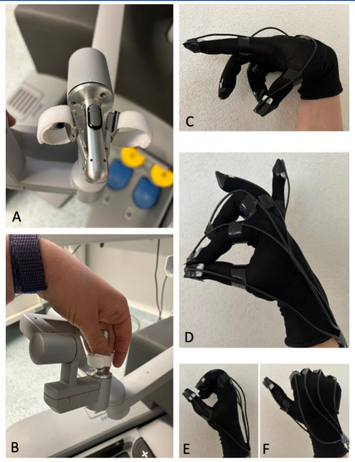
B11(N)

Magnetic Sensor Gloves for Robot-assisted Surgery

Tobias Schmidt, Robert Bergholz (PI), Gerhard Schmidt (PI)

biomagnetic sensing SFB 1261

Motivation and Objectives



- A and B: State o the art input devices
- C and D: Example of a way to determine the position of the wrists and the finger posture
- E and F: Enables the possibility to detect bottle grip gesture or others.
- Better control tool for future robotic instruments (small hands)

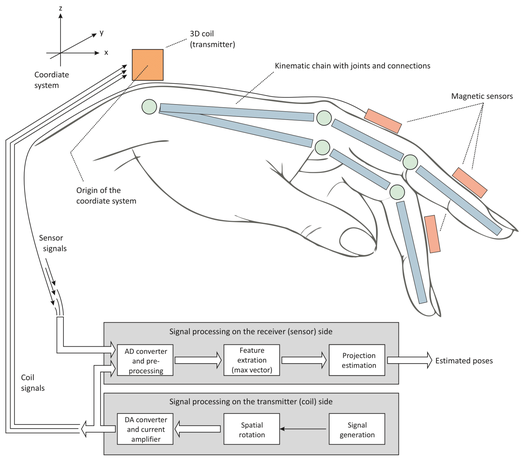
Main objectives: New input device for robot assisted surgery, better handling for surgeons

New approach: Nested localization, model based localization, AI based gesture recognition algorithms

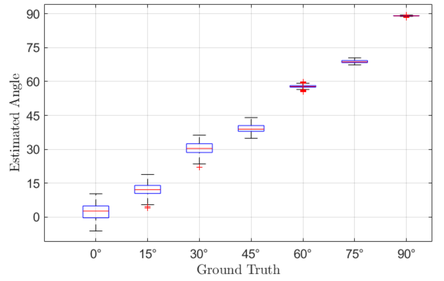
Preliminary Work

New algorithm for pose estimation of a kinematic chain

- Use of spatio-temporal rotating magnetic field actuation
- Simple feature extraction
- Combining knowledge about the kinematic chain and the magnetic field

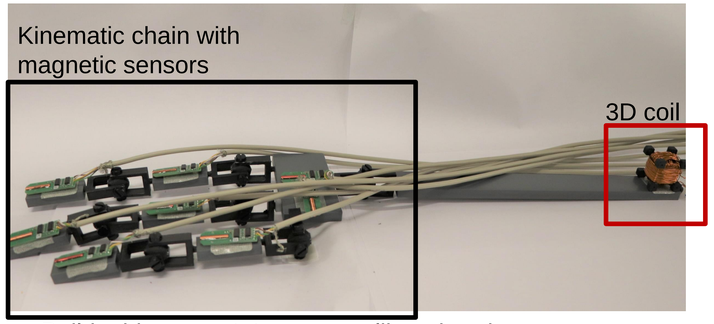


- Use the self-consistency of the kinematic chain
- Reduce number of degrees of freedom from 5 to 2
- Very fast computation: around 5 µs per chain element



First laboratory tests

- Simple prototype
- 3D coil and fluxgate sensor on a kinematic chain
- First results show principle working function
- Remaining model errors have to be solved



- Build a bigger prototype, more like a hand

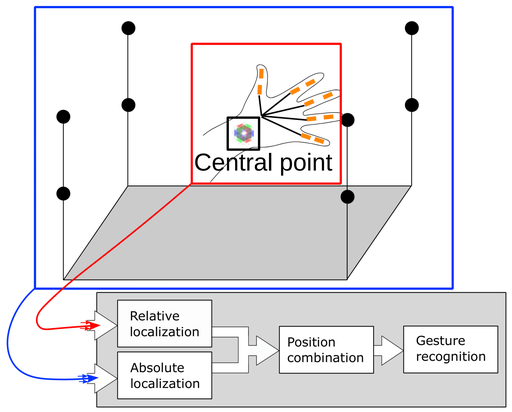
Work Plan for Third Funding Period

Research methods

- Use of various magnetic sensors and actuators
- Innovative localization algorithms
  - Nested localization methods
- Machine learning algorithms for gesture recognition
  - Use of prototype to generate data
  - Simulated artificial data

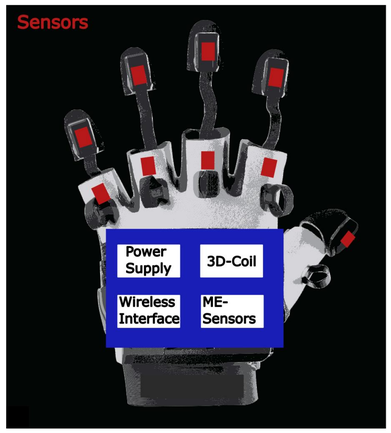
Absolute localization

- Build a setup for absolute localization in a predefined volume
- Close collaboration with projects B2 and B9
- Used to localize a central position on the hand (wrist)
- Equipped with a 3D actuator/sensor



Relative localization

- Glove equipped with actuators and sensors
- Algorithms for fast estimation of finger attitude
- Use knowledge about the hand for efficient signal processing



Gesture recognition

- Generate data with magnetic prototype and OMC systems
- Use simulation pipeline from B9 to generate artificial magnetic signals
- CNNs combined with fully connected Layers

Tests and evaluation

- Continuous evaluation of the hardware and used sensors
- Comparison with industrial alternatives
- Test of the prototype in clinical environment

		2024		2025				2026				2027				2028	
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WP1 – Hardware and Magnetic Setup Investigations	Engineer PhD (100%)																
	Study nurse (25%)																
WP2 – Localization and Motion Capturing Algorithms	Engineer PhD (100%)																
	Study nurse (25%)																
WP3 – Gesture Recognition Algorithm Development	Engineer PhD (100%)																
	Study nurse (25%)																
WP4 – Evaluation	Engineer PhD (100%)																
	Study nurse (25%)																

Collaborations

A1, A2, A4, A7, A9: Sensor Evaluation and provide application specific feedback

A2: Utilization of flexible circuits, connectors and sensor holders

A8, A10: Include sensor models and finding forward models

B1, Z2: Work together on dedicated amplification boards and sensor calibration procedures

B2, B9, B10: Work together in same real-time framework and cooperate on pose estimation algorithms

Z1: Use fabricated sensors for measurement setups

Z2: Use sensor characterization in forward model

Participation in focus groups

F3: Comparison of Sensor Concepts

F6: Biomedical Applications

Funds Requested

1 Doctoral researcher, 0.25 study nurses, consumables: 58,7k€

[B11-1] **Schmidt, G.**, **Bergholz, R.**, Klinkenbusch, L., Bald, C., Schmidt, T. (2023). Patent application DE 10 2023 119 167.5. - **B2**

[B11-2] **Schmidt, G.**, **Bergholz, R.**, Quandt, E., Sun, N., Klinkenbusch, L., Bald, C., Schmidt, T. (2023). Patent application DE 10 2023 116 342.6. - **B2**

[B11-3] Krebs, T. F., Kayser, T., Lorenzen, U., Grünewald, M., Kayser, M., Saltner, A., ... & **Bergholz, R**. (2023). *Preprint*.

[B11-4] Hoffmann, J., Roldan-Vasco, S., Krüger, K., Niekiel, F., Hansen, C., Maetzler, W., ... & **Schmidt, G.** (2023). *Sensors*, *23*(7), 3594. - **B9, Z1**

[B11-5] Krebs, T. F., Egberts, J. H., Lorenzen, U., Krause, M. F., Reischig, K., Meiksans, R., ... & **Bergholz, R.** (2021). *Journal of Robotic Surgery*, *16*(1), 215-228.

[B11-6] Hoffmann, J., Hansen, C., Maetzler, W., & **Schmidt, G.** (2022, September). In *Current Directions in Biomedical Engineering* (Vol. 8, No. 2, pp. 451-454). De Gruyter. - **B9**

[B11-7] Elzenheimer, E., Bald, C., Engelhardt, E., Hoffmann, J., Hayes, P., Arbustini, J., ... & **Schmidt, G.** (2022). *Sensors*, *22*(3), 1018. - **A7, B1, B2, B9, B10, Z2**

[B11-8] Hoffmann, J., Elzenheimer, E., Bald, C., Hansen, C., Maetzler, W., & **Schmidt, G.** (2021). *Sensors*, *21*(23), 8000. - **B9, Z2, B2**

[B11-9] **Bergholz, R.**, Botden, S., Verweij, J., Tytgat, S., Van Gemert, W., Boettcher, M., ... & Gidaro, S. (2020). *Journal of Robotic Surgery*, *14*(1), 191-197.

[B11-10] Kittmann, A., Durdaut, P., Zabel, S., Reermann, J., Schmalz, J., Spetzler, B., ... & Quandt, E. (2018). *Scientific reports*, *8*(1), 278. - **A4, B1, B2, B10, Z1**