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

Céline Vergne, Morgan Madec, *Member, IEEE,* Simone Hemm, *Member, IEEE,* Thomas Quirin, Dorian Vogel, Luc Hébrard, *Member, IEEE*, and Joris Pascal

***Abstract*— This paper proposes a three-dimensional (3D) orientation tracking method of a 3D magnetic sensor embedded in a 2.5 mm diameter electrode. Our system aims to be used during intraoperative surgery to detect the orientation of directional leads (D-leads) for deep brain stimulation (DBS).**

I. Introduction

Solving the positioning challenges of neurosurgical tools like deep brain stimulation (DBS) electrodes using electromagnetic tracking (EMT) has recently been investigated [1], but their orientation is still not completely handled. Especially for DBS, the tracking of the orientation is getting more interest with the development of directional leads (D-leads) [2]. D-leads are designed to adapt the volume of stimulation to avoid stimulation induced adverse effects by steering the directions of horizontal currents. A precise positioning with a known orientation around the electrode axis (yaw angle) for the programming of D-leads requires therefore a good control of their orientation making it more challenging to implant than conventional DBS leads. D-leads often exhibit large deviations from the intended implantation direction [2]. The aim of the present work is to evaluate the precision of yaw angle detection using an EMT system under development.

II. Methods

Our EMT system is composed of a magnetic field generator (in-house 3D Helmholtz coil) and a single 3D integrated magnetic field sensor (Hall effect sensor AK9970D [3], maximal output data rate of 100Hz) mounted at the tip of a brass tube mimicking the DBS electrode. Due to prototyping constraints, we have designed the tip with 2.5 mm diameter.

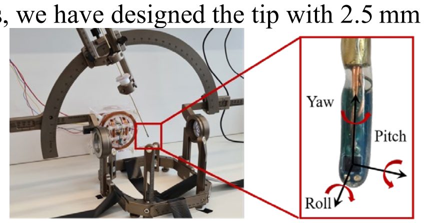

Figure 1. Experimental setup: 3D Helmholtz coil (left), Leksell Stereotactic frame, magnetic field sensor (right red zoom) and the three associated angles.

The tracking algorithm was based on Kuipers' resolution method [4]. To compare the outcomes of our algorithm, we used the stereotactic Leksell frame and arc (Elekta, Sweden) as a reference to control the rotation over the yaw axis (see Figure 1). The yaw angles were measured between 0° and 340° with 20° steps. An average of 70 magnetic field acquisitions for each angle measurement was used.

III. Results

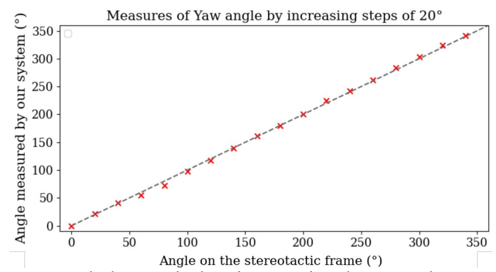

Figure 2. Scattered plot graph showing rotational yaw angles measured by our EMT system with the Kuipers' algorithm.

The EMT system tracked the angle with a mean absolute error of 2.46° and a standard deviation of 2.17°.

Discussion

The results we obtained approach the standard deviation 1.5° measured using a CT-artifact detection algorithm [2]. Smaller commercially available sensor chips, possibly with a wafer-level packaging, will allow further miniaturization probably leading to a higher measurement accuracy and integrability into clinical DBS leads (1.27-1.4 mm diameter).

This new approach could be used by the surgical team to detect internal rotation of the electrode during the implantation and to provide relevant information to tune the stimulation parameters accordingly.

References

[1] Burchiel KJ, Kinsman M, Mansfield K, Mitchell A. Verification of the Deep Brain Stimulation Electrode Position Using Intraoperative Electromagnetic Localization. Stereotact Funct Neurosurg. 2020;98(1):37-42. doi: 10.1159/000505494. Epub 2020 Feb 4. PMID: 32018272.

[2] Dembek TA, Hoevels M, Hellerbach A, Horn A, Petry-Schmelzer JN, Borggrefe J, Wirths J, Dafsari HS, Barbe MT, Visser-Vandewalle V, Treuer H. Directional DBS leads show large deviations from their intended implantation orientation. Parkinsonism Relat Disord. 2019 Oct; 67:117-121. doi: 10.1016/j.parkreldis.2019.08.017. Epub 2019 Aug 27. PMID: 31495733.

[3] Asahi Kasei Microdevices (AKM), "AK09970D 3D Magnetic Sensor with Programmable Switch," [019009115-E-00] datasheet, Aug. 2019.

[4] Kuipers, J. B. (1980). SPASYN—An Electromagnetic Relative Position and Orientation Tracking System. IEEE Transactions on Instrumentation and Measurement, 29(4), 462–466. https://doi.org/10.1109/TIM.1980.4314980W.-K

Céline Vergne, Simone Hemm, Thomas Quirin, Dorian Vogel and Joris Pascal are with the Institute for Medical Engineering and Medical Informatics, School of Life Sciences, University of Applied Sciences and Arts Northwestern Switzerland (FHNW), Muttenz, Switzerland (correspondence e-mail: celine.vergne@frnw.ch).

Céline Vergne, Thomas Quirin, Morgan Madec and Luc Hébrard are with the iCube laboratory, University of Strasbourg - CNRS, Strasbourg, France.