Tactile Sensing for Robotic Applications

RICH WALKER
MANAGING DIRECTOR

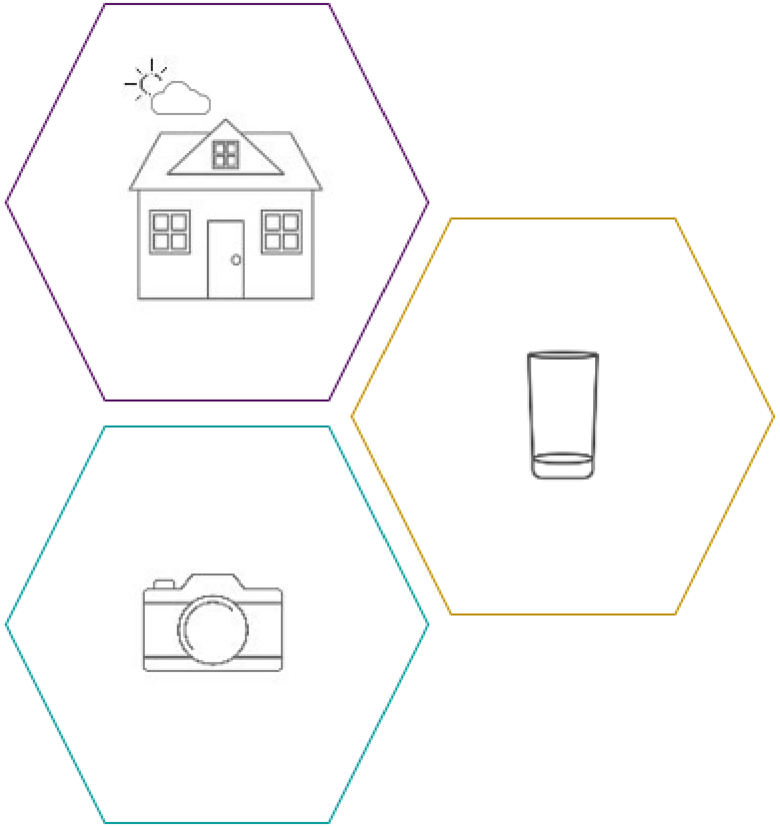
Shadow Robot Company

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2019

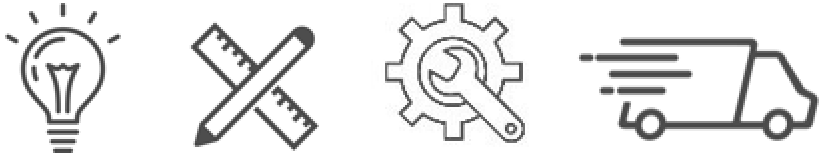
The AIconics
BEST INNOVATION IN AI HARDWARE 2019

A BIT ABOUT US

HOW WE STARTED



- 1997, Longest running robotics company in UK
- Experts in grasping & manipulation within robotics technology
- 35 staff spanning robotics hardware & software
- Global distribution and sales in research
- Global network of collaborators and partners



CLIENTS

NASA
HITACHI
Carnegie Mellon University
esa
European Space Agency
SIEMENS
ANA
UCL
gsk GlaxoSmithKline
MIT Massachusetts Institute of Technology
SynTouch
JAXA
OpenAI

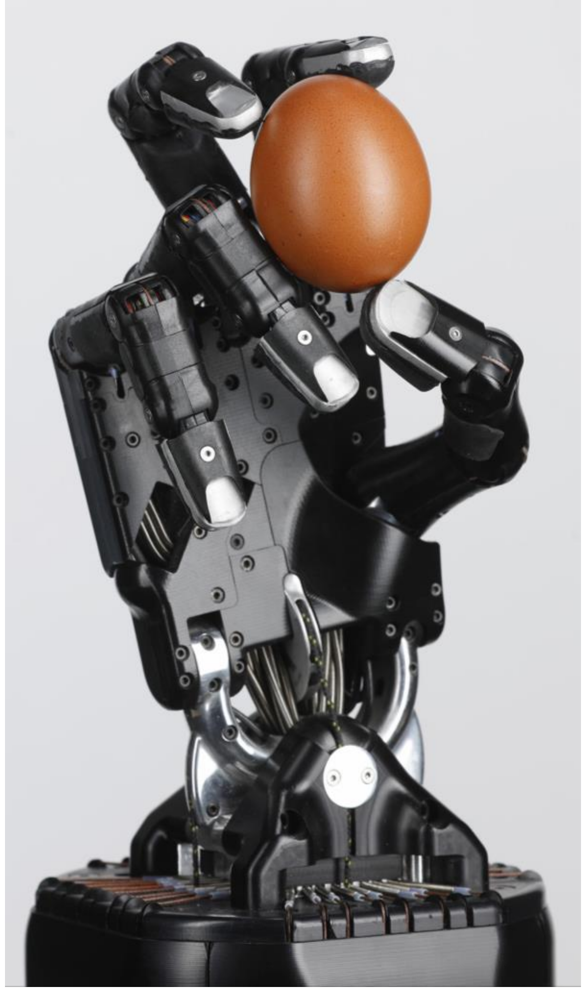
RESEARCH & DEVELOPMENT

- Many clients buy our robot hands for research and development purposes
- We also do a significant amount of internal and collaborative R&D as a company
- 7 Innovate UK projects
- 3 H2020 projects

MOVING ON FROM INDUSTRY RESEARCH TO INDUSTRY APPLICATIONS

More and more industries are recognising how valuable our products can be and are using it to advance their sector

SHADOW DEXTEROUS HAND - FLAGSHIP PRODUCT

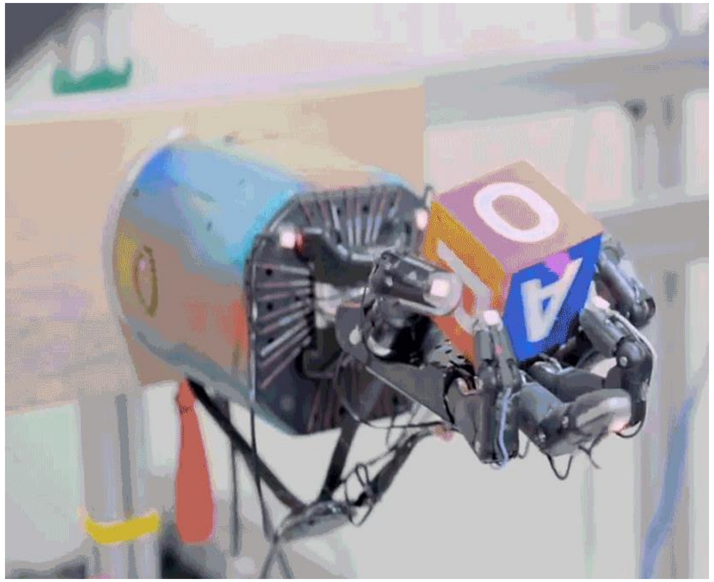


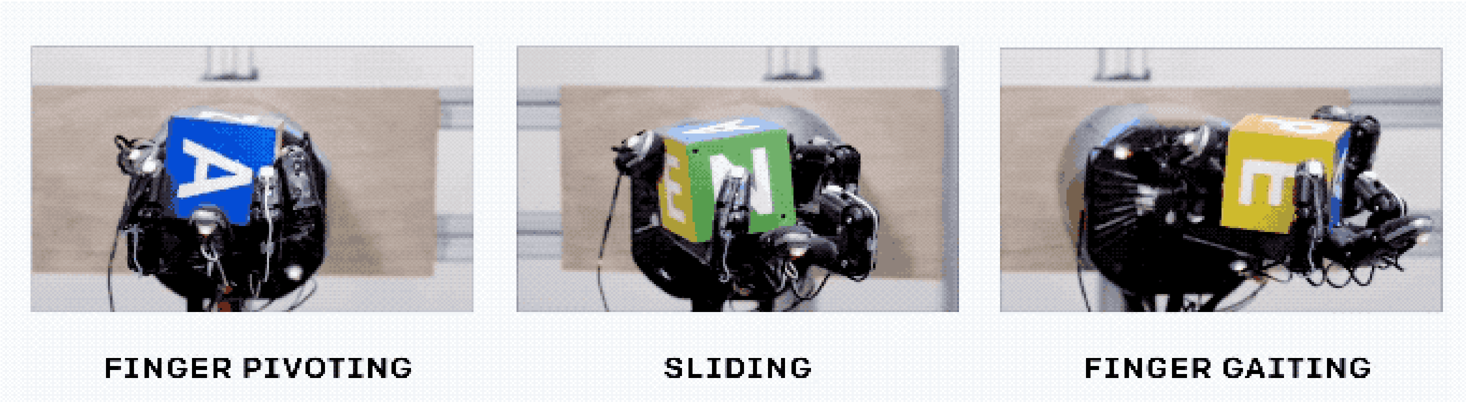
World's most human-like robot hand

Advanced grasping and manipulation

Can be controlled remotely (teleoperation)

A key component in our TACTILE TELEROBOT

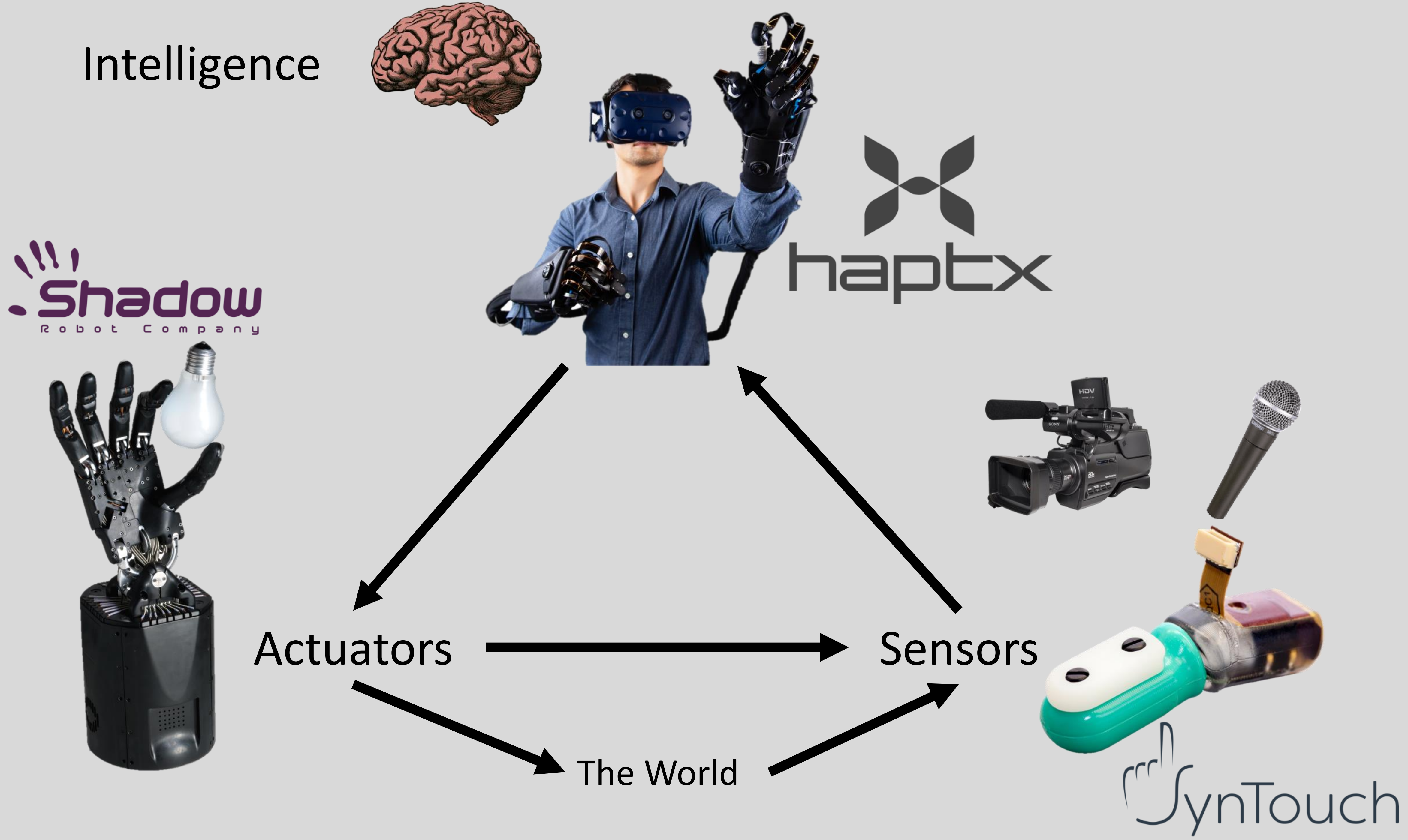




OUR NEW TACTILE TELEROBOT WITH TACTILE SENSING

TACTILE TELEROBOT – ROBOTS THAT CAN FEEL

SynTouch haptx® Shadow Robot Company

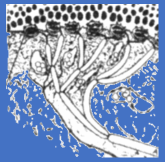

Intelligence
Shadow
Robot Company
haptx
Actuators
Sensors
The World
SynTouch

WHAT INFORMATION CAN TACTILE SENSING PROVIDE?

Biological Touch

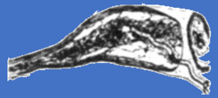
Cutaneous Touch

Merkel Disc



Force & Deformation

Ruffini Ending



Tree Nerve Ending

Thermal

Two types: hot & cold

Meissner Corpuscle

Vibrations

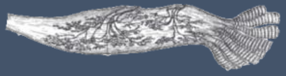
Pacinian Corpuscle

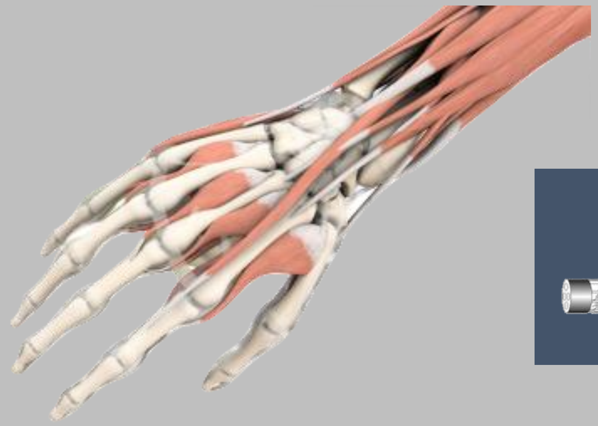
Pain

Proprioceptive Touch

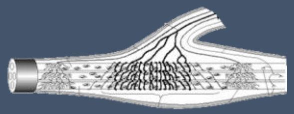
Actuator Force

Golgi Tendon Organ





Muscle Spindle



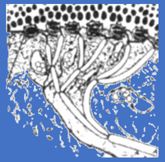
Position & Velocity

Type Ia and Type II

Artificial Touch

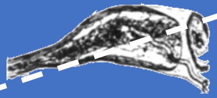
Cutaneous Touch

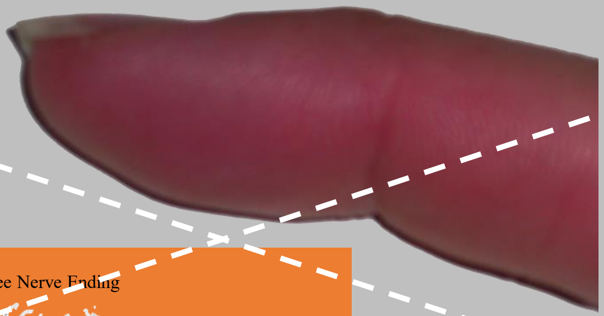
Merkel Disc



Force & Deformation

Ruffini Ending





Tree Nerve Ending

Thermal

Two types: hot & cold

Meissner Corpuscle

Vibrations

Pacinian Corpuscle

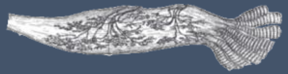
Not an easy problem

Pain

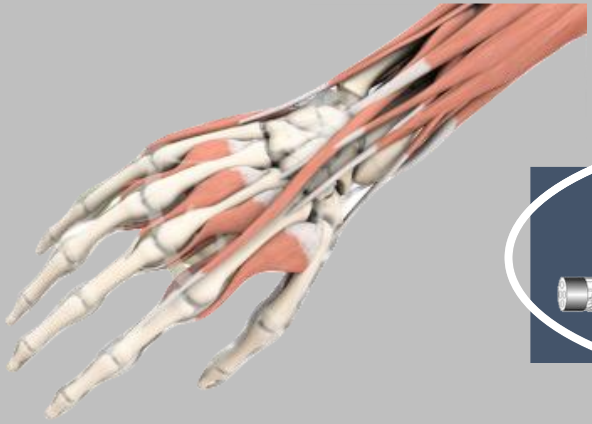
Proprioceptive Touch

Actuator Force

Golgi Tendon Organ

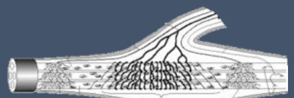


Strain Gages



Position Encoders

Muscle Spindle



Position & Velocity

Type Ia and Type II

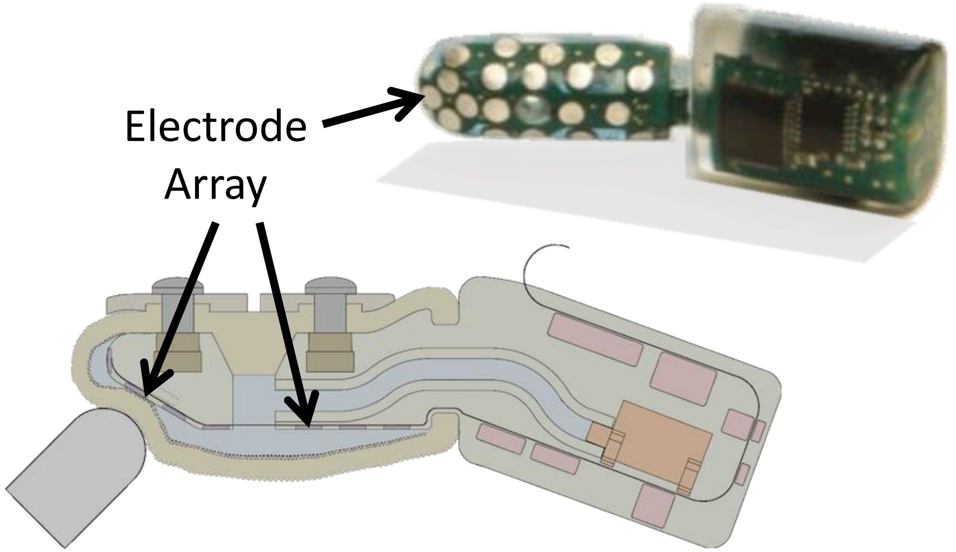
Force Sensing

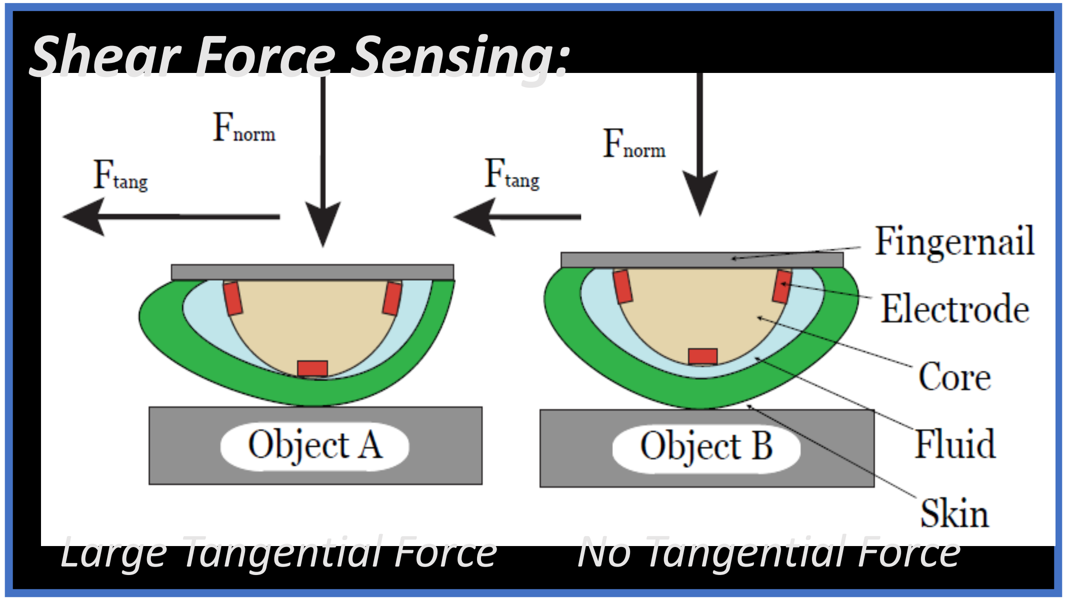
Forces deform skin and fluid

Impedance changes are sensed by electrodes

Raw data can be used to extract features:

- Normal Force
- Point of Contact
- Shear Force
- Radius of Curvature
- Compliance





ML and Analytical Solutions to Calculate 3-Axis Force, Torque and Point of Contact

Publications:

Wettels et al., Advanced Robotics, 2008

Wettels et al., IEEE BioRob, 2008

Wettels & Loeb, IEEE ROBIO, 2011

Su et al., Frontiers in Neurorobotics, 2012

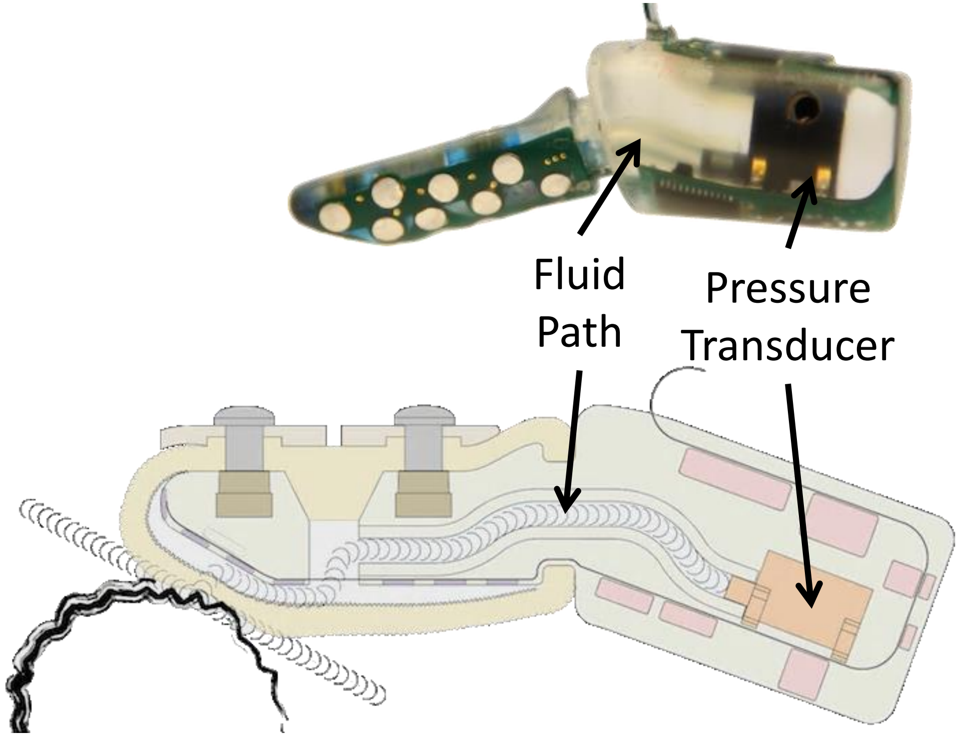
Vibration Sensing

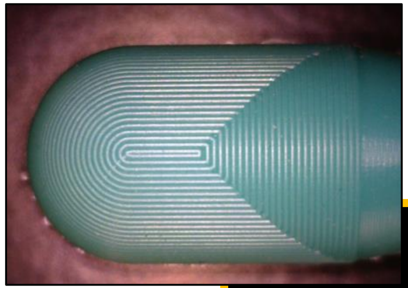
Sliding over textured objects results in vibrations

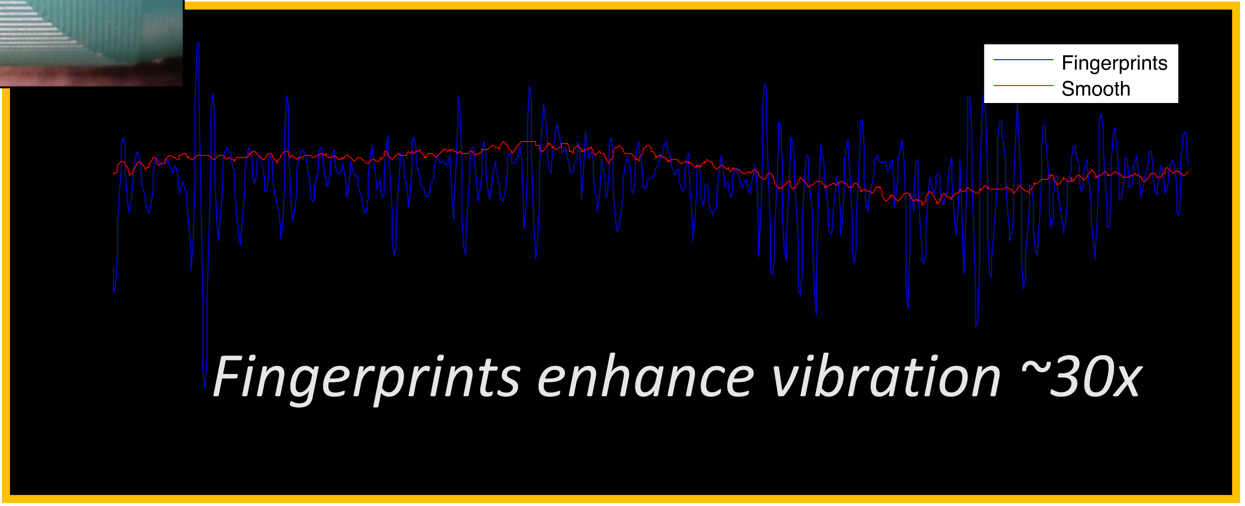
Vibrations travel efficiently through incompressible fluid

Vibrations sensed by transducer can be used to:

- Detect Slip
- Identify Texture Properties







Publications:

Fishel et al., BioRob, 2008

Fishel & Loeb, *DoD Physics of Biology*, 2009

Fishel & Loeb, BioRob, 2012

Fishel & Loeb, *Frontiers in Neurorobotics, 2012*

Temperature Sensing

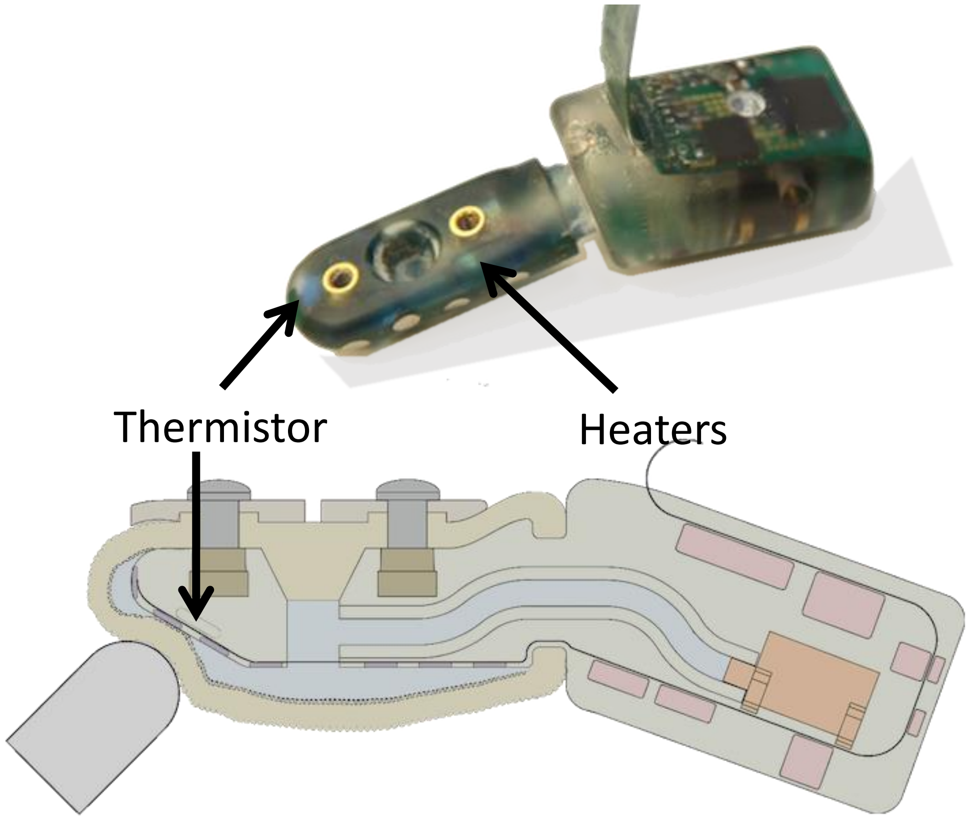
Finger is heated above room temperature

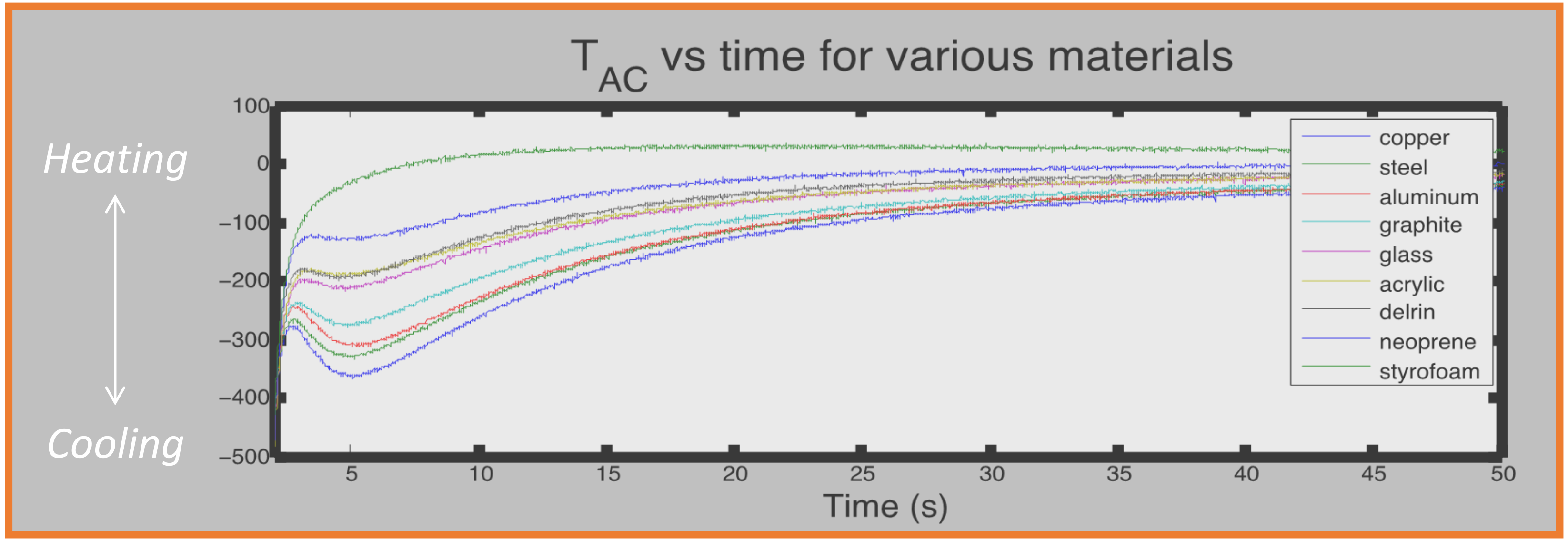
Contacted object draws heat

Temperature (and derivative) are measured

Data can be used to determine:

- Object temperature
- Material's thermal properties



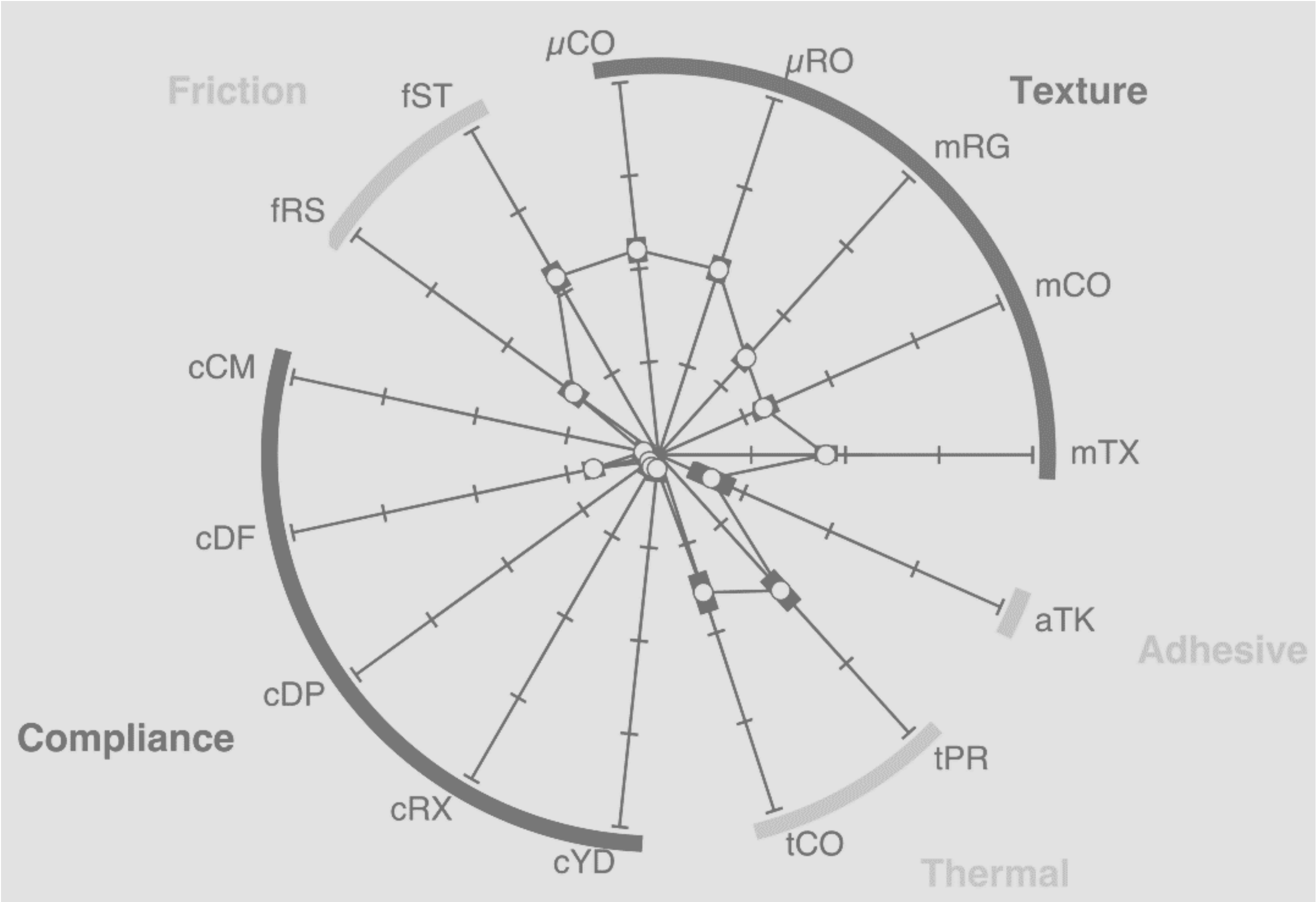


<u>Publications:</u>

Lin et al., ROBIO, 2009

Xu et al., ICRA 2013

OVERALL, IT CAN QUANTIFY TOUCH BETTER THAN HUMANS

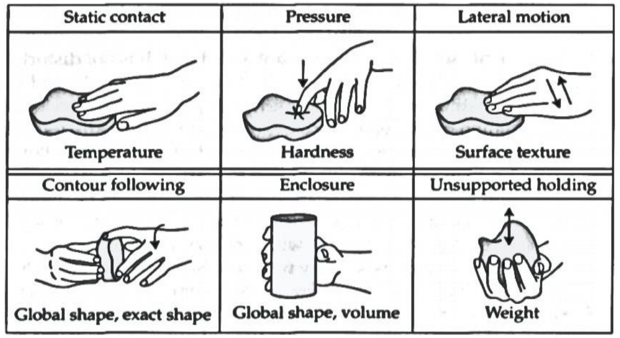


WHY IS TACTILE SENSING FOR TOUCH IMPORTANT IN ROBOTICS?

Touch connects us with the world

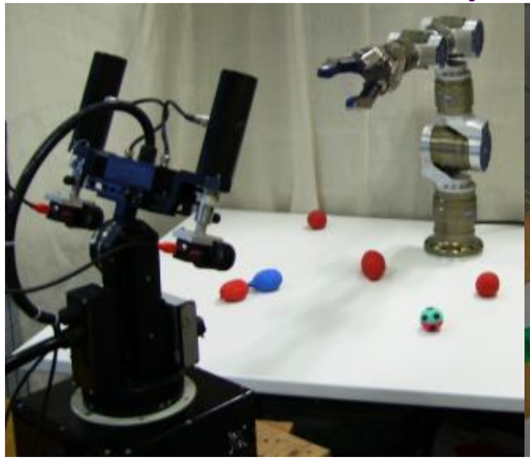
ROBOTIC CAPABILITIES WITHOUT TOUCH

No tactile perception or discrimination of objects



Source: Jones, 2006

Vision is necessary to compensate



Aberystwyth University

Jesse Sullivan

Not very dexterous or graceful →

PR2 – Destroys Can, RSS 2011

TOUCH, VISION AND DEXTERITY

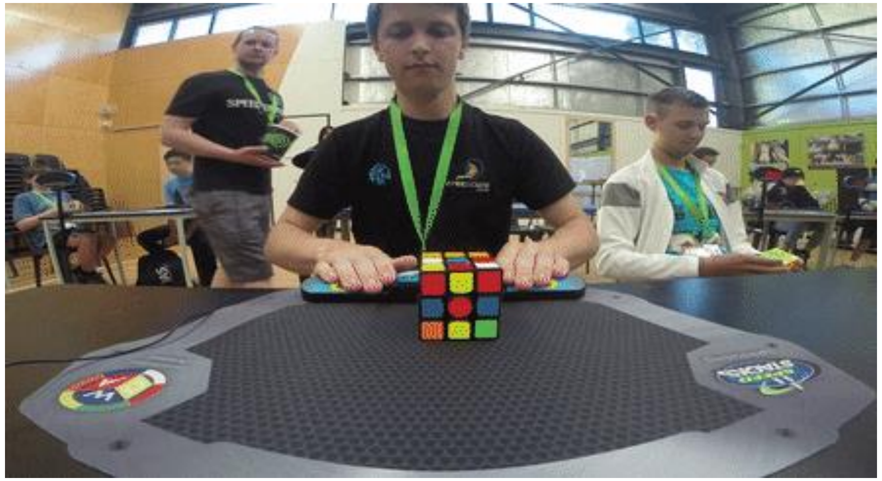
In Fully-Defined Environments:

Robots w/ precision, speed, and optimal planning will always outperform humans.

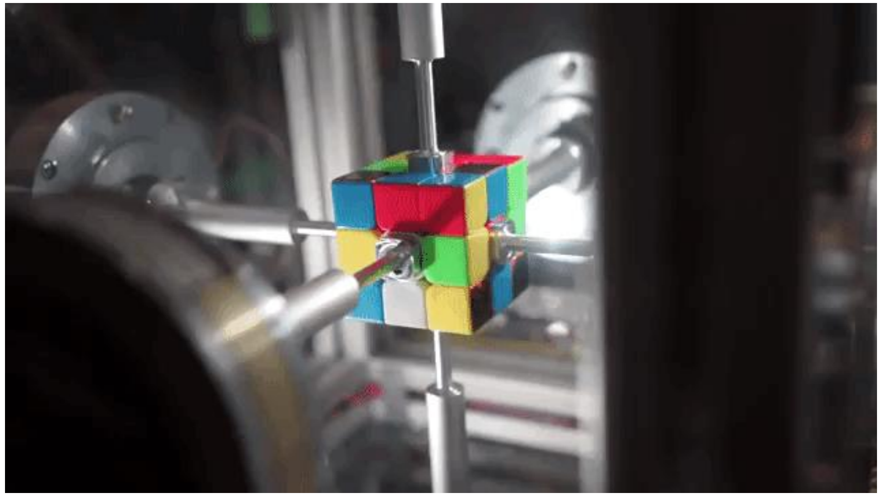
In the Real World (unstructured/unknown):

Vision is very useful for **planning**, but touch is necessary for **dexterity** in manipulation.

Dexterity: The ability to respond intelligently to the unexpected



HUMAN: 4.22 SECS



ROBOT: 0.38 SECS

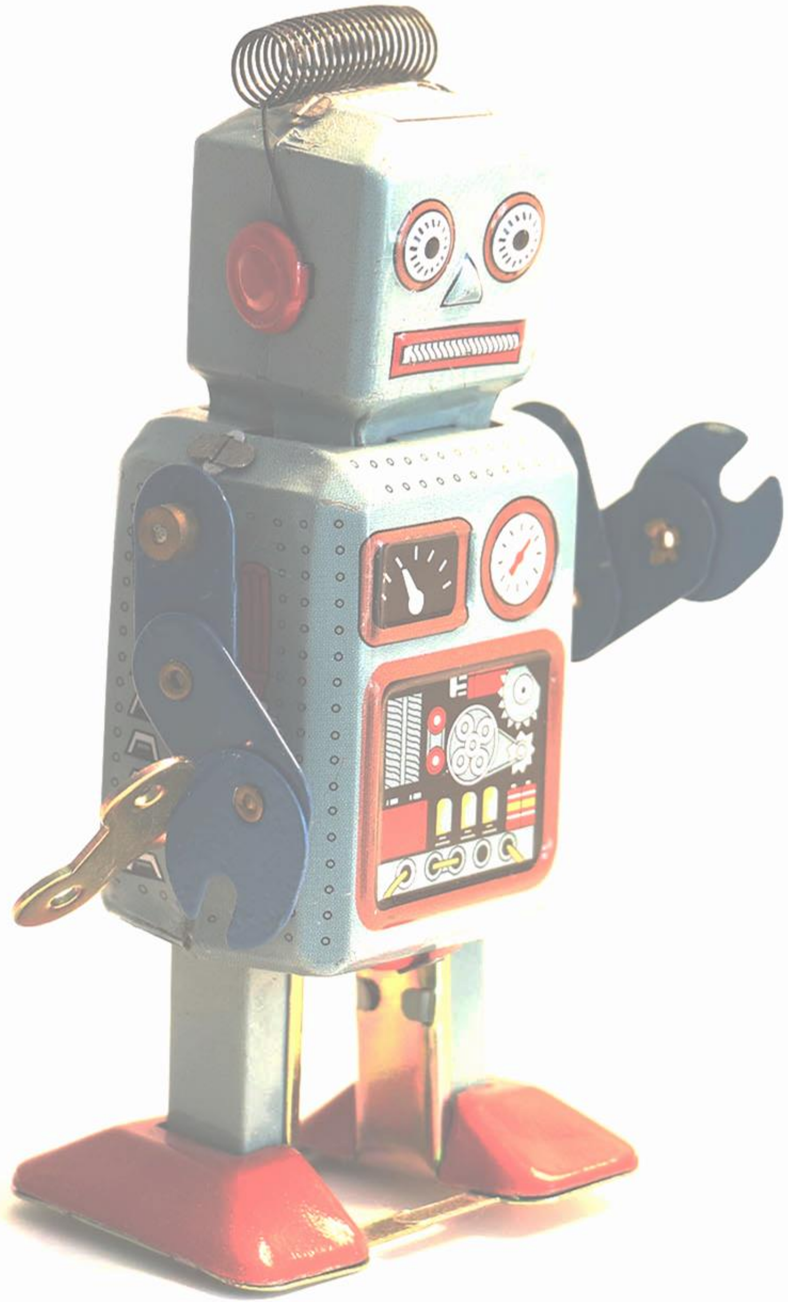
HOW CAN ROBOTS WITH TACTILE SENSING HELP IN INDUSTRY APPLICATIONS?

Dirty. Dangerous. Dull. Inaccessible.

Robots are being deployed for these tasks but lack intelligence, dexterity, and/or human touch!

SEND A HUMAN

NUCLEAR DECOMMISSIONING



OUR OBJECTIVE: YOUR HANDS. ANYWHERE

Teleporting Skills

When an expert is needed (doctors, repair tech, etc.)

Dangerous or Inaccessible Environments

Nuclear, Space, Deep sea etc.

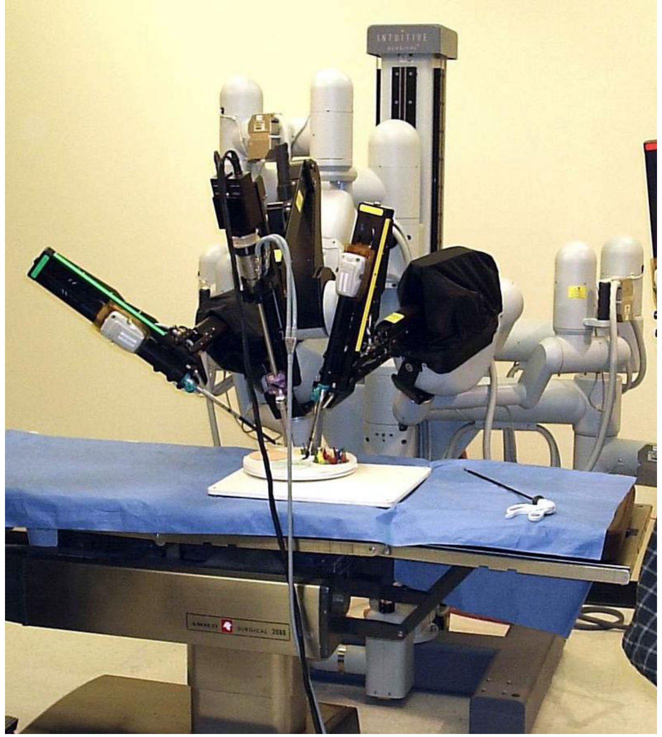
Machine Learning

Demonstration/ reinforcement learning of how to perform tasks

Semi-Autonomy & Efficiency

One person can control many robots

Telerobots Without Touch



Training + Preparation Time + Careful and Slow = Expensive

Telerobots With Touch

Intuitive + Natural

Human intelligence and dexterity infused with robotics

JEFF BEZOS, AMAZON'S CEO

"WEIRDLY NATURAL"

"THE TACTILE FEEDBACK IS AMAZING!"

EXAMPLE CASE STUDY:
HOW ROBOTS WITH TACTILE SENSING CAN HELP IN NUCLEAR DECOMMISSIONING

NUCLEAR DECOMISSIONING SECTOR

£250 BILLION

The international market in nuclear decommissioning and waste management is estimated to be in the region of £250B…

100 YEARS

with the operations requiring an excess of 100 years to complete

£70 BILLION

The UK component of this is estimated to be approximately £70 billion, with completion on similar timescales

NUCLEAR DECOMISSIONING SECTOR

- Using robots is recognised as an alternative to reducing the need for sending workers into hazardous areas
- UK Government will invest £93 million to develop new safer technologies to use within extreme environments
- An aspect of nuclear decommissioning that still relies on humans going in are glove box related tasks
- However, there are many challenges with glove boxes that interfere with safety & productivity that tactile telerobots can help solve

Glove box: workers manipulate nuclear materials in a windowed, sealed container equipped with two flexible gloves

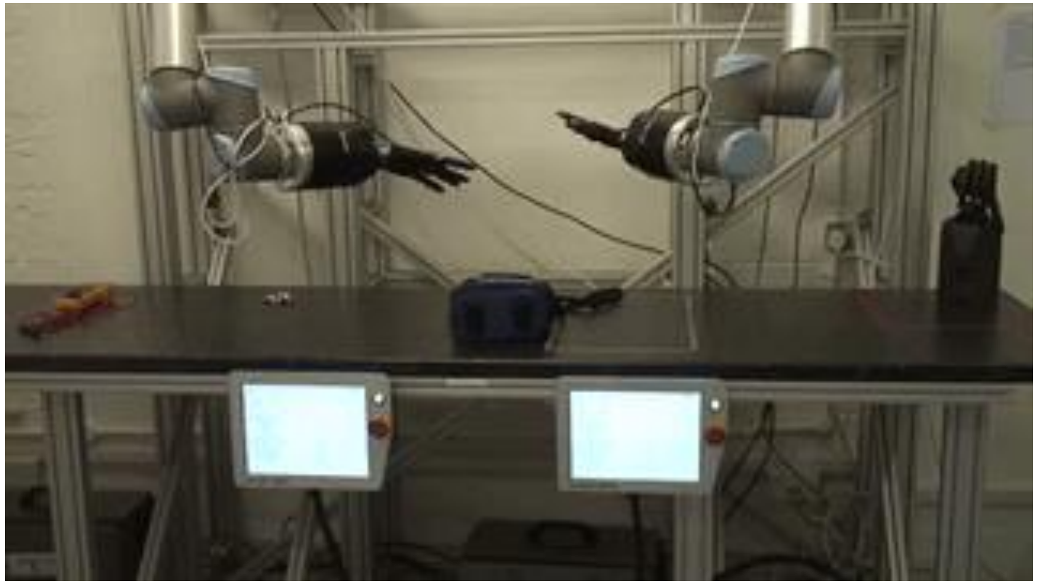
HOW IT WORKS

1. The Tactile Telerobot is set-up at a glove box using existing glove ports

2. You control the Tactile Telerobot at a safe distance, even in another room or vicinity, wearing the haptic glove

3. The robot hand mimics your hand movements, handling hazardous materials so you don't have to

4. Sensors on the robot hand relay information to your hand wearing the glove, so you can really feel present in the teleoperation site creating a more realistic and human experience as well as greater control when grasping and manipulating radioactive materials



- No radiation dose
- More productive work hours
- No more restrictive PPE
- Reduced cost
- Less waste

IN CONCLUSION…

- Tactile Sensing for touch is critical for manipulation and perception
- Most tasks are still possible with vision alone BUT touch makes difficult tasks easy and intuitive
- High-fidelity teleoperation with touch can revolutionise dull, dirty or dangerous industries as well as be an excellent source of training data for AI and ML

WE'RE SELLING OUR TACTILE TELEROBOT

Visit: WWW.TACTILETELEROBOT.COM

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