A Metric for Hand Comfort/Discomfort Evaluation
Towards Expressivity in Spatial Control

Bachelor Thesis Presentation

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Garching, July 13th 2016

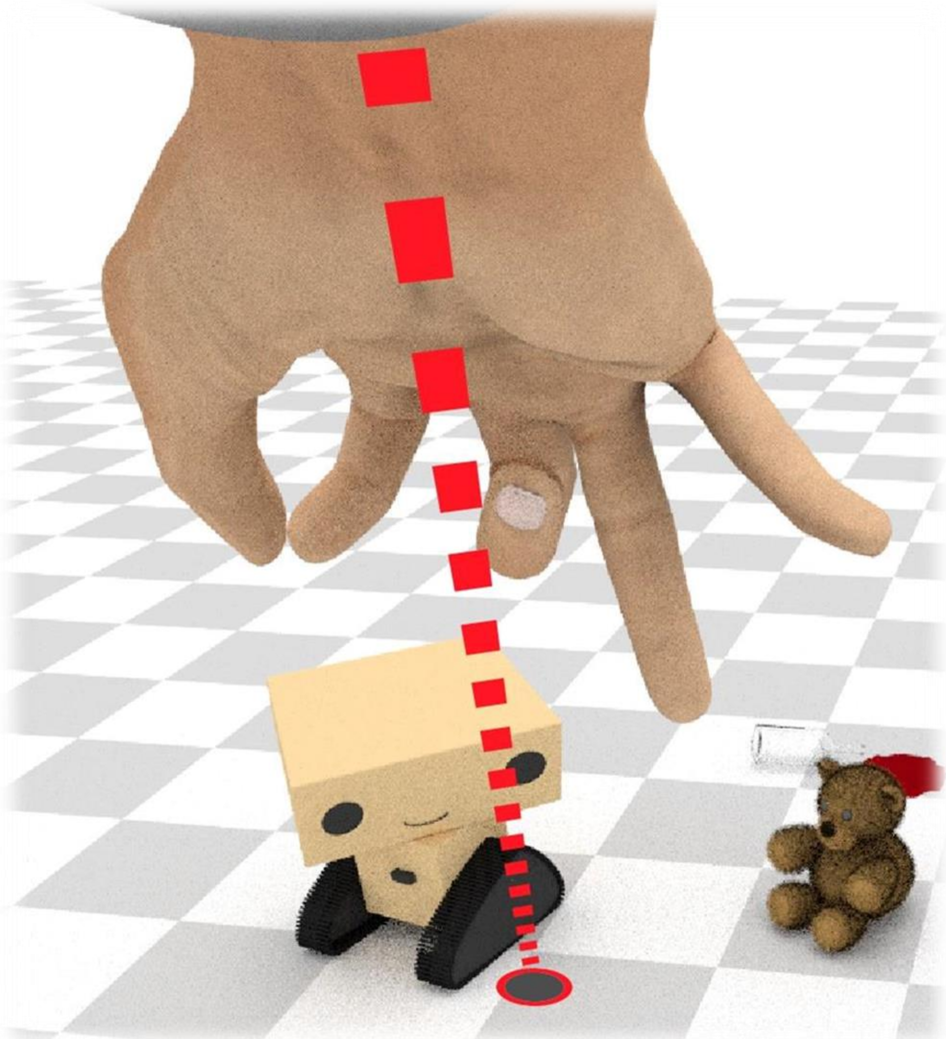
Motivation: Controlling a Robot

Traditional input methods and speech not optimal

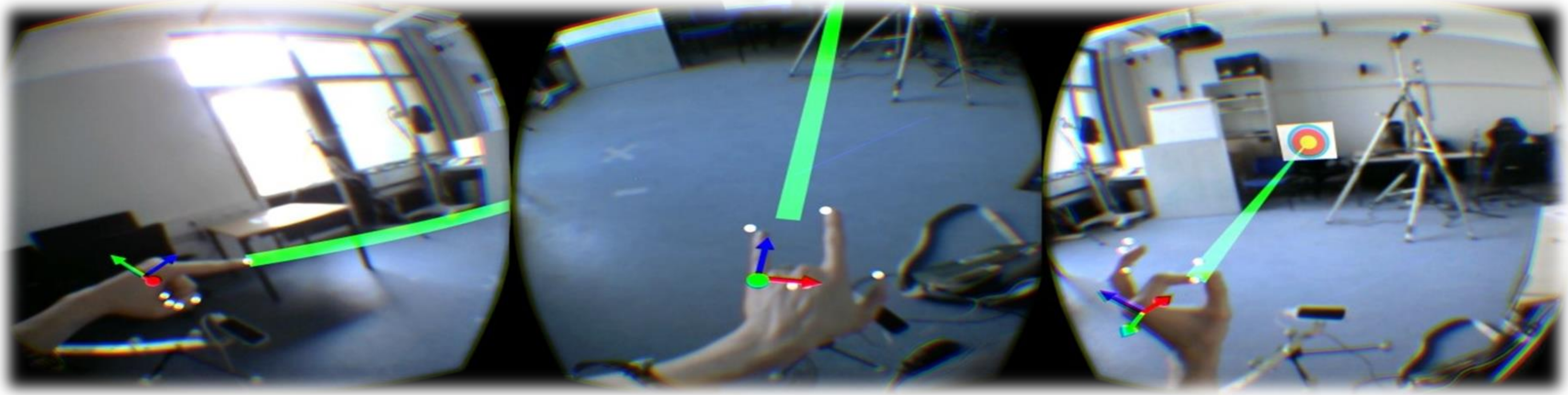
→ Use gestures and postures

→ Designer challenge: which hand postures are the best for

– Performance?
– User Experience?



Related Work: Nicholas Schneider (TUM)



Compare three different hand postures

- Point
- Spiderman
- Pinch

in a target shooting test regarding performance and user experience.

Results:

- Pointing posture generally best

Study Goal

Problem

Hand posture evaluation either subjective or work intensive

Hypothesis

Hand posture comfort and discomfort affect performance and obviously user experience.

Goals

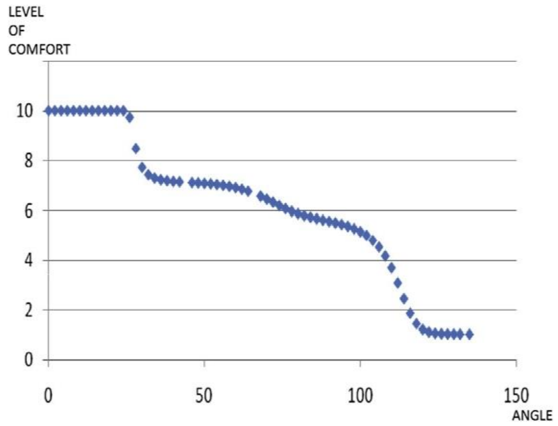
1. Create a metric for quick and objective hand posture comfort/discomfort evaluation
2. Show its effect on performance in a pointing task

Related Work

Apostolico et al:

- Introduce and determine the Range of Rest Posture for human joints (later more)

Naddeo et al:



- Propose a quantitative method for postural comfort evaluation
- Comfort based on the distance to the range of rest posture

Short et al:

- Comfortable postures generally generate higher accuracy

Related Work: Comfort and Discomfort (Vink et al.)

Comfort

- “pleasant state or relaxed feeling of a human being”
- Influenced by subjective impressions and expectations

Discomfort

- “an unpleasant state of the human body”
- Caused by physical stress

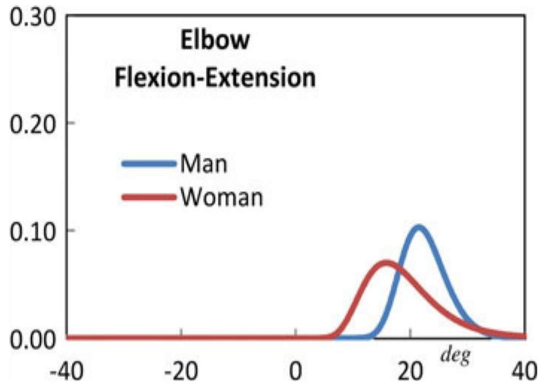
Hand Comfort/Discomfort Components

Four components affect hand comfort/discomfort:

- Deviation from Range of Rest Posture (RRP)
- Inter Finger Angles (IFA)
- Finger Hyperextension (HE)
- Finger Abduction (FA)

Hand Comfort/Discomfort Components

Deviation from Range of Rest Posture (RRP)



Apostolico et al:

- Every joint has a rest posture
- When in the rest posture, maximum comfort is perceived

→ Deviation from rest posture should decrease comfort

- Due to anatomical differences: look at Range of Rest Posture
- In our case: look at the RRPs for all hand joints

Hand Comfort/Discomfort Components

Inter Finger Angles (IFA)

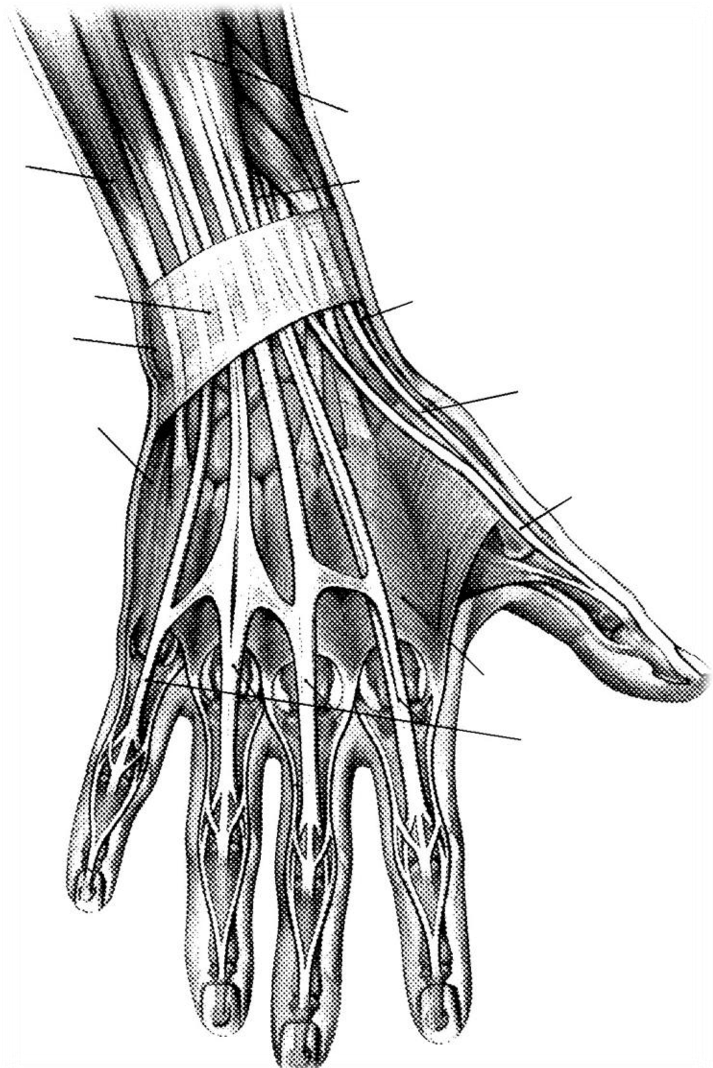
Complex Hand Anatomy:

- Finger extendors and flexors share same muscles
- Inter-finger tendons

→ Individual finger movement limited

- High inter finger angle differences create stress on tendons, muscles

→ Discomfort



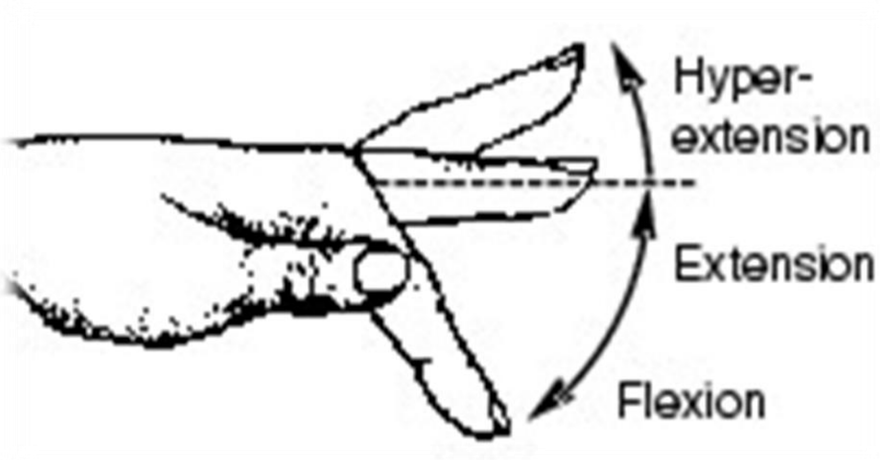
Hand Comfort/Discomfort Components

Finger Hyperextension (HE)

- LaViola et al. : “[hyperextension] puts more strain on the [MCP] joints and tendons than the hand is accustomed to”

→ High stress on joints, tendons, muscles

→ Discomfort



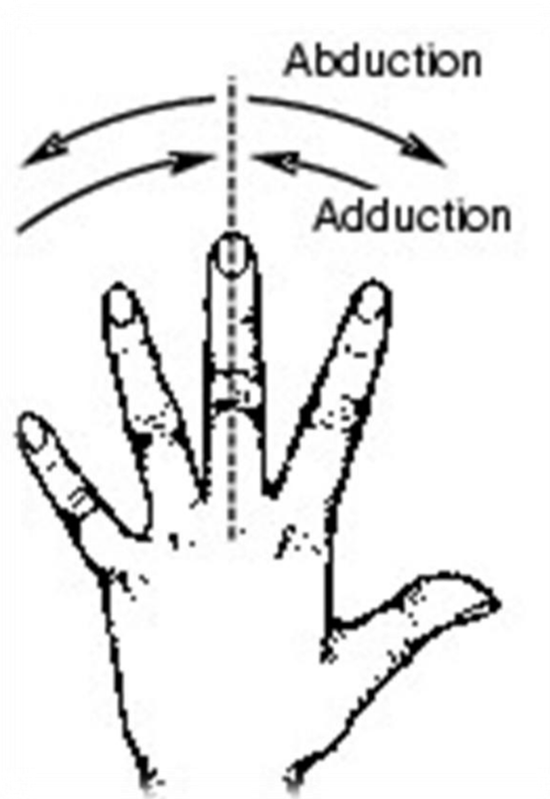
Hand Comfort/Discomfort Components

Finger Abduction (FA)

Analog to hyperextension:

- High abduction creates stress on joints, tendons, muscles, soft tissue

→ Discomfort



Concrete Implementation: RRP Metric Comp.

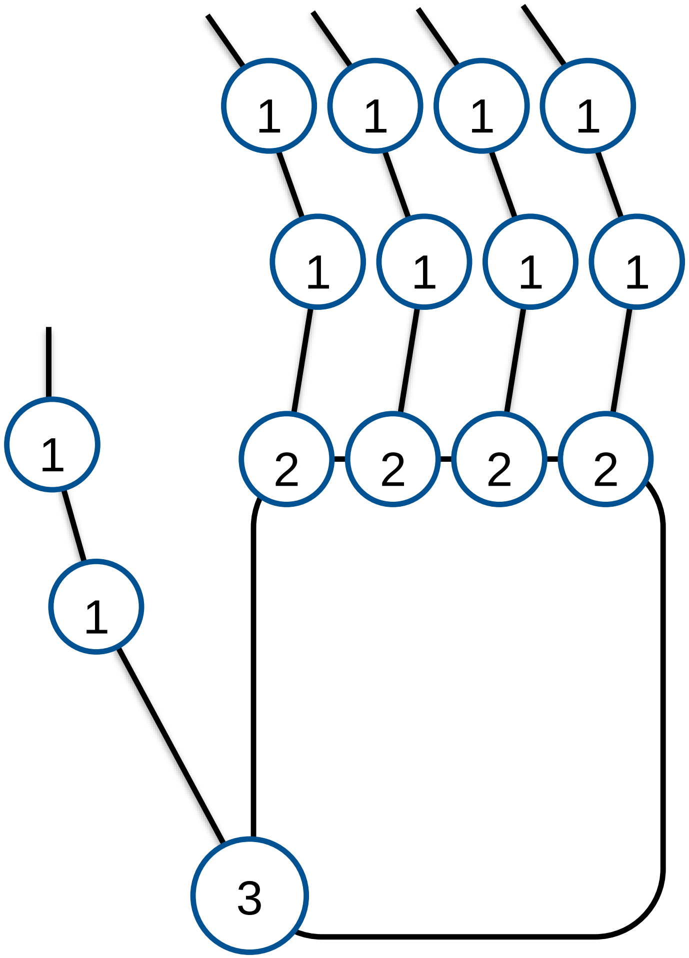
Hand Model:

21 DOF Angle Based Hand

→ Interpret Hand as a vector of length 21

In Theory:

- There is a RRP for each DOF
  - → Identify RRP for each DOF
  - → For a particular hand posture, add up the distances to the RPP for each joint



Concrete Implementation: RRP Metric Comp.

For simplicity:

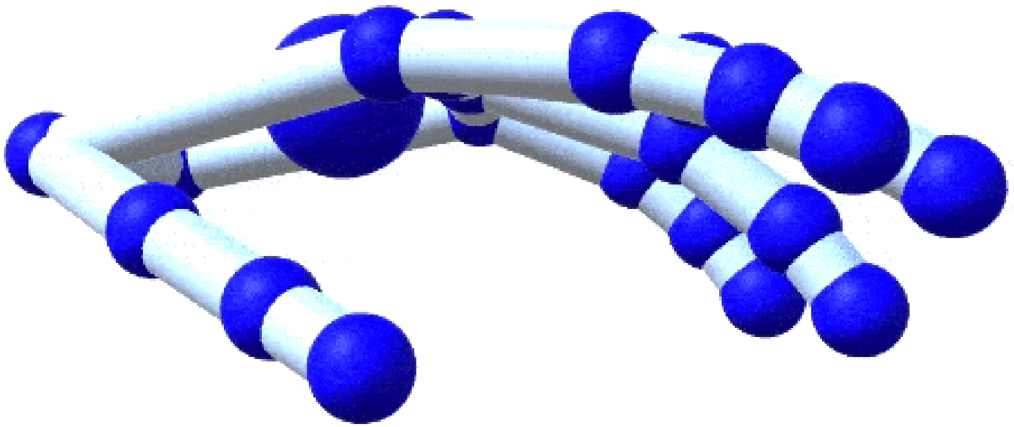
- Define RRP for whole hand as a set of 50 relaxed hand postures
- Calculate minimum Euclidian distance to RRP set for particular hand

$\rightarrow$ Yields RRP component for whole hand

$\rightarrow$ Metric value 0: maximum comfort

$\rightarrow$ Perceived comfort decreases when metric value increases

Concrete Implementation: RRP Metric Comp.



RRP-Component: 4.817713

Naïve & Improved Metric

Naïve Metric

- Add up metric components for whole hand
- Weight components with estimated importance coefficients
- Resulting metric:
  - Metric value = 0 → maximum comfort, minimum discomfort
  - Metric increases → comfort decreases, discomfort increases

Naïve & Improved Metric

Improved Metric

- Naïve Metric ignores anatomical differences of fingers

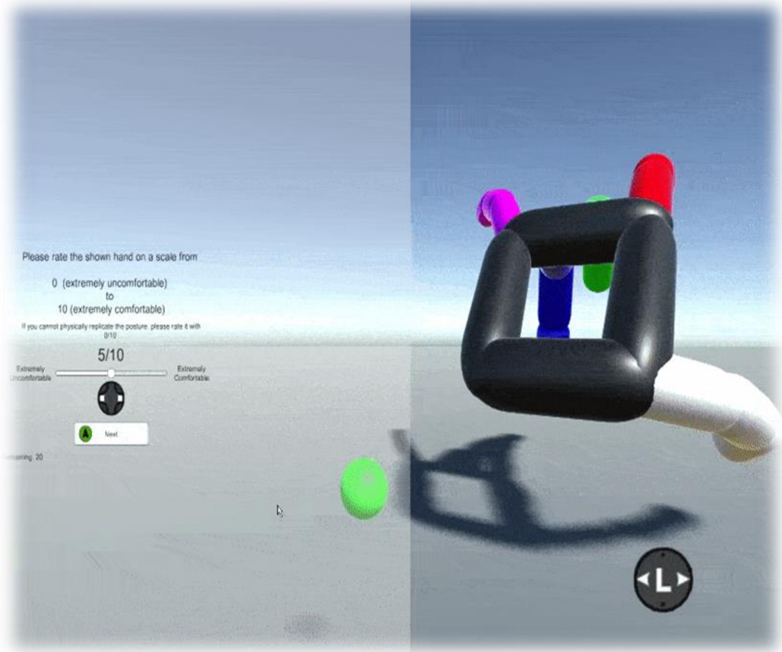
  → Compute the metric components for each finger, weight components differently
- Problem: 17 coefficients hard to estimate

  → Collect data in user study

  → Use machine learning to find optimal coefficients

User Study

Task 1: Hand Posture Rating

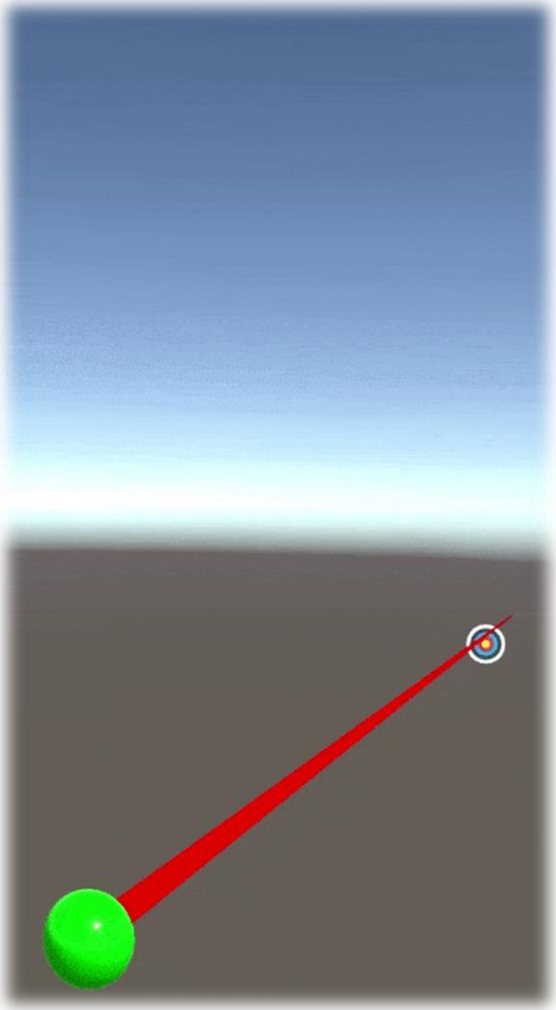


- Show subject randomly generated hand posture
- Subject has to mimic hand posture
- Subject has to rate hand posture on a intuitive comfort/discomfort scale from 0 to 10
- Beforehand: show relaxed and extremely uncomfortable hand posture for reference

User Study

Task 2: Target Shooting

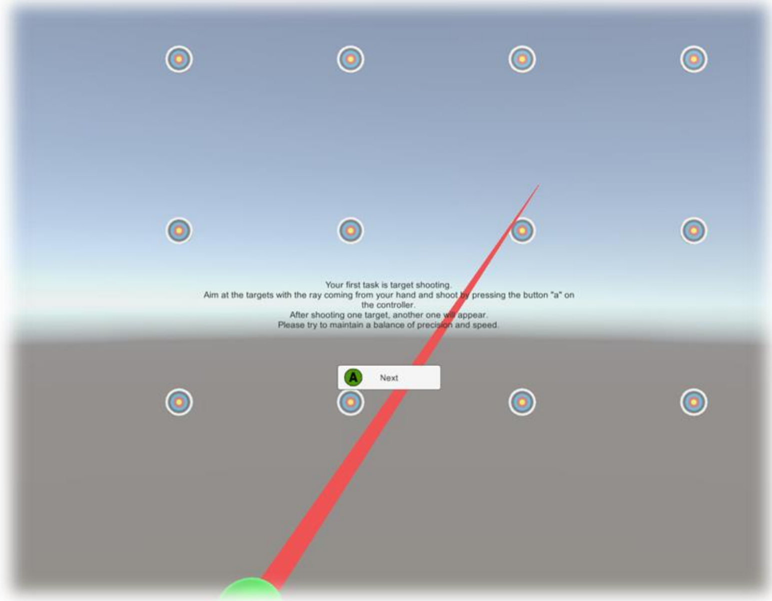
- Again show subject randomly generated hand posture
- Again mimic and rate
- Subject has to perform target shooting test using that posture
- Detect palm pose with ART
- Track hand posture with Leap



User Study

Task 2 (contd.)

- Total of 12 randomly sorted targets
- Measure for performance: total task completion time
- Logged Parameters:
  - User Rating
  - Comfort/Discomfort Components
  - Total Task Time
  - Complete hand



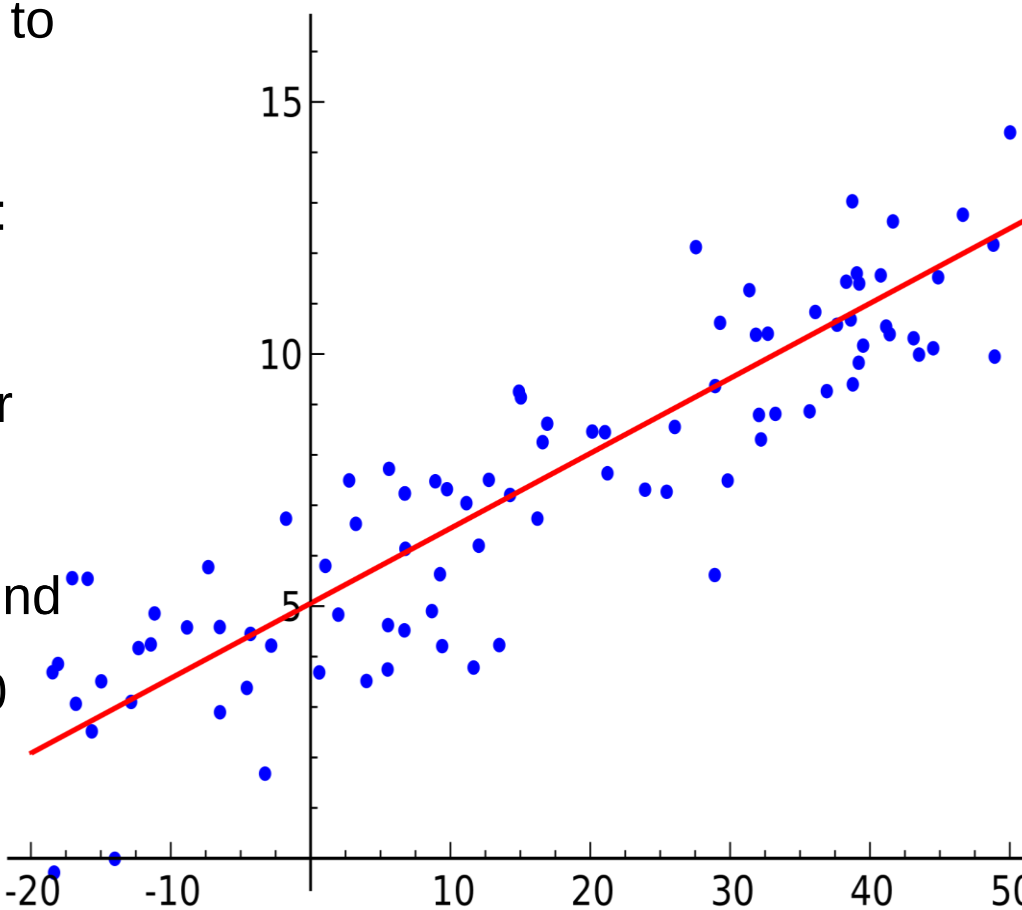
Rating	Time	TrackingTime	Discomfort	Comfort	InterDis	AbductionDis	Hyp
7	24.35302	24.35302	211.1105	86.28854	25.34901	58.50742	28.03
4	27.03682	27.03682	582.1575	155.1629	228.6278	86.03073	33.57
10	27.23485	27.23485	97.4476	67.92812	13.18796	19.57844	19.25
10	27.81598	27.81598	192.4765	74.12668	20.34395	56.77102	24.20
0	65.49729	65.44778	887.3972	132.4908	501.8463	67.31384	0
10	17.56067	17.56067	92.06805	62.72218	33.25956	8.7363	12.35
1	45.81142	45.81142	325.3717	139.8513	126.8197	67.57104	0
10	23.49111	23.49111	143.0759	45.85537	31.82211	34.8491	12.82
9	27.96473	26.75558	437.5583	157.6621	181.3869	82.739	0
9	26.93743	20.21042	215.1297	45.26986	40.25454	38.06713	39.30
6	24.28728	24.28728	330.3411	150.1753	86.89615	99.99842	0
8	23.3255	20.67521	291.0479	77.15829	119.5171	55.88611	0
7	17.44468	17.44468	659.526	150.4418	324.4739	75.38029	11.02
0	25.87739	25.87739	638.7302	97.06744	368.3328	43.11551	0
8	17.27813	17.27813	141.5535	65.75641	10.19526	41.70477	21.42
9	44.94618	44.87933	445.2013	140.9173	226.0821	53.03904	0
1	47.43057	42.04634	658.1998	143.8268	351.5622	65.42825	0
9	34.24342	31.95808	273.7015	95.52207	91.5384	68.19698	0
9	28.95937	28.95937	205.4704	46.38785	76.49554	45.36353	0
9	27.84843	27.84843	57.26177	61.30162	16.26954	11.40188	5.026

User Study

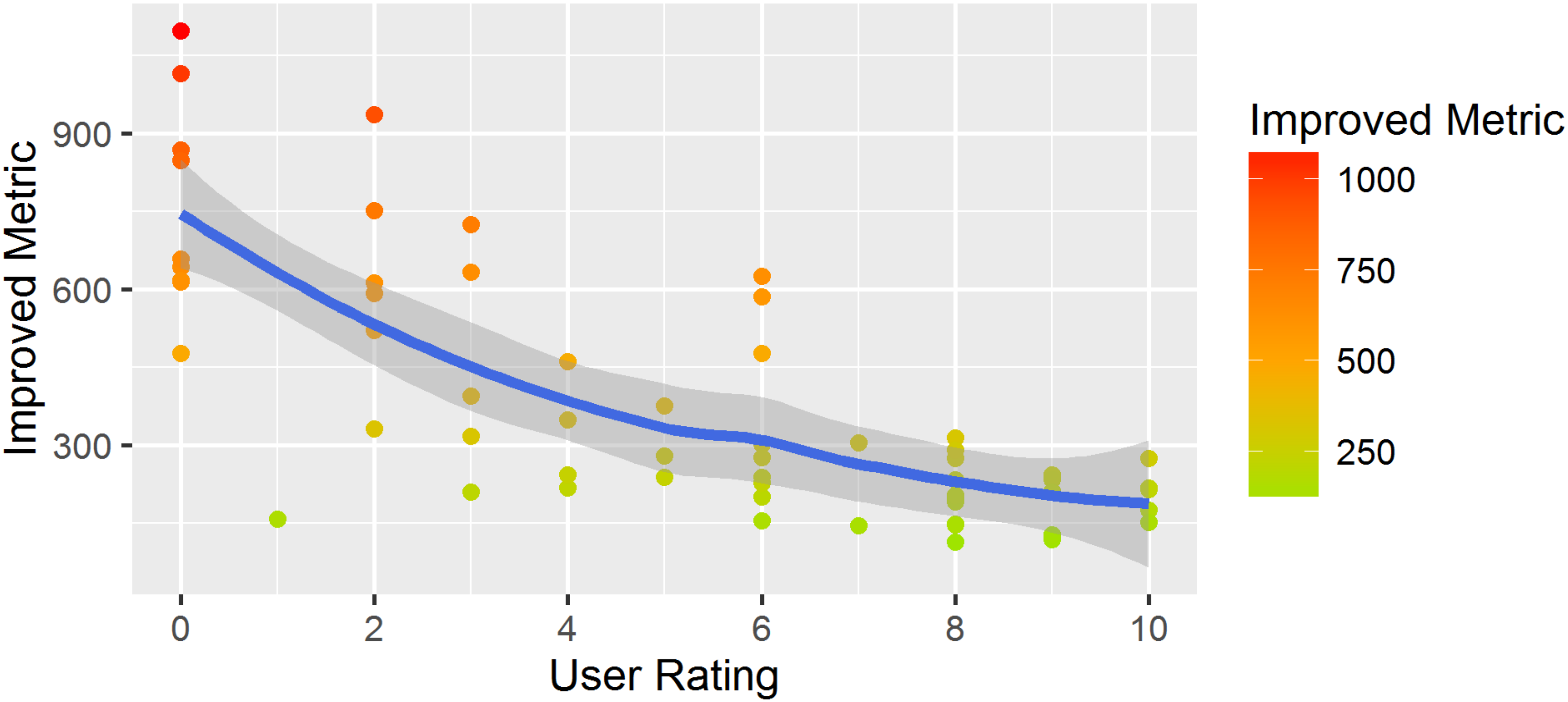
- Total of two user studies
- Total of 21 participants
- 310 data sets from User Rating
  - 250 for training the metric
  - 60 for testing the metric
- 35 data sets from Target Shooting

Improving the Metric

- Problem: finding 17 coefficients, to fit the metric to the user ratings
  - Similar to a line fitting problem:
  - We want to find parameters to minimize the error between our metric and the user rating
- Use least squares algorithm to find optimal coefficients from the 250 datasets

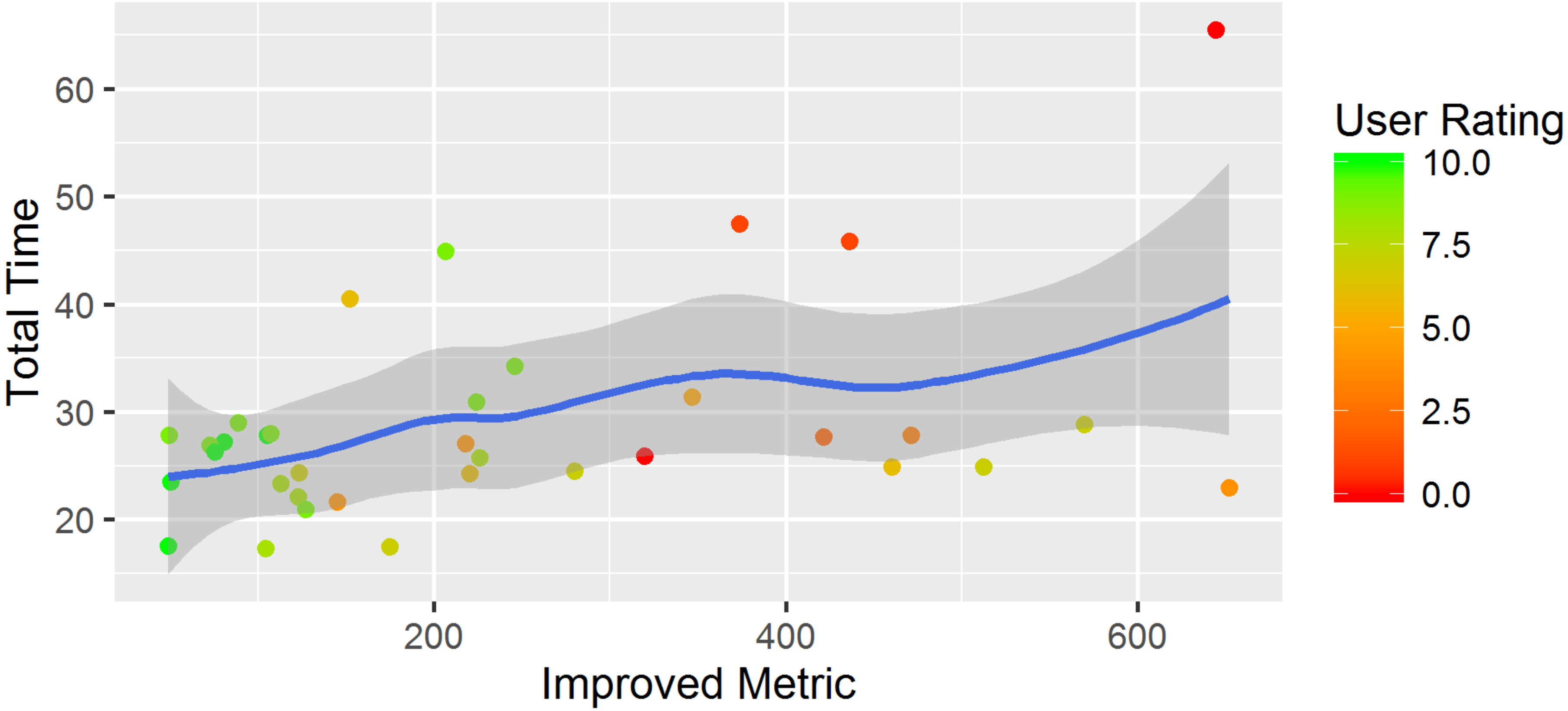


Results: Improved Metric in User Rating



Pearson Correlation: -0.748993, p-value: 5.89e-12

Results: Improved Metric in Target Shooting



Pearson Correlation: -0.6651999, p-value: 6.73e-9

Discussion

Testing the improved metric against test data

Shows reasonable correlation

→ Improved metric is good extrapolation of training data

→ The created metric reflects perceived comfort/discomfort

Target shooting test

→ Hand posture comfort does influence performance

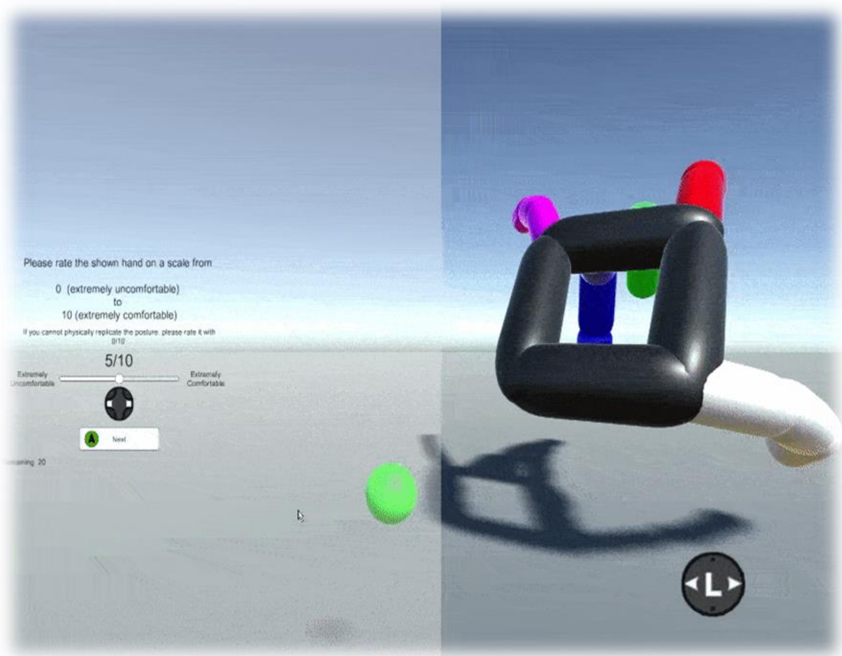
→ Strengthens Short et al. (comfort → accuracy)

But: small dimensions of study limit expressiveness

Conclusion

1. Creating a Comfort/Discomfort Metric

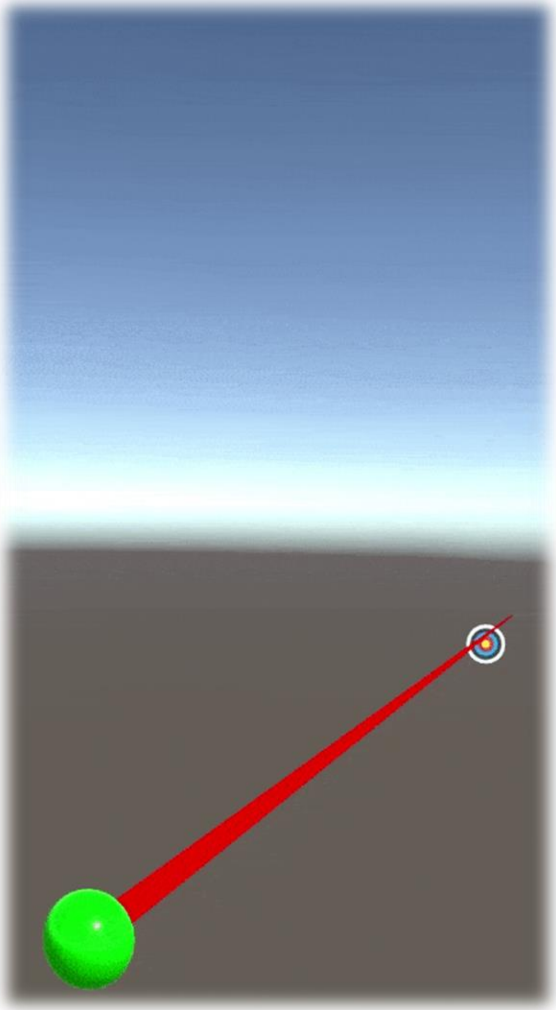
- Goal: Metric for quick, objective hand posture evaluation
- Creation based on
  - Comfort/Discomfort Models
  - Hand Anatomy and Ergonomics
- Tweaked the metric using data from a user study
- Verified the metric in a testing user study



Conclusion

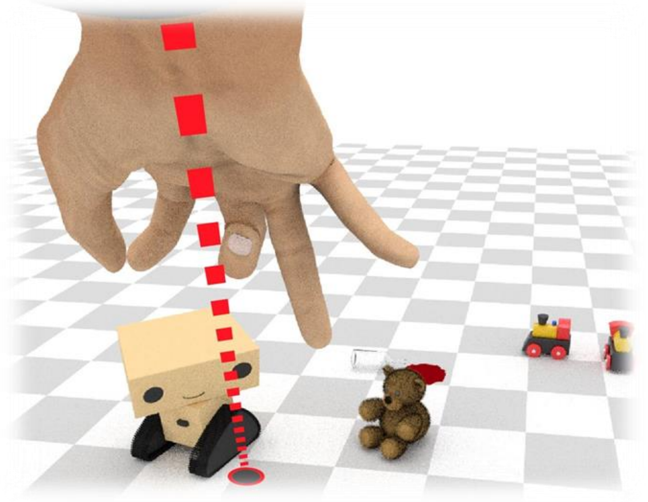
2. Showing Importance of Metric

- Goal: Show Comfort/Discomfort-Performance Correlation
- Tested in Target Shooting Task
- Test Results indicate that hand posture comfort/discomfort do affect performance



Future Work

1. Long Term Effects of Comfort and Discomfort



- Our study neglects long term effects
  - Strong discomfort symptoms are known to occur after long periods of time
  - For other contexts long term effects might be relevant

2. Create Metrics for other Contexts

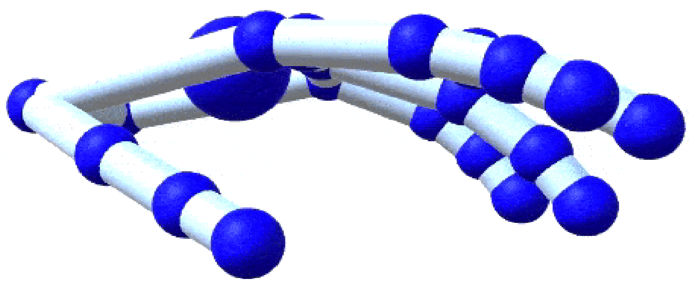
- Automotive, Seats, Mattresses (Whole Body)
- Shoes (Feet)

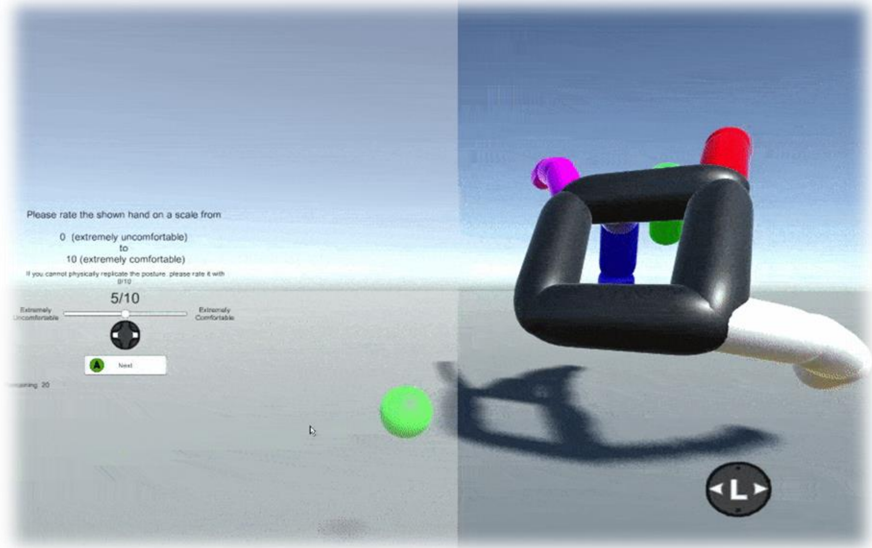
Acknowledgements

Nicholas Schneider

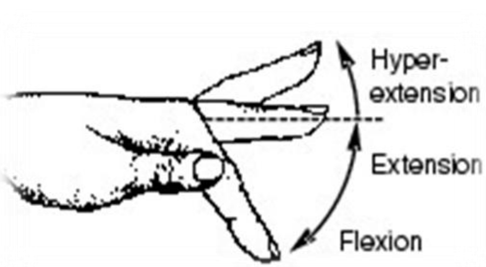
Dr. Frieder Pankratz

Questions?

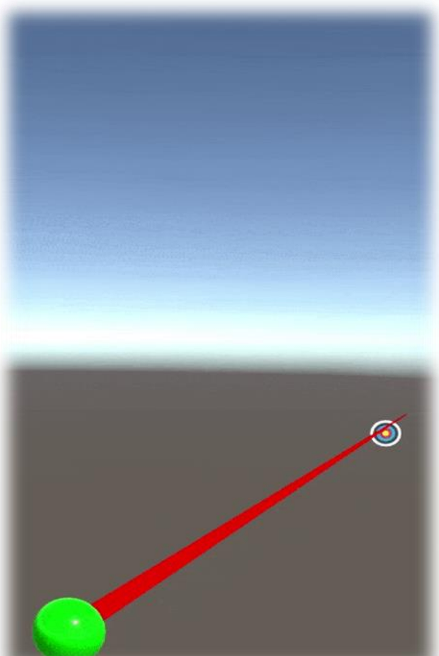


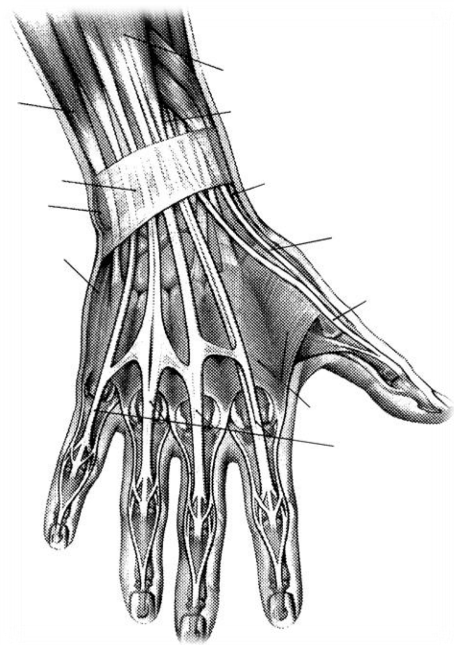


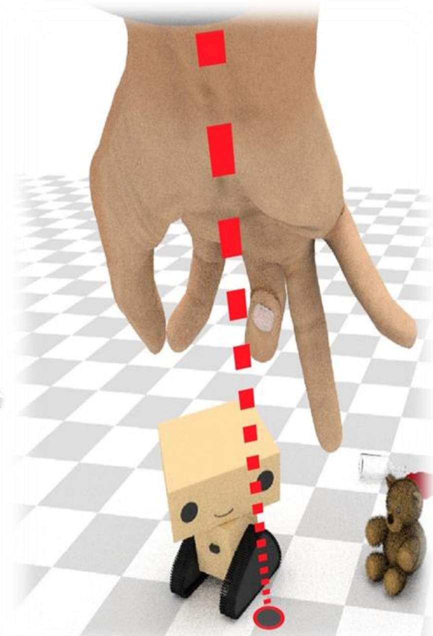
Please rate the shown hand on a scale from
0 (extremely uncomfortable)
to
10 (extremely comfortable)
5/10



Hyper-
extension
Extension
Flexion





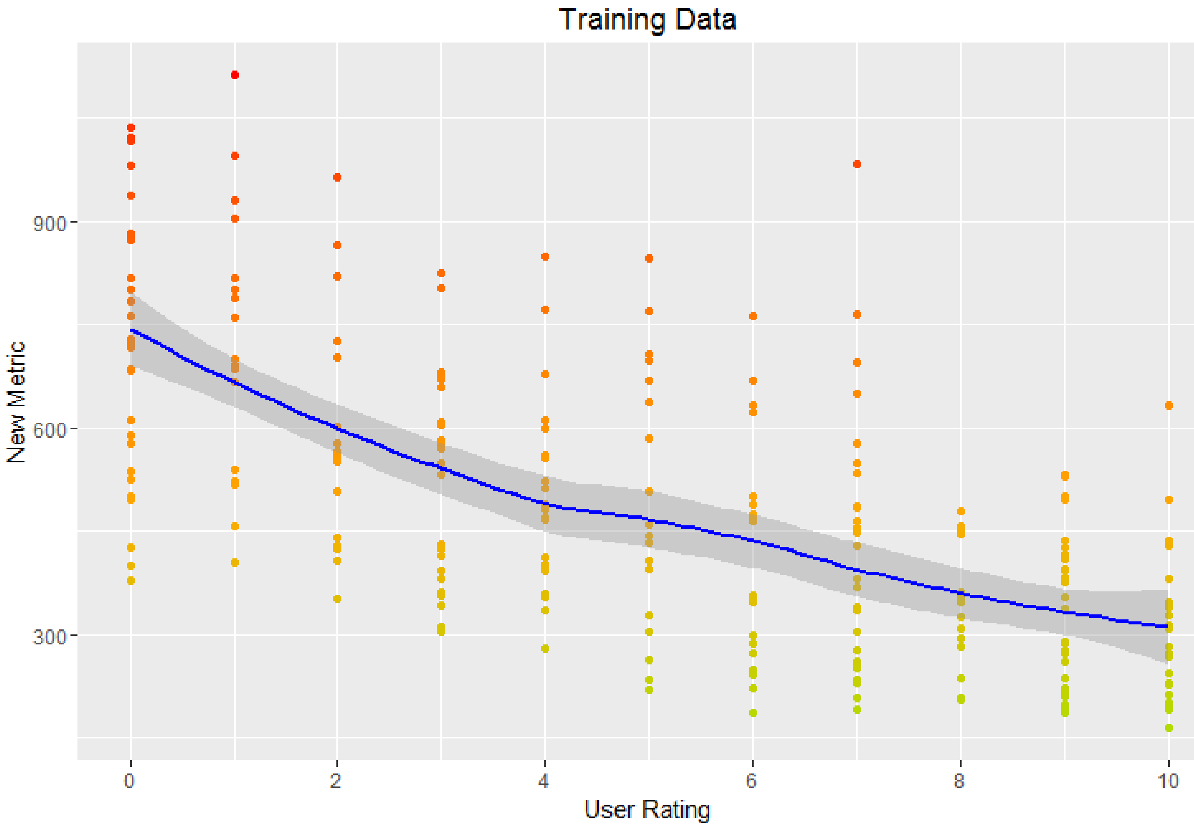


Appendix

Results

Training Data: Improved Metric and User Rating

- Pearson Correlation: -0.6453242
- p-value: < 2.2e-16
- Not perfect:
  - Anatomical and psychological differences
  - Short term effects only
  - Few discrete steps



Results

Test Data: Naive Metric and User Rating

- Pearson Correlation: -0.6651999
- p-value: 6.73e-9
- No big difference on first sight
- However, standard error is smaller, better correlation