Machine-learning algorithm applied to magnetic localization

Manon LAMBERT[1], Corentin FERY[2], Thomas QUIRIN[2], Céline VERGNE[1,2], Simon LEMOIGNE[2], Sarah CHOUCHENE[1], Vincent NOBLET[1], Ralf SCHUMACHER[3], Joris PASCAL[2], Luc HEBRARD[1] and Morgan MADEC[1]

[1]Laboratoire ICube, UMR 7357 (University of Strasbourg / CNRS), 300 bd Sébastien Brant, F-67400 Strasbourg
[2]Institute for Medical Engineering and Medical Informatics / School of Life Sciences FHNW, Hofackerstrasse 30, CH-4132 Muttenz
[3]BellwaldTEC, Bellwalderstrasse 471, CH-3997 Bellwald

Magnetic localization application

Magnetic localization is a technique widely used in the biomedical field to track objects in environments where there is **no line of sight**. The **versatility of this technology** allows applying it to different problems such as indoor localization [1], needle tracking for surgery [2], and motion tracking in the entertainment industry [3]. Beyond traditional uses, magnetic localization is now enabling advanced applications like **body scanning**. In such applications, a set of magnetic sensors is placed on the object whose shape needs to be determined. The position of each sensor is calculated by magnetic localization and the **point cloud is used to reconstruct the shape**.

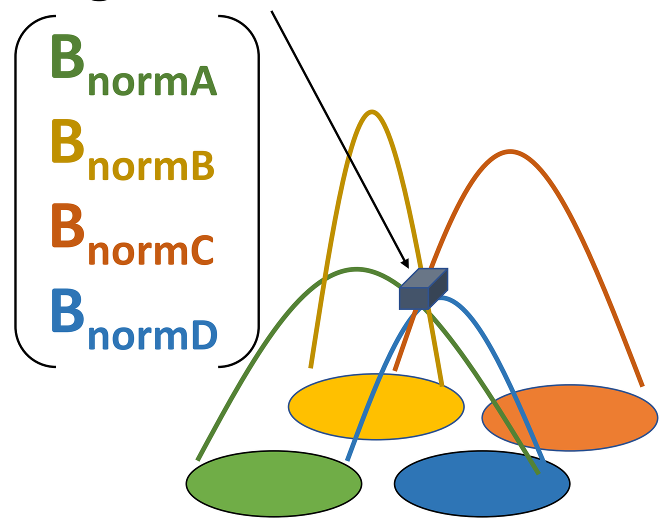
Scan to see our application

Experimental setup

Magnetic localization principle

Biot-Savart law:

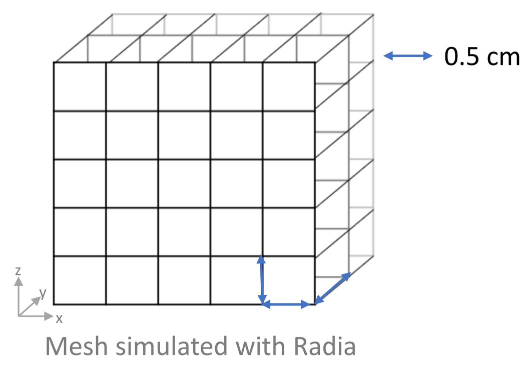
$$\boldsymbol{B}(r) = \frac{\mu_0}{4\pi}\int_C \frac{\mathrm{I}\,\mathrm{d}\boldsymbol{l} \times \boldsymbol{r'}}{|\boldsymbol{r'}|^3}$$



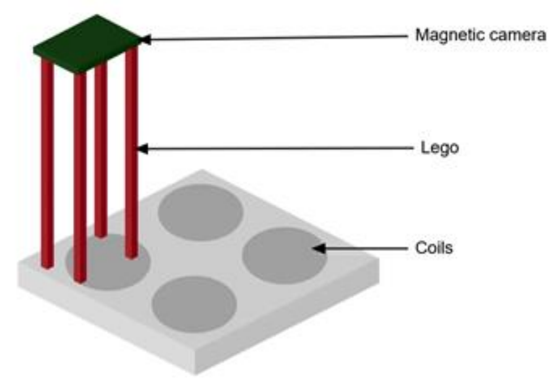
B magnetic field (T)
μ_0 air permittivity (T)
I current (A)
r distance to the surface

- Four coils are activated sequentially allowing to obtain four magnetic field strength
- The distance to each coil is calculated with the Biot-Savart equation
- These distances allow to locate the magnetic sensor thanks to the trilateration principle

Data generation



400 221 simulated points



4 992 experimental points

- **Experimental dataset**: collected by moving a magnetic field camera composed of 8x8 MMC5603NJ sensors at 78 different camera positions across a 40x40x40 cm³ volume
- **Simulated dataset** : generated using the Radia library in Python to avoid time-consuming remapping when coil design changes

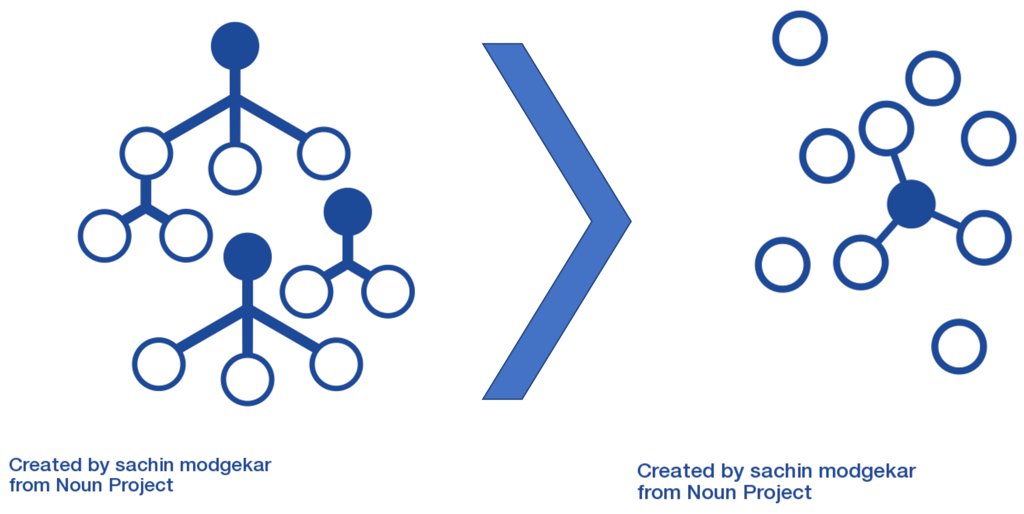
- **Trained** on the high-resolution simulated dataset
- **Tested** on simulated data to assess the performance of the algorithm
- **Tested** on experimental data to assure their relevance in real conditions

Results and discussion

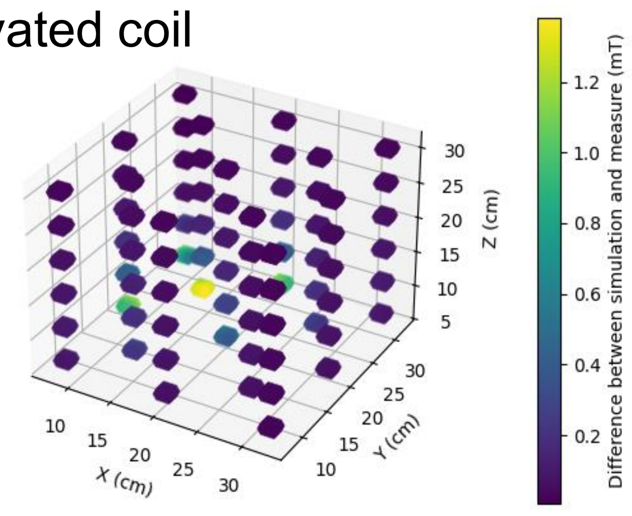
	Test dataset	MAE (mm)	Error rate (%)	Prediction time/point (µs)
KNN	*Simulated*	1.48	41	2.0 ± 0.3
	Experimental	1.56	54	2.0 ± 0.1
RF	*Simulated*	0.71	23	10 ± 1.7
	Experimental	1.16	48	18 ± 6.0

Error rate : percentage of predictions exceeding ±1 mm

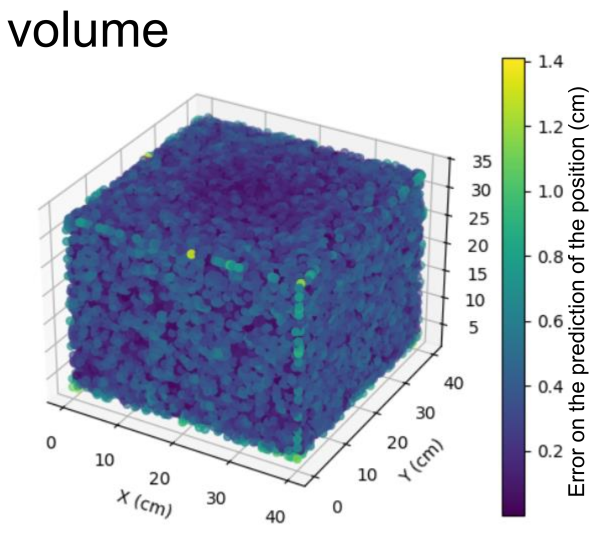
Random Forest (RF) outperforms K-Nearest Neighbors (KNN)



The discrepancy between results on simulated and measured data can be explained by a difference in the data around the activated coil



The use of KNN or RF exposes to edge effects. They can be avoided by predicting in a smaller volume



Outlook

Possible sources of error and how to tackle them:

- Use sparse experimental data to correct the simulation results

Learning quality:

- Explore Physics-Informed Neural Networks to ensure physical consistency
- Transformers have shown good results in the literature [4]

References

[[1] H. Obeidat, W. Shuaieb, O. Obeidat, and R. Abd-Alhameed, “A Review of Indoor Localization Techniques and Wireless Technologies,” Wireless Pers Commun, vol. 119, no. 1, pp. 289–327, Jul. 2021, doi: 10.1007/s11277-021-08209-5.

[2] I. Umay, B. Fidan, and B. Barshan, “Localization and Tracking of Implantable Biomedical Sensors,” Sensors, vol. 17, no. 3, Art. no. 3, Mar. 2017, doi: 10.3390/s17030583.

[3] J. Yi, J. Liu, C. Zhang, and X. Lu, “Magnetic Motion Tracking for Natural Human Computer Interaction: A Review,” IEEE Sensors J., vol. 22, no. 23, pp. 22356–22367, Dec. 2022, doi: 10.1109/JSEN.2022.3215285.

[4] Li, B., Chi, Y., & Wang, Y. (2024). Magnetic Field Data Calibration with Transformer Model Using Physical Constraints: A Scalable Method for Satellite Missions, Illustrated by Tianwen-1. arXiv preprint arXiv:2501.00020.

Interreg Rhin Supérieur | Oberrhein
Cofinancé par l'Union Européenne
Kofinanziert von der Europäischen Union
ICUBE
Fachhochschule Nordwestschweiz
BellwaldTEC