

SmartHort 2019

Fruit production at Tiptree

Andrey Ivanov

History

- Wilkins family have farmed in Tiptree for almost 300 years.
- Over 150 years of fruit growing.
- Four farms - combined land of around 750ac.
- Jam making since 1885.
- Proud holders of the Royal Warrant since 1911.





Tiptree

Growing techniques

Old days – raised soil beds on ground level. Difficult for picking, plants are more exposed to a range of pests.



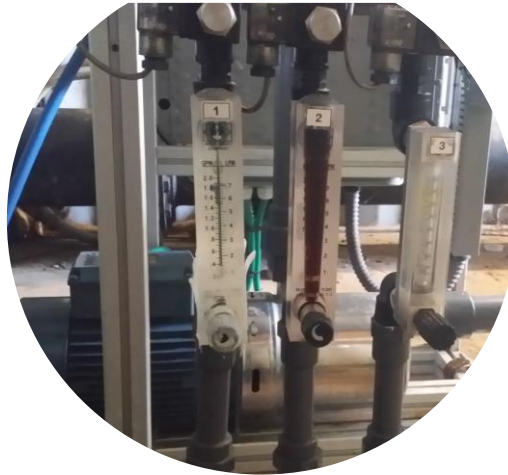
Raised soil bed with mulch and under poly tunnels



In 2010 we introduced the Table Tops System – much more efficient way of growing. Significantly reduced pest and disease issues and about 40% reduction in picking cost.



In 2010 a new Micro Irrigation System has been introduced for a greater water control and nutrients



In 2015, the first NGS Oscillating system was introduced on the Farm.

Also, first **structure** of its kind in the country for strawberry growing.

100% surface growing area is used.

90% self-sufficient on water, as we harvest all the water from the structure.

Fully automated climate control (temperature and humidity).

Fully automated Dream console Irrigation and Fertigation System.



Innovation, Innovation, Innovation...

How everything has changed with each step taken in introducing a new system/technology.

- Strawberries on soil – the traditional way of growing – around 5 -10 tonnes/ha
- Strawberry on soil with the raised bed system with irrigation – 15 – 25 tonnes/ha
- Strawberries on Table Tops with drip irrigation – 35 – 55 tonnes/ha with the new modern varieties and improvement in picking speed by 40%
- Strawberries with the oscillating system with fully automated irrigation, fertigation and climate control – 100 – 120 tonnes/ha and potentially more in the future with new varieties

2019 and beyond

Joint up forces with Essex University to develop a solution for our system.





COLLABORATIVE ROBOTS FOR SOFT FRUIT HARVESTING

VISHVANATHAN MOHAN AND ANDREY IVANOV





**THE PICKING
CHALLENGE**



TODAYS MENU
VERY SPICY CHILLY SAUCE



THE PICKING CHALLENGE

IDENTIFY

LOCALIZE

PREDICT/SIMULATE

COORDINATE
(MULTIPLE
EFFECTORS/TOOLS)

SOFT INTERACTION

CONFIGURATION IS
NOT STATIC



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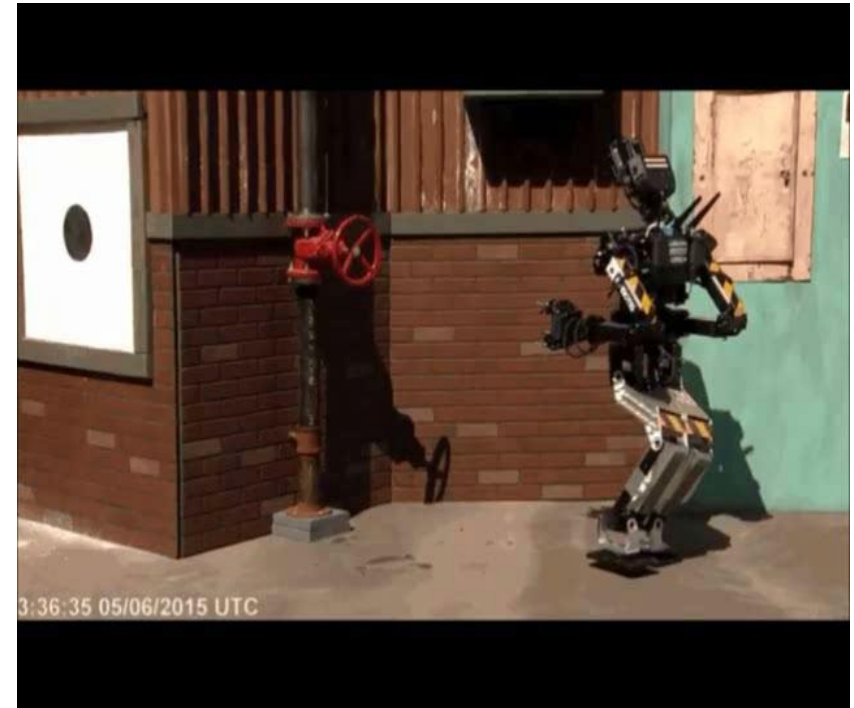
TODAYS MENU





THE PICKING
CHALLENGE

HUMANS ARE REMARKABLY GOOD!!



HUMANLIKE DEXTERITY WHILE OPERATING IN UNSTRUCTURED SETUPS

AMAZON PICKING CHALLENGE
ROBOCUP AT WORK- EU
IROS MOBILE MANIPULATION HACKATHON
[HTTP://IROS18-MMH.PAL-ROBOTICS.COM/](http://iros18-mmh.pal-robotics.com/)

- NATURAL LIVING SPACES
- INDUSTRIAL WORKCELLS, WAREHOUSES
- EXTREME ENVIRONMENTS

DEXTEROUS BERRY PICKING COBOTS - WHY/ WHY NOW



DEMOGRAPHICS

- **LABOR** AVAILABILITY FOR LOW SKILLED, PHYSICALLY DEMANDING, LESS REWARDING TASKS
- AGEING POPULATION
- POLITICAL PRESSURES AFFECTING MIGRATION

ECONOMICS

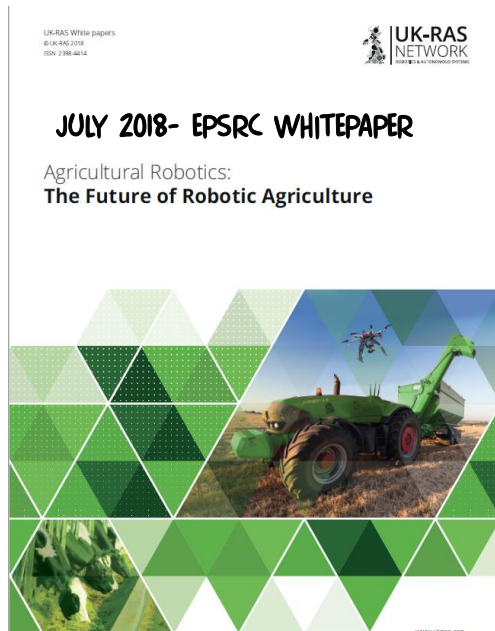
1/3RD OF THE TOTAL **PRODUCTION** COSTS
INCREASING **DEMAND** FOR PRODUCE
RELIANCE ON **IMPORTS**- LOCAL BUSINESS

INNOVATION IN GROWING TECHNOLOGY (TIPTREE)

CLIMATE CHANGE, **PESTICIDE FREE FARMING**

HEALTH AND **HYGIENE**

FROM BATCH ORIENTED TO **CONTINUOUS OPERATION**



<https://www.ukras.org/>

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WHY IS THE PROBLEM DIFFICULT ?

- INFINITE SOLUTIONS
- MULTIPLE TASK-CONSTRAINTS
(UNDERSPECIFIED)
- COMPLEX INTEGRATION OF VISION, TOUCH,
FORCE, PROPRIOCEPTION
- RUNTIME CONFIGURABILITY/ADAPTIVITY
- SOFT DEFORMABLE, PERISHABLE OBJECTS
- ACTIVE 'BERRY SEEKING, MOTION
PLANNING, PREDICTION'
- AS ROBUST, FAST, EFFICIENT...



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**THE BRAIN SOLVES
THIS IN A FRACTION OF
A SECOND !!**





STRAWBERRY PICKING THE PERCEPTION-ACTION LOOP AND BEYOND

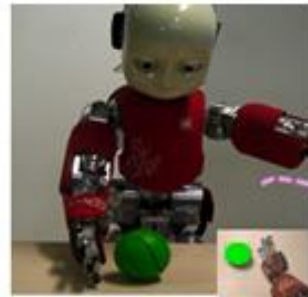
PERCEPTION-ACTION LOOP - THE BACKGROUND

ICUB HUMANOID (53 DOF IN THE BODY)

ASSEMBLY OF ELECTRONIC COMPONENTS



Tool Use



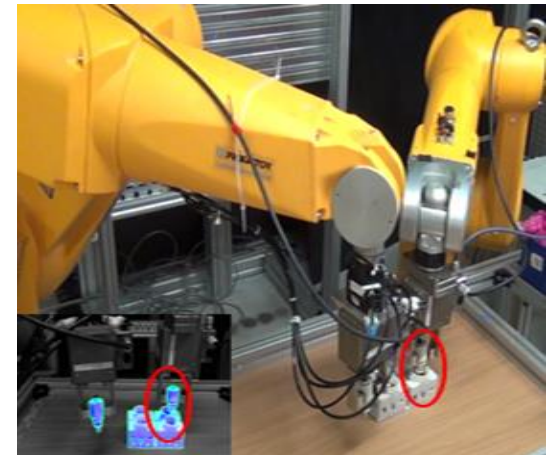
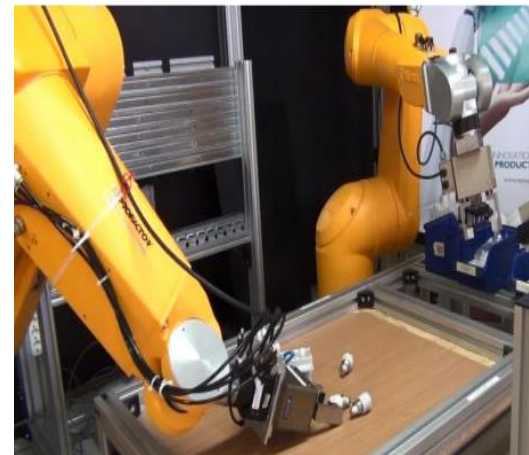
Pushing. Internalize How objects move



Construt the tallest possible tower given arandom set of objects



More complex Assembly tasks

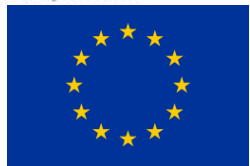
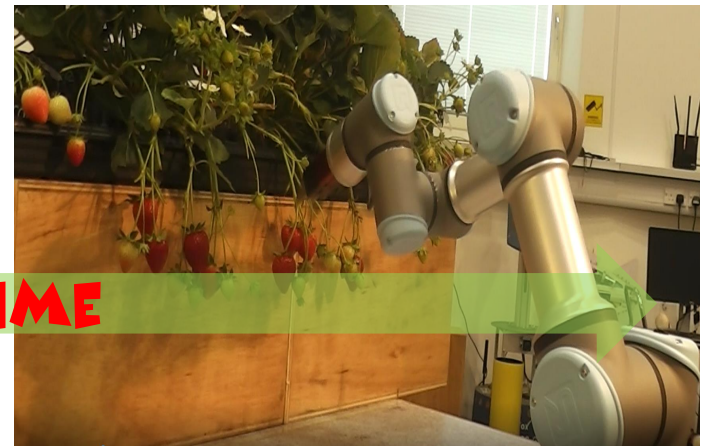


WHOLE BODY SYNERGIES
UNDER LOADING
CONDITIONS

BERRY PICKING / PACKING



TIME



1979-1985
BIZZI LAB, MIT
HOGAN LAB, MIT

Neville Hogan

Associate Professor,
Department of Mechanical Engineering
and Laboratory for Manufacturing
and Productivity,
Massachusetts Institute of Technology,
Cambridge, Mass. 02139

Impedance Control: An Approach to Manipulation:

Part I—Theory

Manipulation fundamentally requires the manipulator to be mechanically coupled to the object being manipulated; the manipulator may not be treated as an isolated system. This three-part paper presents an approach to the control of dynamic interaction between a manipulator and its environment. In Part I this approach is developed by considering the mechanics of interaction between physical systems. Control of position or force alone is inadequate; control of dynamic behavior is also required. It is shown that as manipulation is a fundamentally nonlinear problem, the distinction between impedance and admittance is essential, and given the environment contains inertial objects, the manipulator must be an impedance. A generalization of a Norton equivalent network is defined for a broad class of nonlinear manipulators which separates the control of motion from the control of impedance while preserving the superposition properties of the Norton network. It is shown that components of the manipulator impedance may be combined by superposition even when they are nonlinear.

EQUILIBRIUM POINT
HYPOTHESIS (BIZZI ET
AL, FELDMAN ET AL)

KINEMATIC NETWORKS
(SANDRO MUSSA IVALDI,
MORASSO ET AL)

PASSIVE MOTION
PARADIGM (MOHAN,
MORASSO, ET AL)

SIMULATION THEORY/
IDEMOTOR THEORY
(JEANNEROD..)

ACTIVE INFERENCE/FREE
ENERGY PRINCIPLE
(FRISTON ET AL.)

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reviews

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Review

*Muscleless motor synergies and actions without movements:
From motor neuroscience to cognitive robotics*

Vishwanathan Mohan ^{a,*}, Ajaz Bhat ^b, Pietro Morasso ^c

^a School of Computer Science and Electronic Engineering, University of Essex, Wivenhoe Park, CO34SQ, UK

^b Dept. of Psychology, University of East Anglia, UK

^c Robotics, Brain and Cognitive Sciences Dept., Via Enrico Melen 83, 16152 Genova, Italy

Received 31 December 2017; received in revised form 12 April 2018; accepted 16 April 2018

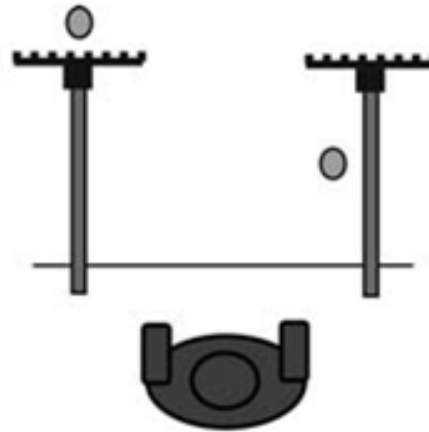
Communicated by J. Fontanari

2018

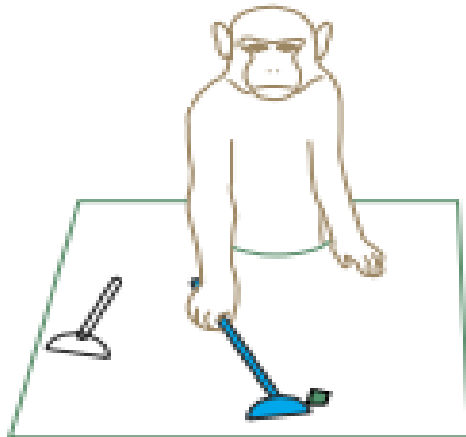


MOTOR NEUROSCIENCE TO COGNITIVE ROBOTICS

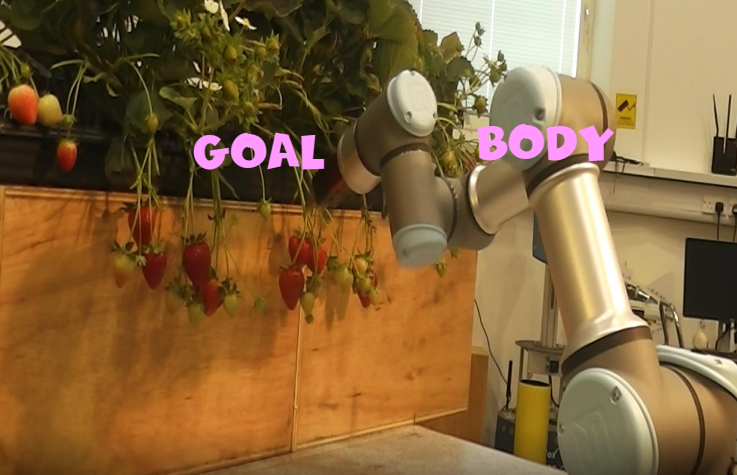
ACTION GENERATION, IMAGINATION AND UNDERSTANDING SHARE CORTICAL NETWORKS IN THE BRAIN



FORWARD SIMULATION
FOR MOTION
PLANNING/
PREDICTION



COOPERATING WITH
SOME ONE ELSE
(ROBOT, HUMANS)

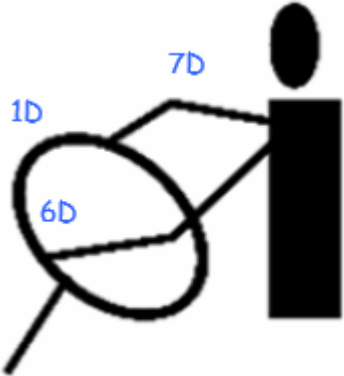
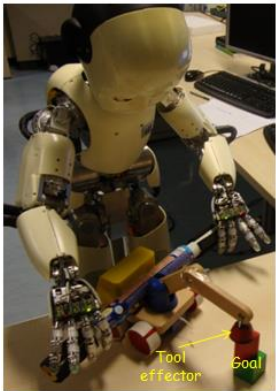


STRAWBERRY PICKING ROBOT (PERCEPTION ACTION LOOP)

CENTRAL FEATURES

- COORDINATE COMPLEX NETWORKS OF 'BODY-TOOLS-OTHER BODIES' (ELECTRICAL CIRCUITS)
- SYNTHESIZED AT RUNTIME BASED ON THE GOAL
- ANY NUMBER OF DEGREES OF FREEDOM
- MULTIPLE TASK SPECIFIC CONSTRAINTS
- MULTIREFERENTIAL (FORCE / POSITION)
- NO INVERSE KINEMATICS, PREDEFINED COST FUNCTIONS
- SYNCHRONIZATION THROUGH TERMINAL ATTRACTORS
- INTERNAL BODY MODEL IS LEARNT – NEURAL NETWORK
- GENERATE ACTION / PREDICT CONSEQUENCES OF POTENTIAL ACTIONS

CONFIGURABLE BODY MODELS - REPRESENTATION



MOTOR SPACES
GROUNDING

HAND
POSITION/DISP



JOINT
POSITION



ONE ARM



HAND FORCE



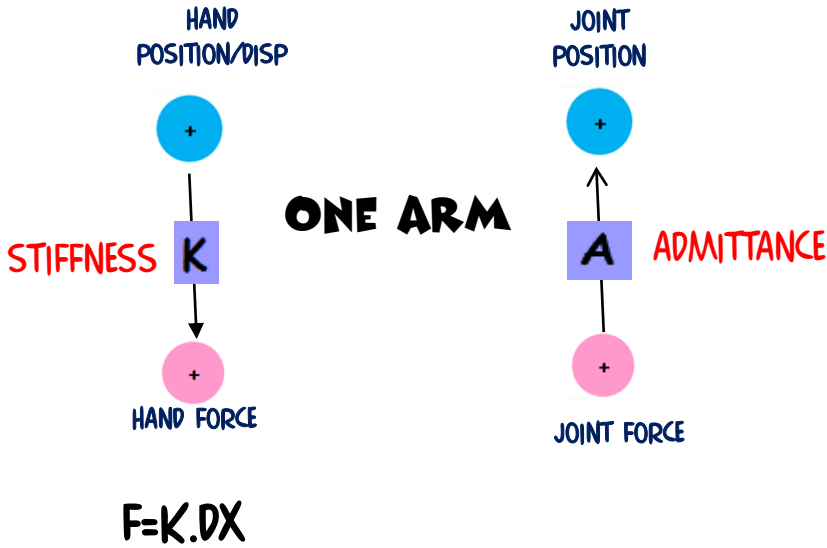
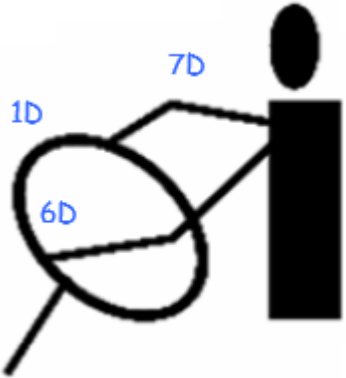
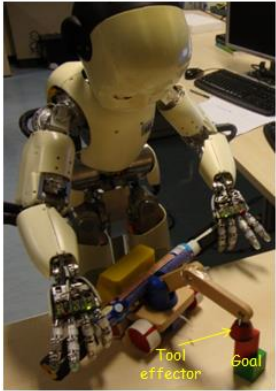
JOINT FORCE

MOTOR SPACES

BLUE-DISPLACEMENT NODE

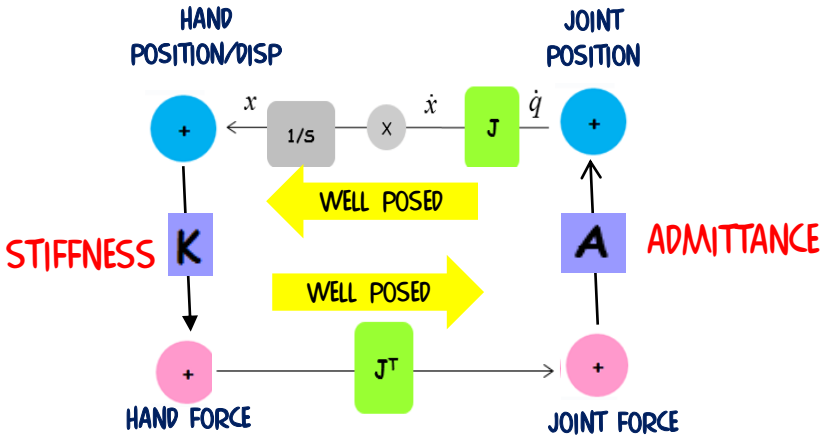
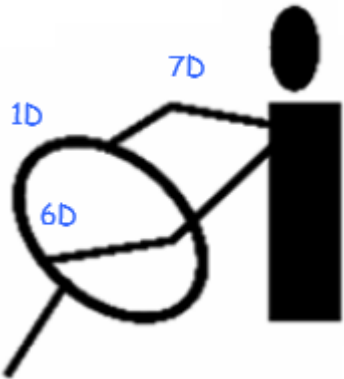
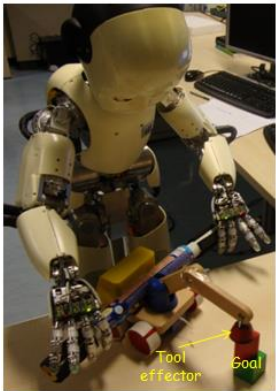
PINK- FORCE NODE

CONFIGURABLE BODY MODELS - CONNECTIVITY



MOTOR SPACES
GROUNDING
CONNECTIONS
VERTICAL
HORIZONTAL

CONFIGURABLE INTERNAL MODELS - CONNECTIVITY



J- JACOBIAN

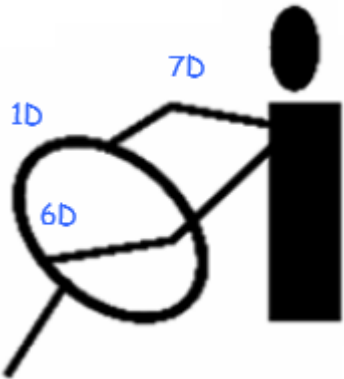
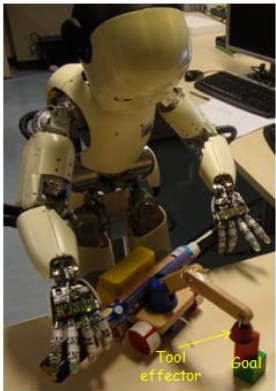
HORIZONTAL- GEOMETRIC CAUSALITY
BETWEEN MOTOR SPACES

VERTICAL- ELASTIC CAUSALITY (BETWEEN
FORCE AND POSITION)

MOTOR SPACES
GROUNDING
CONNECTIONS
VERTICAL
HORIZONTAL
WELL POSED

NO INVERSE
KINEMATICS

CONFIGURABLE INTERNAL MODELS - CONNECTIVITY



**GOAL
ANIMATES
THE BODY**



GOAL x_G

HAND
POSITION/DISP

JOINT
POSITION

STIFFNESS

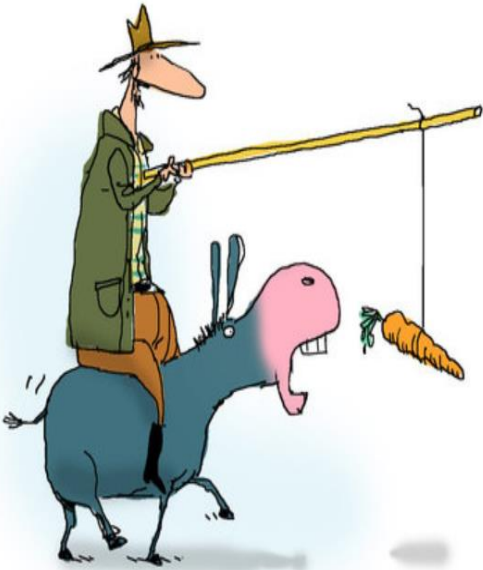
ADMITTANCE

HAND FORCE

JOINT FORCE

WELL POSED

WELL POSED



MOTOR SPACES

GROUNDING

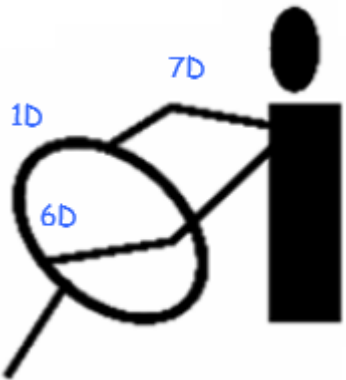
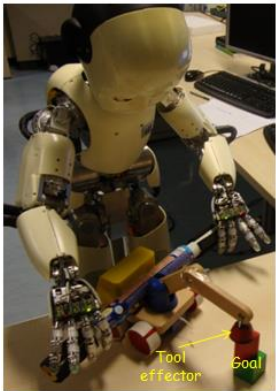
CONNECTIONS

VERTICAL

HORIZONTAL

WELL POSED

CONFIGURABLE INTERNAL MODELS - CONNECTIVITY



**GOAL
ANIMATES
THE BODY**



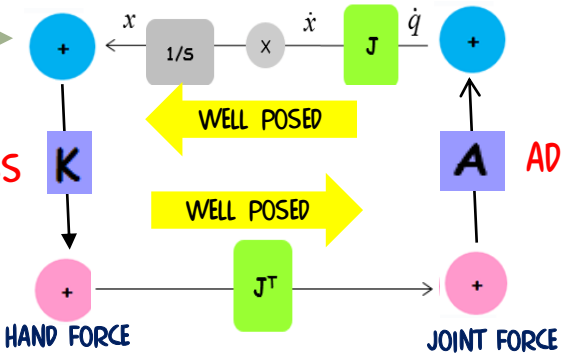
GOAL x_G

HAND
POSITION/DISP

JOINT
POSITION

STIFFNESS

ADMITTANCE



MOTOR SPACES

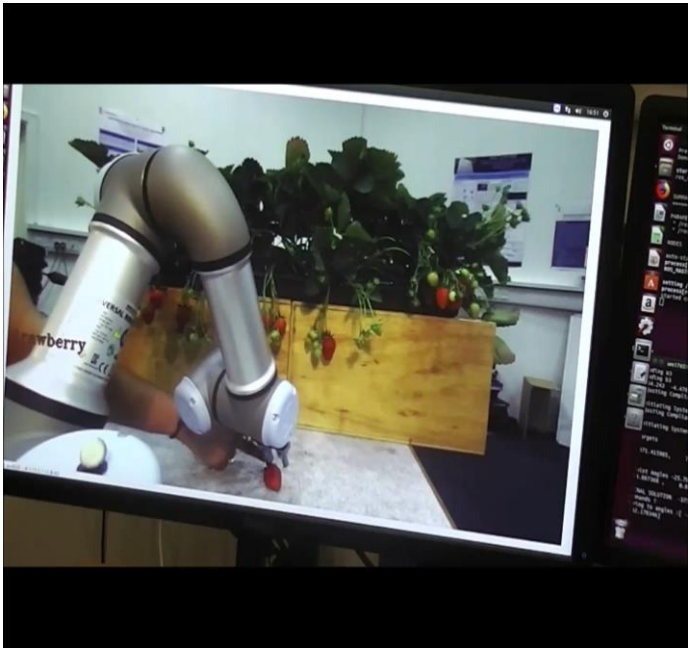
GROUNDING

CONNECTIONS

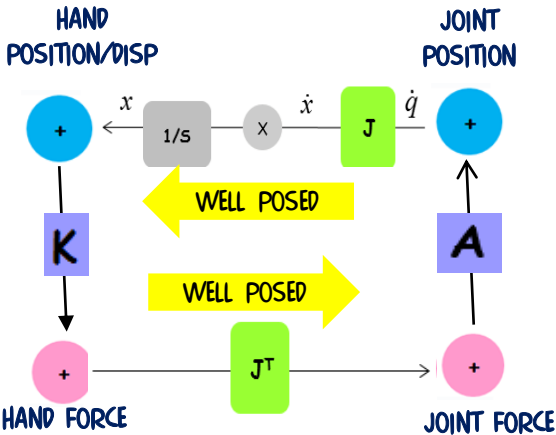
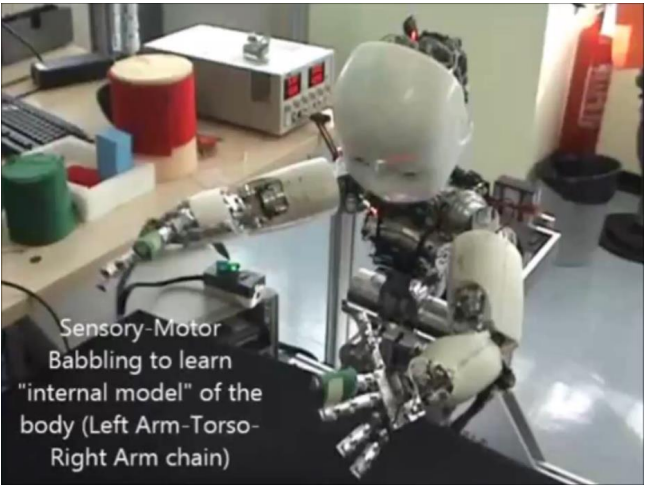
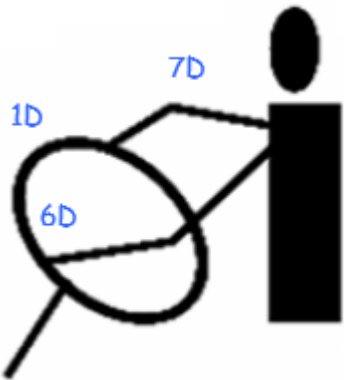
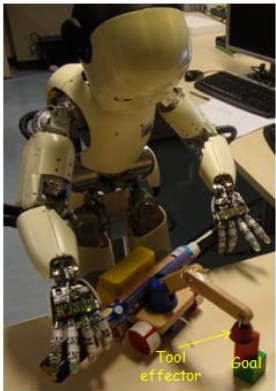
VERTICAL

HORIZONTAL

WELL POSED



CONFIGURABLE INTERNAL MODELS - LEARNING

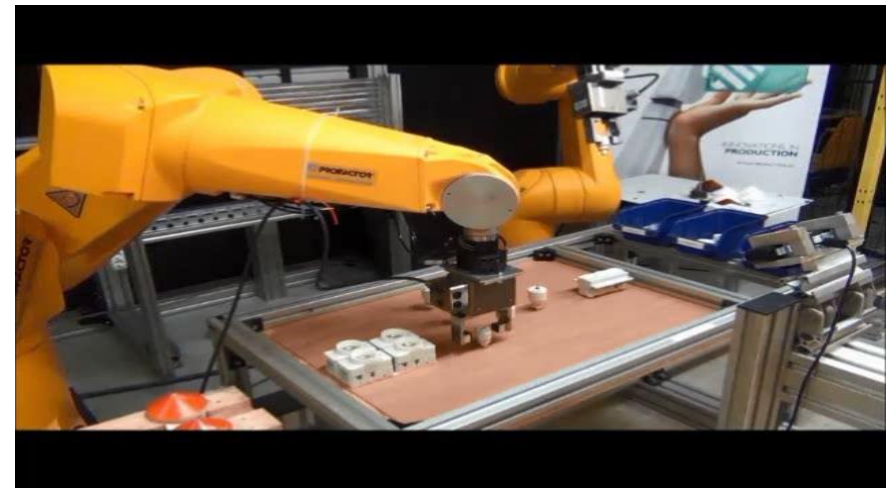
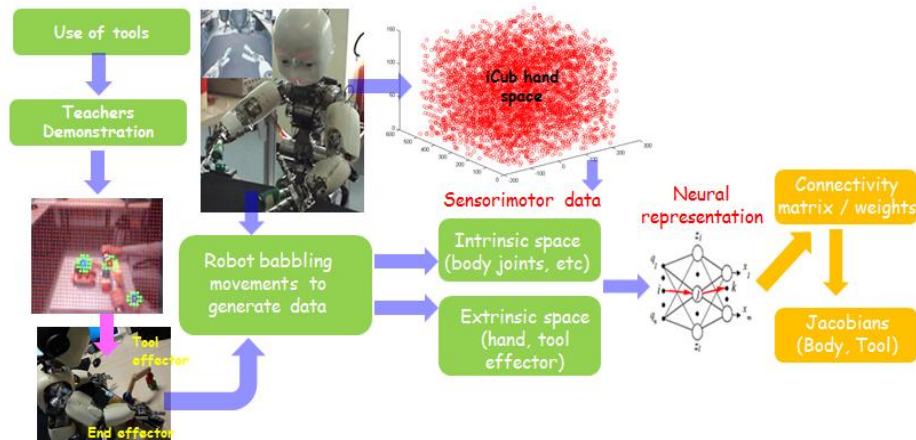
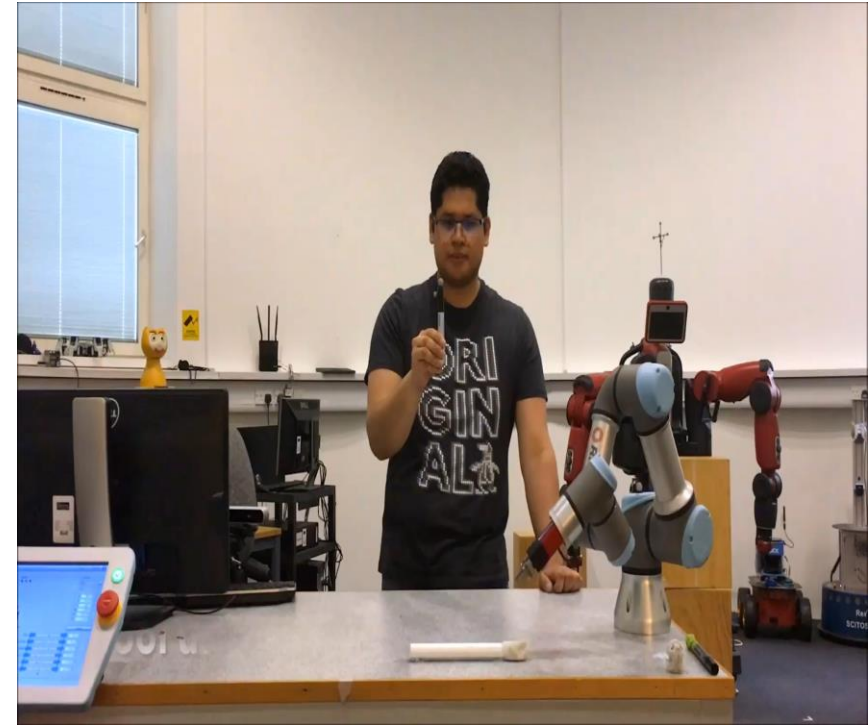
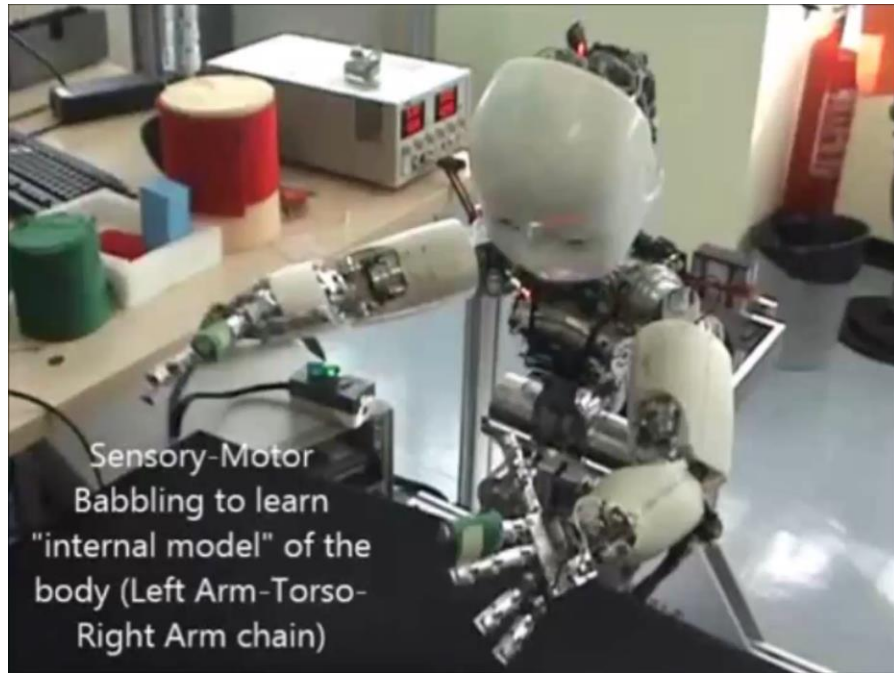


MOTOR SPACES
GROUNDING
CONNECTIONS
VERTICAL
HORIZONTAL
WELL POSED
LEARNING

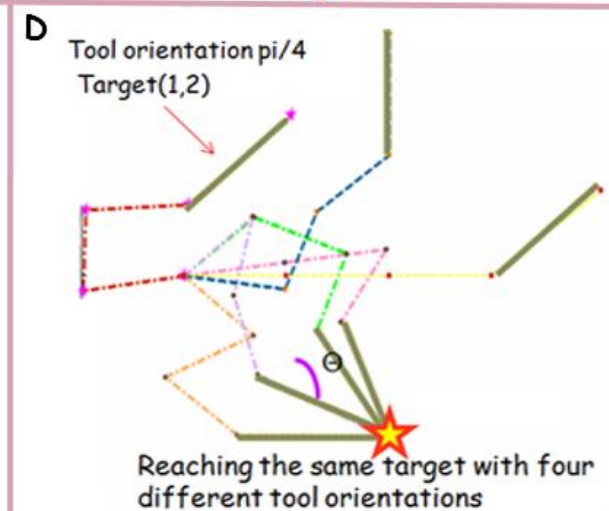
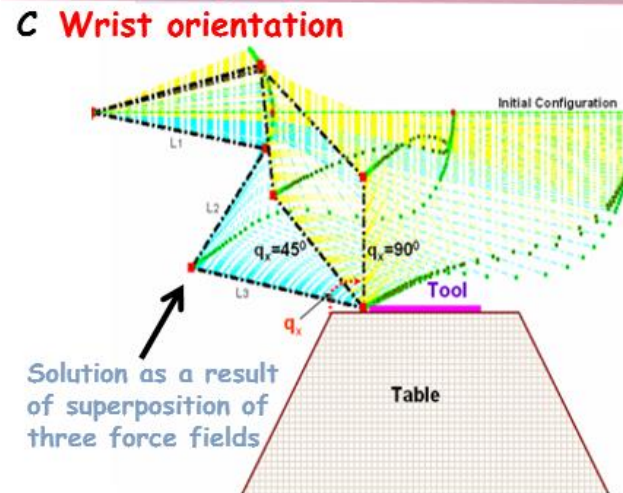
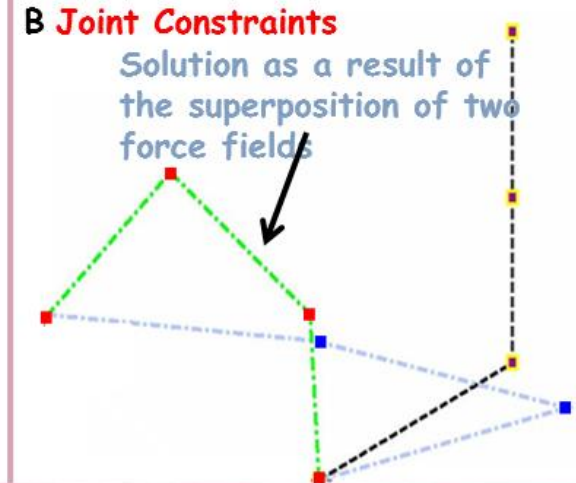
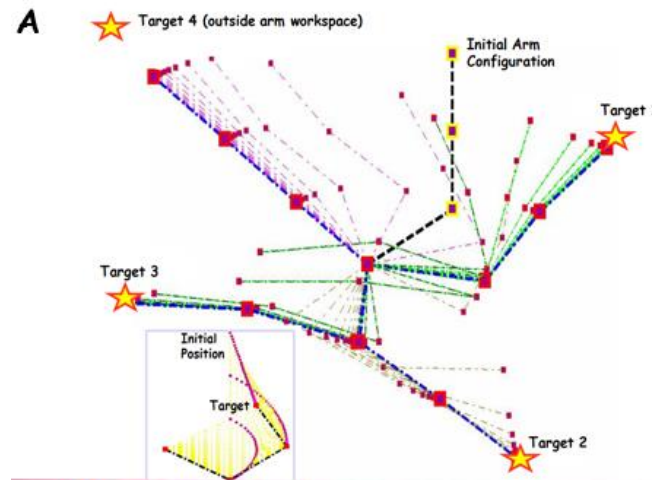
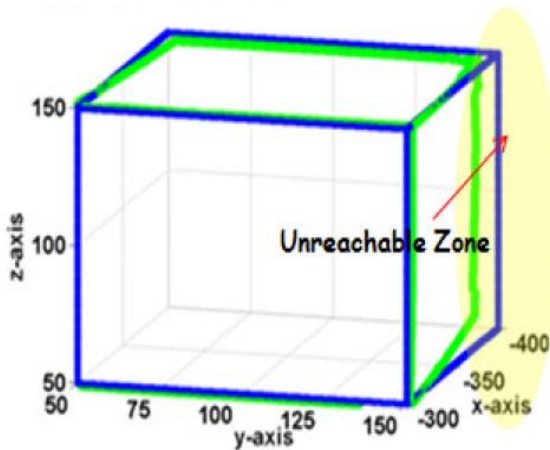
NEURAL NETWORK IS LEARNT (INTERNAL BODY MODEL)

COMBINATION OF MOTOR BABBLING,
IMITATION AND REUSE OF PAST MOTOR
EXPERIENCE

LEARNING THE INTERNAL BODY MODEL AND TRIGGERING ACTIONS



MULTIPLE CONSTRAINTS, ACCURACY



PERCEPTION-ACTION LOOP- TRIALS IN LAB

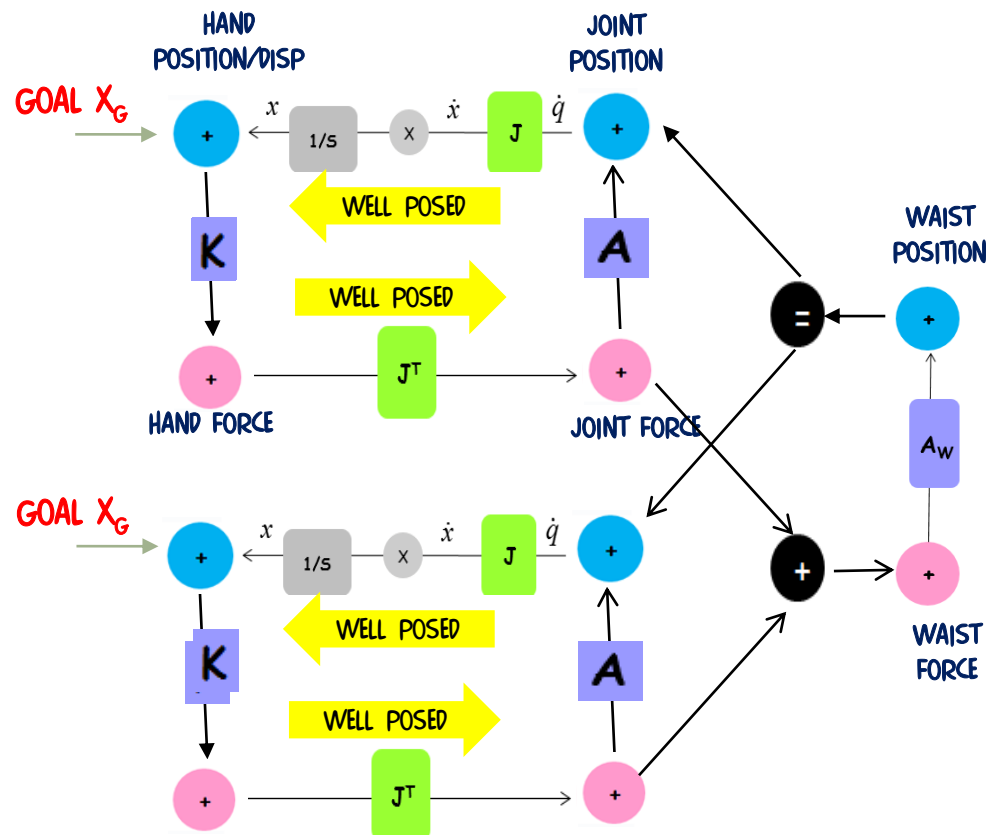


- COLOR BASED RECOGNITION
- ACCESS THE DEPTH MAP
- TRANSFORMATION TO ROBOT FRAME
- CONNECT TO THE ACTION SYSTEM

HYPERSPECTRAL IMAGING
MACHINE LEARNING (ADRIAN CLARK, TRACY LAWSON,
DIMITRI OGNIBENE WITH DEPT. OF BIOLOGICAL
SCIENCES)- EPIC (AGRITECH EAST 2018)

INTEGRATION ONGOING!!!

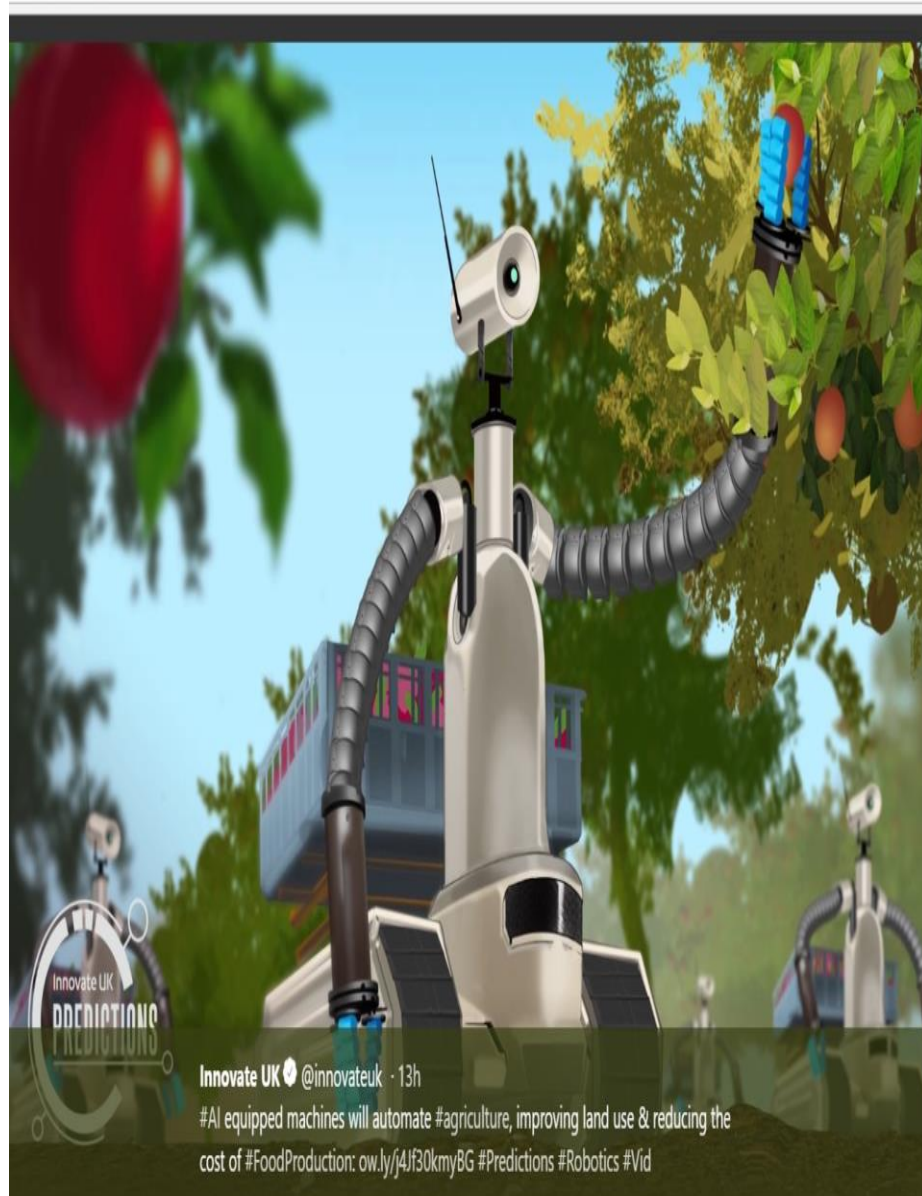
WHOLE BODY COORDINATION- TWO HANDS + TORSO



- MOTOR SPACES
- GROUNDING
- CONNECTIONS
- VERTICAL
- HORIZONTAL
- WELL POSED
- LEARNING
- GOAL
- (DISTURBANCE)
- BRANCHING
- CIRCULARITY
- WHOLE UPPER BODY

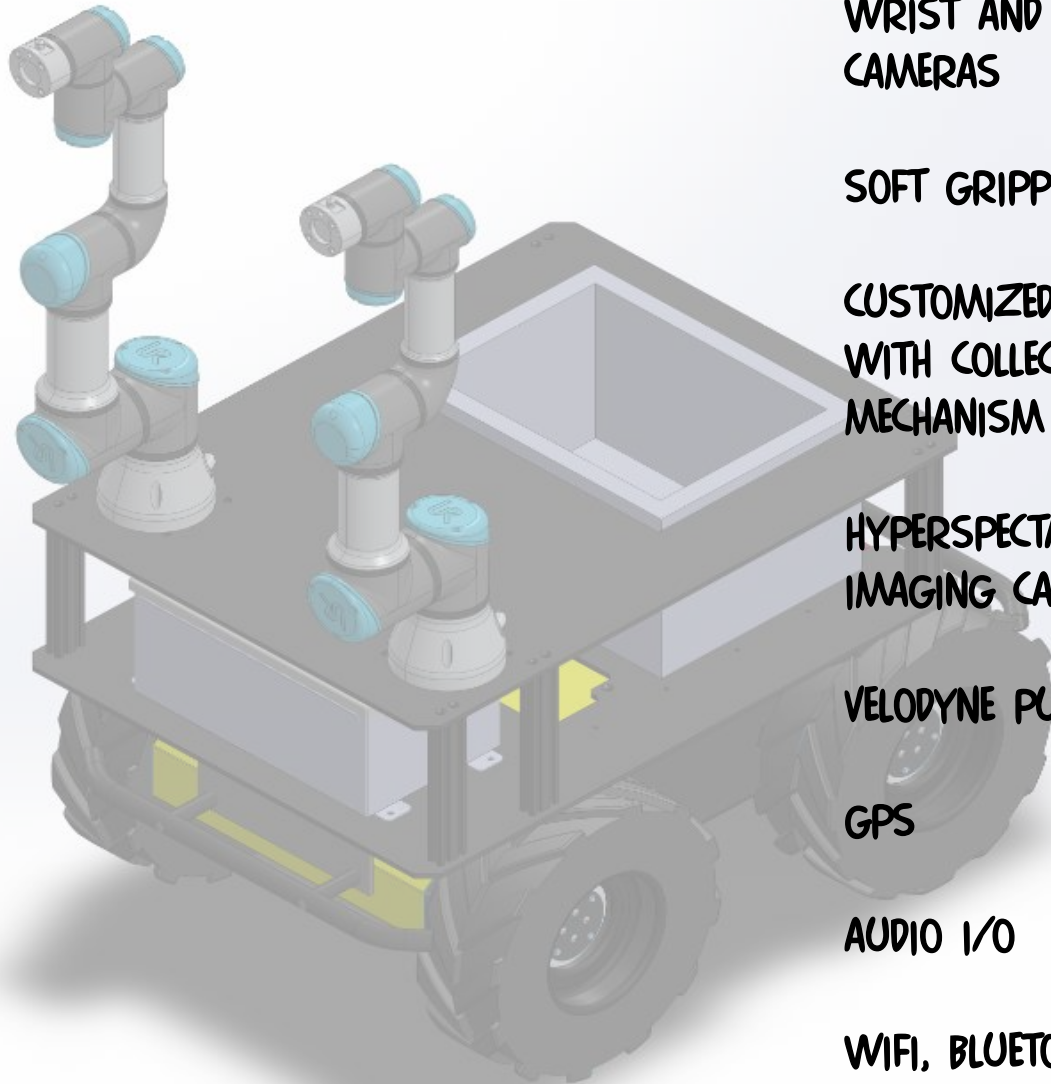
ONGOING WORK- THE BEAST

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ONGOING WORK- THE BEAST

INTEGRATION ONGOING AT THE MOMENT - PLAN TO HIT THE FIELD BY MID APRIL



WRIST AND BASE
CAMERAS

SOFT GRIPPER

CUSTOMIZED GRIPPER
WITH COLLECTION
MECHANISM

HYPERPECTRAL
IMAGING CAMERAS

VELODYNE PUCK LIDAR

GPS

AUDIO I/O

WIFI, BLUETOOTH, 4G

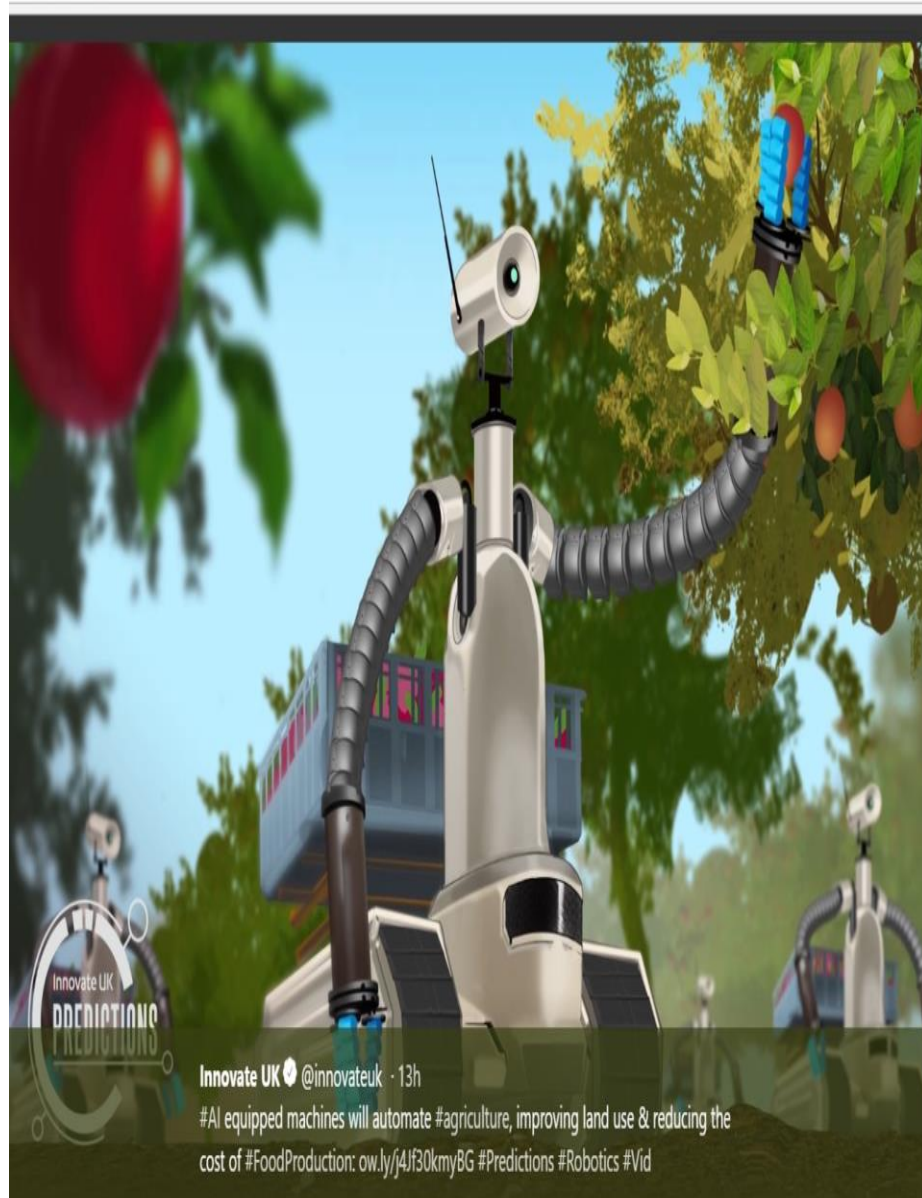


MOBILE
BIMANUAL
BIO-MIMMETIC
COLLABORATIVE
ROBOT

- NEURAL CONTROL OF MOVEMENT
- ACTIVE PERCEPTION
-

ONGOING WORK- THE BEAST

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BIMANUAL BERRY PICKING/PACKING

GRIPPING/CUTTING MECHANISM
(WITH WILKIN AND SONS)

HYPERSENSITIVE IMAGING,
ENHANCED PERCEPTION (ADRIAN CLARK
DIMITRI OGNIBENE, TRACY LAWSON) - --
BIOLOGICAL SCIENCES

ACTIVE VISION (BERRY SEEKING VS
PICKING)

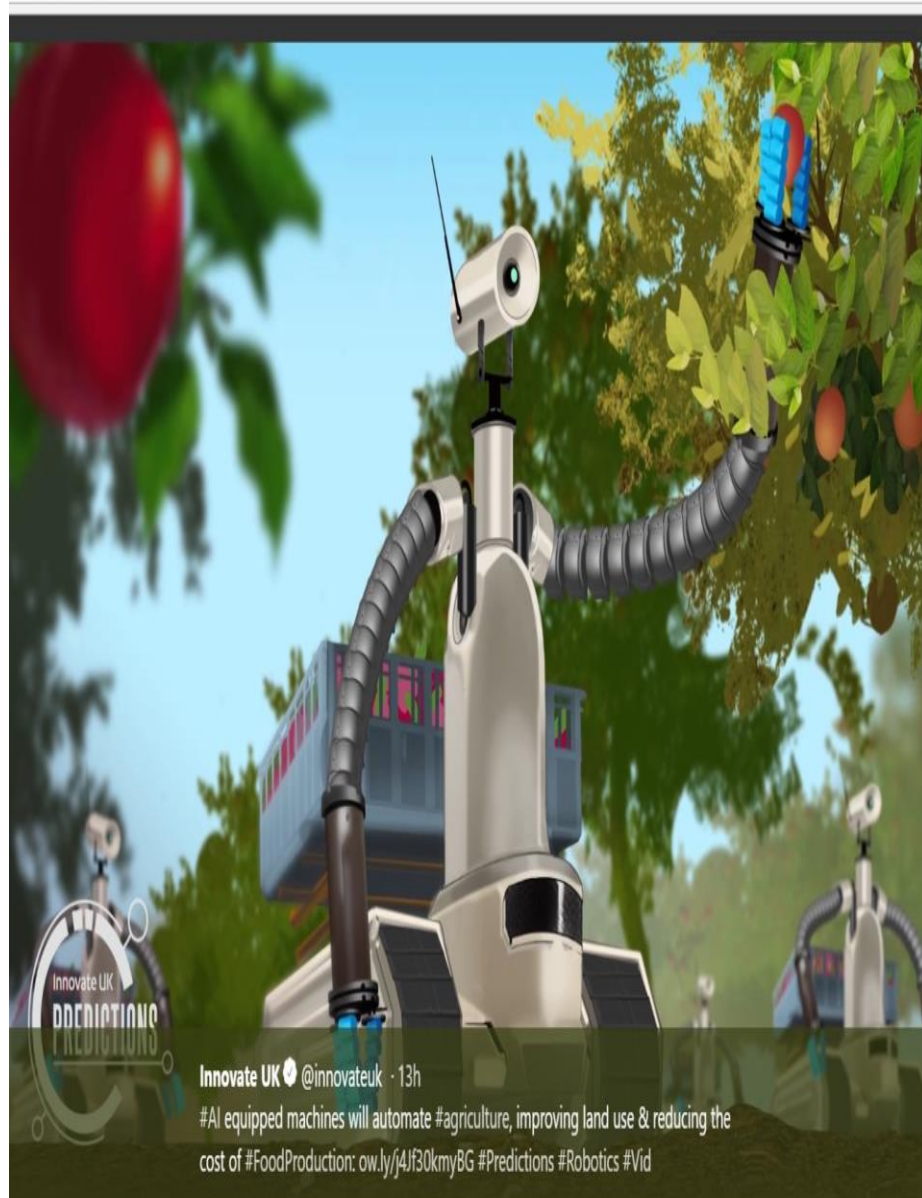
ENHANCED FEEDBACK LOOP
(VISION)

MOBILE BASE (YIELD PREDICTION)

UNDERSTAND WHAT MAKES
HUMANS SO GOOD (WITH ESSEX
PSYCHOLOGY DEPT.).....

ONGOING WORK- THE BEAST

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BIMANUAL BERRY PICKING/PACKING

GRIPPING/CUTTING MECHANISM
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ONGOING WORK- THE BEAST

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BIOLOGICAL SCIENCES

**PSYCHOLOGY/
NEUROSCIENCE**

ROBOTICS

**EXPERTS IN FARM
INNOVATION- TIPTREE AND
END USER DRIVEN**

ON A DECEPTIVELY SIMPLE AND EFFORTLESSLY
HUMAN PROBLEM.....

Innovate UK
DECEMBER 10
Innovate UK - 13h
equipped machines will automate #agriculture, improving land use & reducing the
cost of #FoodProduction: ow.ly/4Jf30kmyBG #Predictions #Robotics #Vid

BIMANUAL BERRY PICKING/PACKING

GRIPPING/CUTTING MECHANISM
(WITH WILKIN AND SONS)

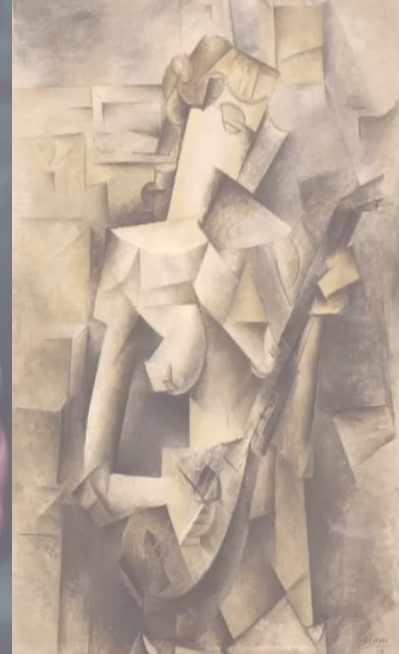
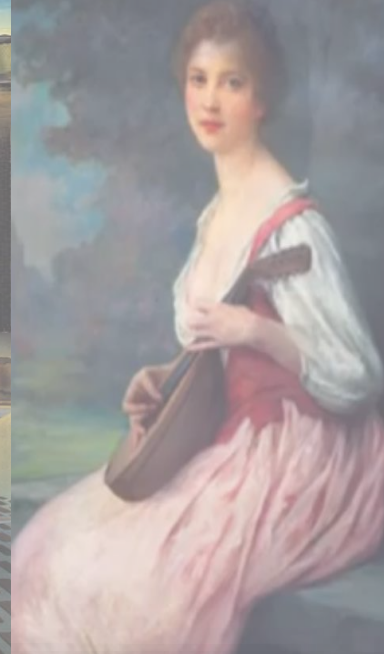
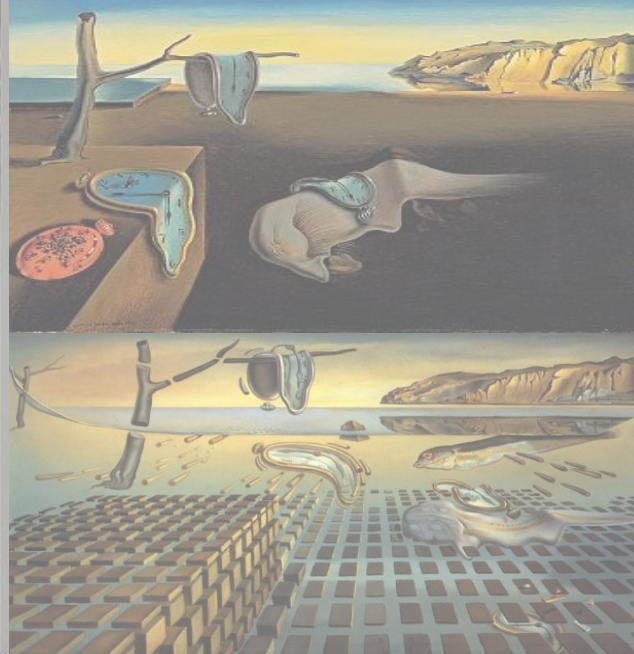
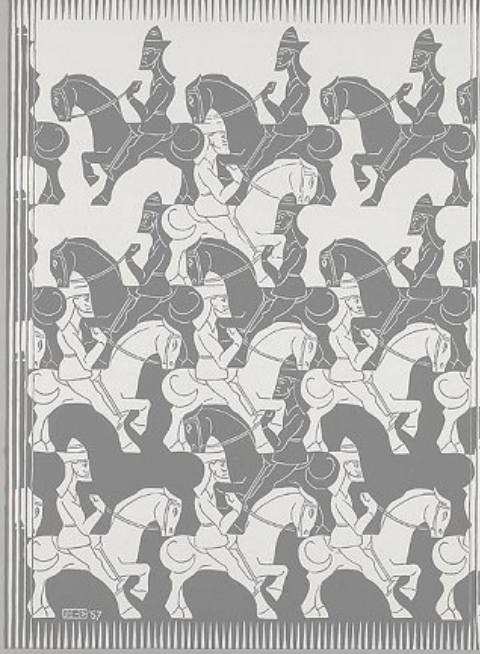
**HYPERSENSITIVE IMAGING,
ENHANCED PERCEPTION** (ADRIAN CLARK
DIMITRI OGNIBENE, TRACY LAWSON) - --
BIOLOGICAL SCIENCES

**ACTIVE VISION (BERRY SEEKING VS
PICKING)**

**ENHANCED FEEDBACK LOOP
(VISION)**

MOBILE BASE (YIELD PREDICTION)

**UNDERSTAND WHAT MAKES
HUMANS SO GOOD** (WITH ESSEX
PSYCHOLOGY DEPT.).....



Thank You + ??????

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