Wearable Sensor Technology for Individual Grip Force Profiling

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2. Materials and Methods
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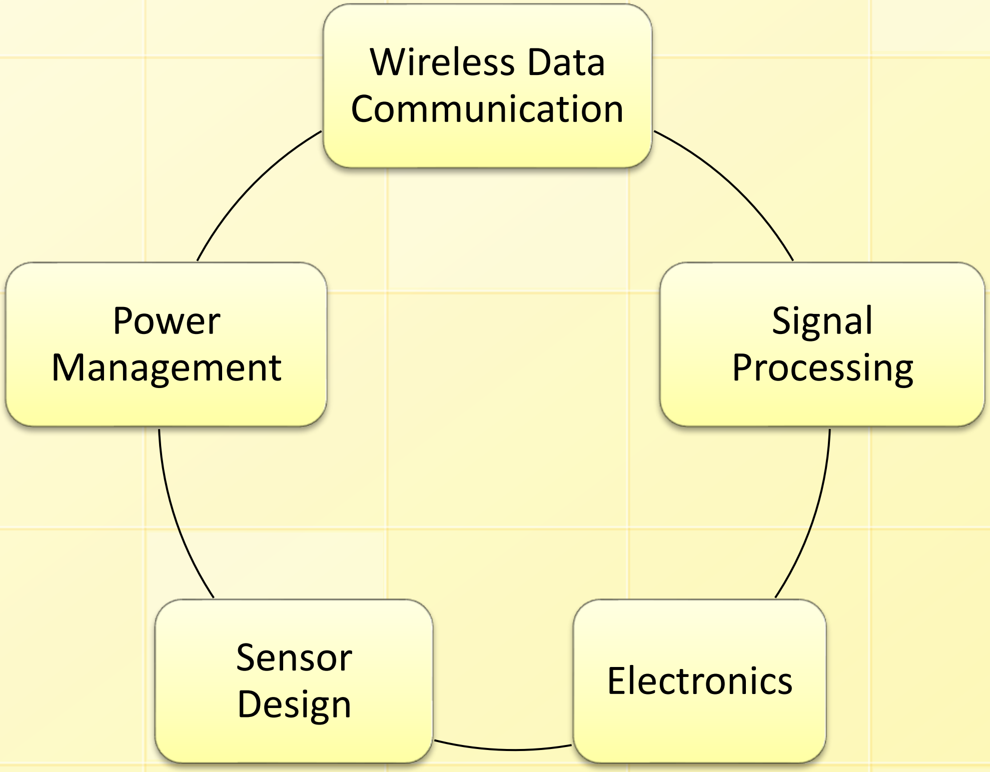
Introduction

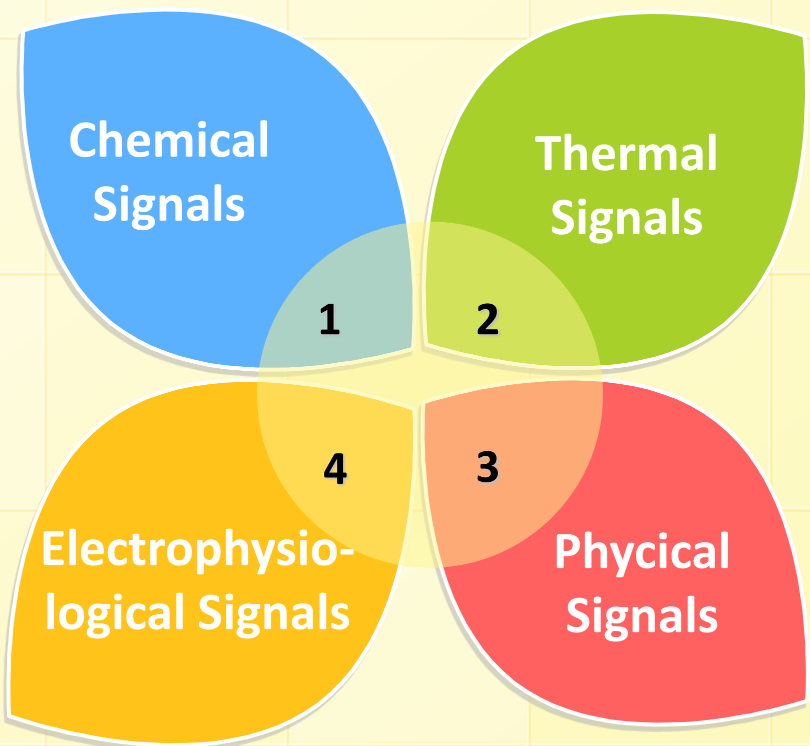
Wearable wireless biosensors

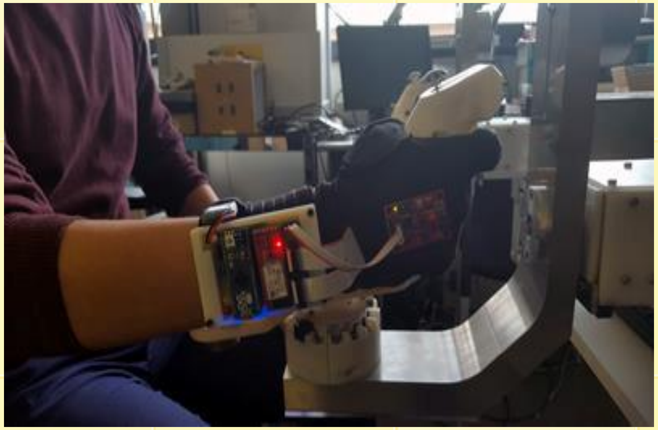


Introduction

Wearable wireless biosensor signals

- Convenient
- Continuous
- Unobtrusive





Grip Force Signals

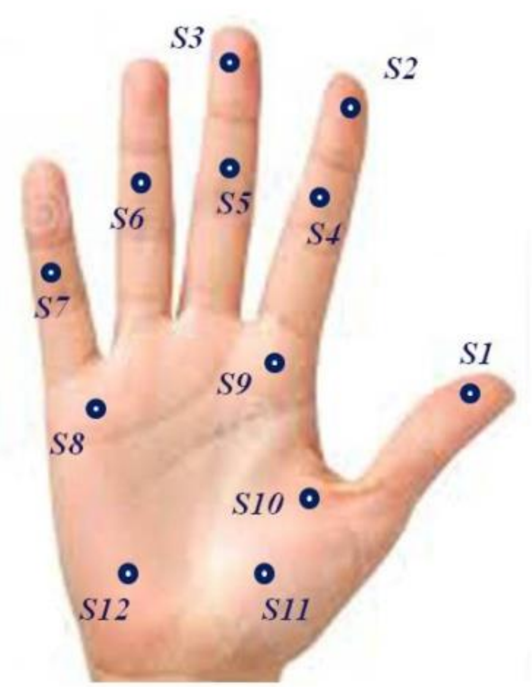
Materials and Methods

Wearable wireless sensor glove system[1]

[1] M. de Mathelin, F. Nageotte, P. Zanne, B. Dresp-Langley, Sensors for expert grip force profiling: towards benchmarking manual control of a robotic device for surgical tool movements, Sensors (Basel), Vol. 19, Issue 20, 2019, 4575.

Materials and Methods

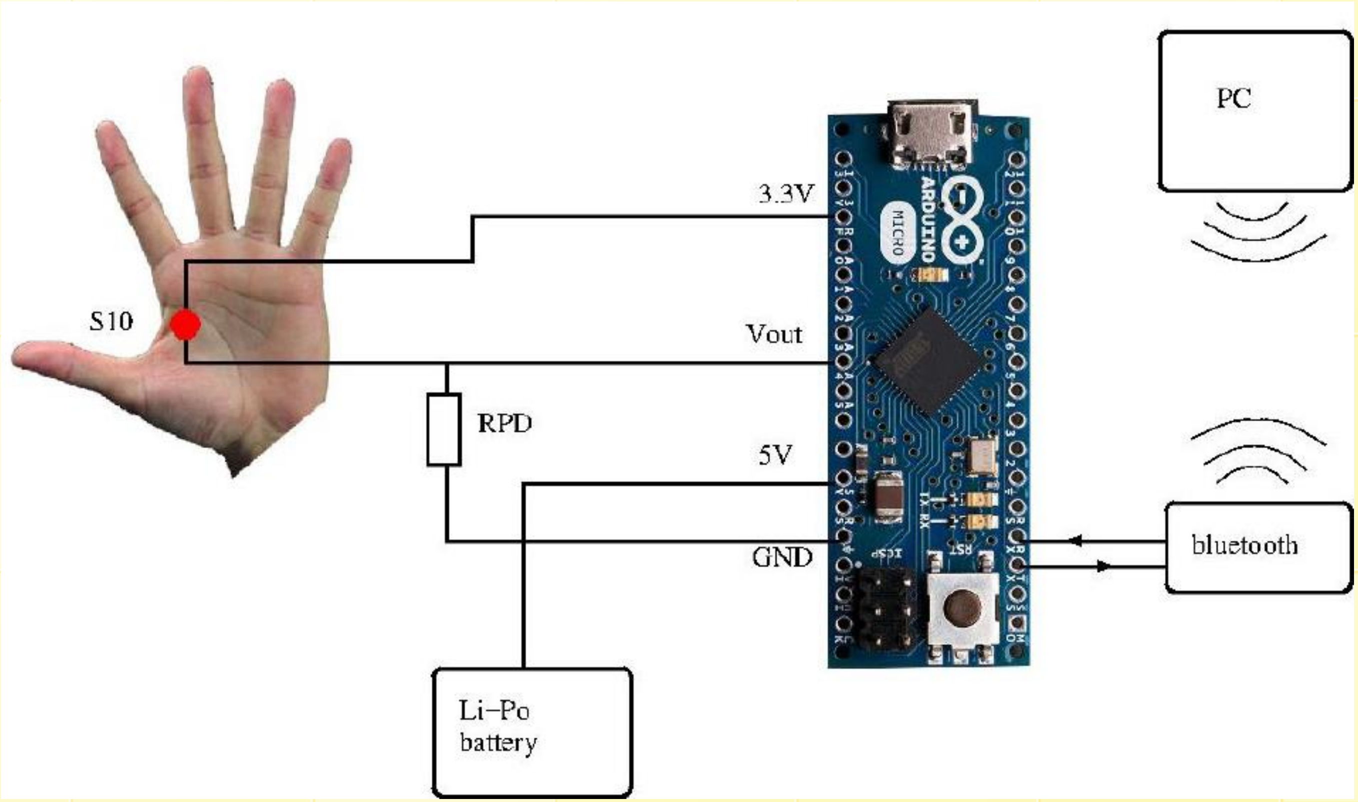
Force sensor locations



Sensor	*Hand region*	*Anatomical reference*
S1	Thumb	Distal Phalanx
S2	Index	Distal Phalanx
S3	Middle	Distal Phalanx
S4	Index	Middle Phalanx
S5	Middle	Middle Phalanx
S6	Ring	Middle Phalanx
S7	Pinky	Middle Phalanx
S8	Palm	Head Metacarpal
S9	Palm	Head Metacarpal
S10	Palm	Shaft Metacarpal
S11	Palm	Base Metacarpal
S12	Palm	Base Metacarpal

Materials and Methods

Data acquisition system

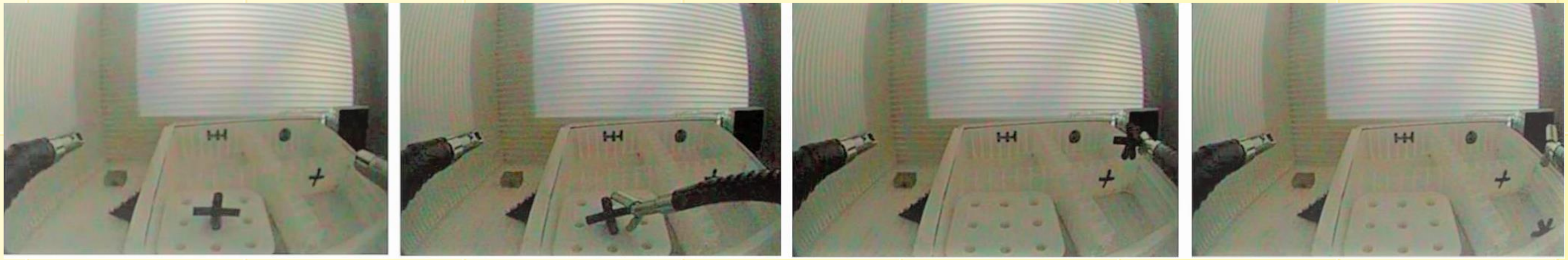


Materials and Methods

Experimental task design

Four-step pick-and-drop task

Step	Description
1	Activate and move tool towards object location
2	Open and close grippers to grasp and lift object
3	Move tool with object to target location
4	Open grippers to drop object in box



Four snapshot views of the four successive steps

Materials and Methods

Experimental Platform: STRAS endoscope [2]

[2] De Donno, A.; Zorn, L.; Zanne, P.; Nageotte, F.; de Mathelin, M. Introducing STRAS: A new flexible robotic system for minimally invasive surgery. 2013 IEEE International Conference on Robotics and Automation. IEEE, 2013, pp. 1213–1220

Results

Ten successive task sessions for both hands of three users

Number of grip force signals for each sensor

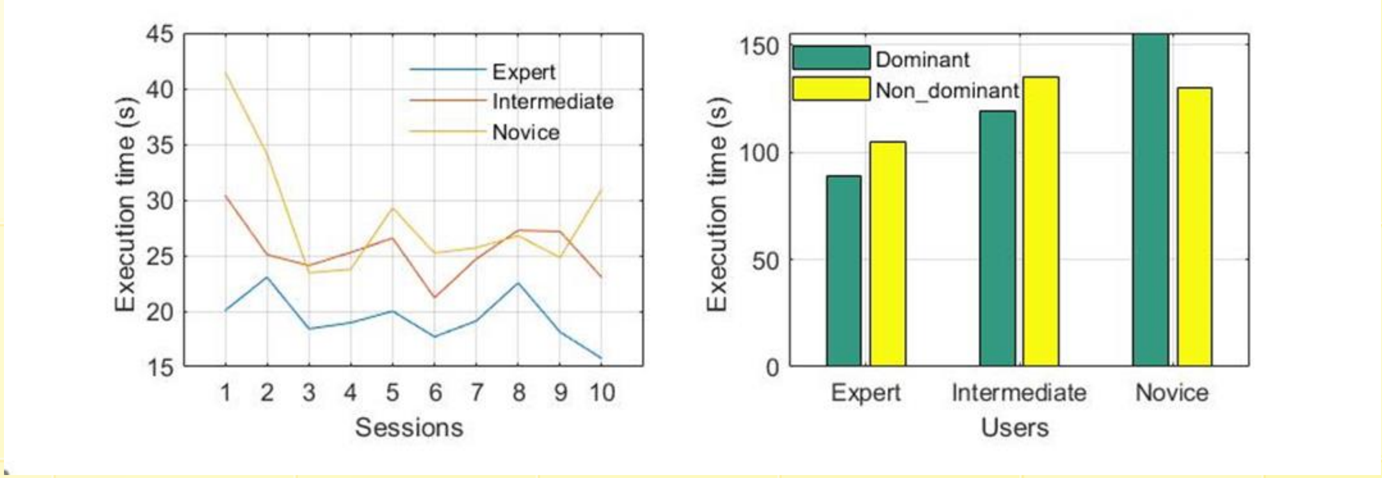
User	Dominant hand	Non-dominant hand
Proficient expert	4442	5244
Trained user	5974	6764
Complete novice	7780	6497

Results

Task execution time

Results from two-way ANOVA on time data as a function of user and handness

Source of variation	Degree of freedom	F	P
User	2	15.65	< 0.001
Handness	1	0.09	Not significant
User × Handness	2	4.13	<0.05



ANOVA: Analysis of variance

Results

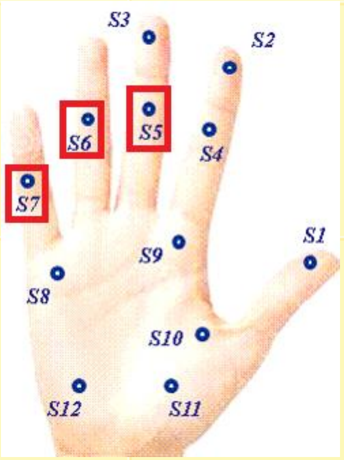
Total force across sessions (V)

Sensor	Expert_D	Expert_N	Intermi_D	Intermi_N	Novice_D	Novice_N
1	0.63	3.40	0	0.00	0	0
2	6.23	0	9.16	58.67	793.23	447.29
3	10.96	0	0	0	5328	0
4	9.03	46.90	37.50	0.60	6.07	0
5	437.13	1811.11	2901.79	283.75	5946.81	1926.19
6	2009.06	1895.47	3327.50	3520.78	3915.37	6910.31
7	2607.76	115.71	60.63	3638.08	664.06	3420.98
8	0	487.50	1064.15	38.27	5022.85	1512.46
9	2.50	534.02	786.74	0	8838.14	0.66
10	2106.27	900.44	489.66	499.17	5062.52	3246.43
11	0	3966.70	0	0	6842.42	0
12	5.15	2242.13	1593.11	0	6585.59	2.71
Total	7194.10	12003.39	10270.23	8039.33	48405.31	17467.03

Results

Three sensors on middle phalanx chosen

Sensor	Finger	Role in grip force control [3]
S5	Middle	Gross grip force deployment
S6	Ring	No meaningful role in grip force control
S7	Pinky	Precision grip force control



[3] H. Kinoshita, S. Kawai, K. Ikuta, Contributions and coordination of individual fingers in multiple finger prehension. Ergonomics, Vol. 38, Issue 6, 1995, pp. 1212-30.

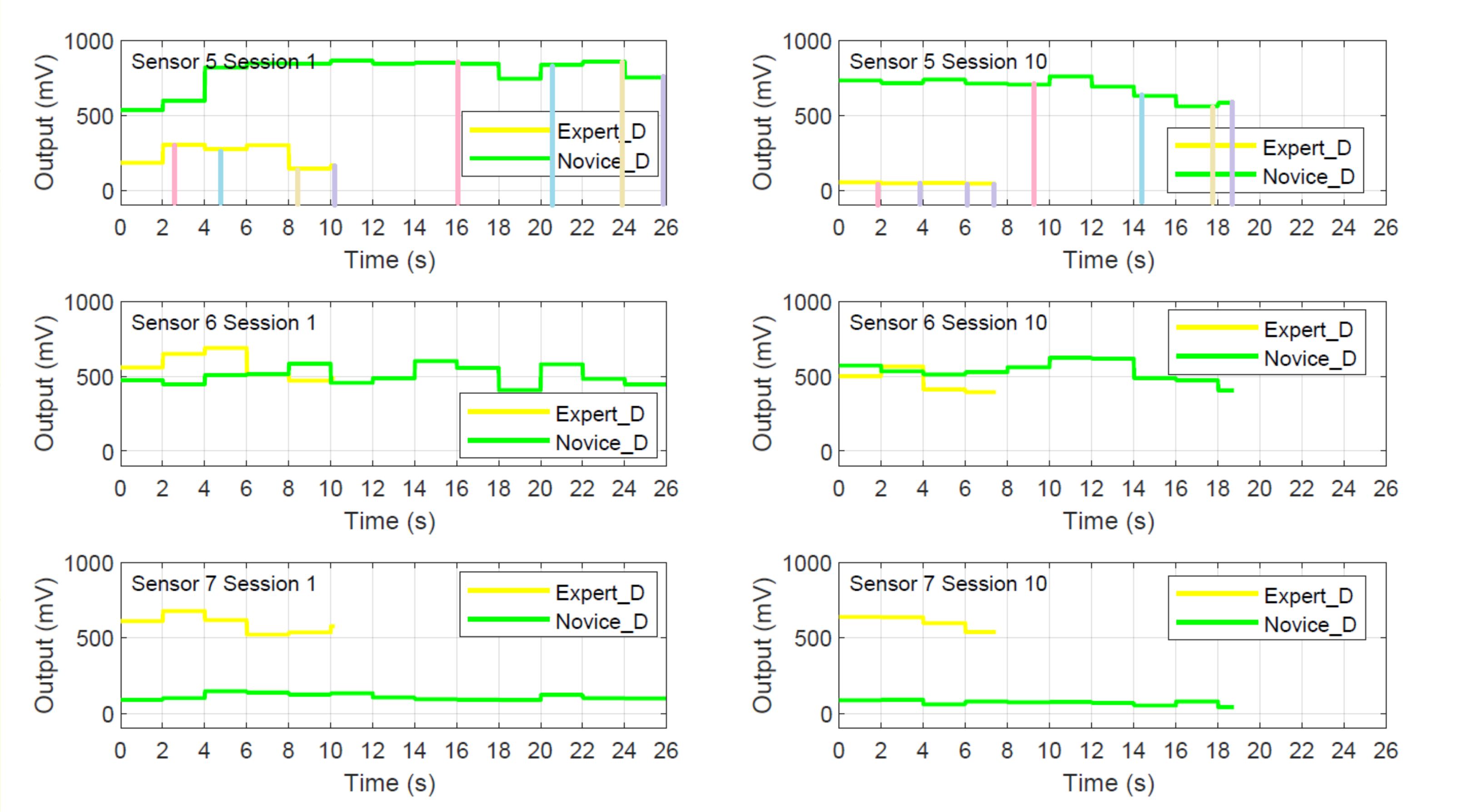
Results

Statistical comparison on raw data

Sensor	Session	Mean (m)/ SEM(sem)		Interaction significance
		Expert_D	Novice_D	
S5	First	m=240mV /sem=4.6	m=790mV /sem=3.0	F(1,3120)=169.39; p<0.001
	Last	m = 48mV /sem=0.4	m=692mV /sem=2.2	
S6	First	m=576mV /sem=4.5	m=504mV /sem=2.4	F(1, 3120)=394.24; p<0.001
	Last	m=474mV /sem=5.2	m=540mV /sem=2.2	
S7	First	m=594mV /sem=3.4	m= 111mV /sem=0.8	F(1, 3120)=260.72 p<0.001
	Last	m=609mV /sem=2.4	m= 73mV /sem=0.6	

Results

Average peak amplitudes

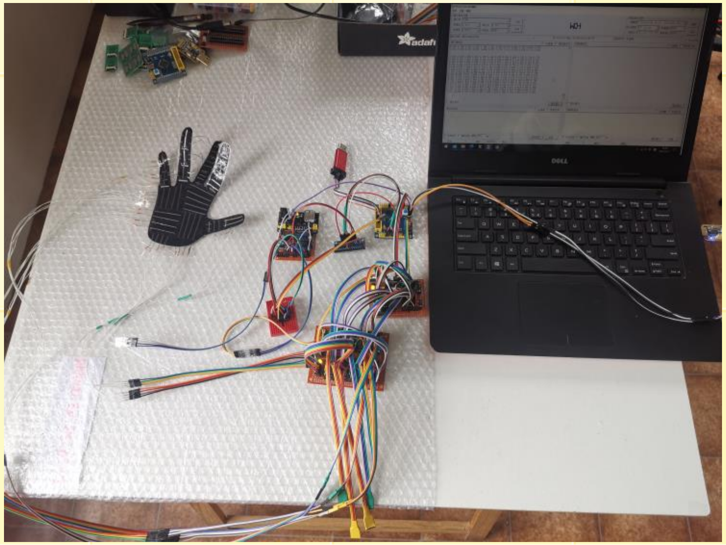


Discussion

- ✓ Spatiotemporal grip force analysis for wearable wireless biosensor
- ✓ Wireless wearable sensor technology makes it easier for real-time tracking of the evolution of individual force profile
- ✓ Grip force strategy revealing task skill evolution and expertise
- To deliver insight to
  - risk prevention in robotic assisted surgery systems
  - feed-back to junior surgeons during training
  - rehabilitation robot assisting for precision tasks

Ongoing work

Updated glove system with more advanced sensors [4]

[4] Sundaram S, Kellnhofer P, Li Y, et al. Learning the signatures of the human grasp using a scalable tactile glove[J]. Nature, 2019, 569(7758): 698-702.

Acknowlegement

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Thanks for your attention