

SHAIL, 14 DECEMBER 2017



## TODAY FROM: MALAGA, SPAIN

ROLF PFEIFER, DR. SC. TECHN. ETH

LIVING WITH ROBOTS LTD., SHANGHAI JIAO TONG UNIVERSITY, CHINA

PROF. EM. UNIVERSITY OF ZURICH



Living with Robots Ltd.



LIVING WITH ROBOTS LTD.



Department of Automation, Shanghai Jiao Tong University, China

SHAIL, 14 DECEMBER 2017

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# HOW THE BODY SHAPES THE WAY WE THINK - 10 YEARS LATER

ROLF PFEIFER, DR. SC. TECHN. ETH  
LIVING WITH ROBOTS LTD., SHANGHAI JIAO TONG UNIVERSITY, CHINA  
PROF. EM. UNIVERSITY OF ZURICH

SHAIL, 14 DECEMBER 2017

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# THE “ROBOT/AI HYPE”, EMBODIED INTELLIGENCE, SOFT ROBOTICS, AND DEEP NEURAL NETWORKS

ROLF PFEIFER, DR. SC. TECHN. ETH  
LIVING WITH ROBOTS LTD., SHANGHAI JIAO TONG UNIVERSITY, CHINA  
PROF. EM. UNIVERSITY OF ZURICH

# WHY DO PLANTS NOT HAVE BRAINS?

(Lewis Wolpert, British biologist)

...

# WHY DO PLANTS NOT HAVE BRAINS?

**"The answer is actually quite simple: they don't have to move! "**

**(Lewis Wolpert, British biologist)**

...

# THERE ARE OTHER THINGS BESIDES DEEP NEURAL NETWORKS

...

# ROBOTICS\* 2017 HAS A PROBLEM

\* CONSUMER ROBOTICS, SOCIAL ROBOTS - NOT INDUSTRIAL ROBOTICS

- ▶ Random Interviews with consumers, 04/ 2016

# EXPECTATION

# VS.

# REALITY

# EXPECTATION

- perfect functionality
- polished look

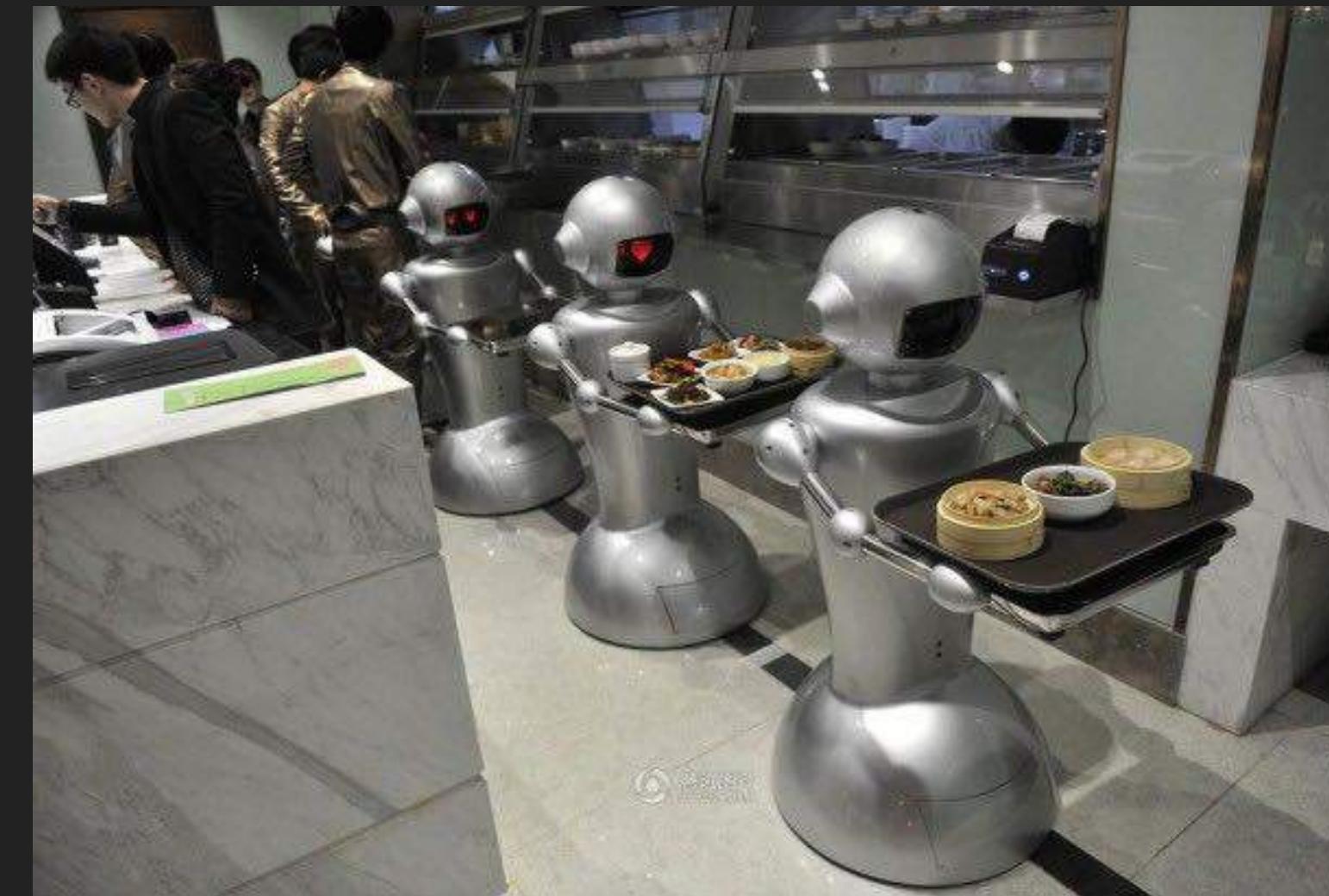


# REALITY



- toy look
- little functionality

# REALITY OF „ROBOTICS-REVOLUTION“ 2016/2017



Hefei (China)

# THERE IS A ROBOTIC HYPE !

# THERE IS A ROBOTIC HYPE !

The Robot Revolution Has Begun  
– Toward Heartwarming Society

**iREX 2017**  
INTERNATIONAL ROBOT EXHIBITION

Nov.29wed.-Dec.2sat. 2017 10:00-17:00 / Tokyo Big Sight, Japan  
Organizers : Japan Robot Association(JARA), THE NIKKAN KOGYO SHIMBUN,LTD

About iREX ▾ Find Exhibitor ▾ Various Forums / Event ▾ Pre-registratiton ▾ PRESS ▾

Pre-registration      Visitor Mypage      Group Registration (15 people and above)      Exhibitor Mypage

| FAQ | Japanese |

# THERE IS A ROBOTIC HYPE !



The image shows a screenshot of the iREX 2017 International Robot Exhibition website. At the top left is the iREX logo. To the right are four buttons: "Pre-registration" (red), "Visitor Mypage" (red), "Group Registration (15 people and above)" (blue), and "Exhibitor Mypage" (yellow). Further right are links for "FAQ" and "Japanese". Below the header, there's a navigation bar with links: "Nov.29wed.-Dec.2sat. 2017 10:00-17:00 / Tokyo Big Sight, Japan", "Organizers : Japan Robot Association(JARA), THE NIKKAN KOGYO SHIMBUN,LTD", "About iREX", "Find Exhibitor", "Various Forums / Event", "Pre-registraiton", and "PRESS". The main banner features large blue text "2017国際ロボット展" and "INTERNATIONAL ROBOT EXHIBITION 2017" above a robotic hand holding a globe. It also displays the exhibition dates "Nov.29wed. - Dec.2sat. 2017" and time "10:00~17:00", and the location "Tokyo Big Sight East Hall 1~6". A small note at the bottom states "Organizers: Japan Robot Association (JARA), THE NIKKAN KOGYO SHIMBUN, LTD.".

# THE “ROBOTIC HYPE”

CBS News / CBS Evening News / CBS This Morning / 48 Hours / 60 Minutes / Sunday Morning / Face The Nation

©CBS MONEYwatch Markets Money Work Small Business Retirement Tech Trending

## CBSNEWS, December 2013

By JONATHAN BERR / MONEYWATCH / December 16, 2013, 1:18 PM

# Google buys 8 robotics companies in 6 months: Why?

5 Comments / f Shares / 91 Tweets / Stumble / Email More +

Google's (**GOOG**) acquisition of military robotics maker Boston Dynamics has certainly gotten tongues wagging but has left one key question unanswered: Why?



Media reports about the deal didn't provide much insight other than to note that Boston Dynamics makes cool stuff. The search engine giant has named Andy Rubin, who oversaw the development of the Android operating system, to head its robotics endeavors, which the company has without irony called a "moonshot." A

# THE “ROBOTIC HYPE”

CBS News / CBS Evening News / CBS This Morning / 48 Hours / 60 Minutes / Sunday Morning / Face The Nation

©CBS MONEYwatch Markets Money Work Small Business Retirement Tech Trending

## CBSNEWS, December 2013

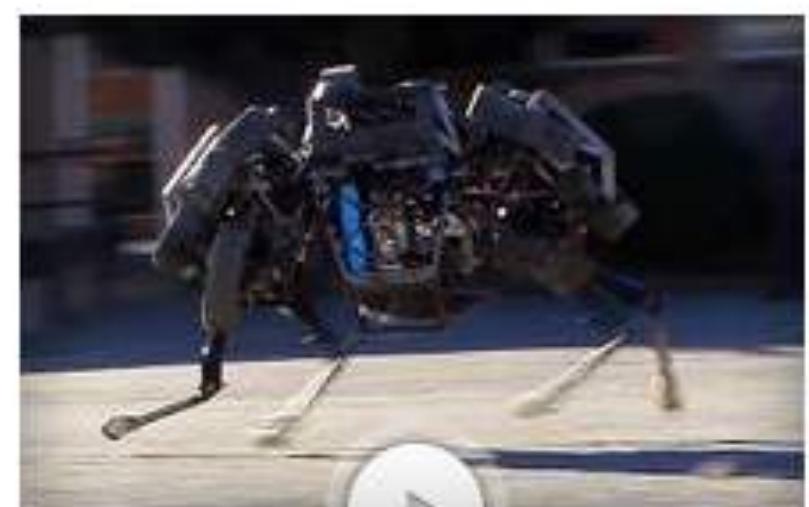
By JONATHAN BERR / MONEYWATCH / December 16, 2013, 1:18 PM

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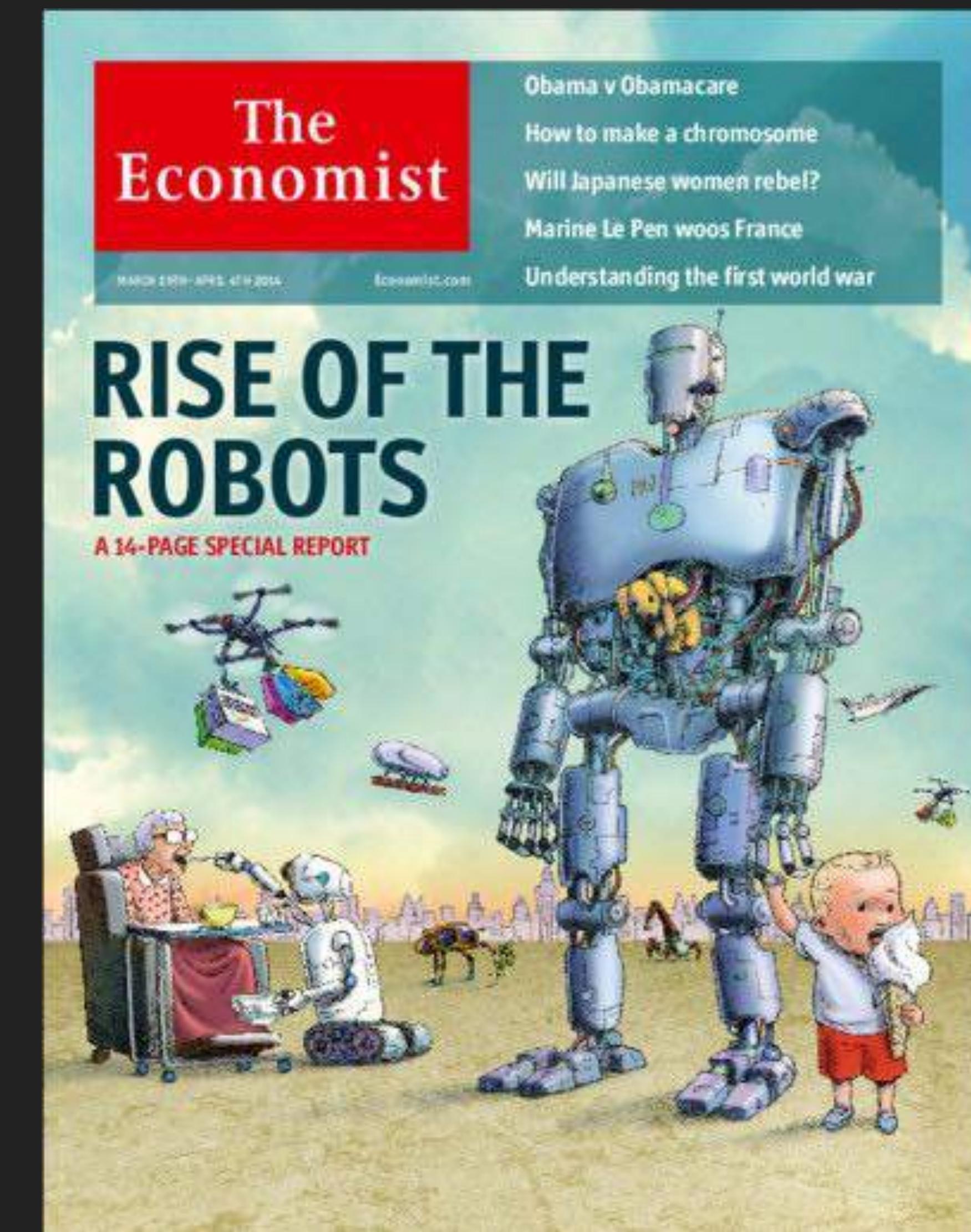
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More +

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# THE “ROBOTIC HYPE”

“The dawn of the age of robotics”

Frankfurter Allgemeine Zeitung  
9 February 2017, p. 21

Fliege und leuchtenden Augen: ein Roboter namens Pepper

## Das Zeitalter der Roboter bricht an

Die Zeiten, als Computer in Kästen waren, sind vorbei. Die Roboter werden immer menschlicher: Sie sehen aus wie Menschen, sie lernen, sie springen, und sie schwitzen sogar. Warum eigentlich?

liert sein. Derzeit sind alles in allem 2,6 Millionen Roboter in der Industrie im Einsatz. Allein in Deutschland werden jedes Jahr mehr als 20 000 Roboter in Fabriken und Betrieben installiert.

Unternehmen wie Siemens, BMW, Toyota oder auch General Electrics haben schon viel Geld in die Hand genommen, um in die Forschung und Entwicklung zu investieren. Apple, Google und Samsung haben sprachgesteuerte Handys mit selbstlernenden Systemen be-

einen Roboter entwickelt, der Personalabteilungen von Unternehmen bei der Auswahl von Bewerbern für einen Arbeitsplatz helfen kann. Die Maschine namens Matilda sieht ein wenig aus wie ein zu groß geratener Reiskocher, hat zwei Augen, einen Lautsprecher und zwei Mikrofone, kann ans Internet und an große Datenbanken angeschlossen werden. Sie soll einem Job-Bewerber binnen einer halben Stunde 76 Fragen stellen, ihn bei den Antworten beobachten, das Minen-

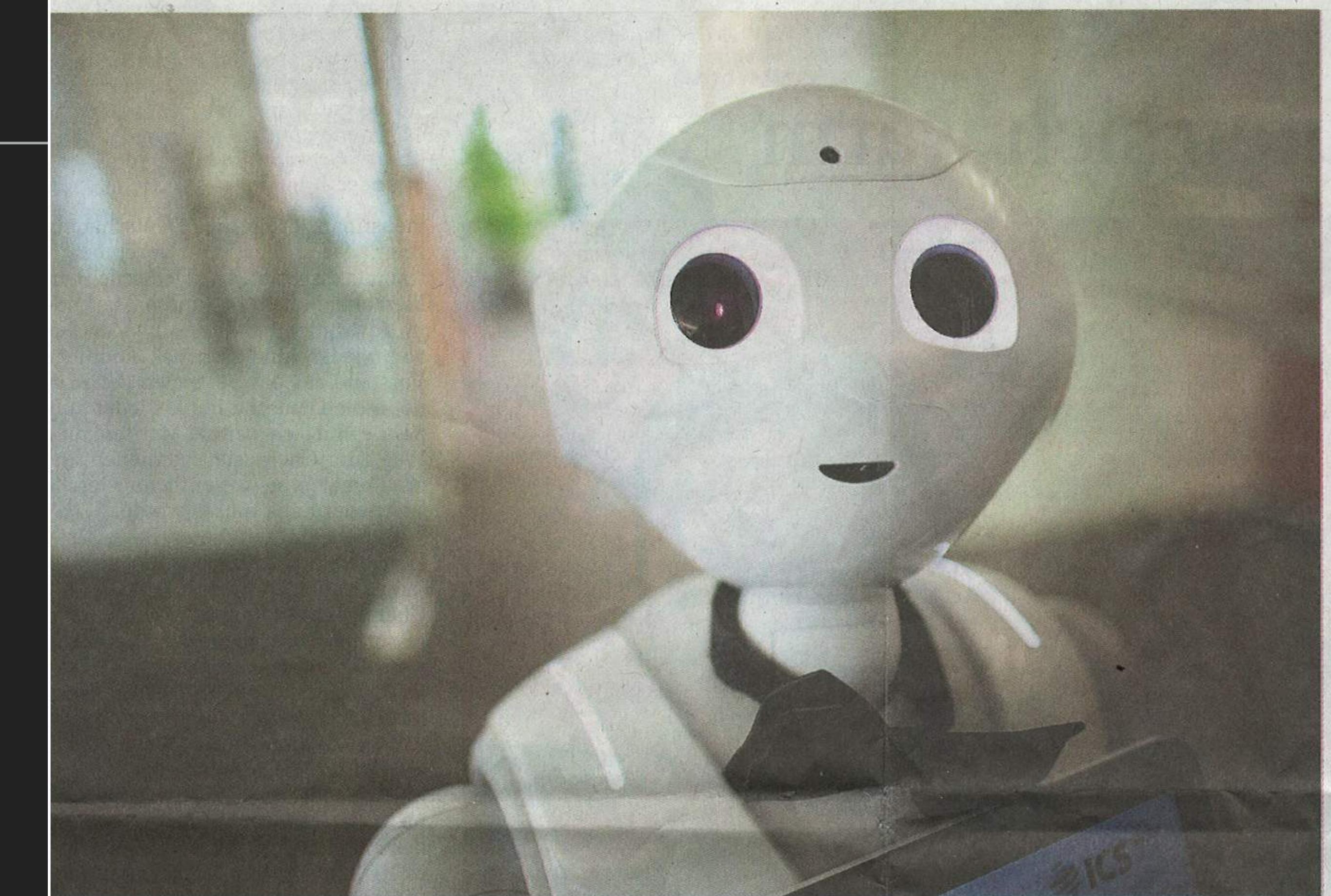


Foto Marcus Kaufhold

THE "ROBOTIC/AI HYPE"

2017

# THE TABLOID PRESS

What is Artificial Intelligence?

Martin Vetterli, President EPFL

18 October 2017

Blick

Ihre Meinung • Zürich 20° ☀  
Home News Sport Politik Wirtschaft People Leben Digital Auto Virtual Reality Video Services

Q. Suche

Anmelden

Professor Vetterli erklärt

## Was ist künstliche Intelligenz?

Martin Vetterli - Präsident der EPFL Lausanne -

➤ @MartinVetterli

Martin Vetterli ist Präsident der EPFL in Lausanne und führender Experte für Digitalisierung. Jede Woche erklärt er Begriffe aus der digitalen Welt.



THE "ROBOTIC/AI HYPE"

2017

# THE TABLOID PRESS



20min, Tabloid  
19 Mai 2017

de fr lt Zürich 12°

20 Minuten

Schweiz Ausland Wirtschaft Sport People Entertainment Digital Wis

News Börse Dossiers PostFinance News Krankenka

Ihre Story, Ihre Informationen, Ihr Hinweis? [feedback@20minuten.ch](mailto:feedback@20minuten.ch)

Männer Spielzeug 19. Mai 2017 10:33; Akt: 19.05.2017 10:33

## Roboter übernehmen im Garten das Kommando

von K. Wolfensberger - Die Verkäufe von Rasenmährobotern gehen durch die Decke. Im Trend sind Mäher, die sich via App bedienen lassen. Wenig Freude daran haben Tierschützer.



# UBS: AI TO BOOST TRADERS' PERFORMANCE

FINANCIAL TIMES

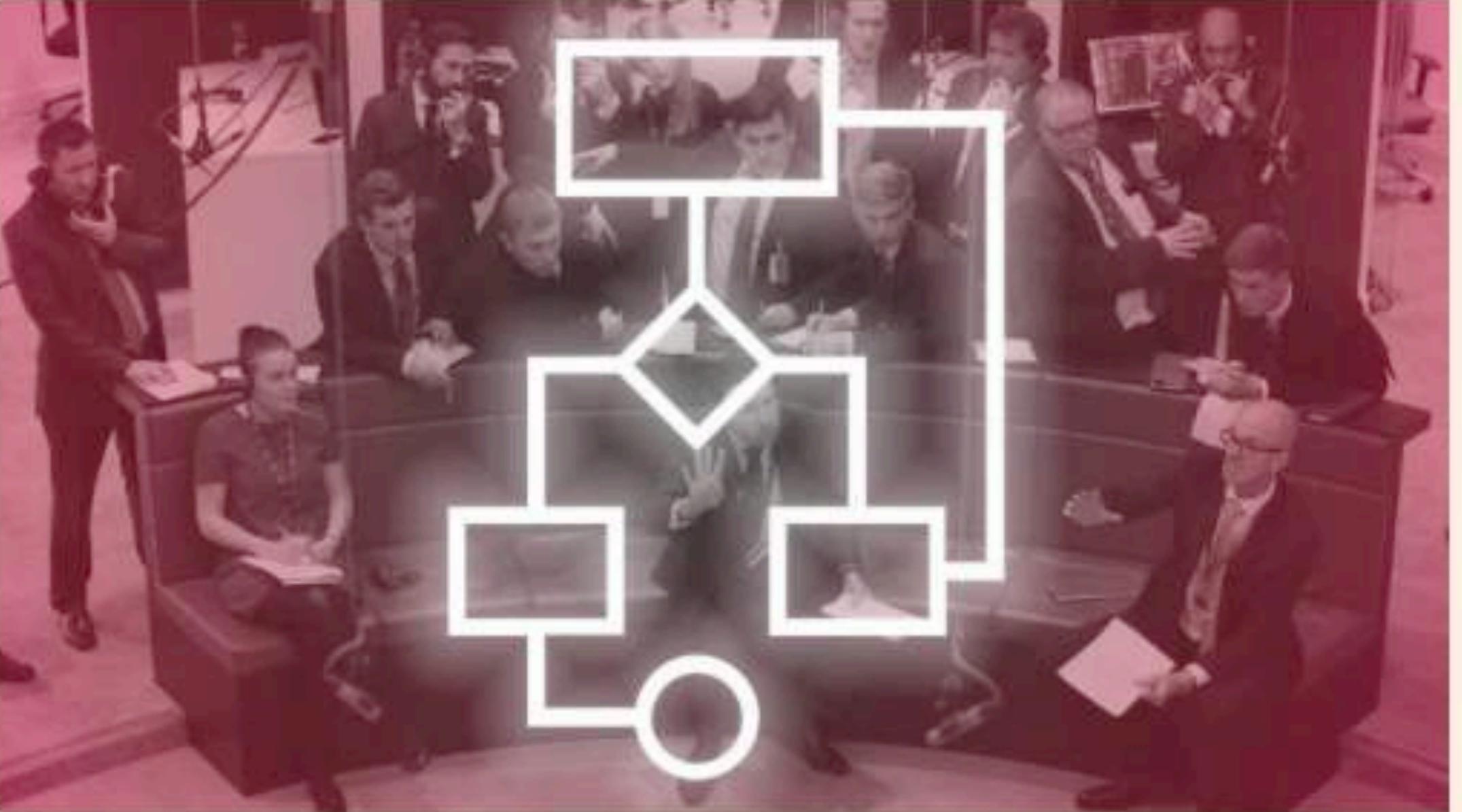
WORLD US COMPANIES MARKETS OPINION WORK & CAREERS LIFE & ARTS

Artificial intelligence in real workplaces

Artificial Intelligence and Robotics + Add to myFT

## Robots enter investment banks' trading floors

UBS among the banks looking to AI to boost traders' performance



Financial Times  
7 July 2017

UBS as “Pionier”



# DEEPMIND - DEVELOPER OF ALPHAGO

# 2017

A L P H A G O      HOME      FILMMAKERS      GALLERY      PRESS      SCREENINGS      CONTACT      TRAILER

**"We think of DeepMind as kind of an Apollo program effort for AI. Our mission is to fundamentally understand intelligence and recreate it artificially."**

Demis Hassabis  
Co-Founder & CEO, DeepMind

The whiteboard behind Demis Hassabis contains the following handwritten notes:

- (N2) VENUE
- (N2) FEELING
- (DM) DELEGATES
- (Goo) SECURITY
- (Goo) RUNNING ALL
- (N2) ENTERTAINMENT
- (N2) HOST (MK)
- ENTERTAINMENT
- THE SHOW
- STAGE SET
- STUDIO / LIGHT
- KNIFE (N2)
- CATERING (N2)
- DELEGATES (Goo)
- SECURITY (Goo)
- PR (Goo)
- BROADCASTING (Goo)
- YouTube (Goo)
- AV (Goo)
- TECH INFRASTRUCTURE (Goo)
- PROOCE!
- SPLITTERS
- OVERLAY
- GO BOARD (MK)
- CAM 2000 (MK)
- MONITOR (MK)



MINDFIRE

Pascal Kaufmann  
*Starmind International*



# FOUNDACTION

## THE RACE FOR HUMAN LEVEL AI

We need a new approach to progress human level Artificial Intelligence (AI). And this is why Mindfire was created.

### Cracking the brain code

the Moonlanding of our time



# ROBOTS IN FACTORIES

welding robots

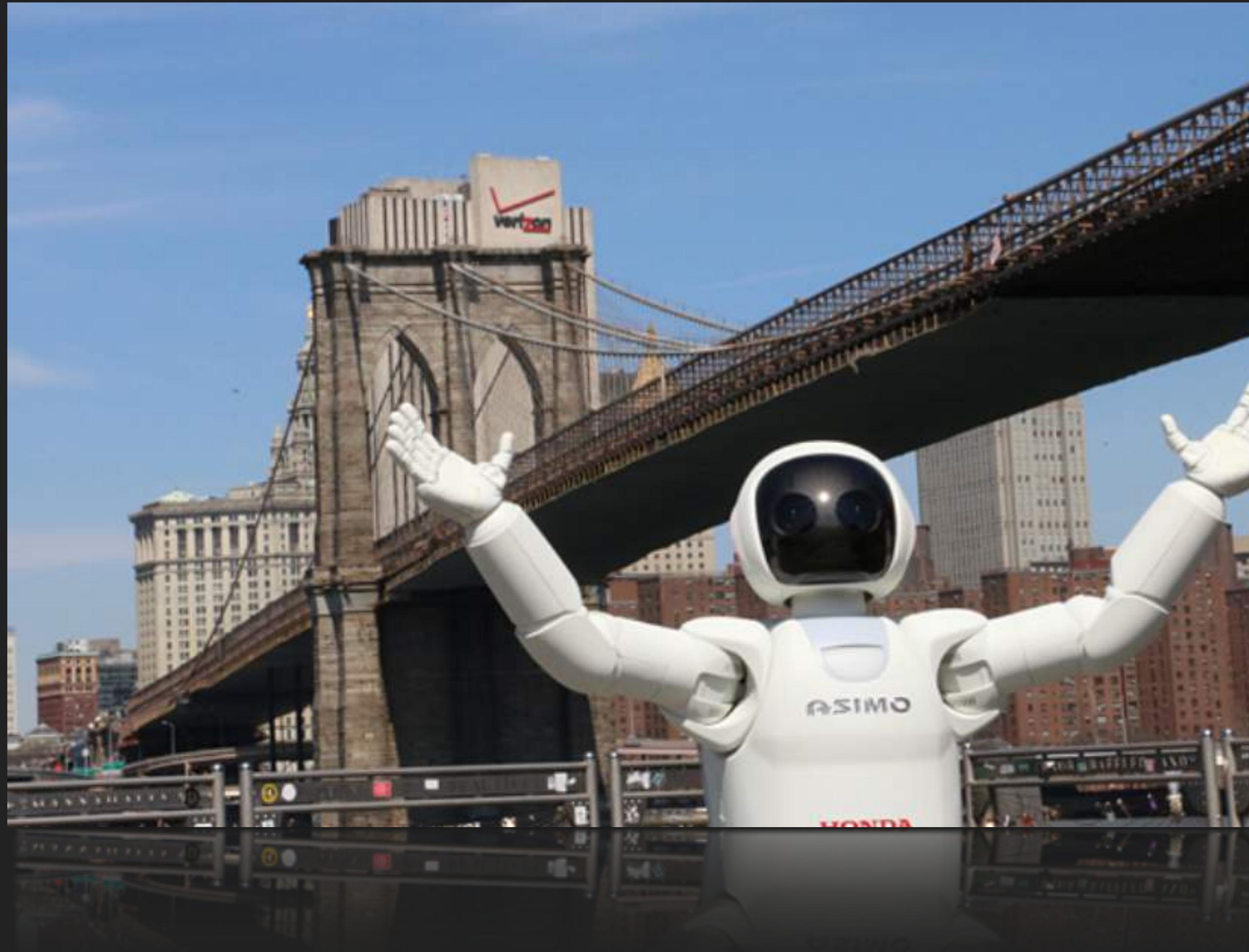


# ROBOTS IN FACTORIES

welding robots



# ROBOTS LEAVING THE FACTORY HALLS



THE “CHAMPION”: HONDA ASIMO



# ROBOTS LEAVING THE FACTORY HALLS



THE “CHAMPION”: HONDA ASIMO



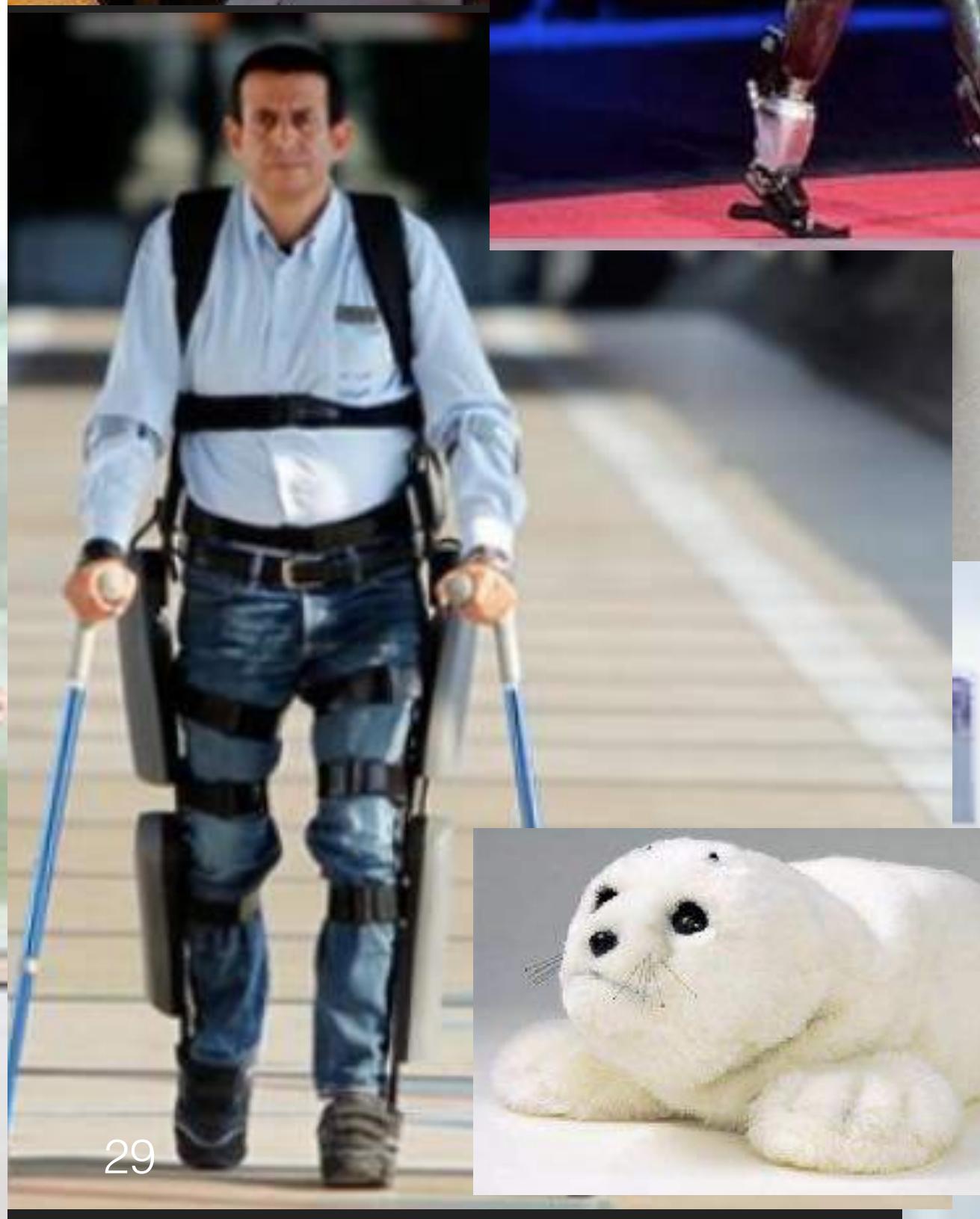
# ROBOTS LEAVING THE FACTORY HALLS - MOVING INTO OUR OWN LIVING SPACE



THE “CHAMPION”:  
HONDA ASIMO



# Service Robotics



# Service Robotics



Darwin-OP (Trosson)

# "Social Robots"



Plen2 (Plen2 Proj.)



Jibo



Robohon/Robi (Robo Garage)



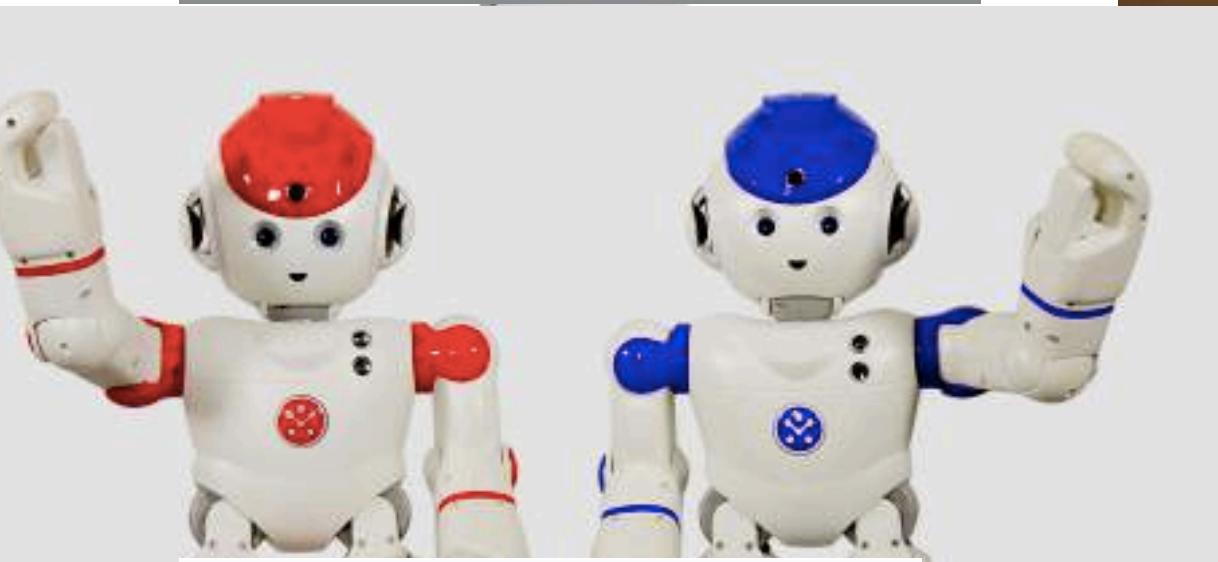
Alpha 1s (UBTECH)



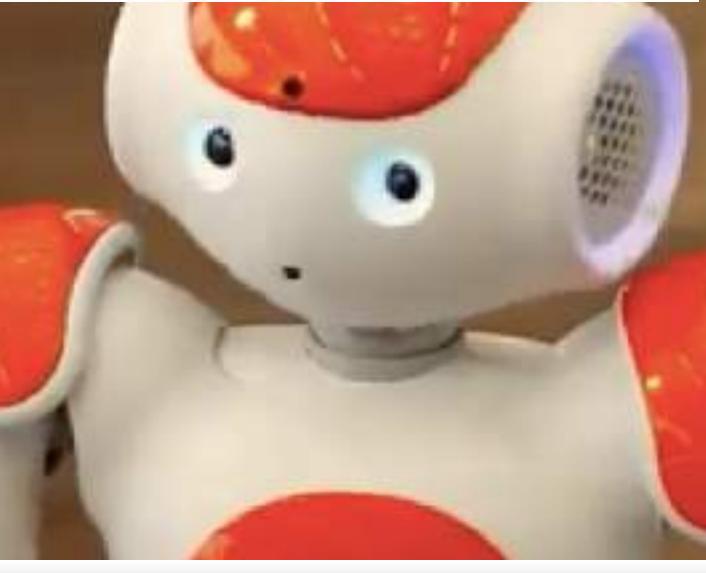
Balro (Fujisoft)



Kiribo (Toyota)



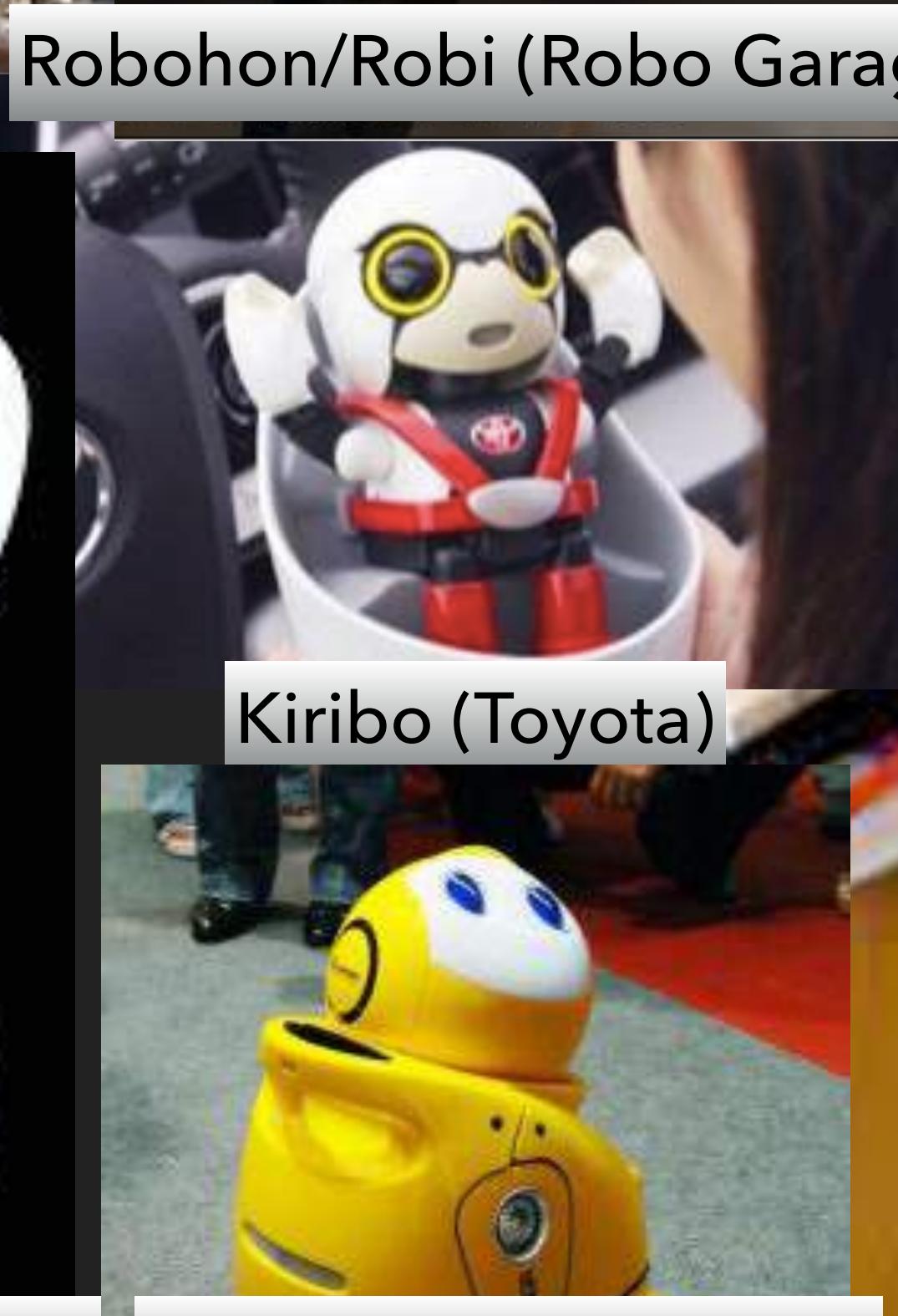
Alpha 2 (UBTECH)



Nao (Ald./Softbank)



Buddy (Blue Frog Rob.)



Unisrobo (UNIS Corp.)



Tapia (MJI Robotics)

# Jibo-Imitations



Jibo (original)



ElliQ (Intuition Robotics)



Jibo imitation



JD.CC



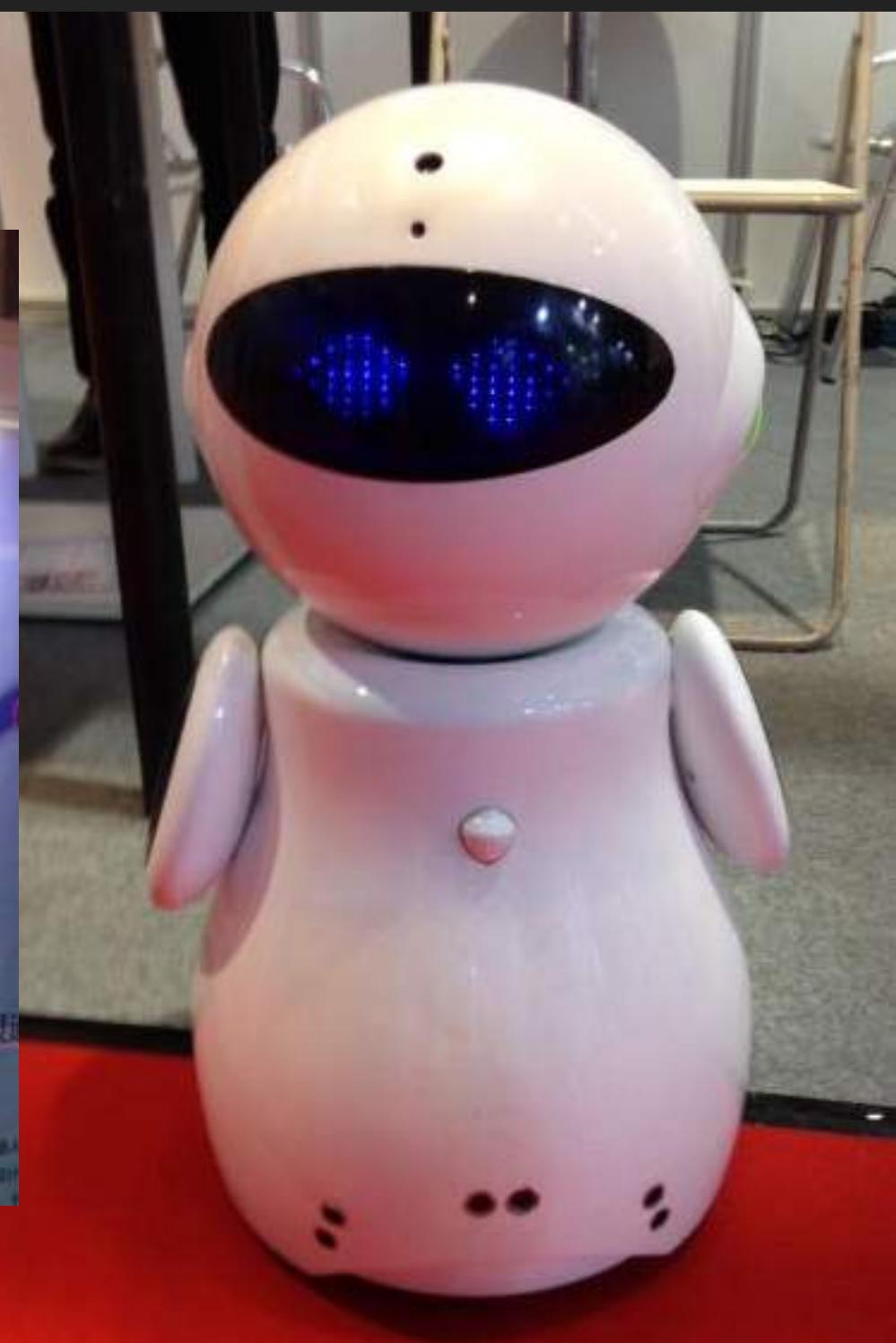
HowAreYou?



Pebble (Rokid)



Olly (Emotech)



From: WRC Oct 2016



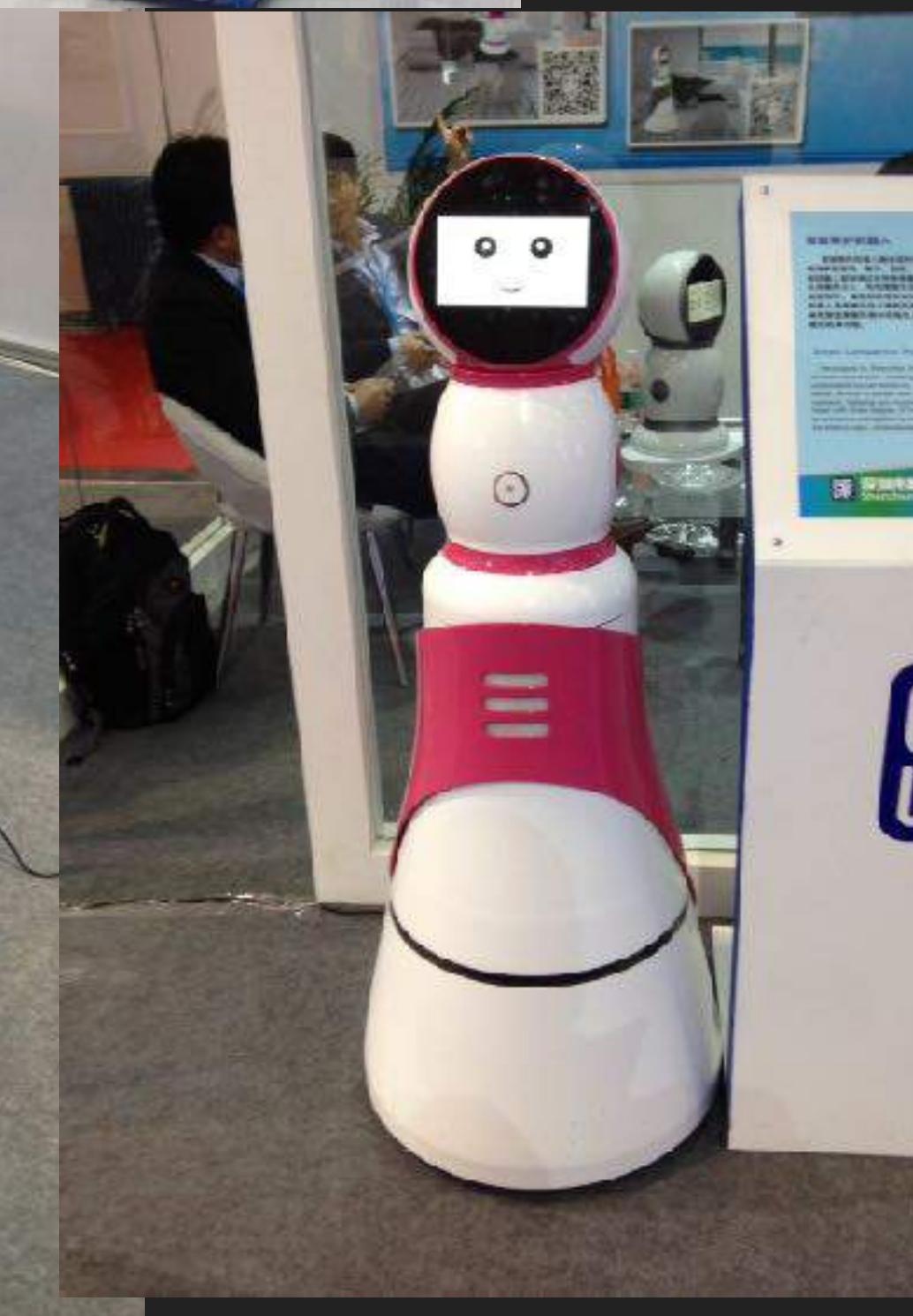
# "Social Robots"

From: WRC Oct 2016



# "Social Robots"

From: WRC Oct 2016



# "Social Robots"



From: Robot Show, Shanghai, July 2017



# "Social Robots"

From: Robot Show, Shanghai, July 2017



# "Social Robots"

From: WRC, Beijing, 2017, August 2017



# "Social Robots"

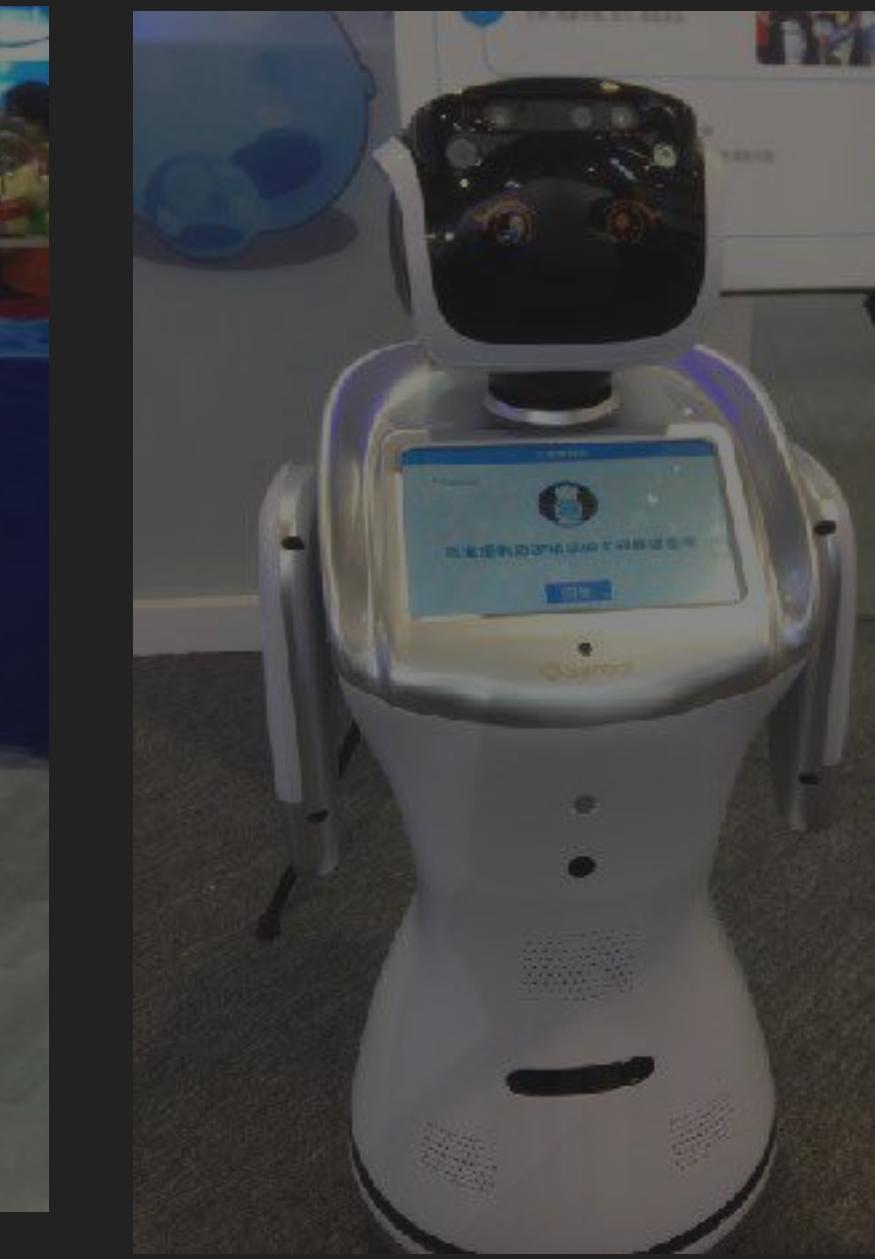
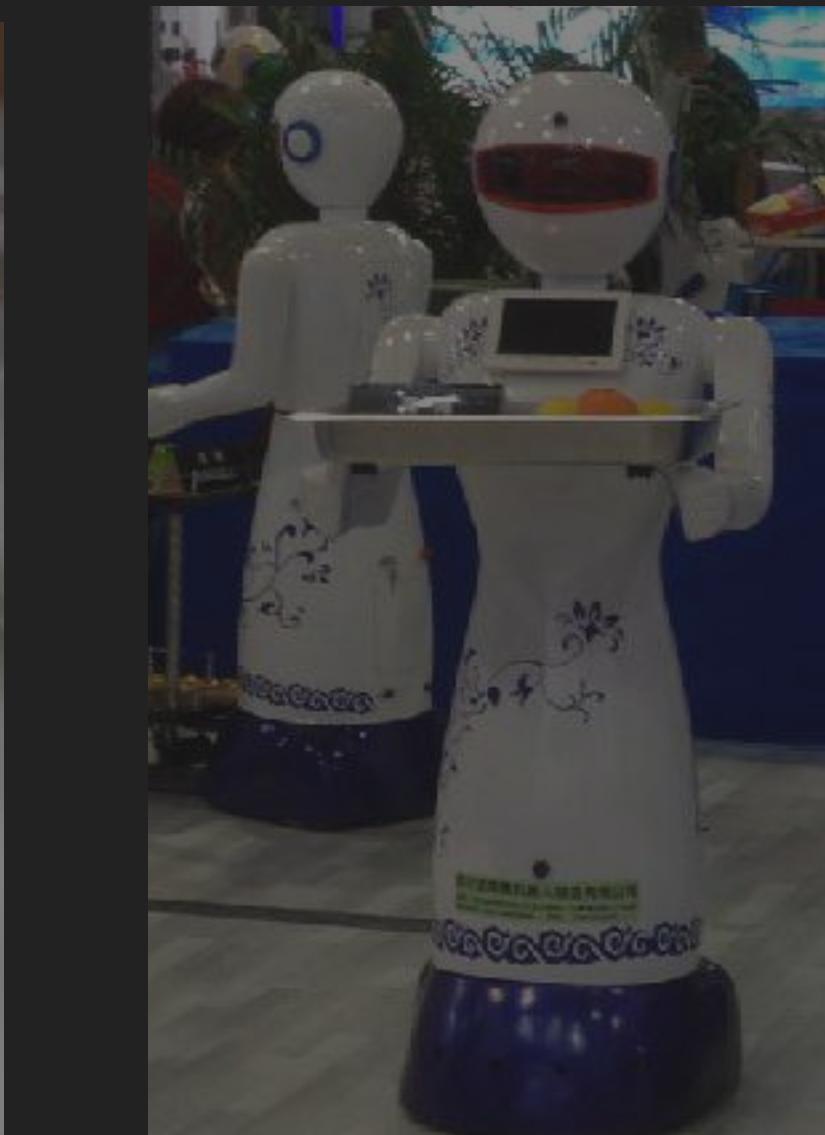
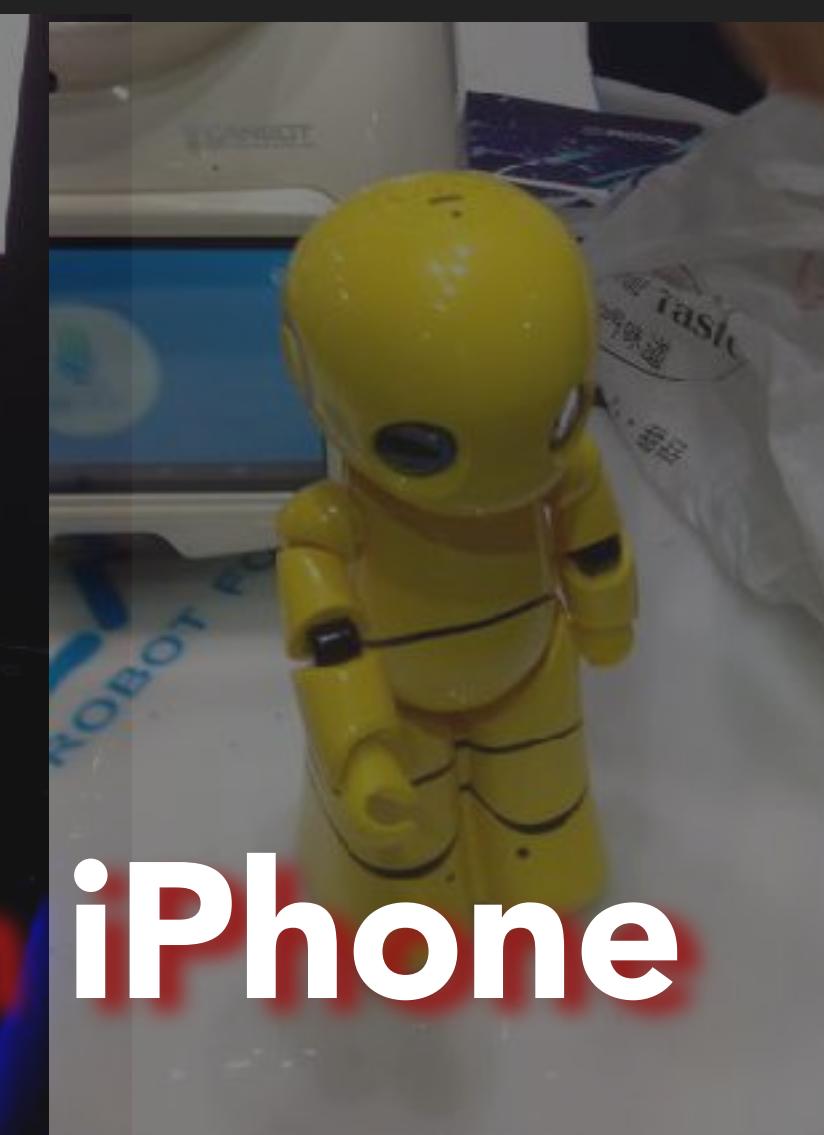
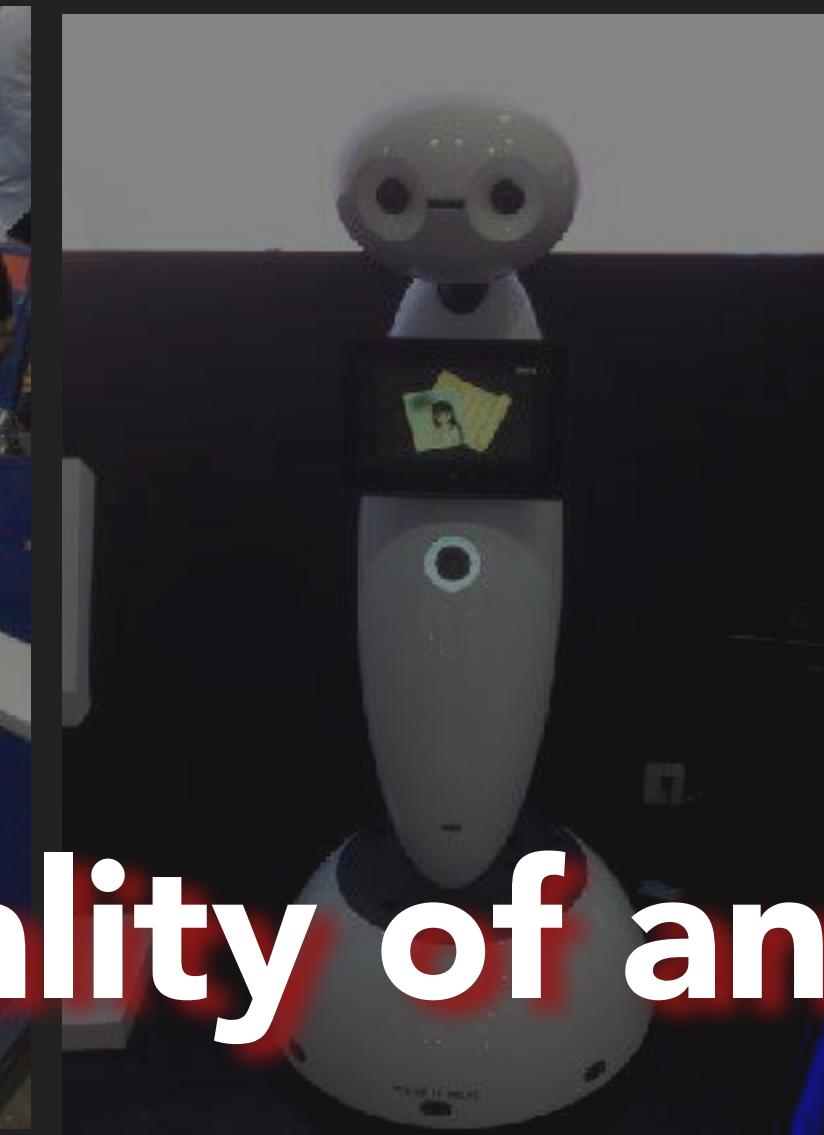


From: WRC, Beijing, 2017, August 2017



# "Social Robots"

functionality of an iPhone



## SOCIAL ROBOTS 2017 - A SOBERING EXPERIENCE ?



Rolf with Softbank's  
“Pepper” - the ‘STAR’



Café Nescafé  
Harajuku, Tokyo  
November 2015

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Rolf with Softbank's  
“Pepper” - the ‘STAR’



Café Nescafé  
Harajuku, Tokyo  
November 2015

SPIEGEL 43, 2016



Rolf with Softbank  
"Pepper"

# Pepper? Hallo?

Eine Meldung und ihre Geschichte Warum  
ein dummer Roboter-  
international Schlagzeilen machte

"Hello, Pepper?"

Why a stupid robot gets into the  
headlines?

Spiegel 43, 2016



ULLEN  
ER  
hten eines Untergangs

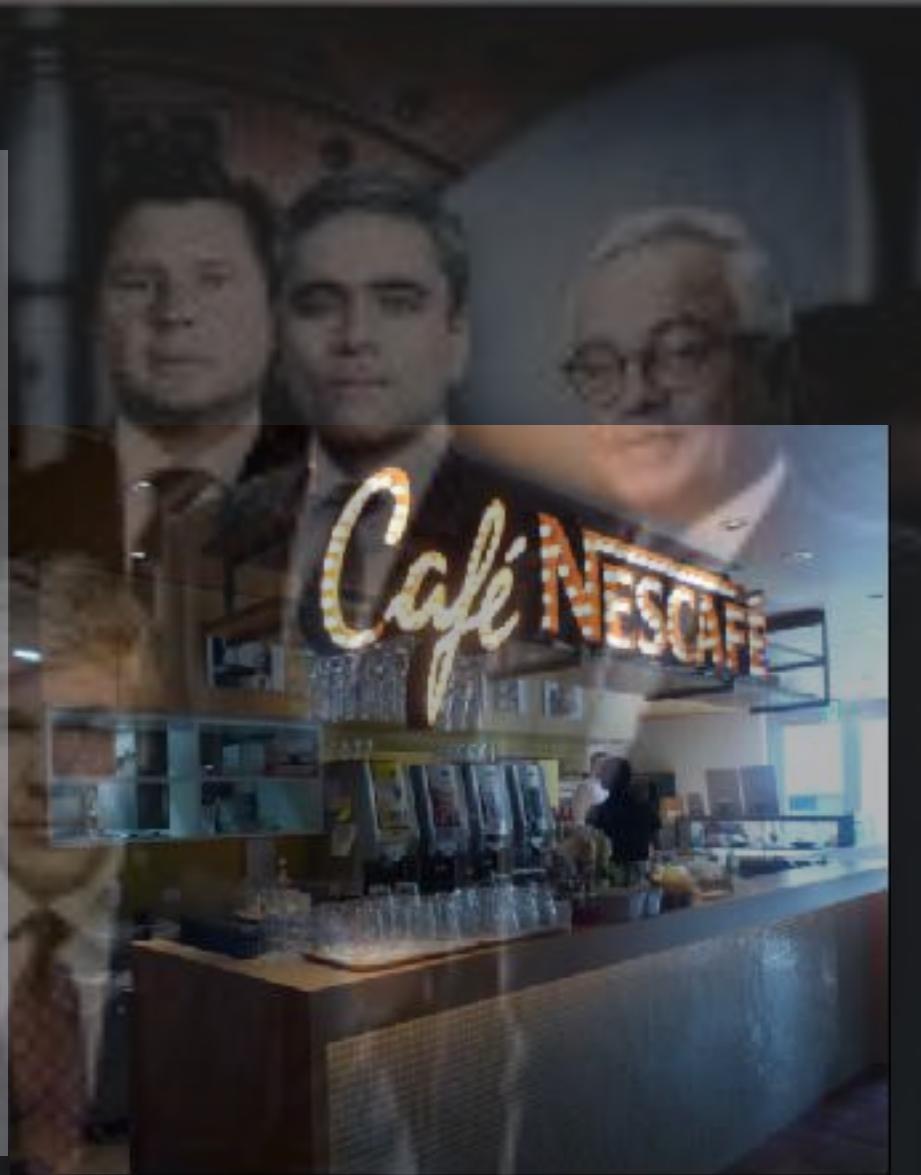
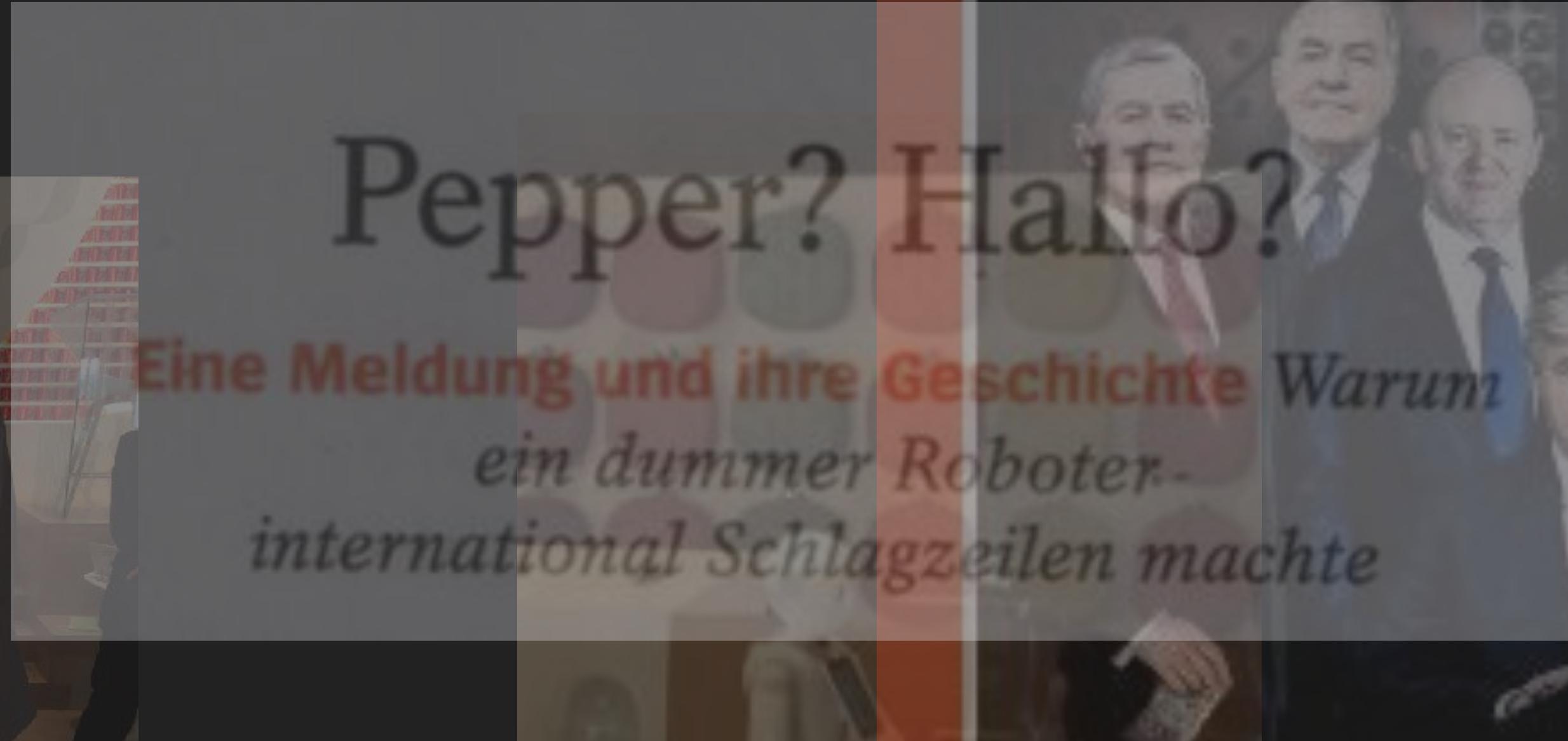
Krieg mit Gefangen?  
Eine Reise an die Front  
von Mossul

Verbindlichkeit

SPIEGEL 43, 2016



Rolf with Softbank  
"Pepper"



"Hello, Pepper?"

Why a stupid robot gets into the  
headlines?

Spiegel 43, 2016

Nescafé  
ULLEN  
raku, Tokyo  
ovember 2015

nte eines Untergangs

Krieg mit Erfolg?  
Eine Reise an die Front  
von Mossul

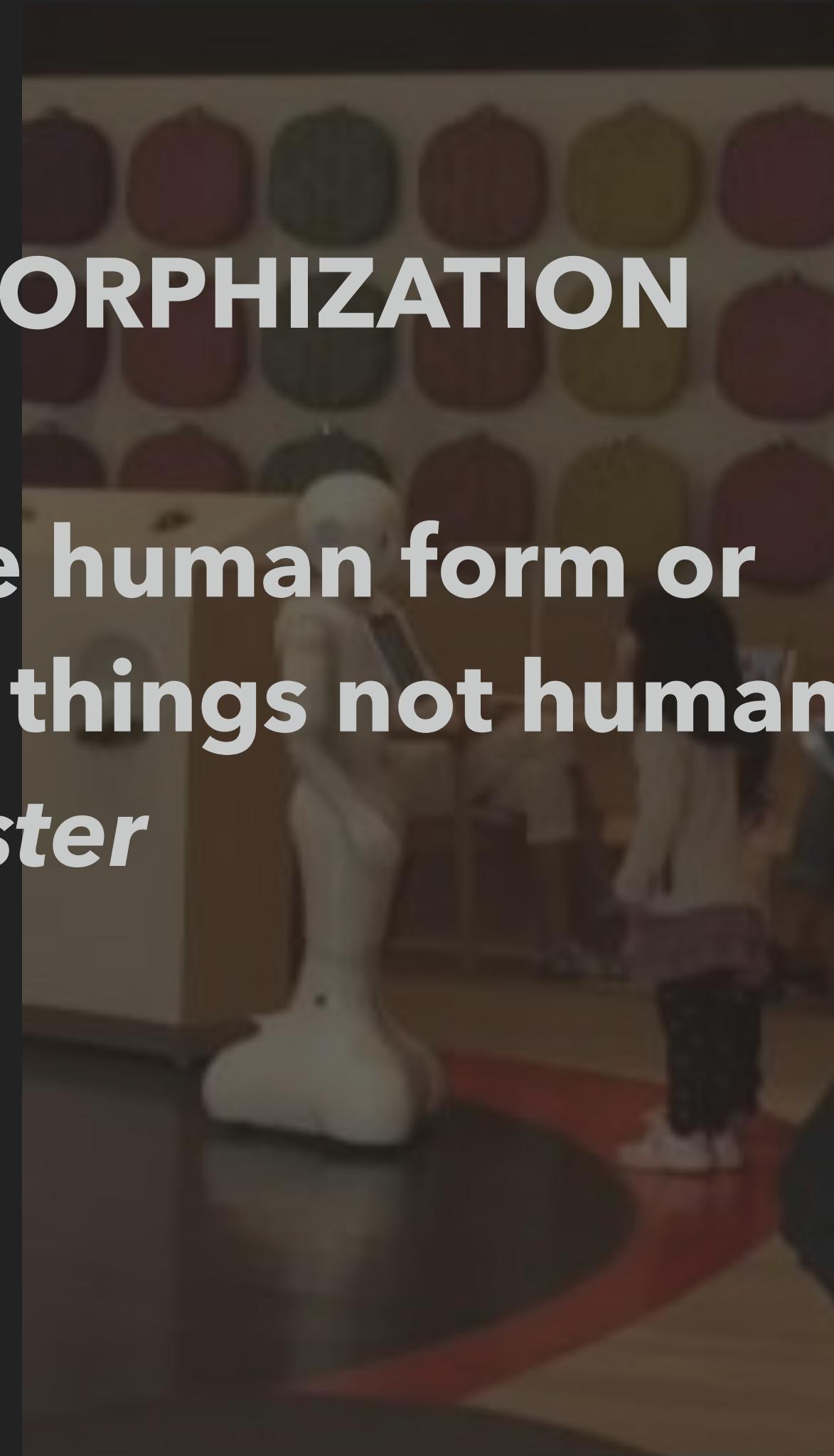
## CAREFUL: ANTHROPOMORPHIZATION!



### ANTHROPOMORPHIZATION

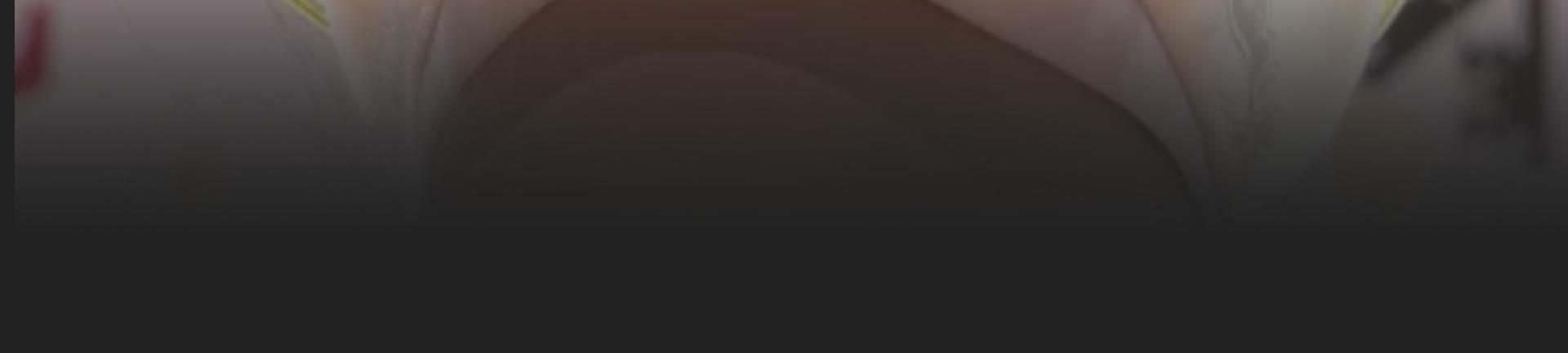
**“... to attribute human form or personality to things not human.”**  
***Merriam Webster***

Rolf with Softbank's  
“Pepper”

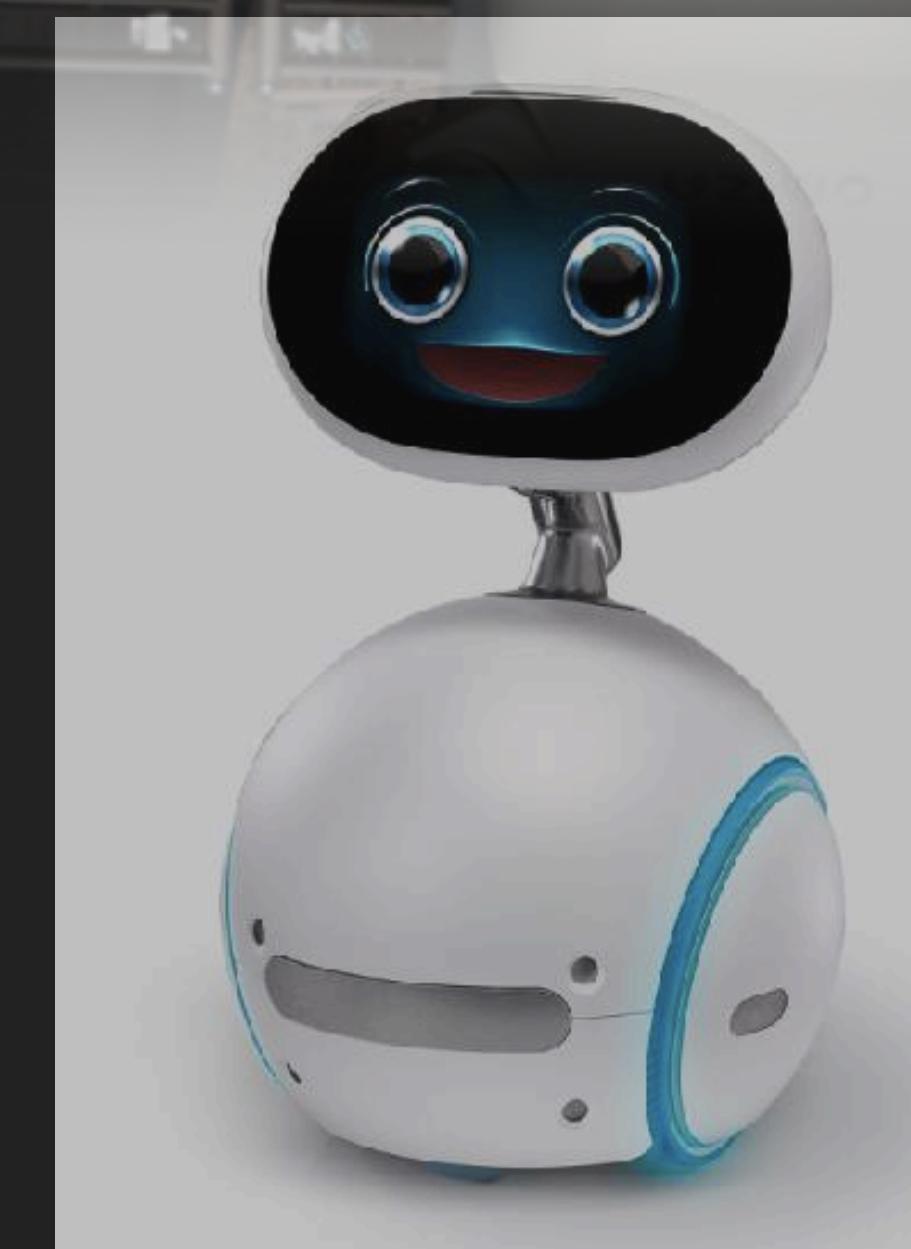


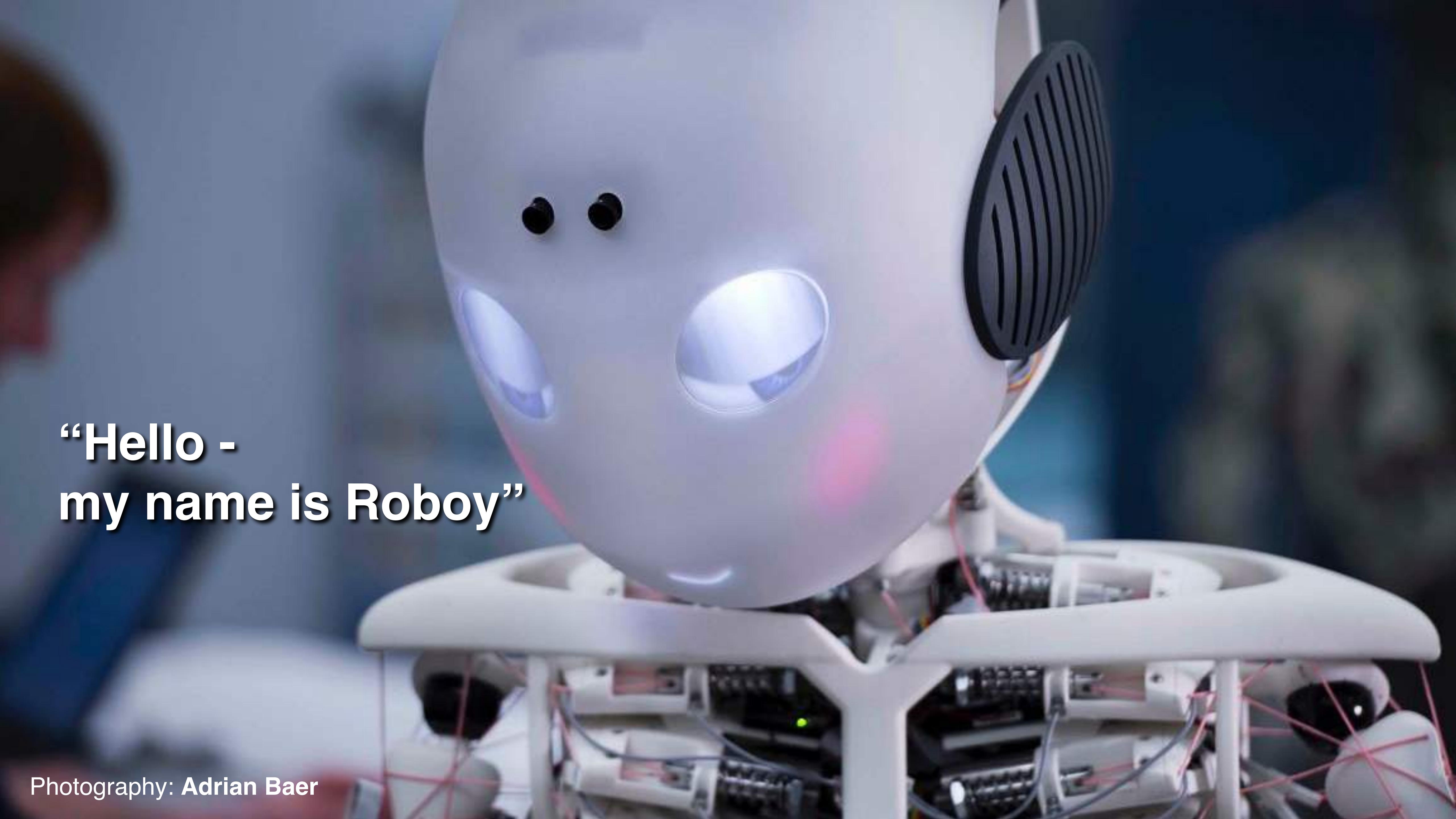
Café Nescafé  
Harajuku, Tokyo  
November 2015

## ANTHROPOMORPHIZATION



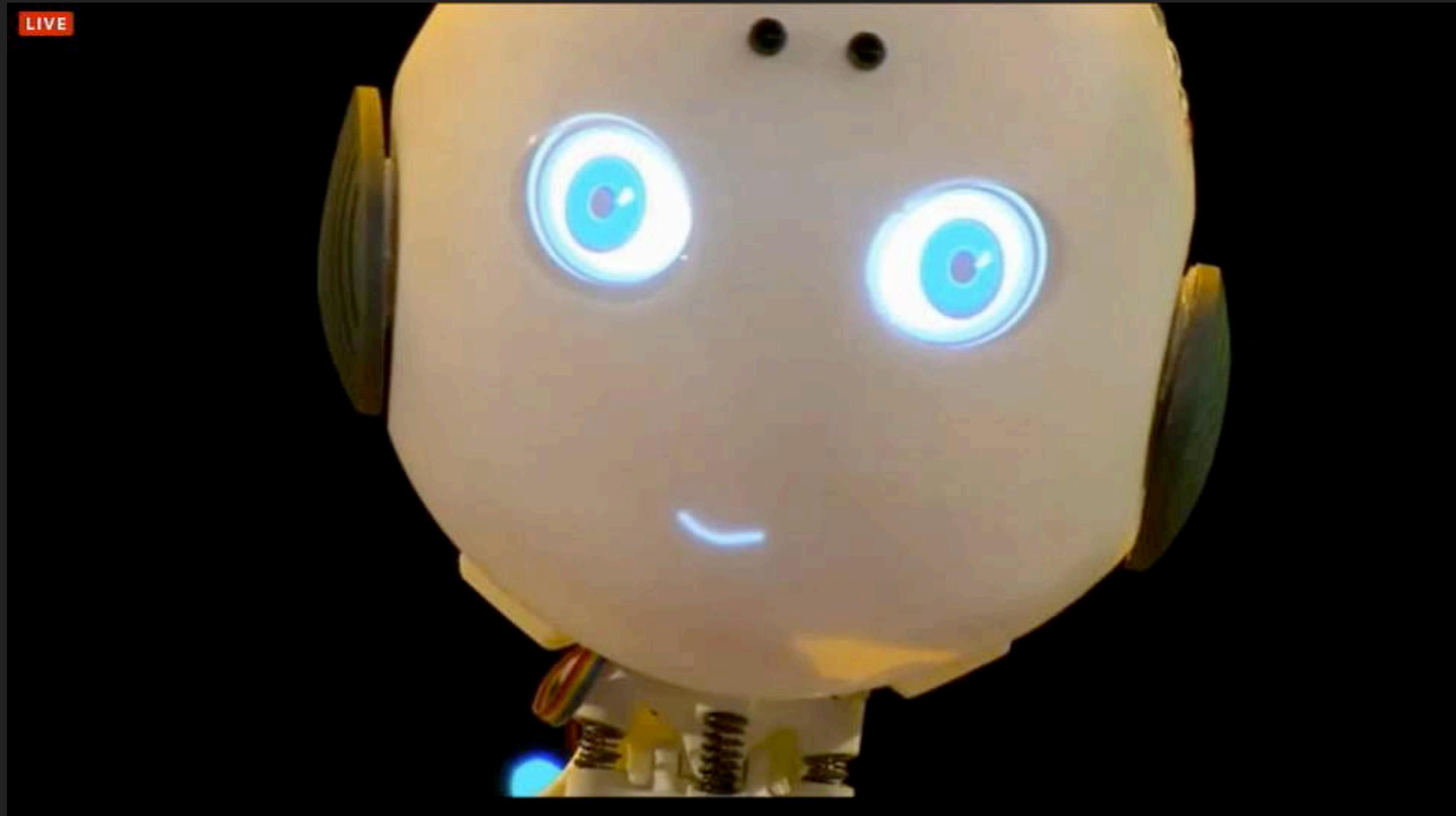
## ANTHROPOMORPHIZATION





**“Hello -  
my name is Roboy”**

## ROBOY: FACIAL EXPRESSION



Credit: TEDx Zurich

## SOCIAL ROBOTS - REALITY CHECK

- ▶ mostly children's toy look
- ▶ social interaction but lack of manipulation skills in real world
- ▶ movement and locomotion limited
- ▶ novelty wears off quickly
- ▶ in essence: functionality of iPhone

# **“Social Robots”**

---

- ▶ “iPhones in tin cans”
- ▶ “iPhones on wheels”

# "Social Robots"

- ▶ "iPhones in tin cans"
- ▶ "iPhones on wheels"



From: WRC 2017, August 2017

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FULL-FEATURED HUMANOIDS NOT ANYWHERE IN SIGHT

# DEEP NEURAL NETWORKS

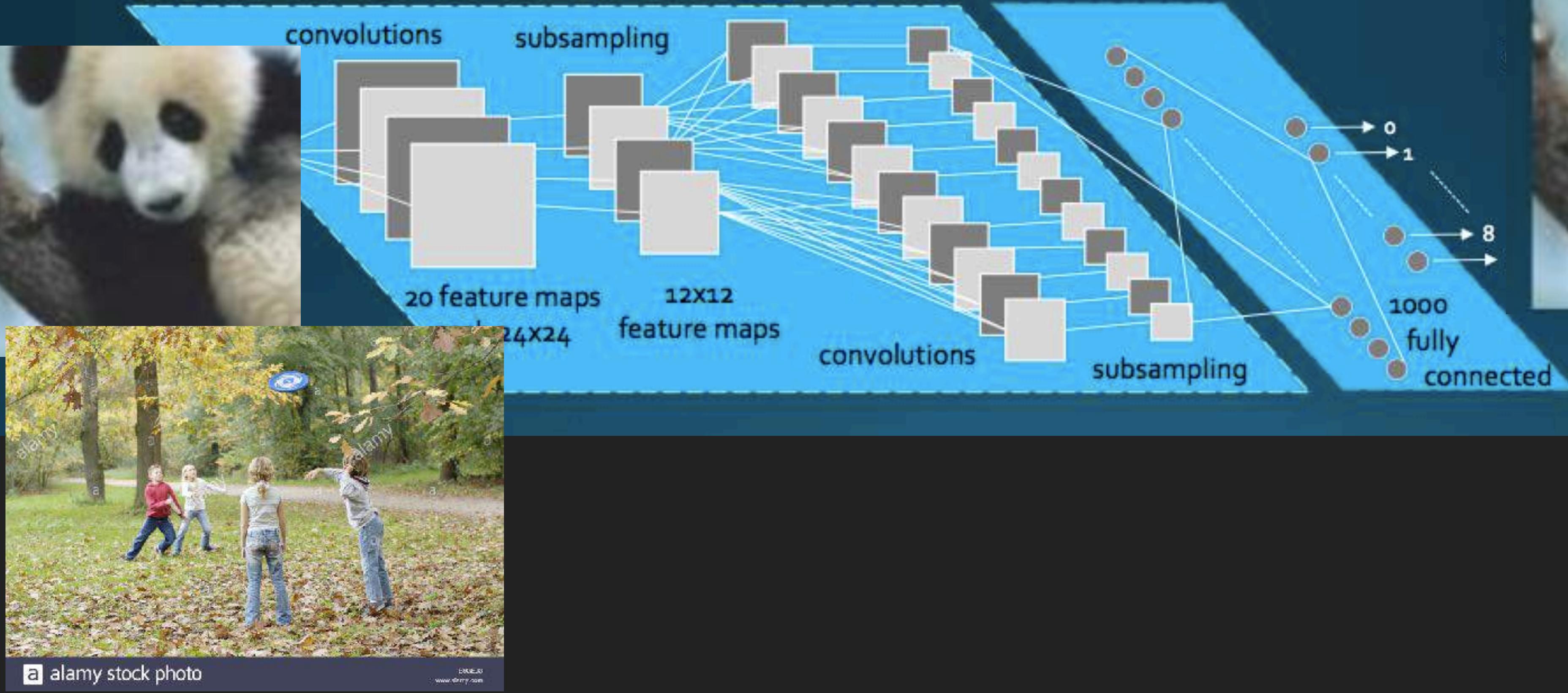
# DEEP NEURAL NETWORKS

- ▶ **image processing**
- ▶ **AlphaGo**
- ▶ **speech and language**
- ▶ **self-driving vehicles**
- ▶ **medical diagnostics**
- ▶ **Big Data**
- ▶ **etc.**

# DEEP NEURAL NETWORKS

*Each "feature map" performs a local analysis over the whole input space*

*Fully-connected layers perform global analysis*



"Panda"

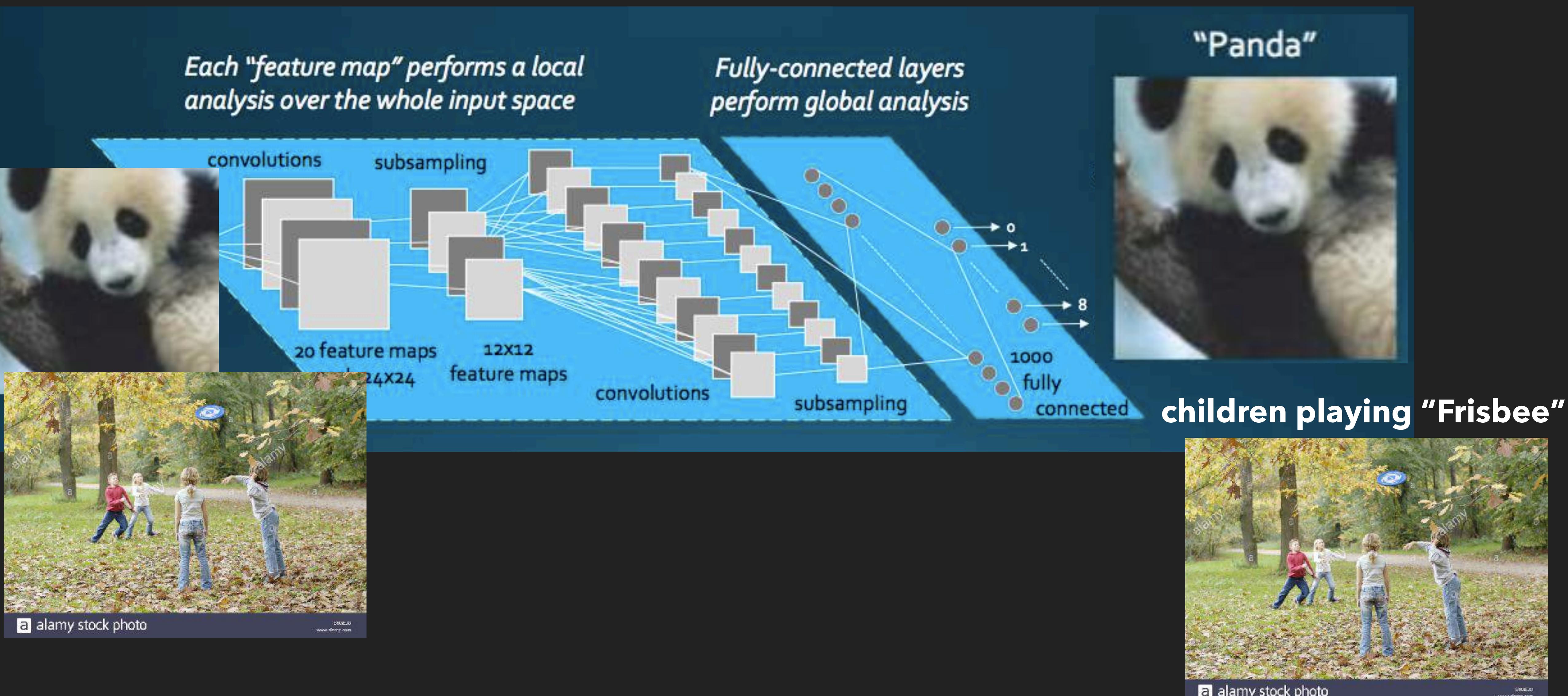


"children playing Frisbee"



a alamy stock photo

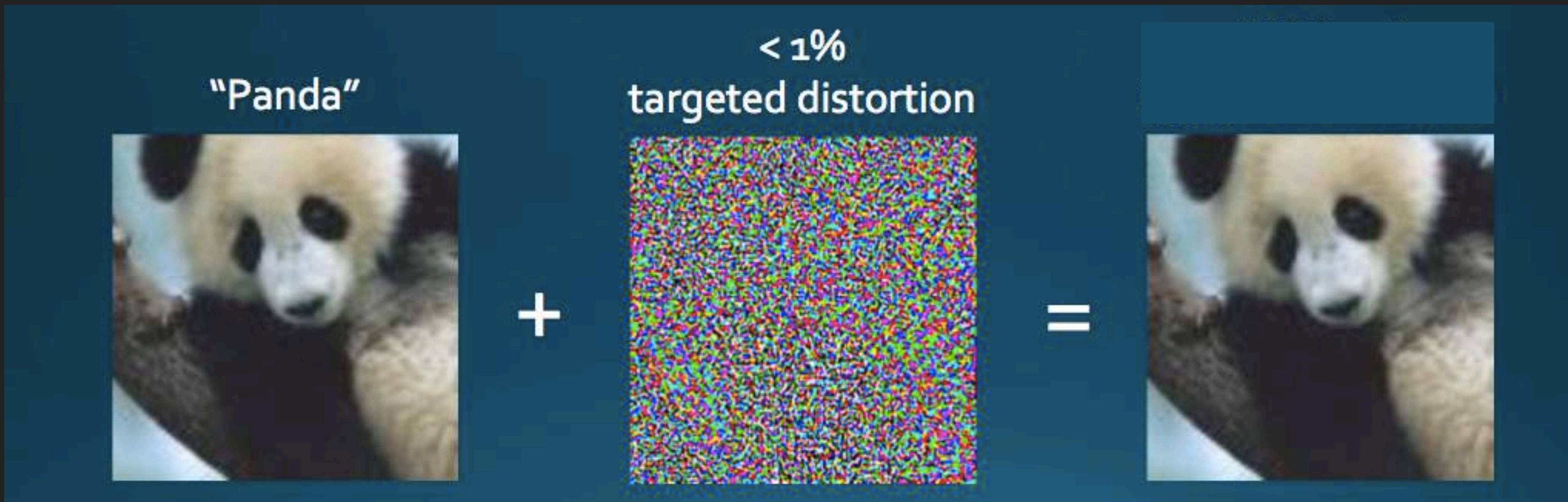
# DEEP NEURAL NETWORKS - HUGE AMOUNTS OF DATA REQUIRED



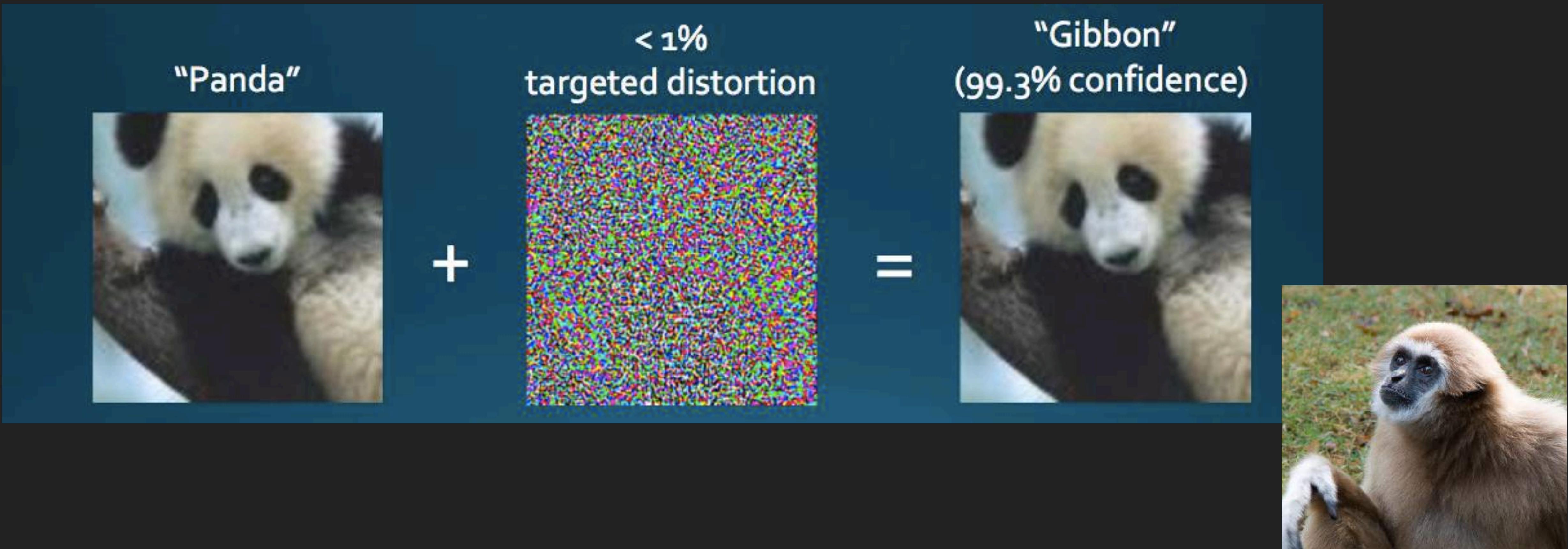
# DEEP NEURAL NETWORKS

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- ▶ etc.

# DEEP NEURAL NETWORKS

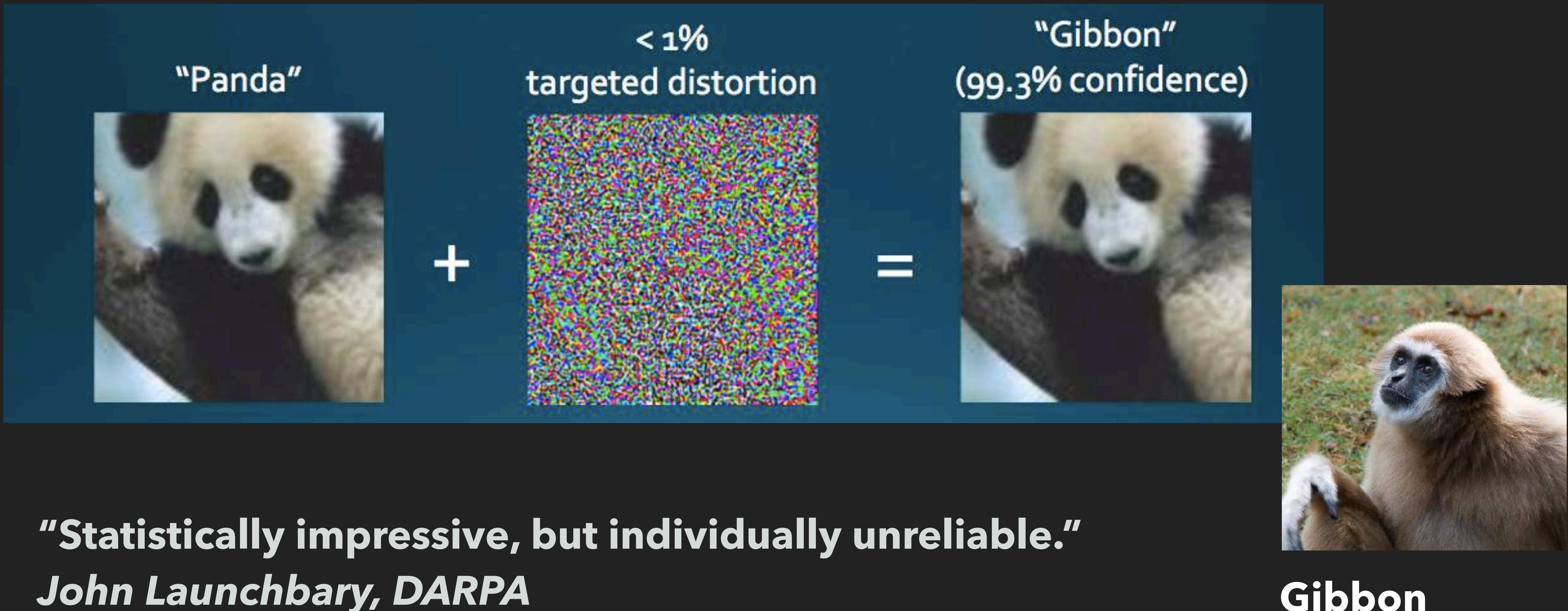


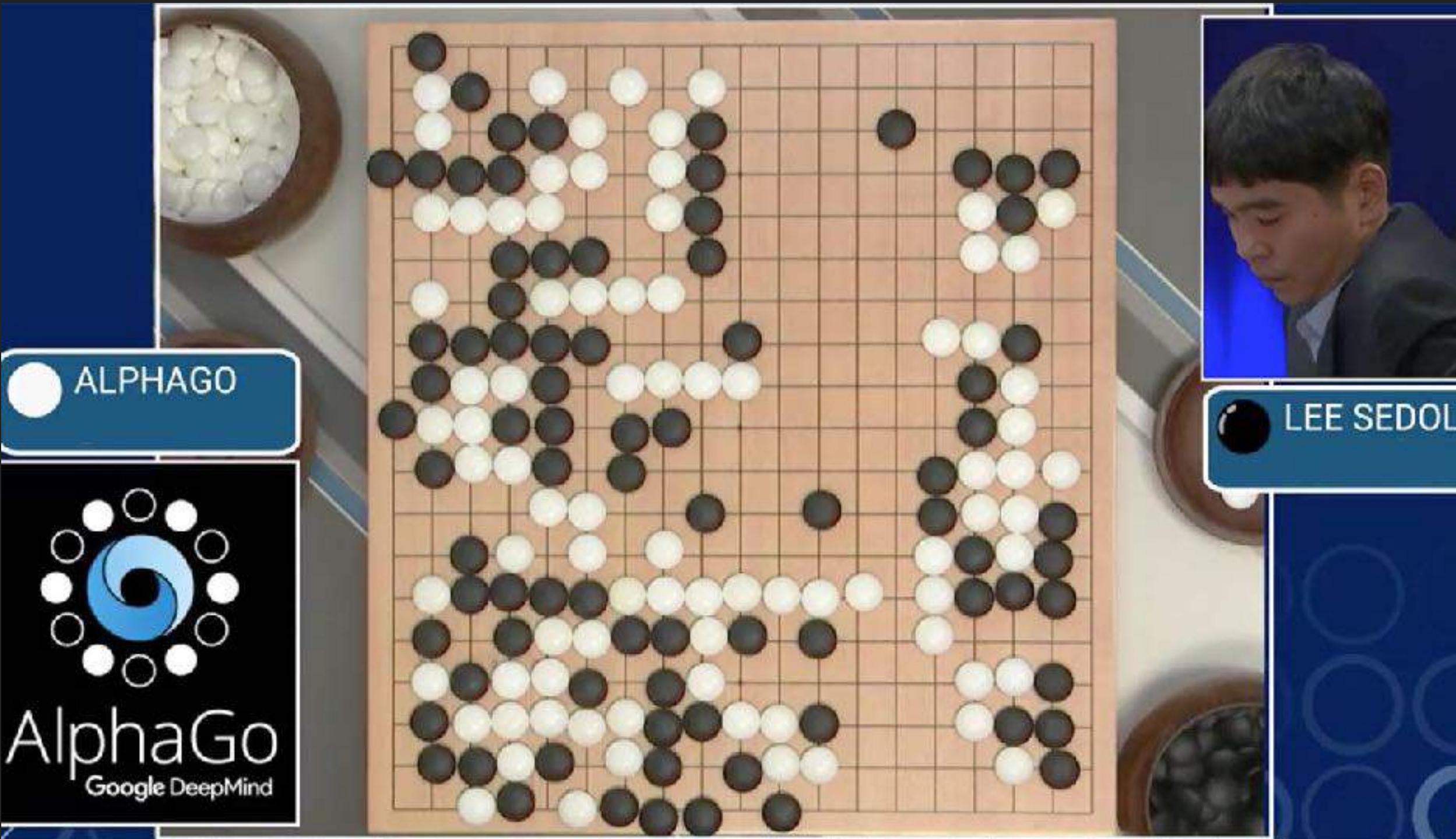
# DEEP NEURAL NETWORKS



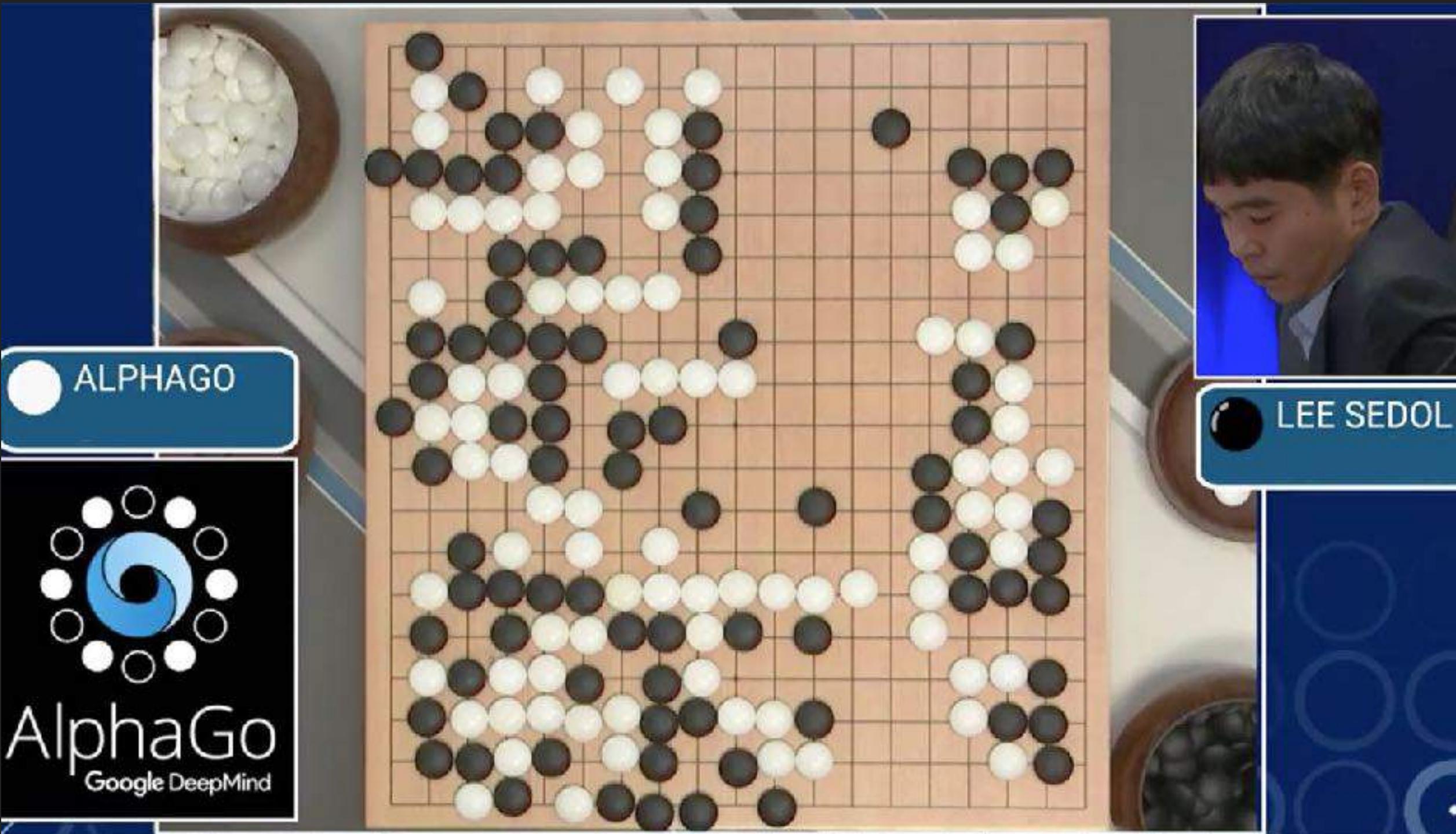
Gibbon

# DEEP NEURAL NETWORKS

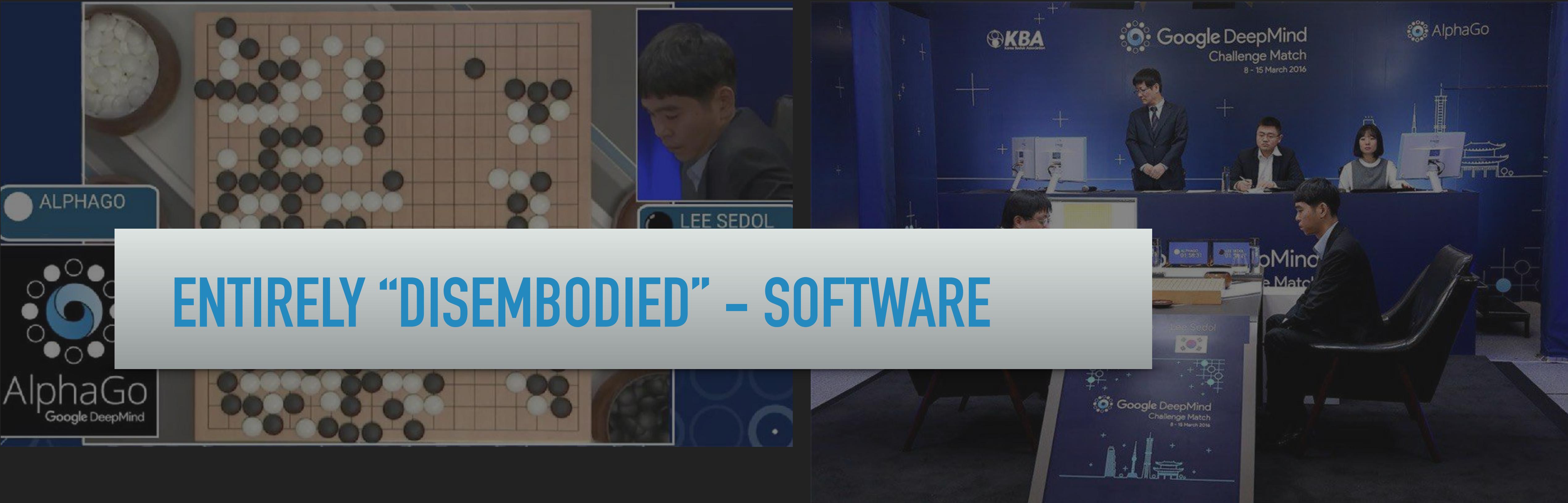




GO: AlphaGo against Lee Sedol, 2016

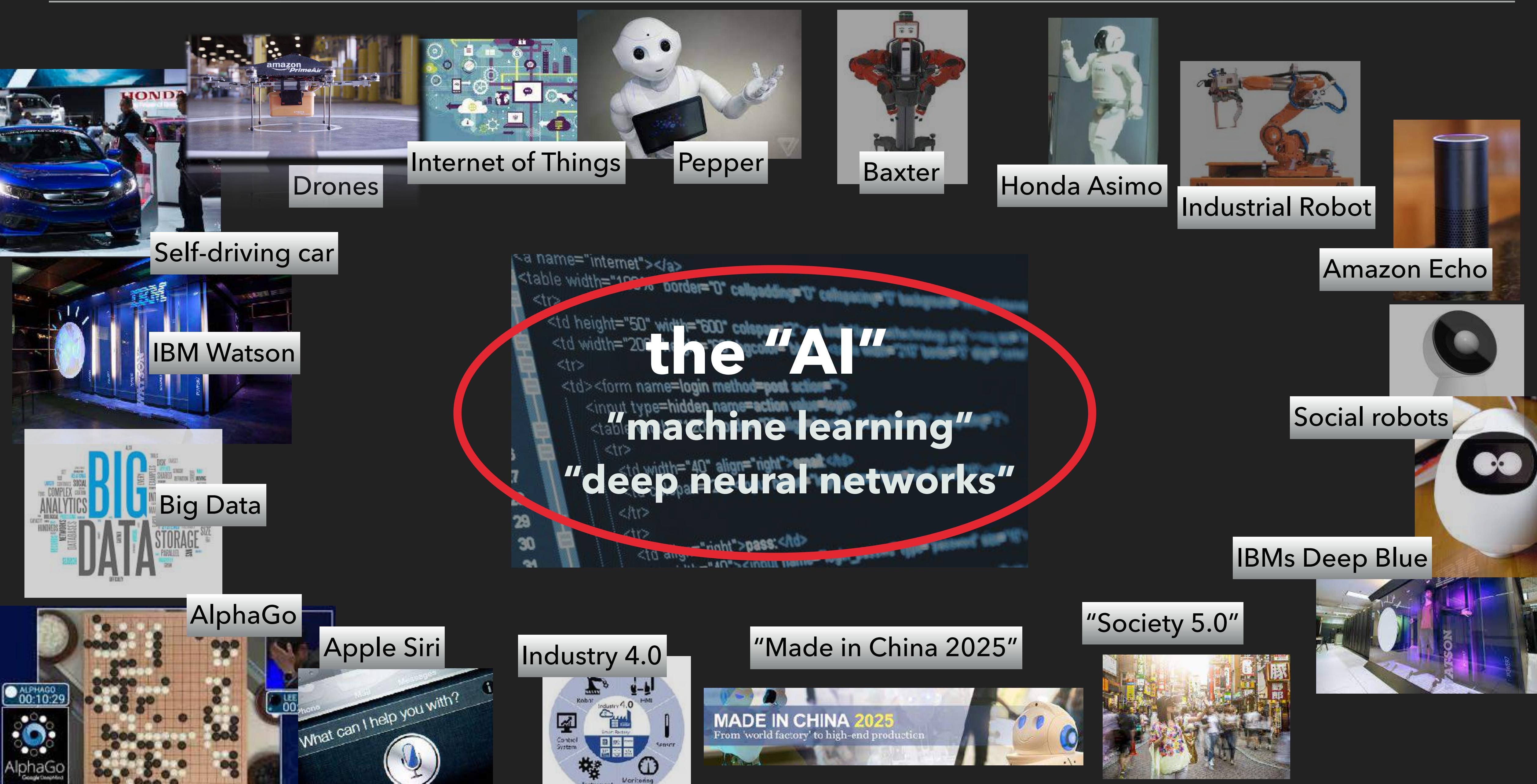


GO: AlphaGo against Lee Sedol, 2016



ENTIRELY “DISEMBODIED” – SOFTWARE

GO: AlphaGo against Lee Sedol, 2016



- complete separation of hardware and software
- intelligence = software
- unintelligent mechatronic structure
- morphology/materials completely ignored
- input-processing-output
- interaction with environment neglected

the "AI"



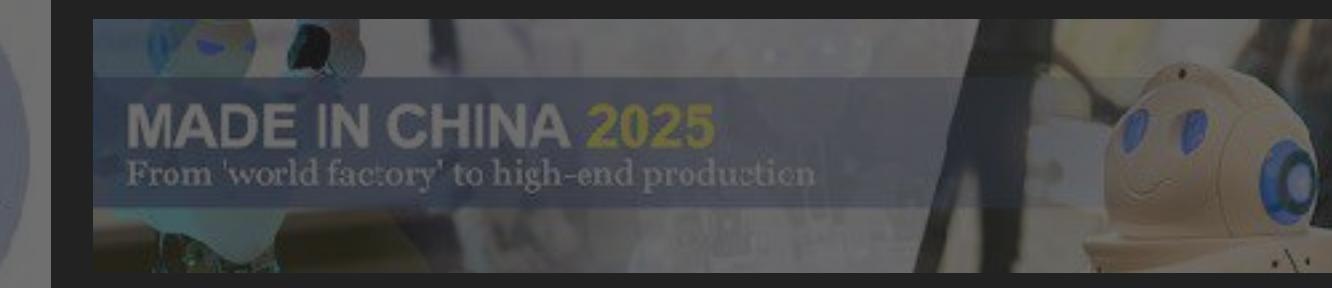
AlphaGo



Apple Siri



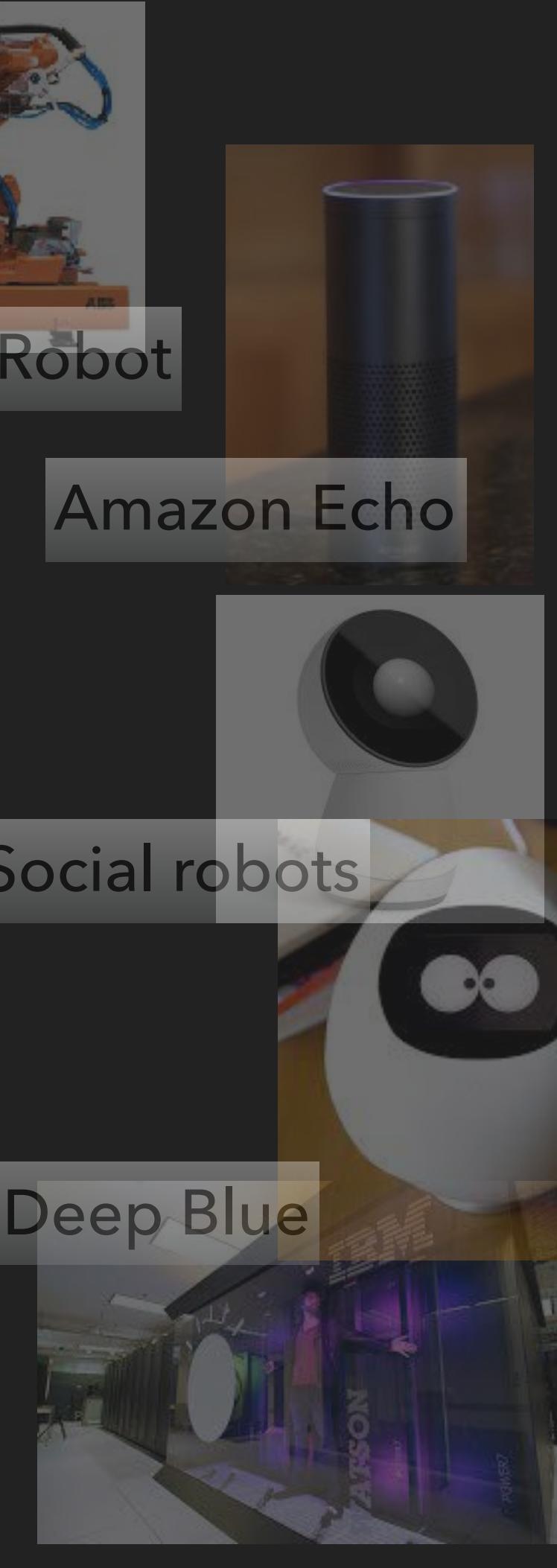
Industry 4.0



"Made in China 2025"

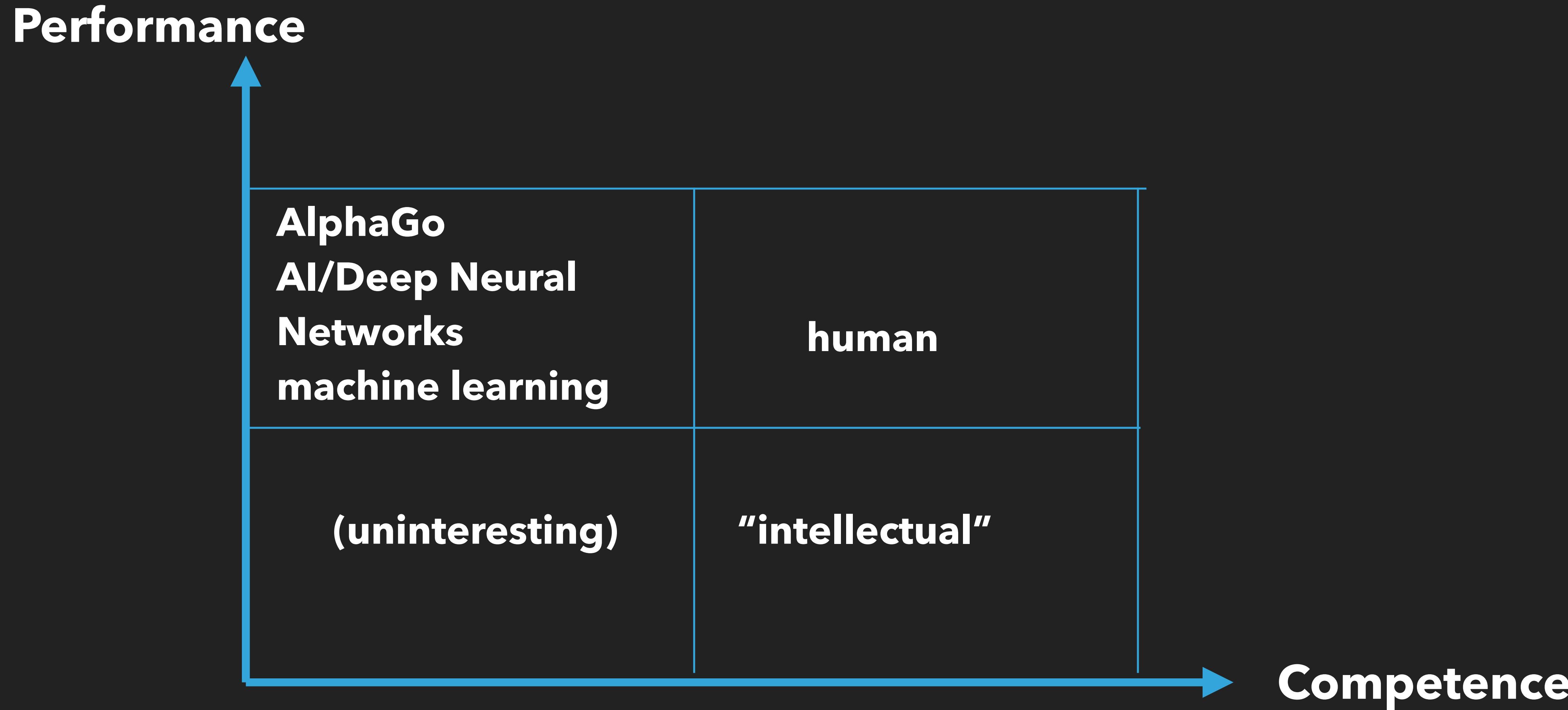


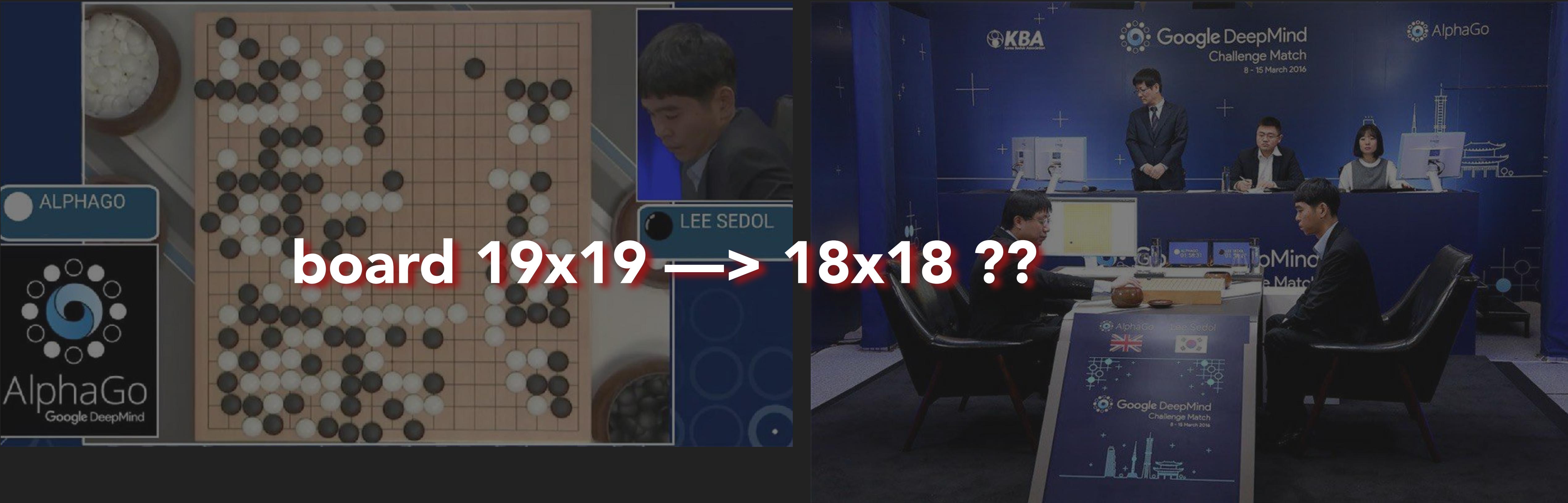
"Society 5.0"



# PERFORMANCE VS. COMPETENCE

# PERFORMANCE VS. COMPETENCE





GO: AlphaGo against Lee Sedol, 2016

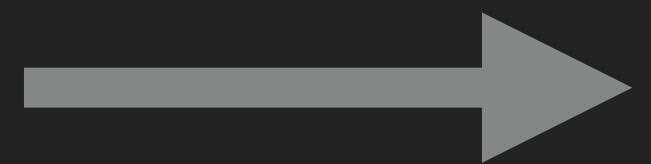
## BACK TO “SOCIAL ROBOTICS” - ROBOLOUNGE PROJECT

- ▶ fulfill expectations of public, deliver on promises
- ▶ functionality beyond speech and facial expression
- ▶ comfortable, engaging, exciting interaction, high “coolness factor”

**NOT: REPLACING HUMANS, BUT ENHANCING EXPERIENCE**

## THE ROBOLOUNGE PROJECT

**Design and make available a space where people can experience the future (not only talk about it)**



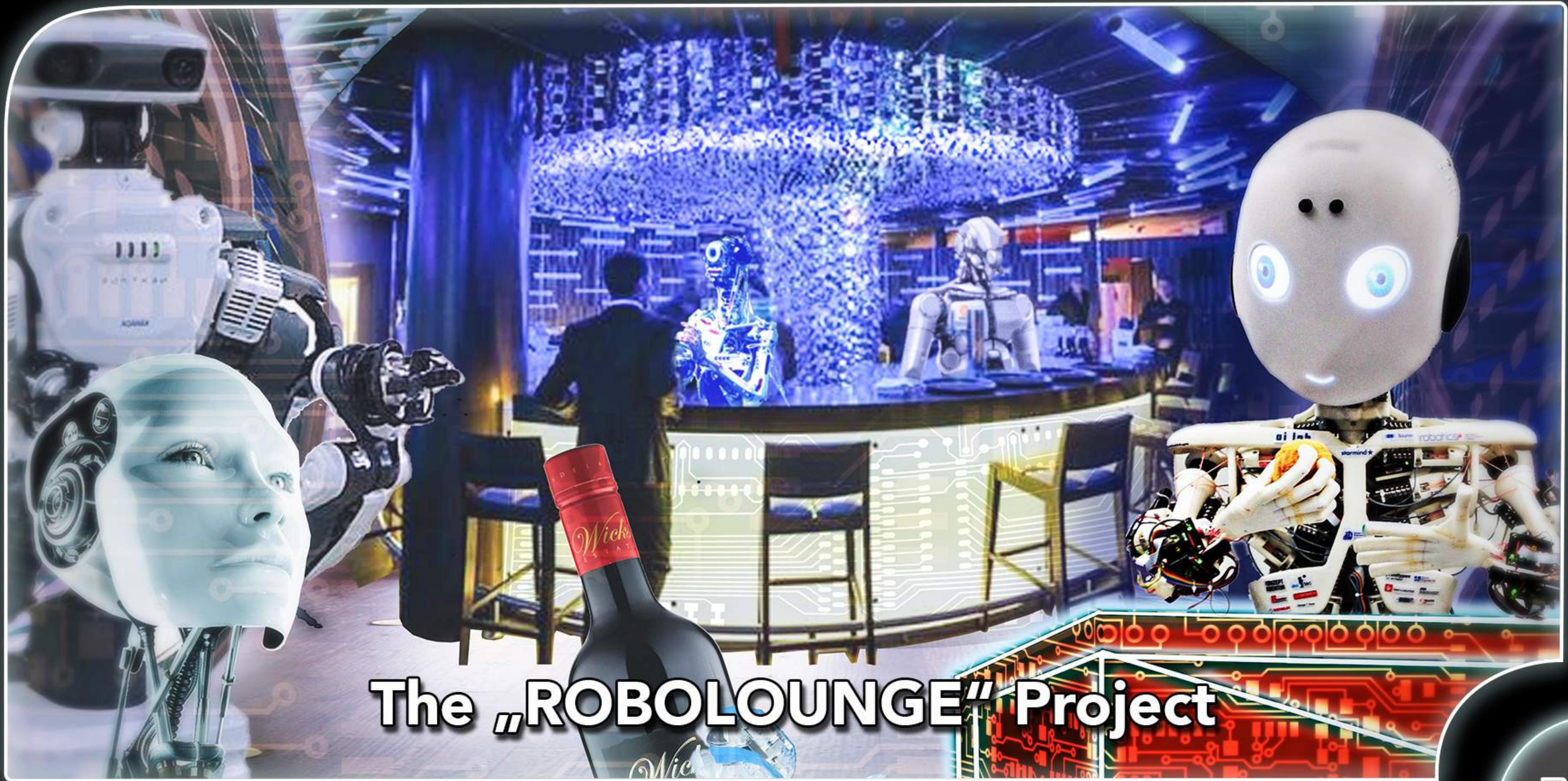
**The “Robolounge”**

...

# Experience a touch of tomorrow !



# Experience the future !



## The „ROBOLOUNGE“ Project

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**VIDEO: “HOW WILL IT BE . . .”?**

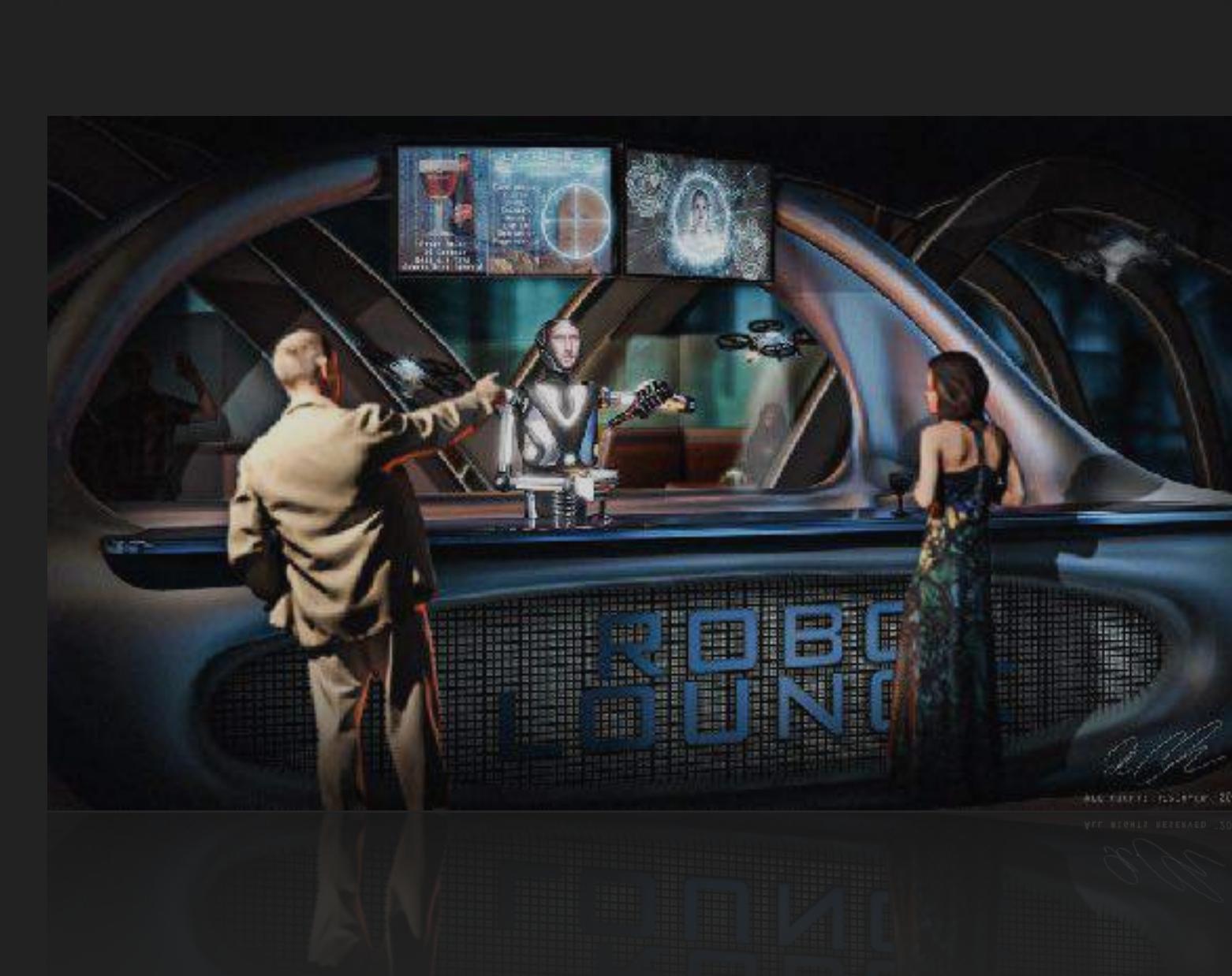
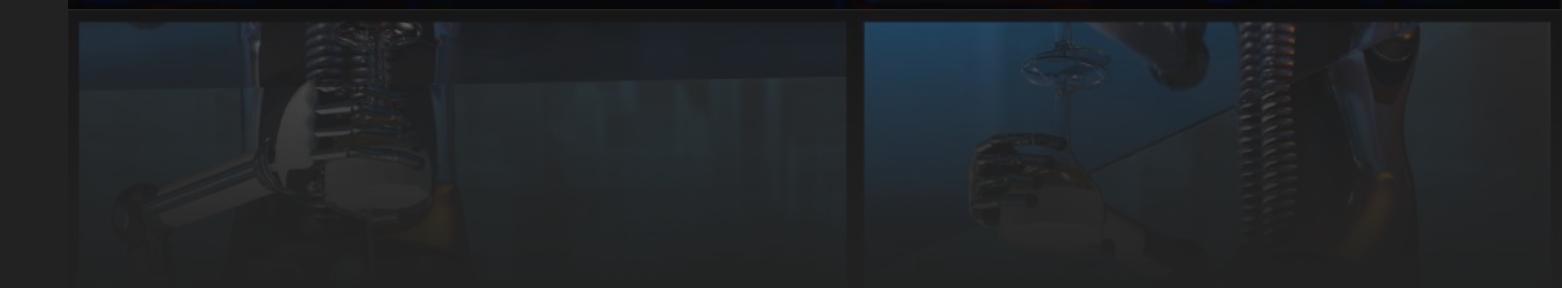
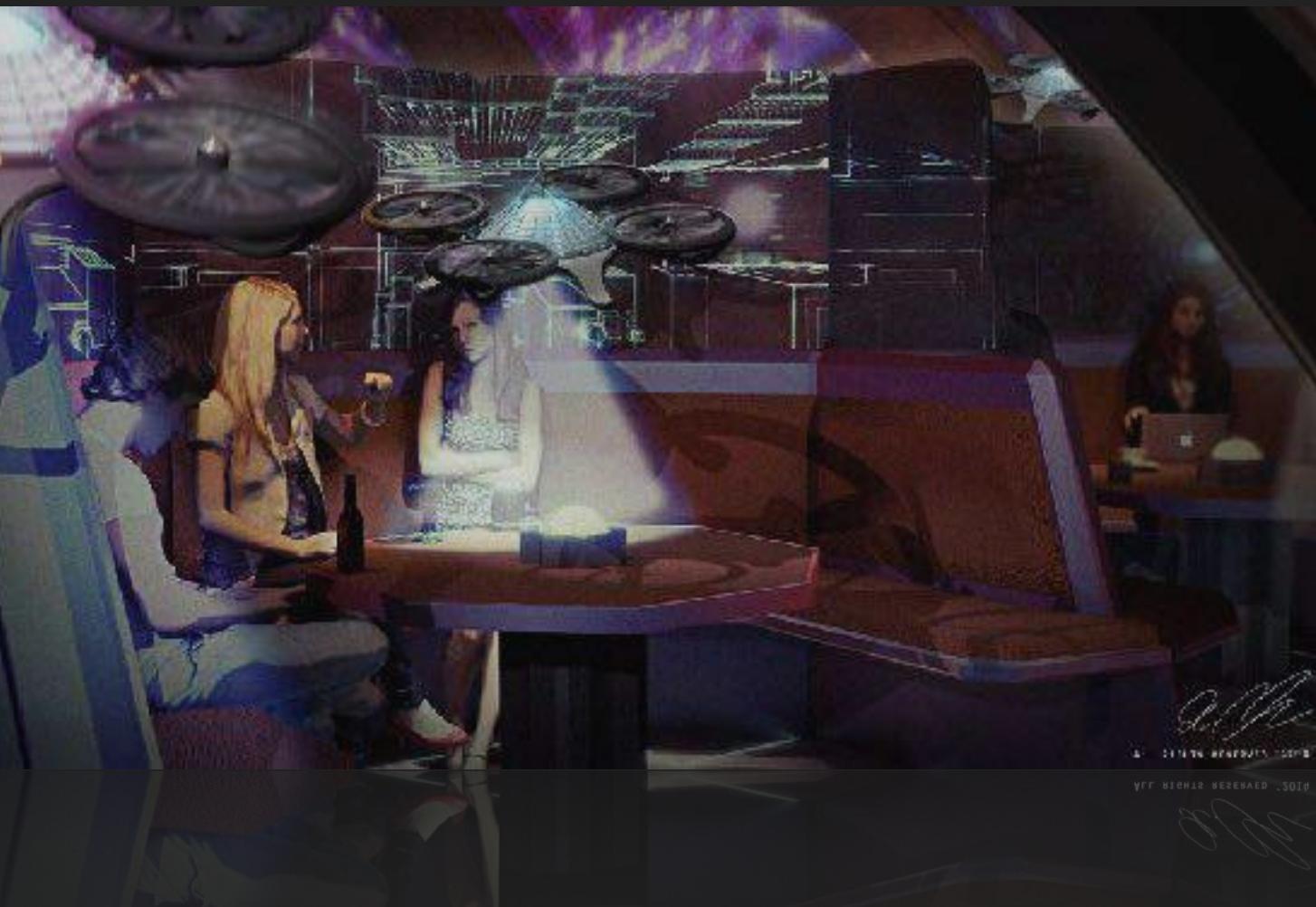
# ROBOLOUNGE ROBOTS

receptionist

bartender

security (“bouncer”)

“Drone waiters”



# ROBOLOUNGE ROBOTS

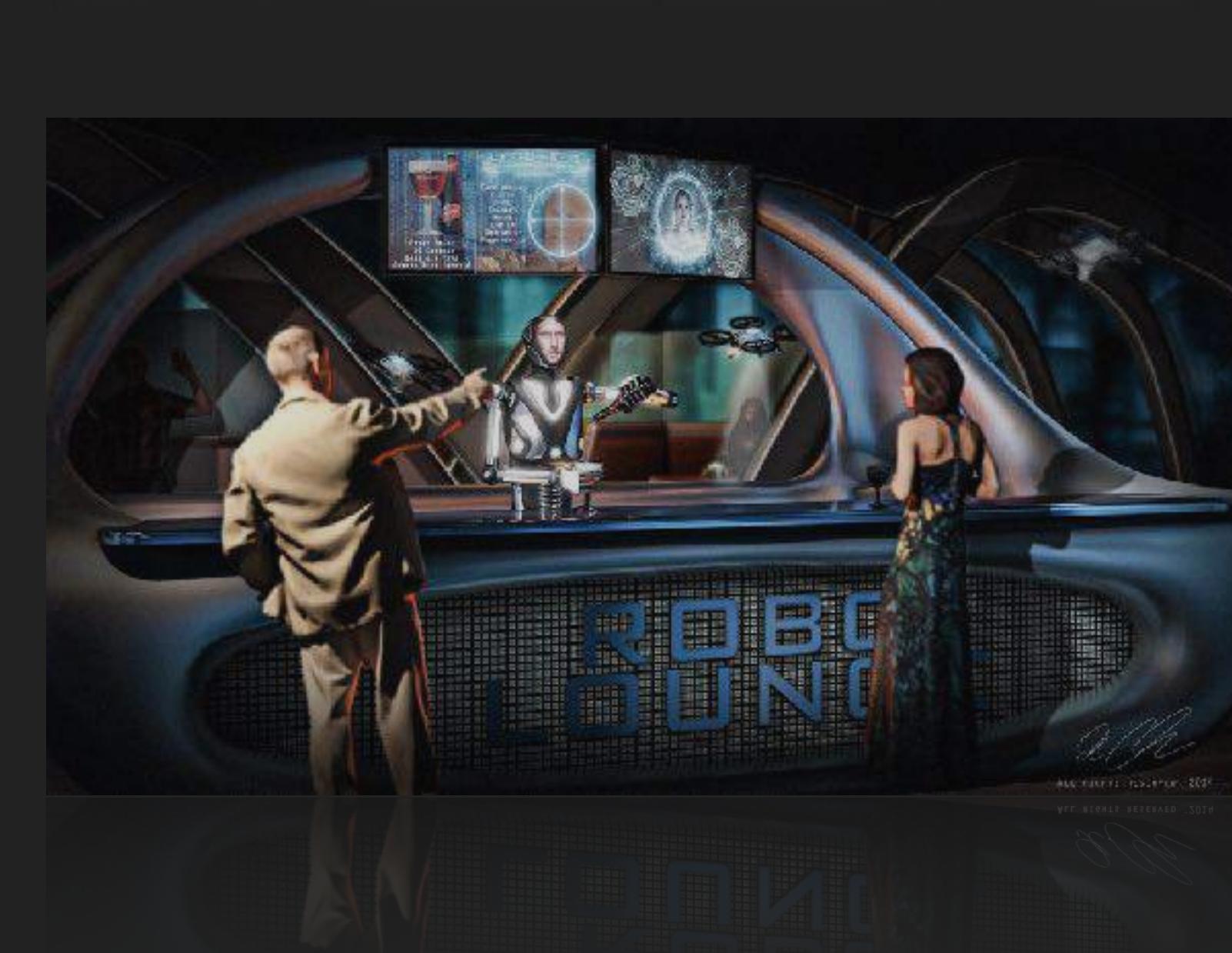
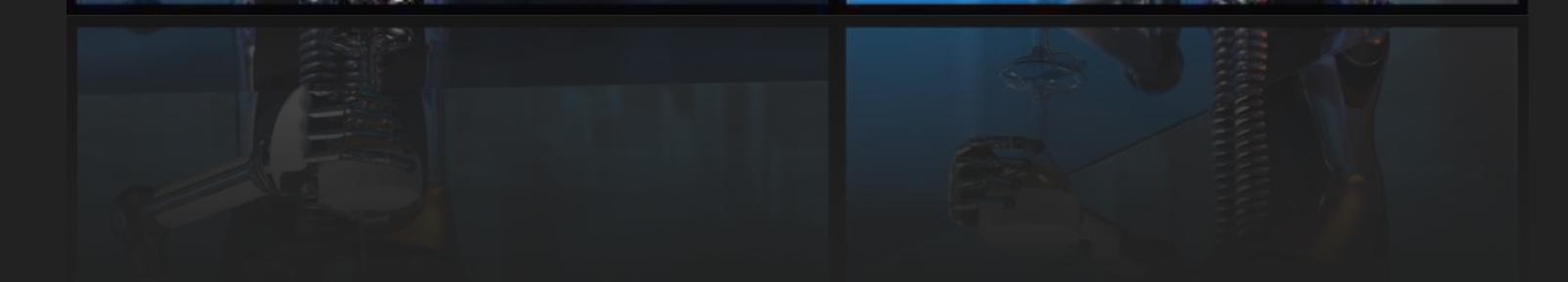
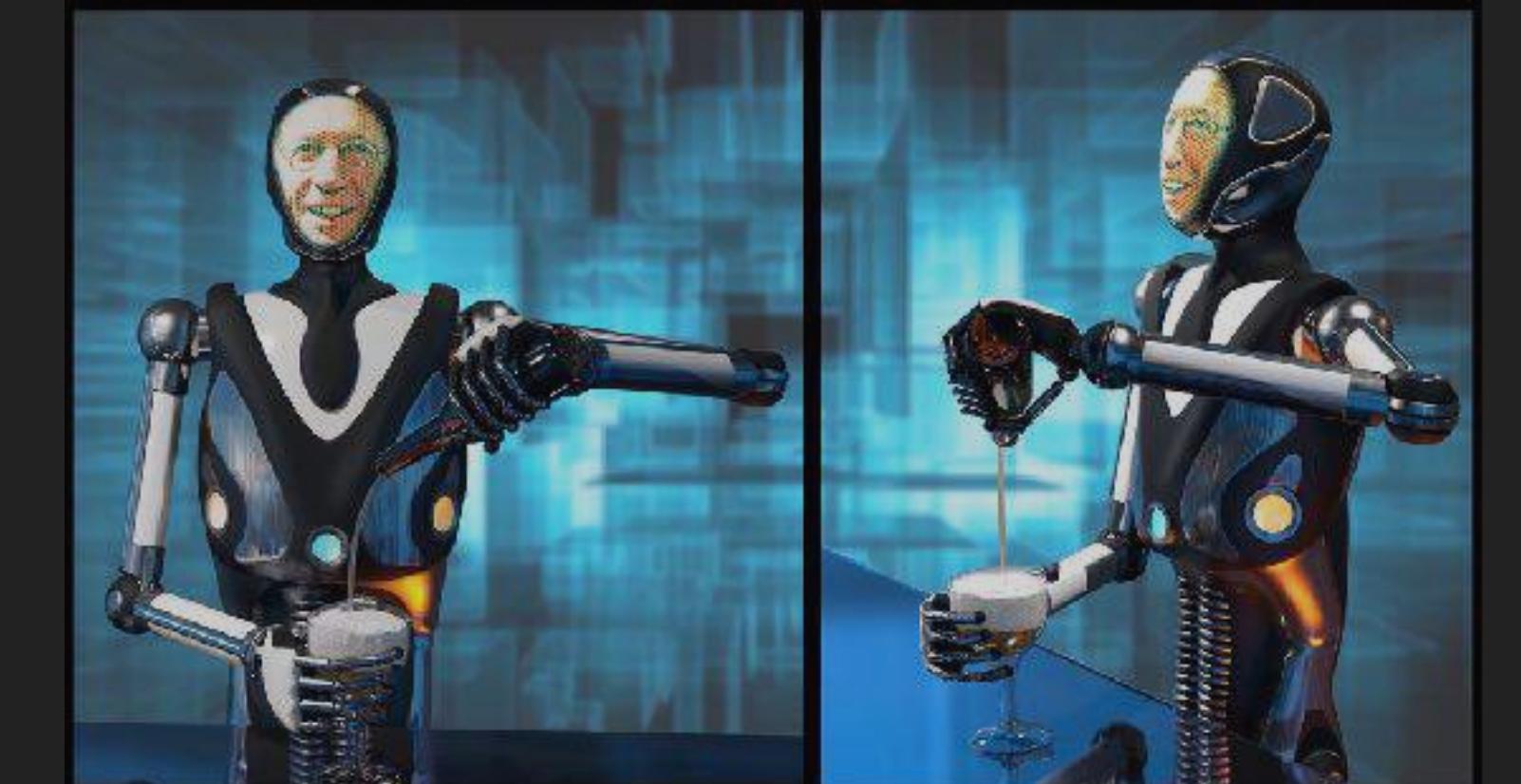
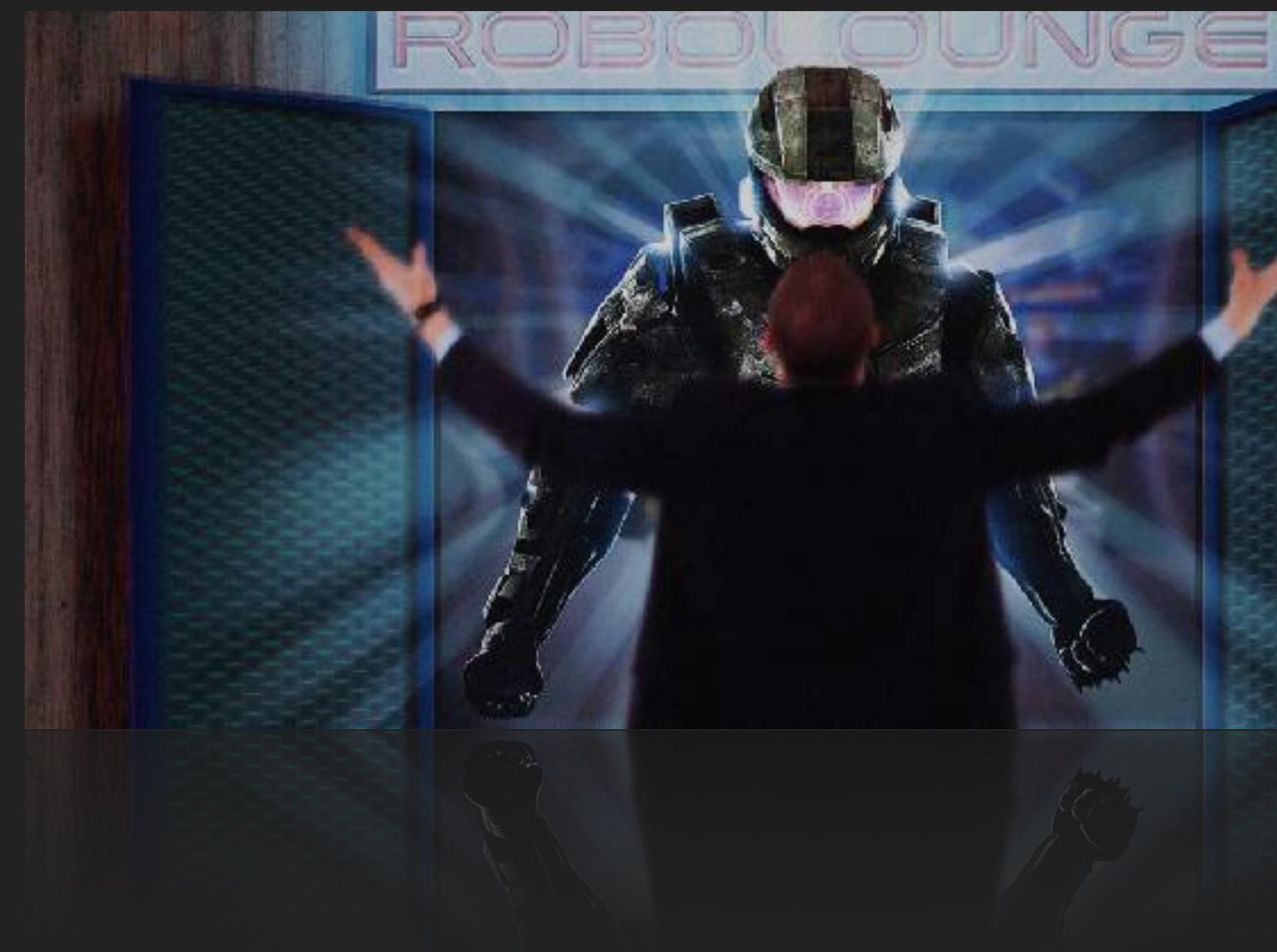
receptionist

bartender

security (“bouncer”)

“Drone waiters”

...



# WHY A “BARTENDER” ROBOT ?

...

## THE “BARTENDER” ROBOT

- ▶ **needed for the “Robolounge”**
- ▶ **sophisticated sensory-motor and social communication skills required**
- ▶ **skills transferable to many other domains**
- ▶ **great markets**
- ▶ **it's fun!!**

## THE ROBOT BARTENDER – CAPABILITIES

- ▶ **customer presence recognition, visual contact**
- ▶ **voice recognition, limited speech recognition**
- ▶ **understand order, move to beer storage, fetch bottle, pour desired beer**
- ▶ **info about specials, drinks, offering humorous comments and jokes**
- ▶ **handle payment**

## THE ROBOT “BARTENDER”: WHY WILL IT WORK ?

- ▶ embodiment
- ▶ soft robotics
- ▶ scaffolding

MUST EXPLOIT THESE FACTORS !

## THE ROBOT “BARTENDER”: WHY WILL IT WORK ?

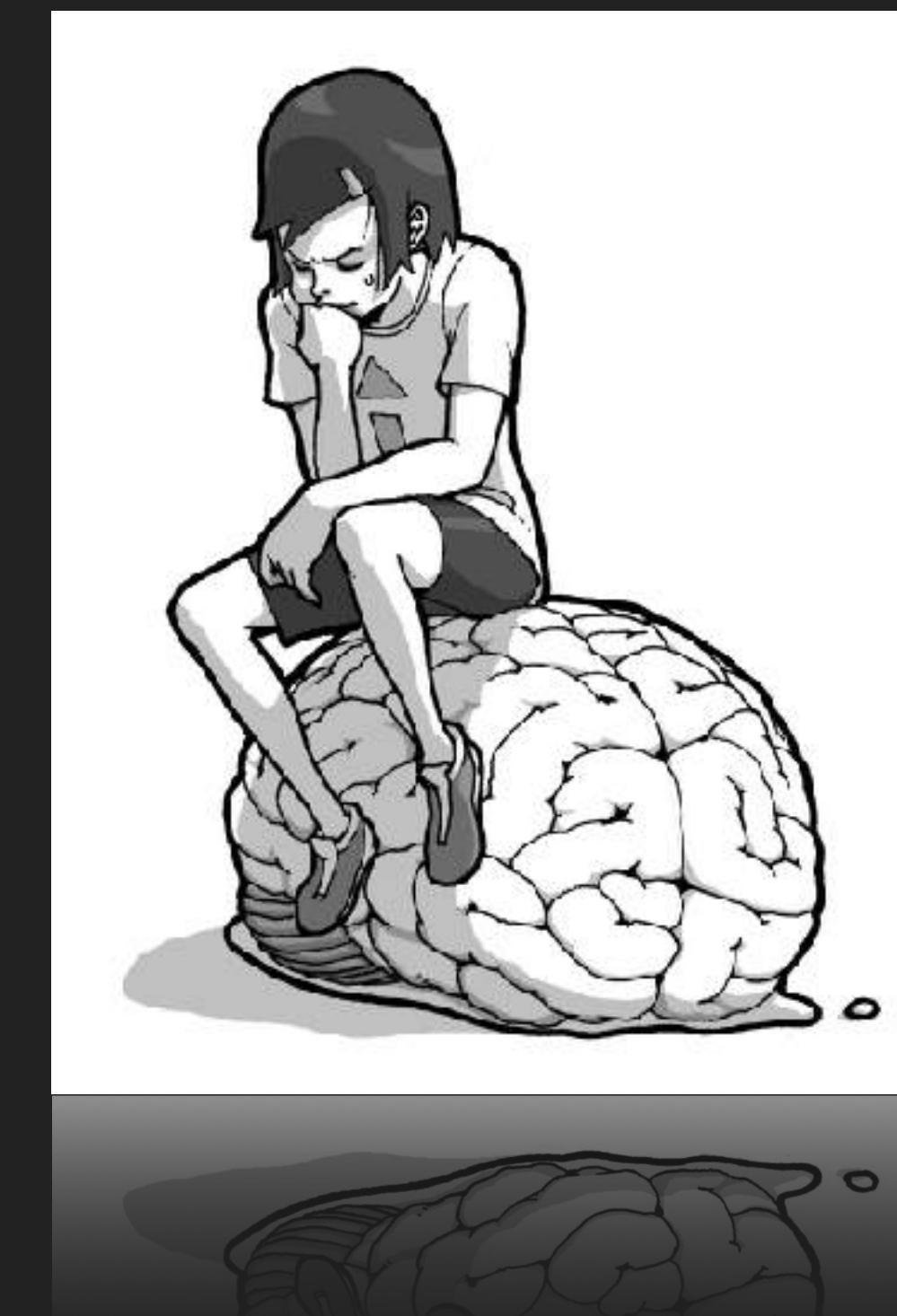
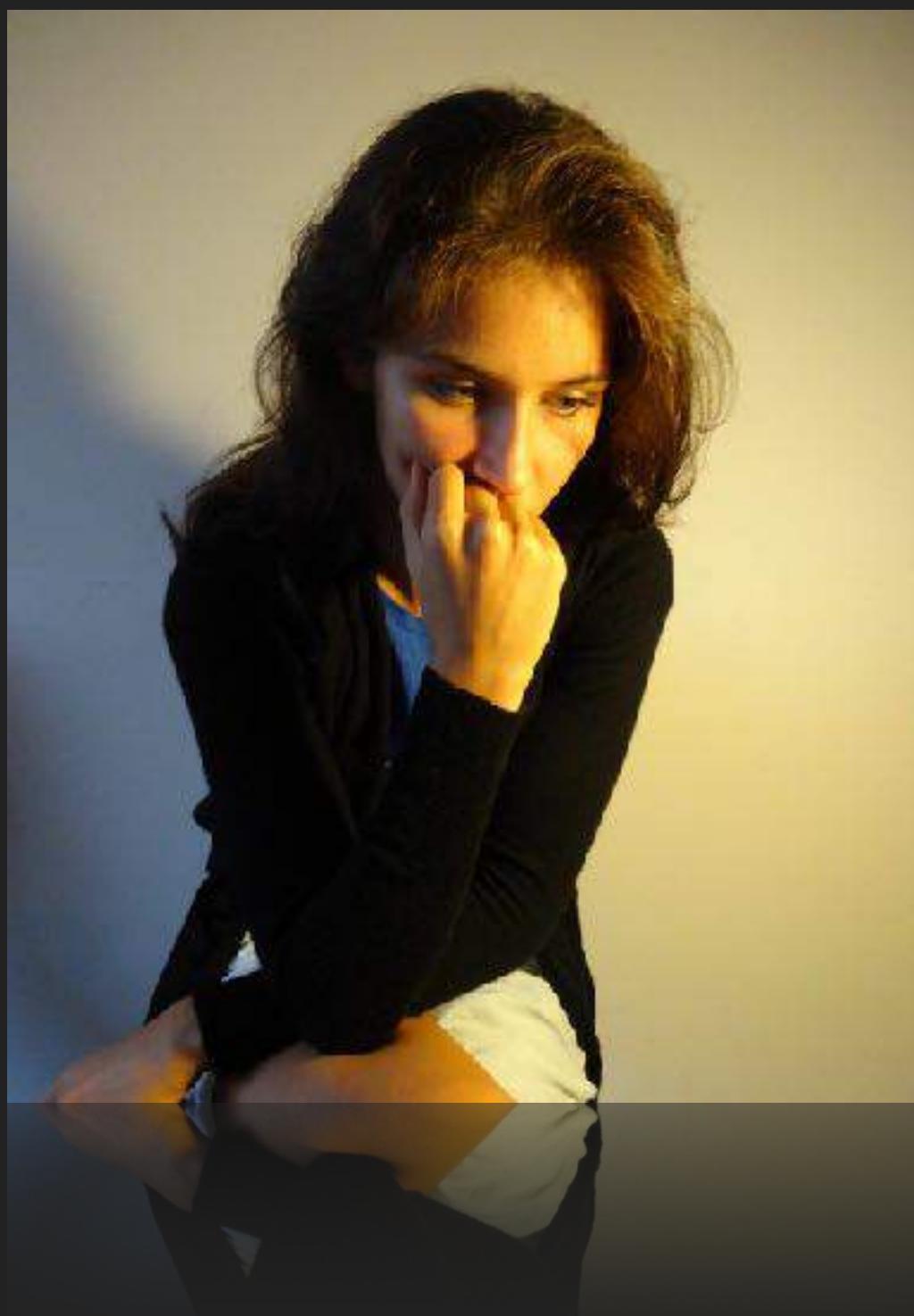
- ▶ embodiment
- ▶ soft robotics
- ▶ scaffolding

MUST EXPLOIT THESE FACTORS !

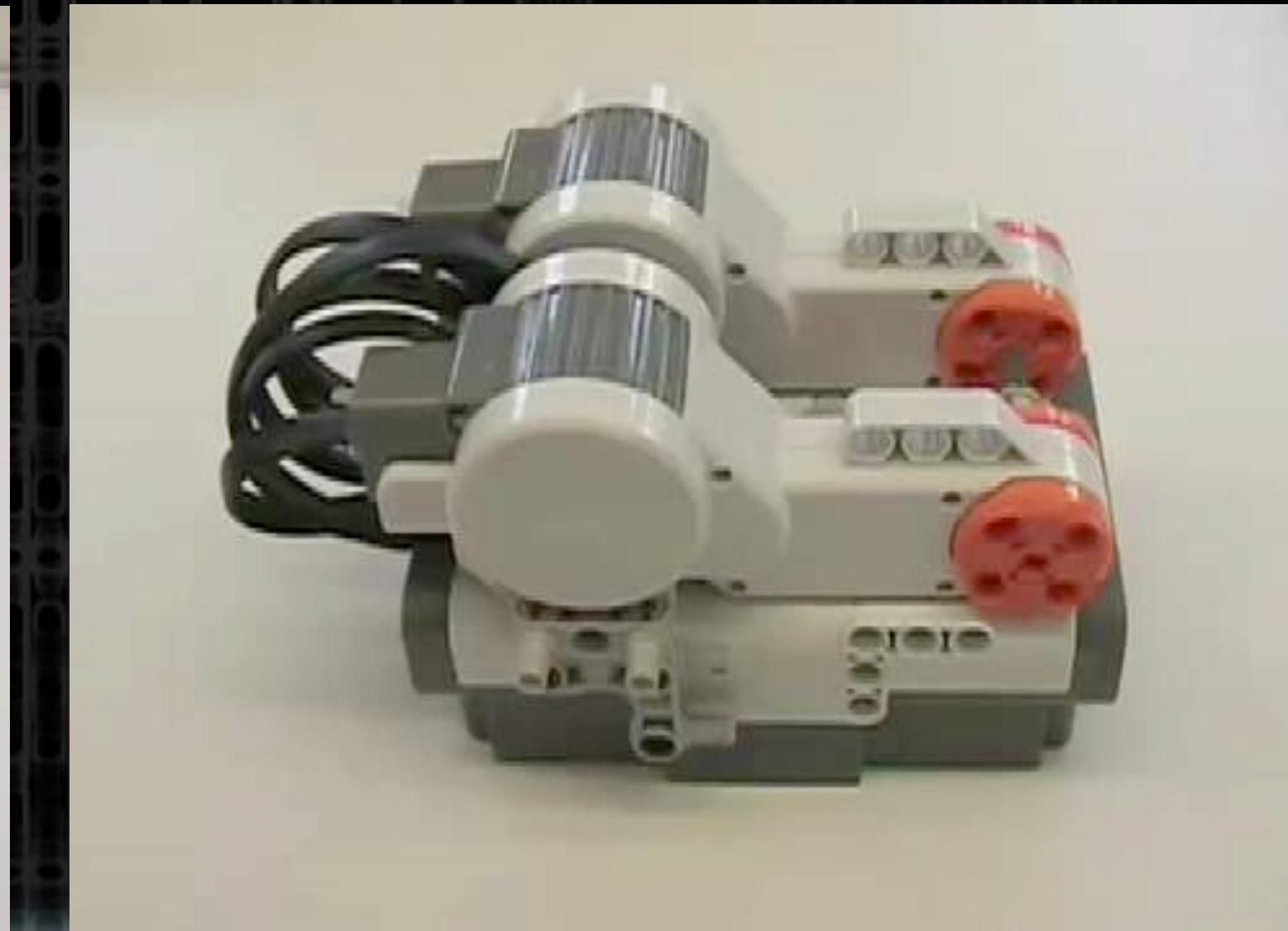
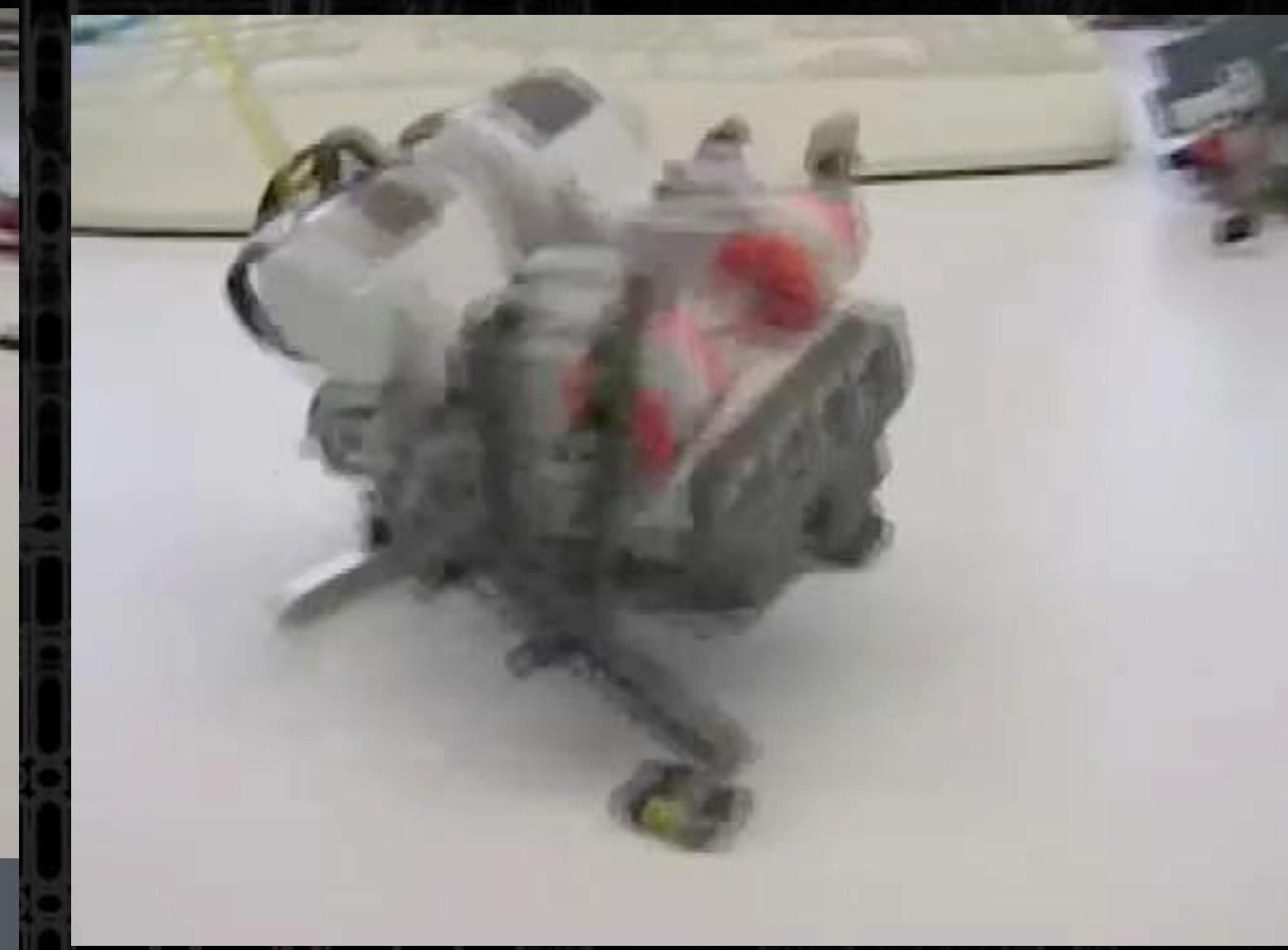


"I THINK — THEREFORE I AM"

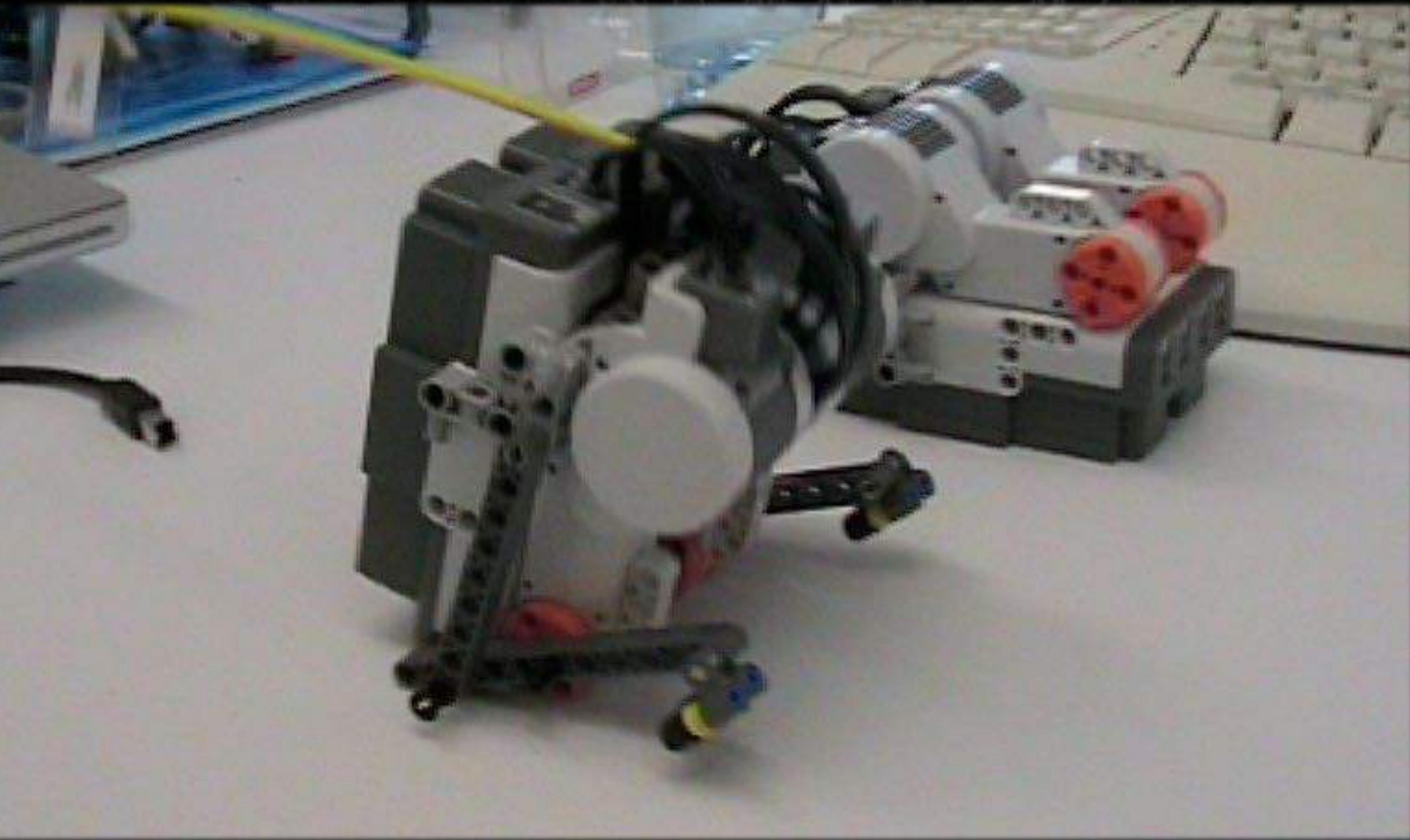
René Descartes  
*Discours de la Méthode, 1637*



# Lego Mindstorms "creatures"



# "Crazy Bird"



loosely hanging feet  
random component  
rubber/plastic

Design and construction : **Mike Rinderknecht**

# Physical embedding ("embodiment")

85

only brain (control): not sufficient

*must understand:*

- embedding of brain into organism
- morphology (shape) and material characteristics of robot
- environment

# The “Passive Dynamic Walker”

86



Design and construction : **Andy Ruina, Martijn Wisse, Steve Collins** - Cornell University, Ithaca, New York

# The “Passive Dynamic Walker”

87



passive structure  
exploiting embodiment  
“cheap design”

Design and construction : **Andy Ruina, Martijn Wisse, Steve Collins** - Cornell University, Ithaca, New York

# The “Passive Dynamic Walker”



passive structure  
exploiting embodiment  
“cheap design”

*trade-off:*  
narrow ecological niche

Design and construction : **Andy Ruina, Martijn Wisse, Steve Collins** - Cornell University, Ithaca, New York

# The “Passive Dynamic Walker”

89

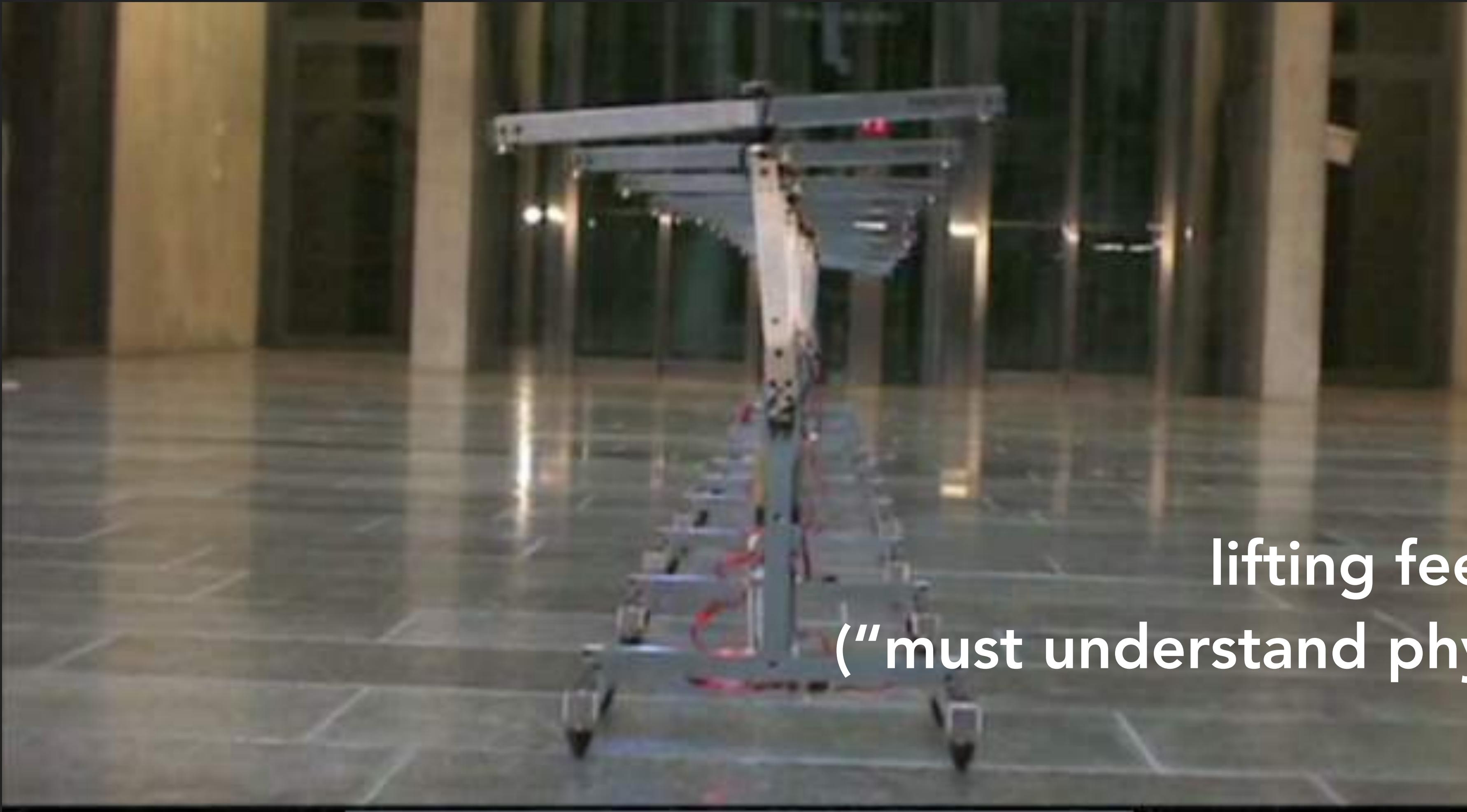


Memory for walking?



Video : Max Lungarella, Raja Dravid - Dynamic Devices, Zurich

## THE DANCING ROBOT "STUMPY"



## THE DANCING ROBOT "STUMPY"

EMERGENCE  
lifting feet off the ground  
("must understand physical dynamics")

Video : Max Lungarella, Raja Dravid - Dynamic Devices, Zurich



THE UNIVERSITY OF TOKYO

Ryuma Niiyama, Yasuo Kuniyoshi,

"Mowgli: A Bipedal Jumping and Landing Robot", ICRA 2007.

## ROBOT "FROG"

**Task distribution:**  
**brain (control) – body**  
**(morphology, materials)** –  
**environment**

i.e.

**no clear separation:**  
**control – hardware**

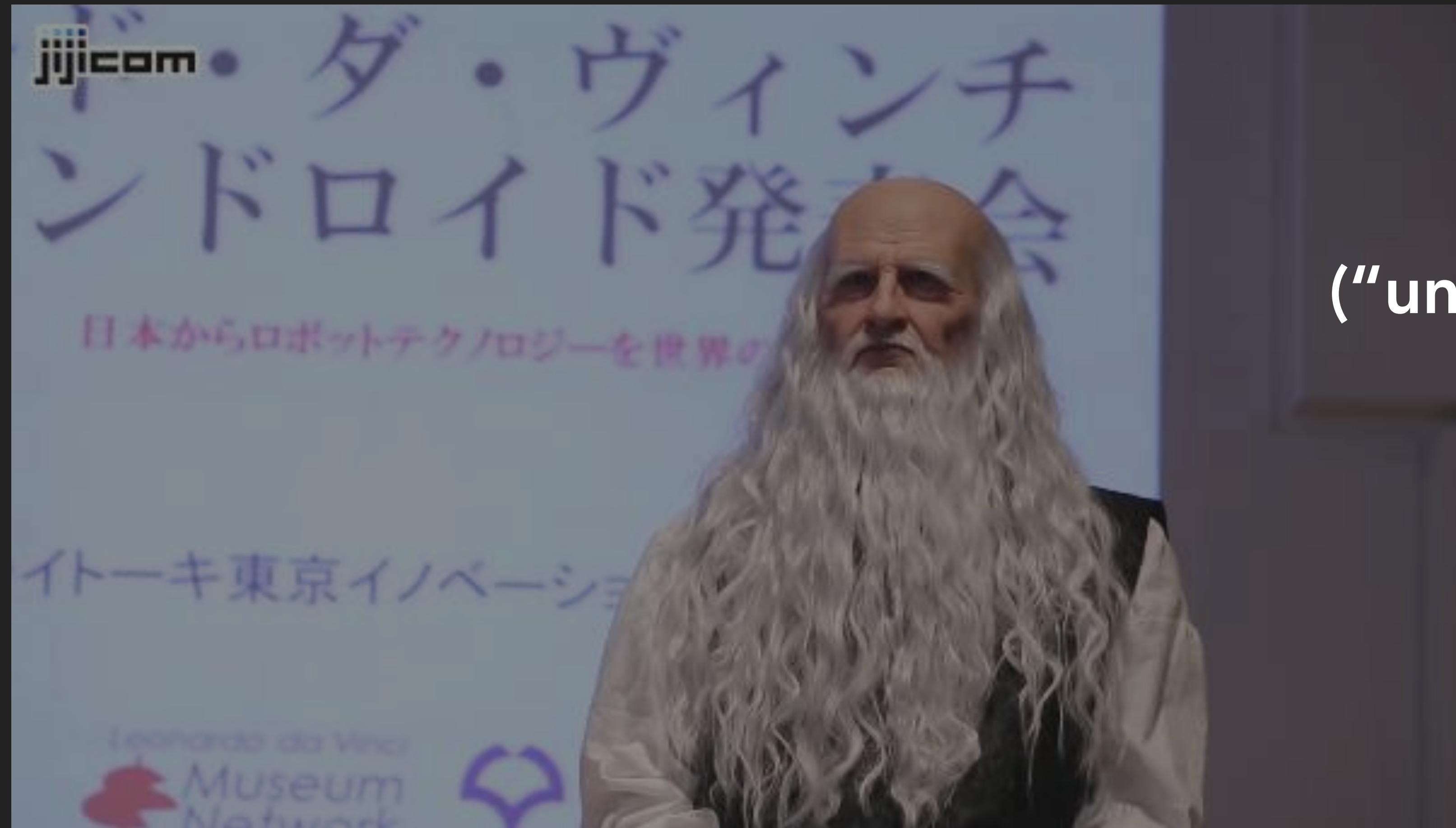
→ "Soft Robotics"

## SOFT ROBOTICS : LEONARDO DA VINCI



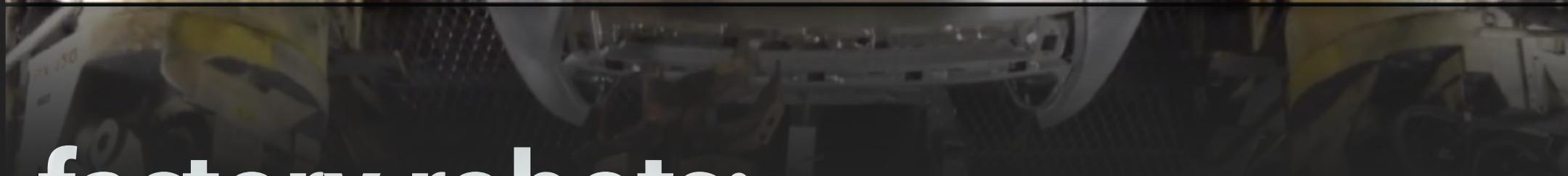
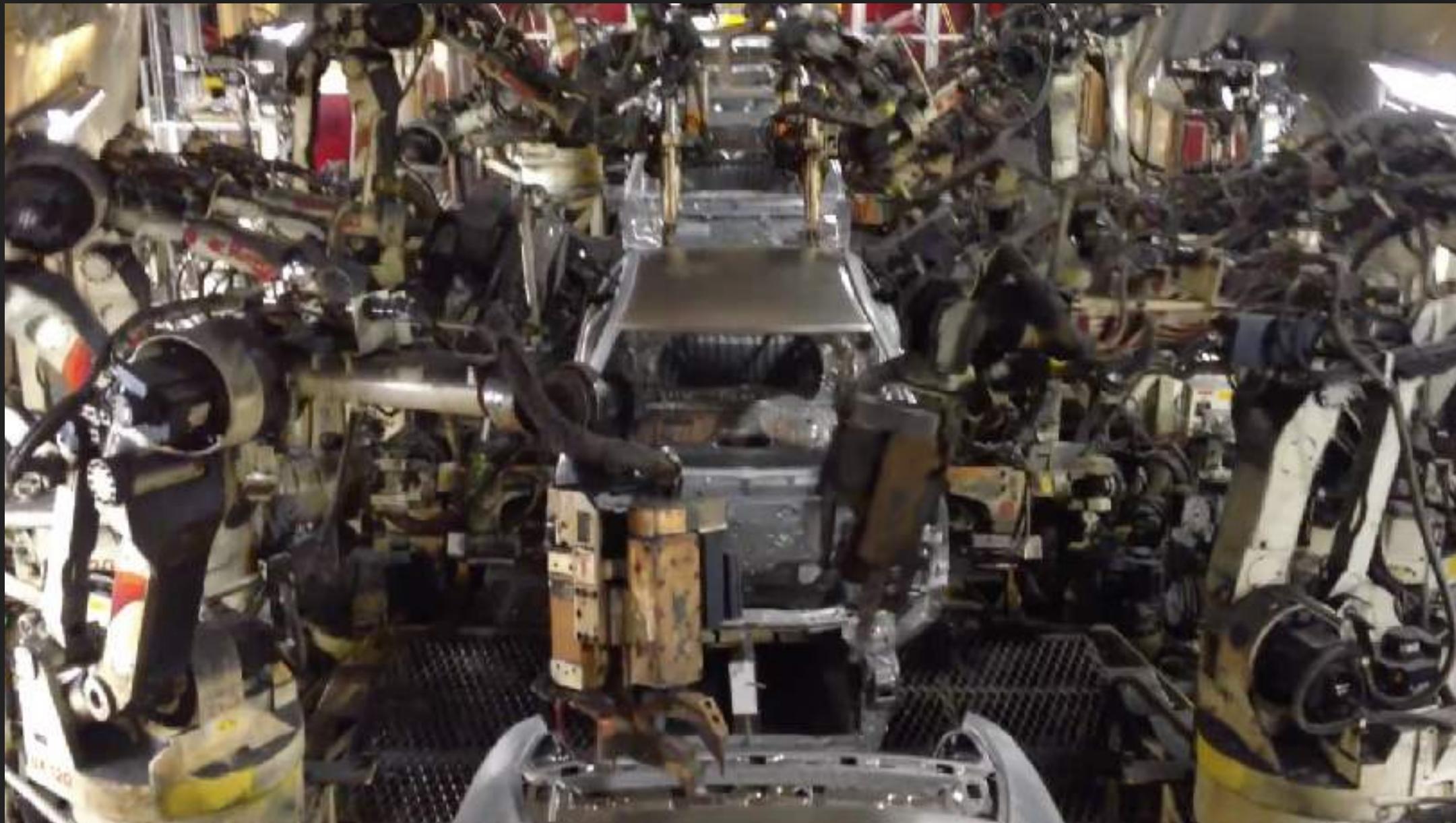
Credit: Hiroshi Ishiguro and Minoru Asada, Osaka University, Japan

## SOFT ROBOTICS : LEONARDO DA VINCI



EMERGENCE  
soft materials crucial  
for facial expression  
("underactuated system")

Credit: Hiroshi Ishiguro and Minoru Asada, Osaka University, Japan



**factory robots:**

***hard materials: steel, plastic,  
electrical motors***



**humans:**

***85 % soft materials !***

**HUMANS: LARGELY “SOFT”**

## SOFT ROBOTICS : THE “POWER OF MATERIALS”

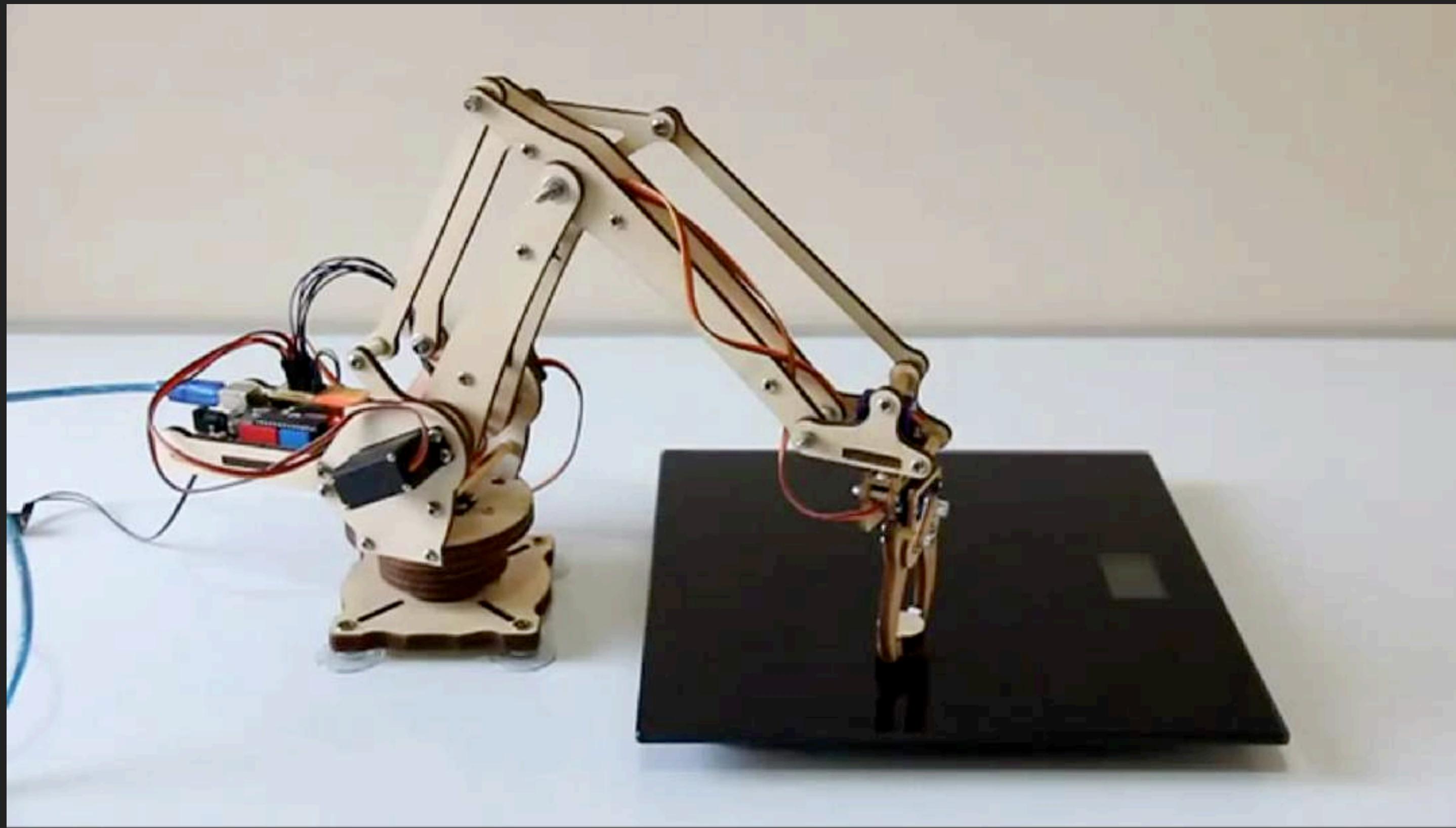
**“soft” to touch**

**built from soft materials**

**“soft”, natural movements**

**“soft”, pleasant, safe interaction**

## GRASPING: TRADITIONAL ROBOT



grasping small object

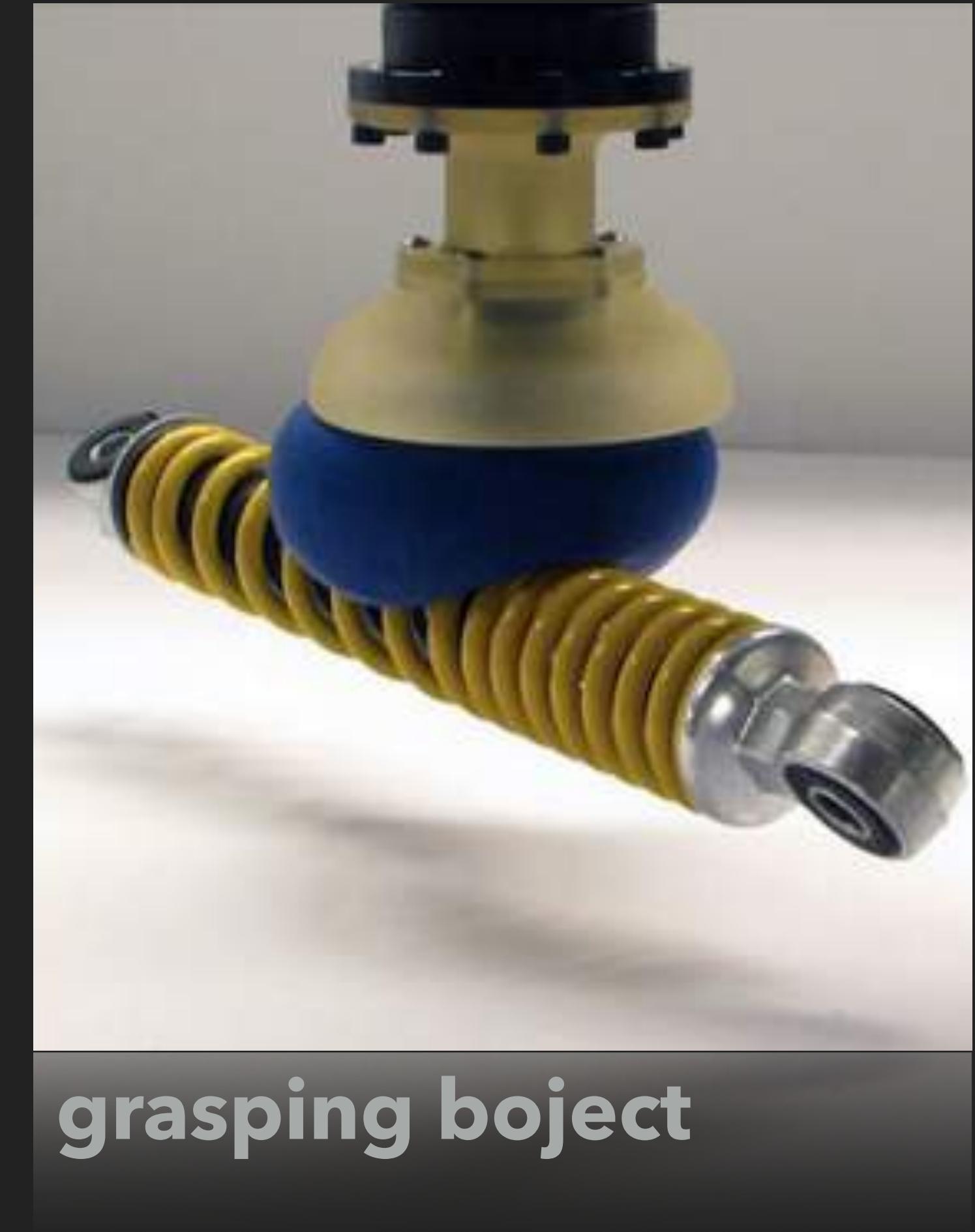
## THE “UNIVERSAL COFFEE-BALLOON GRIPPER”



**balloon filled with  
ground coffee  
vacuum pump**



**balloon with ground  
coffee**



**grasping boject**

# THE “UNIVERSAL COFFEE-BALLOON GRIPPER”



all objects with same  
control

# adaptivity at periphery (not centrally controlled)

credit: Jaeger/Lipson – Univ. of Chicago and Cornell Univ., New York

# exploitation of material properties

## HOLDING A HARD OBJECT



deformable  
tissue

adaptivity at the  
periphery  
(not centrally  
controlled)

exploitation of material properties

## GRASPING GLASS WITH THIMBLES - THE "THIMBLES EXPERIMENT"



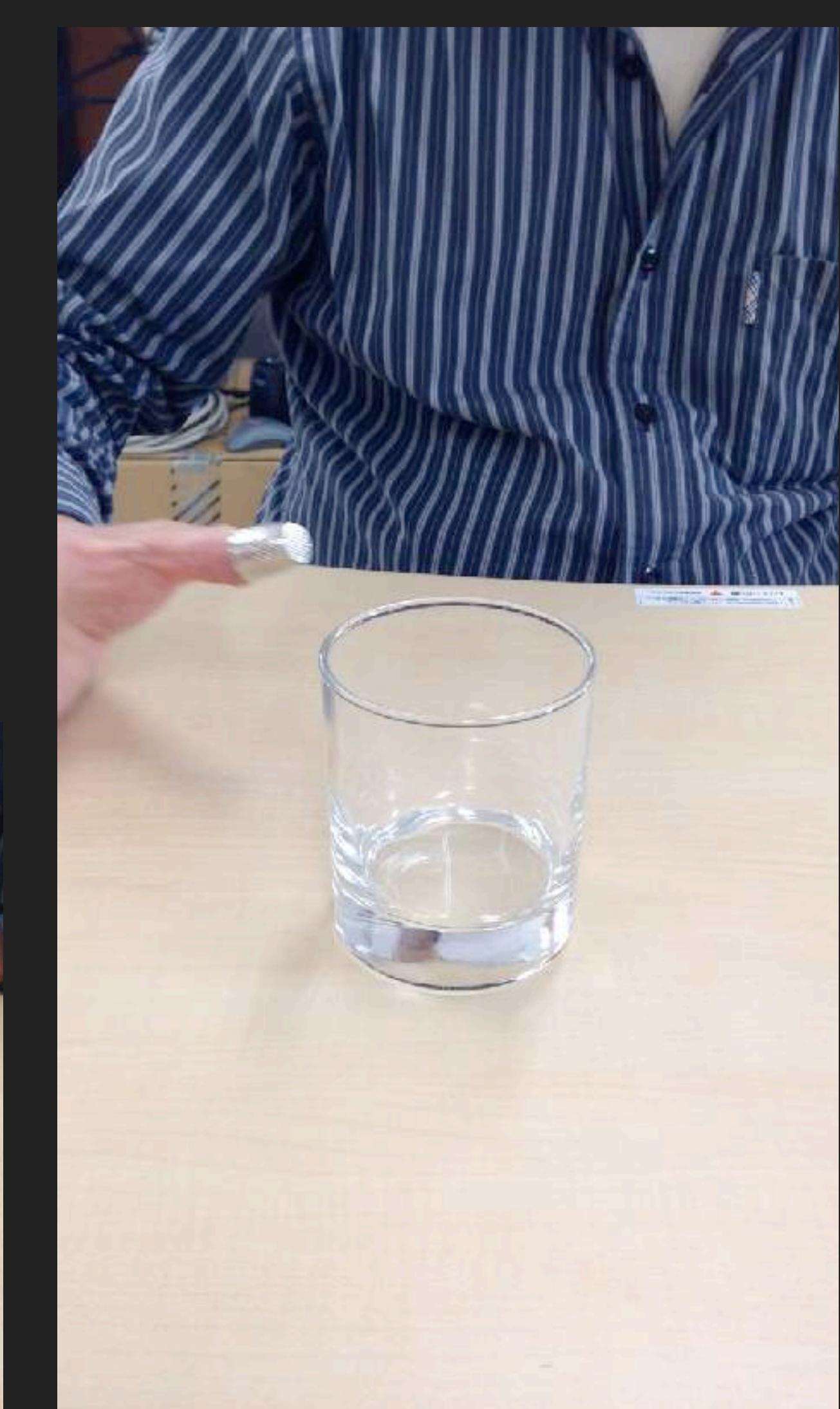
effortless



Try it !  
impossible !

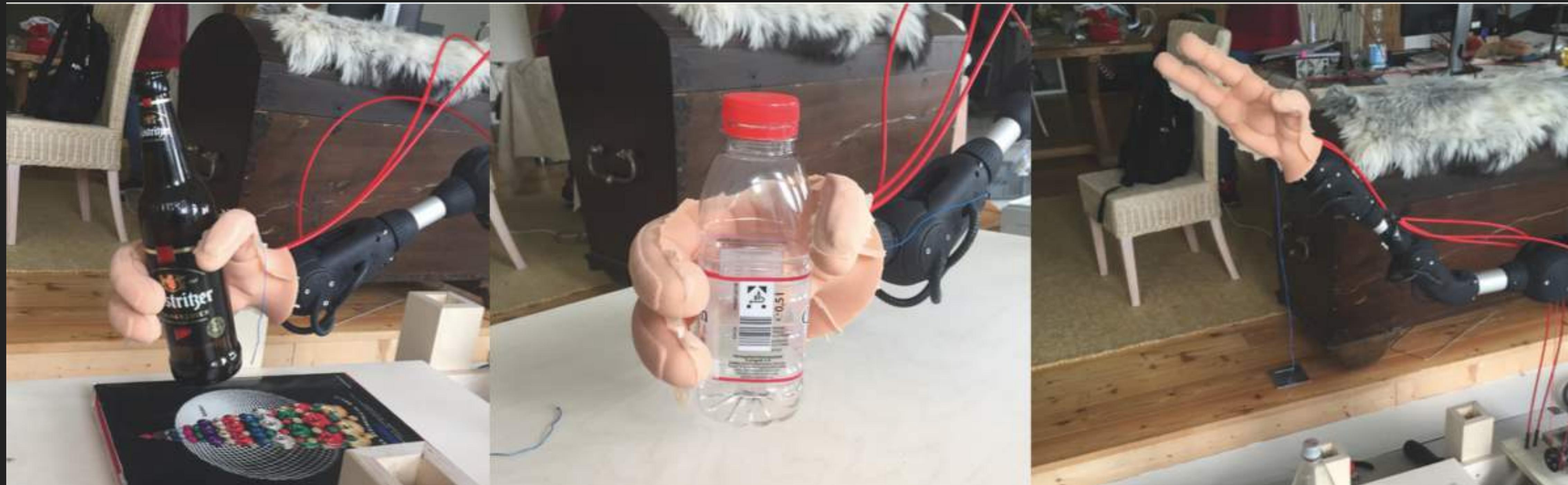
experience what materials do for you !

## THE THIMBLES- EXPERIMENT



THE “POWER OF MATERIALS”

## THE “SOFT ROBOTICS GRIPPER”



## SOFT ROBOTIC ARM - FOR BARTENDER ROBOT

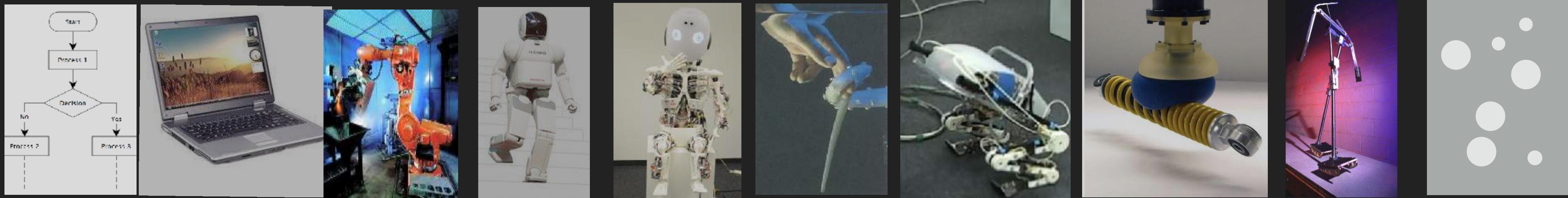
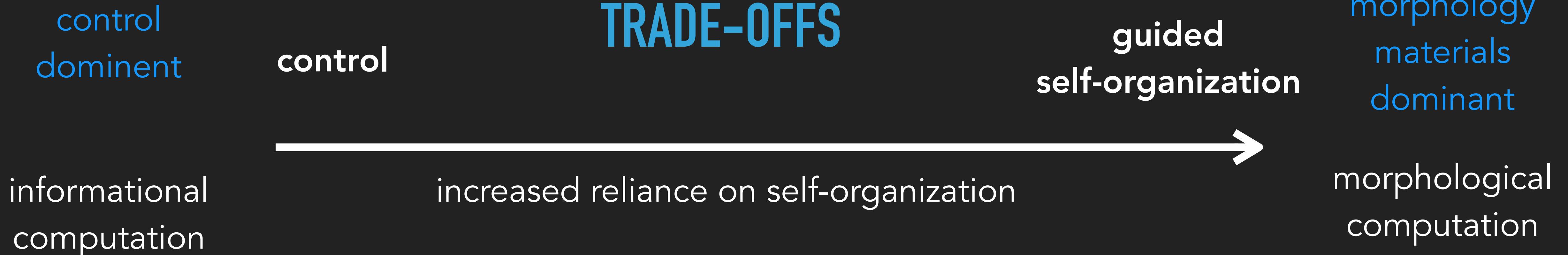


## EXPANSION OF DESIGN SPACE

morphologies and materials (physical structure, sensory distribution, actuators)

***design decision:***

what to put into morphology, materials, control, environment?



pure computer industrial Asimo Roboy Octopus "Frog" Universal Passive vesicles  
algorithm (running robot (and (compliant (soft (compliant, "coffee- Dyn. W. molecules  
algorithm) (centralized similar tendon- contin- pneumatic) balloon" (exploiting  
control) robots) driven) uous) gripper morph.)

## MORE TROUBLE

### **fundamental behavioral principle**

- induction of sensory stimulation through action  
**(NOT:** “input-processing-output”)
- raw material for information processing of brain
- learning about environment

*(cf. John Dewey: “The reflex arc concept in psychology”, 1896 !!)*

## JOHN DEWEY, PHILOSOPHER, PSYCHOLOGIST, EDUCATOR, 1896

"We begin not with a sensory stimulus, but with a sensory-motor coordination [...] In a certain sense it is the movement which is primary, and the sensation which is secondary, the movement of the body, head, and eye muscles determining the quality of what is experienced. In other words, the real beginning is with the act of seeing; it is looking, and not a sensation of light."

*'The reflex arc concept in psychology,' John Dewey, 1896*

## MORE TROUBLE: COMPLEXITY OF DESIGN SPACE

### **fundamental behavioral principle**

- induction of sensory stimulation through action  
(NOT: “input-processing-output”)
- raw material for information processing of brain
- learning about environment

*(cf. John Dewey: “The reflex arc concept in psychology”, 1896 !!)*

**induction of correlations:** information structure  
information overlap between sensory channels

# PHYSICAL DYNAMICS AND INFORMATION STRUCTURE

## **Essence:**

self-structuring of sensory data through physical interaction with world

## **Note:**

- physical process – not computational
- prerequisite for learning
- predictions, expectations

## **Inspiration:**

John Dewey, 1896 (!)

Merleau-Ponty, 1963

Bajcsy, 1963; Aloimonos, 1990; Ballard, 1991

Sporns, Edelman, and co-workers

TheLEN and Smith (developmental studies)

## NOT: INPUT-PROCESSING-OUTPUT (FOR HUMAN INTELLIGENCE)

→ ***sensory-motor contingencies, SMCs***

**SMCs:** law-like relations between movements and associated changes in sensory stimulation; O'Regan and Noë: *A sensorimotor account of vision and visual consciousness*, 2001)

## NOT: INPUT-PROCESSING-OUTPUT (FOR HUMAN INTELLIGENCE)

→ ***sensory-motor contingencies, SMCs***

**SMCs:** law-like relations between movements and associated changes in sensory stimulation; O'Regan and Noë: *A sensorimotor account of vision and visual consciousness*, 2001)

**dependence on:**

- morphology (sensor type and distribution), materials
- action (emergent behavior)
- environment (e.g. object)

## HOW IT ALL FITS TOGETHER

**loosely swinging arm:**

arm/joints self-organize into preferred trajectory

**exploration:**

- constrained ("soft", biomechanical constraints - morphology, materials)
- preferred trajectories: easy control, energy-efficient
- generation of rich, useful patterns of sensory stimulation (SMCs)
- induction of information structure - self-structuring (correlations in different sensory channels)
- learning, cross-modal associations
- predictions

## THE ROBOT “BARTENDER”: WHY WILL IT WORK ?

- ▶ embodiment
- ▶ soft robotics
- ▶ scaffolding

MUST EXPLOIT THESE FACTORS !

...

## STRUCTURING ENVIRONMENT - EXPLOITING CONSTRAINTS

**limited space**

**movement on tracks**

**predefined positions  
(customers, bottles,  
glasses)**

**narrow context  
(conversation)**



## STRUCTURING ENVIRONMENT - EXPLOITING CONSTRAINTS

limited space

movement on tracks

predefined position  
(customers, bottles,  
glasses)

narrow context  
(conversation)



DON'T NEED UNIVERSAL WAITER ROBOT !



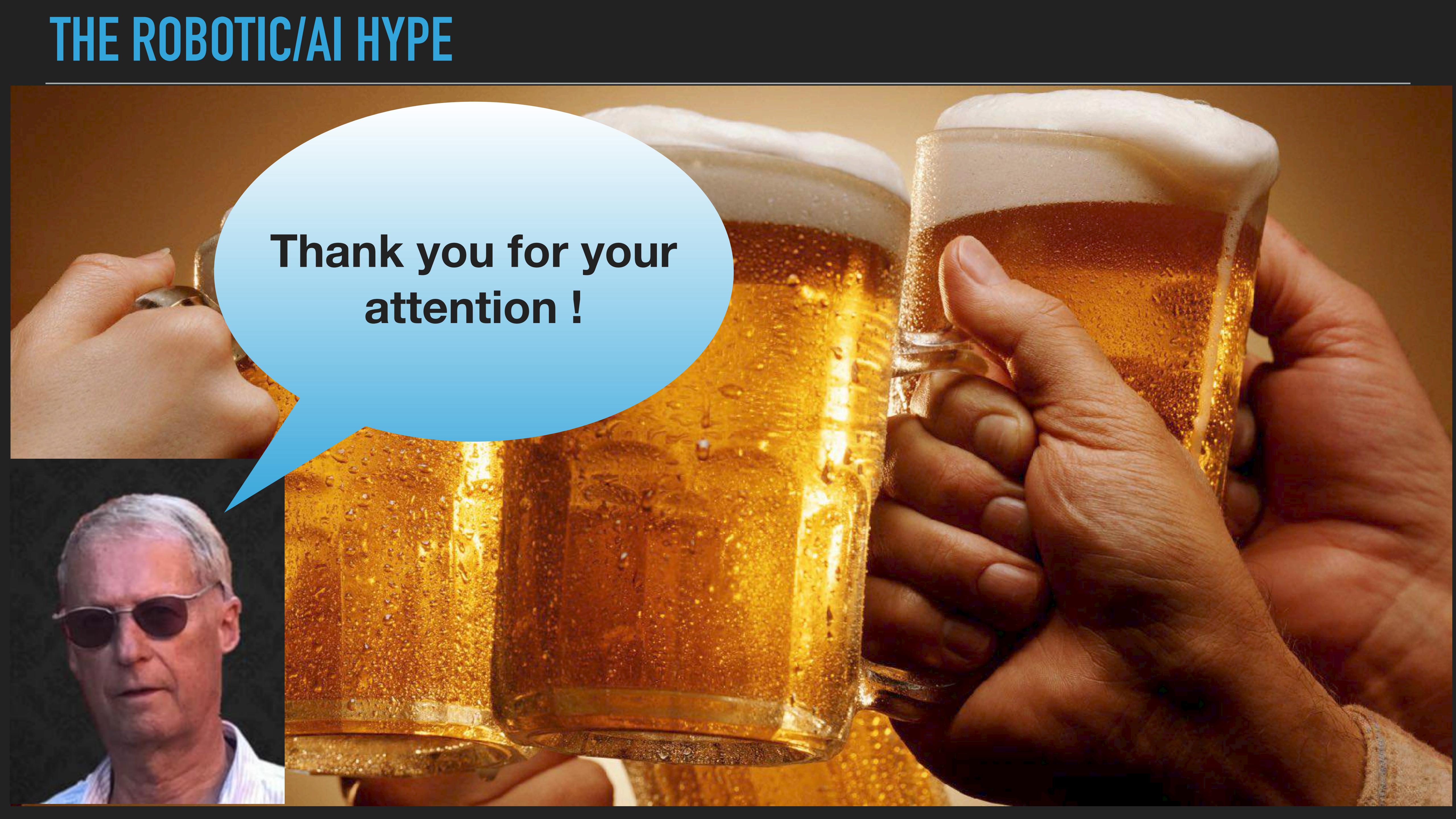
# Experience the future !

**See you in the Robolounge  
in the near future !**

**The „ROBOLOUNGE“ Project**

# BEWARE: ROBOT TECHNOLOGY IS COMPLEX - SLOW ROI

# THE ROBOTIC/AI HYPE



Thank you for your  
attention !