Estimation of forces and displacements during brain surgery using medical phantoms

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Introduction

- **Goals of this work**:

1. Building a setup to estimate the range of forces and deformations applied to brain tissue during surgery.
2. Test the setup performing manual indentation on a brain-mimicking silicone sample with surgical tools.

- **Motivation**:

Estimating force and deformation ranges during surgery is a requirement for the design of a tactile device for in-vivo brain stiffness evaluation.

Those ranges are needed to constrain the choice of sensors during the device design process.

- **Why brain stiffness?**

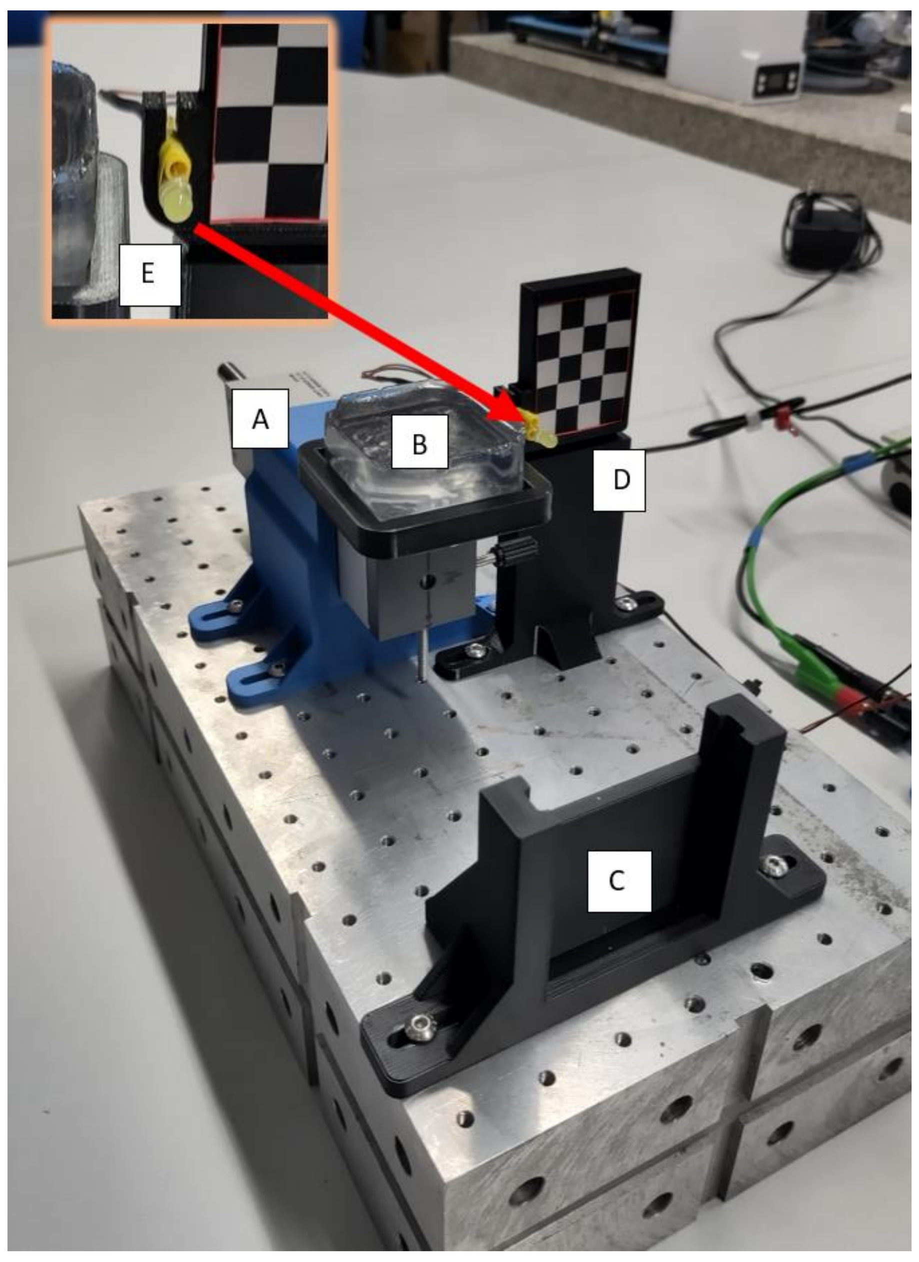
1) Better computational models investigating injury and disease development
2) Improvement of surgical procedures
3) Objective measures to evaluate trauma/pathological conditions

- **Why a tactile device for brain stiffness measurement?**

Currently, the only available method for in-vivo brain stiffness assessment is magnetic resonance elastography (MRE). MRE is not reliable enough to be considered gold standard and cannot be performed during surgery.

Design

- Force measurement: LEYBOLD® 524 060 uniaxial force sensor
- Analog-Digital force conversion: LEYBOLD® 524010 Sensor-CASSY connected to computer.



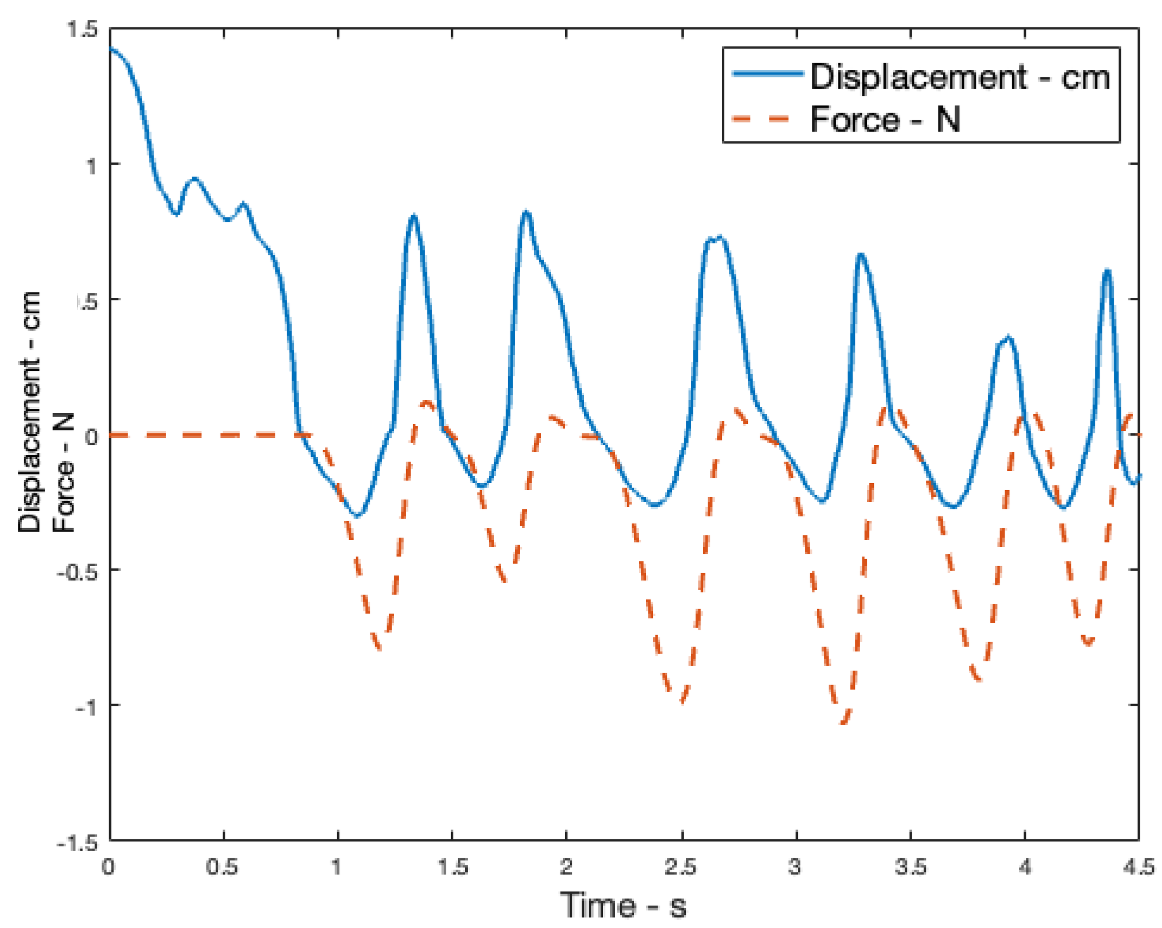
- Deformation measurement: indirect, Kinovea software used to analyze footage obtained with iPhone 12 mini (182.79fps). Calibration grid used to set scale.
- Force-deformation data synchronization: trigger circuit manufactured in laboratory with LED positioned in the frame.
- Surgical tools to deform the samples: bipolar forceps and dissector

Figure 1. Complete view of the setup: force sensor (A), sample holder with sample (B), phone holder (C), calibration grid (D) and LED (E)

Methods

- 2 tactile tests were carried out on a silicone sample by two neurosurgeons using surgical tools.
- Synchronized force and deformation data were obtained and analyzed in MATLAB®.

Results



- Compressive force range: 0 - 1.063 N
- Tissue deformation range: 0 - 2.97 mm

Figure 2. Plot of force and displacement. Negative displacements indicate deformation of sample due to compressive load. Negative force values are used to indicate compressive load.

Discussion

- Deformation peaks anticipate force peaks by approximately 0.1 s. Possible cause: compliance of sensor and inertia of sample. Further tests are needed to confirm hypothesis.
- Additional experiments with more surgeons and optimized measurement conditions are needed.

References

[1] S. Budday, T. C. Ovaert, G. A. Holzapfel, P. Steinmann, and E. Kuhl, "Fifty Shades of Brain: A Review on the Mechanical Testing and Modeling of Brain Tissue," Archives of Computational Methods in Engineering, vol. 27, pp. 1187–1230, Sept. 2020.

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