- Robotic Fine Positioner
- Flexible Needle Transmission
- Raman Imaging System
- 3D US Probe via Secondary Burr Hole
- Intraoperative Haptic Console with live US-MR Imaging Fusion
Needle Subsystem

Medical Grade Bio-Inspired Flexible Needle

Multi-segment needle 2.5 mm Outer Diameter with 4 working channels

This work was supported by the European Research Council under the European Union Seventh Framework Programme (FP7/2007-2013) / ERC grant agreement no. 258642-STING.

2.5mm OD

45° bevel x segment

Ø 0.3mm

1.25mm
Planning Subsystem

Key components
- Based on Neuroinspire™ ecosystem
- Patient Specific Data Fusions between
  - MRI
  - DTI
  - CT
- Semiautomatic planning
  - Entry port and target lesion
  - Automatic trajectory generation
    - Patient-specific therapy prediction
    - Lowest risk optimization
    - Shortest path to multiple targets
- Export to intraoperative subsystem

Neuroinspire™ (Renishaw plc.)
Navigation Subsystem

Key components

- Neuroinspire™ front end
- multiple displays
  - MRI/US fusion
  - Catheter model
  - Dynamic trajectory overlay
  - Live ultrasound feed
- Haptic interface
  - Commercial or bespoke
  - Constrained control of catheter insertion

Neuroinspire™

2nd screen for e.g. live stream?

haptic input
Drug Delivery Subsystem

Key components

- Flexible and compliant multi lumen catheter
- Fused silica inner tube
- Commercial infusion pump (off the shelf)
- Bespoke end-effector
  - Sterile interface
  - Guillotine system
In Situ Diagnostics Subsystem

- **Raman imaging** deployed via optical fibres to identify:
  1. **Transitions** between healthy and malignant tissue
  2. **Characterise** aspects of **tissue morphology** at selected acquisition points during insertion
  3. Explore the ability to **monitor** drug diffusion in time
Technological Advances

A01 | OPTIMIZED THERAPY
consider tumor growth and expansion according to computational evolution data

A02 | PATIENT’S DATA FUSION
pair diffusion imaging data with histology, microstructural measurements and high fidelity diffusion models

A03 | OVERCOME BLOOD BARRIER ISSUE
deploy a CED delivery system that can deliver molecules in various areas of the tumor

A04 | IN-SITU DIAGNOSTICS
by means of RAMAN Spectroscopy to characterise tissue morphology

A05 | INTEGRATE PRE-OPERATIVE IMAGING WITH ONLINE IMAGING VIA ULTRASOUND
to correct for brain shift and to ensure a more accurate targeting
Towards Real Clinical Impact…

• Realistic surgical setup and real clinical need
  – MI drug delivery for complex cancer therapy (UNIMI)

• Dealing with soft and deformable tissue
  – Preoperative imaging for planning (UNSR)
  – 3D intraoperative US for tool/tissue tracking (TUM, UMCG)

• Product certification and eventual commercialisation
  – Exploitation company with interest in this space (RENSHAW)
  – Key OEM provided of medical grade catheters (XOGRAPH)

• A mechanism to bring it all together
  – Funds & coordinator with very clear intentions (IMPERIAL)
  – Top biomedical team to lead integration (POLIMI)
Thank you...

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