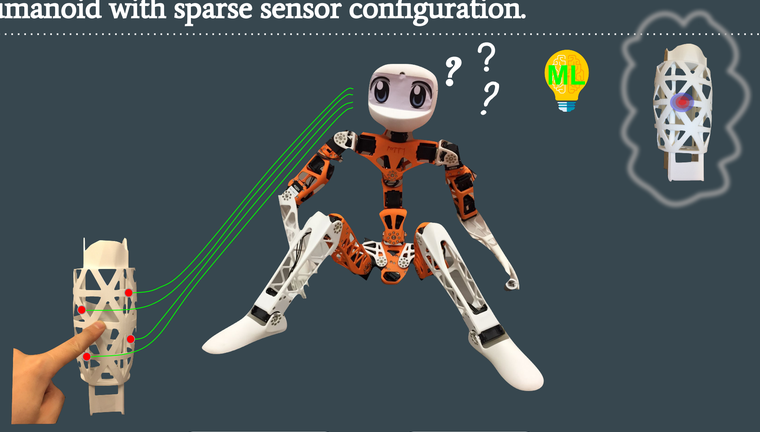
Robust Affordable 3D Haptic Sensation via Learning Deformation Patterns

Huanbo Sun & Georg Martius

Goal

TO design one 3D haptic system capable of covering all surfaces of humanoid with sparse sensor configuration.

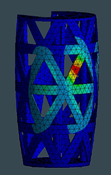
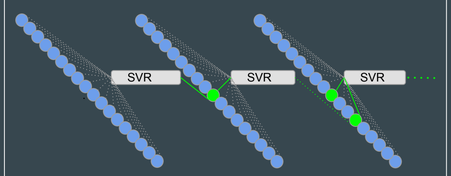
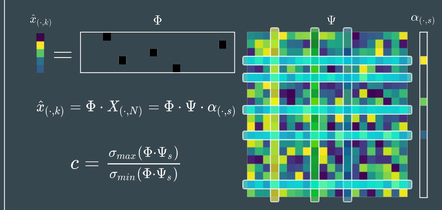
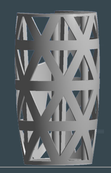
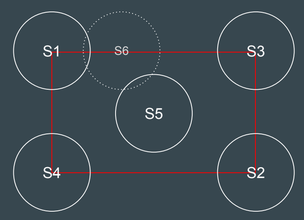
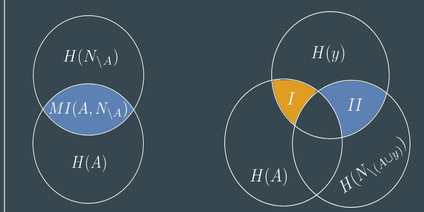


Optimal Positions | All Positions | Sensor Value

$$A = argmin_{A \subset N} \left(\mathbb{E}[\|F(X_{\cdot,A}) - p\|_2^2] < \delta \right)$$

ML Model | Force Information | Prediction Accuracy

Optimal Placement: Methods

Data-driven	Greedy Support Vector Regression	Compressive Sensing
 Dataset: X: Deformation p: Force ✓		 $\hat{x}_{(\cdot,k)} = \Phi \cdot X_{(\cdot,N)} = \Phi \cdot \Psi \cdot \alpha_{(\cdot,s)}$ $c = \frac{\sigma_{max}(\Phi \cdot \Psi_s)}{\sigma_{min}(\Phi \cdot \Psi_s)}$
Model-based	Entropy	Mutual Information
 Dataset: X: Deformation p: Force ✗		

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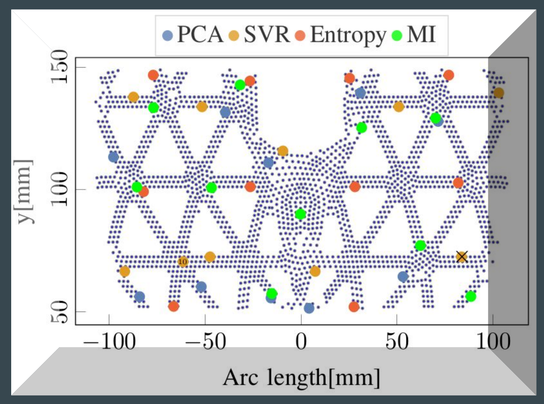
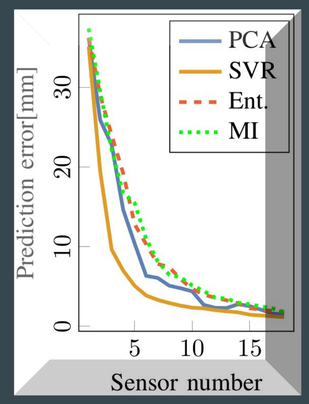
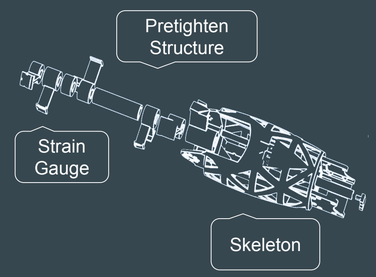
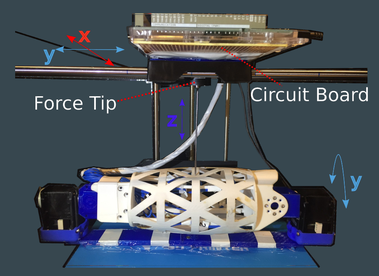
Optimal Placement: Results





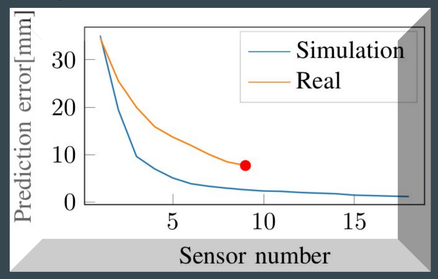
Hardware Implementation





Hardware Implementation: Result

Single touch detection



Force Interval [N]	Position Error [mm]	Amplitude Error [N]
0 - 4.9	25.43 +/- 13.36	1.05 +/- 1.01
4.9 - 9.8	11.95 +/- 11.85	1.19 +/- 1.19
9.8 - 19.6	5.90 +/- 7.79	1.42 +/- 1.78
19.6 - 34.3	4.48 +/- 6.29	1.54 +/- 2.21

Multiple touch detection