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Improving a User's Haptic Perceptual Sensitivity by Optimizing Effective Manipulability of a Redundant User Interface

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OUTLINE

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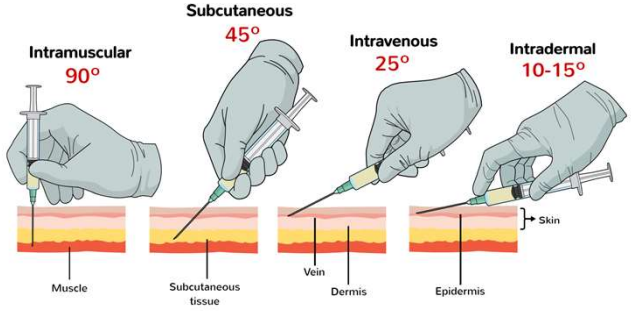
2. Related works
3. Main idea
4. Experimental design
5. Results
6. Conclusion

1 Motivation

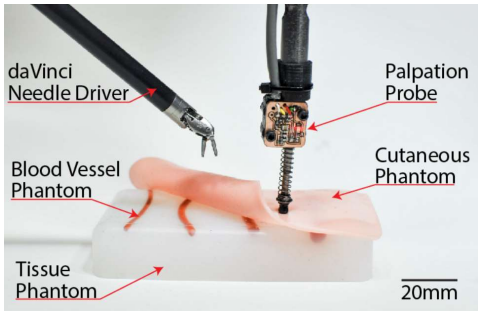
Palpation

(https://learnmuscles.com/blog/2017/08/14/palpation-assessment-neck/)



Needle insertion

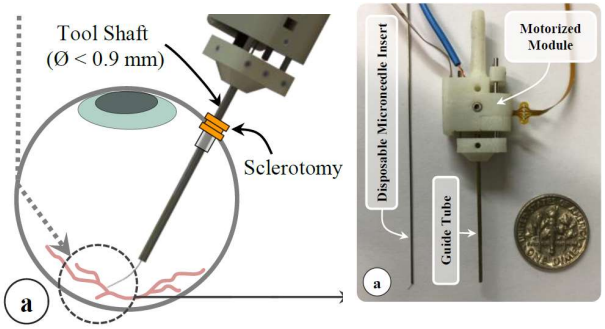
(https://www.pitribe.com/posts/injection-techniques-71201475712078)



Palpation probe for dVRK

(McKinley et al., 2015)

(https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7294253&tag=1)

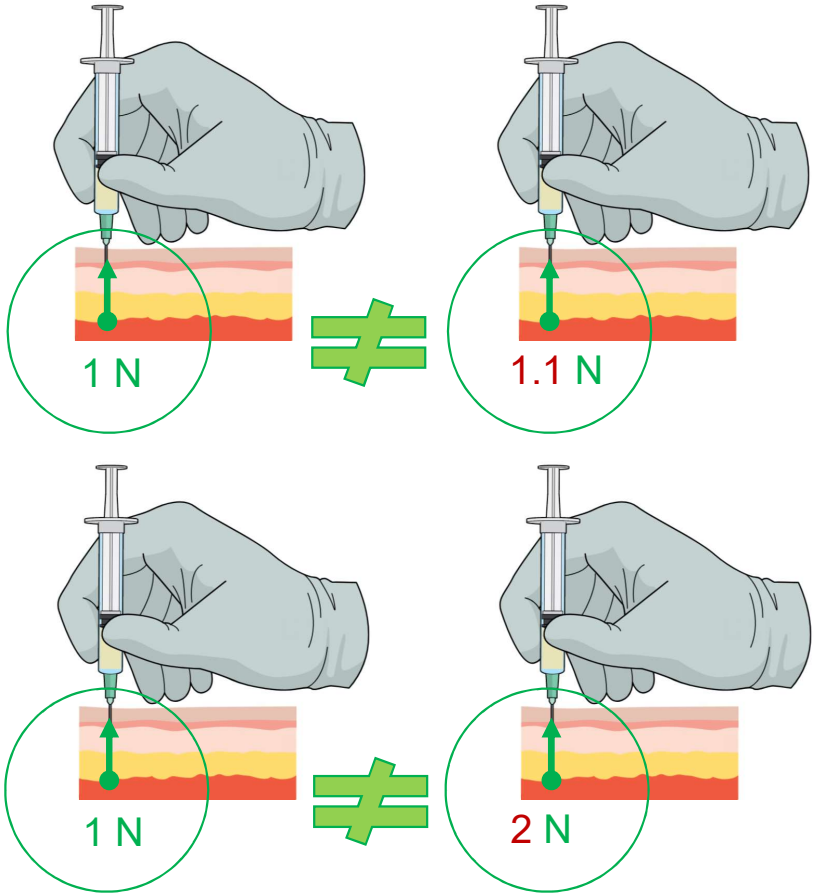


Force sensing microneedle

(Gonenc et al., 2017)

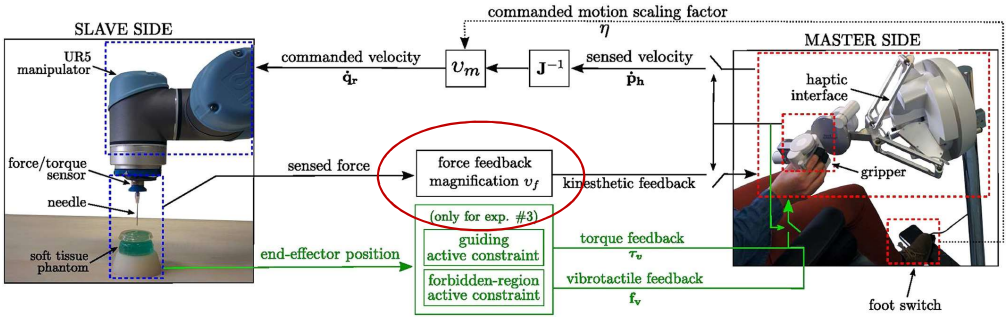
(https://www.mdpi.com/1424-8220/17/10/2195/htm#)

Haptic perceptual sensitivity ?



2 Related works

- **Scaling force feedback**

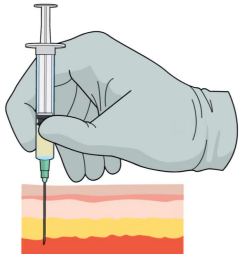


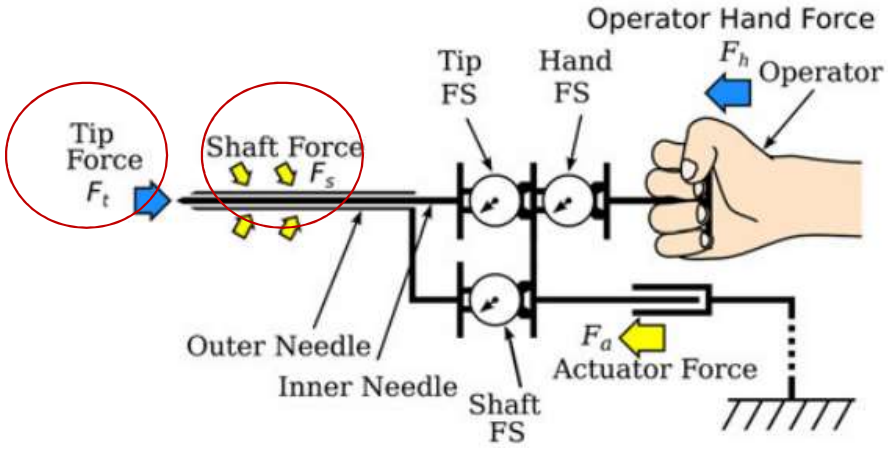
Teleoperation system with haptic feedback

(Meli et al., 2017)

(https://onlinelibrary.wiley.com/doi/10.1002/rcs.1809)

- **New device**





Co-axial needle insertion assistant

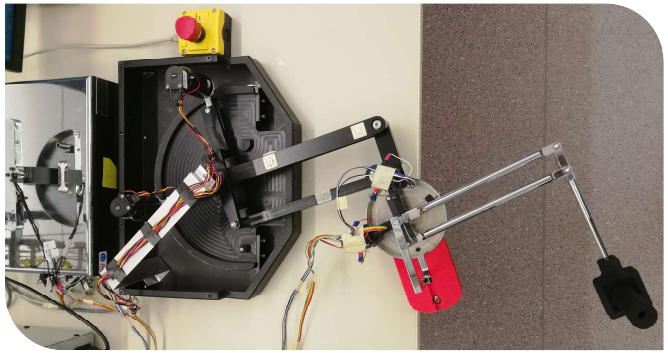
(De Lorenzo et al., 2013)

(https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6353180)

3 Main idea

Highlights:

- focus on one specific redundant robot;
- explore difference optimization methods in robot null space for improving haptic perceptual sensitivity.



OPTIMIZING
Effective manipulability:

$\rho = (u^T(JJ^T)^{-1}u)^{-1/2}$

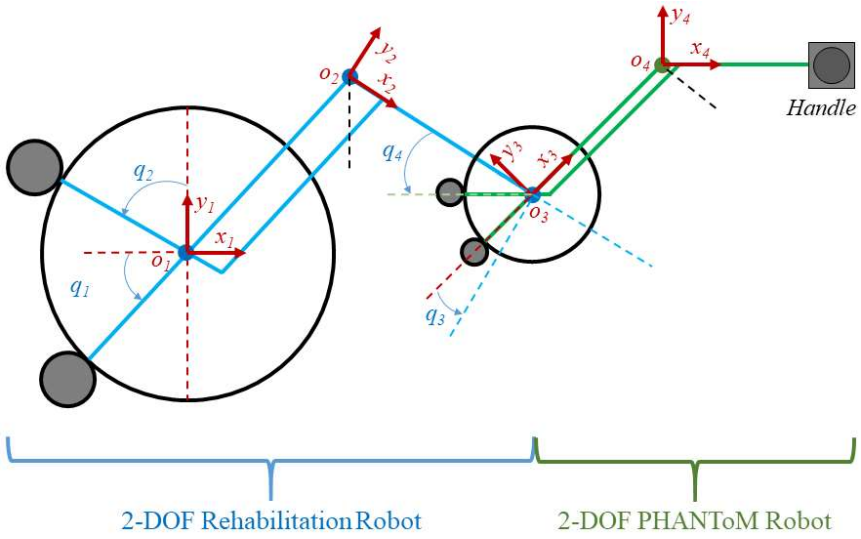
Questions:

1. How perceptual sensitivity of friction and stiffness will be affected by different methods of optimizing the effective manipulability (EM) of a redundant robot?
2. Is there any trade-off effect on the haptic perceptual sensitivity when optimizing the EM to be isotropic?

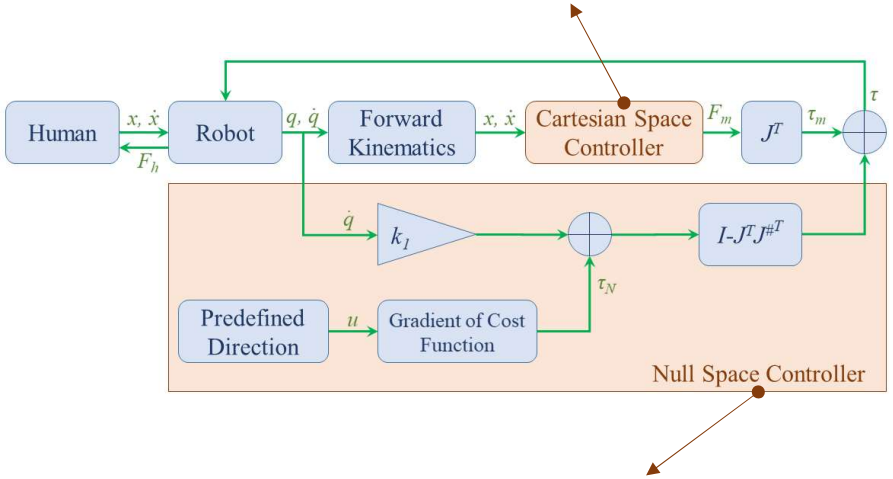
Hypotheses:

1. The perceptual sensitivity of both friction and stiffness CAN BE improved by maximizing the EM along the movement direction.
2. THERE IS a trade-off effect for isotropic condition.

4 Experimental design: (1) Apparatus



Generate haptic stimuli: friction and stiffness



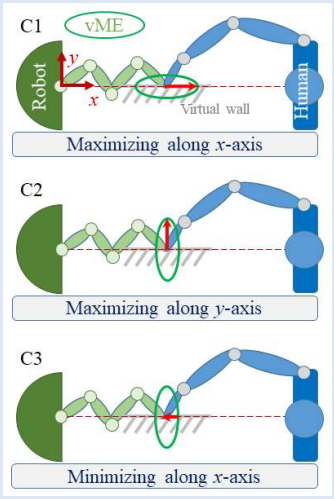
Implement optimization methods

Custom 4-DOF planar robot

Controller for the 4-DOF robot

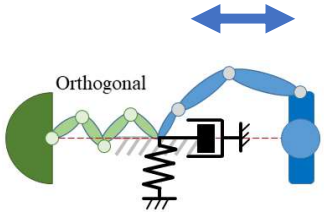
4 Experimental design: (2) 4 optimization methods and 8 conditions

C1, C2, C3

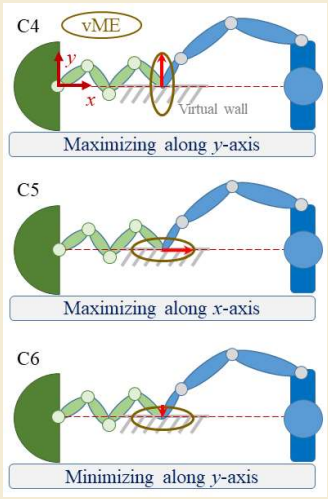


EXP. 1, **friction** discrimination task, mimicking tangential palpation

Movement direction: **x**

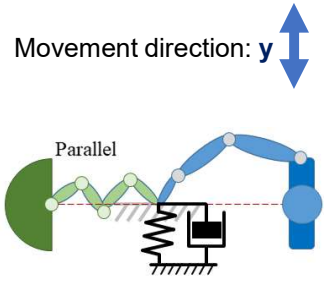


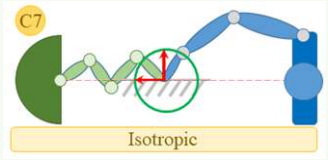
C4, C5, C6



EXP. 2, **stiffness** discrimination task, mimicking needle insertion

Movement direction: **y**





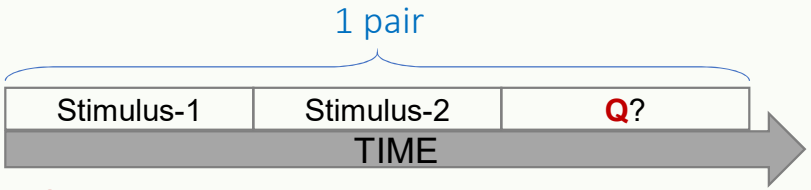
EXP. 3, **isotropic** conditions, one for friction and one for stiffness.

C7, C8

4 Experimental design: (3) Paradigm

Paradigm:

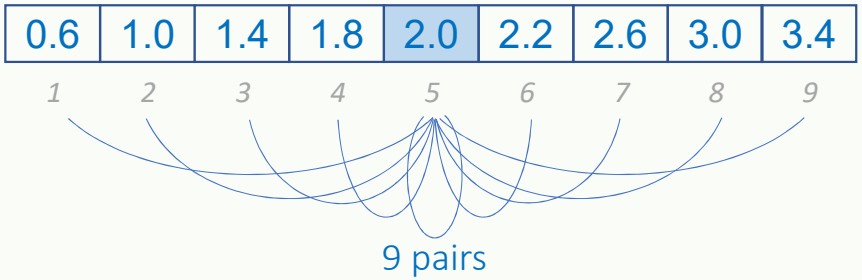
- 2AFC (two alternative forced choice)



Q:
whether the 2nd stimulus (i.e., friction or stiffness) is higher than the 1st one?

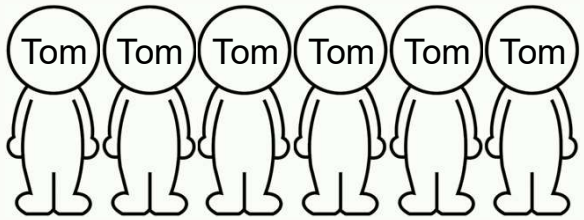
A:
yes or no.

Friction levels (Ns/m):

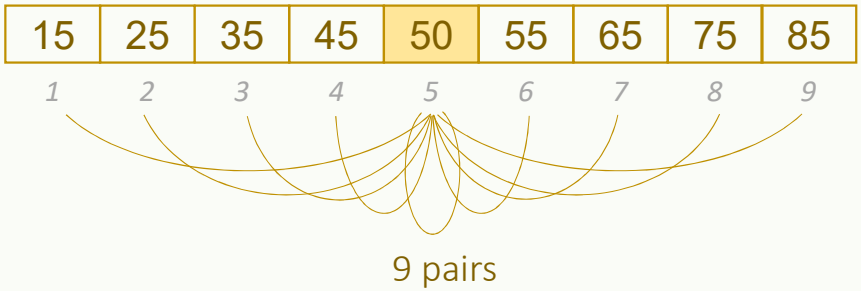


9 pairs x 10 repetitions = 90 trials (each condition)

Subject:



Stiffness levels (N/m):



9 pairs x 10 repetitions = 90 trials (each condition)

5 Results: (1) JND and WF

Fitted psychometric function curve on PF data for each condition

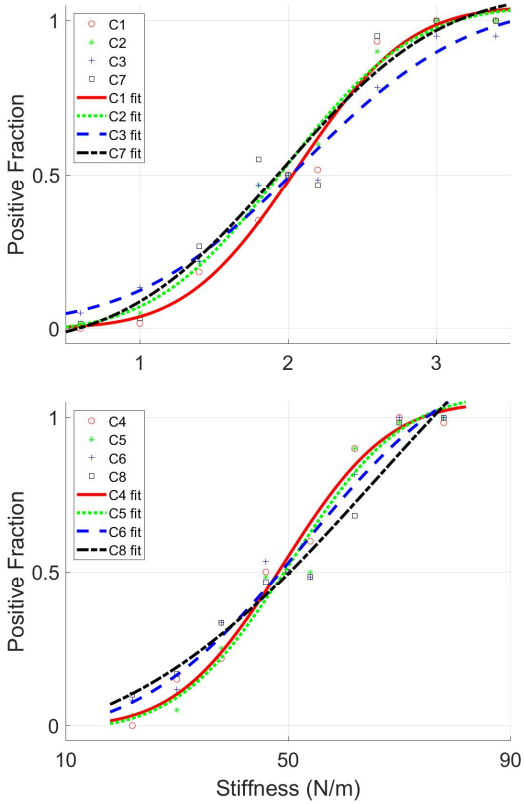


Table 1: Summary of JND and WF in each condition.

Friction Task			Stiffness Task		
Cond.	JND	WF	Cond.	JND	WF
C1	0.3642	0.1819	C4	0.1094	0.2282
C2	0.4317	0.2199	C5	0.1187	0.2399
C3	0.5410	0.2767	C6	0.1534	0.3184
C7	0.4746	0.2474	C8	0.1819	0.3731

UT
(upper threshold)

LT
(lower threshold)

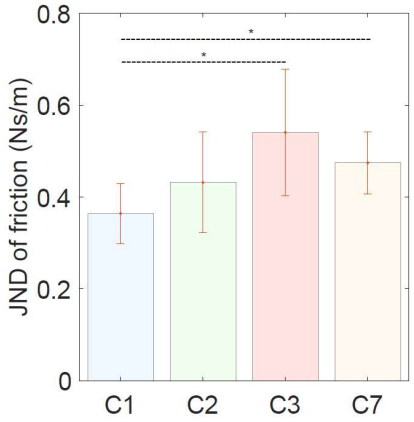
PSE
(point of subjective equality)

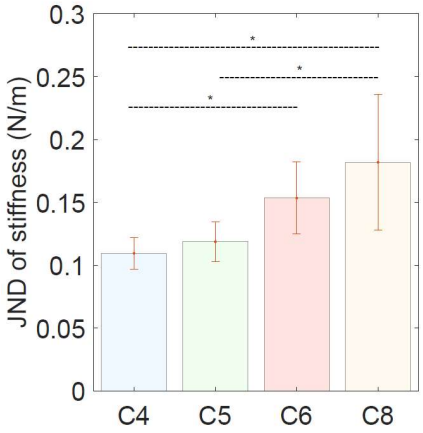
WF
(Weber Fraction)

$$WF = \frac{JND}{PSE}$$

JND
(just noticeable difference)

5 **Results:** (2) Statistical analysis





EXP.1 (C1,C2,C3)

Friction: C1 < C3 (*)

EXP.2 (C4,C5,C6)

Stiffness: C4 < C6 (*)

EXP.3 (C7,C8)

Friction: C1 ~ C7 (*); C7 < C3

Stiffness: C4 ~ C8 (*); C8 > C6

Conclusion-1:

- By maximizing the EM along the movement direction, user's perceptual sensitivity of both friction and stiffness can be significantly improved.

- NO Conclusion, need more experiments.

Limitations:

- Small participants pool
- Potential bias

6 Conclusion

Conclusion:

- User's haptic perceptual sensitivity of friction and stiffness can be significantly improved by appropriately optimizing the effective manipulability (EM) with making use of the intrinsic property of kinematic redundancy.

Future work:

- How masking effect will influence the haptic perceptual sensitivity?
- Whether the same optimization approach used in this paper can also benefit the perceptual sensitivity of other types of forces, e.g., torques, inertia.

ACKNOWLEDGEMENT

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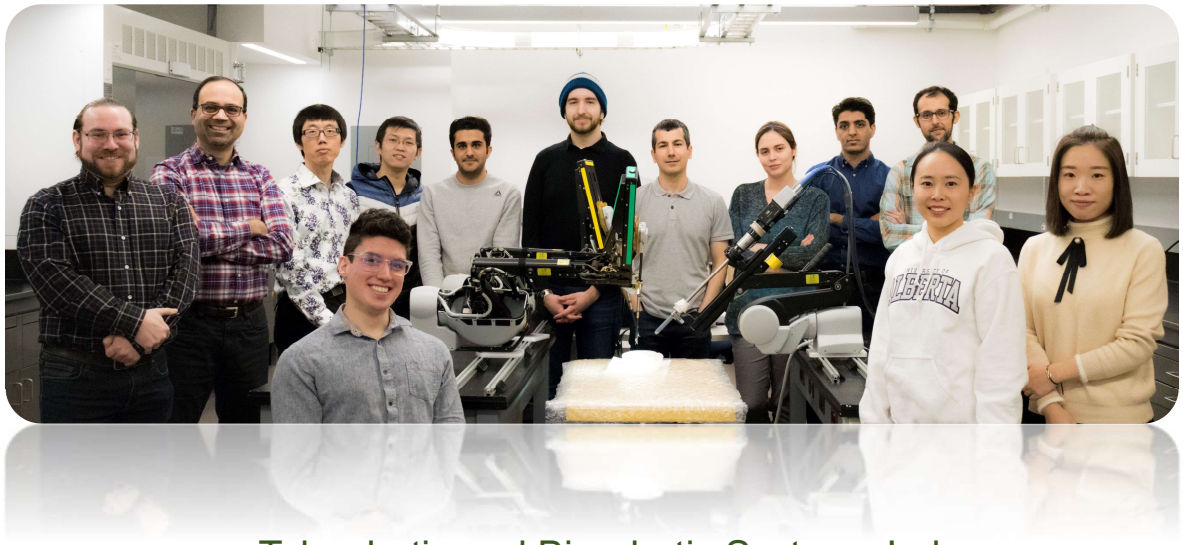
- Natural Sciences and Engineering Research Council (NSERC) of Canada

TBS group:



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