Tracking the orientation of deep brain stimulation electrodes using an embedded magnetic sensor

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Motivation

- **Directional leads** are the most recent technological advancement in DBS. It allows to steer the direction of horizontal currents (see Fig.1).
- Intraoperative 3D verification of the position and orientation of the electrode is still not completely handled.
- Post-operative CT analysis showed **large deviations of the angular position** from the intended implantation direction [2].

Figure 1. Directional lead example

Objective

To evaluate the precision of yaw angle detection using an **electromagnetic tracking** (EMT) system under development.

Materials

- EMT system: Magnetic field generator (in-house 3D Helmholtz coil) + a single **3D magnetic field sensor** (Hall effect sensor AK9970D [3]) integrated inside a brass tube.
- Reference for rotational control : Stereotactic Leksell frame and arc (Elekta, Sweden)

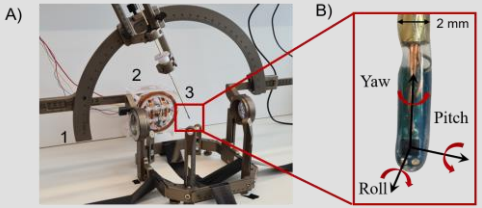

Figure 2. Experimental setup: A) Front view of the stereotactic frame and arc (1) with the magnetic source (2) placed at the back and the electrode demonstrator (3); B) Tip of the electrode integrating a 3D Hall effect sensor (1.35x1.35x0.57 mm) and the three associated angles.

Methods

- Tracking algorithm was based on Kuipers' resolution method [4].
- Yaw angles were set and measured between 0° and 340° with 20° steps (average of 70 magnetic field acquisitions for each angle measurement)

Results

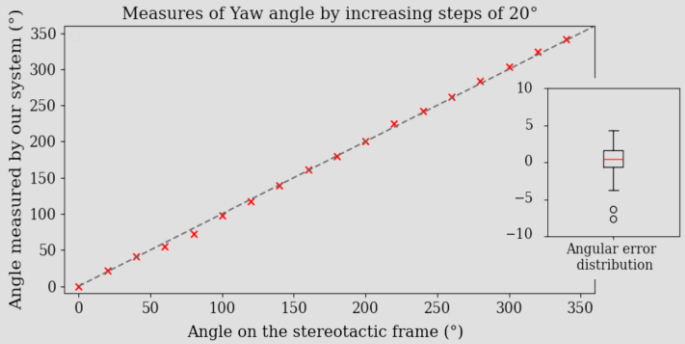

Figure 3. Scattered plot graph showing rotational yaw angles measured and boxplot of the angular error distribution

- Tracking of the yaw angles with a mean absolute error of **2.46°** and a standard deviation of 2.17° (see Figure 3).
- The lead prototype with integrated magnetic sensor has a diameter of 2.5 mm. Smaller commercially available sensor chips, possibly with a wafer-level packaging, will allow **further miniaturization** probably leading to a higher integrability into clinical DBS leads.
- This EMT system can also track the two other orientation angles (pitch, roll) and the radial position of the lead.

Outlook and conclusion

- The obtained results approach the mean error of –0.6° and standard deviation 1.5° measured using a CT-artifact detection algorithm [5].
- This EMT system could be used by the surgical team to **detect variations from the planned 3D position and orientation** of the lead during the implantation.
- Beyond its intraoperative use, a further outlook of the proposed tracking system is to monitor at regular intervals the position and the orientation of the DBS leads after surgery.

References

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