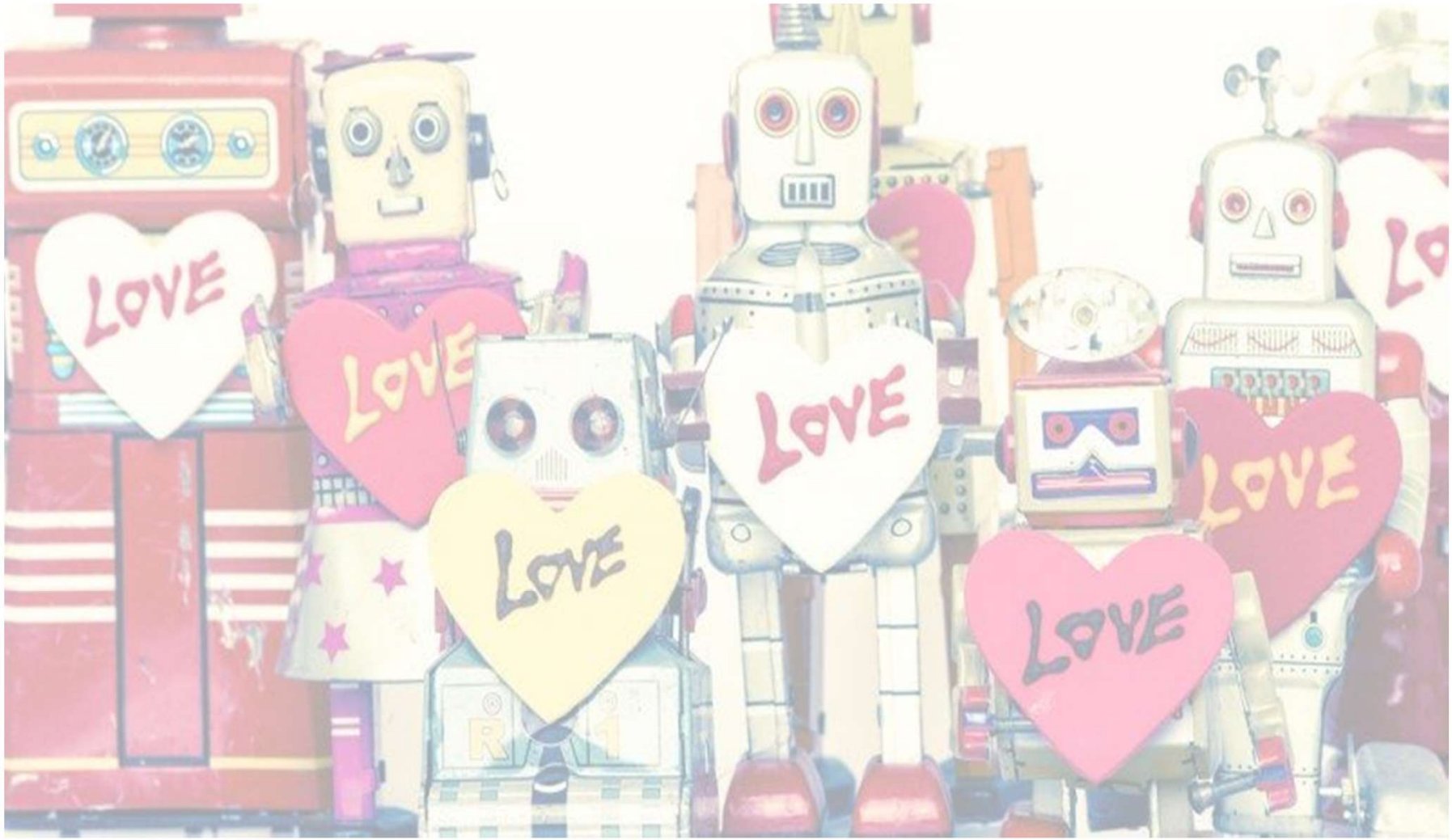
FROM THIRSTY CROWS TO COGNITIVE ROBOTS

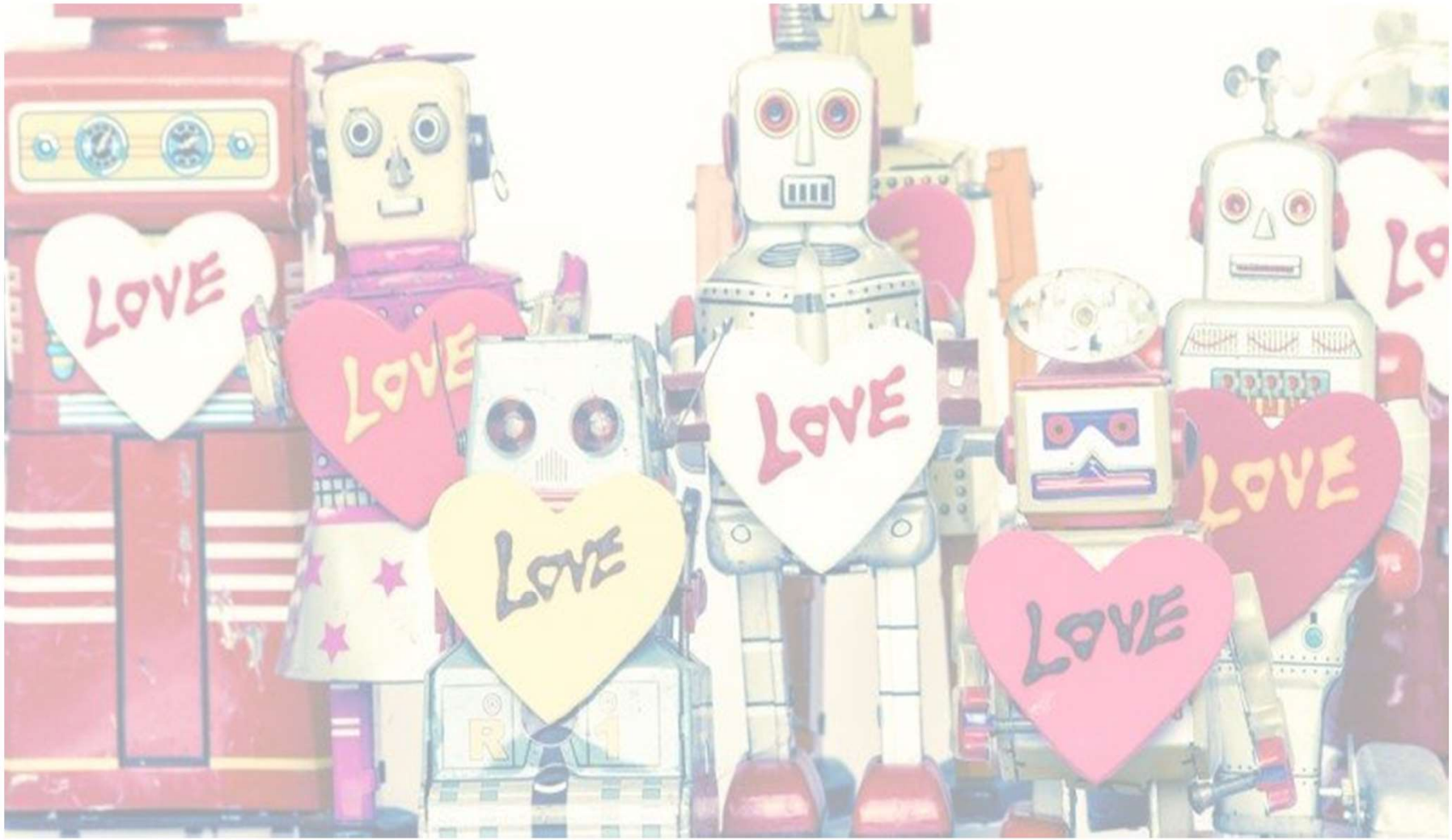
Vishwanathan Mohan (University Of Essex)

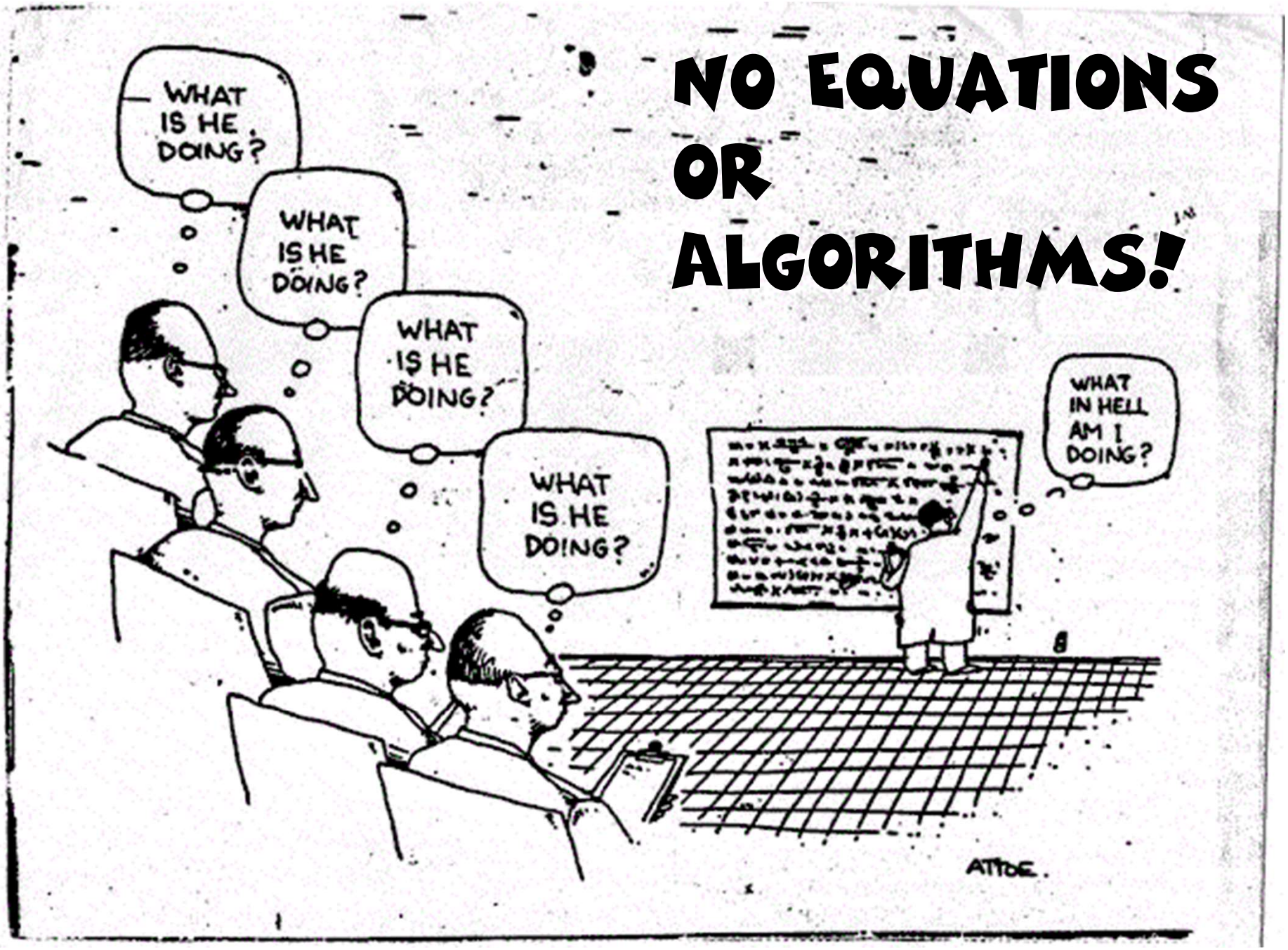
February 14th 2018, Tiptree tea room @ Minories



THANKS FOR BEING HERE ON SUCH A LOVE-LY DAY.....AND...

SO YOU ARE ALL IN THE GOOD BOOKS OF THE ROBOTS !!!!

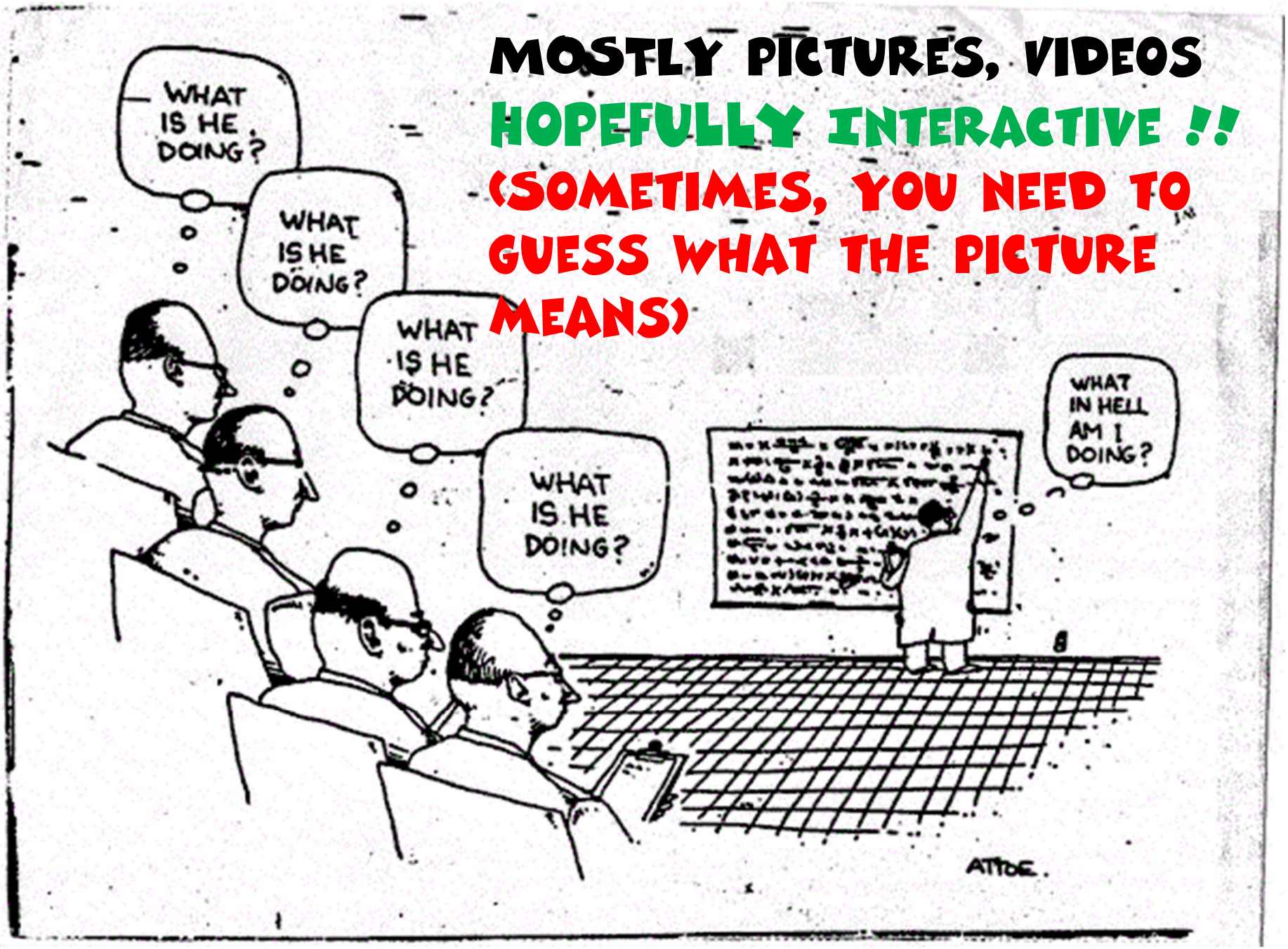



NO EQUATIONS OR ALGORITHMS!
WHAT IS HE DOING?
WHAT IS HE DOING?
WHAT IS HE DOING?
WHAT IS HE DOING?
WHAT IN HELL AM I DOING?
ATTOE.

MOSTLY PICTURES, VIDEOS

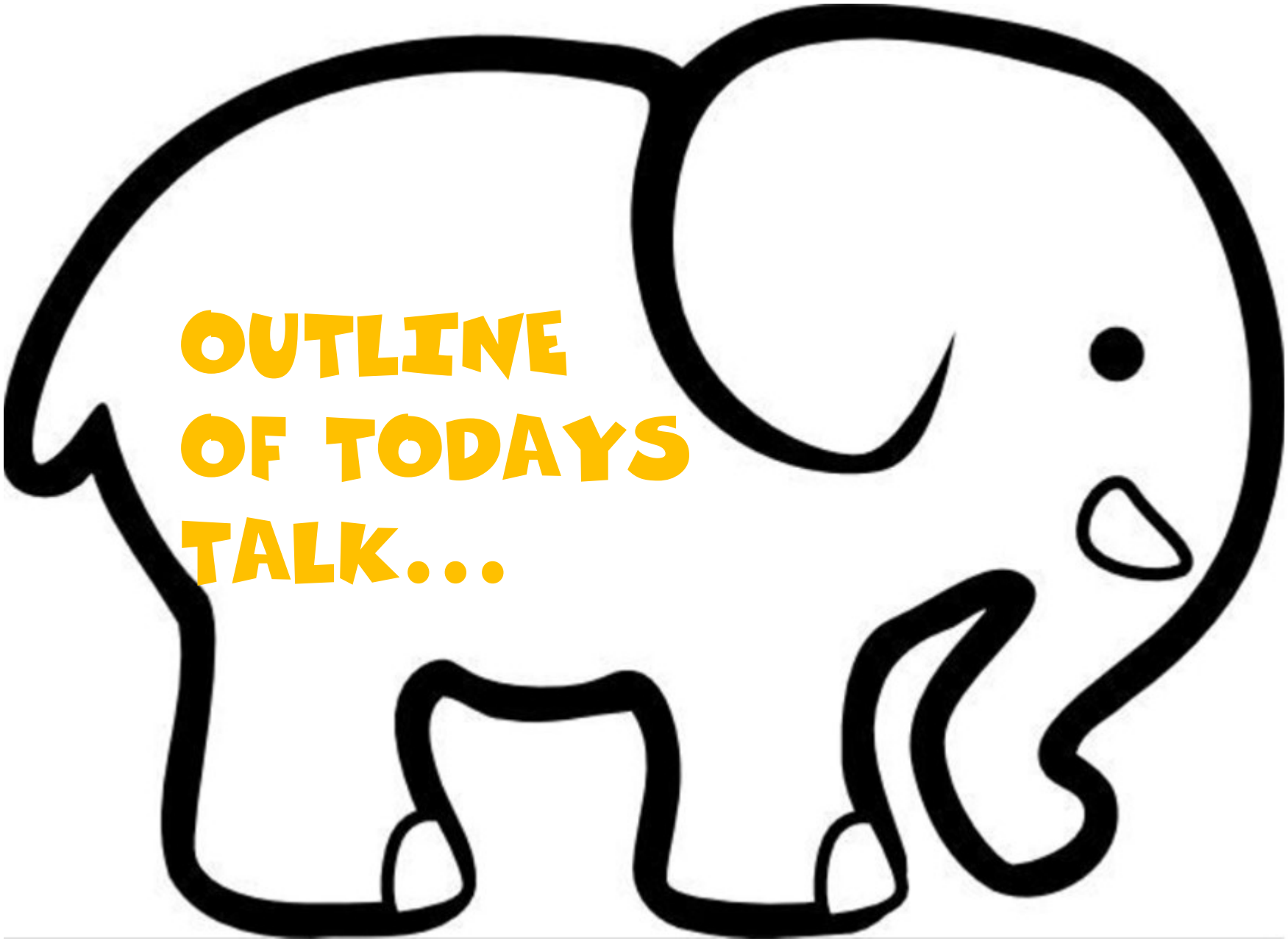
HOPEFULLY INTERACTIVE !!

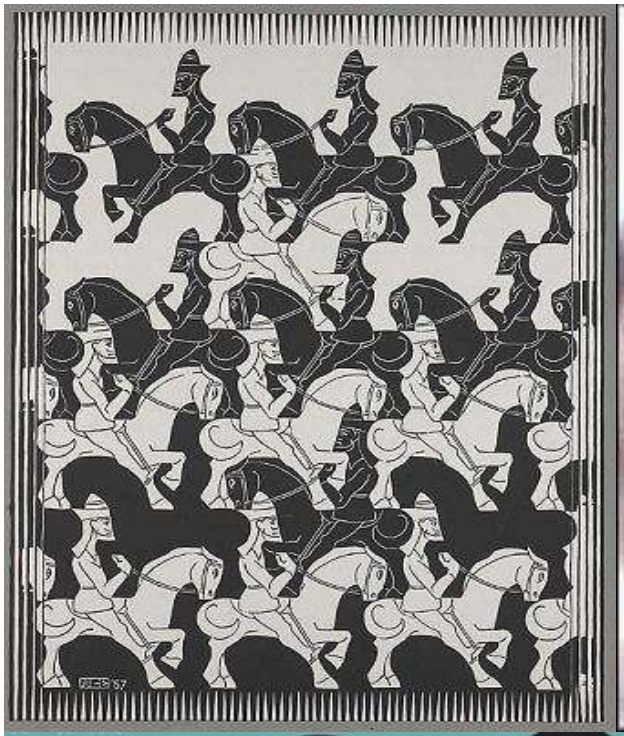
(SOMETIMES, YOU NEED TO GUESS WHAT THE PICTURE MEANS)

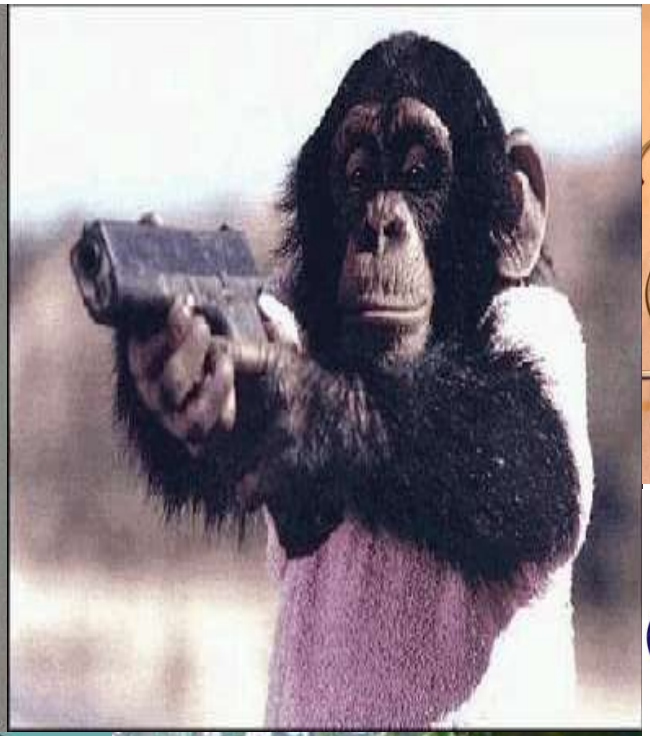


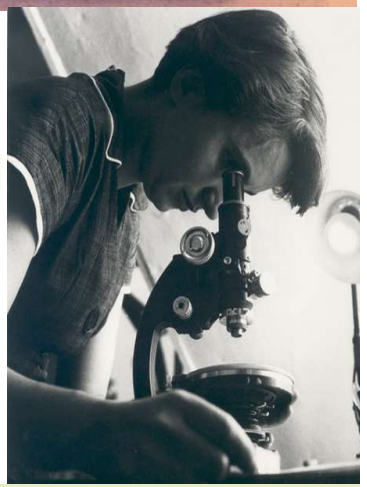
2018
2018

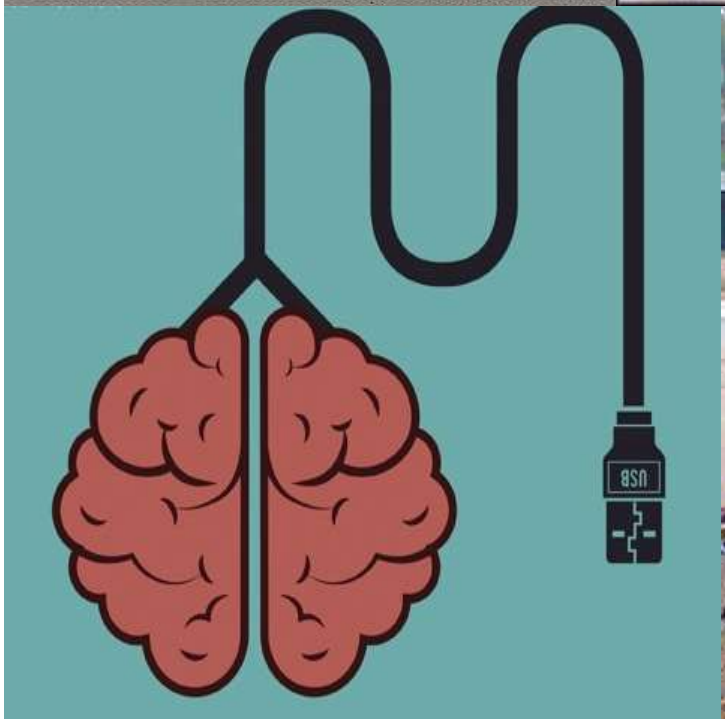
2018
2018


OUTLINE
OF TODAYS
TALK...

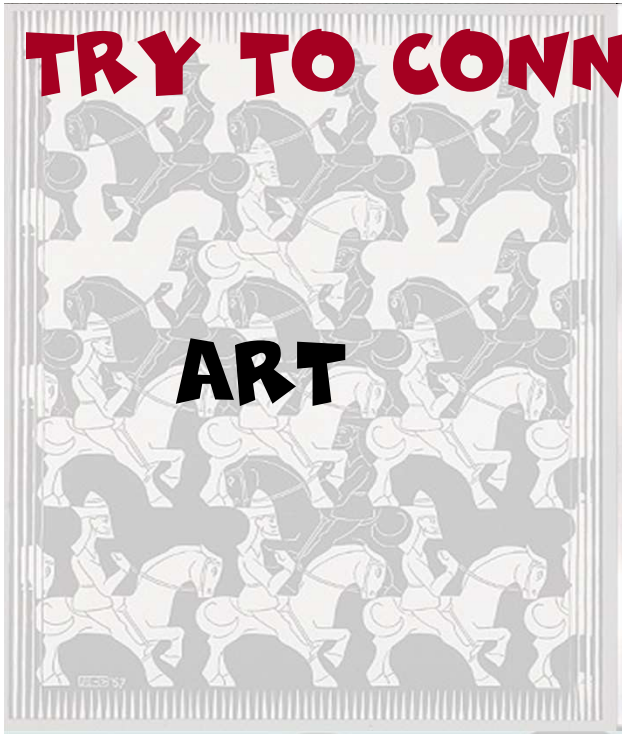






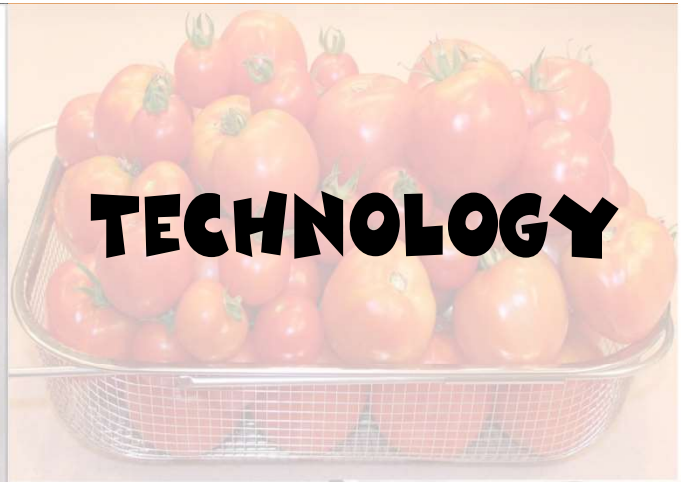

USB

TRY TO CONNECT....

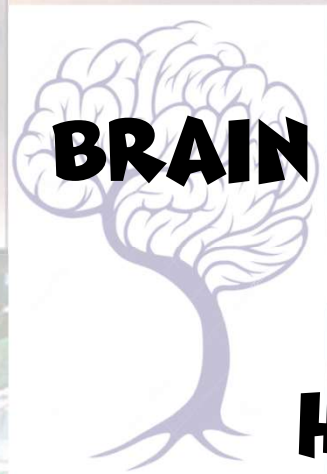


ART

?

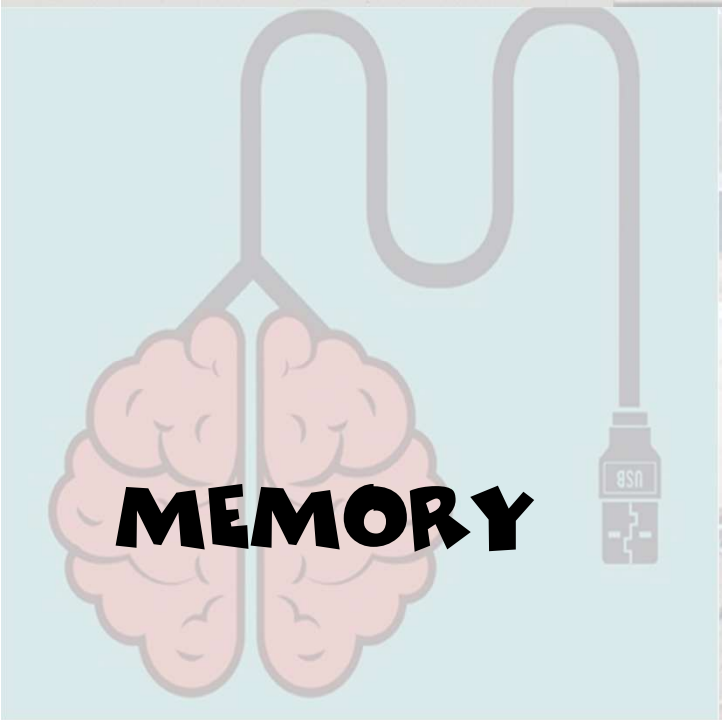


TECHNOLOGY



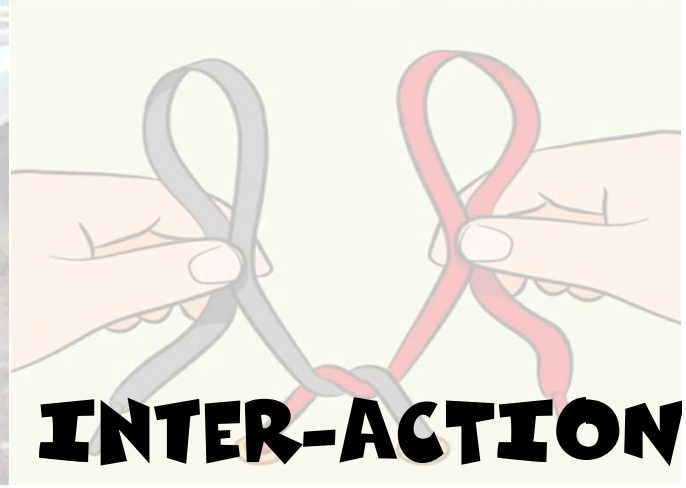
BRAIN

HISTORY

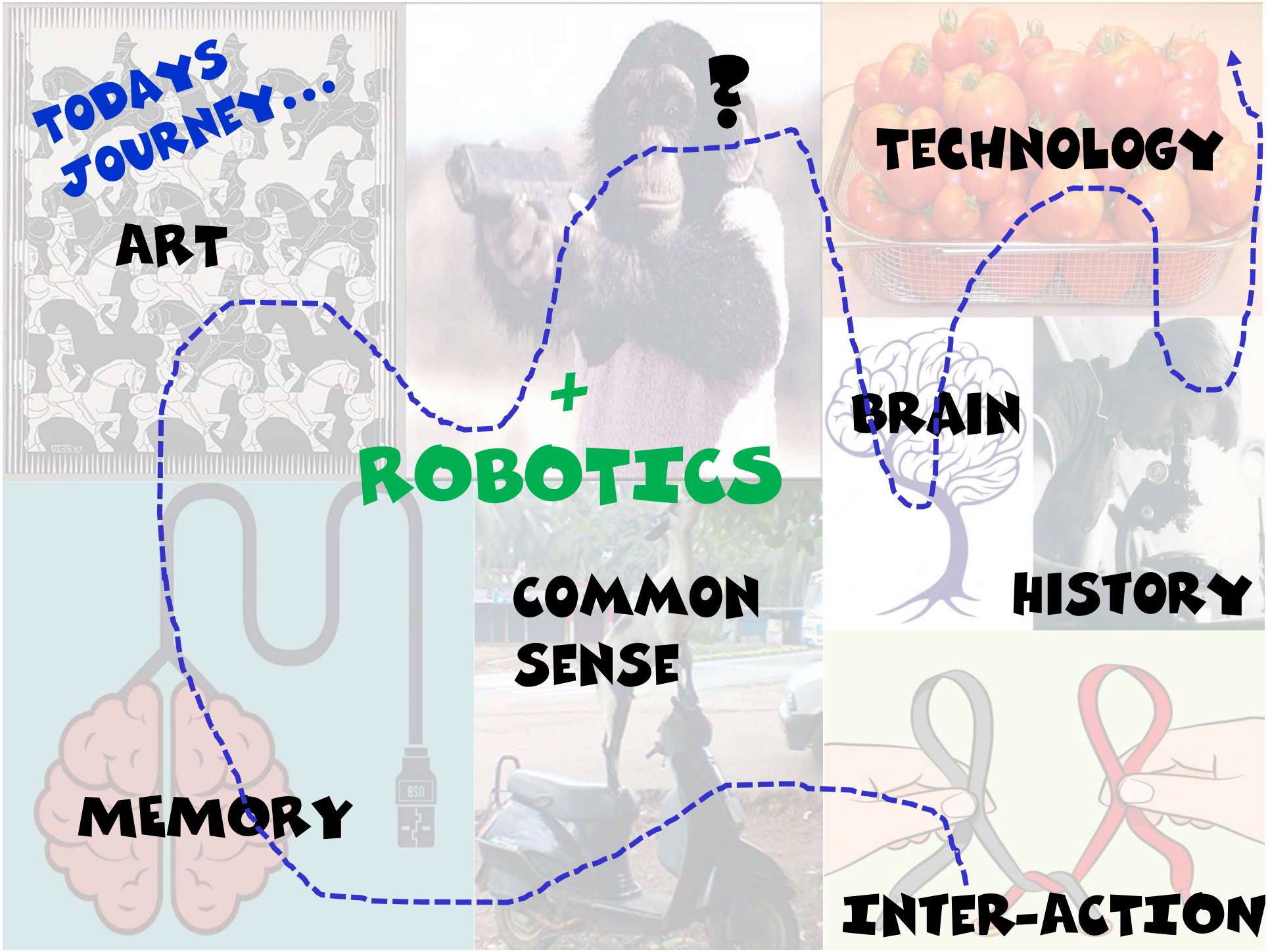


MEMORY

COMMON SENSE



INTER-ACTION


TODAYS JOURNEY...
ART
?
TECHNOLOGY
+
ROBOTICS
BRAIN
HISTORY
COMMON SENSE
MEMORY
INTER-ACTION

THIRSTY CROW- WHY???

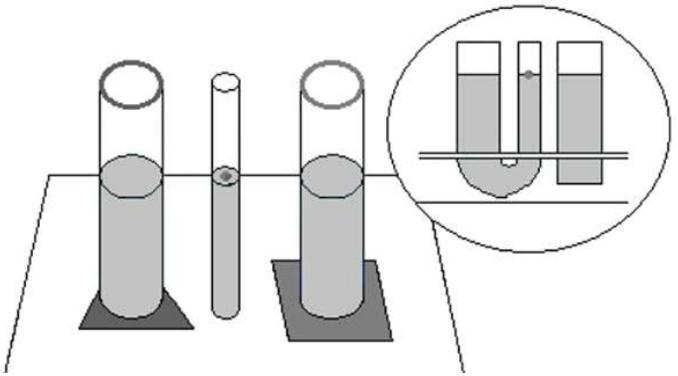
WE ARE ALL CURIOUS PEOPLE THROWING PEBBLES INTO WATER....

THIRSTY CROW OF AESOP'S FABLE IN ACTION

Nicola Clayton's Lab, Cambridge
https://www.psychol.cam.ac.uk/ccl

CORVIDS, MONKEYS, INFANTS..

- HEAVY VS. LIGHT
- SINKING VS. FLOATING
- SAND VS. WATER
- MANY OTHER CASES



EVEN MORE FASCINATING IS THE STORY OF BETTY....

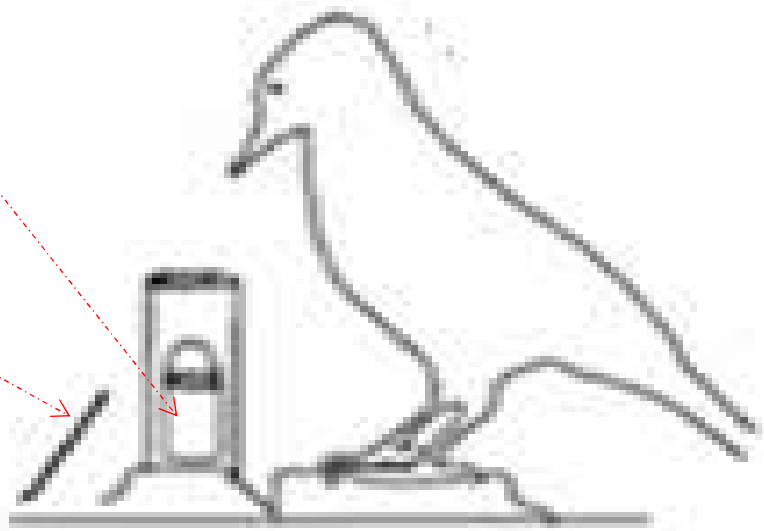
NECESSITY IS THE MOTHER OF INVENTION: THE STORY OF BETTY

A SITUATION NEVER SEEN, EXPERIENCED

DINNER

WIRE

ONE YEAR BACK, BEETY HAD EXPERIENCES OF PLAYIGN IWHT FLEXIBLE PLASTIC WIRES.....



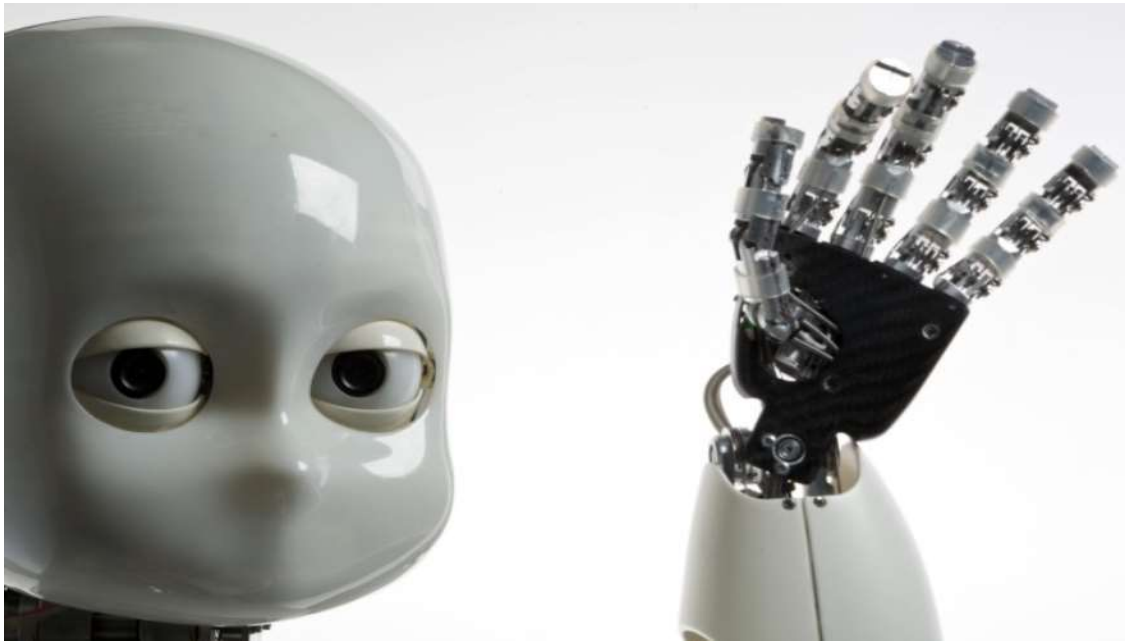
ALEX KACELNIK'S LAB, OXFORD

Necessity is the Mother of Invention: The Story of Betty

IF BETTY WAS A ROBOT INSTEAD ??

- PERCEPTION (BEYOND LABELLING..... UNDERSTANDING THE SCENE)
- INFERENCE (THE GOAL IS NOT ACHIEVABLE)
- MEMORY (RECALL OF A SPECIFIC PAST LEARNT EXPERIENCE: PLAYING WITH WIRES, TWIGS)
- FINE MANIPULATION (CREATING A HOOK TOOL AND USING IT AS AN EXTENSION OF ITS BODY)
- KNOWLEDGE OF CAUSE-EFFECT RELATIONS (PULLING THE BASKET WITH A HOOK TOOL)
- INTEGRATION: THE MAGIC GLUE

BETTY HAD A BRAIN .....



ITS FUN!!

AND

ITS ALSO IMPORTANT!!!

- PERCEPTION (BEYOND LABELLING..... UNDERSTANDING THE SCENE)
- INFERENCE (THE GOAL IS NOT ACHIEVABLE)
- MEMORY (RECALL OF A SPECIFIC PAST LEARNT EXPERIENCE: PLAYING WITH WIRES, TWIGS)
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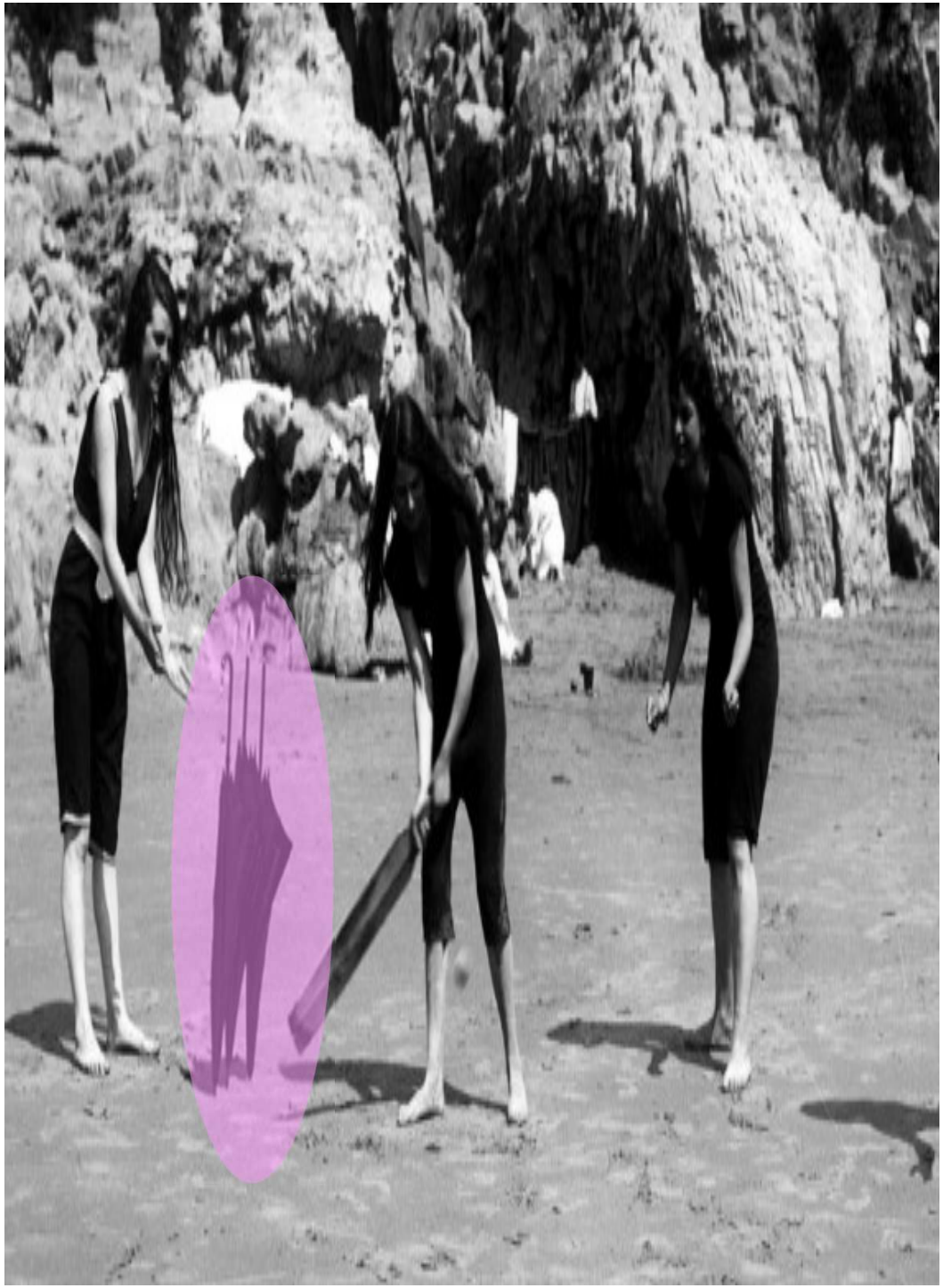
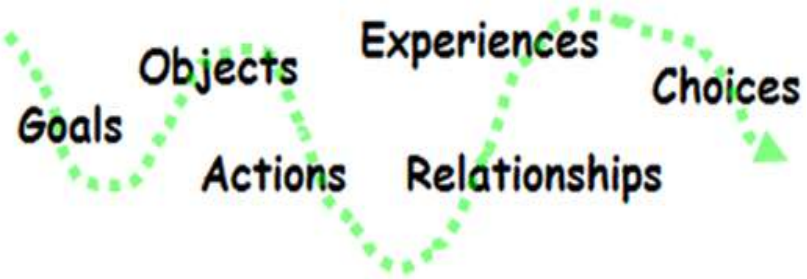


THE UNSTRUCTURED REAL WORLD IS FULL OF SUCH SITUATIONS...

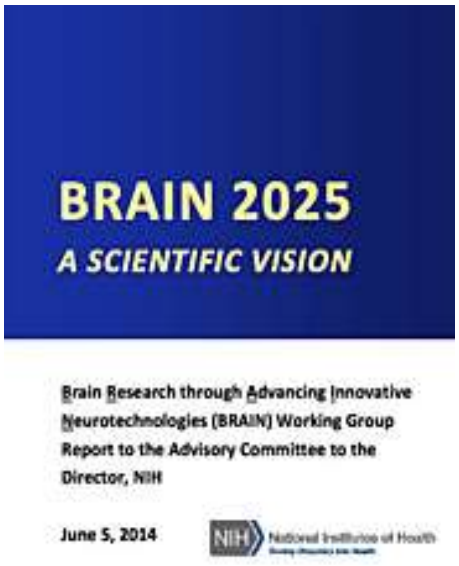
SO IT WILL BE FOR FUTURE CO-BOTS



"CONNECTING THE DOTS"

STEVE JOBS

A CONVERGING POINT FOR MANY DISCIPLINES, ROADMAPS



+

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FACTORIES OF THE FUTURE
Multi-annual roadmap for the contractual PPP under Horizon 2020

Prepared by EFFRA

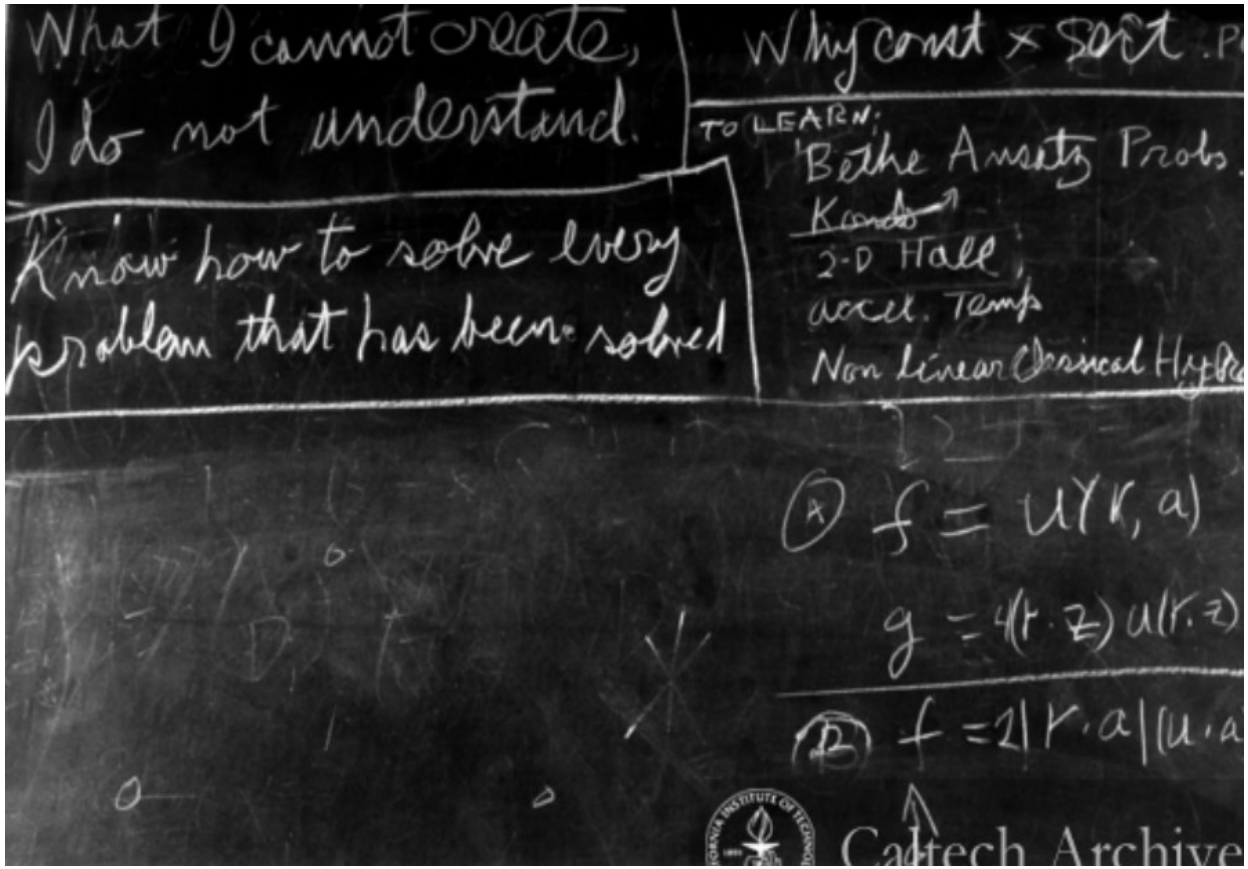
http://www.braininitiative.nih.gov/2025/

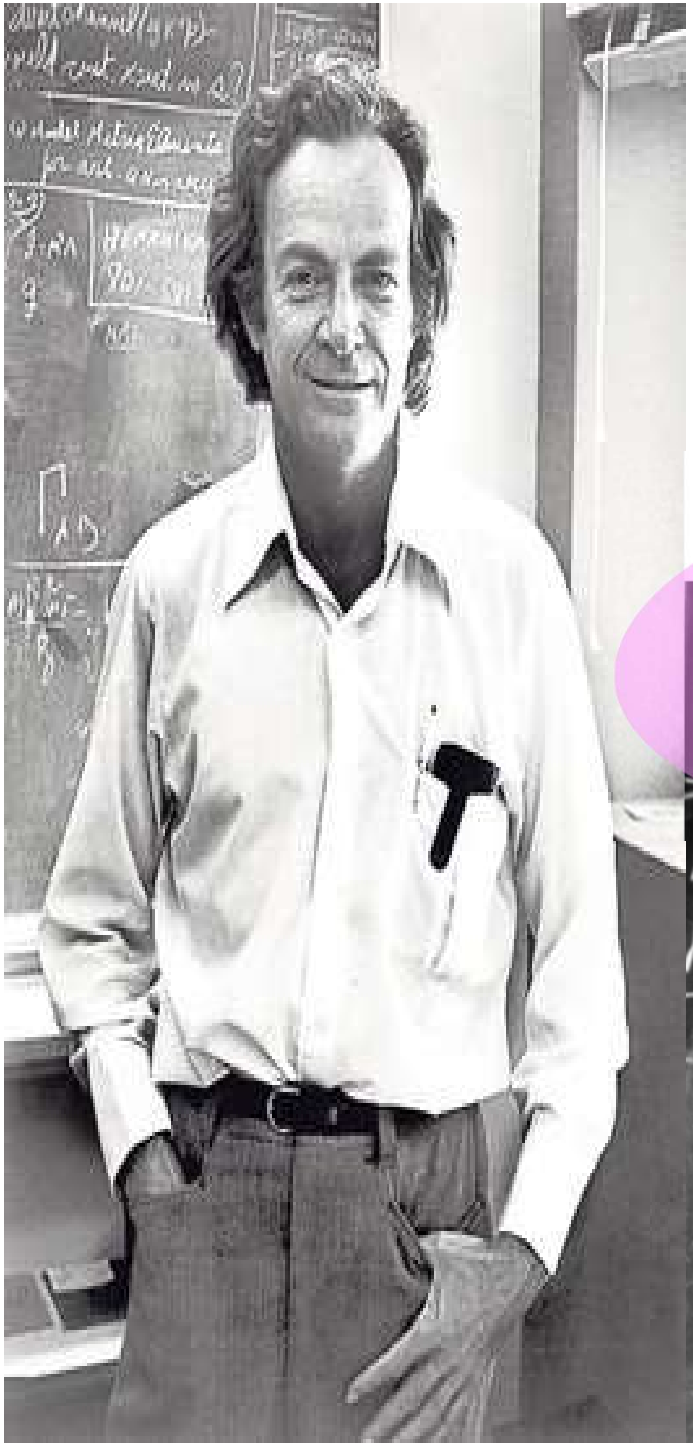
http://sparc-robotics.eu/roadmap
New Robot Era 2030

http://www.effra.eu/

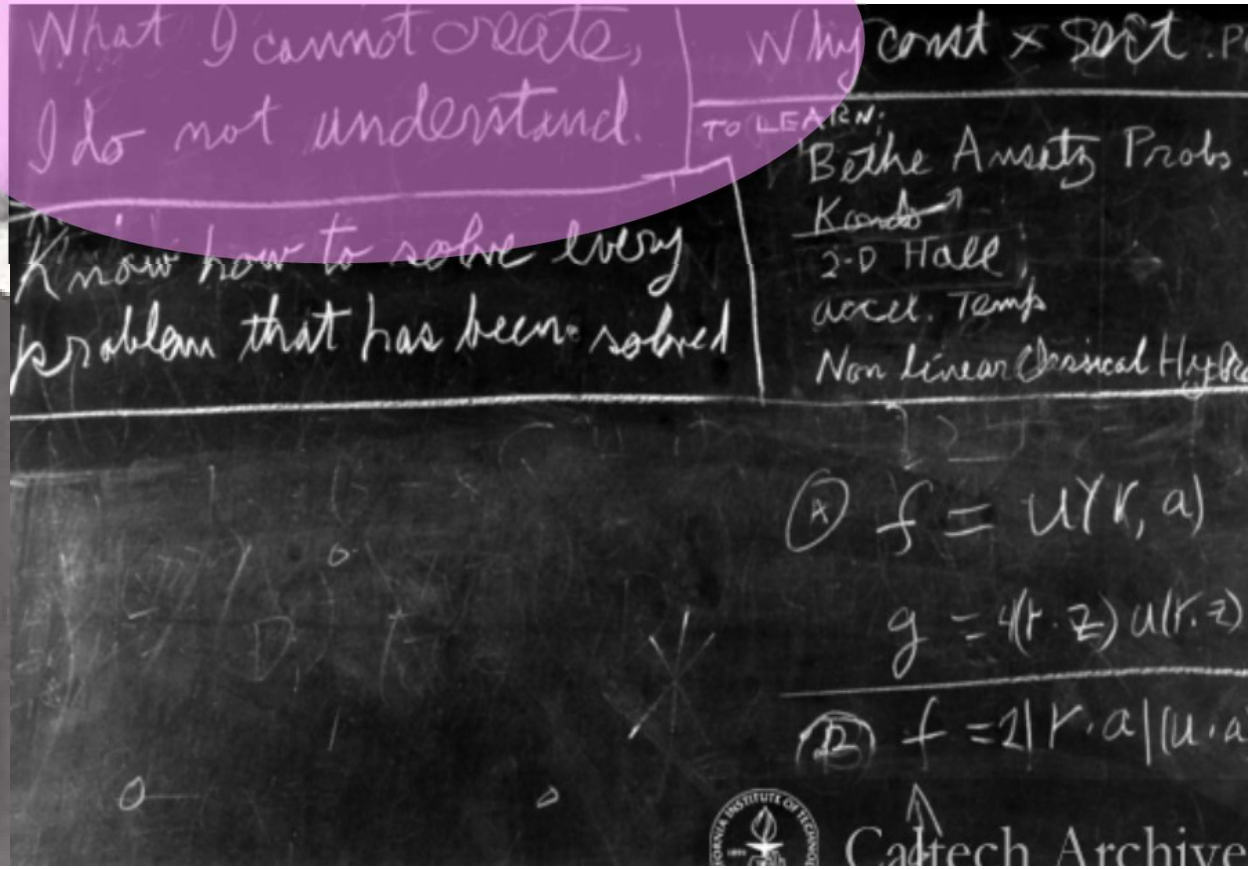
CO-BOTS ARE INVALUABLE **INTEGRATING PLATFORMS** TO BRIDGE DISCIPLINES...

- UNDERSTAND **NATURAL COGNITION** (BY BUILDING ONE....)
- DEVELOP **COGNITIVE TECHNOLOGIES** (DIVERSE END USERS)


What I cannot create,
I do not understand.
Know how to solve every
problem that has been solved
Why const × sort
TO LEARN:
Bethe Ansatz Probs
Kondo
2-D Hall
accel. Temp
Non Linear Classical Hyp
(A) f = u(r, a)
g = 4(r·z) u(r·z)
(B) f = 2|r·a|(u·a
Caltech Archive

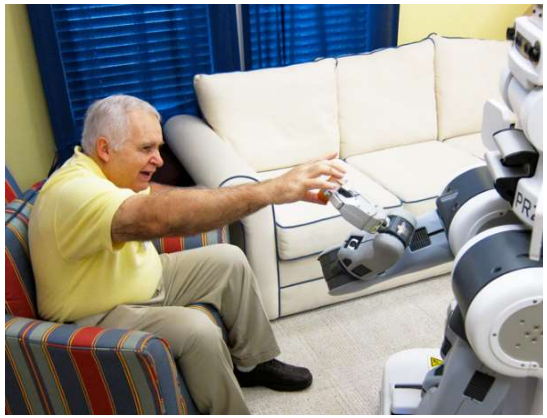


WHILE TRYING TO MAKE ROBOTS ACT, LEARN AND REASON INTELLIGENTLY, WE ENGINEERS ARE SOLVING THE SAME PROBLEM THAT THE BRAIN SOLVES...TO MAKE OURSELVES "ACT, LEARN AND REASON" INTELLIGENTLY



Co-Worker

Co-Inhabitant



Co-Explorer

CO-BOTS OF THE FUTURE....WILL HAVE TO..

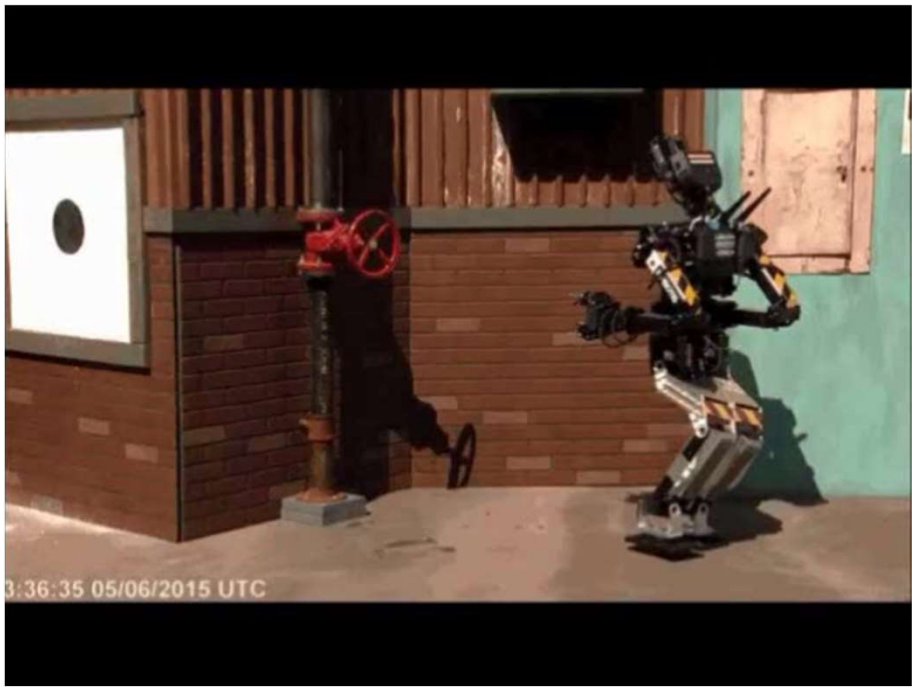
- ACT (**AND ANTICIPATE** CONSEQUENCES..)
- LEARN (**ON THE JOB-** CUMULATILEY)
- **BRAINLIKE** MEMORY- REMEMBER AND INFER
- **SOCIAL** INTELLIGENCE
- **SAFE, REALIABLE, REALTIME**

BETTY
THIRSTY CROW

ACTION SYSTEM- HUMANS VS. ROBOTS

Reach/Grasp, Pick, Place-Effortless

DARPA Disaster Zone challenge (2015



HUMANLIKE DEXTERITY WHILE OPERATING IN UNSTUCTURED SETUPS

WHY IS THE PROBLEM DIFFICULT ?

- INFINITE SOLUTIONS
- MULTIPLE TASK-CONSTRAINTS (UNDERSPECIFIED)
- COMPLEX INTEGRATION OF VISION, TOUCH, FORCE, PROPRICEPTION
- SOFT, DEFORMABLE, PERISHABLE OBJECTS

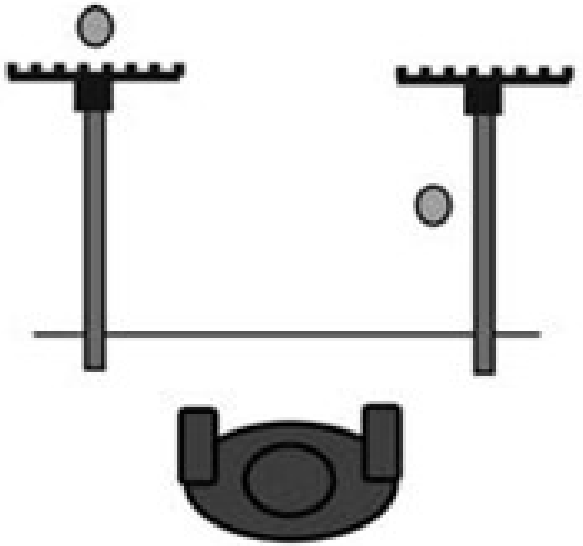
(WITH TIPTREE FARMS)

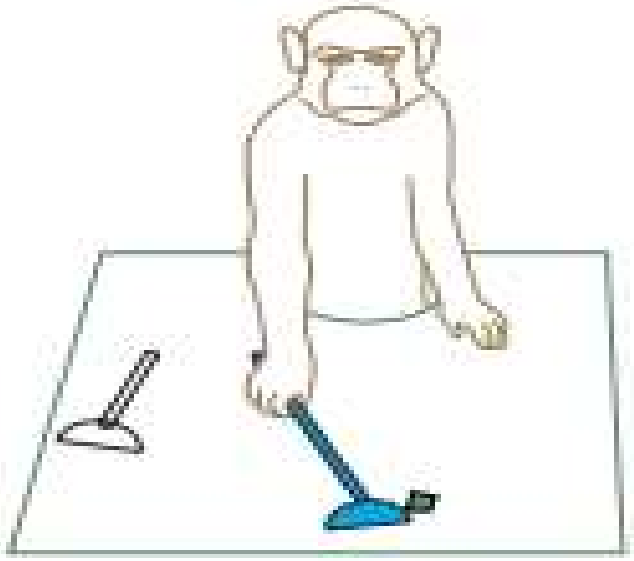
- LABOR AVAILABILITY
- HEALTH AND SAFETY
- PRODUCTIVITY
- 1/3RD OF THE PRODUCTION COST

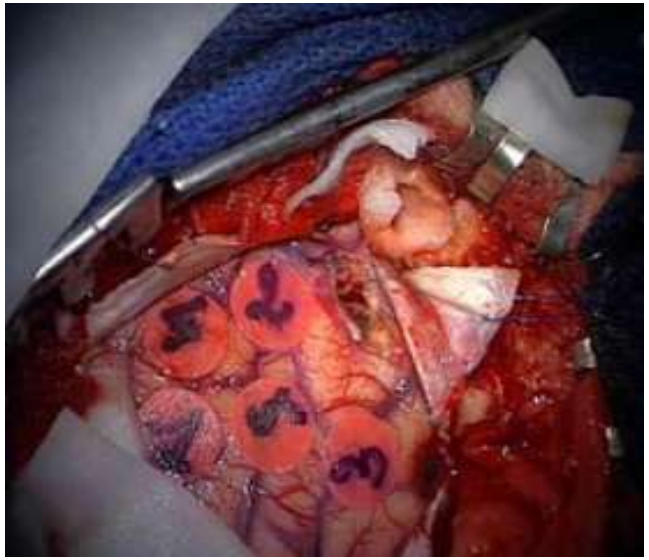
AMAZON PICKING CHALLENGE 2017
https://www.amazonrobotics.com/#/roboticschallenge

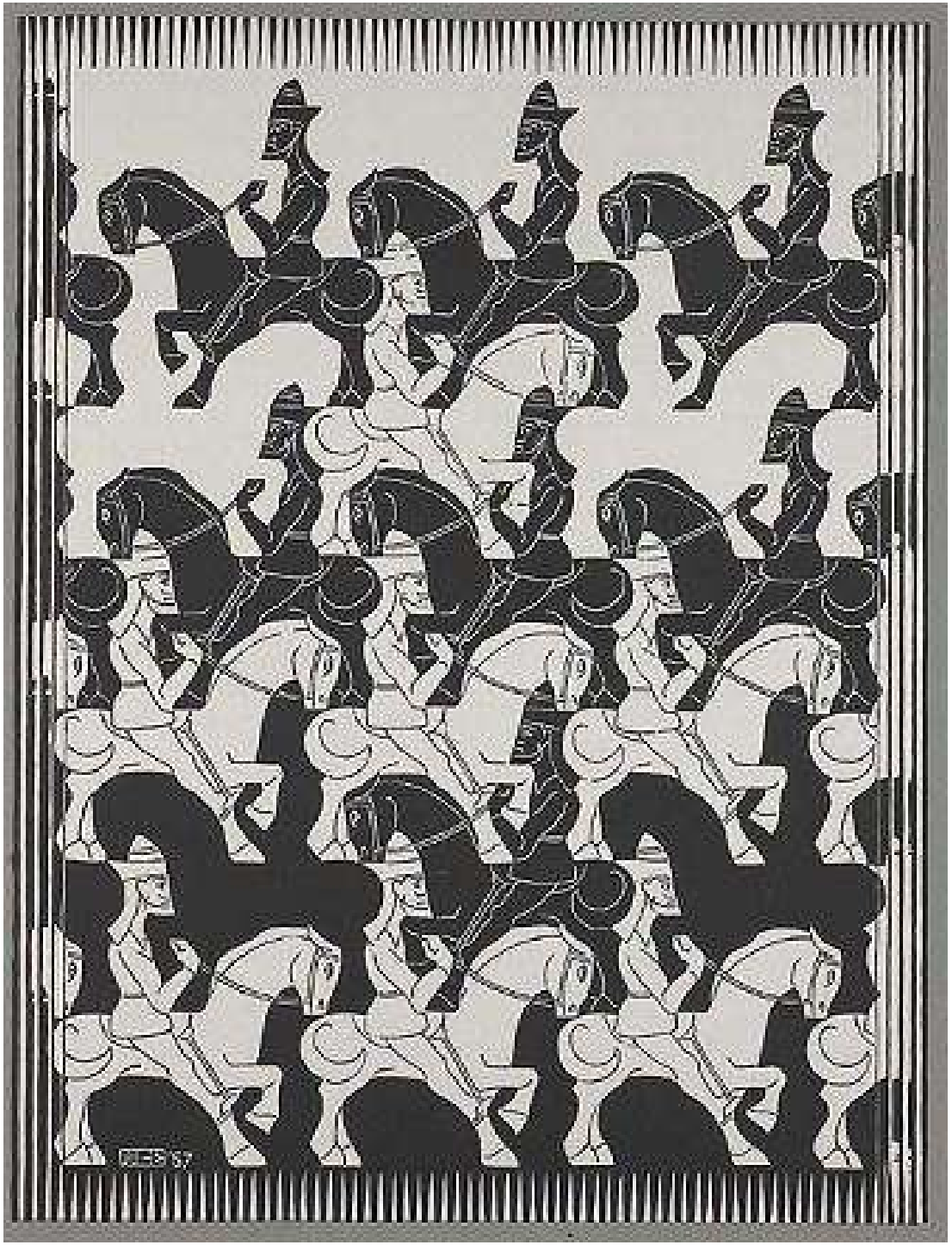
ROBOCUP AT WORK (EU)
http://rockinrobotchallenge.eu/work.php

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









GENERATING DEXTEROUS ACTIONS AND IMAGINING/ANTICIPATING CONSEQUENCE'S OF POTENTIAL ACTIONS OF ONESELF AND OTHER ARE TWO SIDES OF THE SAME COIN

ROBOTS

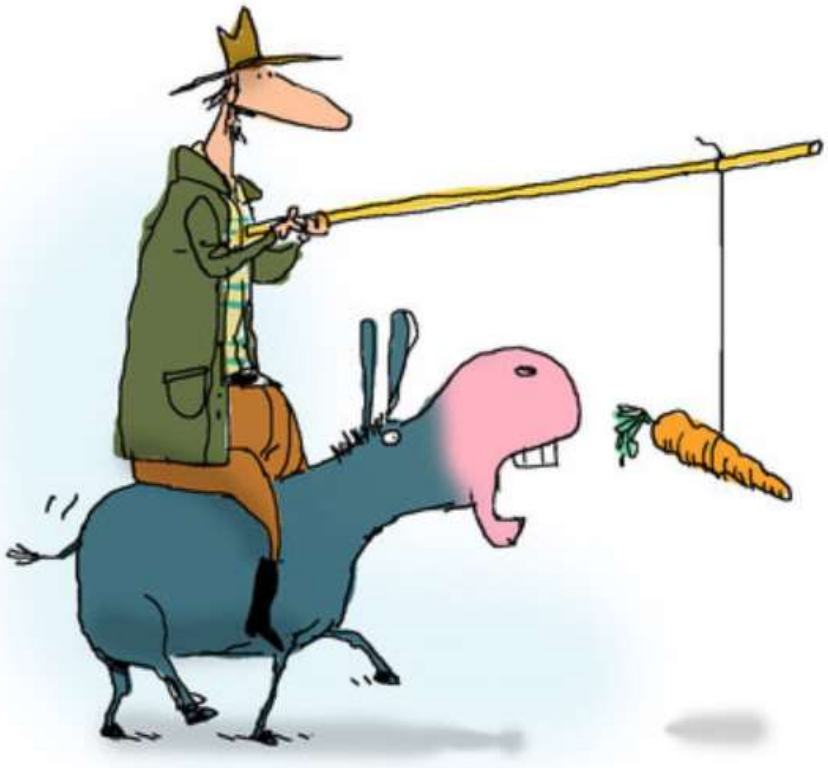
A BRAIN INSPIRED ACTION GENERATION/IMAGINATION SYSTEM FOR COGNTIVE ROBOTS (2006-)

The metaphor

Nina: I am perfect…..

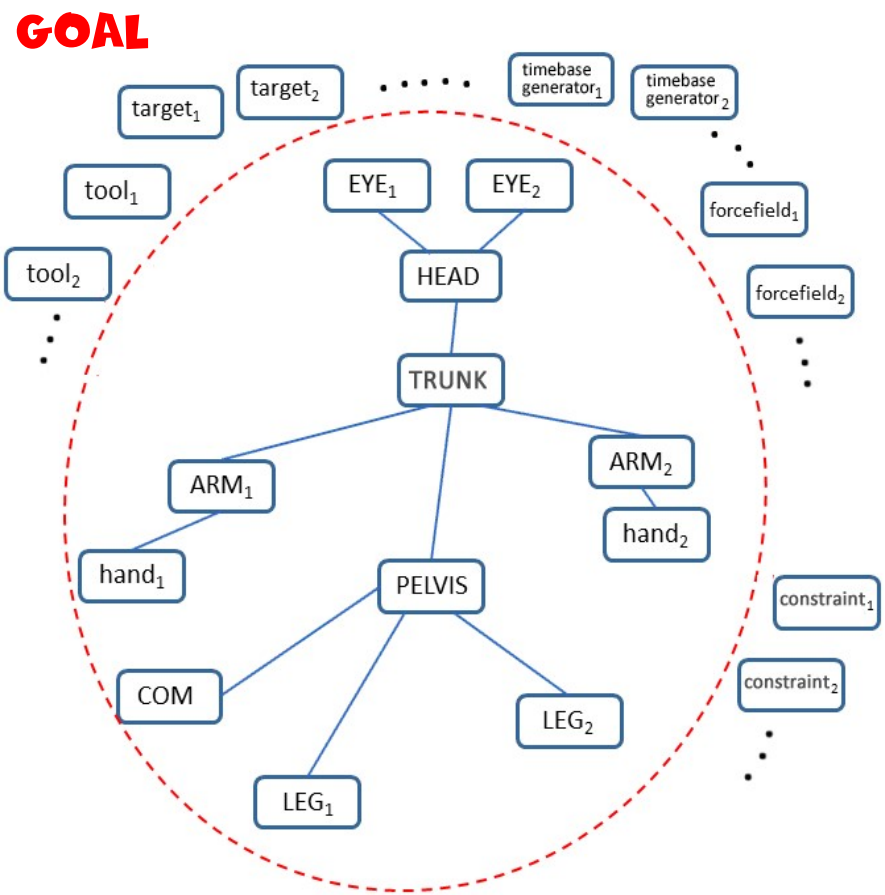
Tomas Leroy: Perfection is not to be in absolute control but to let go…

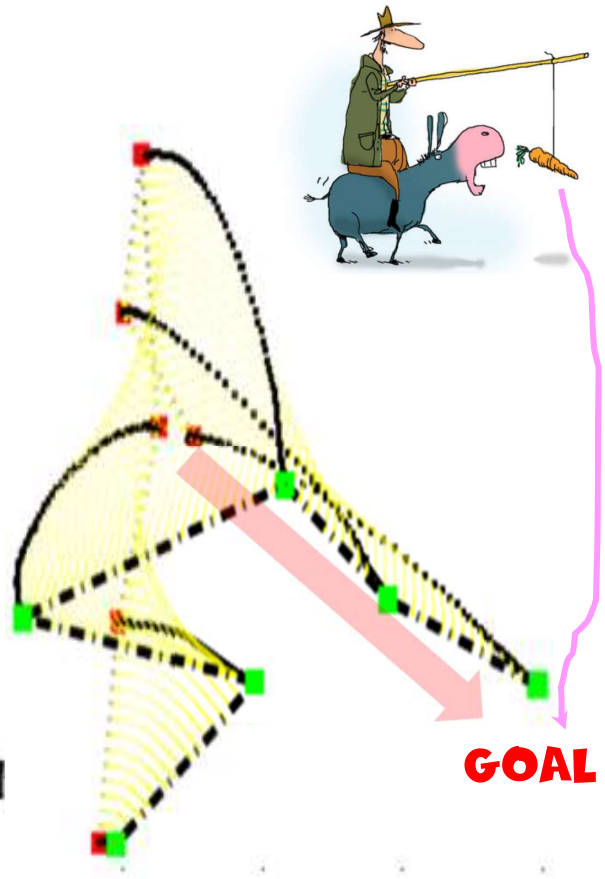
The black swan (Aronofsky 2011)



A BRAIN INSPIRED ACTION GENERATION/IMAGINATION SYSTEM FOR COGNTIVE ROBOTS (2006-)

- **Learn** an Internal model of the body (and use it to Generate/Predict actions)
- **EVEN REAL MOVEMENT IS LIKE A SIMULATION**





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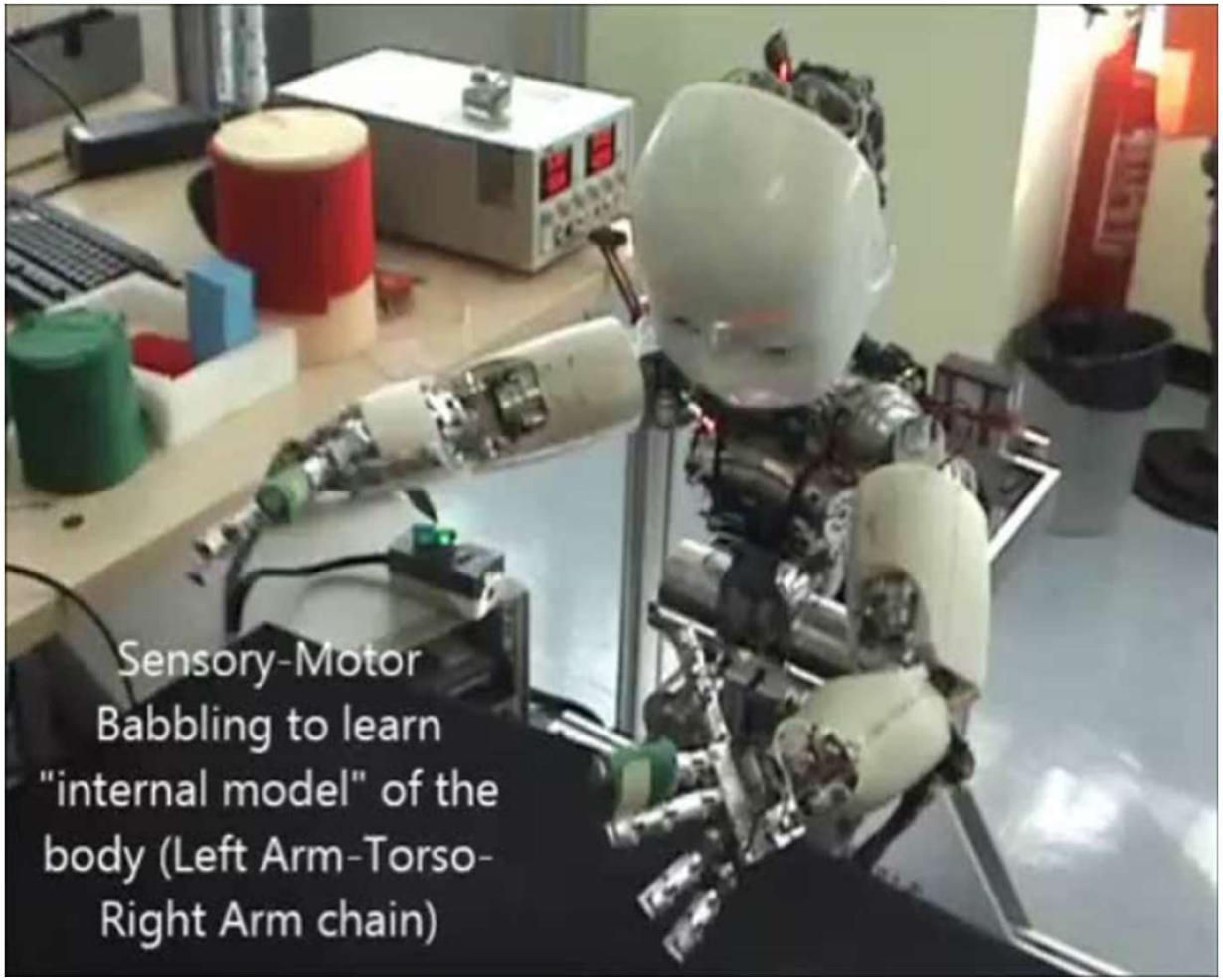
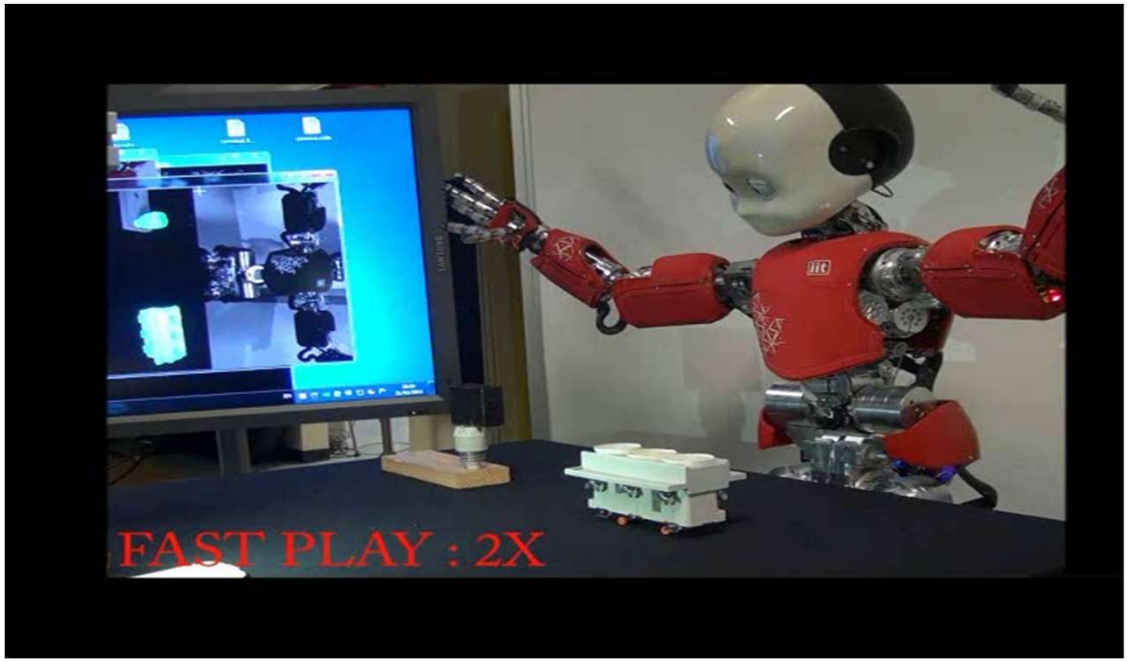


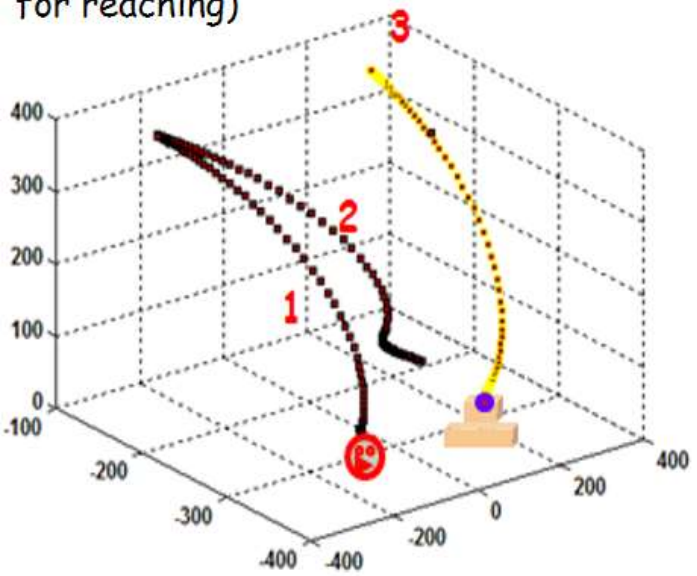
ADVANTAGES

- Learning..
- Body/ Body+Tools networks (configured on the fly)
- Computationally Simple
- Same system is used to both generate and predict actions

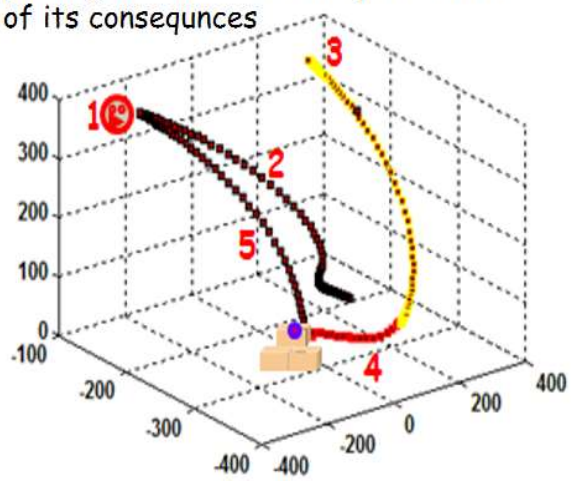
A BRAIN INSPIRED ACTION GENERATION/IMAGINATION SYSTEM FOR COGNTIVE ROBOTS (2006-)



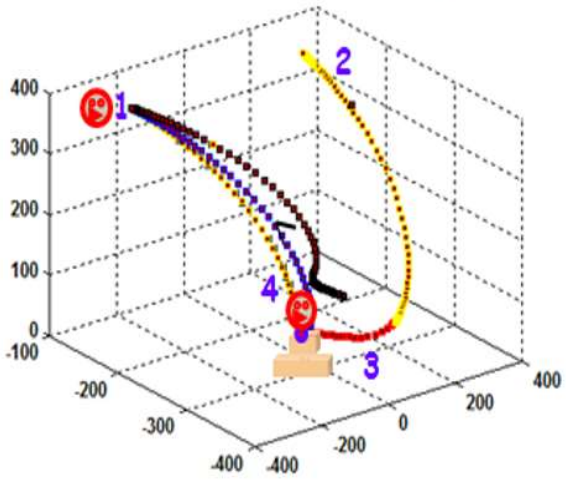
Internal simulations 1-3 leading to the inference that the Goal is Undoable, given the circumstances (F/I model for reaching)



Infer how the environment might change as a result of ones actions i.e pushing the fuse box and prediction of its consequnces



Real actions 1-4 executed by the robot to realize the assembly goal



ACTION GENERATION, PREDICTION SEEMLESSLY ALTERNATE DURING ANY GOAL DIRECTED BEHAVIOUR/ SOCIAL INTERACTION

Spin Offs + Ongoing Extensions

Action Language Coupling
(in collaboration with Plymouth, Hertfordshire, Bielefeld)

"Lick, Pick, Kick"
"Cut an Apple, Cut a Cake"

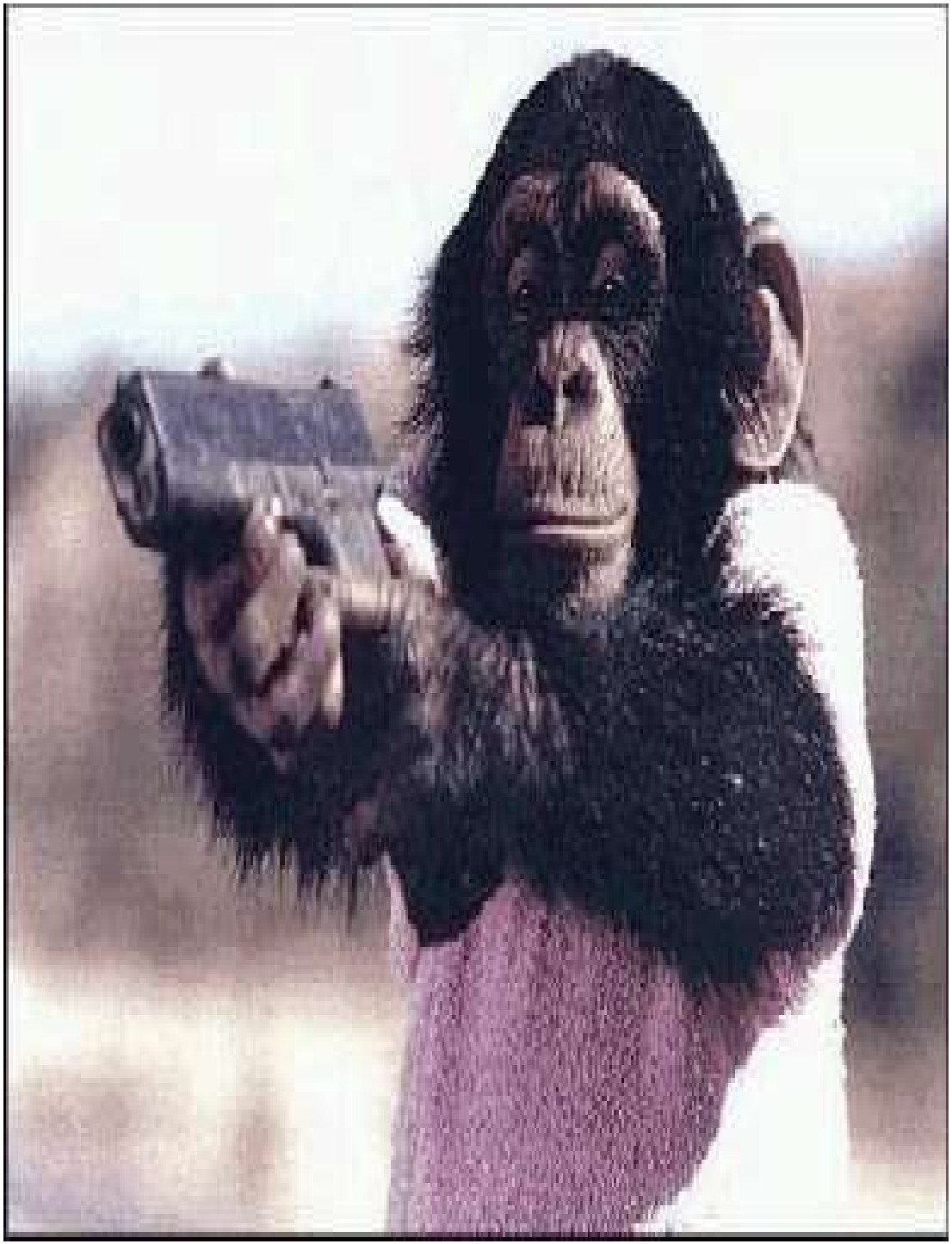
Other's Action Understanding
(in collaboration with Imperial college, INSERM, Sheffield)

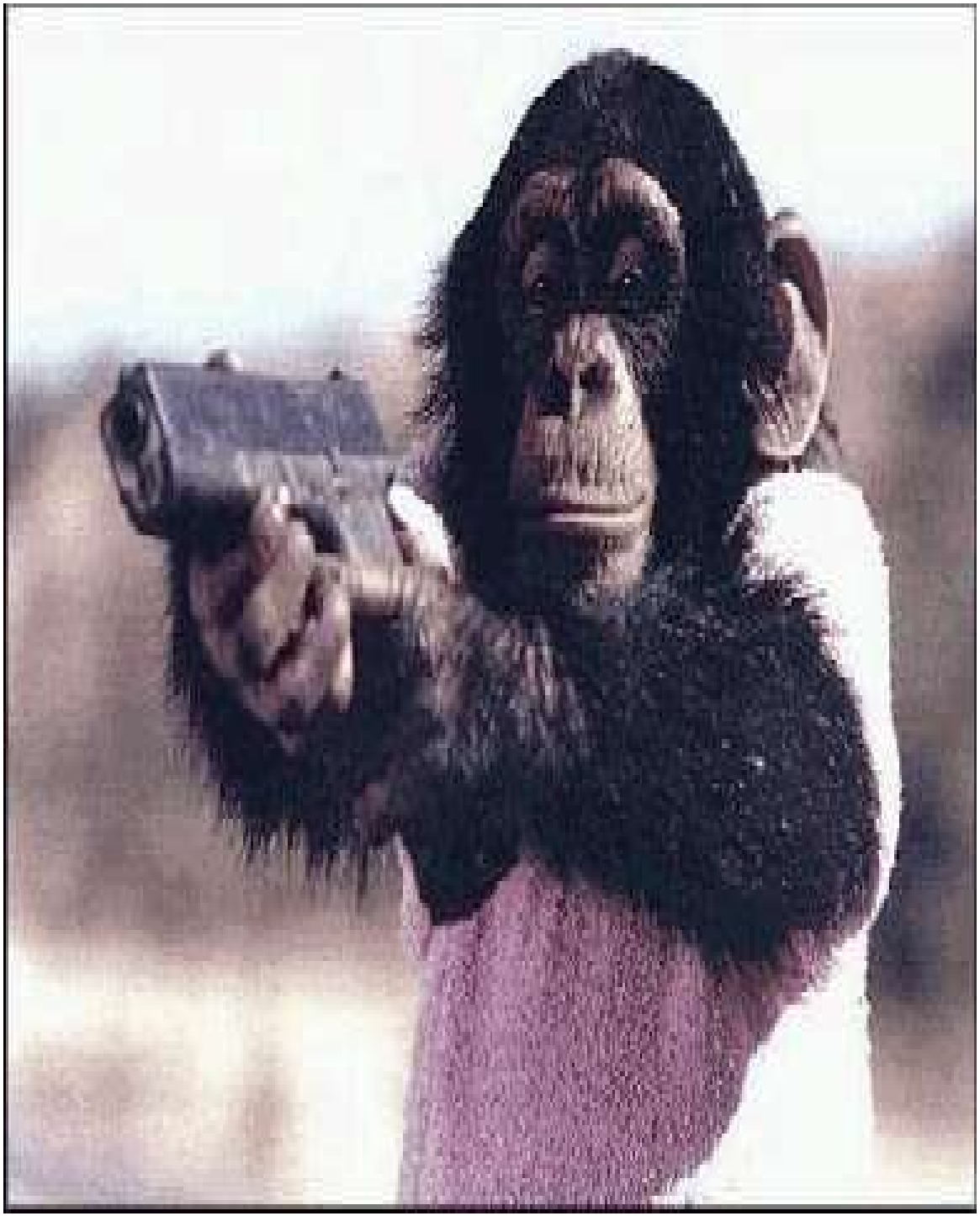
Industrial Assembly
(in collaboration with Profactor, FORTH, Kings College)

Whole body coordination under diverse Perceptual, Motor and Cognitive constraints (US Army)

AgroTech- Pick and Pack (Tiptree farms)

Subsea cleaning of Oil and Gas pipelines using autonomous robots (TubeTech Inc)





Generate-Simulate-Simulate Other's Actions

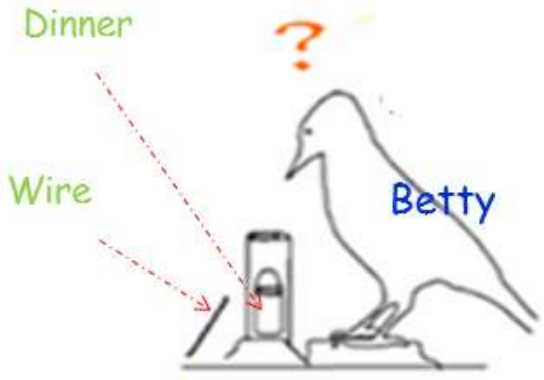
Andrew Meltzoff (2015), Body maps in the infant brain, Trends in Cognitive sciences.
Andy Clark (2016), Embodied Prediction
Mohan Et al (2016), Towards a learnt body schema for dexterous coordination of action in humanoid and industrial robots, Autonomous robots
Rizzolatii et al (2009), When pliers become fingers in the monkey motor cortex, PNAS

BETTY THIRSTY CROW

BETTY THIRSTY CROW

IT'S A POOR SORT OF MEMORY THAT WORKS ONLY BACKWARDS...

WHITE QUEEN TO ALICE (LEWIS CARROLL, 1871)



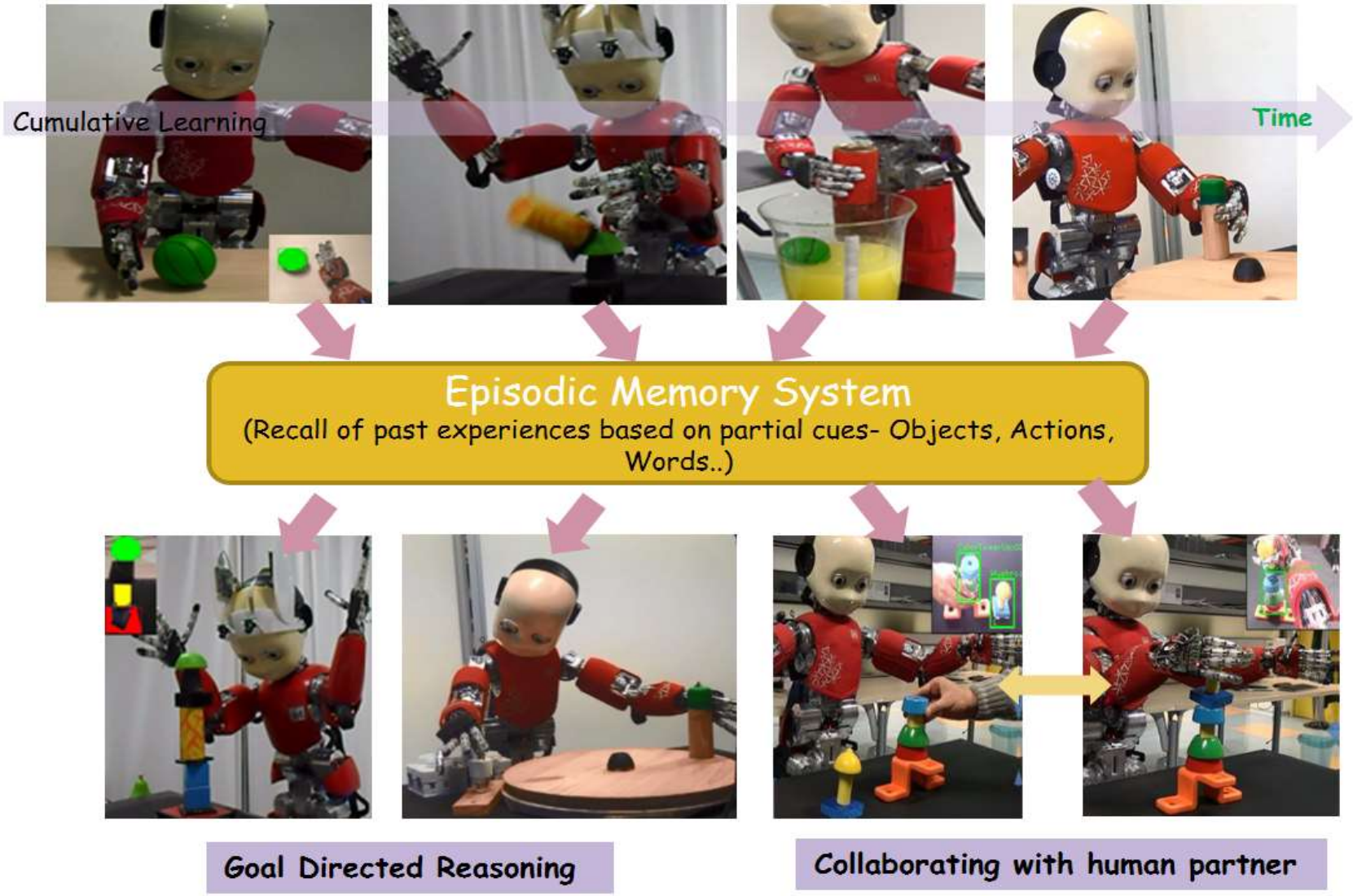
MEMORY IS NOT A PASSIVE STORAGE DEVICE BUT AN ACTIVE INTEGRATIVE MECHANISM TO CONNECT

- **PAST** EXPERIENCES
- **PRESENT** CONTEXT
- **FUTURE** CONSEQUENCES

COGNITIVE SYSTEMS LEARN CUMULATIVELY: LEARNING, REMEMBERING AND GOAL DIRECTED PROSPECTION GO HAND IN HAND.....

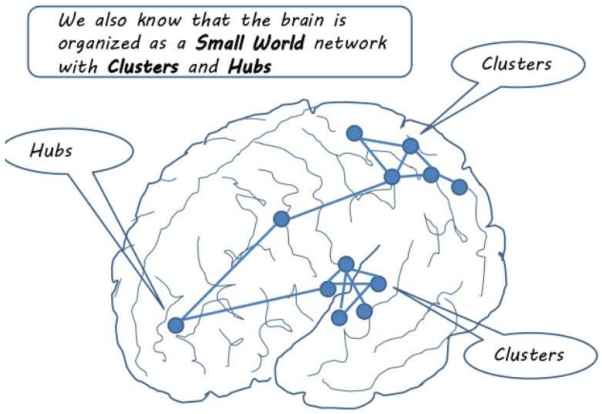
NOT A ONE TRICK PONY- MACHINE LEARNING VS. 'HUMANLIKE LEARNING'

We learn for fun too!!!

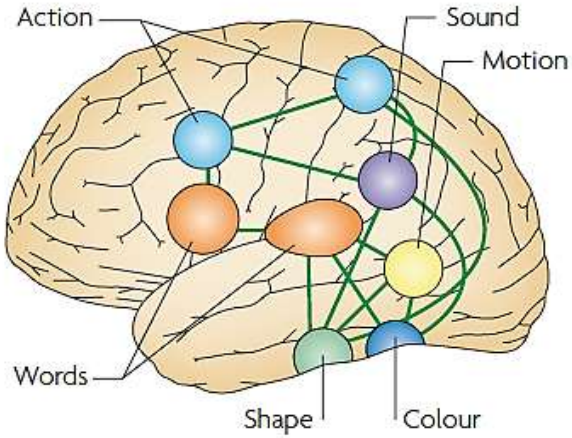


BRAINLIKE MEMORY FOR COGNITIVE ROBOTS..

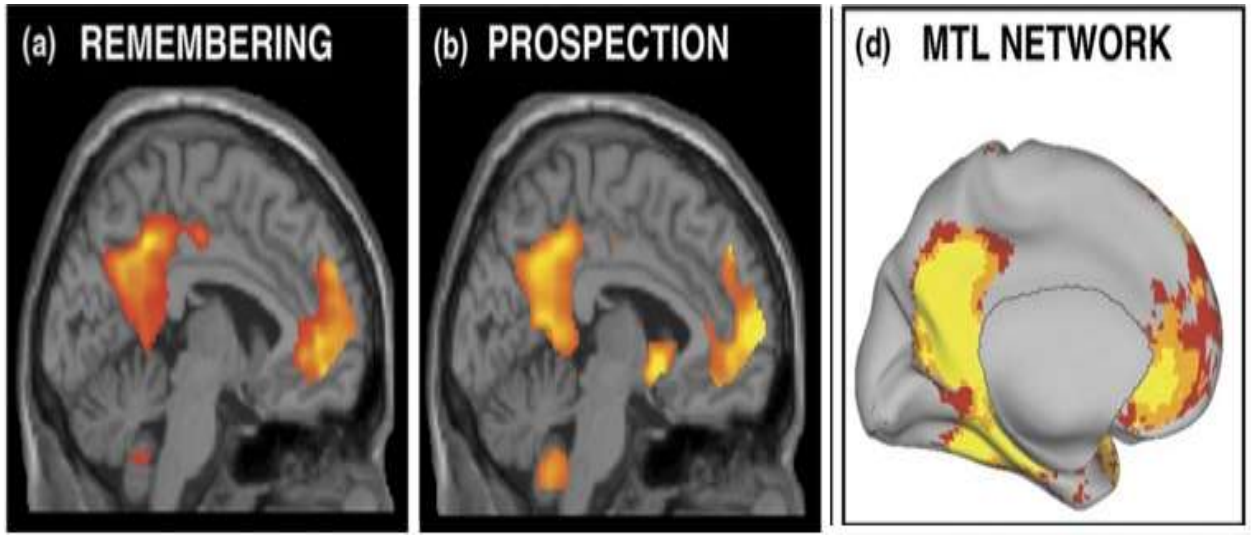
ITS REALLY A SMALL WORLD!



DO OBJECTS REALLY MATTER ?



DEFAULT MODE NETWORK
RECALLING THE PAST AND SIMULATING THE FUTURE

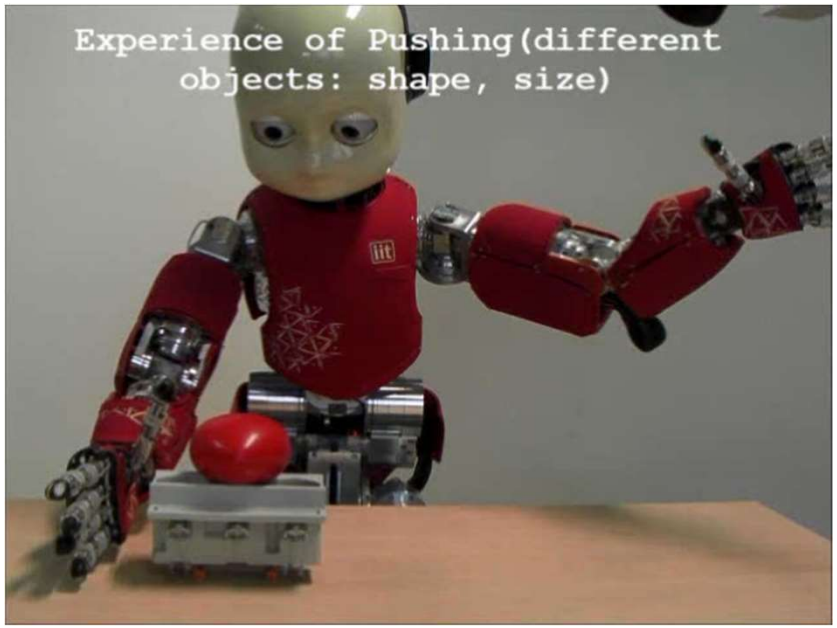


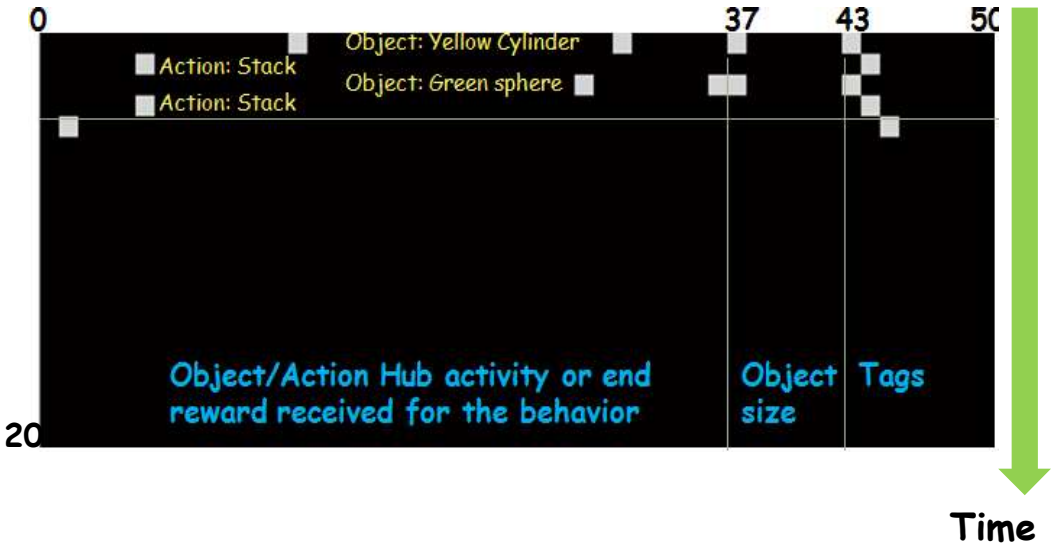
RATS
CROWS
MONKEYS
HUMANS

Growing Episodic Memory for Co-Bots : One possible Implementation

- Auto Associative neural network (Mohan et al, 2014, Hopfield 2008)
- 1000 neurons: arranged as a 50x20 sheet, 10^6 connections (like a Blank Page)
- An experience is a temporal sequence of actions, objects, rewards, body state
- One shot LEARNING (Hebbian)
- **Possible Learning streams:** Exploration, User Demo, Language based instruction

Simple Example: Encoding experience (One shot learning)

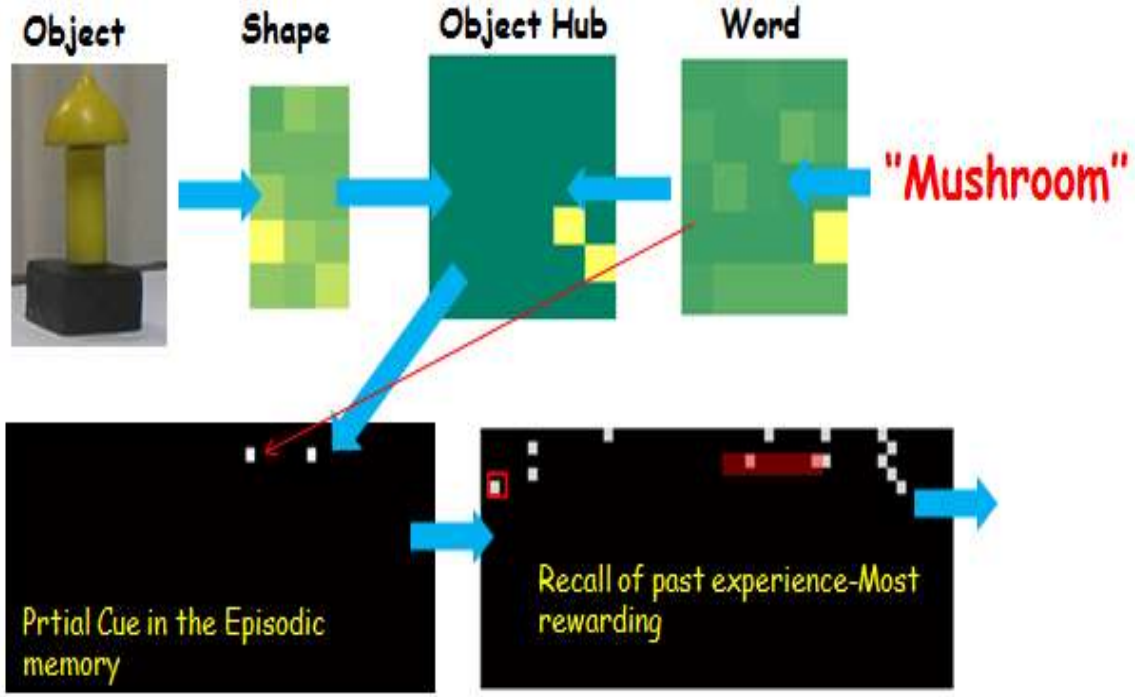


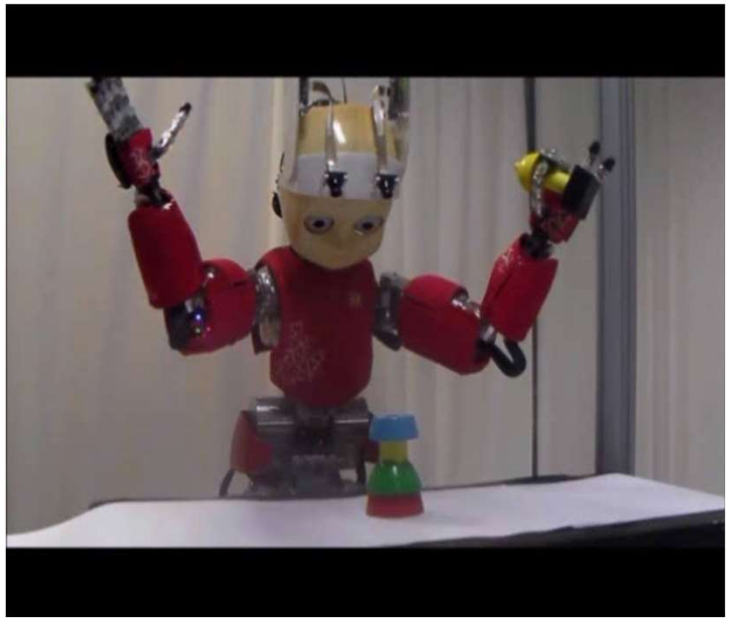


roboearth.eu, robohow.eu, vishwanathanmohan.com. Mohan et al 2014: Neural Computation MIT Press

Memory for Co-Bots : Central Contributions

MULTIMODAL RECALL (BASED ON PARTIAL CUES FROM THE ENVIRONMENT)





ONGOING- PEOPLE, SOCIAL RELATIONS

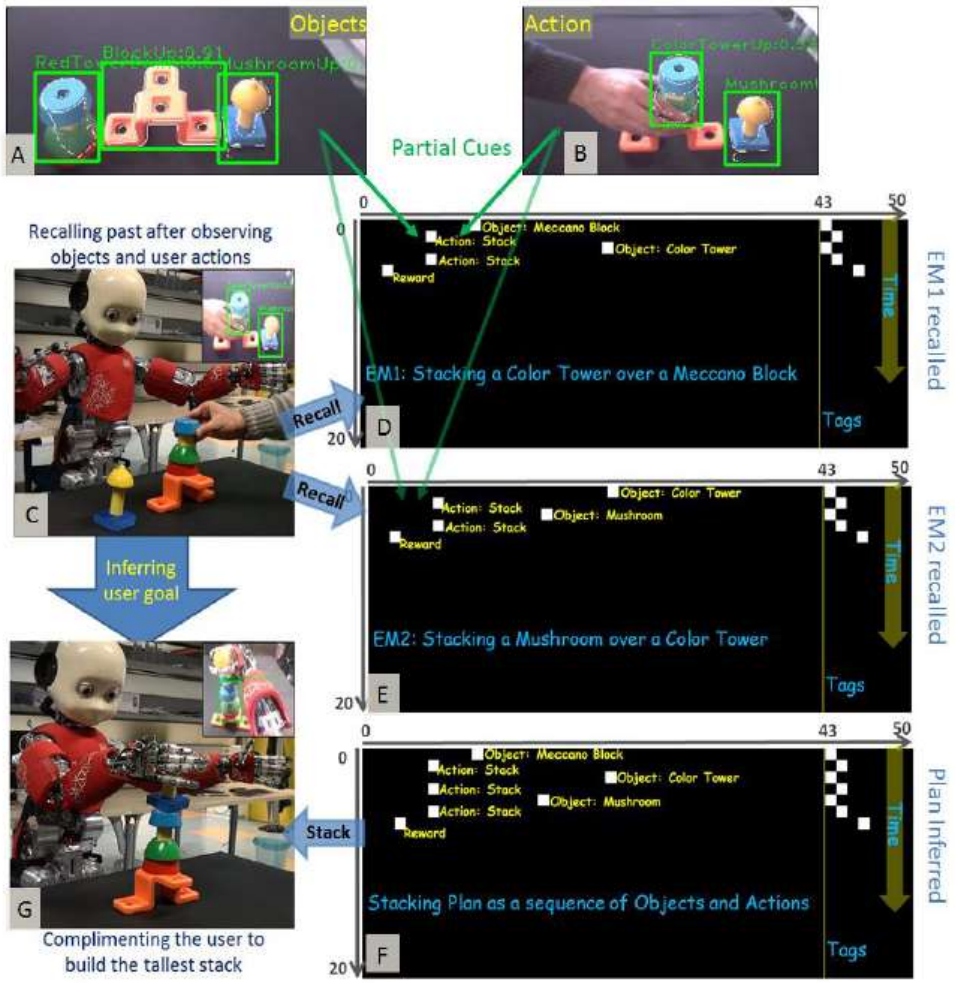
Bhat, A., Mohan, V., Sandini, G., Morasso, P. (2016). *Humanoid robot infers Archimedes' principle*: From cumulative exploration to abstraction of underlying causal relations and affordances. ***Proceedings of the Royal Society Interface***.

Memory for Co-Bots : Central Contributions

MULTIMODAL RECALL (BASED ON PARTIAL CUES FROM THE ENVIRONMENT)

OBSERVED ACTIONS OF OTHERS ARE ALSO PARTIAL CUES...

INFERRING THE GOAL AND COMPLEMENTING THE USER



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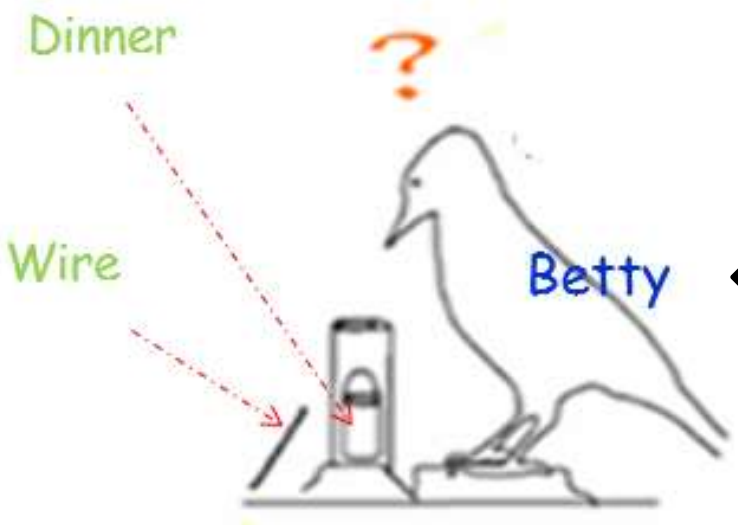
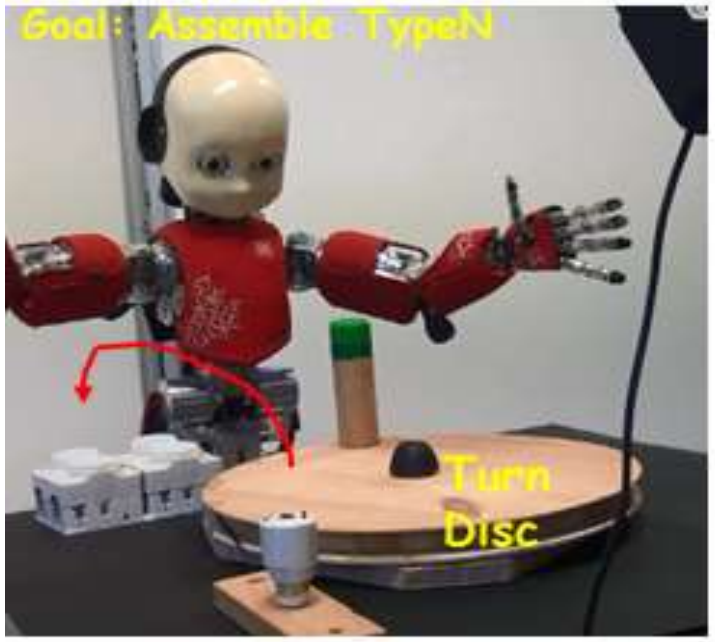
Memory for Co-Bots : Central Contributions, Predictions

GOAL DIRECTED REASONING IS SIMILAR TO NAVIGATION (BUT IN TIME THROUGH MEMORIES)

CONNECTING THE DOTS OF EXPERIENCES.....





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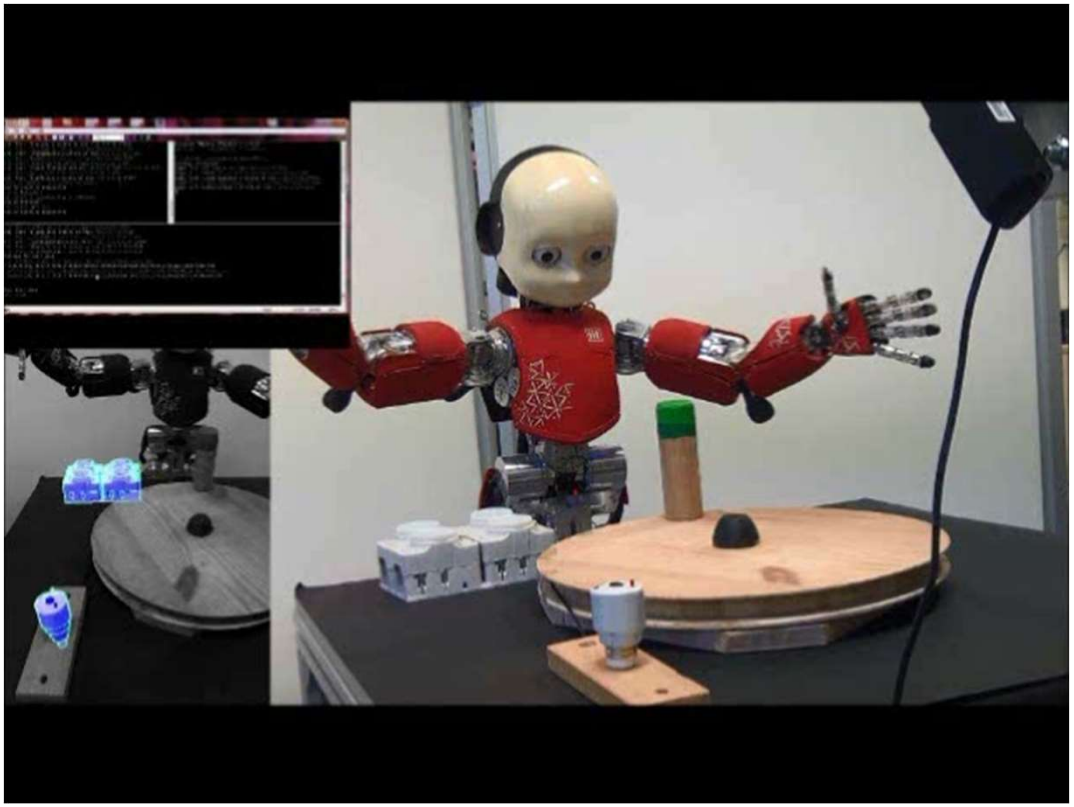
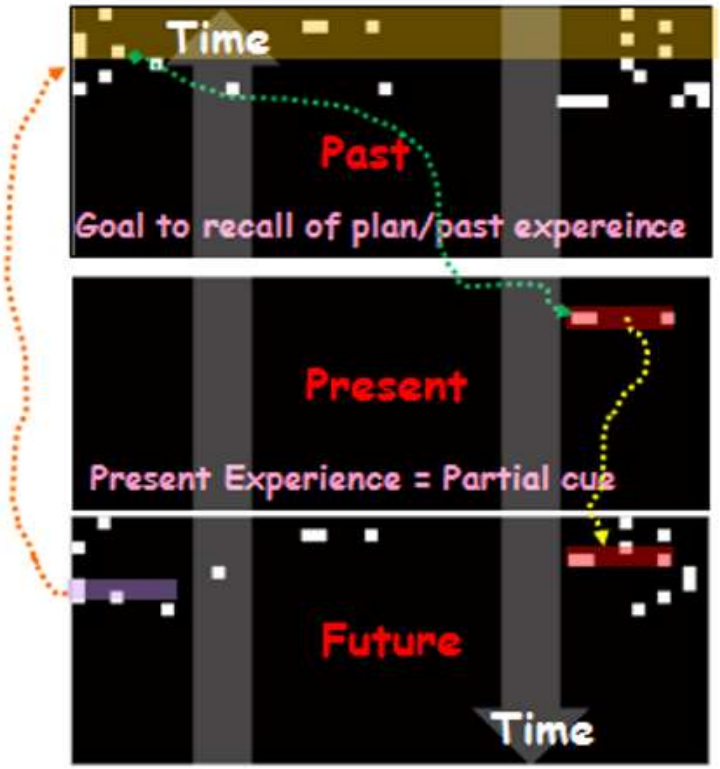


Multiple remembered experiences are combined to generate novel behaviors.....



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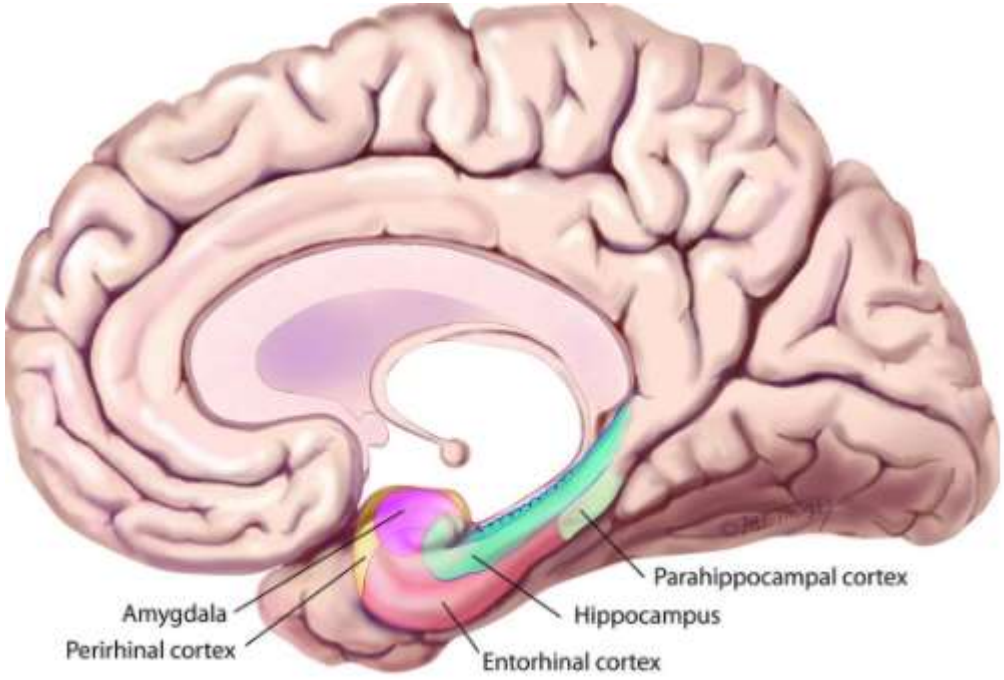
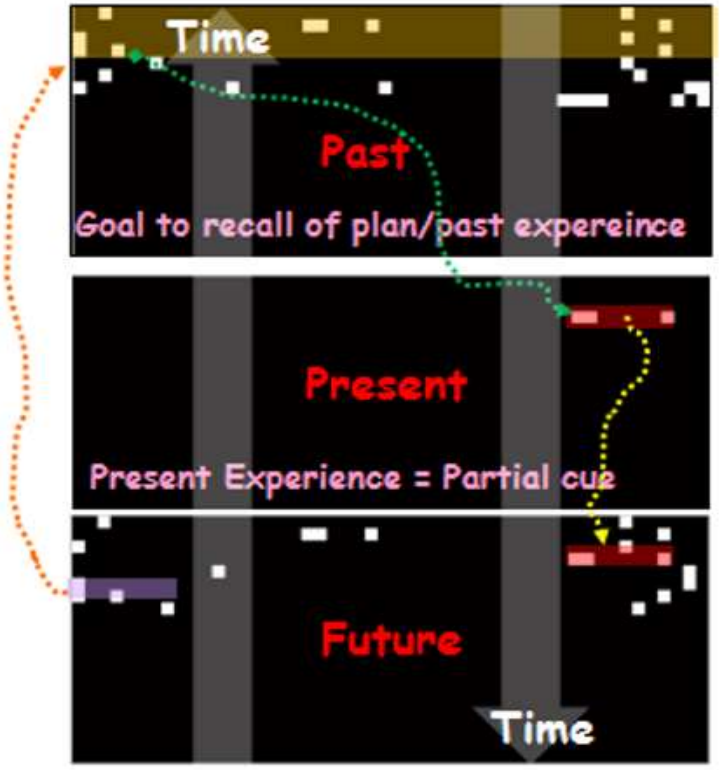
Memory for Co-Bots : Central Contributions, Predictions

GOAL DIRECTED REASONING IS SIMILAR TO NAVIGATION (BUT IN TIME THROUGH MEMORIES)

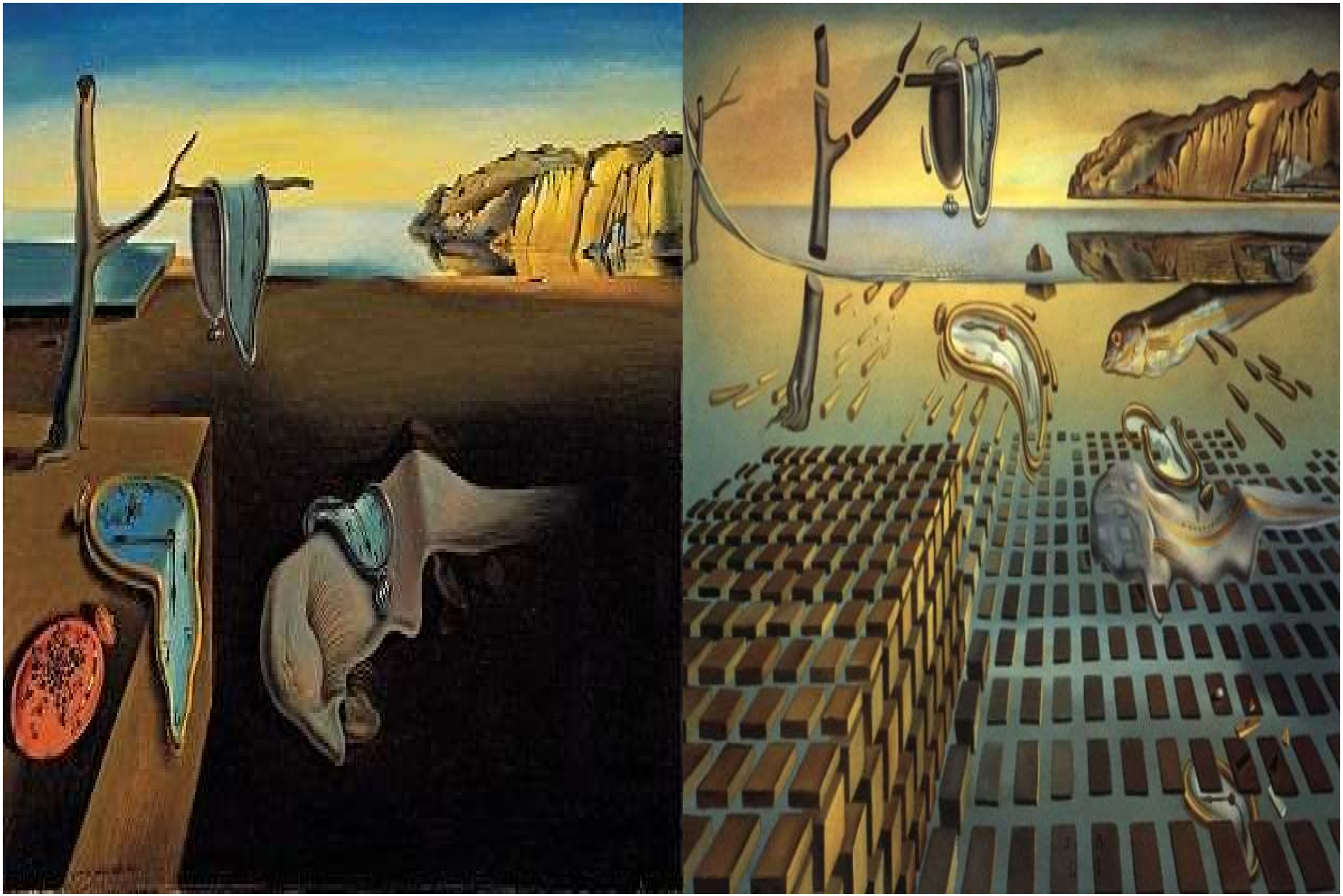
THIS IS COOL BECAUSE....



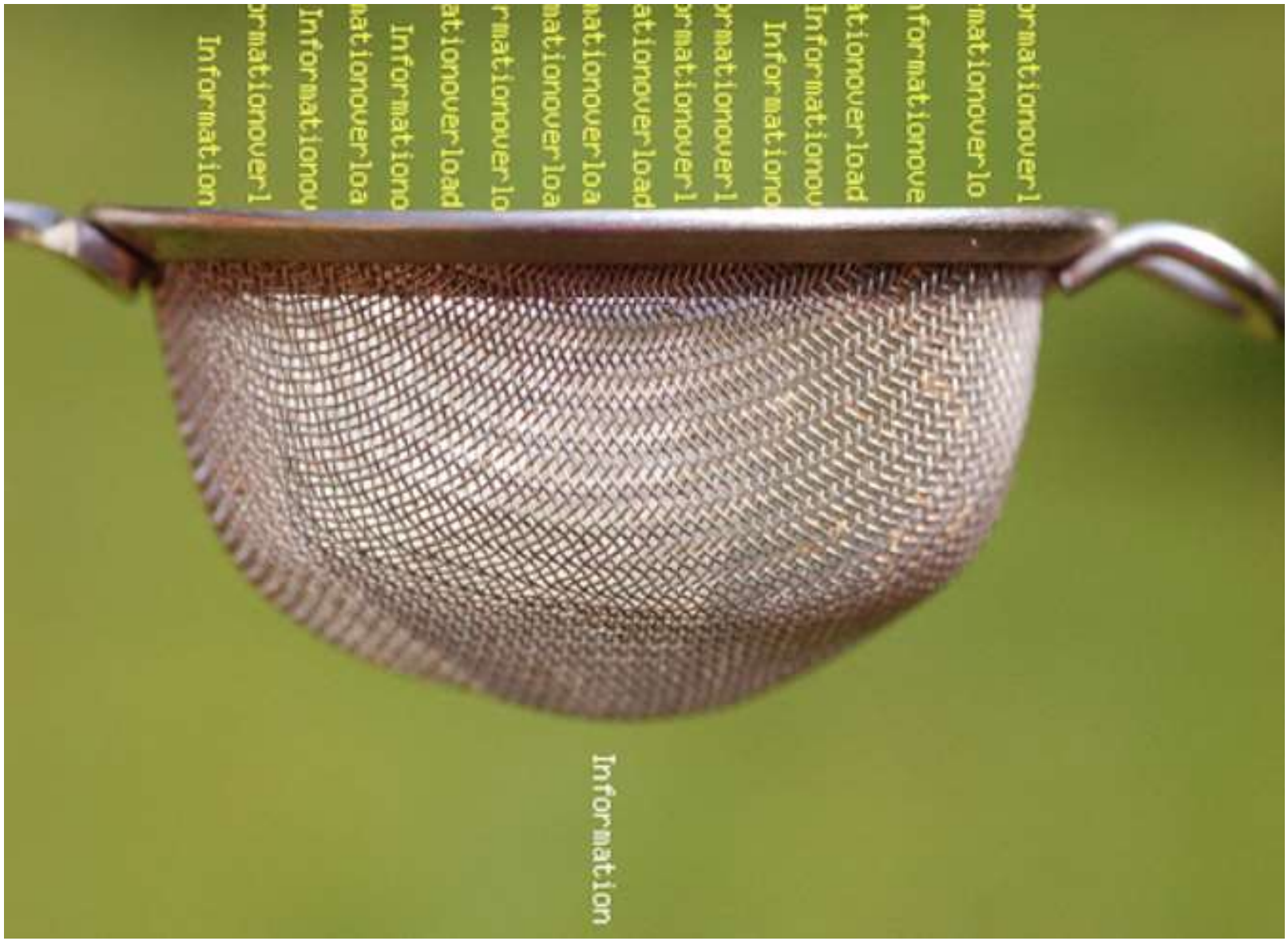


Eichenbaum H, Cohen NJ (2014). Can we reconcile the declarative memory and spatial navigation views on hippocampal function? Neuron.

BUT ART IS A LIE THAT SPEAKS THE TRUTH!

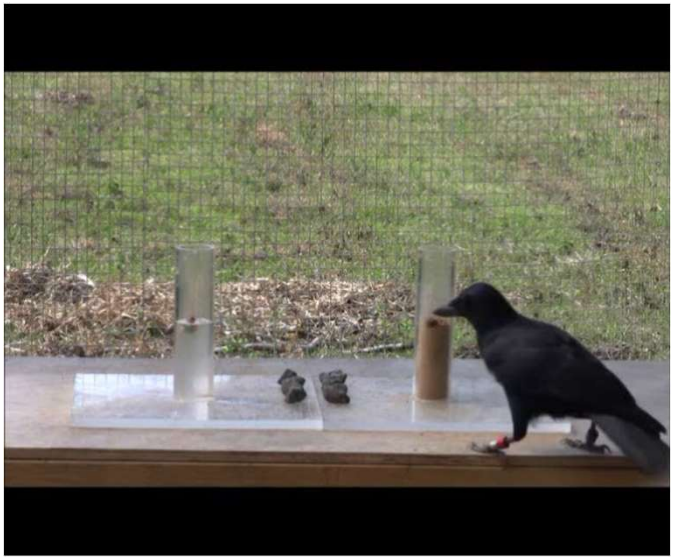


ROBOT MEMORY- FORGETTING AND SENSE-2-COMMONSENSE



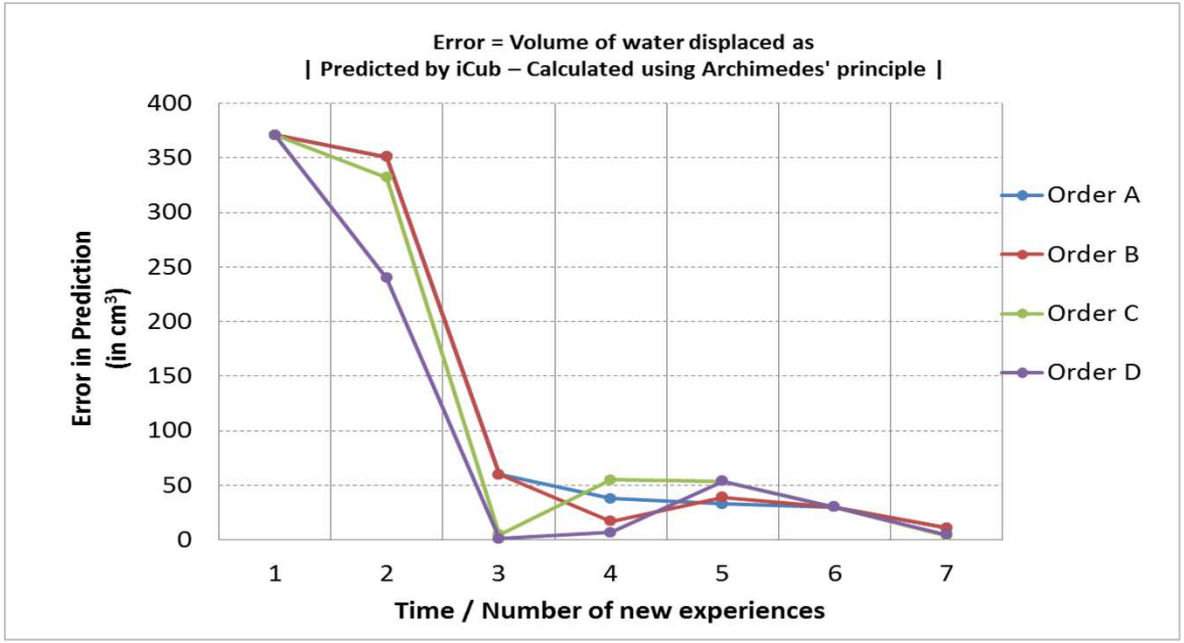
Memory Consolidation : Comparing Remembered past with Present

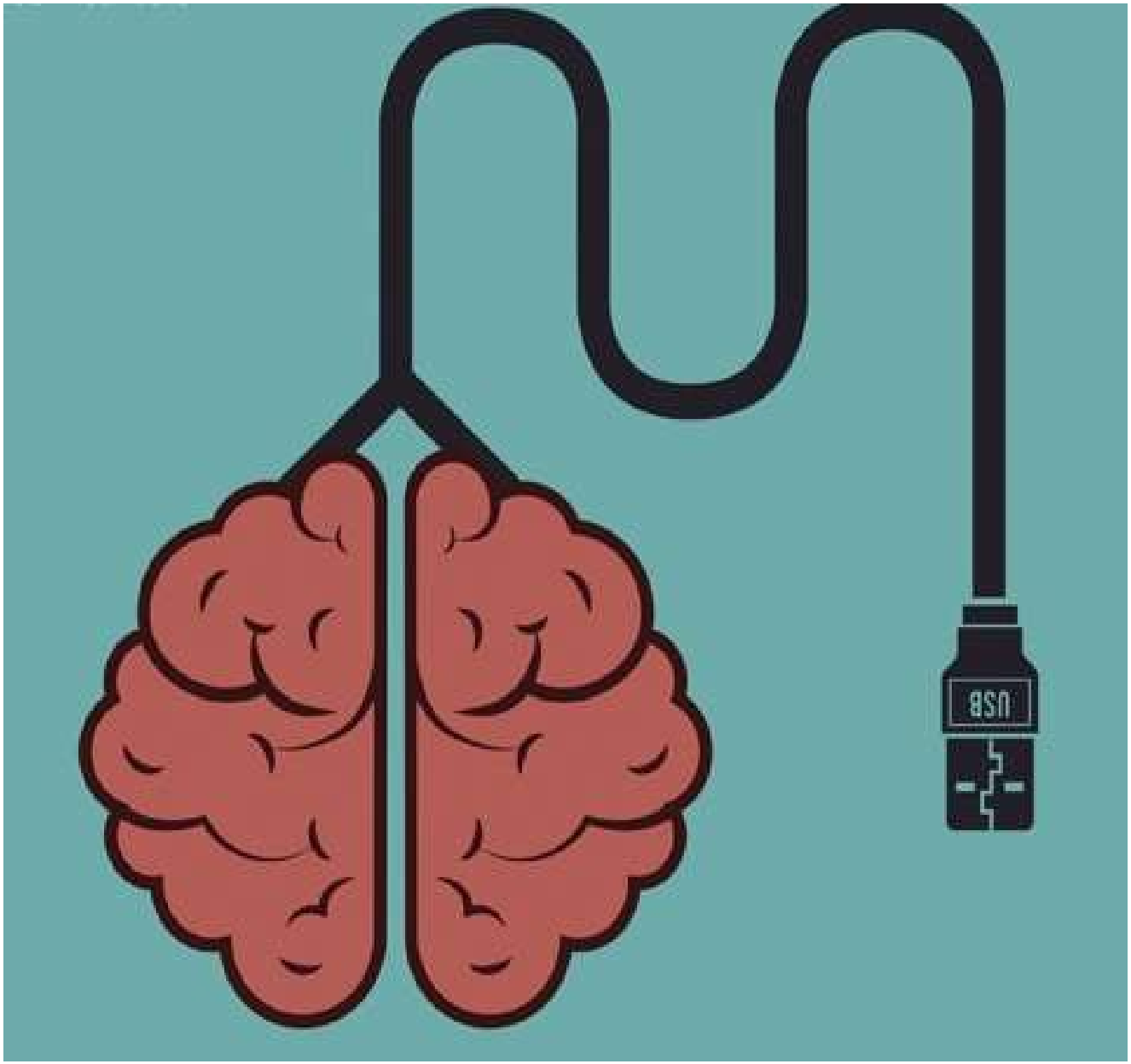
Affordance: From "Object Action" to "Property-Action"



Four Simple Learning rules

Rule	Δ Property (in property-specific maps)	Δ Contradiction (between expected and observed behavior: top-down vs bottom-up)	Update in connectivity strength (between associated property-specific maps and object hub)
Elimination Rule	✓	✗	↓
Growth Rule	✓	✓	↑
Uncertainty Rule	✗	✓	↓
Status Quo Rule	✗	✗	—

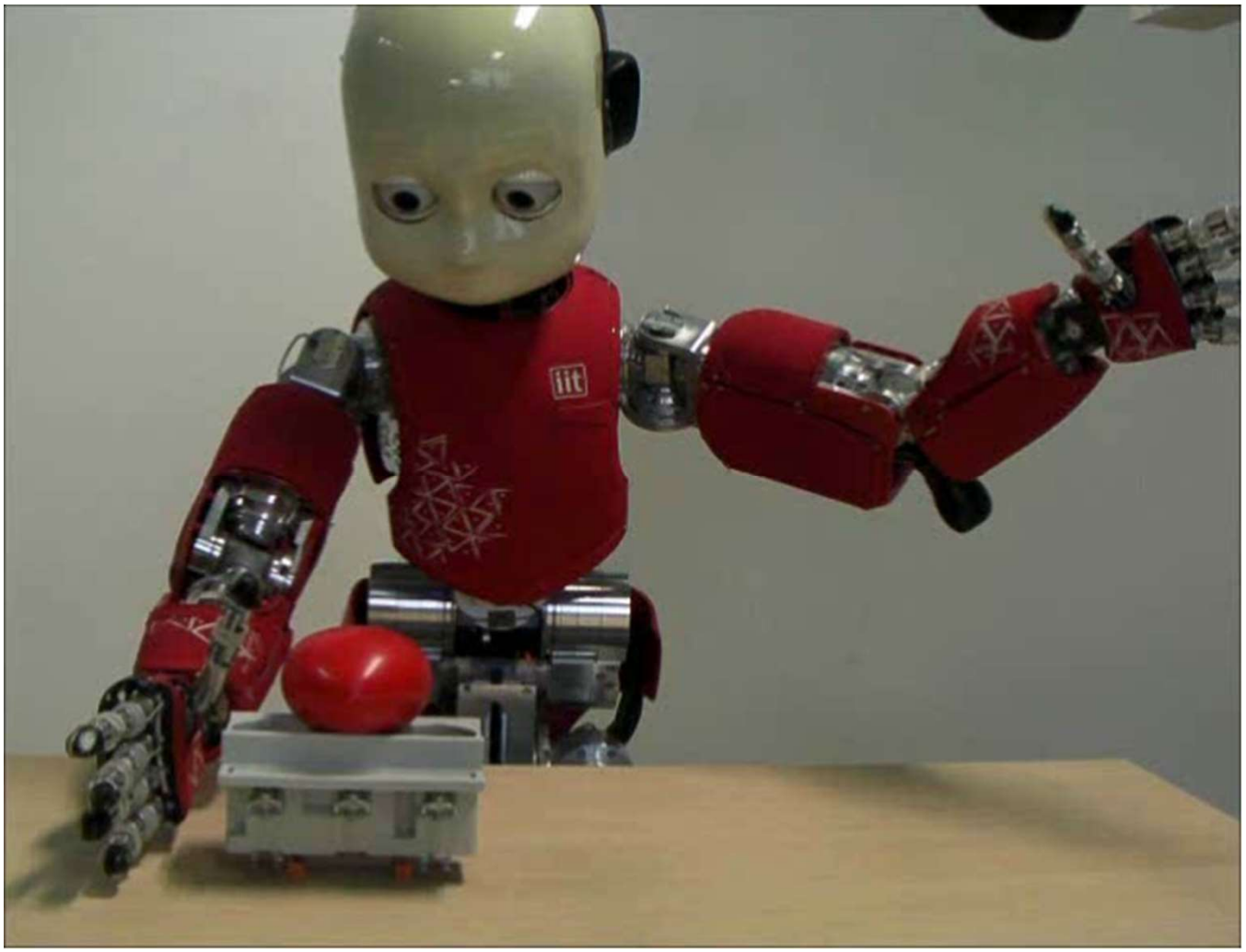


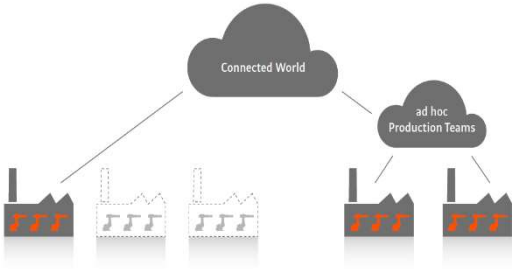


AND SUCH ROBOT MEMORIES ARE TRANSFERABLE

…..TO OTHER ROBOTS

AND SUCH MEMORIES ARE TRANSFERABLE…..BEYOND EMBODIMENTS



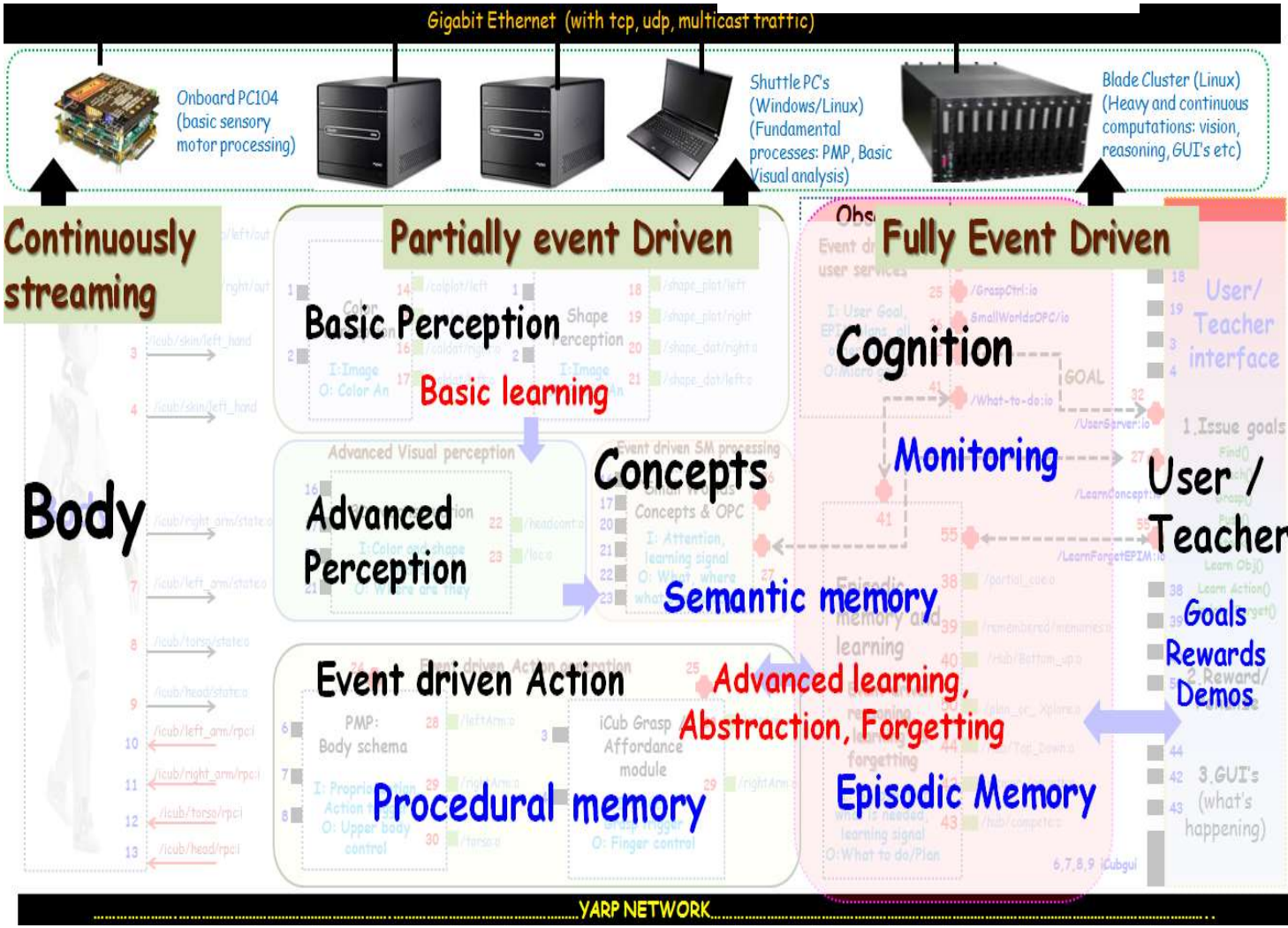


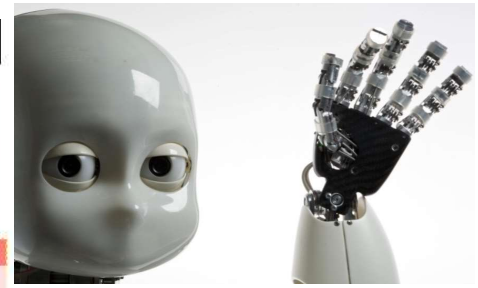
roboearth.eu, robohow.eu, vishwanathanmohan.com

DARWIN COGNTIVE FRAMEWORK

Dextrous
Assembler
Robot
Working with embodied
INtelligence

DOMAIN AGNOSTIC
PARTIALLY EMBODIMENT AGNOSTIC
GROWING/LEARNING
PLUG AND PLAY





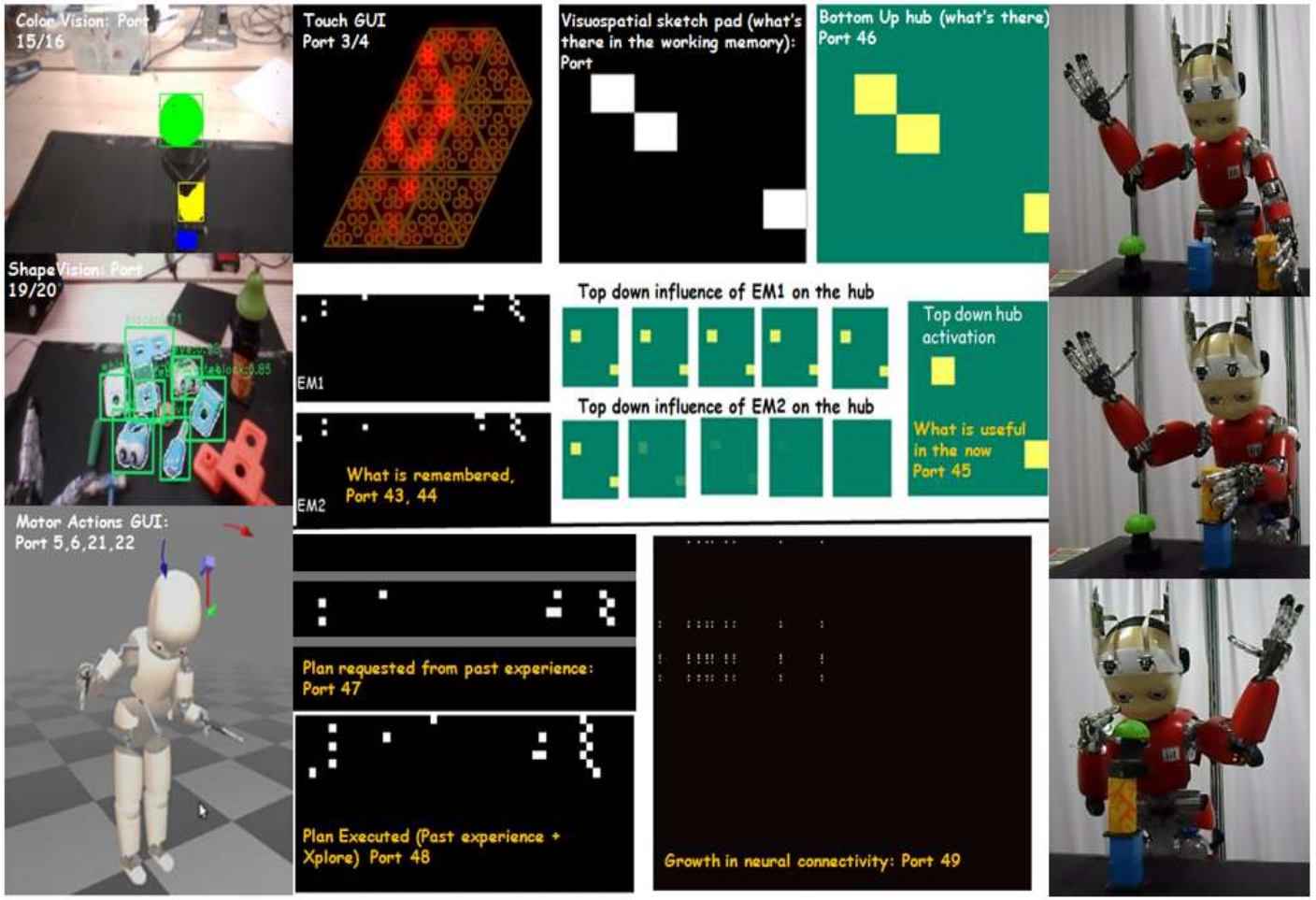
DARWIN COGNTIVE FRAMEWORK

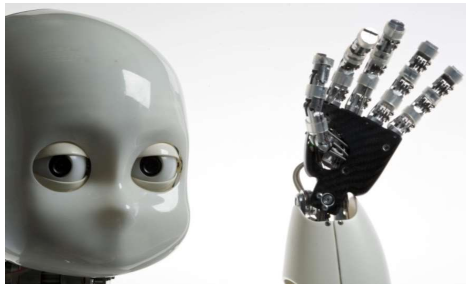
Dextrous
Assembler
Robot
Working with embodied
INtelligence

DARWIN

DOMAIN AGNOSTIC
PARTIALLY EMBODIMENT AGNOSTIC
GROWING/LEARNING
PLUG AND PLAY

- VISUALIZING WHAT IS HAPPENING
- VIRTUAL LEISIONS (DISORDERS OF COGNITION)

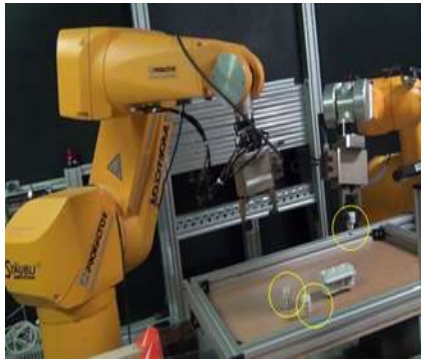




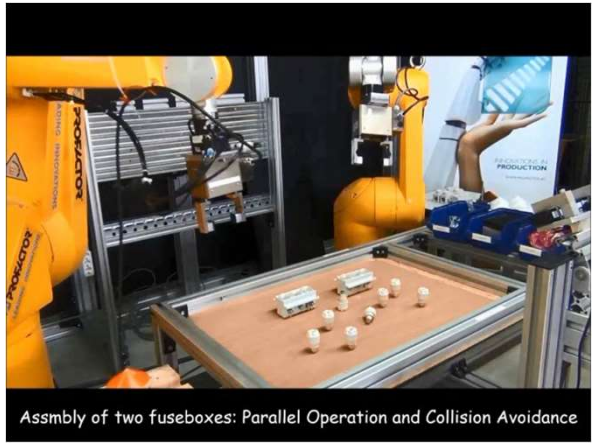
Connecting to the End User (Gradual porting of the Architecture)

Basic Assembly on Industrial Platform (Peception-Action Loop)

Multirobot Assembly (Peception-Action -Spatial reasoning Loop)

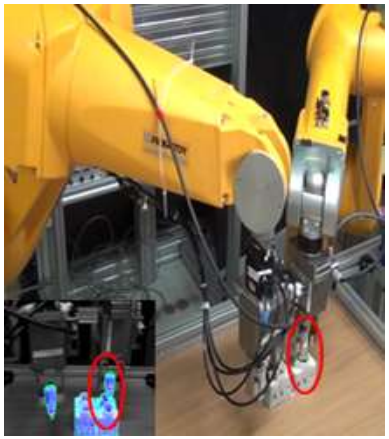


Recovery from Failures (Peception-Action -Spatial reasoning Loop-Top down monitoring)

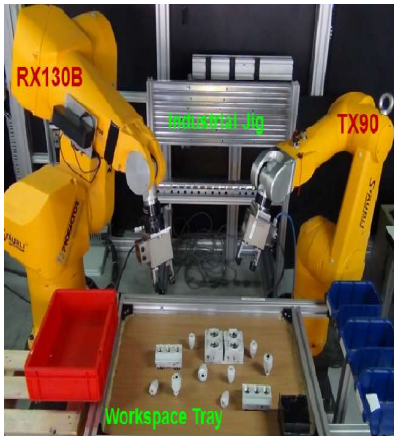


Robot Cooperation (Peception-Action -Spatial reasoning Loop-Top down monitoring-Internal model based Simulation)

Quick Switchover to new tasks (Peception-Action -Spatial reasoning Loop-Top down monitoring-Internal Simulation-Online learning)



Mixed assembly (Goals are triggered by the environment)



Comaprison with Industrial Benchmark system

Demonstration Scenario	DARWIN Cognitive System (Demo specific success rate)	DARWIN Benchmark system (Demo specific success rate)
1.1	31 seconds	29.9 seconds
1.2	90%	100%
2	100%	100%
3.1	100%	100%
3.2	94%	95%
4	88%	85%
5	15 minutes	2-3 hours
6	97% (TSR: 85%)	84% (TSR: 45%)

Demonstration Scenarios:

1.1 Basic assembly with fuses in upright position
1.2 Basic assembly with fuses in arbitrary position
2 Bi-manual operation of robots
3.1 Recovery from grasp failure
3.2 Recovery from insertion failure
4 Robot Cooperation
5 Change over to new task
6 Mixed Assembly
TSR: task success rate

Co-Botics is about making learning, reasoning robots that can do much more!

Connecting to the End User (Gradual porting of the Architecture)

- ROBOTIC COMPANIONS IN HOSPITALS, CARE HOMES (3 HOSPITALS IN THE REGION)
- ONE FULLY FUNDED PHD POSITION JUST ADVERTISED...

Critical Capabilities beyond State of Art

- Dexterous Manipulation
- Multimodal Perception
- Life long Learning
- Context Appropriate/ Goal directed behavior planning
- Human Behavior Understanding
- Perspective Taking
- Social Intelligence
- Natural language communication
- Continuous, Robust and Safe operation
- Privacy and Security

Robotic Platform

End User Targets in Assistive/Healthcare robotics

- Lifelong Independence
- Enhanced Mobility, Manipulation
- Robot assisted Rehabilitation
- Coaching and Motivation
- Patient Monitoring-Data Collection
- Companionship, Personalized Care
- Improved Prevention
- Health and Wellness promotion
- Assistant for Daily chores
- Social Assistance and Behavioral Therapy

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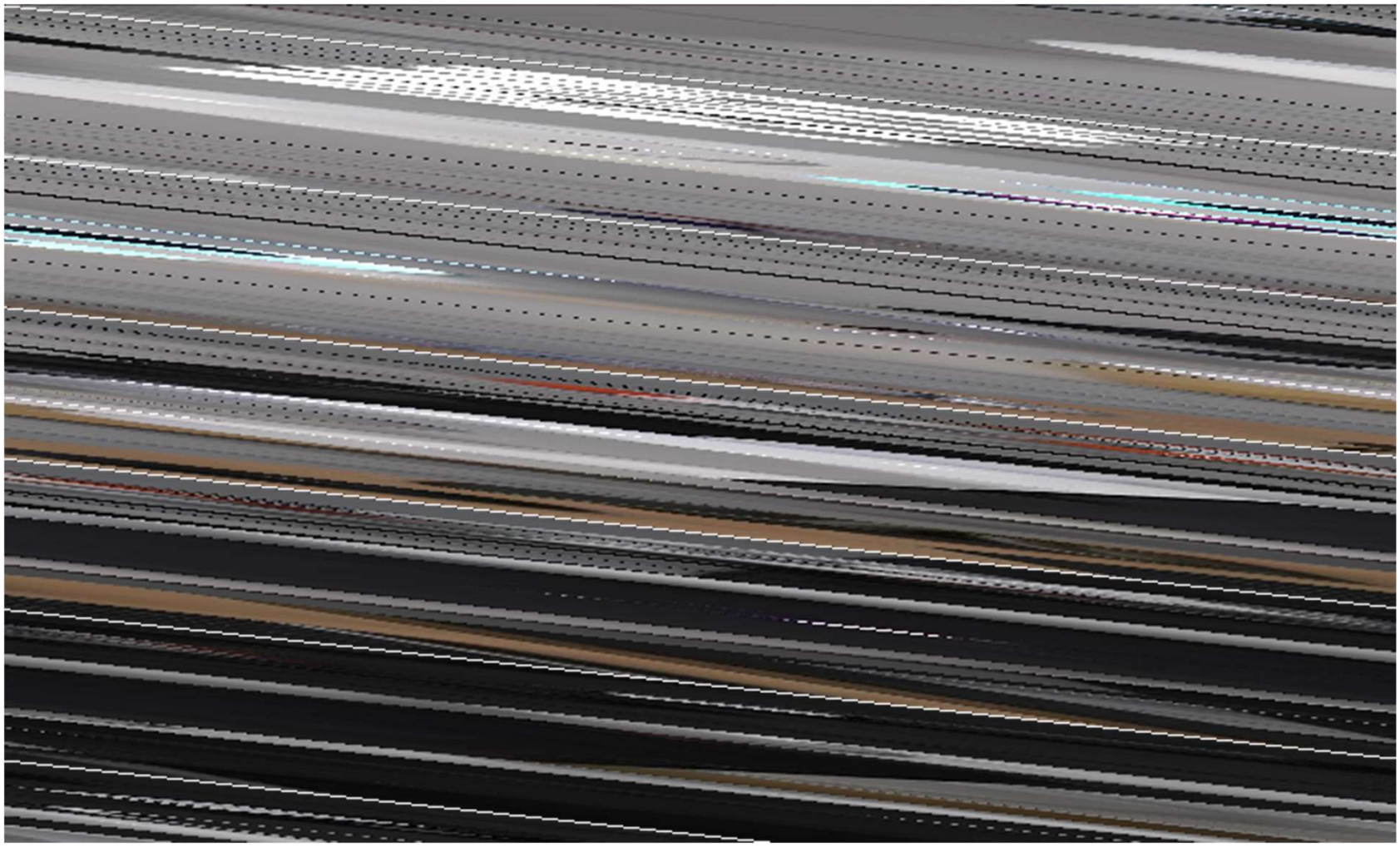
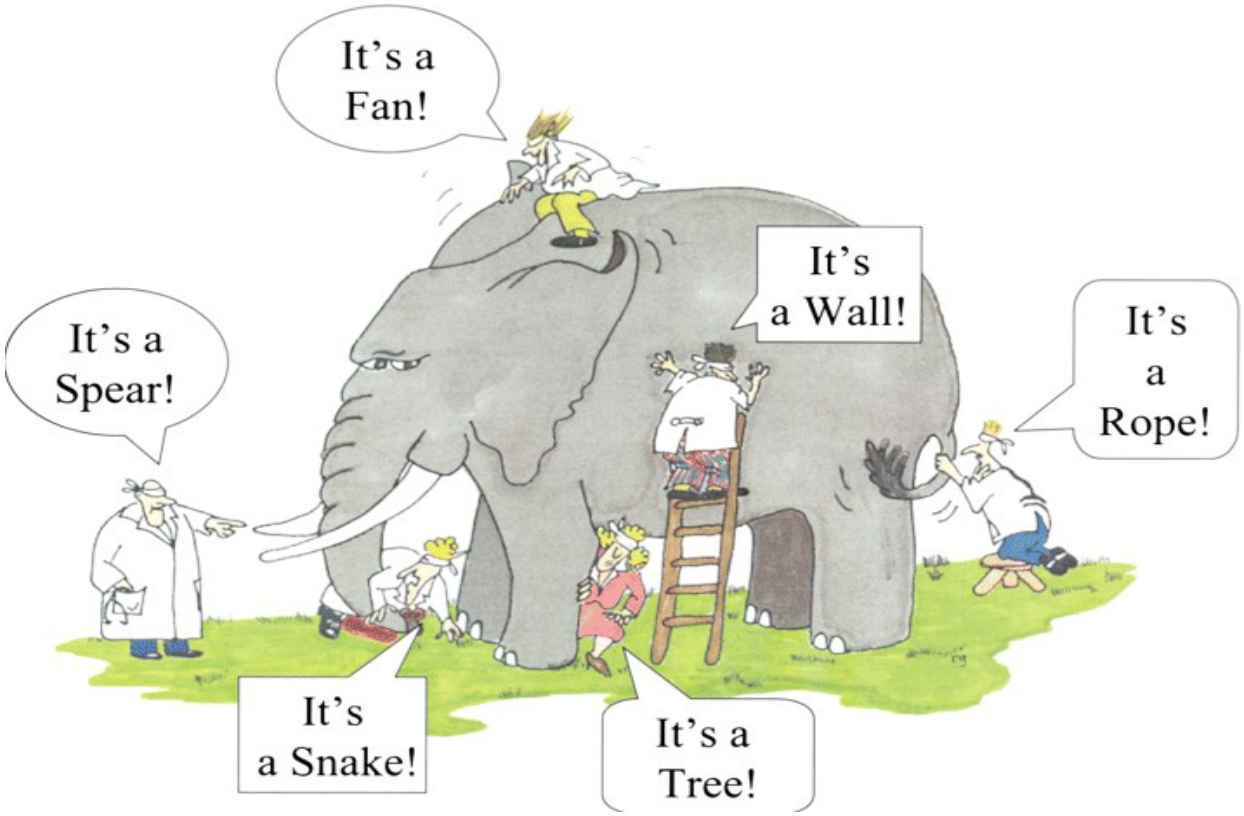


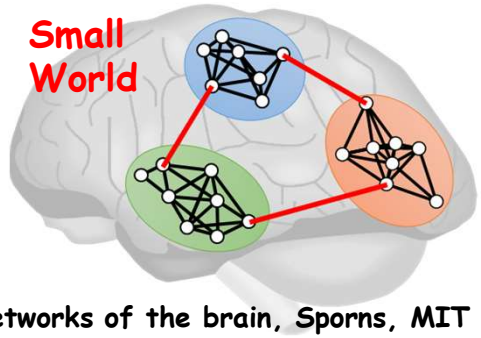
Co-Botics is about making learning, reasoning robots that can do much more!

Going back to Neurosciences (Why and Why Now?)

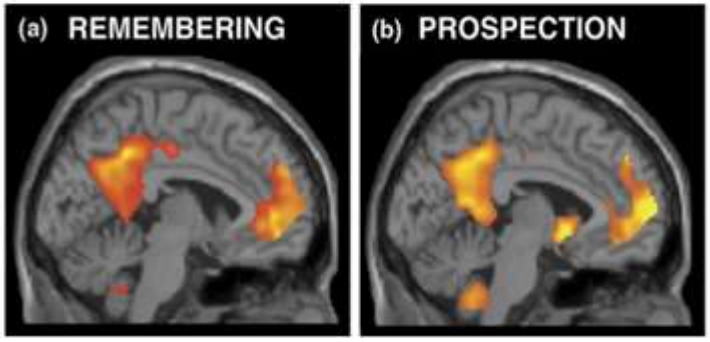


Going back to Neurosciences (Why and Why Now?)

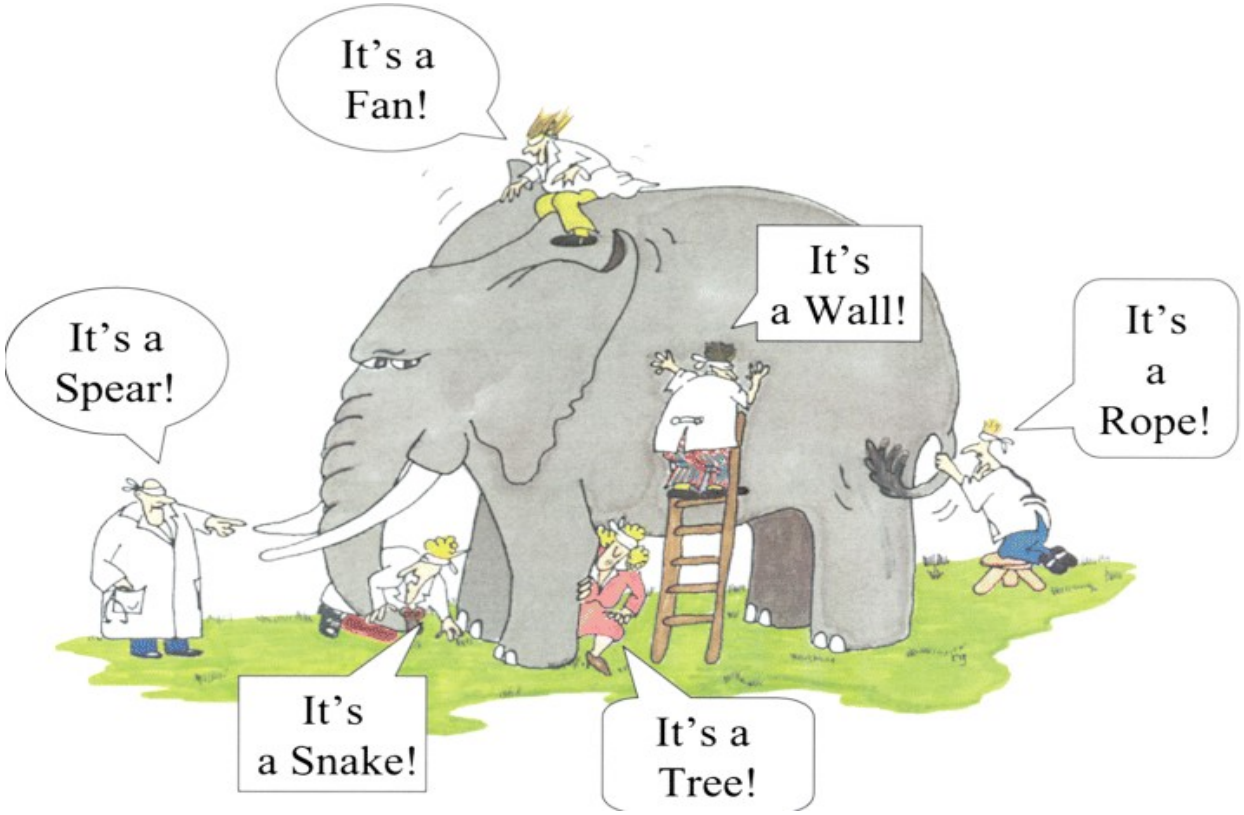
Action Gen-Sim



Networks of the brain, Sporns, MIT



Brain: Just like a big elephant problem



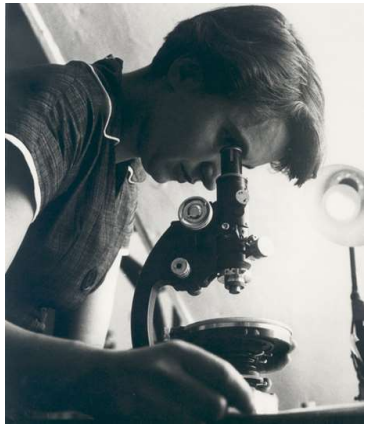
Data to Useful engineering Principles

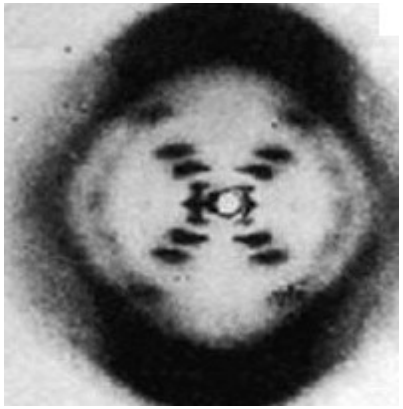
Need an Integrative approach

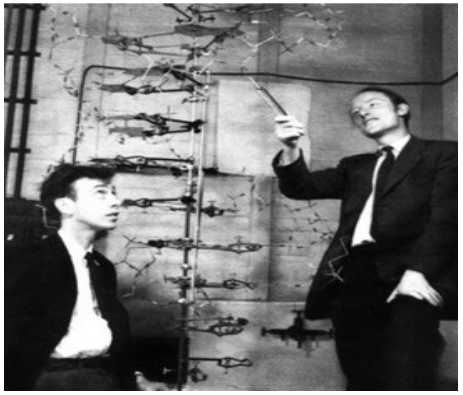
Co-Bots are such Integrative platforms

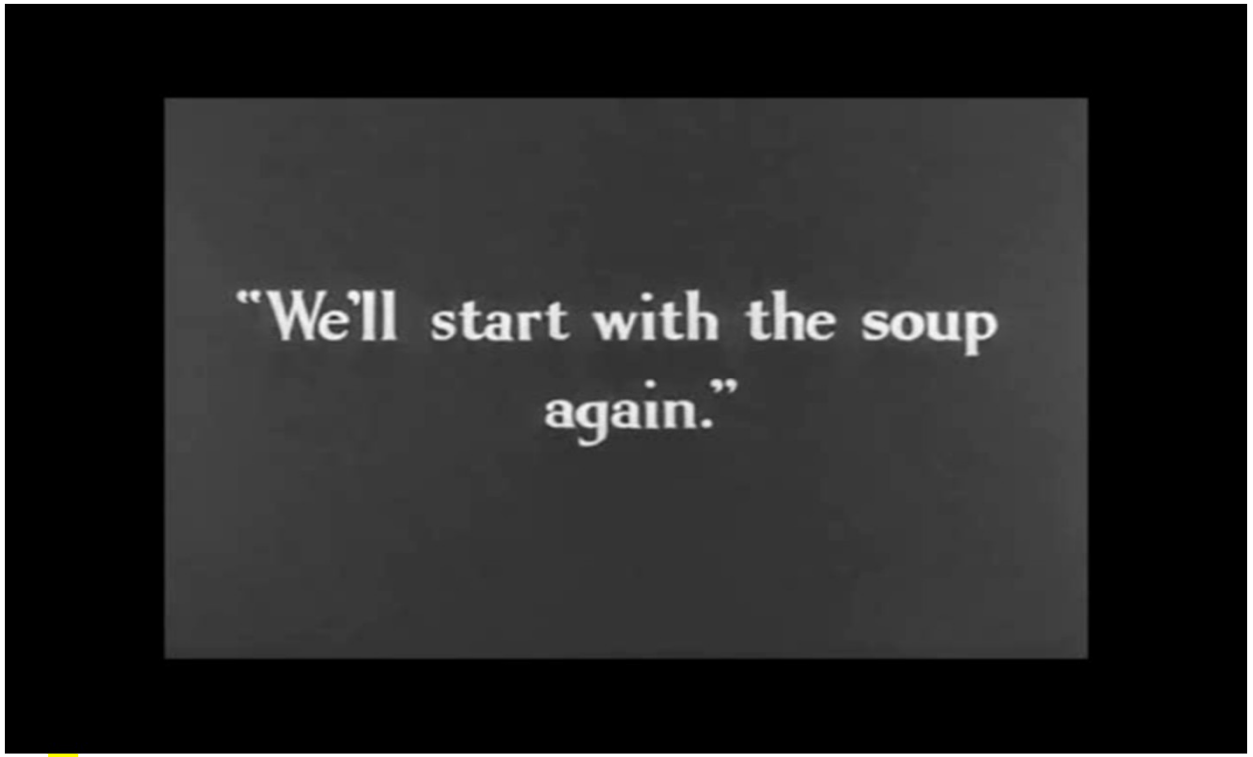
Going Back to History of Science

DNA- Interdisciplinary efforts









Our quest to understand brain function and designing artificial systems exhibiting cognitive behaviors is at a crucial juncture

Concluding message from Charlie Chaplin's Eating Machine!!!!!

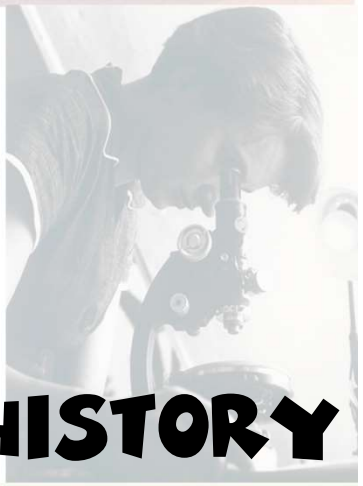
RECAP..

ART

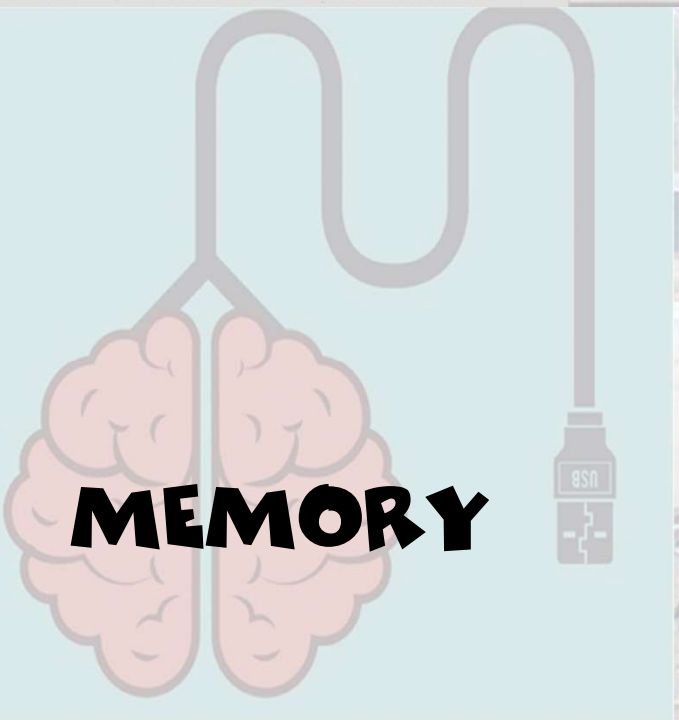
?

AGRO-TECH
HOSPITALS
MANUFACTURING

BRAIN

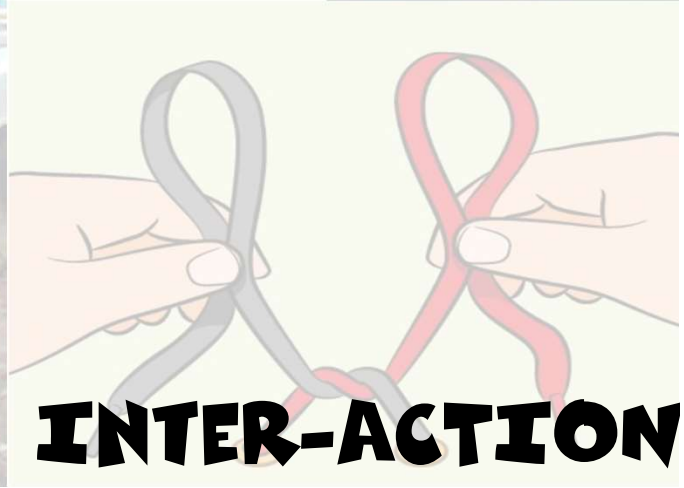


HISTORY

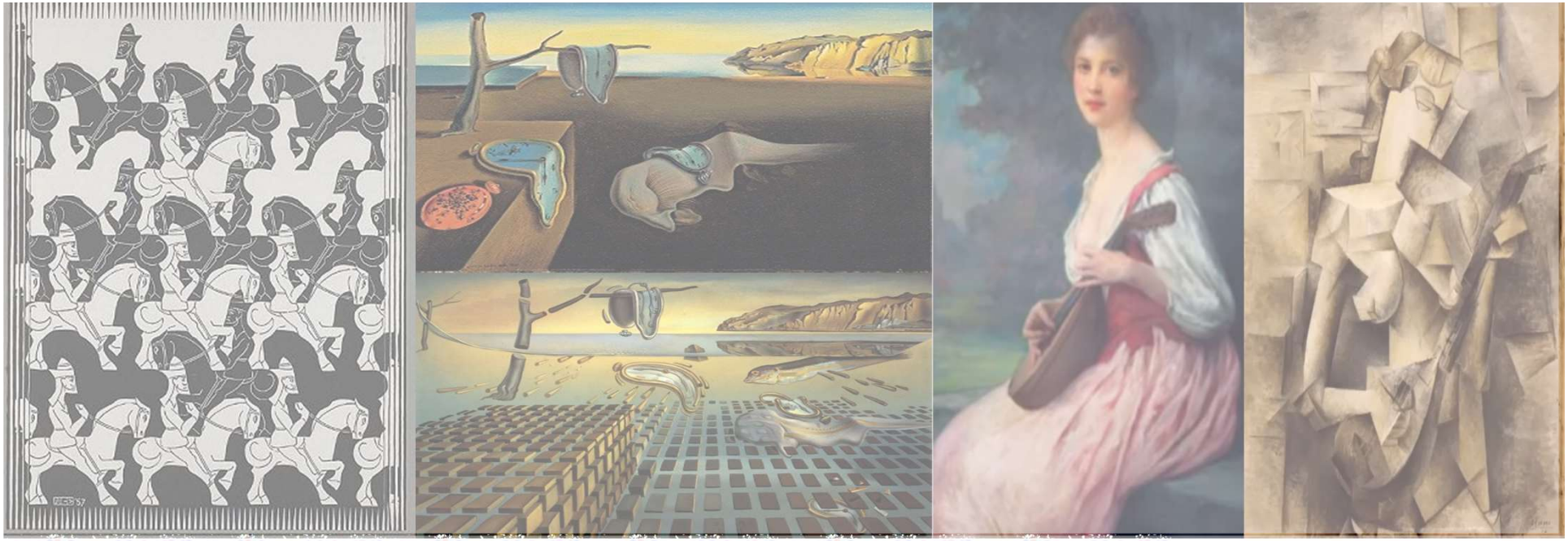


MEMORY

COMMON
SENSE



INTER-ACTION



Thank You + ?????

Further Info+ Contact + Software → www.vishwanathanmohan.com