

# Robotic Proxies for Understanding Human Design

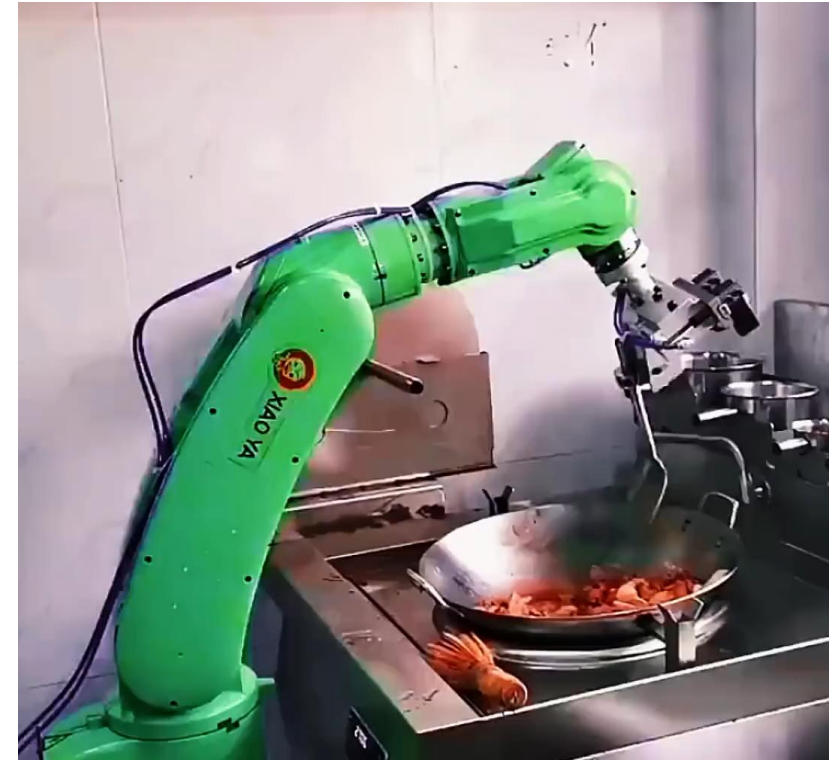
Chapa Sirithunge  
PhD, AFHEA  
Marie Skłodowska-Curie fellow  
Bio-Inspired Robotics Laboratory  
University of Cambridge

# Moravec's paradox

What's easy for robots is hard for humans

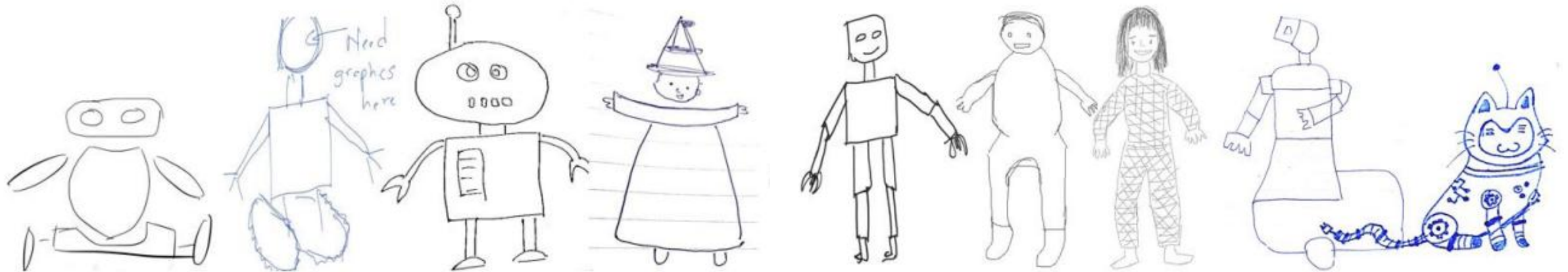
and

What's easy for humans is hard for robots!





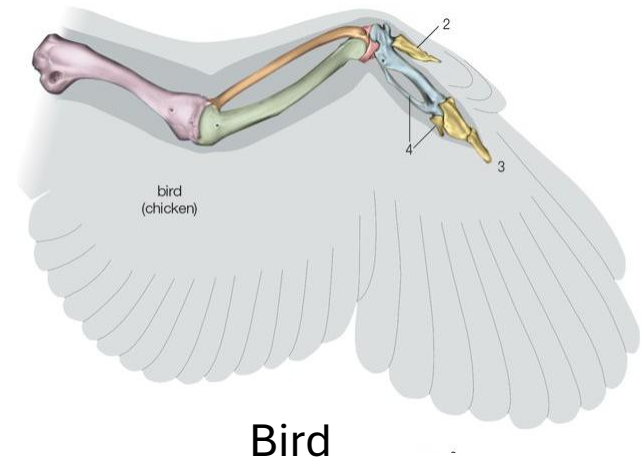
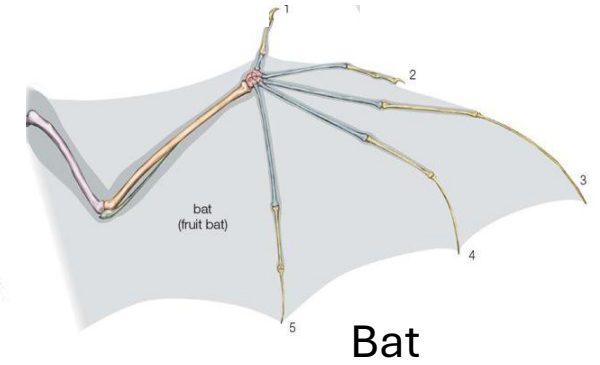
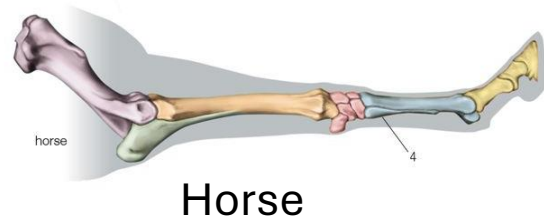
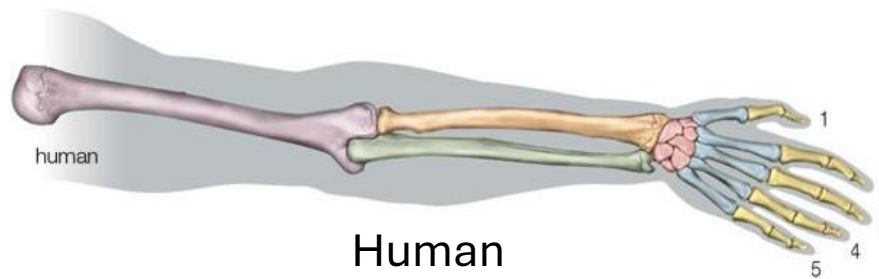
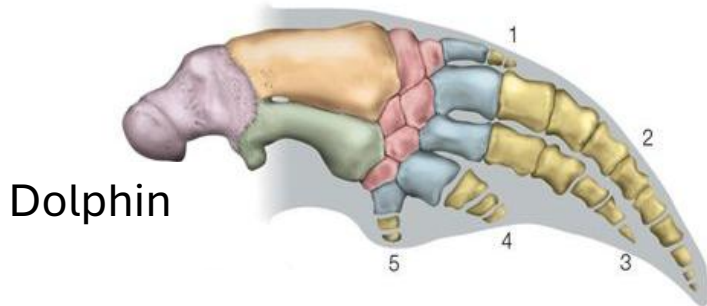
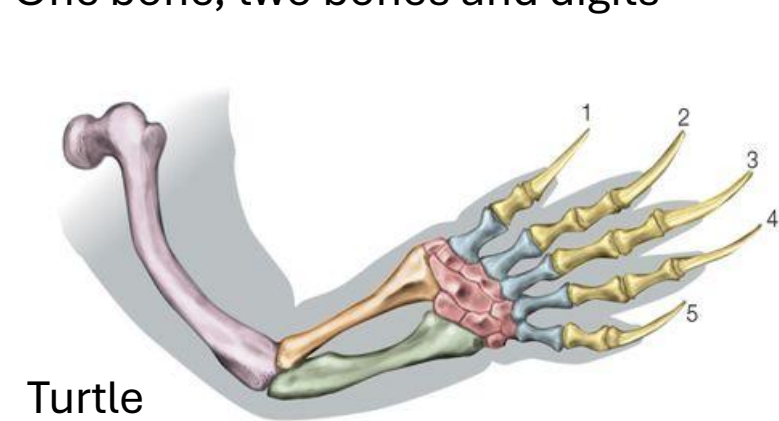
# Designs, Preferences and Skills



Flexible about **robot embodiment** but strongly prefer robots that display **perceptual cues** and demonstrate **functional competence**

# Evolution at its finest

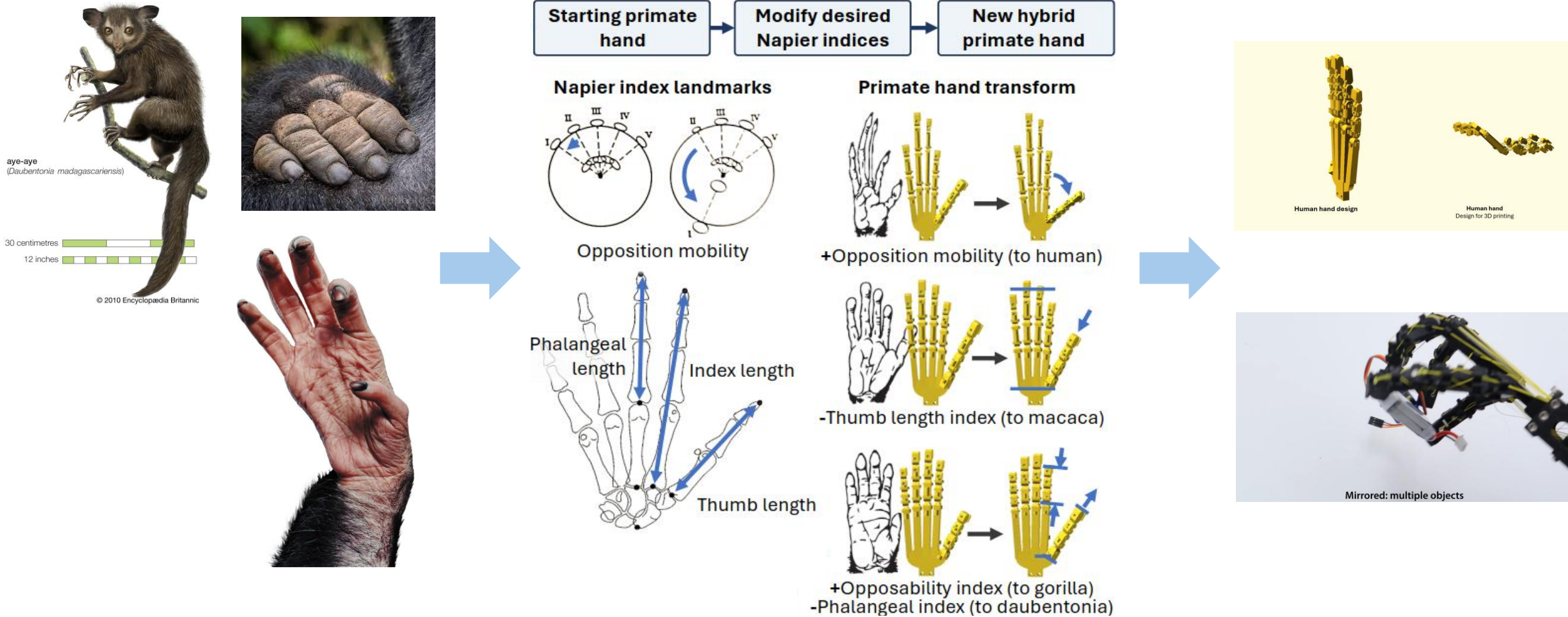
One bone, two bones and digits

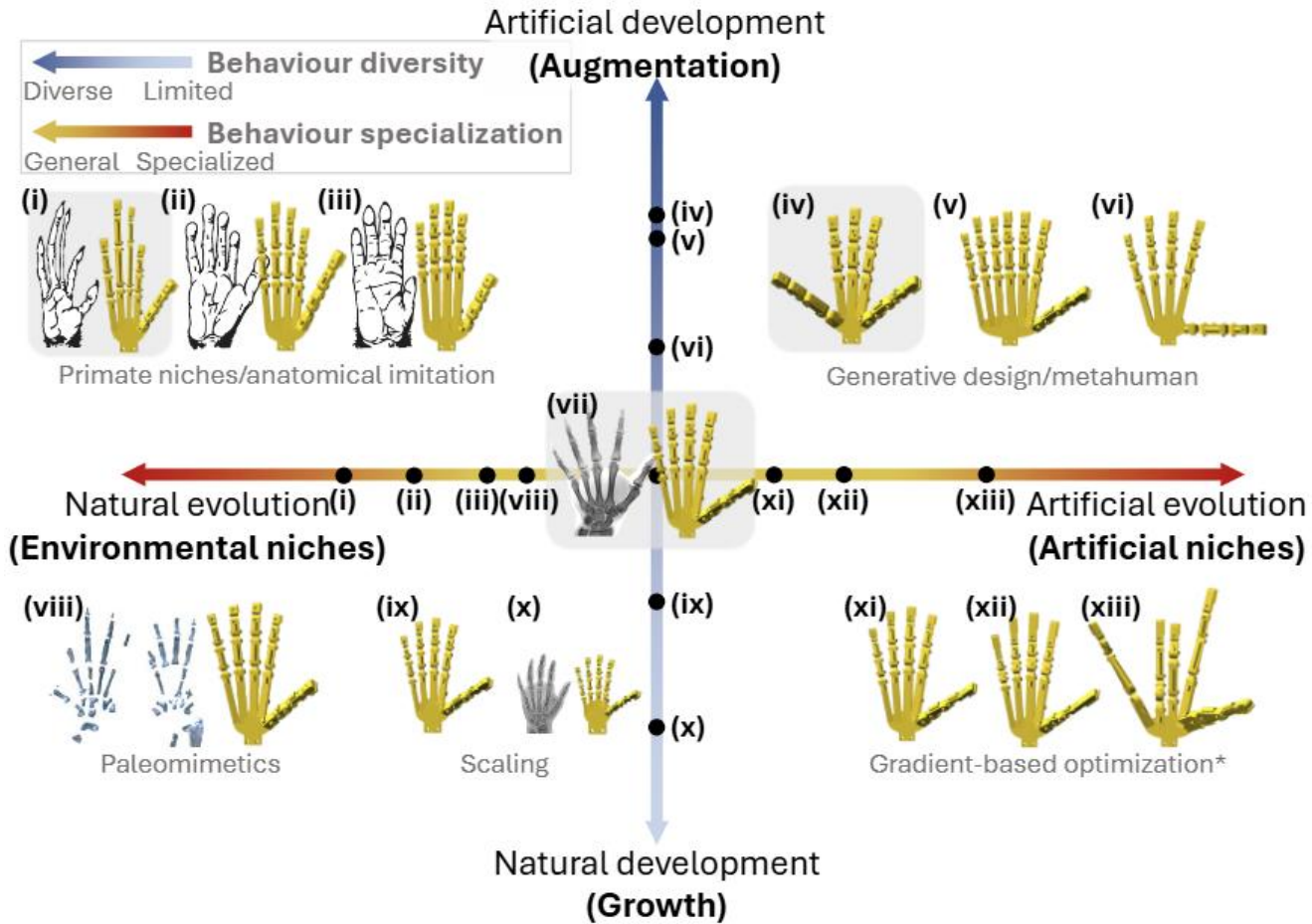


Environment: Water, land, air

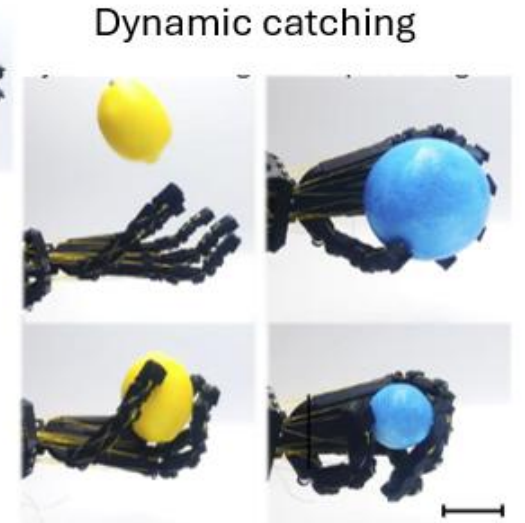
# Robots as a surrogate

## Exploration of human and primate anatomical behaviour





Heavy lifting



Dynamic catching

OPH: Single-piece 3D printable, anatomical, robotic hand

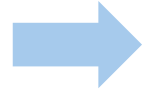
33 GRASP types  
 Single variable stiffness change  
 up to 290%  
 Multi-variable up to 660%

# Exploration of human behaviour

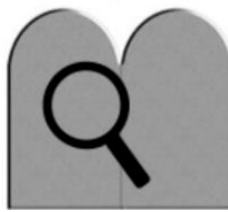
Reveals which skills are embodied, intuitive, and evolutionarily refined



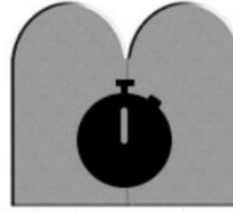
HuggieBot 2.0



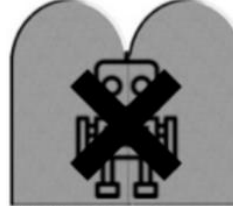
## Visual and haptic perception



Classify gestures

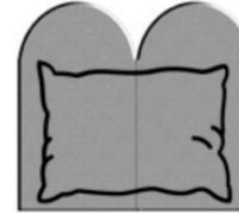


Synchronize for user approach



Be non-robotic

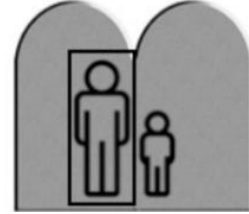
## Physical properties



Be soft



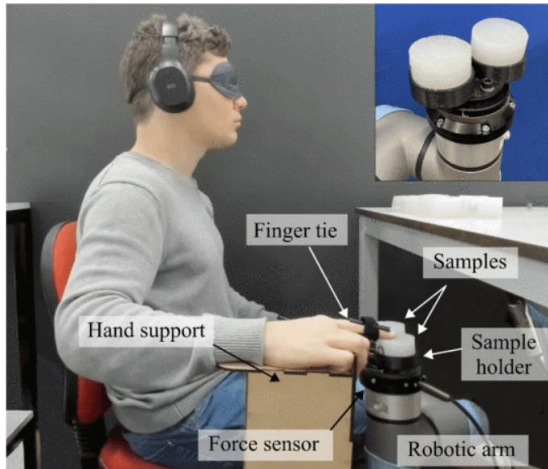
Be warm



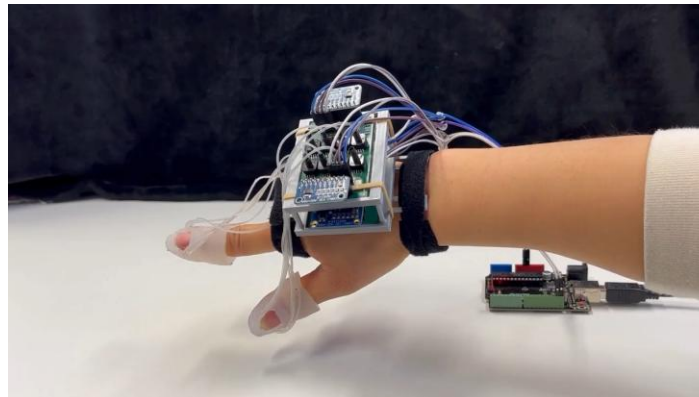
Be human sized

How can robots embody and support core aspects of human nature?

## Human robot physical interaction



## Human fine manipulation skills



## Human robot nonverbal interaction



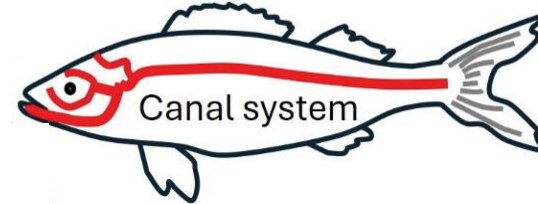
# Sensing solutions and exploration strategies

Bio-inspired solutions

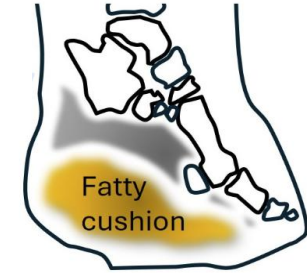
Distributed sensing: proprioception



Fluidic pressure sensing



Morphological adaptation



Emergent exploration strategies

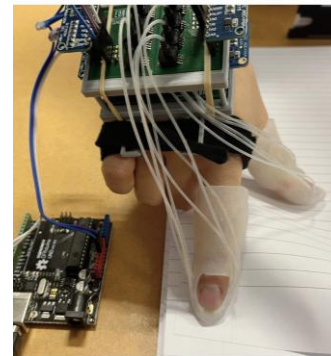
Soft sensing

Assessment of human skills

Fine manipulation skills

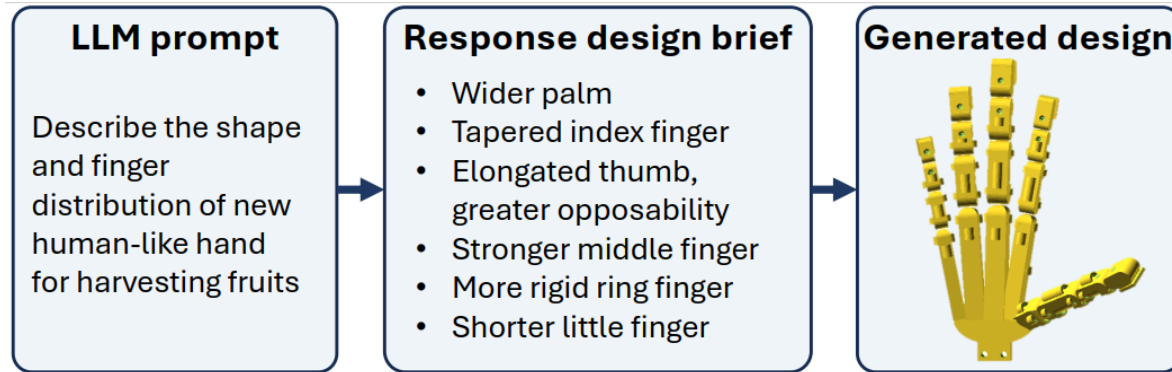
Tetsushi Nonaka  
Graduate School of Human Development and  
Environment,  
Kobe University

Arsen Abdulali, Chapa Sirithunge, Kieran Gilday and Fumiyuki  
Bio-inspired Robotics Lab,  
Department of Engineering,  
University of Cambridge

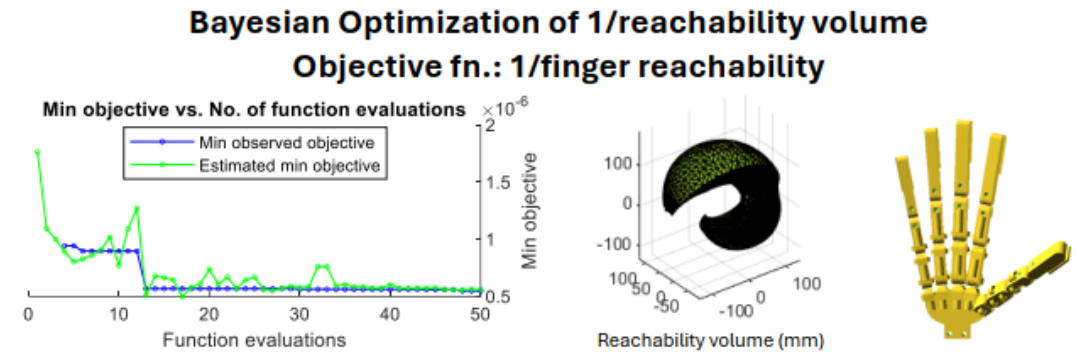


# Machine Learning-guided Design

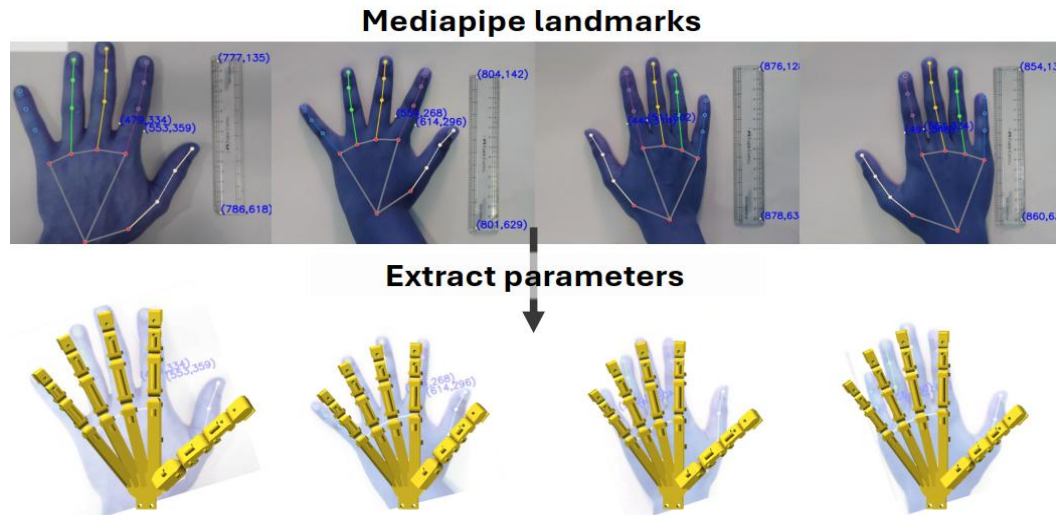
## Generation of new designs



## Design optimization

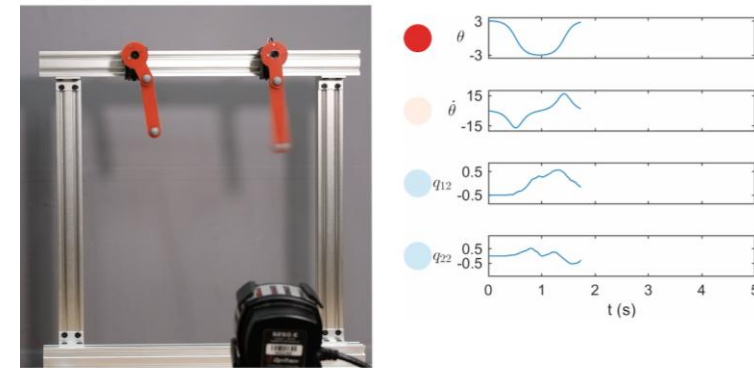


## Feature extraction



## Modelling dynamical systems

### Reservoir computing

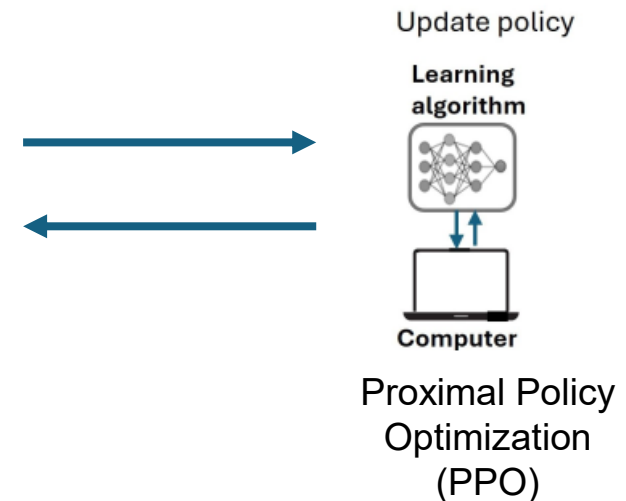
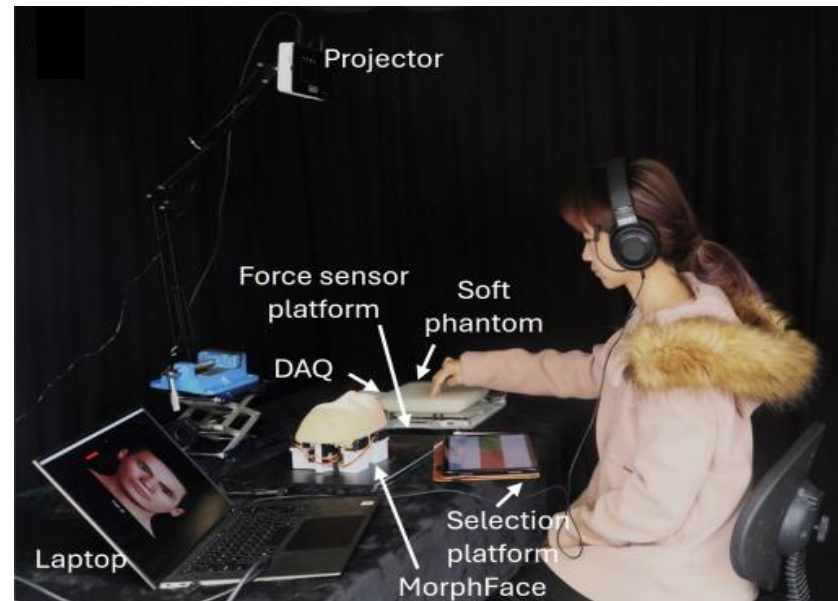
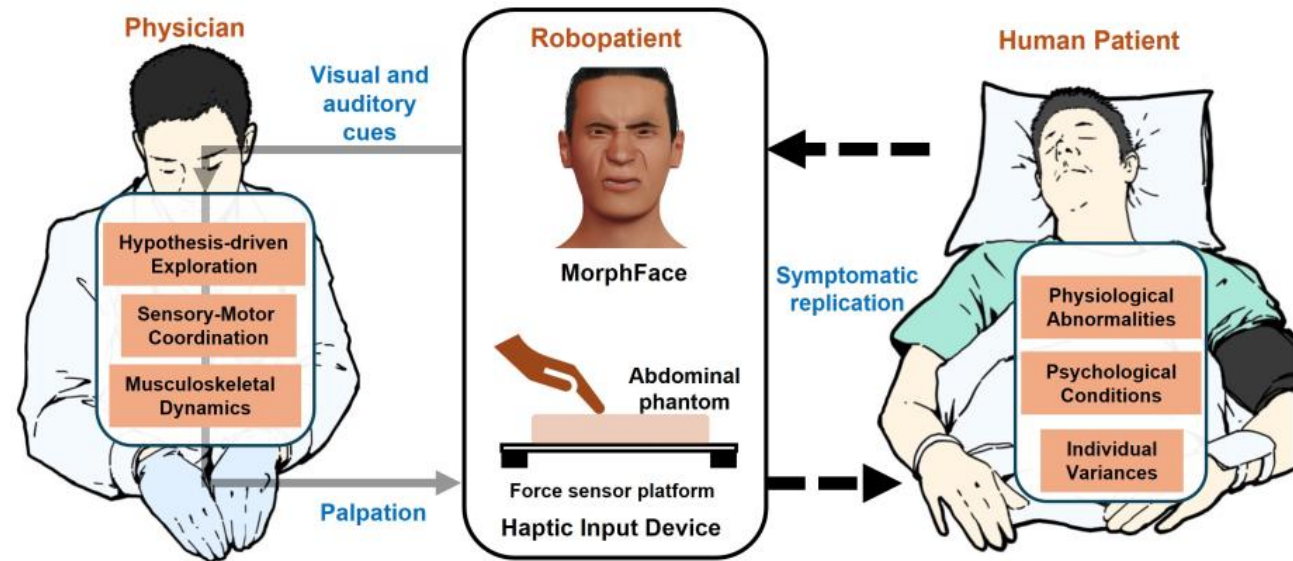


# Use case 1: Human- ML co-optimization

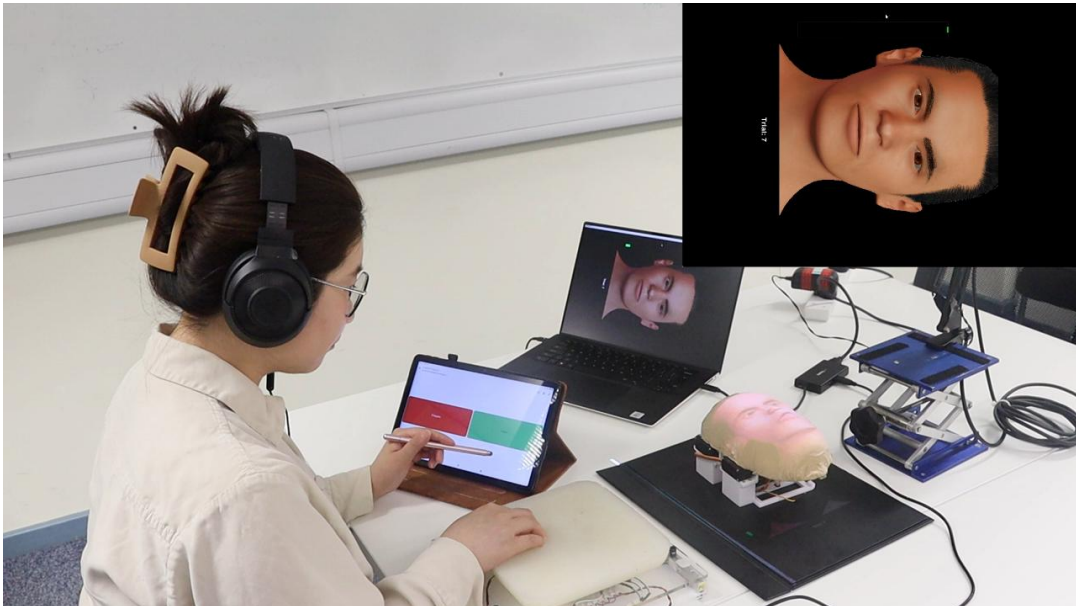
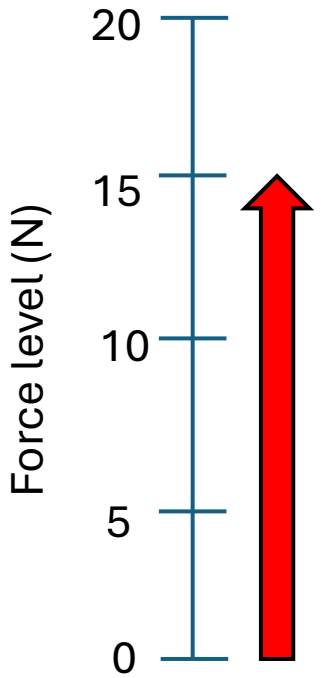
Study of high dimensional human features  
Eg: Pain

Synthetic generation of pain expressions  
through medical robotic simulator

Requirement of extensive human studies:  
Human-machine learning co-optimization



# Experiment Procedure



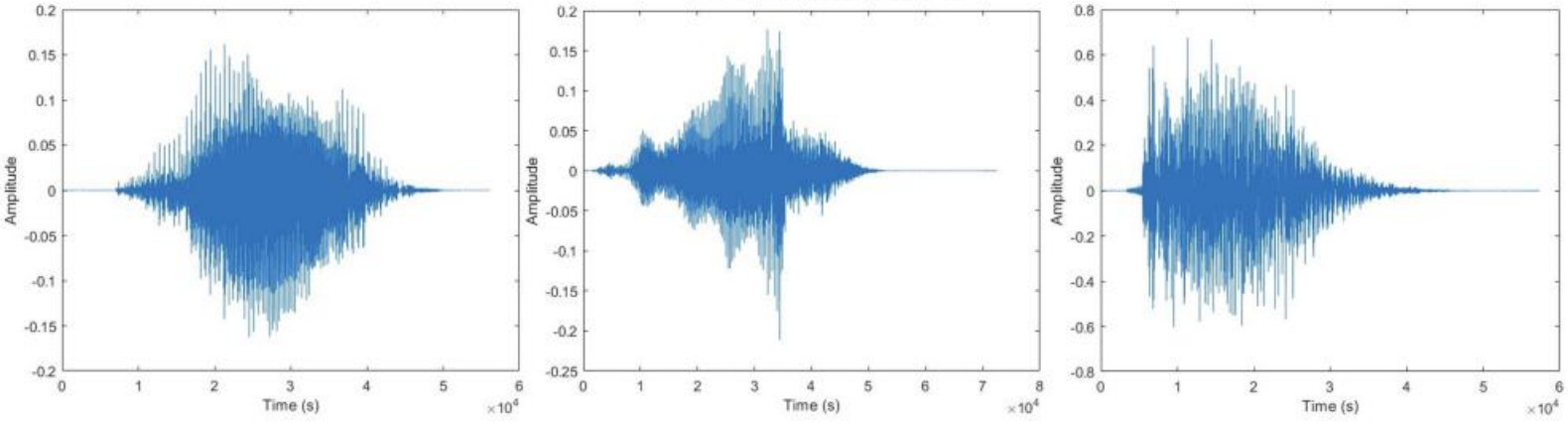
Human feedback on robot's behaviour

# Pain Expressions

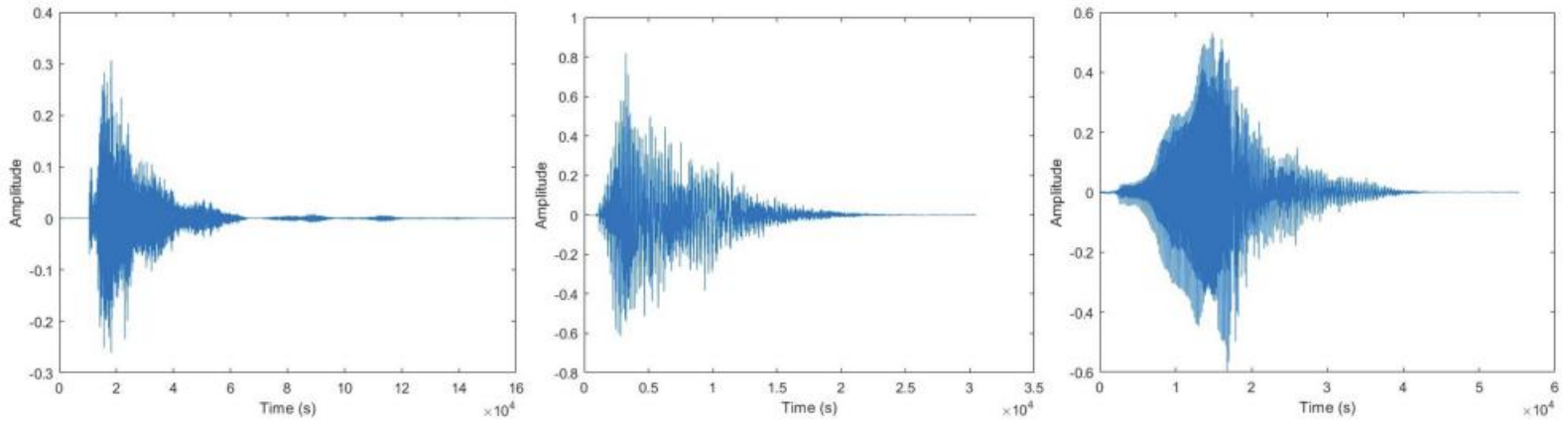
## Pain sound

## Facial expressions

### Male pain sounds



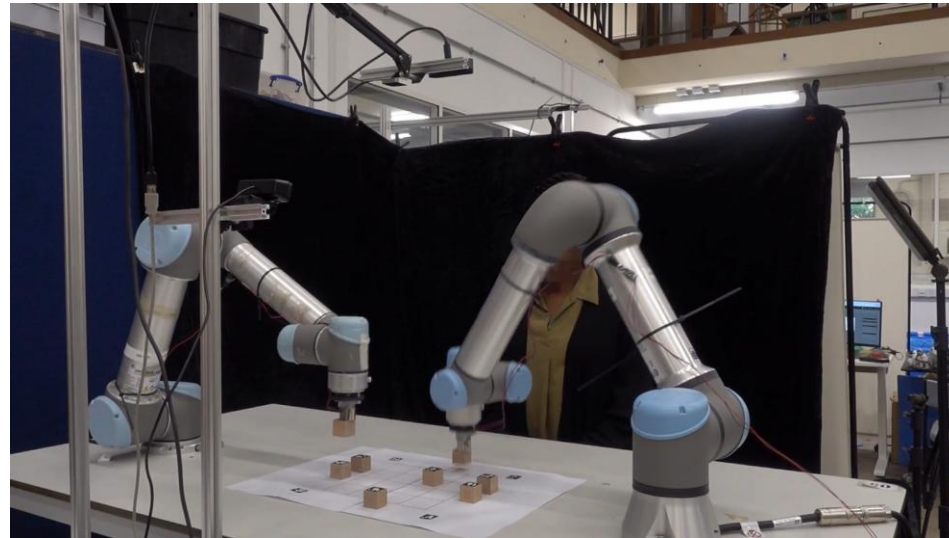
### Female pain sounds



# Use case 2: Robotic Assistance for Risk-Aware Human–Machine Collaboration

Future Roads Project: £6.3M, 24 industry partners

Robotics in construction

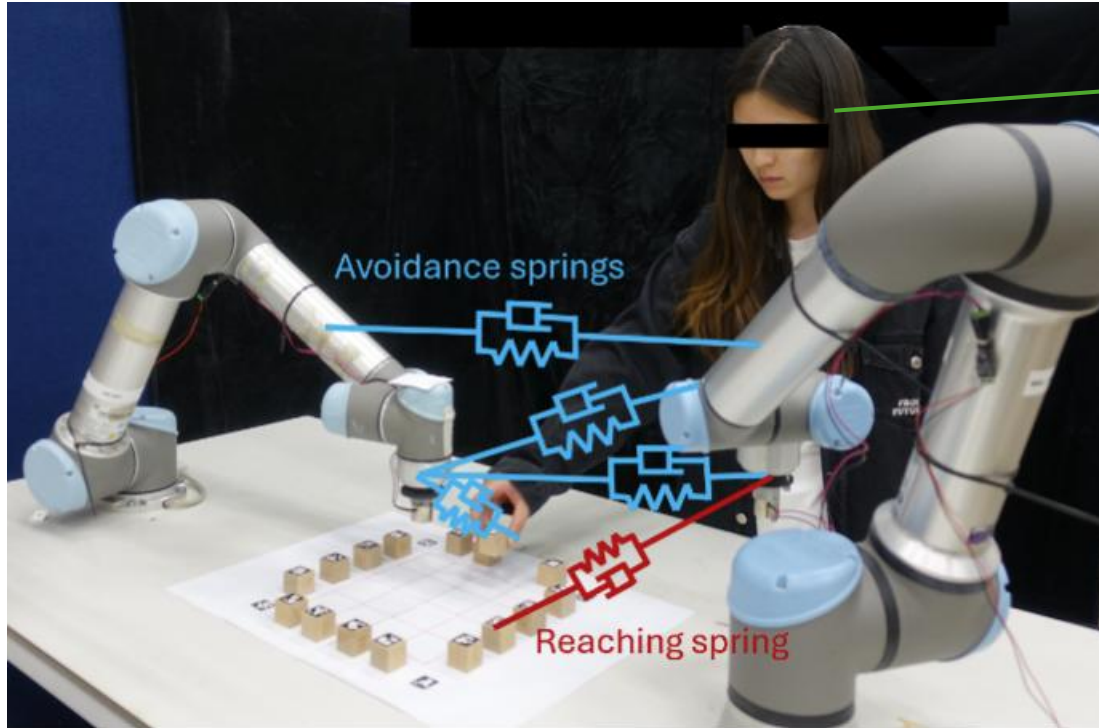


Human multi-robot teams



Lancashire, UK  
[nationalhighways.co.uk/](http://nationalhighways.co.uk/)

# Information-theoretic Scalar Indicators

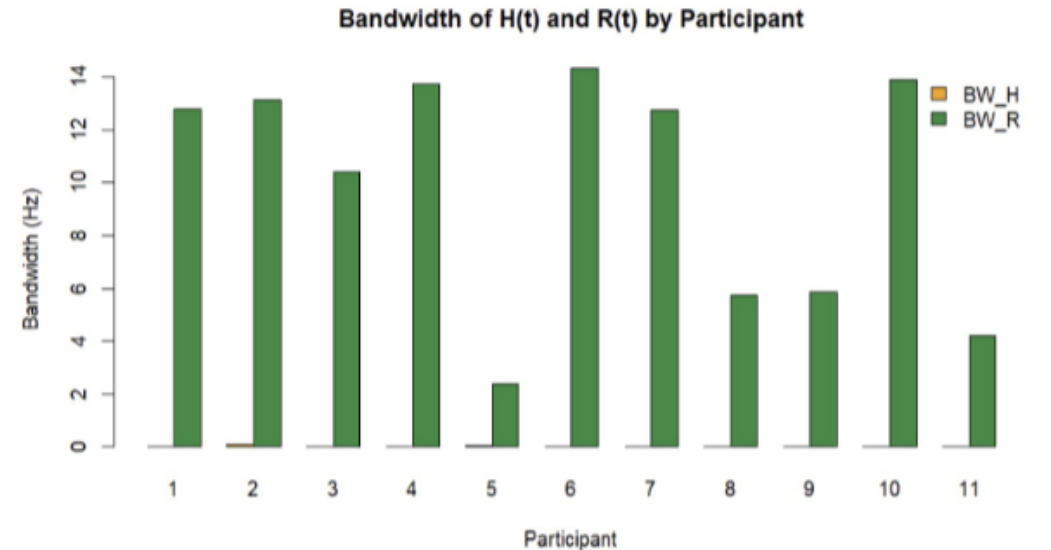
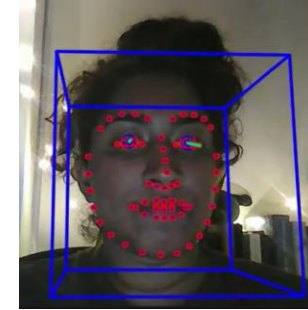


Virtual Model Control

Insights: Gaze entropy was stable  
Action units change

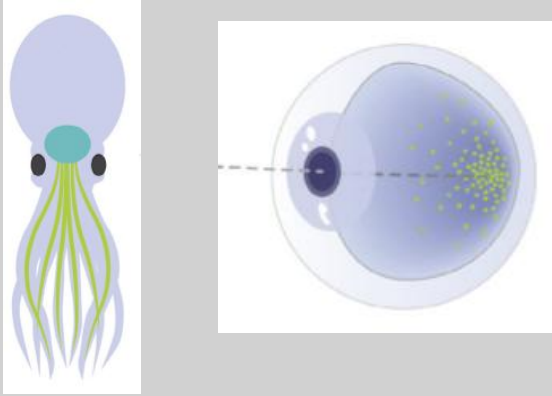
$$p_i(t) = \frac{AU_i(t)}{\sum_{j=1}^n AU_j(t)}$$
$$R(t) = \frac{H(t + \Delta t) - H(t)}{\Delta t}$$

25-50 bps



# Soft robotic approaches to Embodied Intelligence

## Decentralized control



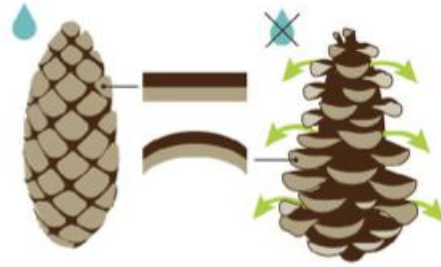
Decentralized control system of the octopus

The decentralized sensing system of the eye



Reflexive pain responses

## Adaptive shape

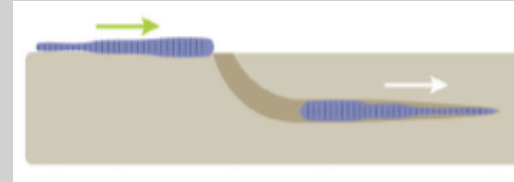


A pinecone opens its scales due to humidity of the environment



Deformation of skins

## Adaptive functionality



Earthworm adapting its shape to optimize its functionality



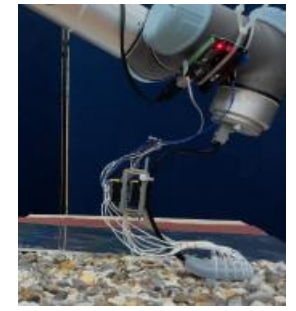
Passive robotic hands

## Adaptive mechanics



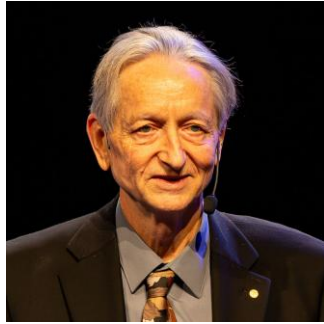
Kortman et al, 2024

Tendril coil serving as a spring-damper system to support the plant



Adaptive robot legs

# Prognostics in Robotics and AI



Jeffrey Hinton,  
Nobel prize 2024



Bernard L. Feringa,  
Nobel prize 2016



Bill Gates,  
Microsoft

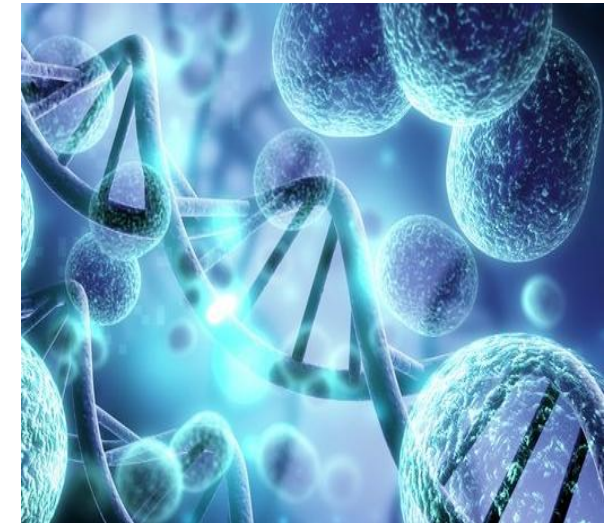
“Tasks requiring *physical dexterity* and *real-world adaptation* won’t be easily replaced by robots.”



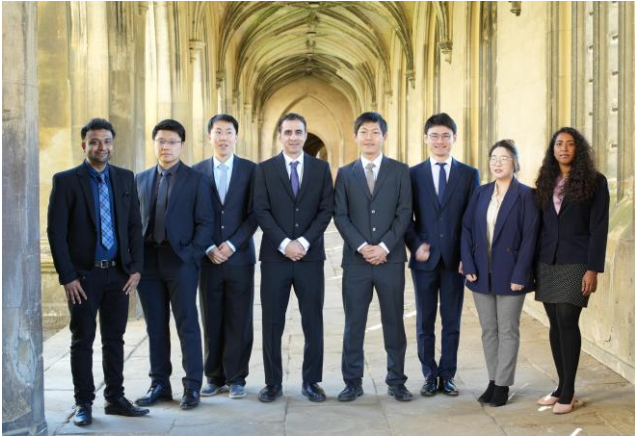
“Future robots will increasingly rely on molecular- and material-level machines.”



“Biologists remain among the least impacted by AI automation.”



Thank You!



[csh66@cam.ac.uk](mailto:csh66@cam.ac.uk)