B11(N)

Magnetic Sensor Gloves for Robot-assisted Surgery

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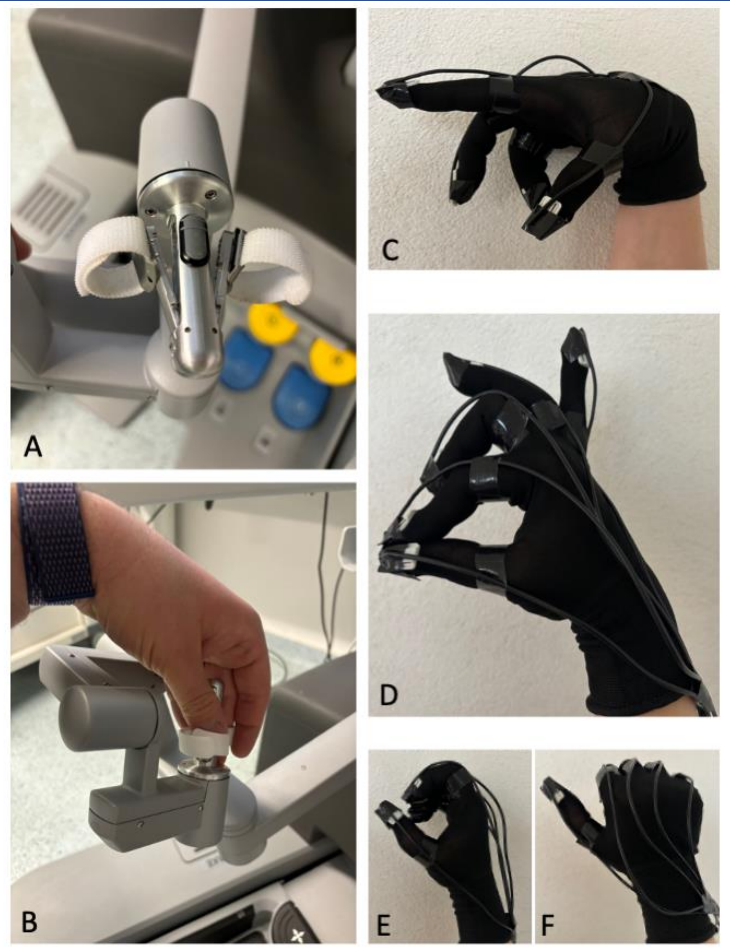
Motivation and Objectives



- 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. Gesture recognition then improves the maneuverability of the surgical robot.

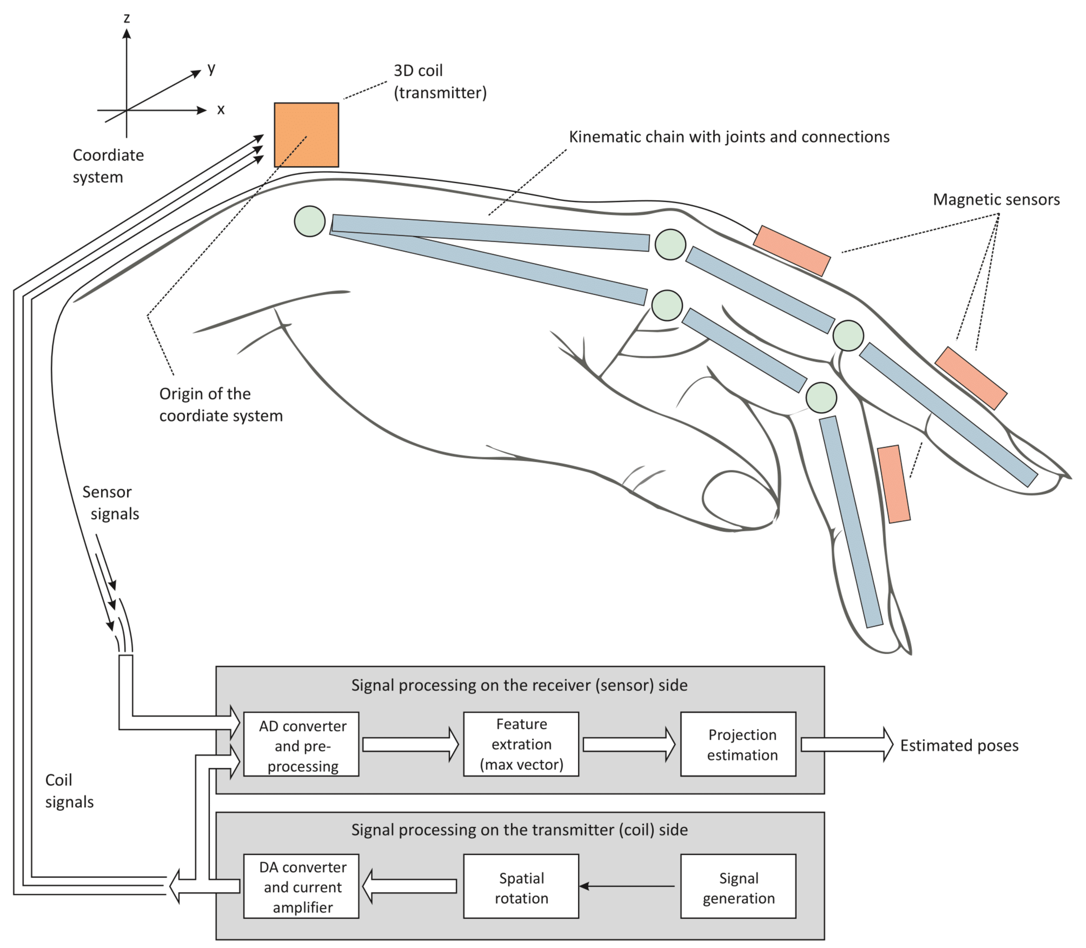
Main objectives: New input device for robot assisted surgery, better handling for surgeons

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

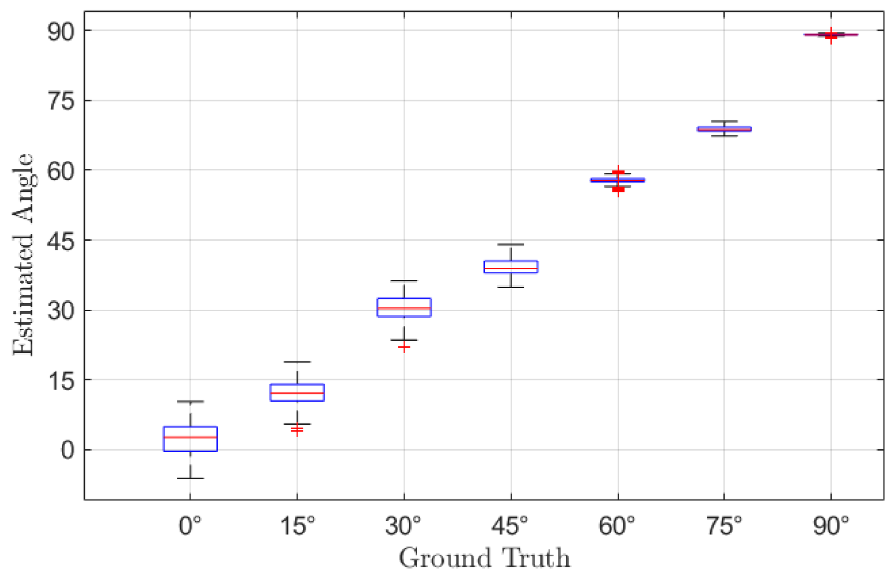
Preliminary Work

New algorithm for pose estimation of a kinematic chain

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

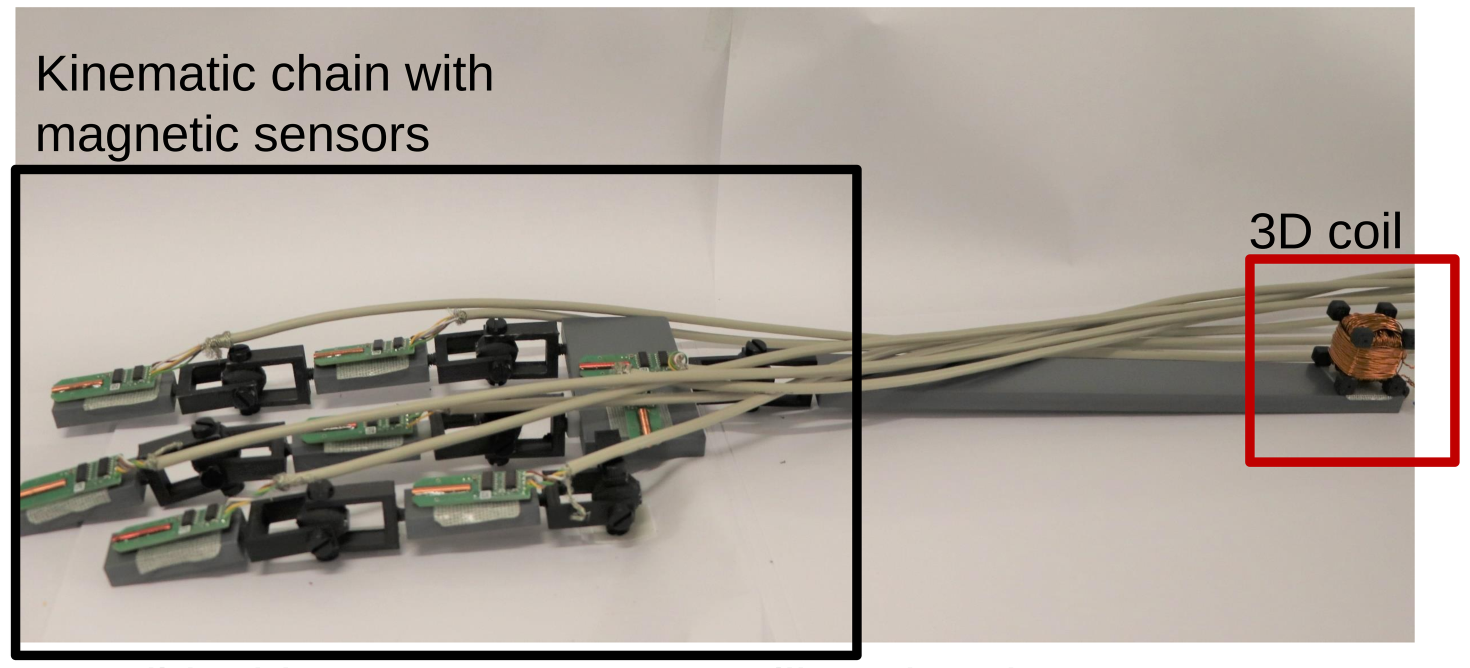


- Use the self-consistency
- Reduce number of degrees of freedom from 5 to 2
- Very fast computation: around 5 us per chain element



First Laboratory Tests

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



- Build a bigger prototype, more like a hand

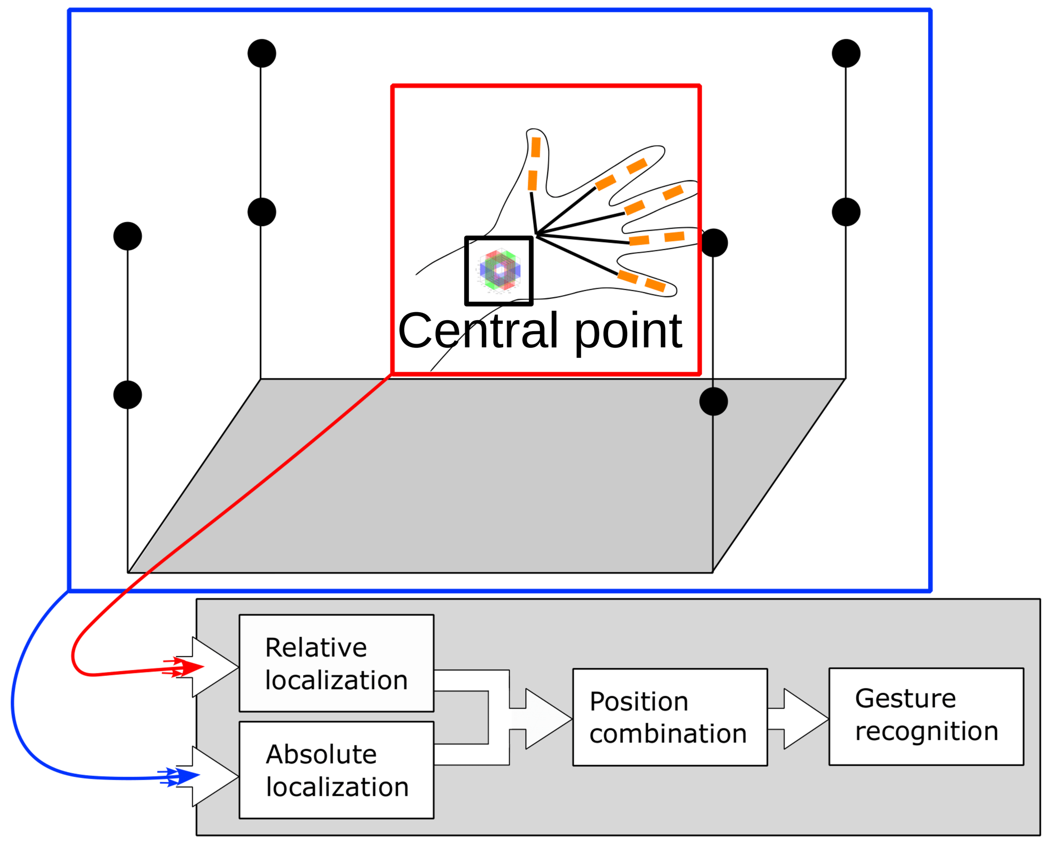
Work Plan for Third Funding Period

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

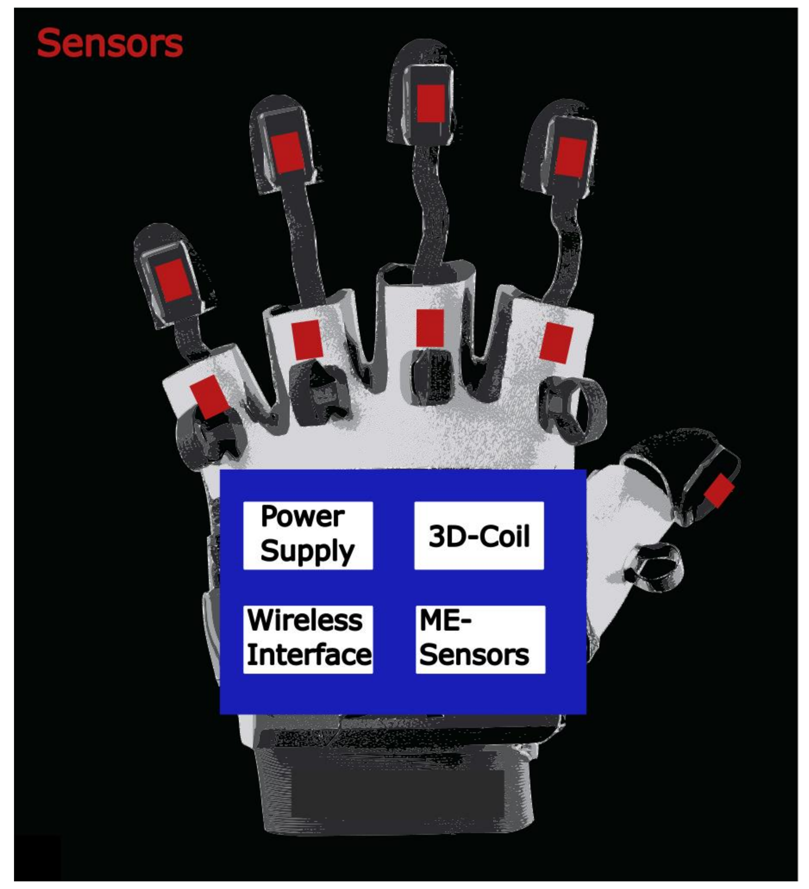
Absolute localization

- 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



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 Cap-turing 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 Nurse, consumables: 58,7k€

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

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

[B11-3] Krebs, T. F.; Kayser, T.; Lorenzen, U.; Grünewald, M.; Kayser , M.; Saltner , A.; **Bergholz , R.**: Children 2023 May 3,831.

[B11-4] Hoffmann, J; Roldan-Vasco, S.; Krüger, K.; Niekiel, F.; Hansen, C.; Maetzler, W.; Orozco-Arroyave, J. R.; **Schmidt, G.**: Sensors. 2023, 23, 3594.

[B11-5] Krebs, T. F.; Egberts, J. H.; Lorenzen, U.; Krause, M. F.; Reischig, K.; Meiksans, R.; Knöchel, R.; Baastrup, J.; Meinzer, A.; Alkatout, I.; Cohrs, G.; Wieker, H.; Lüthje, H.; Vieten, S.; Schultheiss, G.; **Bergholz, R.**: Journal of Robotic Surgery 2022 Feb; 16(1):215-228.

[B11-6] Hoffmann, J.; Hansen, C.; Maetzler, W.; **Schmidt, G.**: In Current Directions in Biomedical Engineering, Vol. 6, No. 2, pp. 451-454.

[B11-7] Elzenheimer, E.; Bald, C.; Engelhardt, E.; Hoffmann, J.; Hayes ,P.; Arbustini, J.; Bahr, A.; Quandt, E.; Höft, M.; **Schmidt, G.**: *Sensors*, *22*(3), 1018.

[B11-8] Hoffmann, J.; Elzenheimer, E.; Bald, C.; Hansen, C.; Maetzler, W.; **Schmidt, G.**: *Sensors. , 21*(23), 8000.

[B11-9] **Bergholz, R.**; Botden, S.; Verweij, J.; Tytgat, S.; Van Gemert, W.; Boettcher, M.; Ehlert, H.; Reinshagen, K.; Gidaro, S.: *Journal of robotic surgery*, *14*, 191-197.

[B11-10] Kittmann, A.; Durdaut, P.; Zabel, S.; Reermann, J.; Schmalz, J.; Spetzler, B.; **Schmidt, G.**; Höft, M.; Knöchel, R.; Faupel, F.; Quandt, E.: *Scientific reports*, *8*(1), 278.