# COMP 50: Autonomous Intelligent Robotics

Instructor: Jivko Sinapov

http://www.cs.tufts.edu/comp/50AIR/

# Robot Training Sessions

- Look for announcement on Trunk with link to document
- If you cannot make any of the listed times, send me an email ASAP so we can find an alternative time

# Today

- Reading Discussion
- Embodiment
- Robot Bodies in ROS
- Homework 4 is out

# Immediate openings @ my lab

- Undergraduate Research Assistants
- Spring 2018, Summer 2018, Fall 2018
- If interested, send me an email with a resume and your availability in terms of terms and hours per week
- Credit options: Directed Study 194

# Announcements

# Reading Discussion

## On explicit rules and planning

"This research seems **particularly applicable to relatively routine environments with fixed patterns and rules governing them.** While an extensive set of rules might cover many possible cases and scenarios, such a scenario may have too complicated a codebase to be easily deciphered by humans. [...] **explicit rules may not provide the flexibility necessary for dynamic environments**, especially those which do not fall into easy "true/false" distinctions." - Selena

## Spatial Distribution of Activities

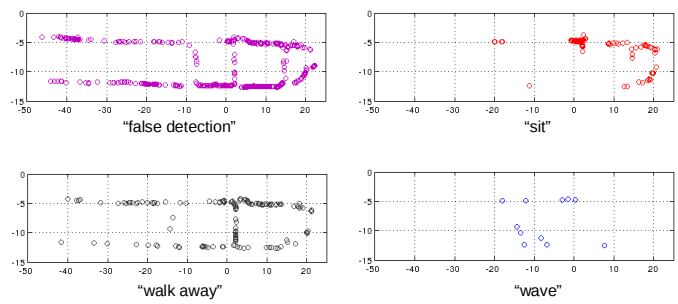
**"Sit" Activity Observations**

## On Activity Recognition

"... the article only mentions the robot using camera-captured image processing to evaluate a human's action, but I would like to know **if it uses any other sensors to collect data on humans.** For example, if the robot hears a human talking, **would it be possible for it to analyze whether or not the person is talking to the robot or to someone else.** The robot could use its speech recognition in combination with image processing to see if the person is directing speech at the robot. Additionally, I was curious about **how a robot responds to the different human activities it detects around it**. […] Would the responses **be hard coded, or would the robot learn them** as secondary requests and goals, similarly to verbal commands?"

- Serena

## Spatial Distribution of Activities




## Spatial Distribution of Activities

## On Object Exploration

"The question I have is that I want to know **if this feature produces specific learning tasks for robots to learn** or **does the exploration happen when no particular tasks are assigned to the robot.** Also, I am doing similar research in robot's action exploration area."

- Yirong

## On Verification

"To begin with, **how does the Verification Principle conflict with some of the new methods of machine learning, such as reinforcement learning.** Does this still count as verifiable? Another similar situation where this verifiability aspect seemed a bit counterintuitive is **what happens if you have not one, but multiple robots trying to collaborate with each other?** Can swarms of robots share information while still keeping this information verifiable? Would they only be able to verify this information **if the robots are similar enough to share some common limitations**?"

- Mateo

## Hard-coded vs. learned knowledge

"Although Alpha Go wasn't technically a robot (not embodied) **it found new strategies in go that humans hadn't thought about**, and have since added to the game. **A human programmed machine wouldn't do this, because it would be playing with human assumptions and strategies.**"

- Anne

## On embodiment

"**What constitutes a body?** There are many experiences and actions that can be performed with a single arm attached to a central body or station. Is this enough? I am curious to know **if the direction of robotics is heading towards building machines that mimic the human body, or if the principle of embodiment only implies that there must be some sort of physical representation of intelligence** – whether that is as basic as a mechanical grabber/arm or as complex as "Leo" (the robot shown in the in-class video)."

- Margaret

## Is AlphaGo a robot?

"... the existence of technologies like the Internet mean that **a robot can indeed interact and verify things that are relevant to humans, without having a physical body**. To again use Alpha Go as an example, **alpha go did interact with the world**, though sometimes through a human agent, and it definitely used a verification process, especially in its training."

- Anne

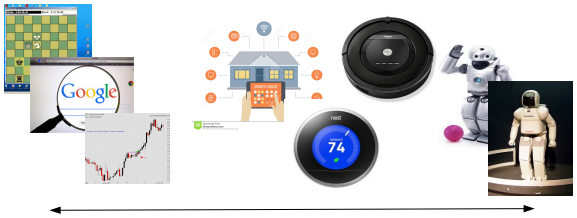
## Embodied AI

"While you can have various forms of AI (think AlphaGo, or Alexa & Siri that focus on responding to natural language processing), these are fundamentally different from robots. **You can have significant advances in AI and create programs that can evolve and learn and improve their behavior for skills** (playing games, conversing with humans), but **what separates them from robots is they cannot interact with the physical world**."

- Matthew

## Go Board

# Embodiment




No body — Body

# Embodied AI

Embodied Intelligence (EI) is a mechanism that learns how to survive in a environment (potentially hostile)

- Mechanism: biological, mechanical or virtual agent with embodied sensors and actuators
- EI acts on environment and perceives its actions
- EI learns so it must have associative self-organizing memory
- Knowledge is acquired by EI

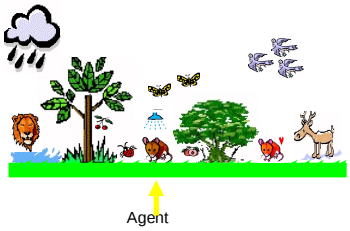
# Traditional View of AI

Mainstream Science on Intelligence December 13, 1994:

An Editorial With 52 Signatories, History, and Bibliography by Linda S. Gottfredson, University of Delaware

*"Intelligence is a very general mental capability that, among other things, involves the ability to* ***reason, plan, solve problems, think abstractly, comprehend complex ideas,*** *learn quickly and* ***learn from experience****."*

# Embodied AI

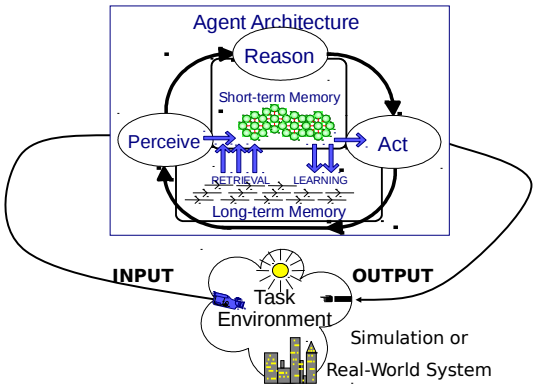



Drawing by Ciarán O'Leary- Dublin Institute of Technology

# Traditional vs. Embodied AI

- Abstract intelligence
  - attempt to simulate "highest" human faculties:
    - language, discursive reason, mathematics, abstract problem solving
- Environment model
  - Condition for problem solving in abstract way
  - "brain in a vat"
- Embodiment
  - knowledge is implicit in the fact that we have a body
    - embodiment is a foundation for brain development
- Intelligence develops through interaction with environment
  - Situated in a specific environment
  - Environment is its best model

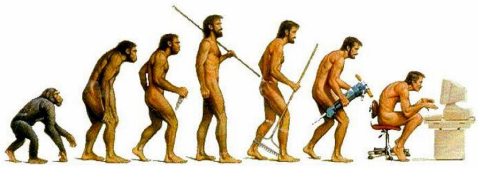
# Embodied AI




From Randolph M. Jones, P : www.soartech.com

# Embodiment in Humans

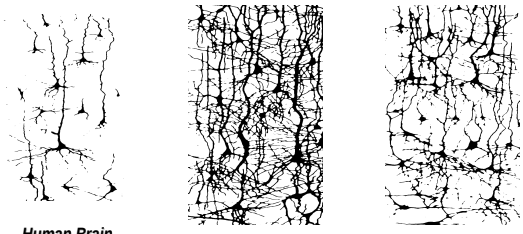
# Embodiment in Humans



# Embodiment in Humans


https://anagnk.files.wordpress.com/2013/03/fetal-growth.jpg

# Embodiment in Humans



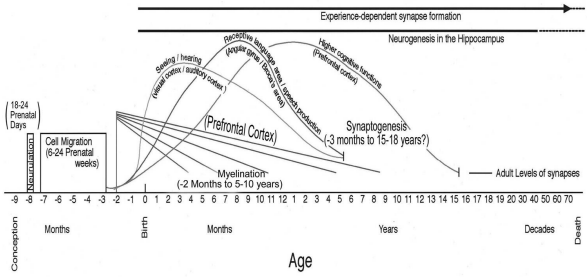
***Human Brain at Birth*** ***6 Years Old*** ***14 Years Old***

**Rethinking the Brain, Families and Work Institute, Rima Shore, 1997.**

# Embodiment in Humans

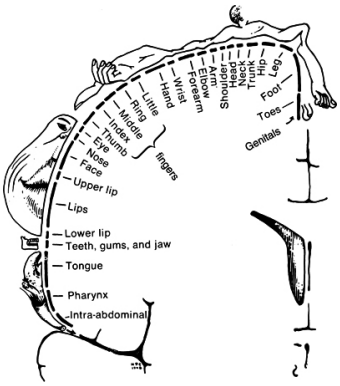

Source: Getty Images

# Synaptic Density over Time




Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media: Early brain development. *American Psychologist, 56(1),* 5-15.

## Penfield (a.k.a. Sensory) Homunculus

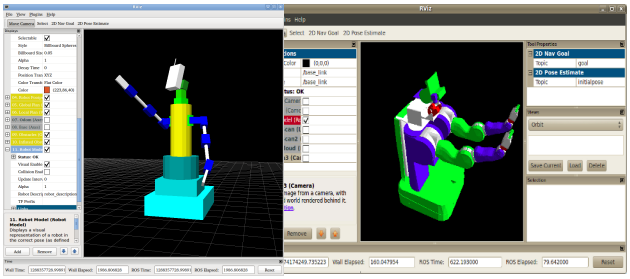


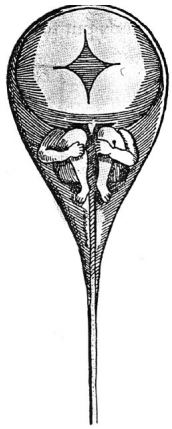

## Discussion

- Would a robot's body ever need to change over time?
- Does AI require a physical body? Why or why not?

## And its 3D Rendering

## Robot Bodies in ROS



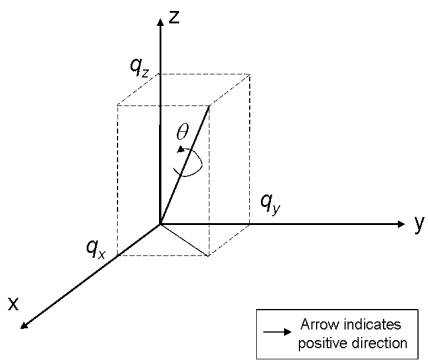


**Origins of the word Homunculus:**

A miniature, fully formed individual believed by adherents of the early biological theory of preformation to be present in the sperm cell.

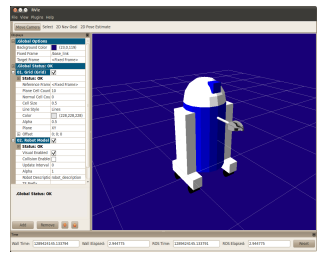
## Position and Orientation in 3D

## Quaternions

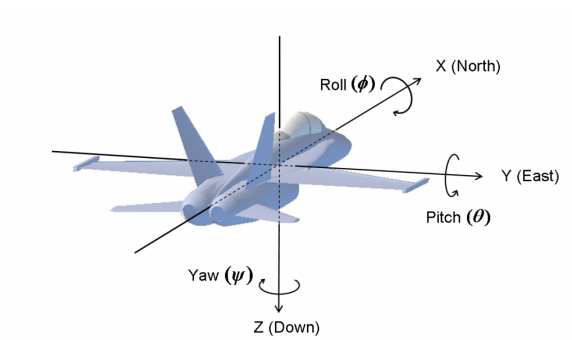



## Robot Bodies in ROS

- http://wiki.ros.org/urdf/Tutorials



## Roll - Pitch - Yaw




[http://www.chrobotics.com/library/understanding-quaternions]

## Homework 4

- Robot Training Session
- URDF Tutorials
- Build your own robot using URDF

## Converting between Quaternions and RPY

$$\begin{bmatrix}\phi\\ \theta\\ \psi\end{bmatrix} = \begin{bmatrix}\arctan\frac{2(q_0q_1+q_2q_3)}{1-2(q_1^2+q_2^2)}\\ \arcsin(2(q_0q_2-q_3q_1))\\ \arctan\frac{2(q_0q_3+q_1q_2)}{1-2(q_2^2+q_3^2)}\end{bmatrix}$$

$$\mathbf{q} = \begin{bmatrix}\cos(\phi/2)\cos(\theta/2)\cos(\psi/2)+\sin(\phi/2)\sin(\theta/2)\sin(\psi/2)\\ \sin(\phi/2)\cos(\theta/2)\cos(\psi/2)-\cos(\phi/2)\sin(\theta/2)\sin(\psi/2)\\ \cos(\phi/2)\sin(\theta/2)\cos(\psi/2)+\sin(\phi/2)\cos(\theta/2)\sin(\psi/2)\\ \cos(\phi/2)\cos(\theta/2)\sin(\psi/2)-\sin(\phi/2)\sin(\theta/2)\cos(\psi/2)\end{bmatrix}$$

## THE END