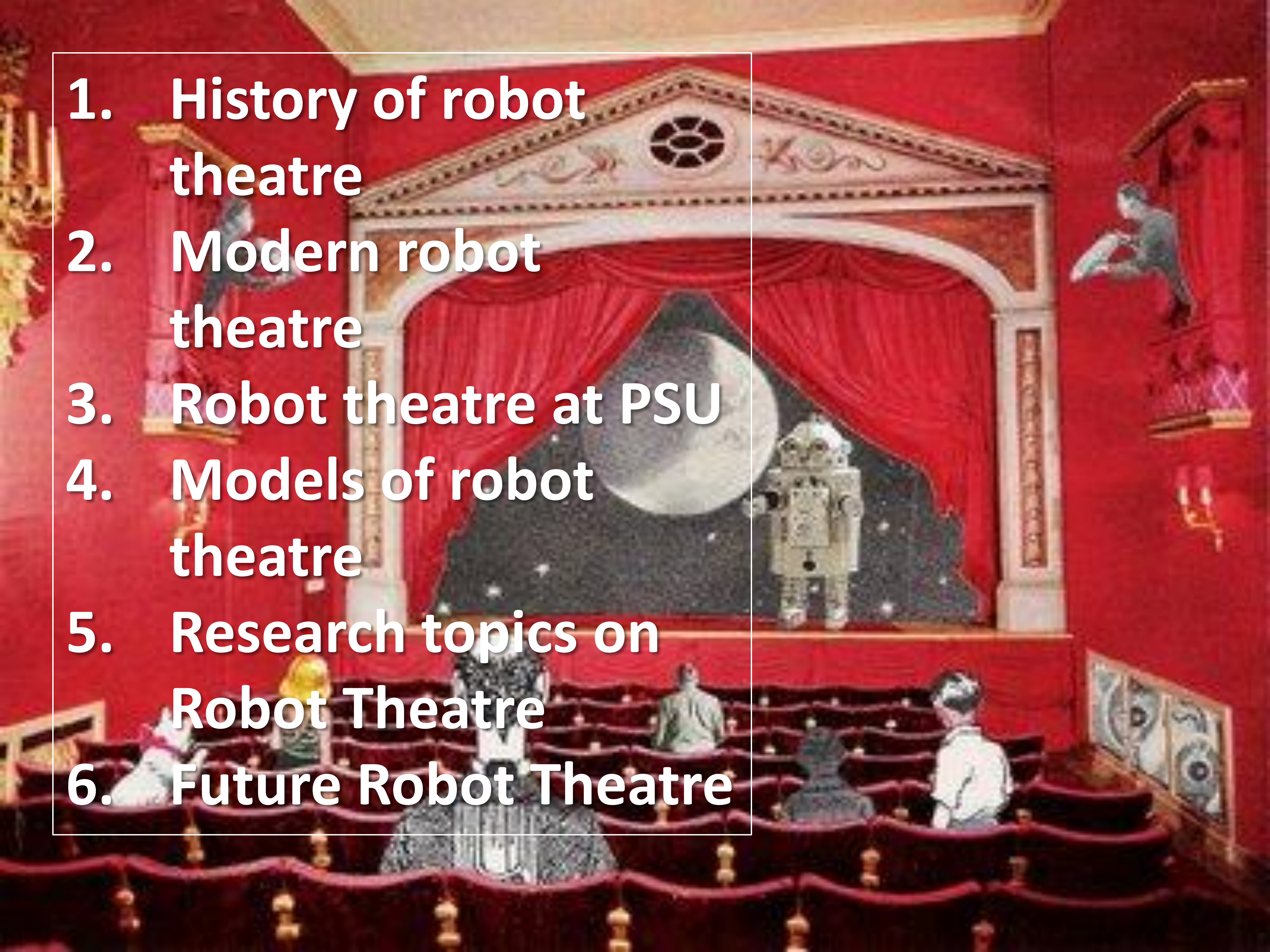
Towards Robot Theatre

Marek Perkowski

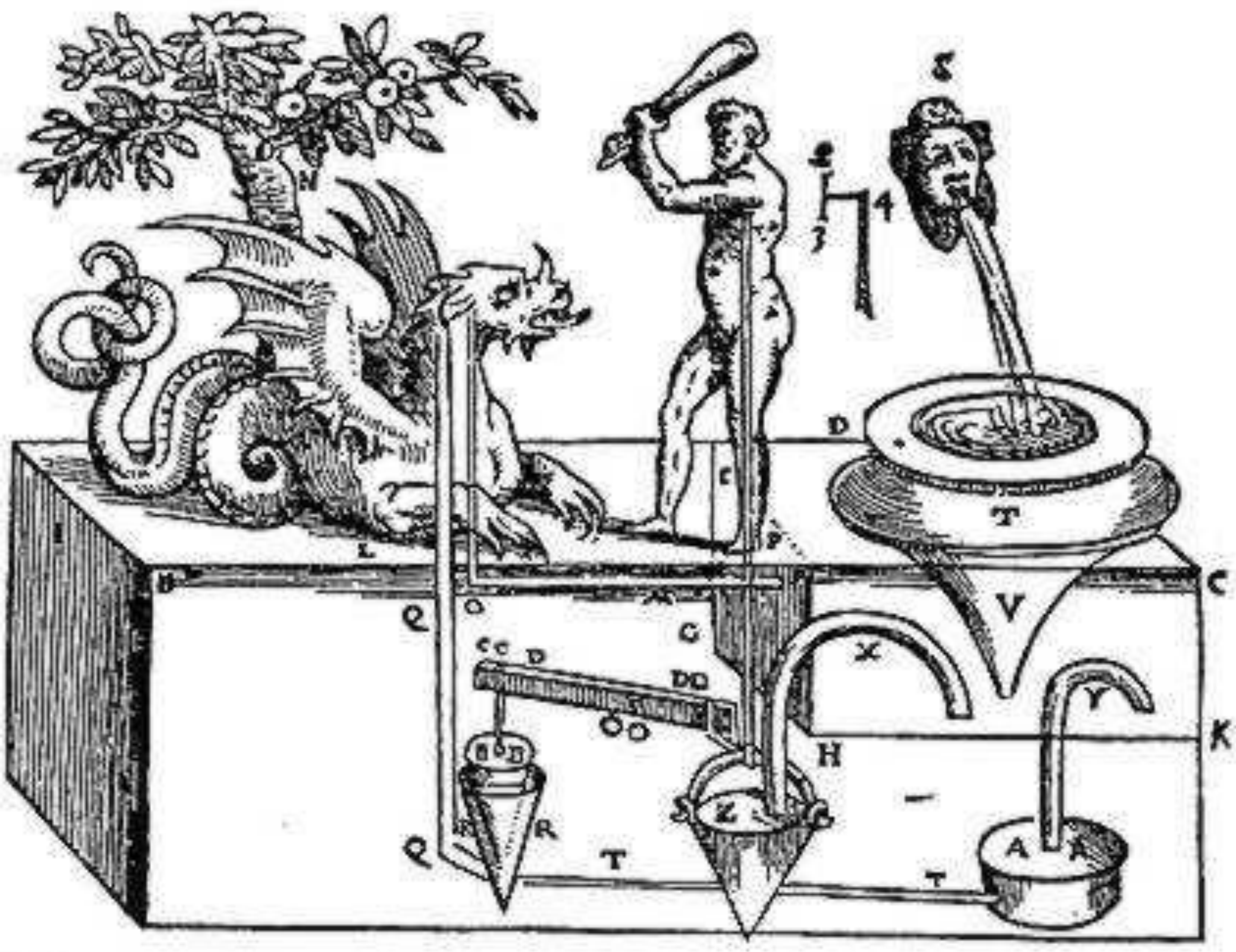


1. History of robot theatre
2. Modern robot theatre
3. Robot theatre at PSU
4. Models of robot theatre
5. Research topics on Robot Theatre
6. Future Robot Theatre

History of Robot Theatre

From antiquity until 1996

Robot Theatre of Hero of Alexandria



Heron's Book Automata

- A collection of constructions called miracles (thaumata) for temples.

- Heron describes automatic rotating objectives, noise such as thunder, automatic opening doors.

- Philon from Byzanz describes the existence of automata in his book Mechaniki syntaxis, that includes pneumatic apparatus and automatic astronomical devices as early as 300 BC.

Albertus Magnus and his robot head

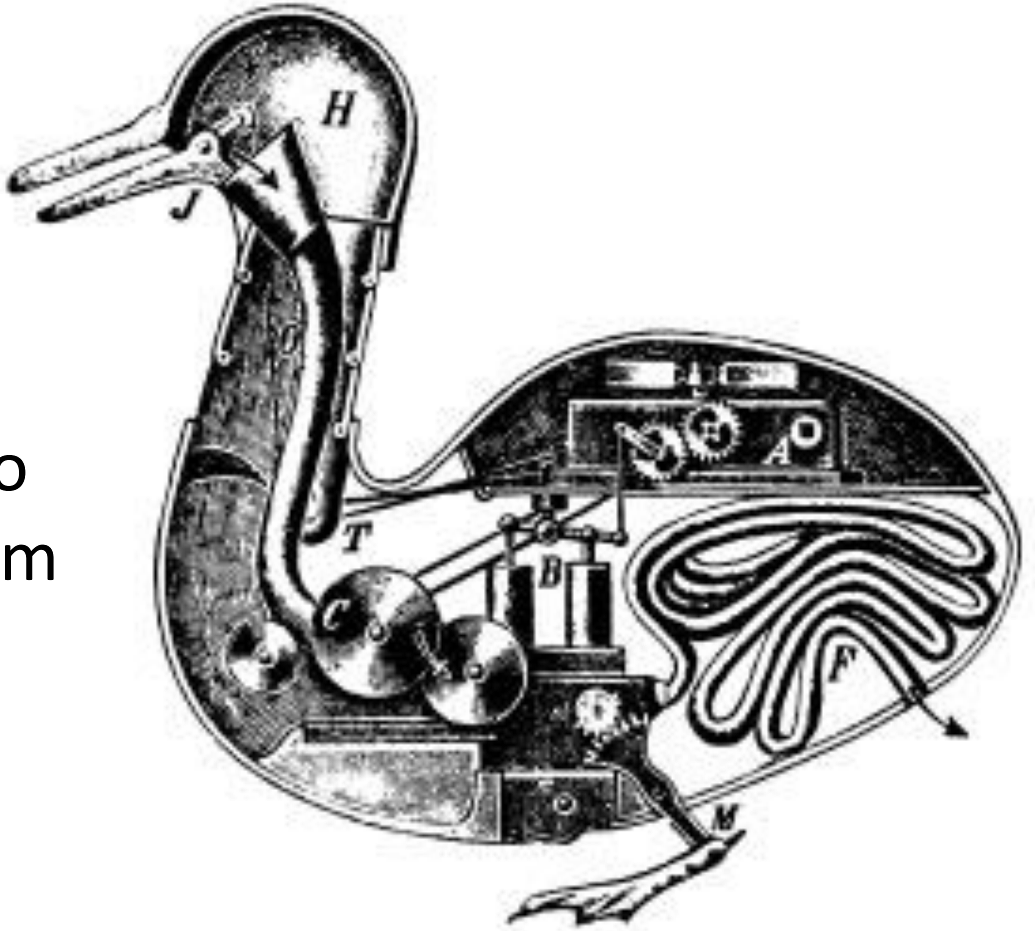
Albertus is recorded as having made a mechanical automaton in the form of a brass head that would answer questions put to it.

Knight of Leonardo Da Vinci

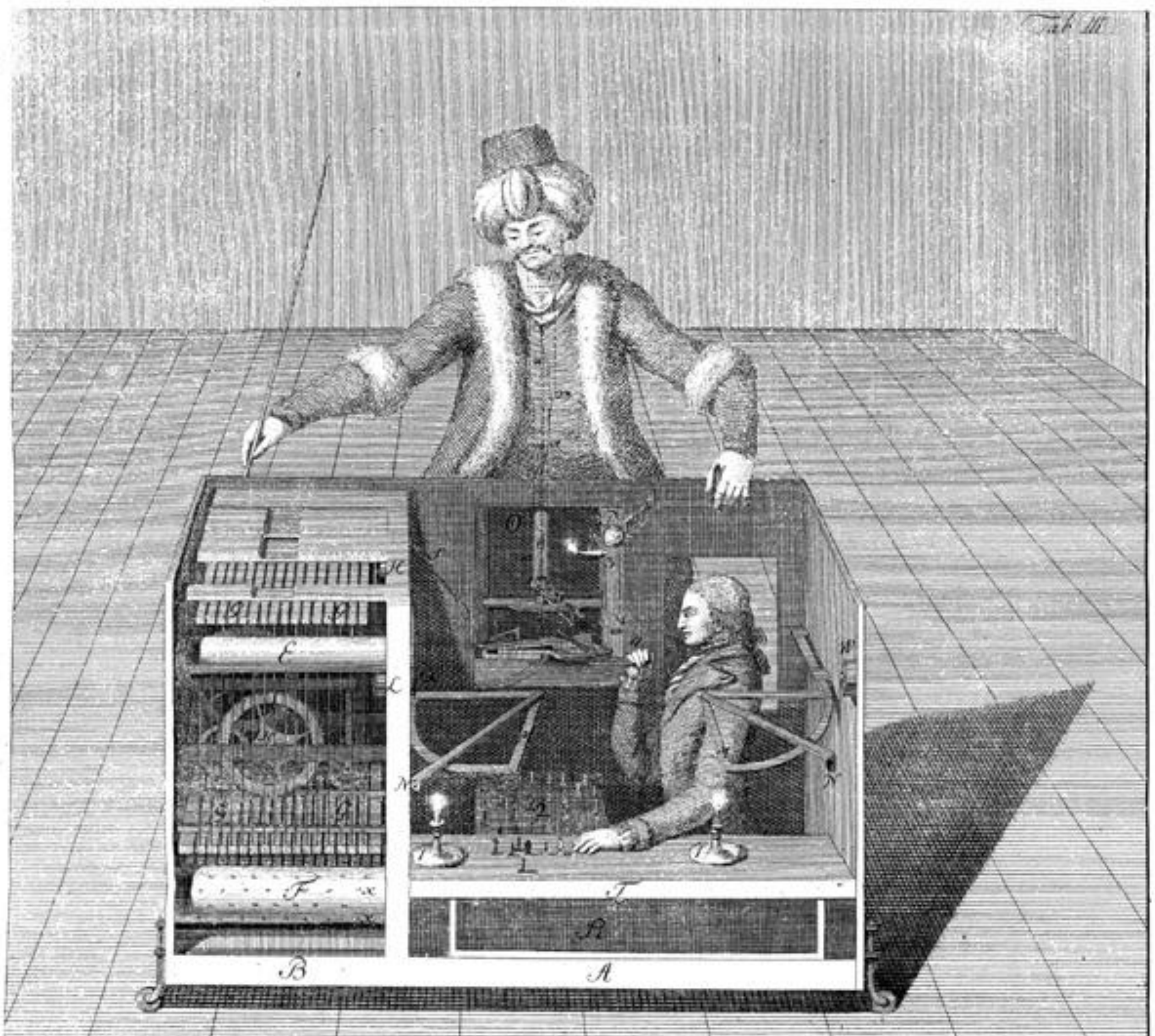
1. **Leonardo's robot** refers to a humanoid automaton designed by Leonardo da Vinci around the year 1495.
2. The design notes for the robot appear in sketchbooks that were rediscovered in the 1950s.
3. It is not known whether or not an attempt was made to build the device during da Vinci's lifetime.
4. Since the discovery of the sketchbook, the robot has been built faithfully based on Leonardo's design; this proved it was fully functional.

Duck of Vaucanson

- The ***Canard Digérateur***, or **Digesting Duck**, was an automaton in the form of a duck, created by Jacques de Vaucanson in 1739.
- The mechanical duck appeared to have the ability to eat kernels of grain, and to metabolize and defecate them



Turk of Kempelen

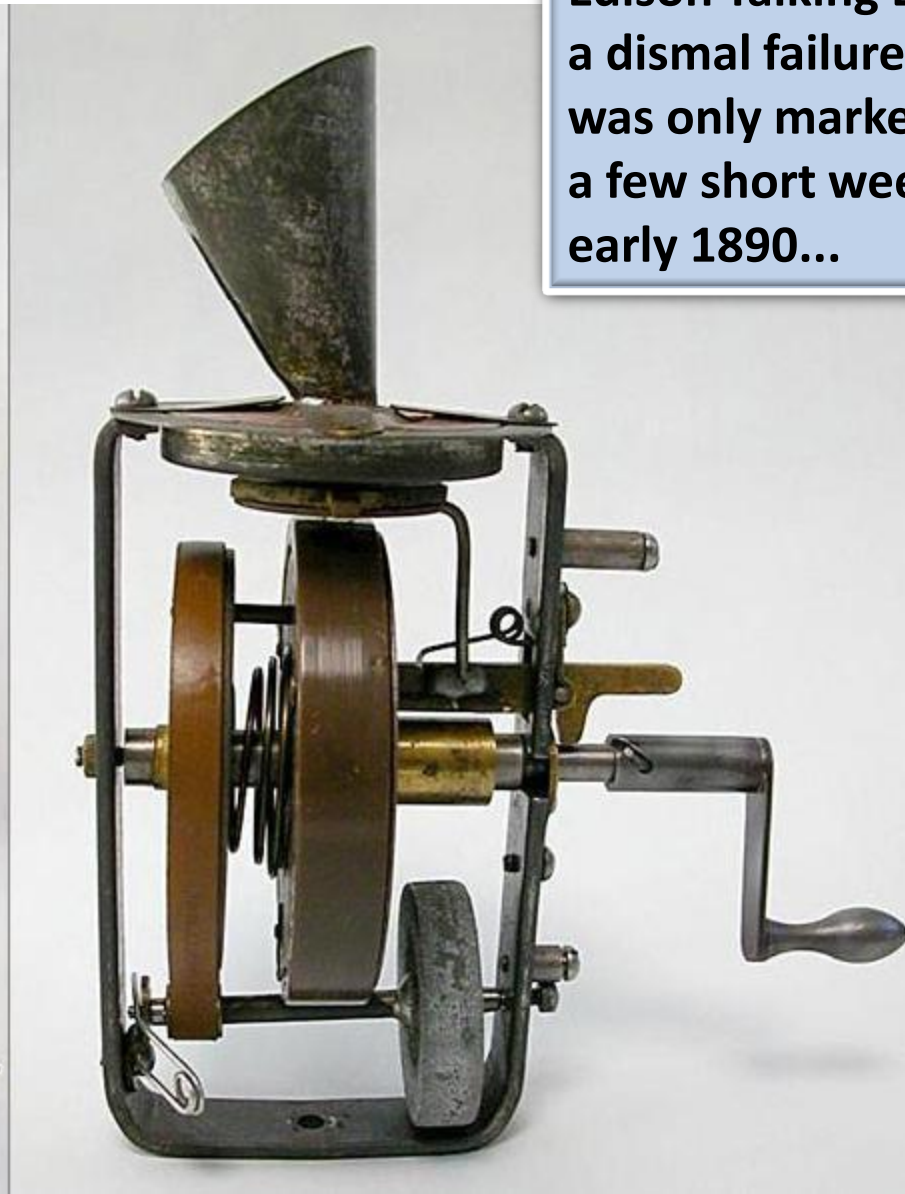


Constructed and unveiled in 1770 by Wolfgang von Kempelen (1734–1804) to impress the Empress Maria Theresa

- The Turk was in fact a mechanical illusion that allowed a human chess master hiding inside to operate the machine.
- With a skilled operator, the Turk won most of the games played during its demonstrations around Europe and the Americas for nearly 84 years, playing and defeating many challengers including statesmen such as Napoleon Bonaparte and Benjamin Franklin.

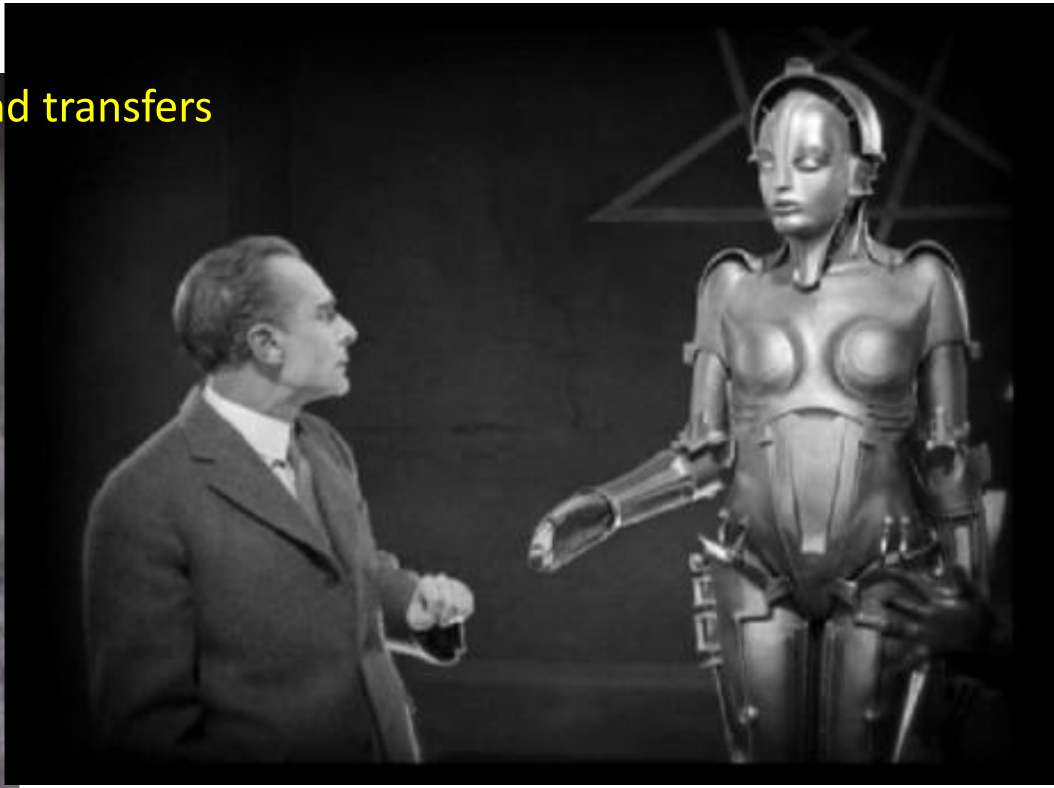
Edison’s Talking Doll

"Despite several years of experimentation and development, the Edison Talking Doll was a dismal failure that was only marketed for a few short weeks in early 1890...



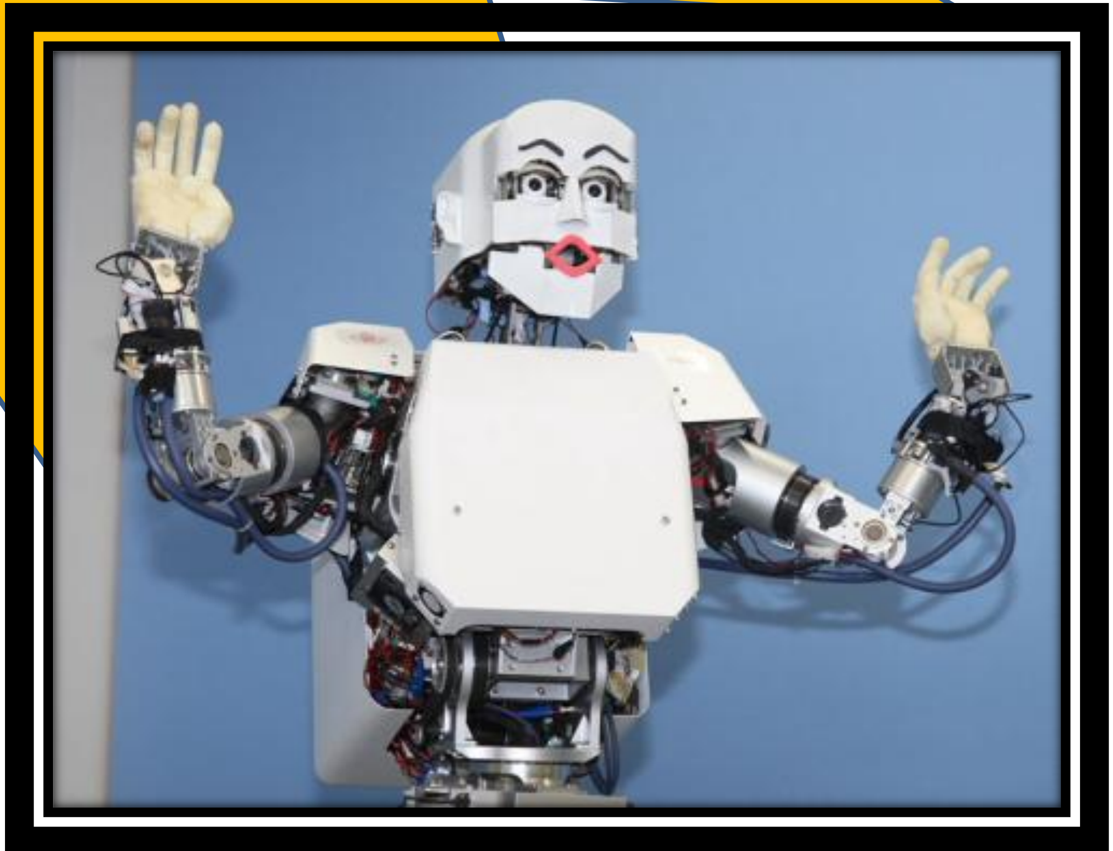
Hel from Fritz Lang's Metropolis 1927

Rotwang brings Maria into his laboratory and transfers her appearance to the machine woman.



Metropolis is set in a futuristic urban dystopia and examines a common science fiction theme of the day: the social crisis between workers and owners in capitalism.

Modern Robot Theatres



Audio-Animatronics from Walt Disney Imagineering

Chuck E. Cheese's Pizza Time Theatre by Nolan Bushnell in **1977**

1996 Ullanta Robot Theatre

Fifi and Josie: A Tale of Two Lesbiots

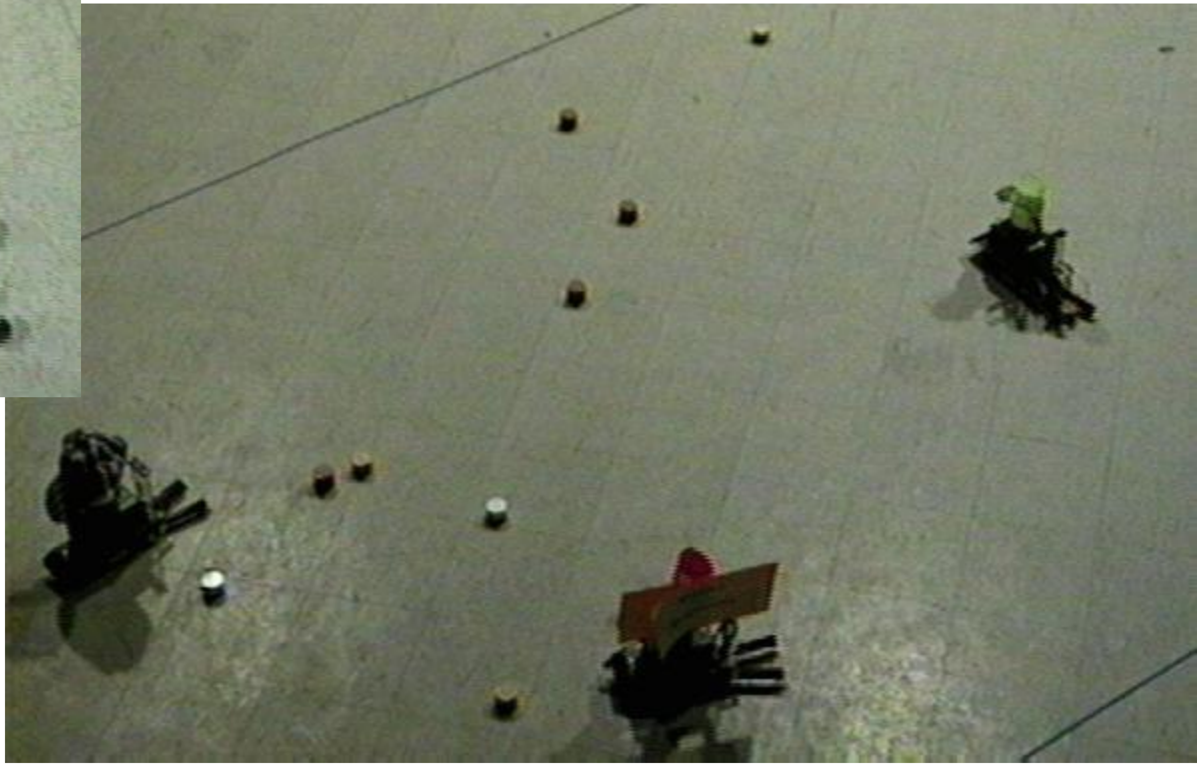
- A Story of Autonomy, Love, Paranoia, and Agency
- Written by Roxanne Linnea Ray

  This play premiered in April 1996, as part of the Brandeis Festival of the Arts, performed by the Nerd Herd.
- A much-improved version, starring Ben, Mae, and Ullanta the Robot Levin was developed by request for the Robotix '97 festival in Glasgow, Scotland, and performed in March of that year.

First robot theatre with mobile and autonomous robots

- Scene 1: Autonomy

- Fifi and Josie inhabit separate spheres of the lesbiot Universe.
- Despite being steeped in lesbiot culture, they each live their lives unaware of the possibilities that love might offer.
- In other words, they perform autonomous robotic actions.



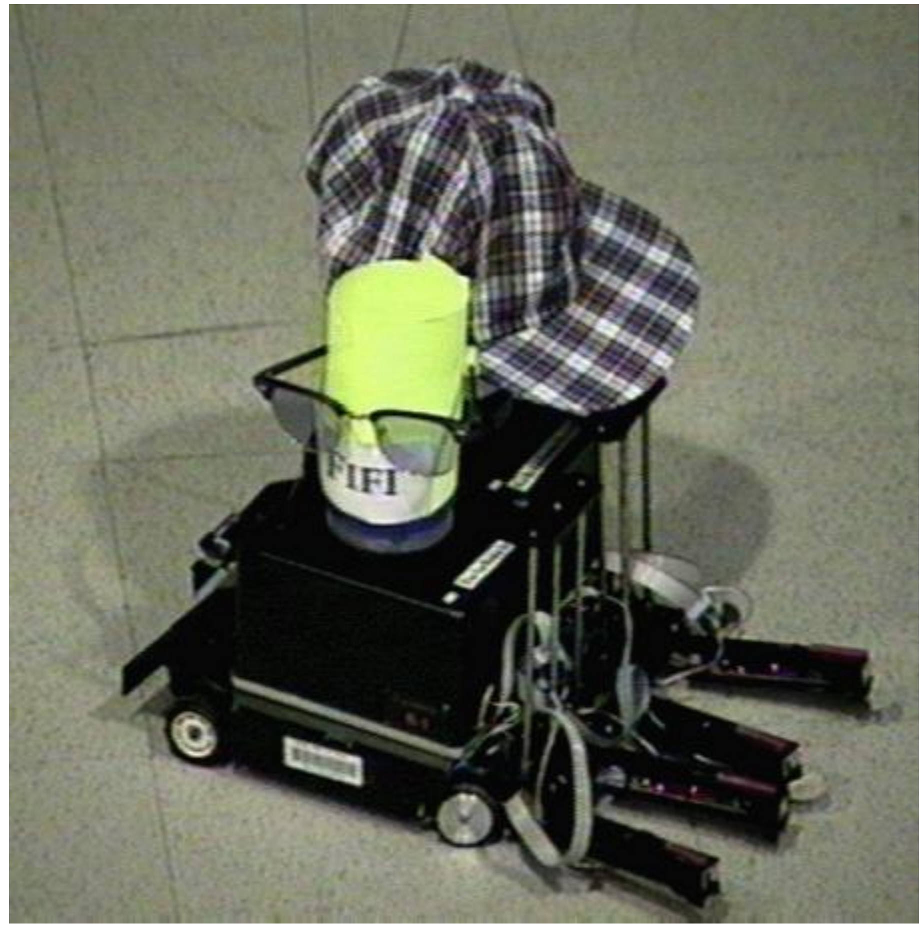
- **Directed by Barry Brian Werger**

- **Scene 2: Love**

- **Fifi and Josie begin to notice the attraction they feel for each other.**
- **They fall in love, slowly.**

  Fifi and Josie approach each other - yet at first, they turn away shyly.
- **When Fifi and Josie do finally make contact, they engage in cooperative actions, slowly negotiating their relationship as all young lovers must.**
- **The new emotions fill their hearts and threaten to overpower them.**

Almost together

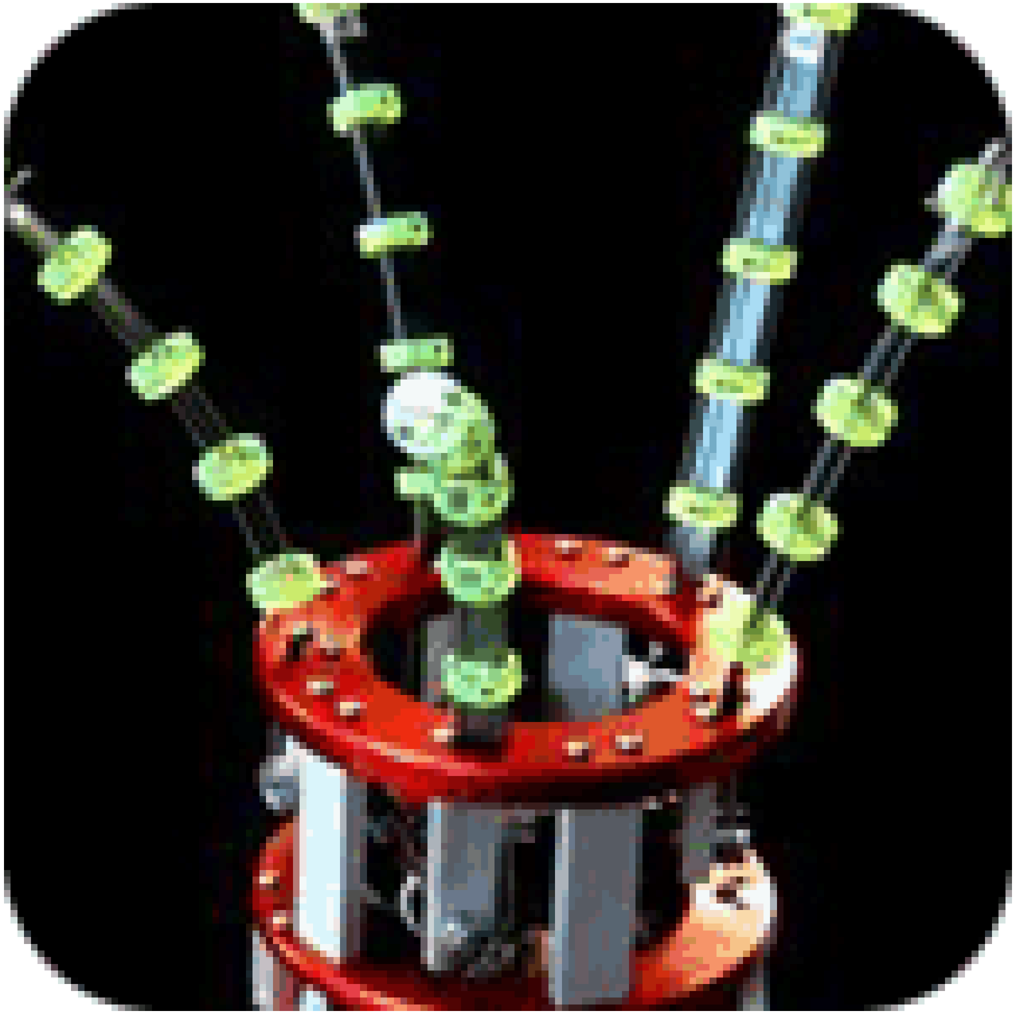


2002. Artificial Life Theatre of Cynthia Breazeal

- SIGGRAPH Emerging Technology Exhibit. This exhibit combined several core technologies: Integrated show controls that turn the terrarium into an intelligent stage; interactive, autonomous robot performers with natural and expressive motion that combines techniques from animation and robot control; and real-time, stereo vision that tracks multiple features on multiple people.
- Together, these elements create a physically interactive, ever changing, multi-sensory experience (including, sight, sound, touch, and even smell).
- The performance follows a storyline where certain elements occur each time, yet audience participation allows the experience to be different every time

A collaboration between the Robotic Life and Synthetic Characters research groups at the Media Lab and MIT's Artificial Intelligence Lab

Public Anemone (January 2002 - August 2002)



1. The exhibit featured several autonmous robots peforming on an "intelligent" stage, featuring computer-controlled special effects.
2. Breazeal envisions that such fully embodied robotic theater could be incorporated into amusement parks, museums, or even interact with human actors on Broadway.

2008

A breakthrough year in robot theatre?

March 2008

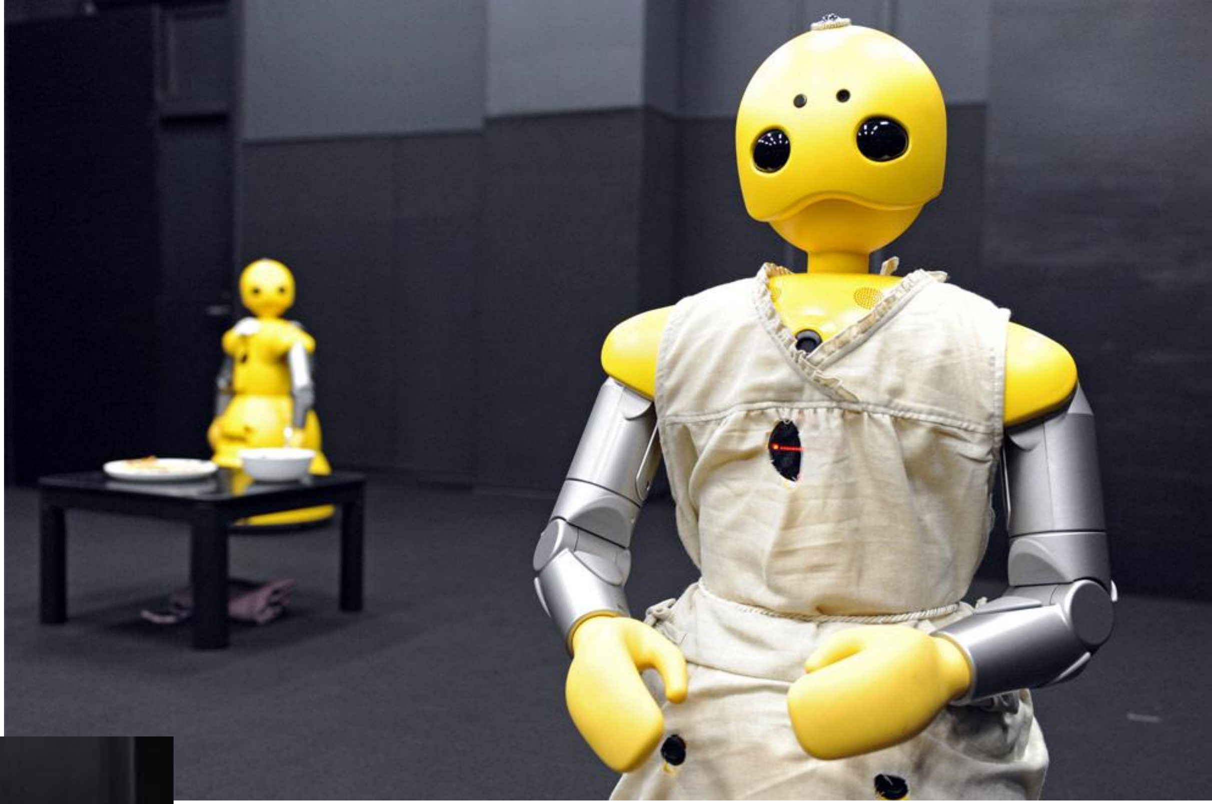
Henrik Ibsen in "Heddatron," the dopey and strangely moving gloss on "Hedda Gabler" by Les Freres Corbusier at the Here Arts Center in the South Village.

Designed by Cindy Jeffers and Meredith Finklestein of Botmatrix, a robot arts collective,

Toyota Motor Corporation partner robots play instruments at the company's showroom in Tokyo on May 4, 2008.

May 2008

Humanoid robots Wakamaru, produced by Japan's Mitsubishi Heavy Industry, named Momoko (R) and Takeo (L) in the performance, take part in a drama for the world's first robot and human experimental theatre, written and directed by Japanese playwright Oriza Hirata, at Japan's Osaka University in Osaka, western Japan on November 25, 2008.



- Commercial robots of mobile base/hands/head type.
- by Mitsubishi
- more commonly used as a house-sitter, secretary or companion for the elderly.
- Actors and robots.

November 25, 2008.

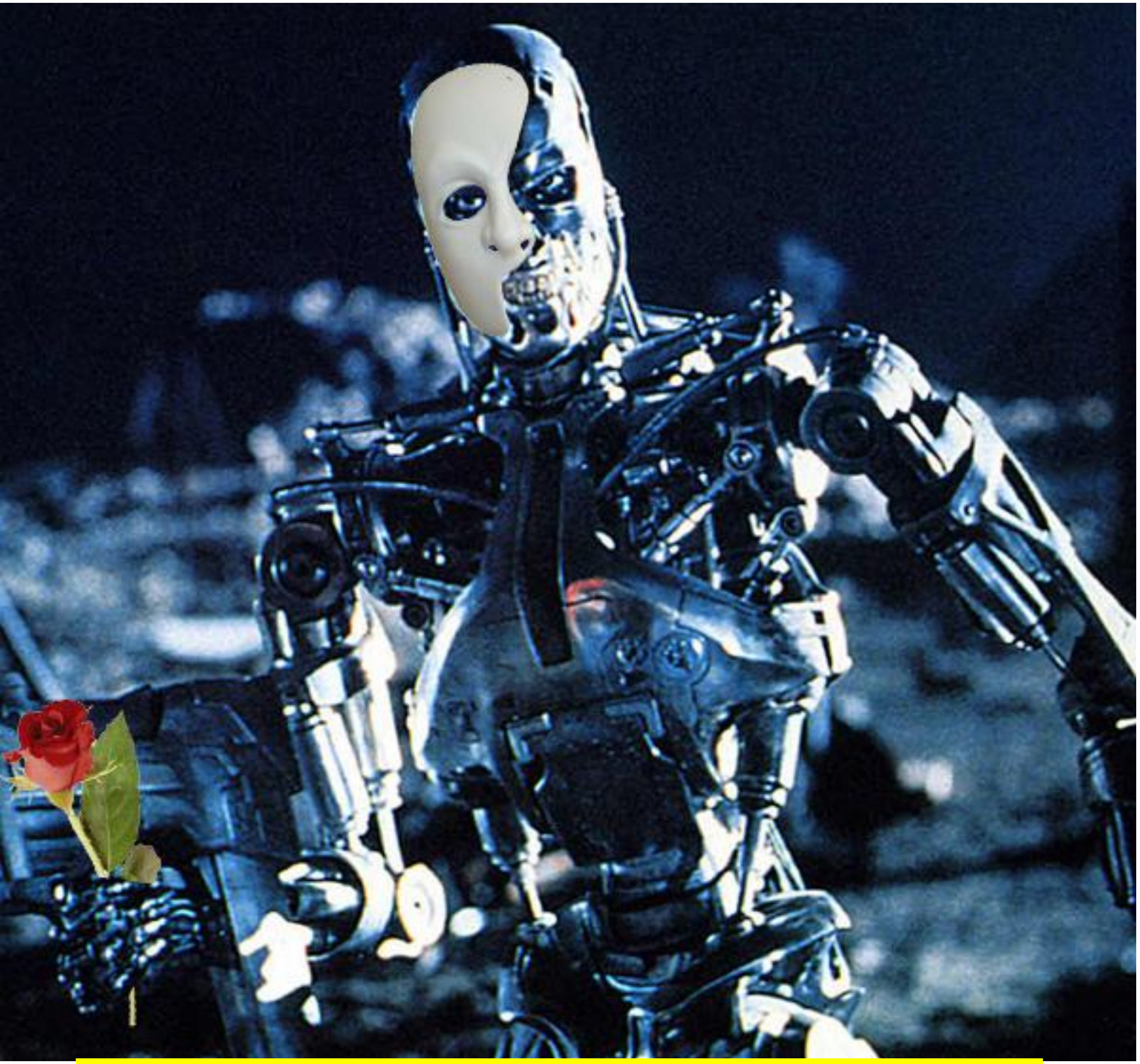
- Tells a futuristic tale of a housekeeping robot who becomes bored with its allotted role in society as a demeaning cleaner.

- 20-minute performance
- robots faultlessly delivered their lines
- interacting with their real-life counterparts.
- Osaka University
- playwright Oriza Hirata
- hoping to expand it to full production length for the public by 2010.
- The alliance between humans and robots performing together live on stage is believed to be a first for Japan's robotics industry.

- The Wakamaru robot uses a laser and cameras to track and identify objects and people.

- It also has the capacity to remember and recognise around 10,000 words necessary for communication in daily life.

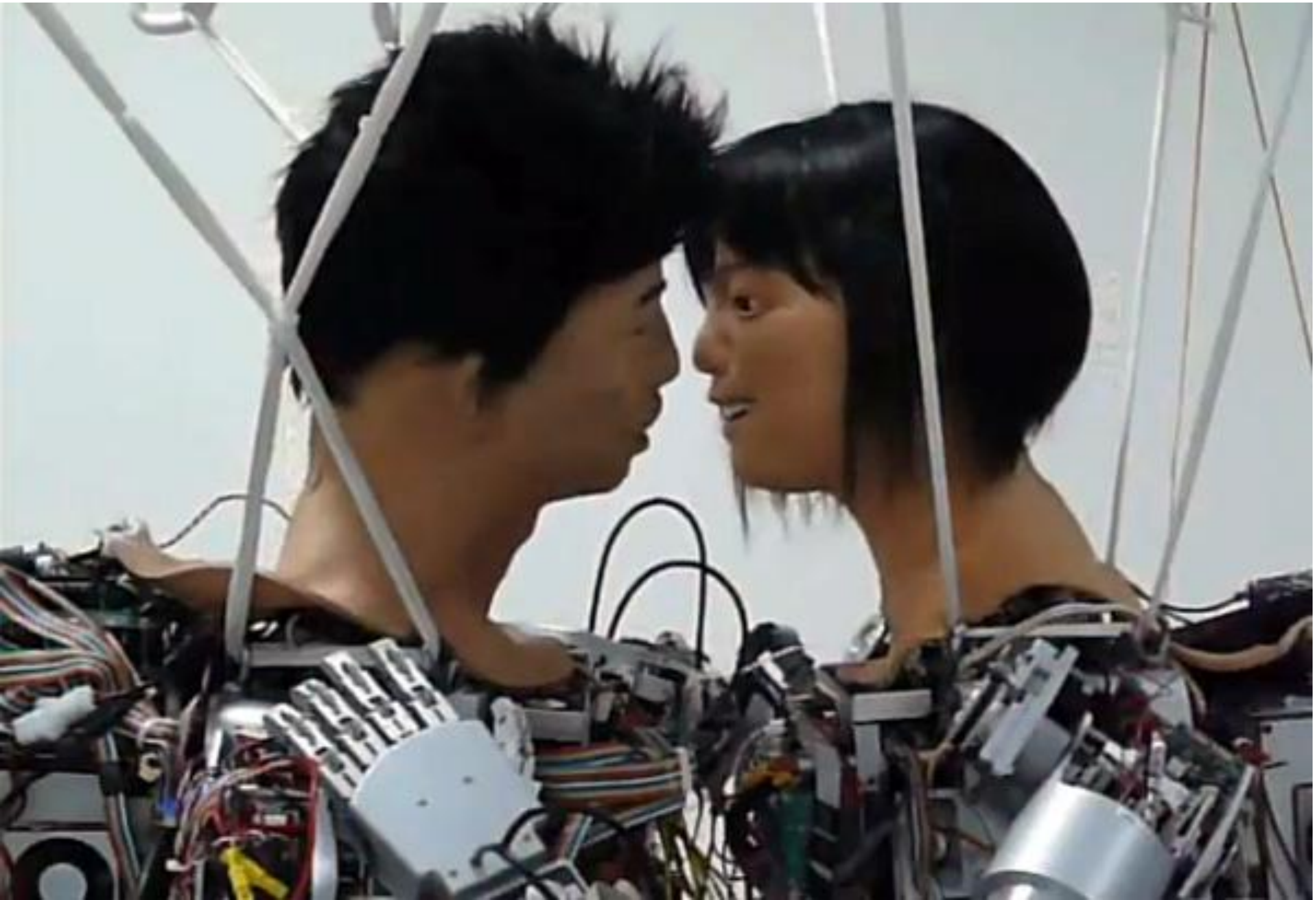
Taiwan casts robots in Phantom of the Opera



December 27th, 2008

- The University of Science and Technology in Taiwan's announced that they're putting on a very special performance of The Phantom of the Opera on December 27th, 2008, in which the two leads will be played by robots.
- The lead bots (named Thomas and Janet) can both walk, and have silicon facial "muscles" that help them mimic human expressions and mouth movements.

1. Our humanoid friends started engaging in public displays of affection.
2. Exhibit A: Thomas and Janet, two performance bots who made out publicly in front of hundreds during a December 2008 robotic production of "Phantom of the Opera" in Taiwan
3. A team at National Taiwan University of Science and Technology spent three years developing and programming the smooching bots, which with the help of servo motors that pull at the face and mouth



Robots – the musical,

May 1 – May 17, 2009

Barnabe Theatre in Servion, Switzerland

- It’s a musical that stars three autonomous robots developed by Bluebotics, a company that makes service bots. Ah, so there’s some promotion involved here

- The Japanese robotics market is currently valued at an estimated £4.9 billion (Y712.3billion)

- This is forecast to boom to £66billion (Y9.63 trillion) by 2030, according to the Japan Robot Association.

Robot Theatre Research at PSU

2001


Robotic Vision
System & Arm Control
...using the Rhino
Robotic Arm

Steve, Professor Perky and Normen at Intel's show.

2003

KAIST Hahoe Robot Theatre

The Hahoe Robot Theatre

Sonbi – the Confucian Scholar

Paekchong – the bad butcher

Yangban the aristocrat with Pune his concubine

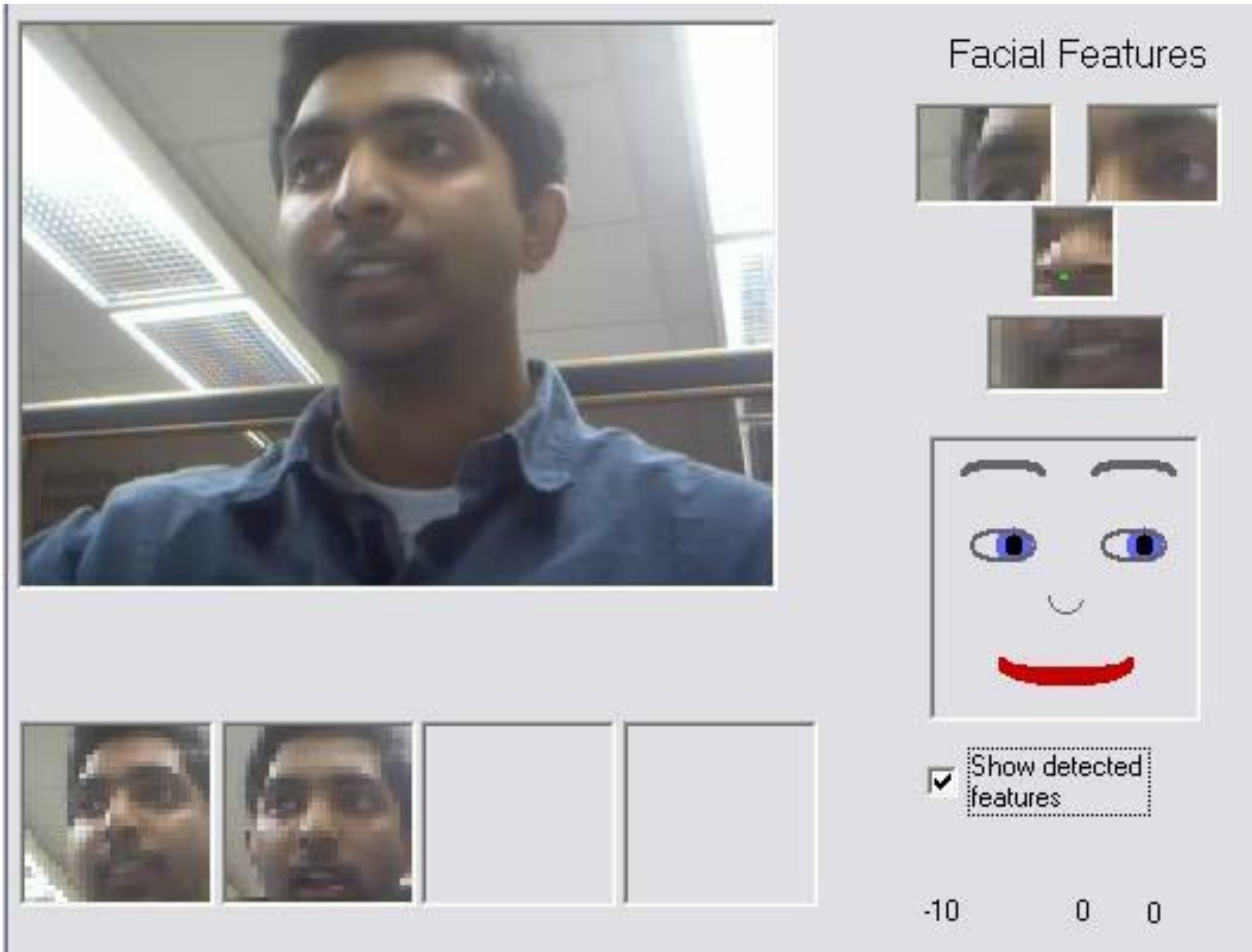
The interpreter robot without face skin

The same robot 2004, June

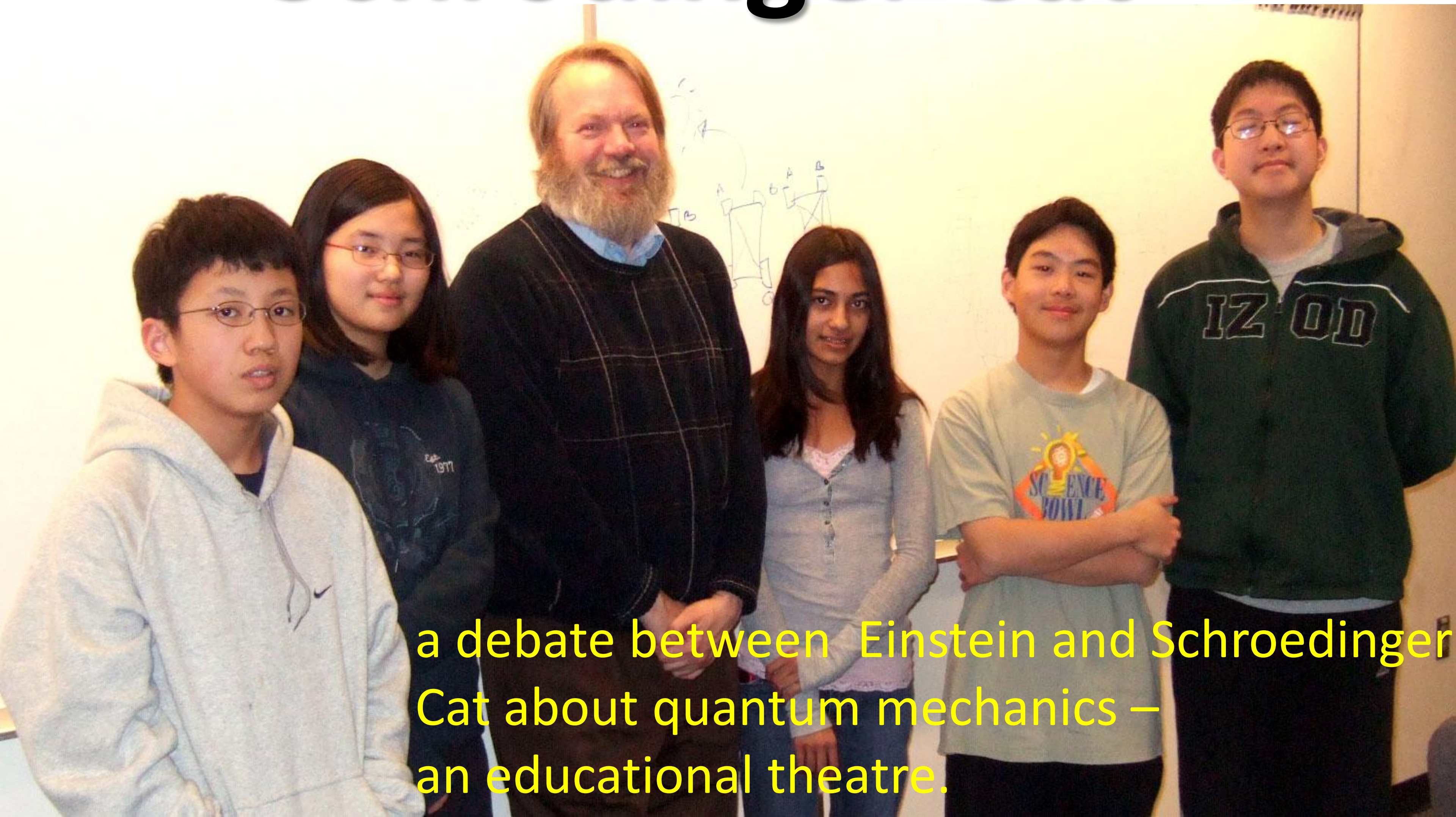
Hahoe Pyliyshyn, new head

Emotional Robot Head – the interpreter

Face features recognition and visualization.



2009 "What's That? Schrödinger Cat"



a debate between Einstein and Schroedinger Cat about quantum mechanics –
an educational theatre.

Improvisational Theatre "What's That? Schrӧdinger Cat"

Schrӧdinger Cat

Professor Einstein

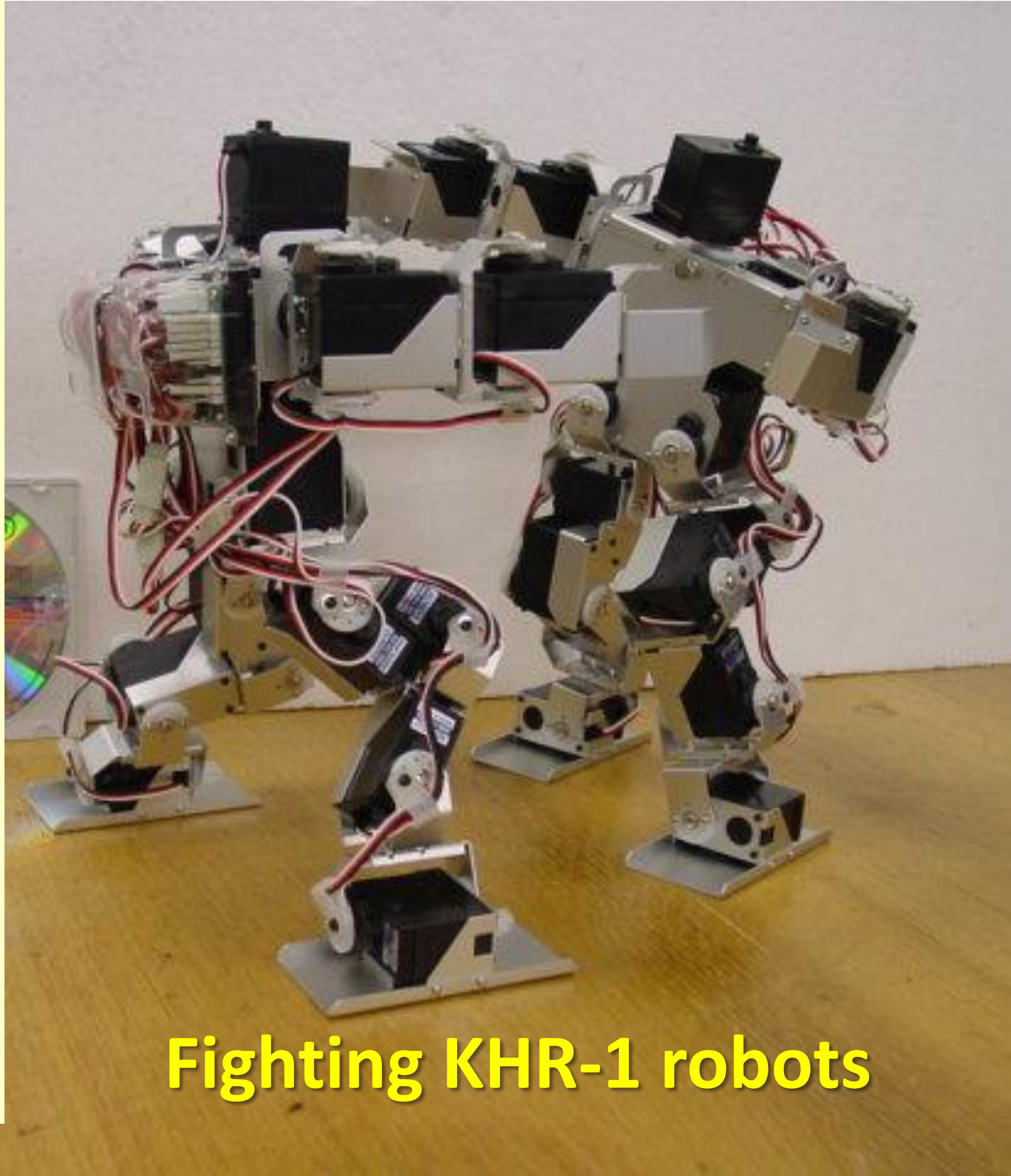
2010 - OUR RECENT BIPED THEATRE

New version of Hahoe
To be shown in 2010

KHR-1
iSOBOT
Lynxmotion Systems

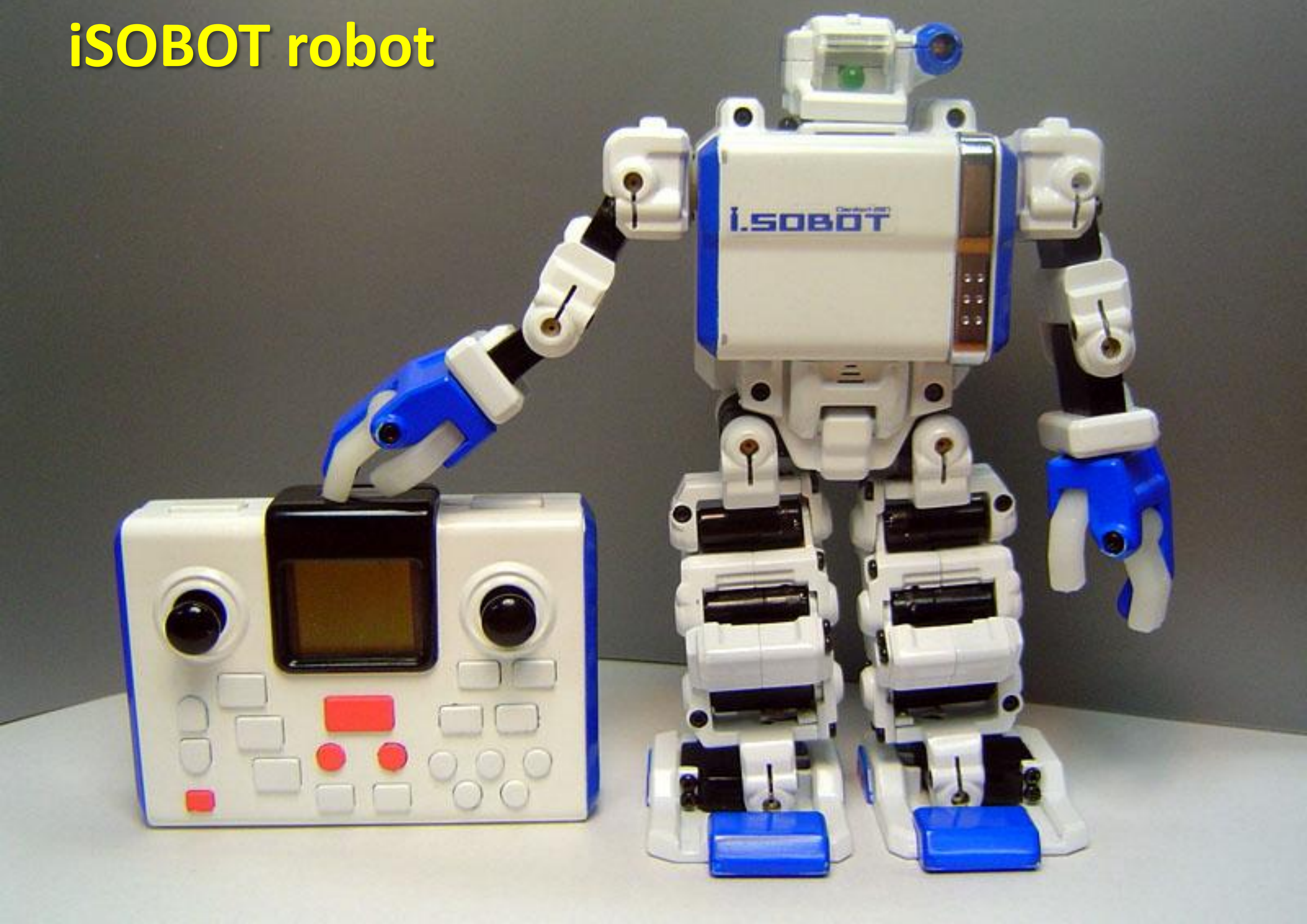
- **Walking biped robot can express the fullness of human emotions:**
  - **body gestures,**
  - **dancing,**
  - **jumping,**
  - **gesticulating with hands.**

- **Emotions can be:**
  - **Emergent - Arushi**
  - **Programmed – Martin Lukac ISMVL**
  - **Mimicked – ULSI**
  - **Learned – Martin Lukac Reed-Muller**



Fighting KHR-1 robots

iSOBOT robot



The stage of Portland Cyber Theatre in FAB building

Robot Theatre Research at PSU

Intelligent Robotics

Computer Vision

Computational Intelligence

Motion Generation

Robot theatre

Hough Transform for Radiation Therapy — Zhao, Hun

PCA for facial emotions — Labunsky

Emotional Robot — Lukac

Constructive Induction Architecture with Perception of emotions — Gebauer, Labunsky

Emotion Based Motion Generation — Sunardi

Common Robot Language for Humanoids — Lukac

Evolutionary generation of robot motions — Raghuvanshi

Robot Design : three theatres

KHR-1

KHR-1

iSOBOT

iSOBOT

The orchestra

The hexapod dancers

Improvisational Musical of small robots

The Narrator

Sonbi the Confucian Scholar

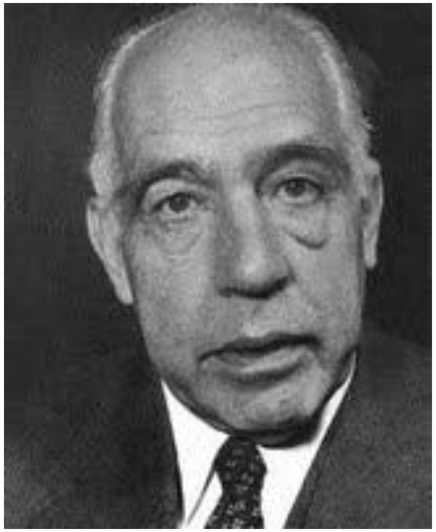
Pune the Courtisane

Paekchong the Butcher

Interactive Hahoe Theatre
Of Large Robots

Physics Debate
Theatre of medium robots

Dr. Niels Bohr



Professor Albert Einstein

Schroedinger Cat

What is robot theatre?

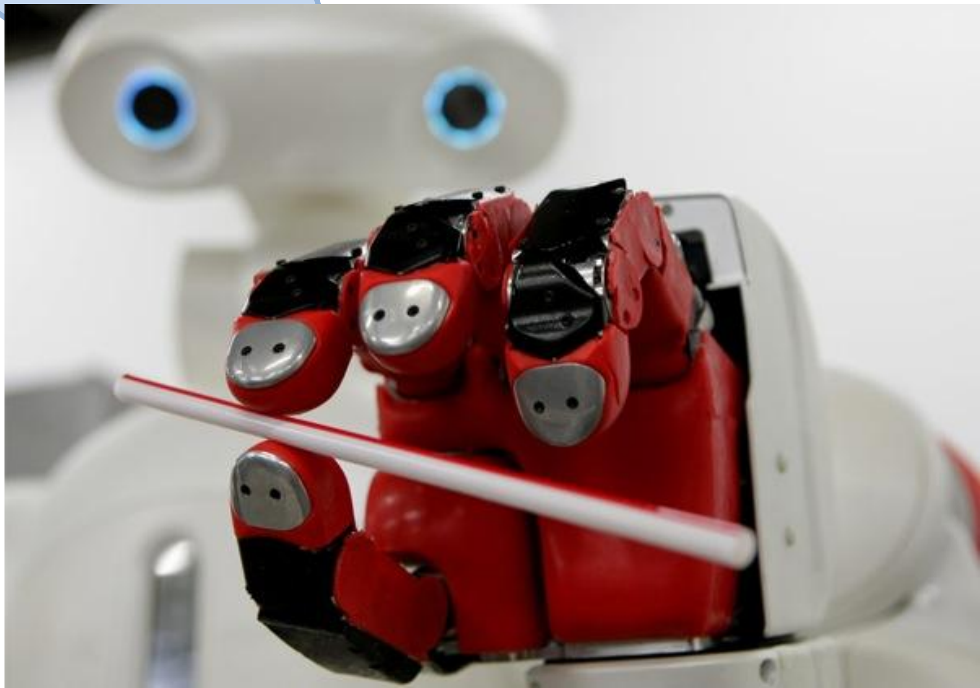
Theory of Robot Theatre?

1. Motion Theory:
   - Motions with symbolic values
2. Theory of sign
   - Creation of scripts, generalized events, motions to carry meaning
3. Robot theories that may be used:
   1. Machine Learning
   2. Robot Vision
   3. Sensor Integration
   4. Motion: kinematics, inverse kinematics, dynamics
   5. Group dynamics
   6. Developmental robots

Realizations of Robot Theatres

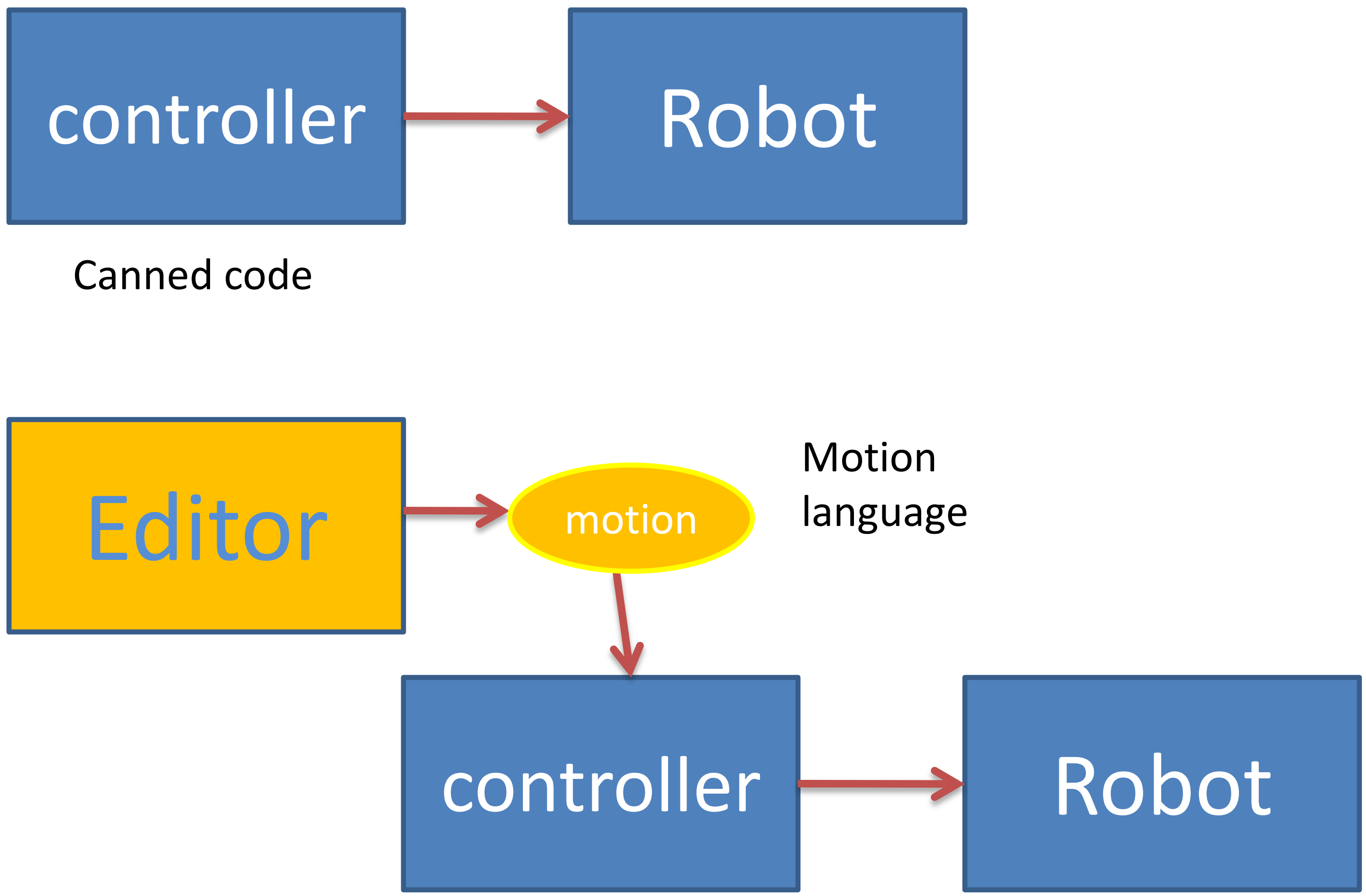
- Animatronic “Canned” Robot theatre of humanoid robots
  - Disneyworld, Disneyland, Pizza Theatre
- Theatre of mobile robots with some improvisation
  - Ullanta 2000
- Theatre of mobile robots and humans
  - Hedda Gabler , Broadway, 2008
  - Phantom in Opera, 2008
  - Switzerland 2009

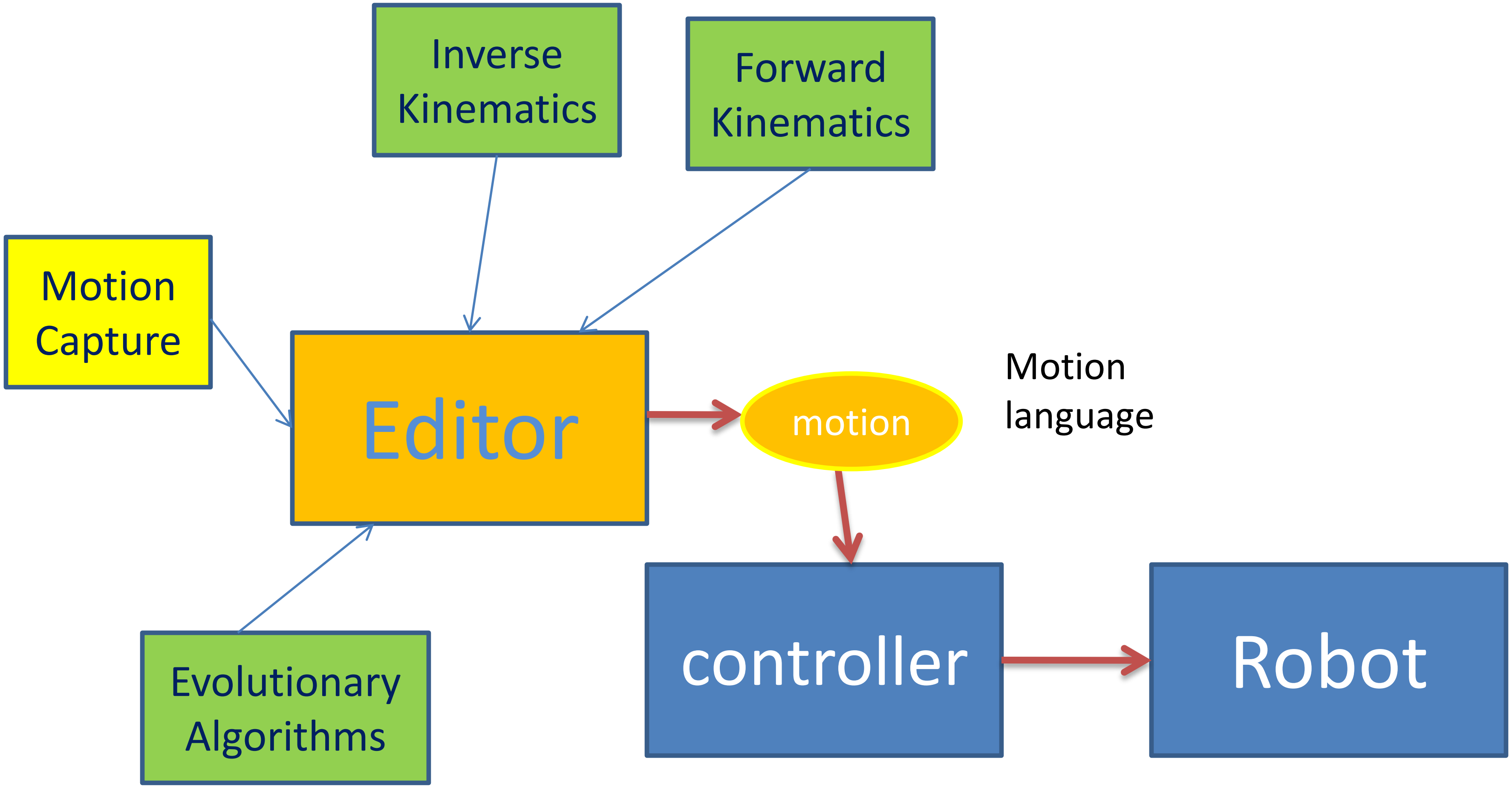
Models of Robot Theatre



Animatronic Theatre

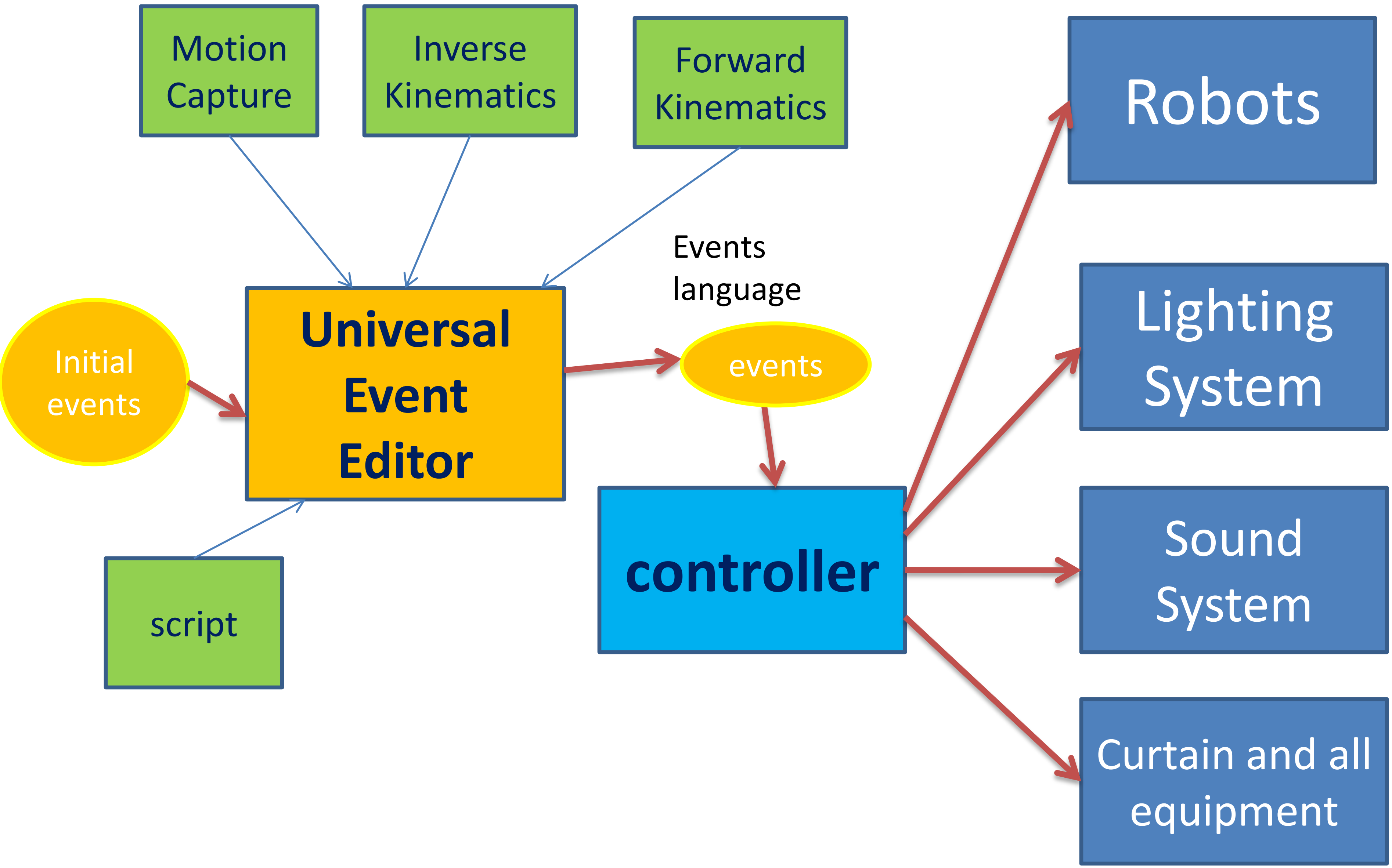
Actors: robots
Directors: none
Public: no feedback
Action: fixed
Example: Disney World


controller
Robot
Canned code
Editor
motion
Motion
language
controller
Robot



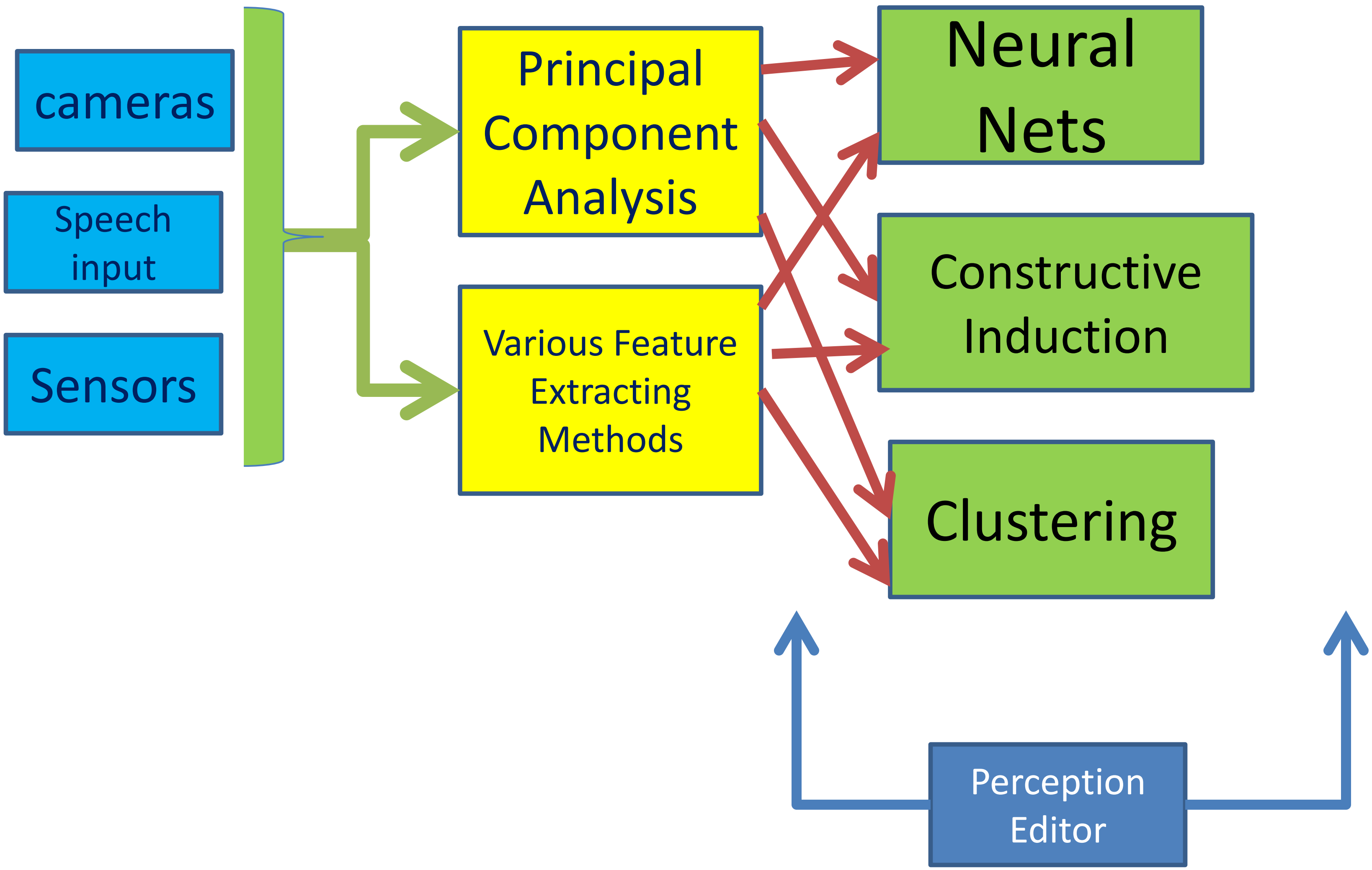
1. A very sophisticated system can be used to create motion but all events are designed off-line.
2. Some small feedback, internal and external, can be used, for instance to avoid robots bumping to one another, but the robots generally follow the canned script.

Universal Event Editor



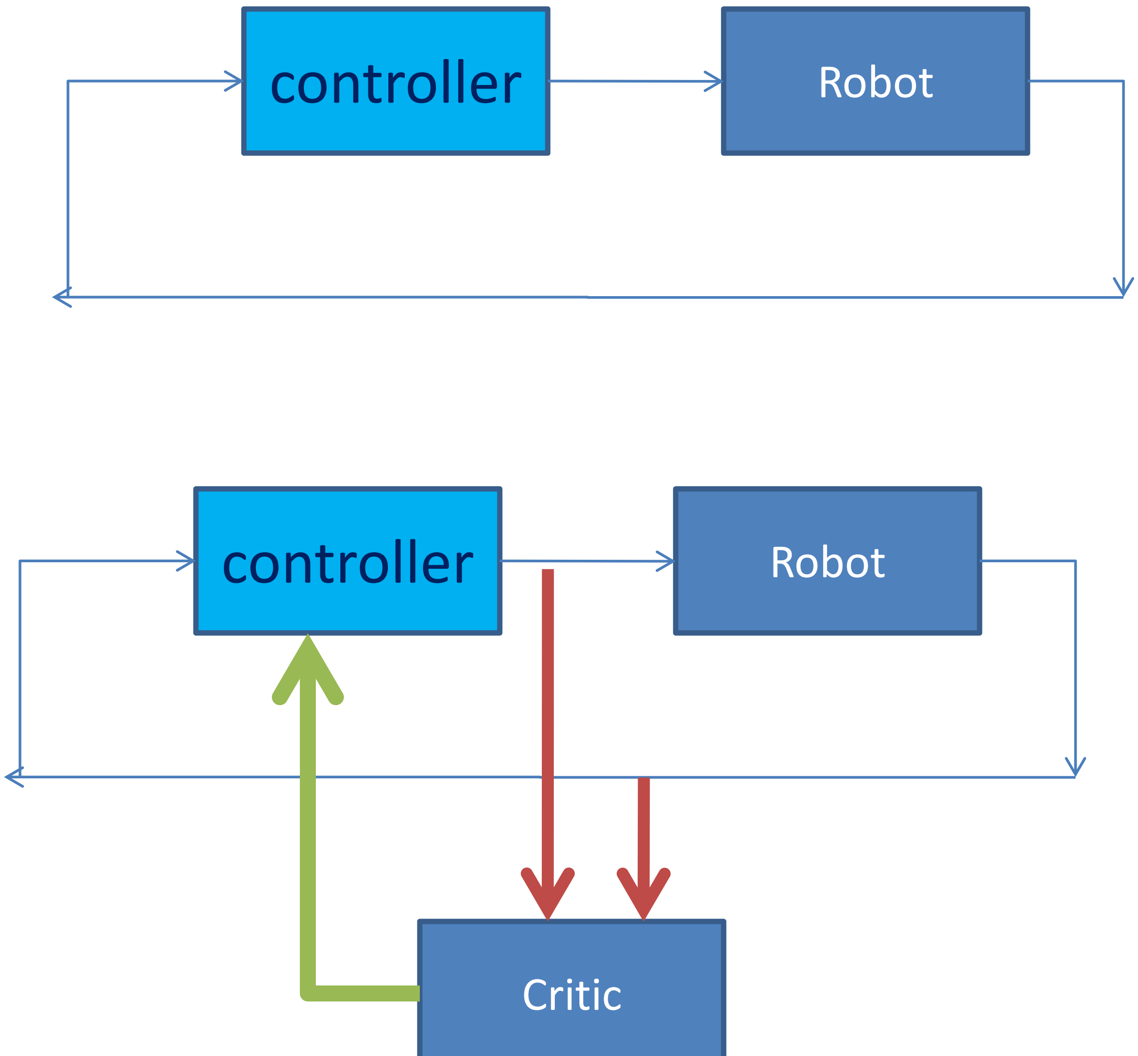
Universal Editors for Robot Theatre

Universal Perception Editor



Examples – input output pairs

Feedback from the environment

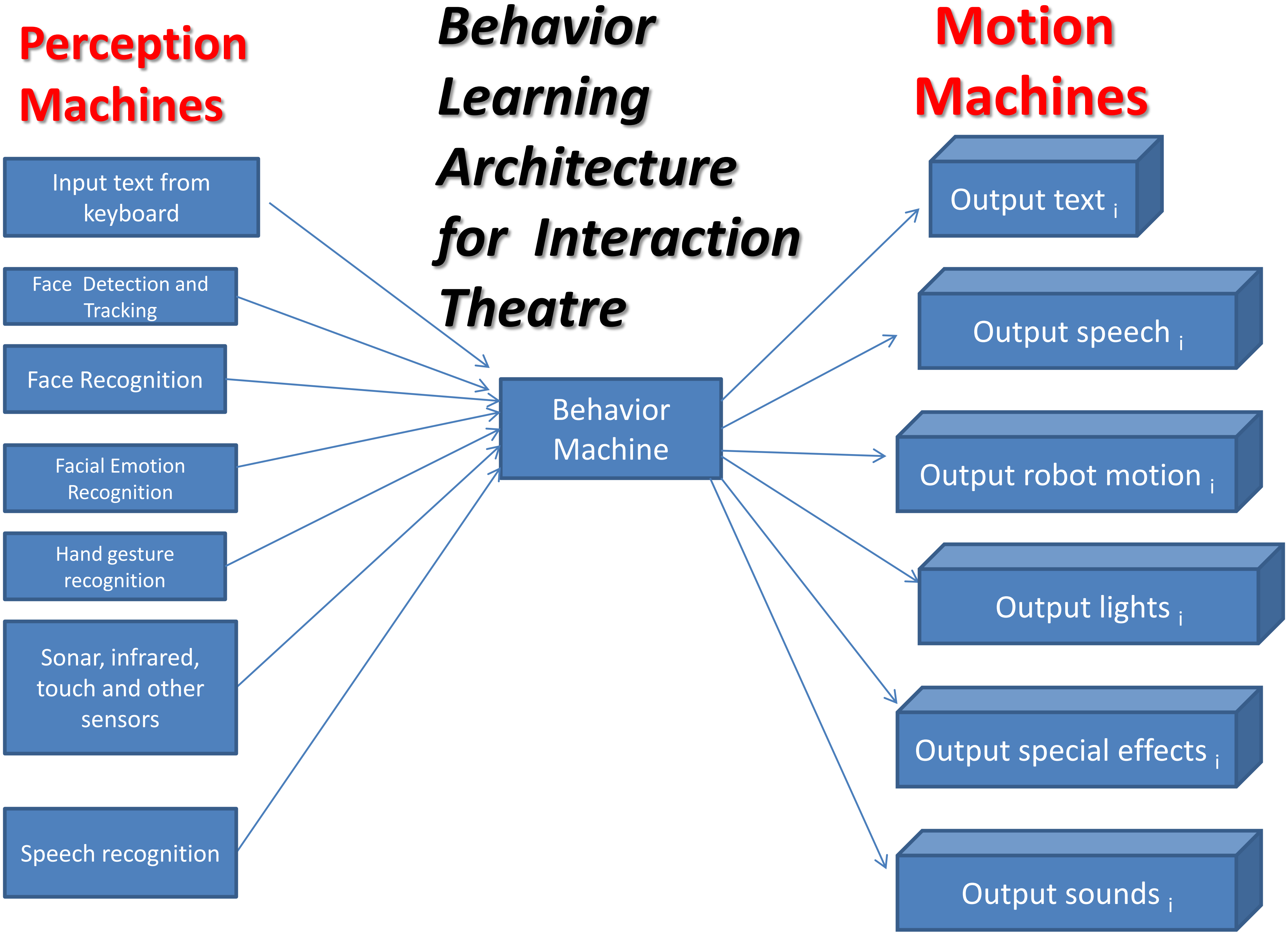


The environment includes:

1. Other robots
2. Human actors
3. Audience
4. The director

Interaction Theatre

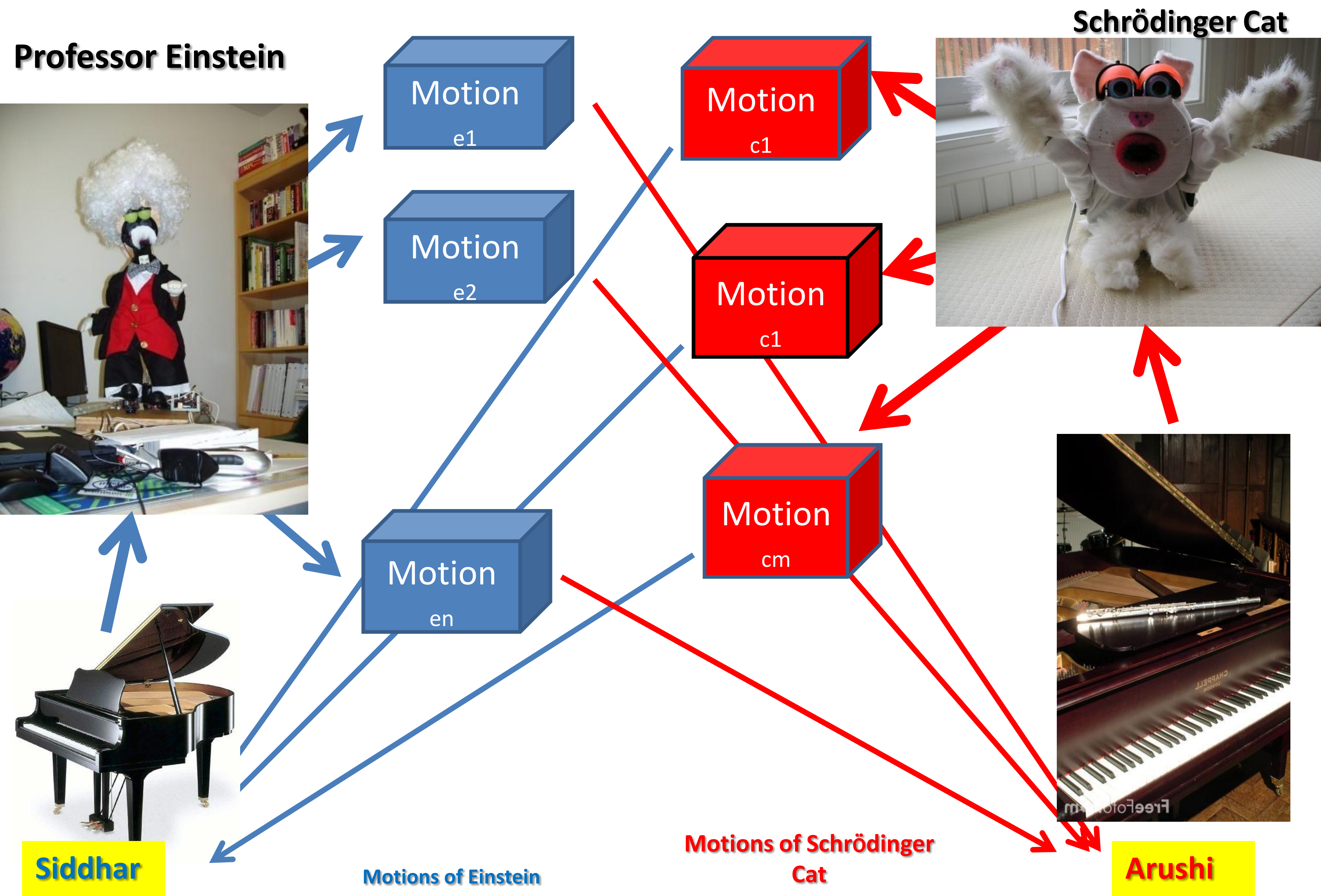
Actors: robots
Directors: none
Public: feedback
Action: not fixed
Example: Hahoe


Perception Machines
Behavior Learning Architecture for Interaction Theatre
Motion Machines
Input text from keyboard
Face Detection and Tracking
Face Recognition
Facial Emotion Recognition
Hand gesture recognition
Sonar, infrared, touch and other sensors
Speech recognition
Behavior Machine
Output text i
Output speech i
Output robot motion i
Output lights i
Output special effects i
Output sounds i

Improvisational Theatre

Actors: robots
Directors: humans
Public: no feedback
Action: not fixed
Example: Schrödinger Cat

Improvisational Theatre "What's That? Schrödinger Cat"



Theatre of Robots and Actors (contemporary)

Actors: robots
Actors: humans
Directors: humans
Public: traditional feedback, works only for human actors
Action: basically fixed, as in standard theatre

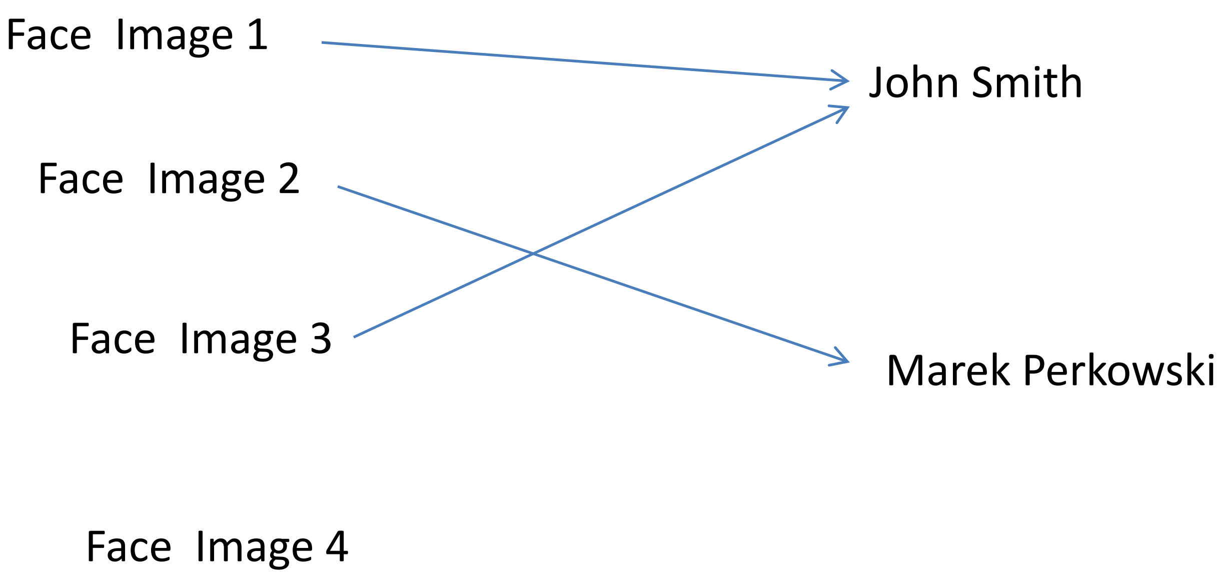
Theatre of Robots and Actors (future)

Actors: robots
Actors: humans
Directors: humans **+ universal editors**
Public: traditional feedback, like clapping, hecking, works for both robot and human actors
Action: improvisational, as in standard improvisational theatre

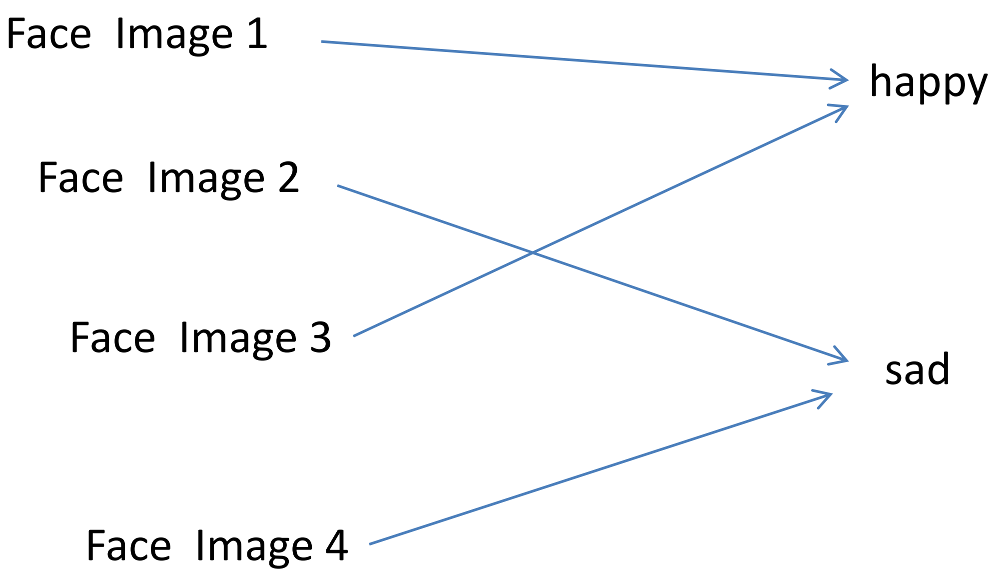
Research Topics in Robot Theatre

Perception

Face Recognition as a learning problem



Face Emotion (Gesture) Recognition as a learning problem



Face	person

Recognition Problems = Who? What? How?

Face	person
Face	emotion
Face	age
Face	gender
Face	gesture

Learning problems in Human-Robot Interaction – Perception problems

Motion

Mouth Motion	text
Hexapod walking	Distance evaluation
Biped walking	Number of falls evaluation
Biped Gestures	Comparison to video evaluation
Hand gestures	Subjective human evaluation

Motion Problems = examples of correct motions – generalize and modify, interpolate

Learning problems in Human-Robot Interaction – Motion Generation problems

The concept of generalized motions and universal event editor to edit:

- robot motions,
- behaviors,
- lightings and automated events

Languages to describe all kinds of motions and events

- Labanotation
- DAP (Disney Animation Principles) and
- CRL (Common Robot Language)

Theory of Event Expressions

- Tool to design motions directly from symbols.
- This theory is general enough to allow arbitrary motion to be symbolically described but is also detailed enough to allow the designer or the robot to precise the generated behavior to the most fundamental details.
- Our main concept is that the motion is a sequence of symbols, each symbol corresponding to an elementary action such as shaking head for answering “yes”.
- We will call them primitive motions.
- The complex motions are created by combining primitive motions.

- What are the factors of motion that are important to generation of symbolic motions, especially in dance and pantomime?
- The research issues are:
  - **(1)** What should be the primitive, basic or atomic motions?
  - **(2)** What should be the operations on motions that combine primitive motions to complex motions?
  - **(3)** How symbolic motions are reflected/realized as physical motions of real robots?
  - **(4)** How to create existing and new symbolic motions automatically using some kind of knowledge-based algebraic software editor.

- Human-robot emotion-augmented communication systems.
- The new extended communication media in addition to:
  - speech
  - will include prosody
  - facial gestures
  - hand gestures
  - body language
    - head and neck,
    - legs,
    - bending of full body,
    - muscle-only motions

  - The gestures used in daily communication,
  - ritual gestures of all kinds,
  - theatric and
  - dance motions

- will be captured or translated to certain algebraic notations.

- <u>the same grammar</u>.
- The unified notations will allow also to transform between various media.
- For instance, a captured motion of a flower can be presented as motion of a pantomime actor.
- A sound pattern can be transformed to a pattern of colored laser lights.
- Sound, light, theatric stage movements, special effects and robot motions have all the same nature of sequences of symbolic event-related atoms.
- Thus the theater itself becomes a super-robot with the ability to express its emotional state through various motions, lights and theater plays orchestration.
- These sequences can be uniformly processed.
- We propose to create <u>universal editors</u> that will be not specialized to any particular medium or robot.
- They will use algebraic and logic based notations.

on-line versus off-line creation of motions

- Film is an art that does not require feedback from the audience and every presented event is always exactly the same.
  - Creation has been done earlier, off-line with the director and his associates as the audience during shooting and editing.

- In contrast, the theatre performance is always slightly different and it depends on the feedback from the audience.
- The public may say “Actor X had a good day today”.
- The research questions are:
  - (1) “will the future robot theatre be more similar to films or theatrical performances?”,
  - (2) “can one create a realistic robot theatre without viewer’s feedback?”
  - (3) “What type of tools do we need to create a theater play off-line versus on-line?”,
  - (4) “Is an off-line sequence generator enough to create art?”
  - (5) “Do we need a sequence generator <u>and</u> a virtual reality simulator before actuate the play on the robot”?
  - (6) “How really important is the feedback from the audience for a human singer or conference speaker to modify their on-stage behaviors? a

- How it should be reflected in the on-line robot theatre?
- Should we have a “character” of each robot simulated together with the performance?
  - (So that a shy robot should run from the stage if it is booed.
  - A strong robot should remain.
  - But maybe the shy robot will know much better how to express the meaning of the play.)

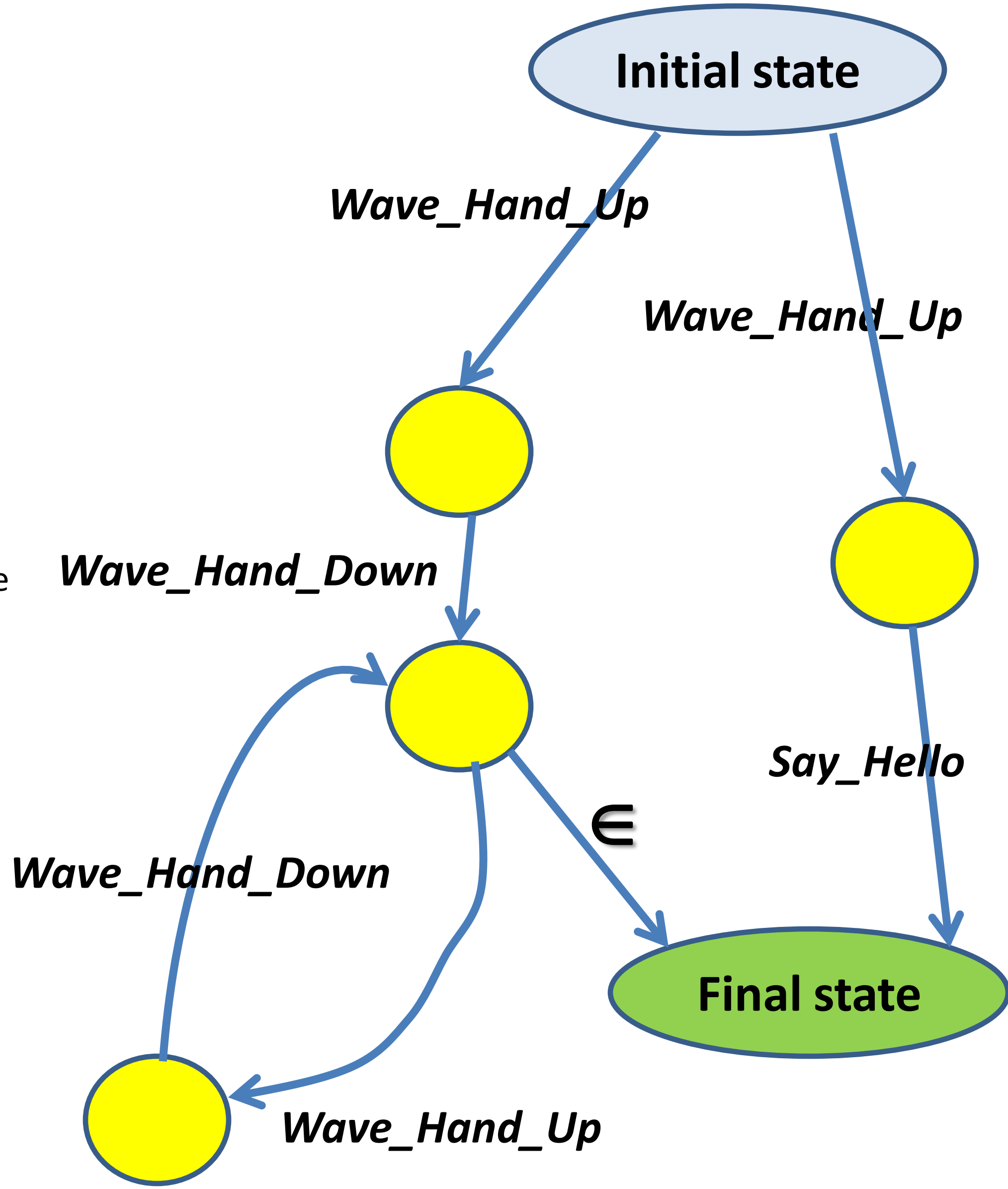
- In general, do we need a “character” to use the feedback from audience or should be this simulated otherwise?”

Event Expressions to specify languages of motions and behaviors

- A *regular expression* is a pattern that matches one or more strings of characters from a finite alphabet.
- Individual characters are considered regular expressions that match themselves.
- Original regular expressions used union, concatenation and iteration operators.
- Regular expressions were next extended by adding negation and intersection to a Boolean Algebra.
- Observe that $X_1 \cap X_2$ is an empty set for atoms $X_1 \neq X_2$, as the meaning of intersection operator is set-theoretical.
- Similarly the interpretation of $\cup$ operator is set-theoretical in regular expressions, thus new symbols are not being created.

- ***Greeting_1 = (Wave_Hand_Up ^{o} Wave_Hand_Down) (Wave_Hand_Up ^{o} Wave_Hand_Down)*** * $\cup$ ***Wave_Hand_Up*** ^{o} ***Say_Hello***

- Which means, to greet a person the robot should execute one of two actions:
  - Action 1: wave hand up, follow it by waving hand down. Execute it at least once.
  - Action 2: Wave hand up, next say "Hello". The same is true for any complex events.
- As we see, the semantics of regular expressions is used here, with atomic symbols from the terminal alphabet of basic events {***Wave_Hand_Down, Wave_Hand_Up , Say_Hello***}.
- The operators used here are: concatenation (^{o}), union ($\cup$) and iteration (*). Each operator has one or two arguments.
- So far, these expressions are the same as regular expressions.



Extending to Event Expressions

- They are now expanded to <u>event expressions</u> by recursively adding more deterministic and probabilistic operators on event expressions
- For instance, if we agree that the meaning of every operator in ***Greeting_1*** is that it executes its first argument with probability ½ and its second argument with the same probability, each possible sequence from the infinite set of motions of ***Greeting_1*** will have certain probability of occurrence.
- One can create event expressions using both deterministic and probabilistic, single-argument and two-argument operators.

Event Expressions to specify languages of motions and behaviors

- The base ideas of event expressions are these:
  - **(1)** Symbol (represented by sequence of characters) is a basic event or a set of basic events synchronized and executed in parallel.
  - **(2)** Symbols can be connected in parallel (for instance, *(a)* text spoken, *(b)* leg motion, and *(c)* hand motion can be created relatively independently and combined in parallel). Connecting symbols in parallel creates new symbols that can be used as macros

- For instance, assuming that concatenation is a deterministic operator and union is a probabilistic operator with equal probabilities of both arguments, there is a probability of ½ that the robot will greet with motion ***Wave_Hand_Up º Say_Hello*** .

- Assuming that all operators are probabilistic operators with equal probabilities of both arguments, for event expression ***Wave_Hand_Up º Say_Hello*** there is a probability of ½ that the robot will greet with one of the following four motions, each with the same probability:
  - **(1)** ***Wave_Hand_Up º Say_Hello*** ,
  - **(2)** ***Wave_Hand_Up ,***
  - **(3)** ***Say_Hello ,***
  - **(4)** Nothing will happen.

Extending to Event Expressions

- As we see, in this case for each of two arguments of concatenation there is the probability of ½ that it happens and probability of ½ that it does not happen.
- Similarly, the user of the editor can use many operators, deterministic or probabilistic to define event expressions.
- Several such operators are created for any standard operator of regular expression.
- Next, the user can define his/her own new operators.
- These operators can have <u>temporal, multiple-valued and probabilistic/deterministic nature.</u>
- Our system of Event Expressions and corresponding state machines uses an expanded set of operators taken from multiple-valued logic; <u>literals, MAX, MIN, truncated-sum, Modulo-addition</u> and others.
- The symbols are interpreted as having numerical values for them.
- This allows also for interpolation (Hermite, Spline, Radial Basis) and spectral operators based on Fast Fourier Transform (FFT).

Brzozowski's derivatives

- All words of *E*, starting from letter $X_j \in X$. If the letter is removed from the front of each word from the set, a new language is created, referred to as left-side-derivative of language *E* by letter X_j.

- This new language is now denoted by E/X_j.

- A **derivative for word s** = $X_{i1}, X_{i2} \ldots X_{in}$ is defined as follows:

  $$E/X_j = \{s \in X^* : X_j s \in E\}.$$

- As inherent laws of Brzozowski's derivative method, the following properties $\mathbf{P_i}$ always hold true.

Recursive Rules for PMG design

- **P1.** $X_i/X_j = e$ for $i = j$
- $= \emptyset$ for $i \neq j$
- **P2.** $(E_1 \cup E_2)/X_i = E_1/X_i \cup \in E_2/X_i$
- **P3.** $\in(E) = e$ when $e \in E$
- $= \emptyset$ when $e \notin E$
- **P4.** $E_1E_2/X_i=(E_1/X_i)E_2 \cup \in (E_1)(E_2/X_i)$
- **P5.** $E/s=E_1/X_{i1}X_{i2}\ldots X_{in}=[[E/X_{i1}]/X_{i2}]\ldots]/Xi_n$
- **P6.** $E^*/Xi = (E/X_i)E^*$
- **P7.** $E/e = E$
- **P8.** $(E_1 \cap E_2)/X_i = (E_1/X_i) \cap (E_2/X_i)$
- **P9.** $(-E)/X_i = -(E/X_i)$
- **P10.** $(E_1 \max E_2)/X_i = (E_1/X_i) \max (E_2/X_i)$
- In our system there are many other rules similar to rule P10 for MIN, MAX and other **MV operators**.
- There are many rules similar to P9 for literals and rules similar to P8, P2, P6 and P4 for probabilistic variants of operators $\cap$, $\cup$, and concatenation, respectively

Example of designing PMG from Event Expression

- Language is given $E_1 = (X_2X_1^* \cup X_1X_2)$.
- Applying the left-side-derivative with respect to first character in string, X_1

$E_1/X_1 = (X_2X_1^* \cup X_1X_2)/X_1$

$= (X_2X_1^*)/X_1 \cup (X_1X_2)/X_1$

by P2

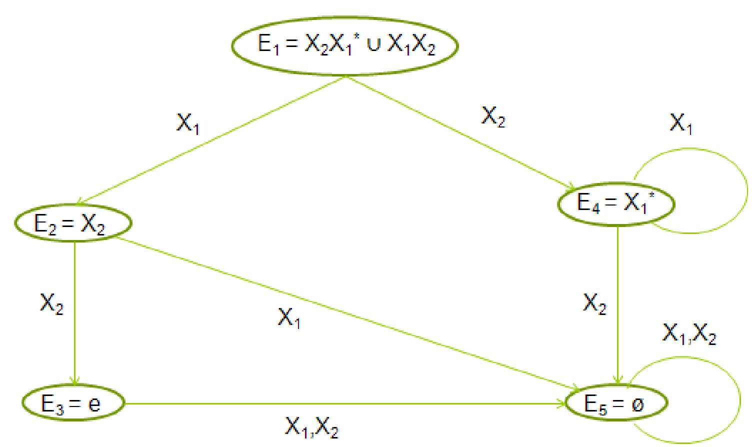
$= (X_2/X_1)X_1^* \cup \in (X_2)X_1{*} \cup (X_1/X_1)/X_2 \cup \in (X_1)(X_2/X_1)$

by P4

$= ø\ X_1 \cup ø(X_1/X_2) \cup eX_2 \cup ø\ ø$

by P1

$= X_2$



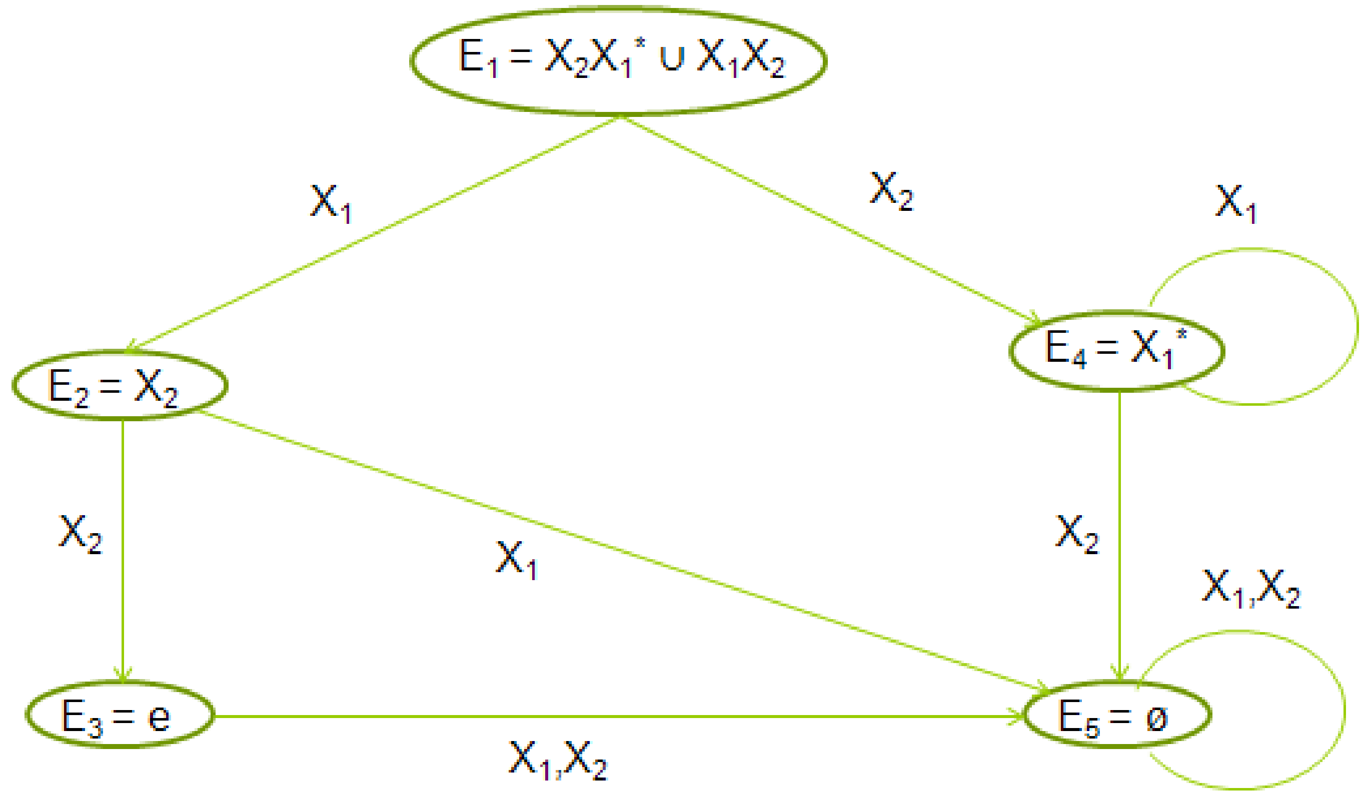


Fig. 2. Graph for regular language

$$E_1 = (X_2X_1^* \cup X_1X_2).$$

It can be interpreted as PMG, EEAM or BM depending on meaning of symbols X_i

Acceptor, generator and transformer

- Observe that this graph can be interpreted as an acceptor, when symbols Xi are inputs.

- It can be interpreted as a generator when symbols Xi are outputs.

- The graph can be thus used to recognize if some motion belongs to some language and can generate a motion belonging to the language.

- This graph is realized in software

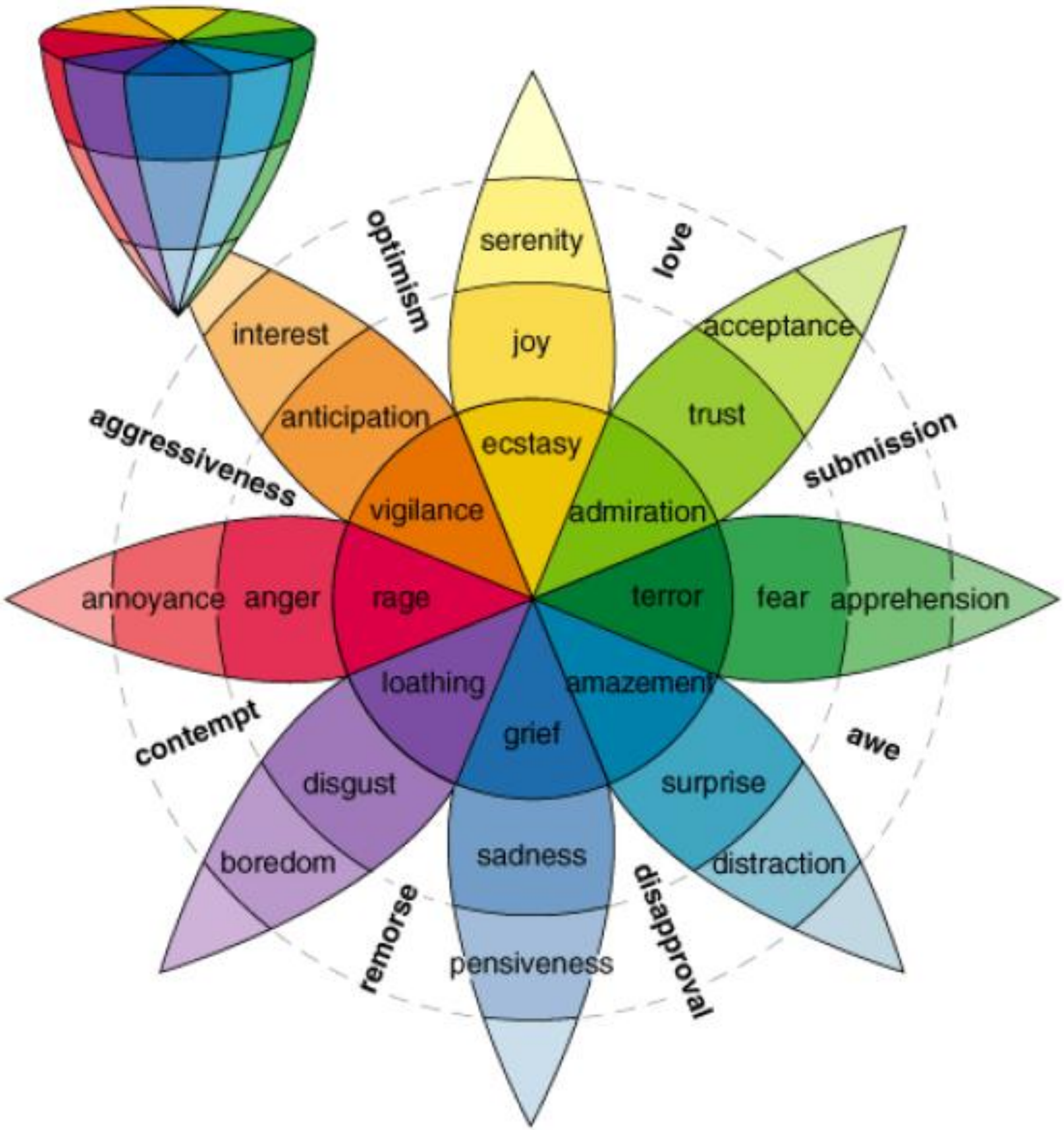
Input text	Output text
Hexapod walking	Distance evaluation
Biped walking	Number of falls evaluation
Biped Gestures	Comparison to video evaluation
Hand gestures	Subjective human evaluation

Behavior Problems = examples of correct motions – generalize and modify, interpolate

Learning problems in Human-Robot Interaction – Motion Behavior (input/output) generation problems

Emotional Robot

Figure 9.2 Plutchik Emotional Model



Emotion Recognition versus Emotion Generation

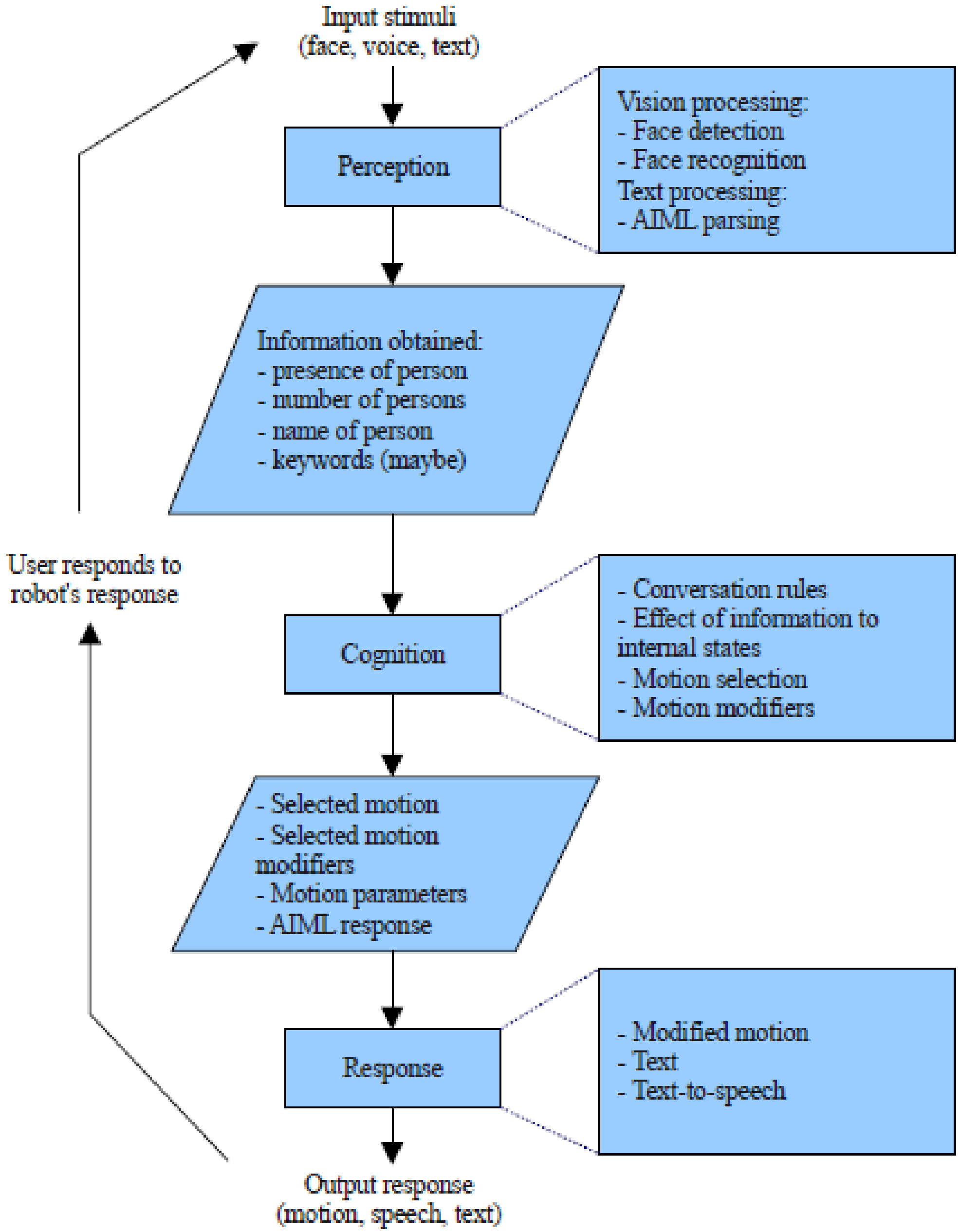
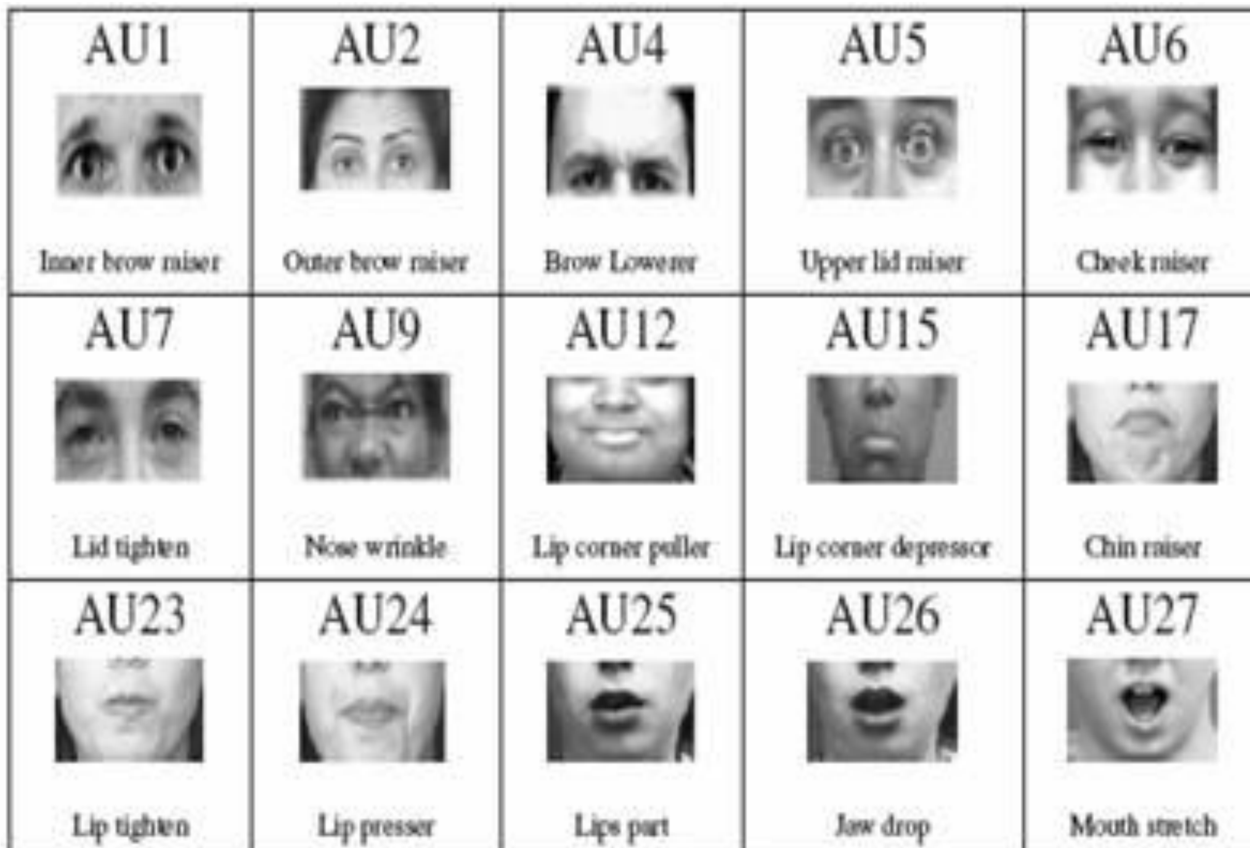


Figure 8.2. Information and processes in the algorithm.

Recognizing Emotions in Human Face



PCA + NN software of Labunsky

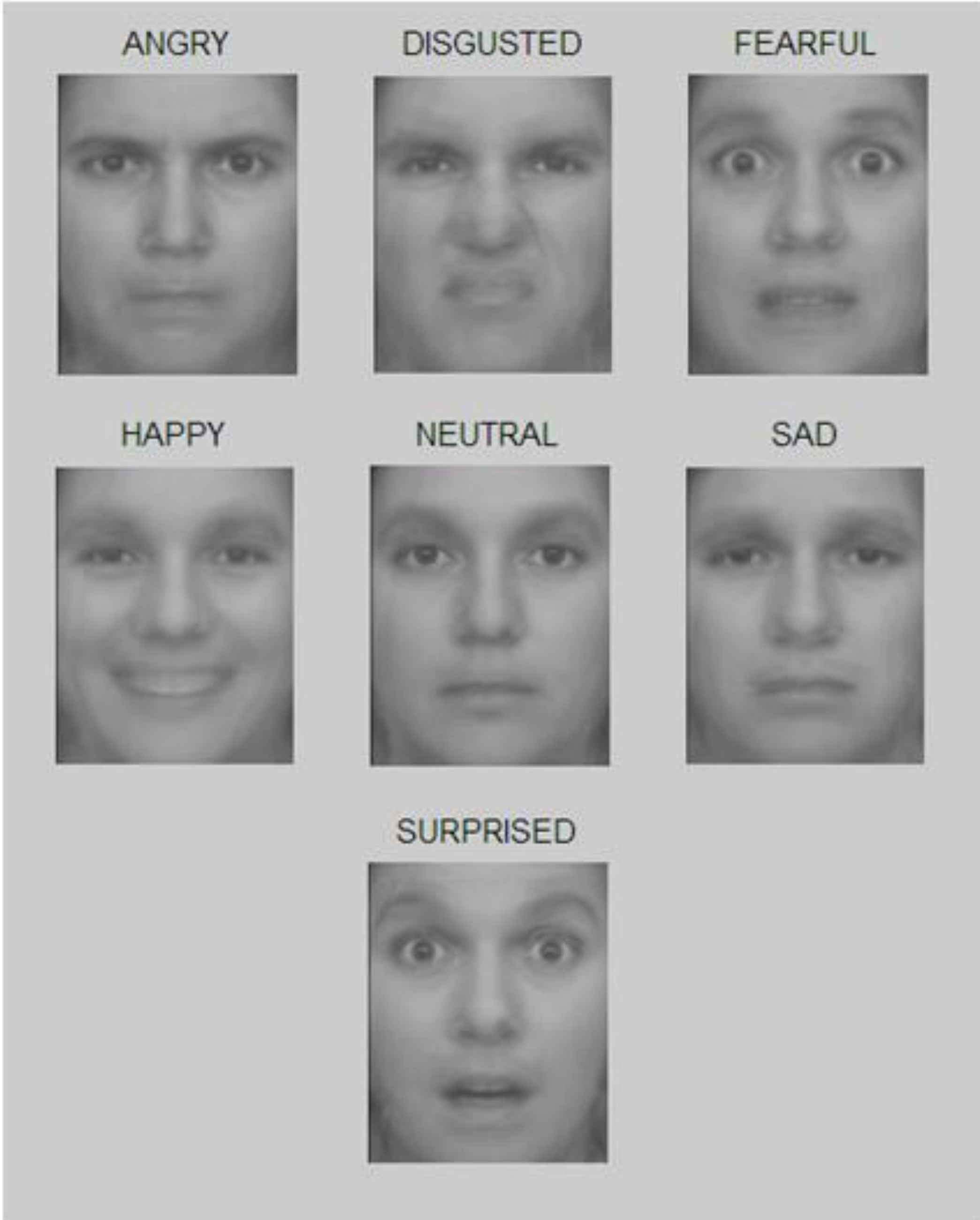


Figure 4.6 – Seven Average Emotions.

Figure 5.2 – ERS User Interface with 100% Accurate Detection.

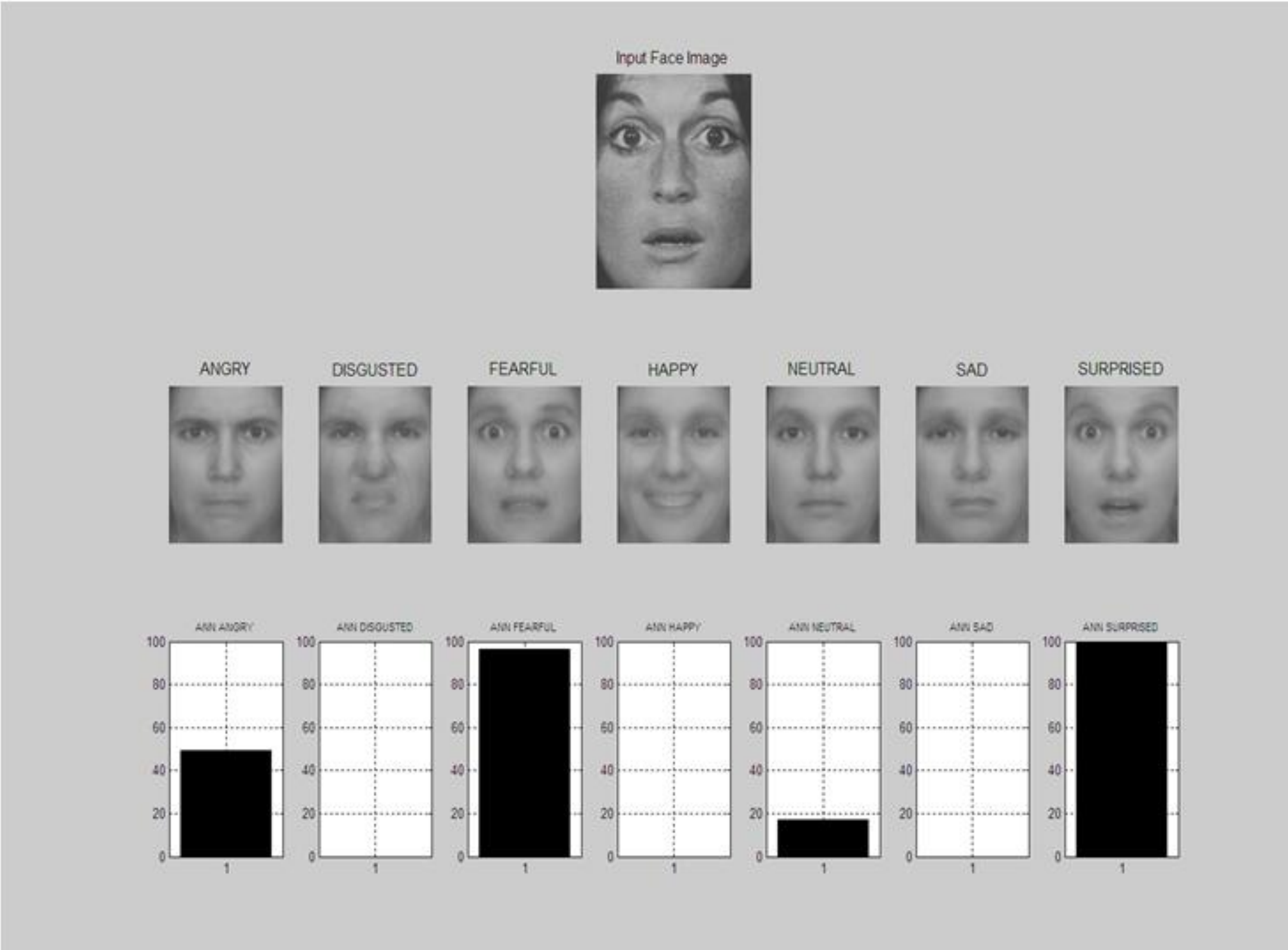
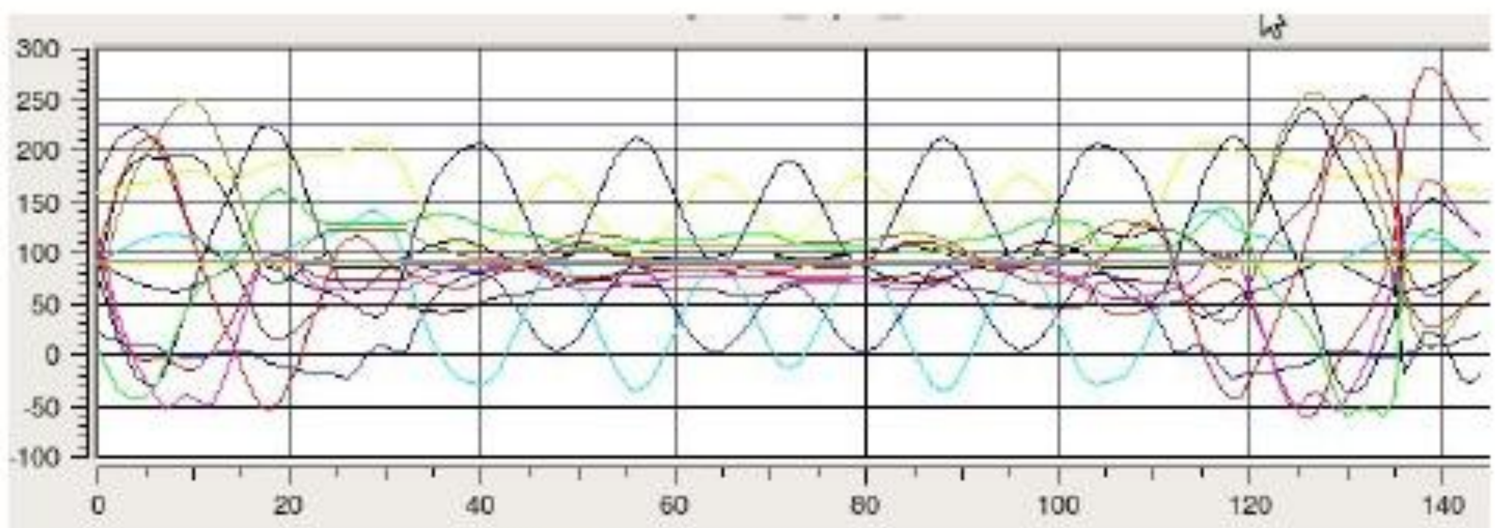


Figure 5.3 – ERS User Interface with Mixed Percentage Detection.

Generating Emotional Motions



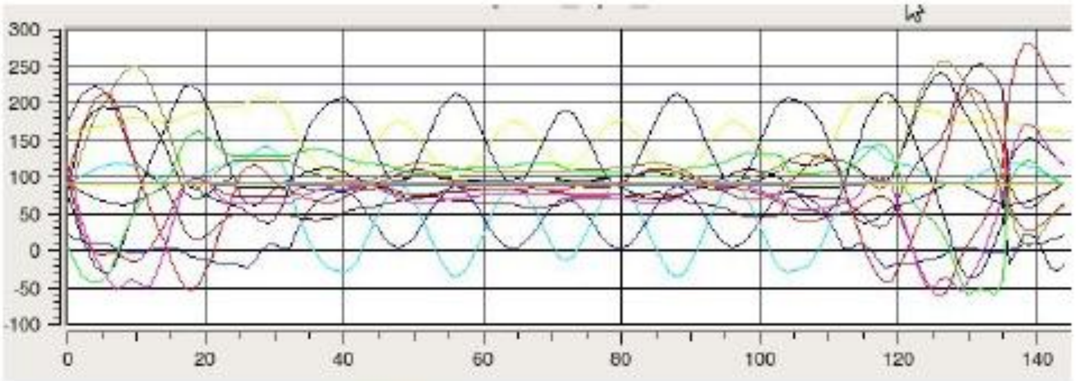
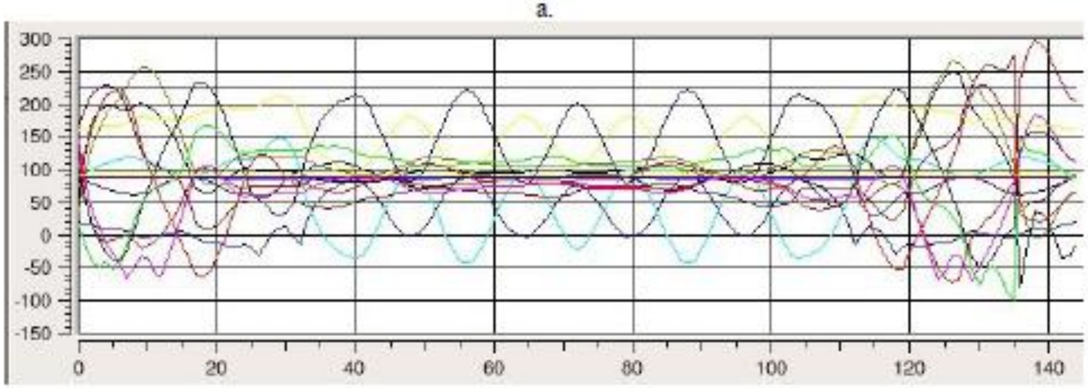


Figure 9.4 Original motion signal

a.



b.

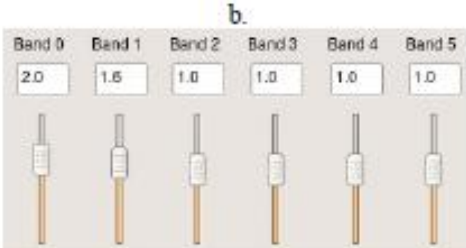
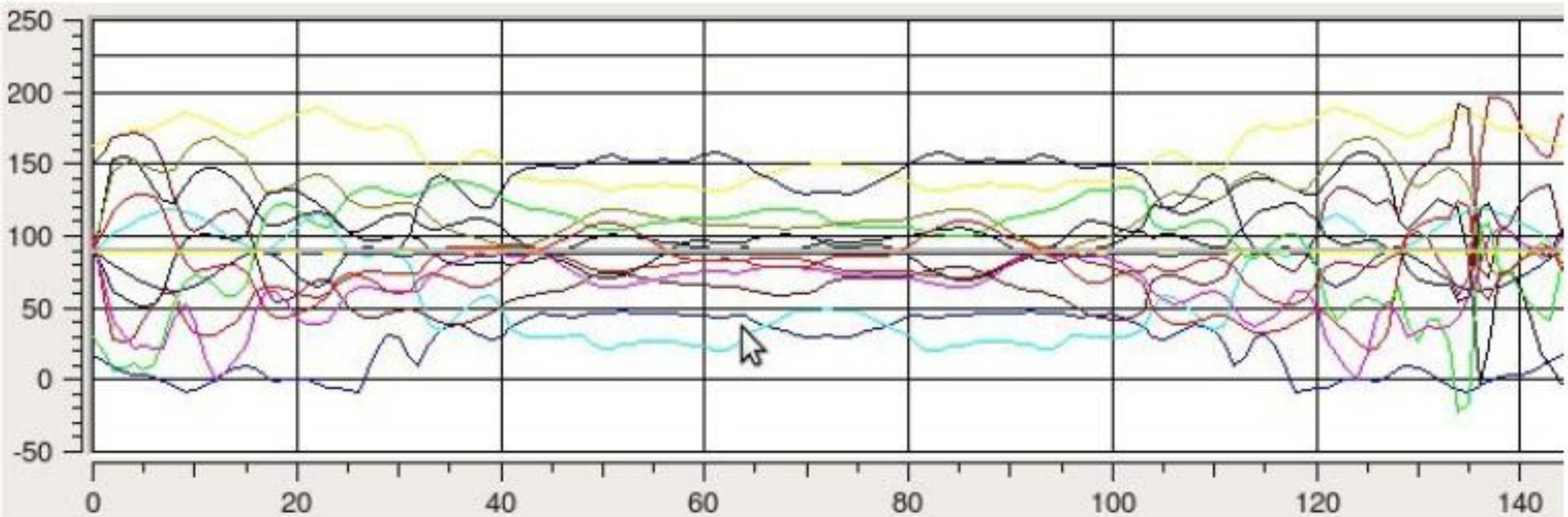


Figure 9.5 a) Increased high frequency components gains, b) Gains settings

- Spectral filtering
- Matched filters
- Hermite interpolation
- Spline Interpolation
- Wavelets
- Repetitions
- Mirrors



a.

b.

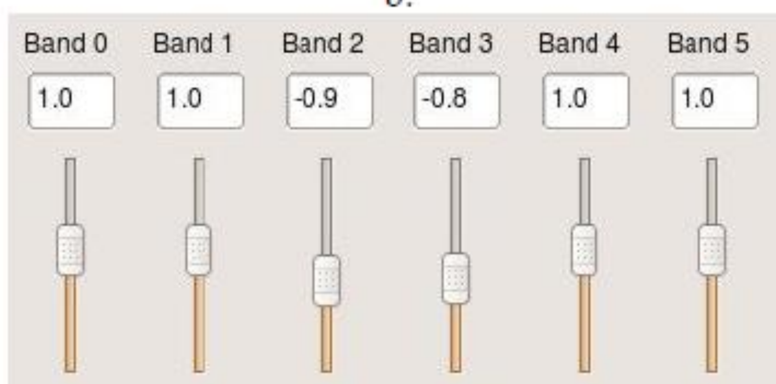
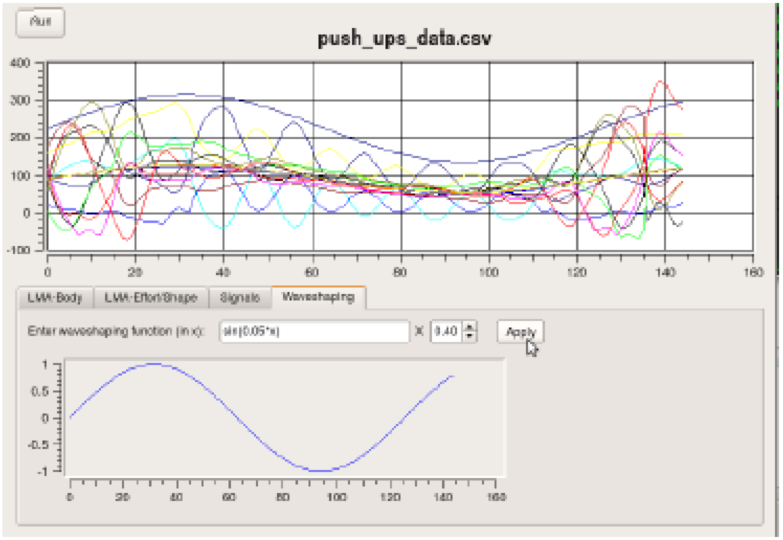
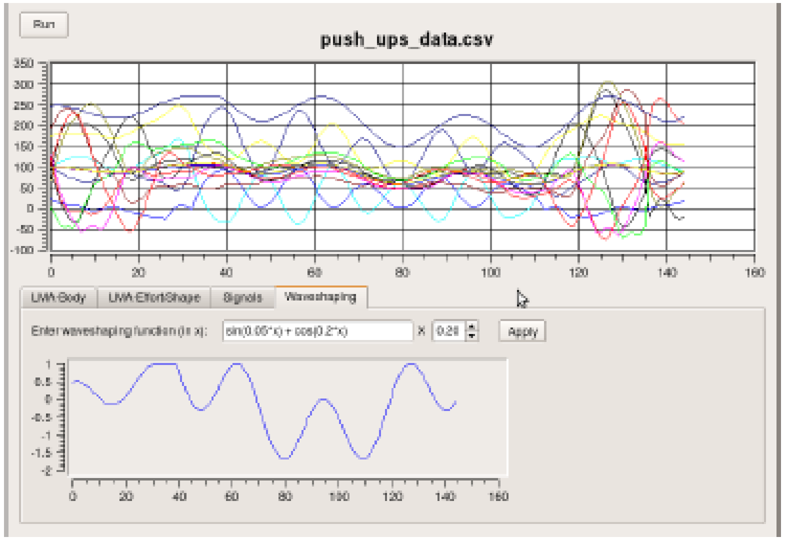


Figure 9.8 a) Reduced middle frequency gains, b) Gains settings



Editor of waveforms

c.



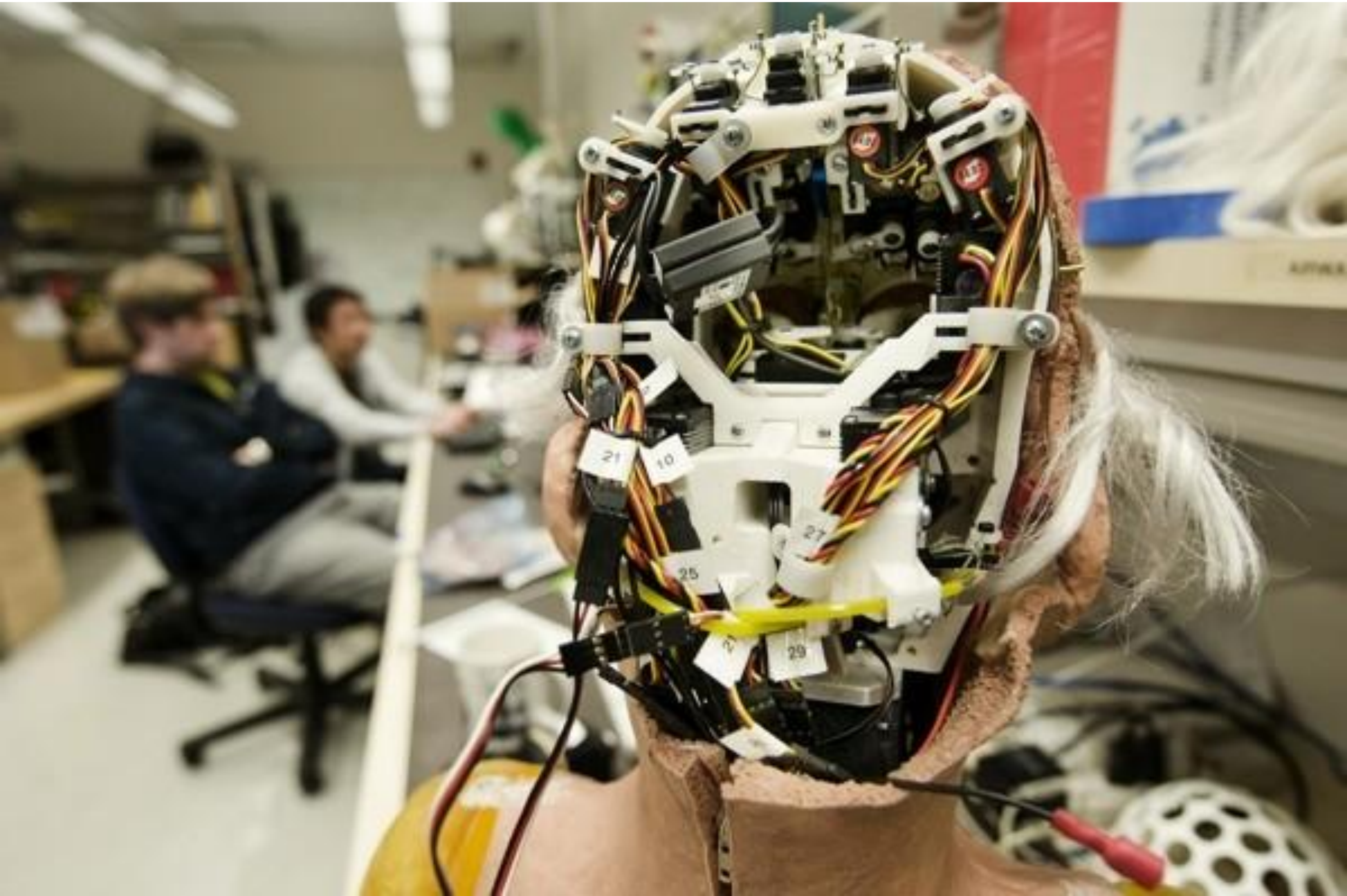
d.

Figure 9.9 a) Original motion signal, b) Applying waveshaping function with multiplier = 1.0, c) Applying waveshaping function with multiplier = 0.4, d) Applying a more complex waveshaping function.

Ideas for Future Robot Theatres and "Installations"

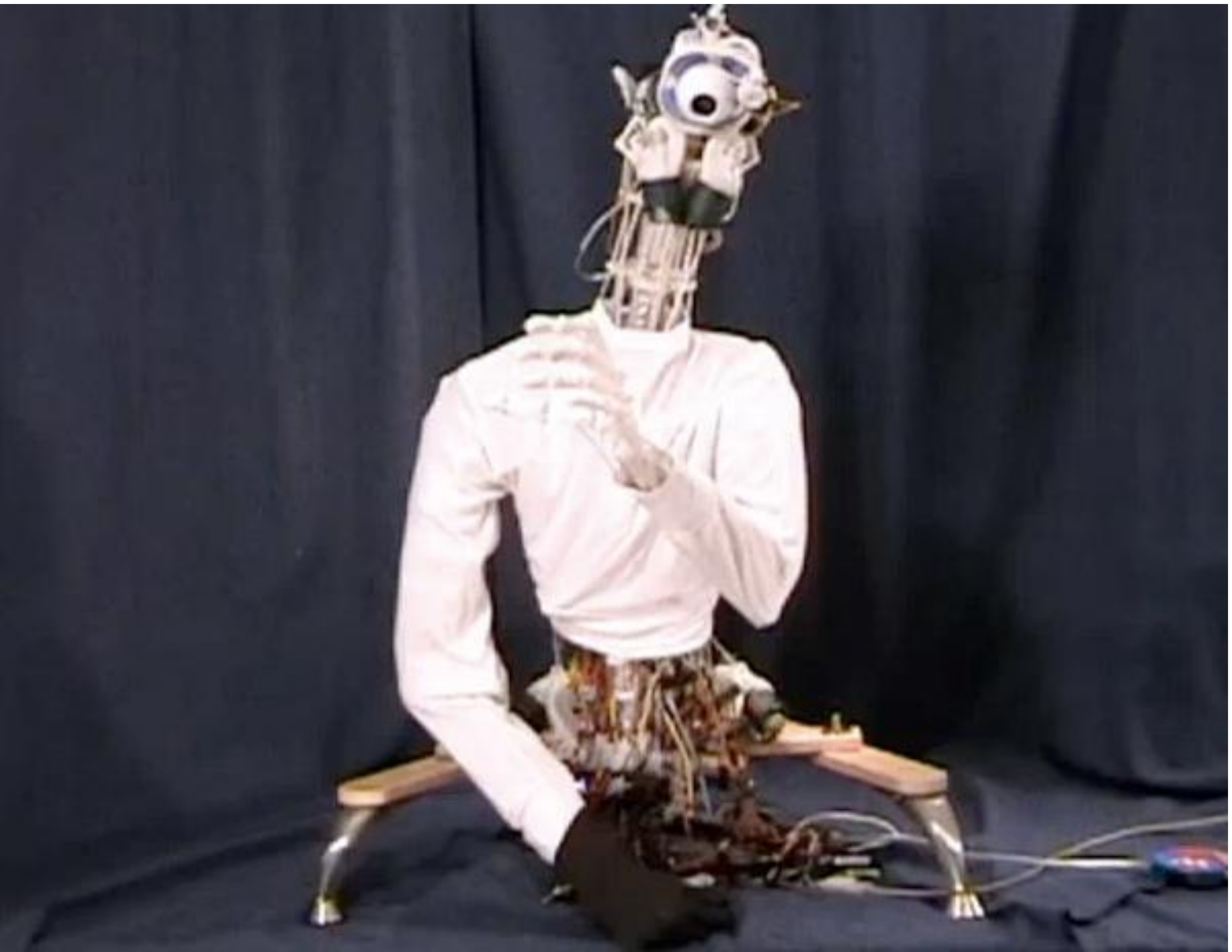
Realistic actors

A need for a better actuator



Anthropomimetic robots.

he ECCEROBOT is just such a robot, and it's really a sight to behold. Developed by a consortium of European robotics labs, the motivation behind the creation is to more accurately copy human internal structure, using thermoplastic polymer for bones, screwdriver motors and shock cord for muscle, and kiteline for tendons.



The results are impressive, if not a bit creepy. According to IEEE Spectrum, scientists hope in the future to use ECCEROBOT's human-like form to "explore human-like cognitive features," which may or may not include starring opposite Christian Bale in science fiction films.

Robot actor as a caregiver and permanent entertainer

Fashion and Hospitability Industry

Women make up a humanoid robot called EveR-3 of the Korea Academy of Industrial Technology (Kaitech), for a show at the Hanover industrial fair in Hanover, Germany, Sunday, April 19, 2009

A place for a female robots - fembots

1. A "cybernetic human" robot code-named HRP-4C bows and greets people on the catwalk during a fashion show as part of the opening day event of Japan Fashion Week in Tokyo, Japan.
2. The 158 centimeter (62.2 inch) tall black-haired robot, developed at the National Institute of Advanced Industrial Science and Technology, a government-backed organization, has trimmed down to 43 kilograms (95 pounds) to make the debut at a fashion show.

Japanese Realistic Androids

Robot to advertise alcohol in Sweden

Robots as providers of information

The entertainment robot Gilberto at the industrial fair in Hanover, Germany, Tuesday, April 21, 2009. Gilberto is intended to work as a guide and information desk in airports, train stations, museums.

Robot Theatre controlled directly from brains of humans: directors, actors, audience?

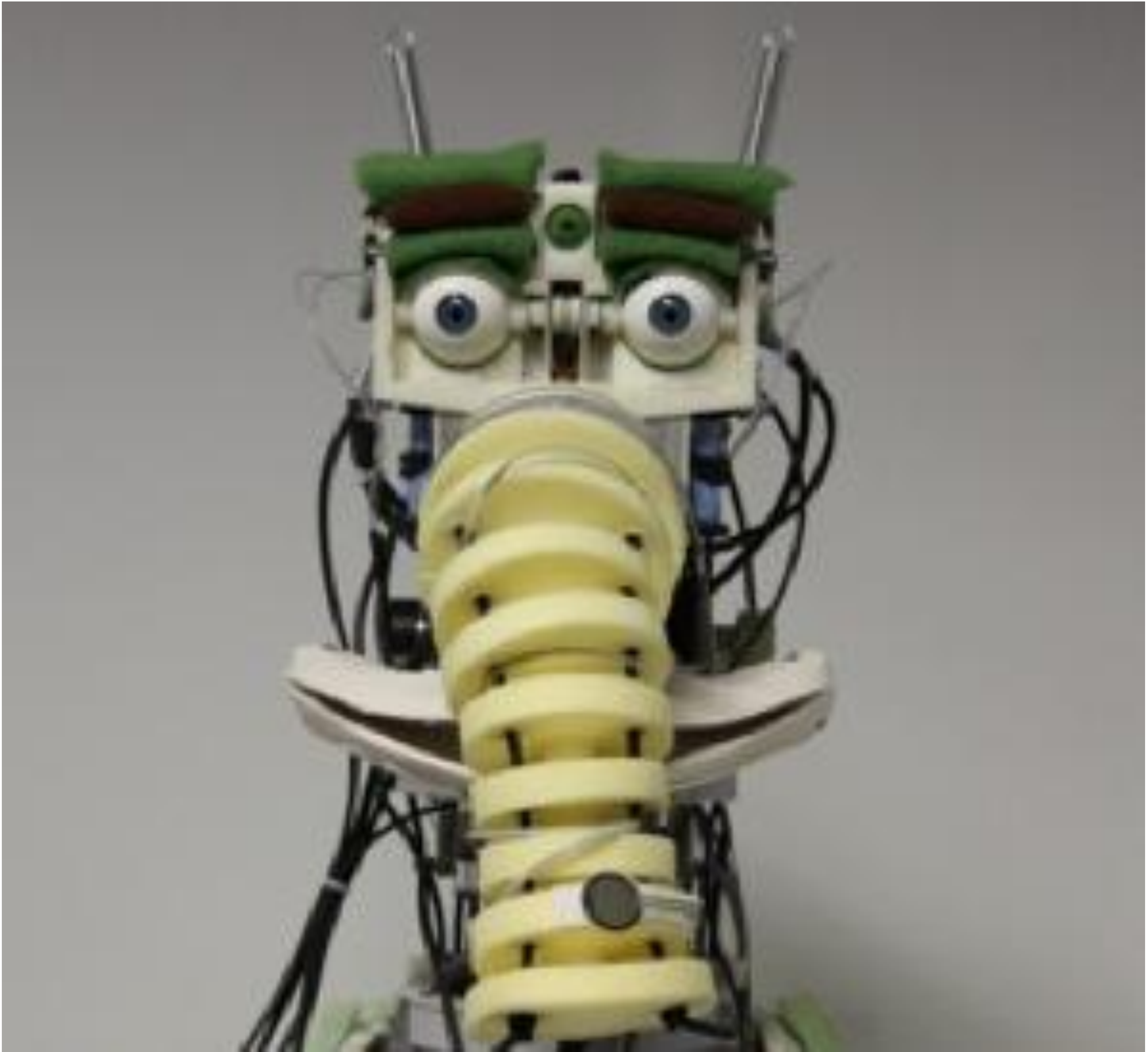
A Honda Motor Co. employee puts on a headgear with codes attached during a demonstration of Honda's new technology linking brain thoughts with robotics at the Japanese automaker's headquarters in Tokyo, Japan. Honda has developed a way to read patterns of electric currents on a person's scalp as well as changes in cerebral blood flow when a person thinks about four simple movements -- moving the right hand, moving the left hand, trotting and eating.

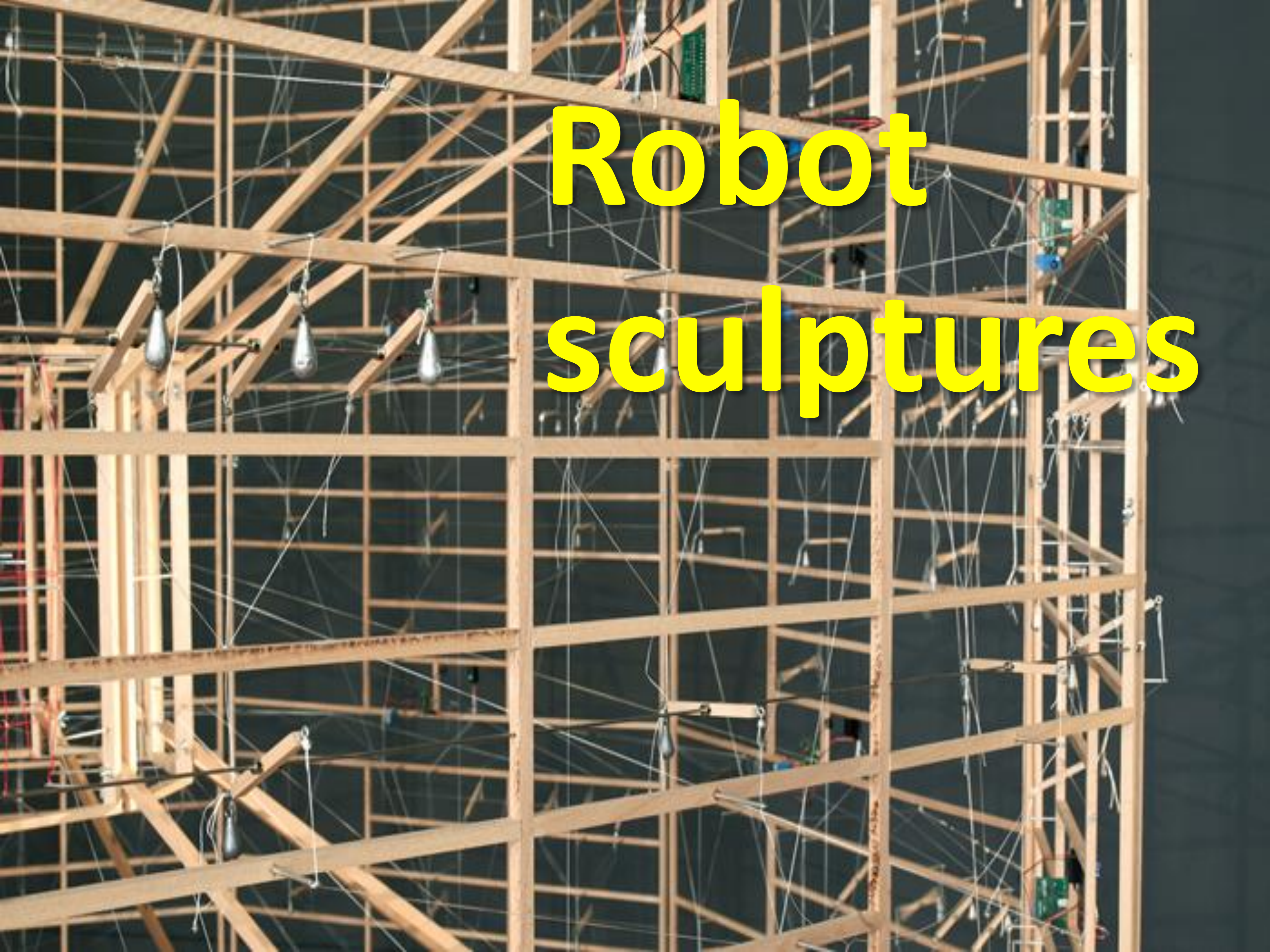
Honda brain activity measuring device controlling ASIMO robot by human thought alone. (AP)

Giant robots

A 7.2-meter (23.6 foot) tall aluminum made robot "Giant Torayan" blows fire into the air during a rehearsal of the "Roppongi Art Night" special art event at Roppongi Hills in Tokyo, Japan. The robot, created by Japanese artist Kenji Yanobe, is one of main art installations for the event that aims to transform the entire area of Roppongi under the theme of "Encounters."

New forms of life

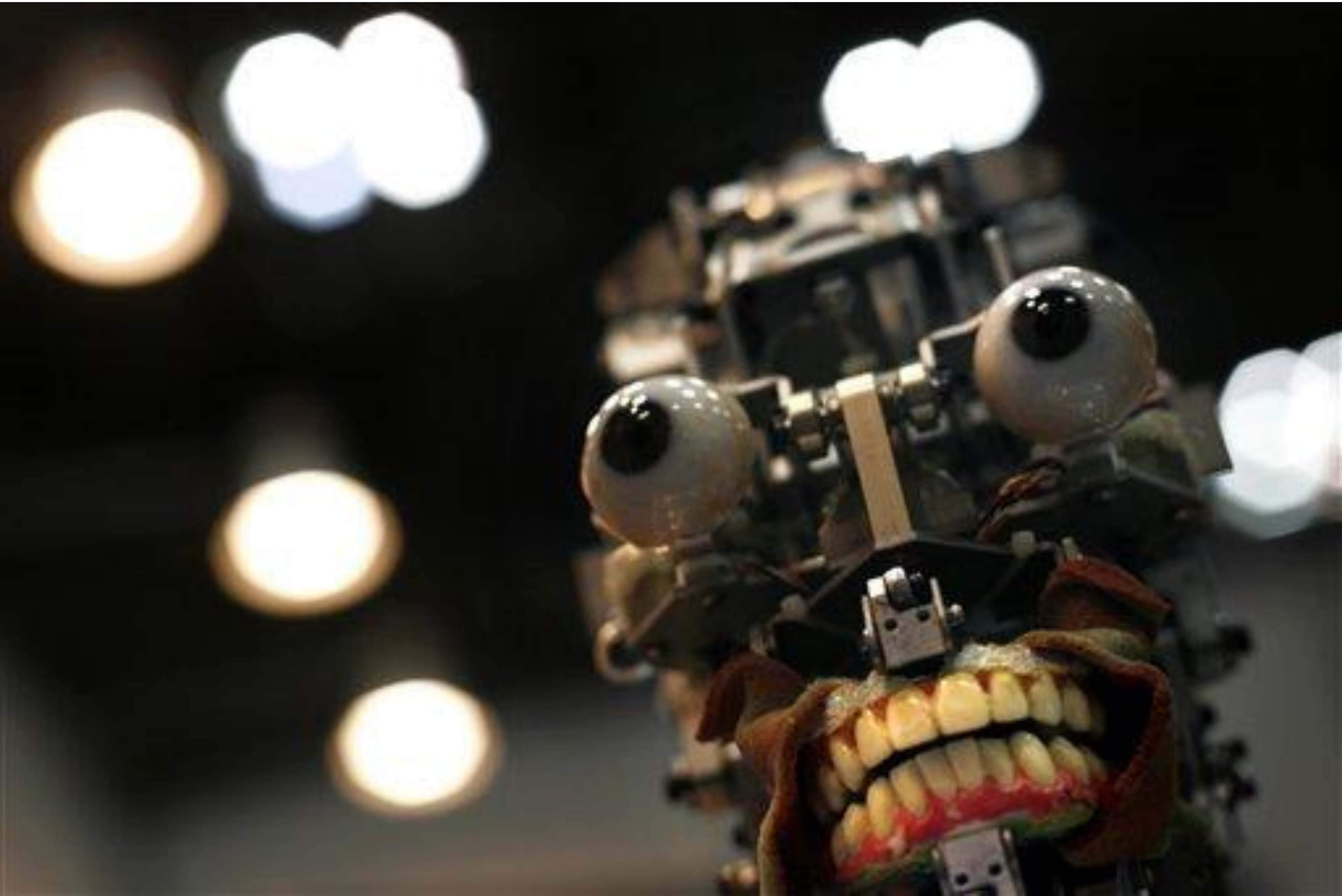



Robot
sculptures

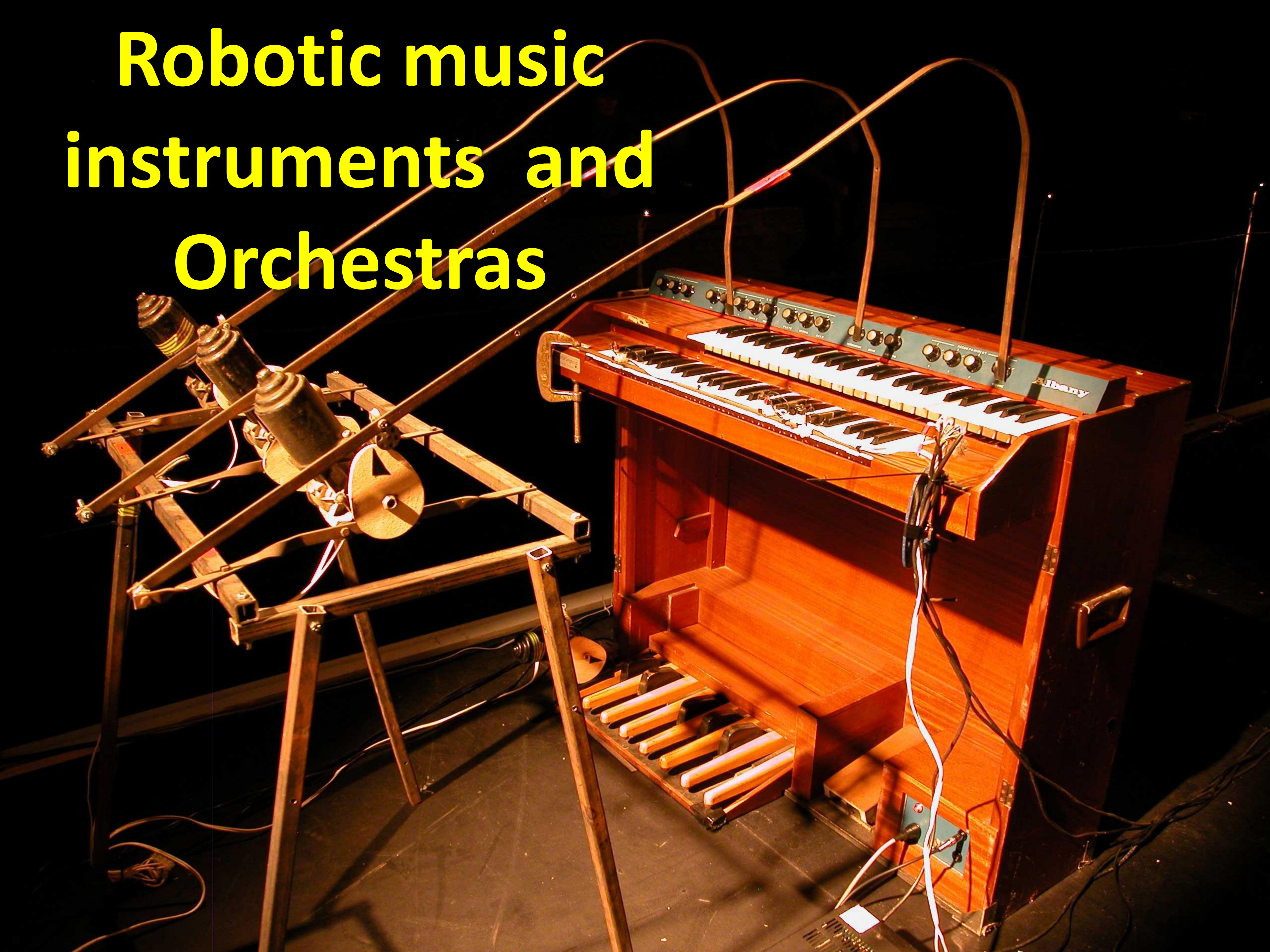
New forms of realism

Michael Jackson Robot Head 2009

Interactive begging robots – sculpture in time - personality



Robotic music instruments and Orchestras



New theatre forms, ritual, spiritual, resurrecting old theatre such as Noh or Bunraku

- ISMAR Workshop on Mixed Reality Entertainment and Art Keynote
- Lecture and demo by World Famous Robot Designer, Japanese television comedian, and NEC PAPERO robot for the first time in Noh Theatre:
- **Topic:** Noh Theatre Version: Research Collaboration for "Humorous Interaction" 2-Man Stand-Up Comedy (Manzai) with a Robot

Shocking concepts in philosophy, art and theatre

QUANTUM ROBOTICS IN ROBOT THEATRE

Quantum Signals and Automata

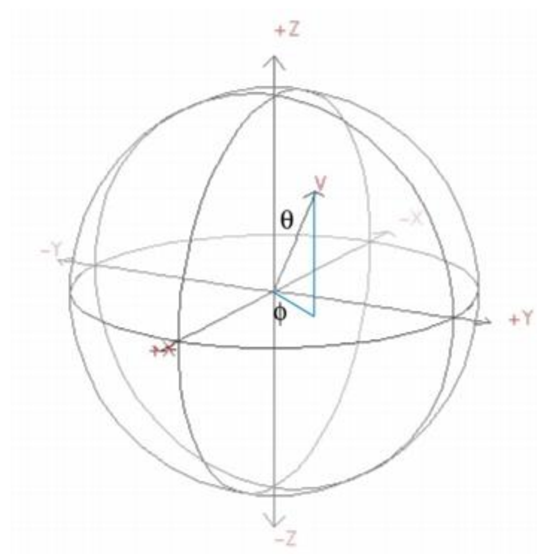
Binary Logic

{0, 1}

Fuzzy Logic

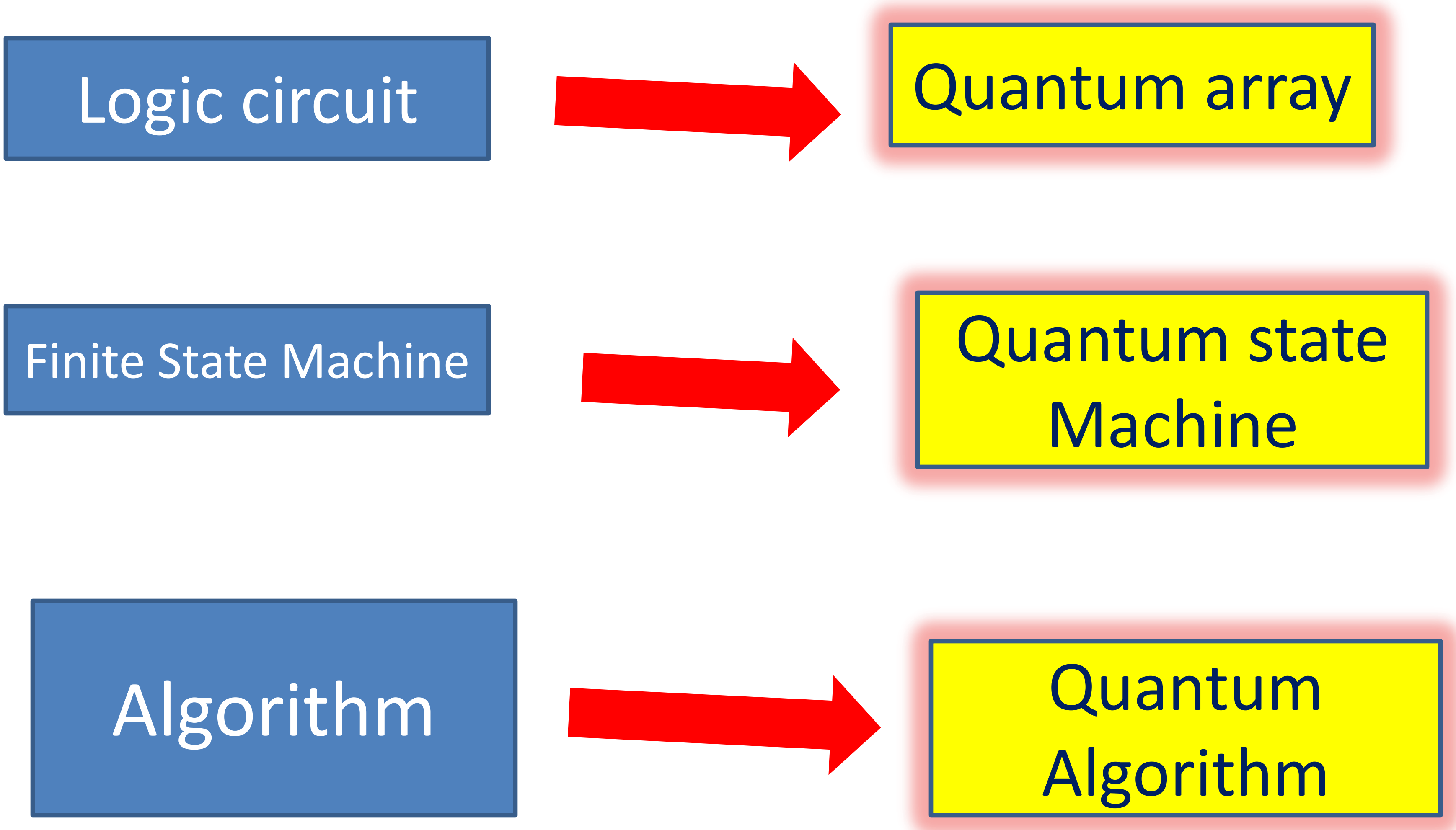
[0,1]

Quantum Logic

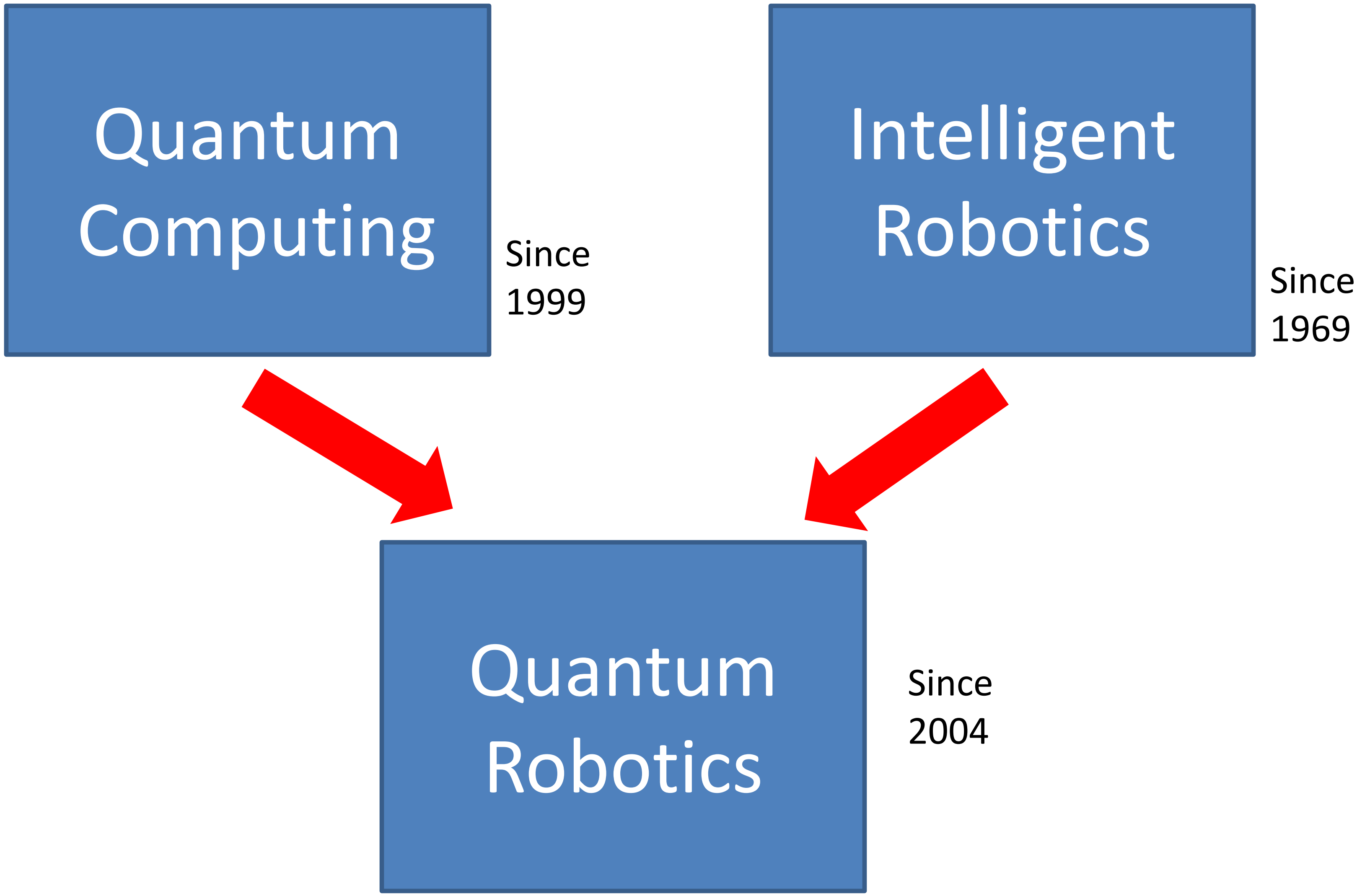


Hilbert Space, Bloch Sphere

Quantum Signals and Automata



Quantum Robot Theatre



Quantum Robotics

Constraint Satisfaction Model for Grover Algorithm

Collaboration:
Martin Lukac, Michitaka Kameyama,
Tohoku University,

Quantum Robot Vision

Vamsi Parasa, Erik Paul

Quantum Fuzzy Logic

Arushi Raghuvanshi
Michael Miller, *Univ. Victoria, BC*

Quantum Braitenberg Vehicles

Siddhar Manoj
Arushi Raghuvanshi

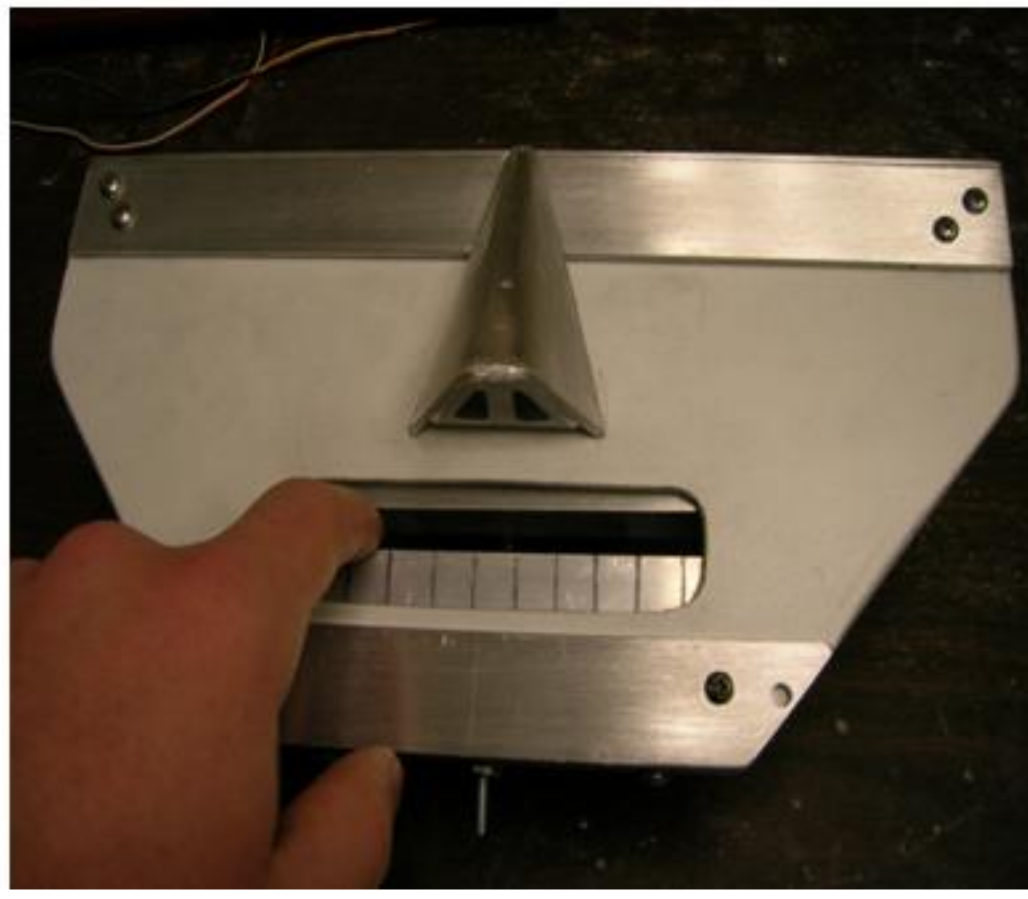
Quantum Emotions

Martin Lukac

Quantum Initialization and Neural Networks

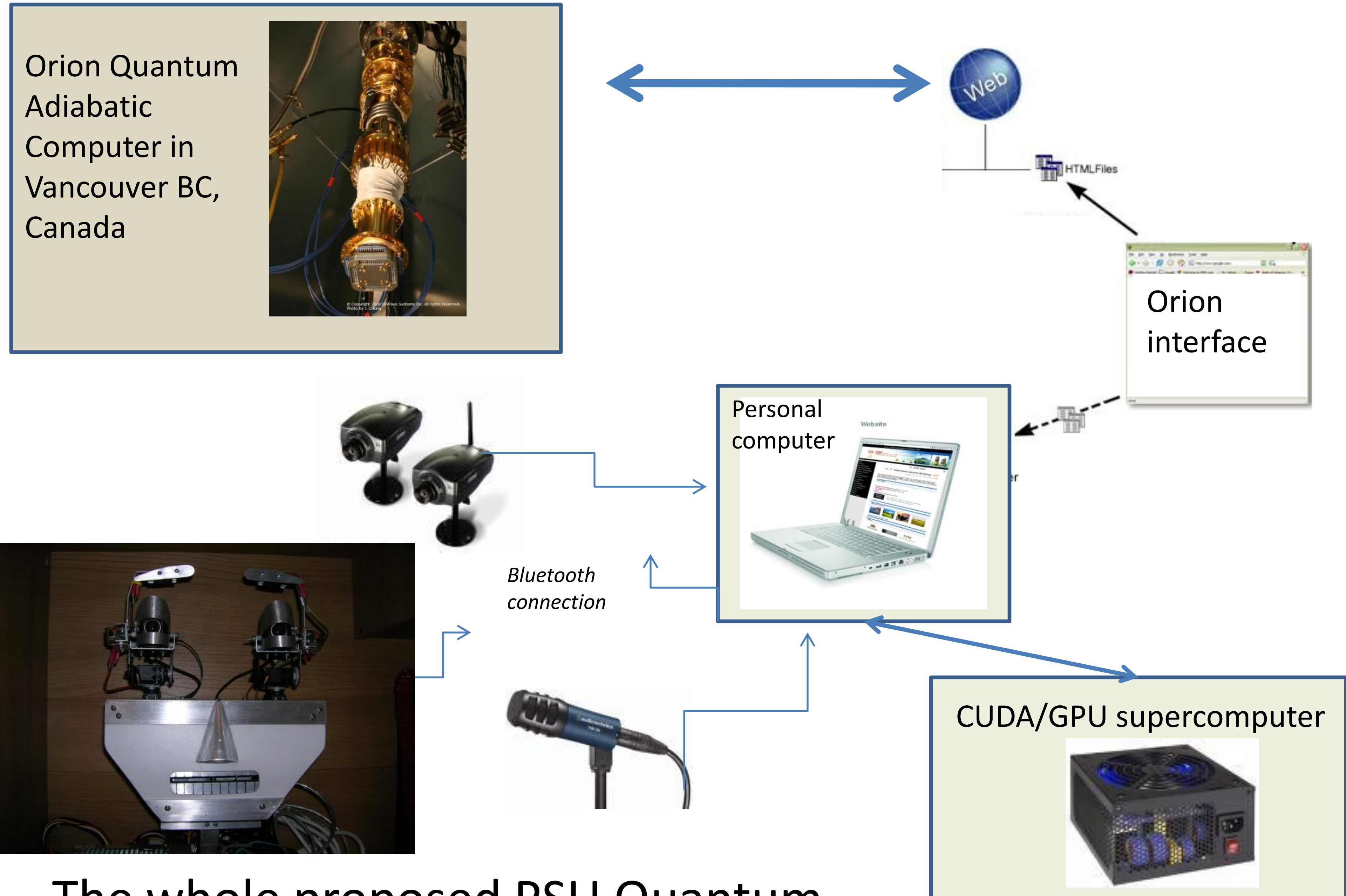
David Rosenbaum

The first quantum robot in the world?



Our concept of quantum robot

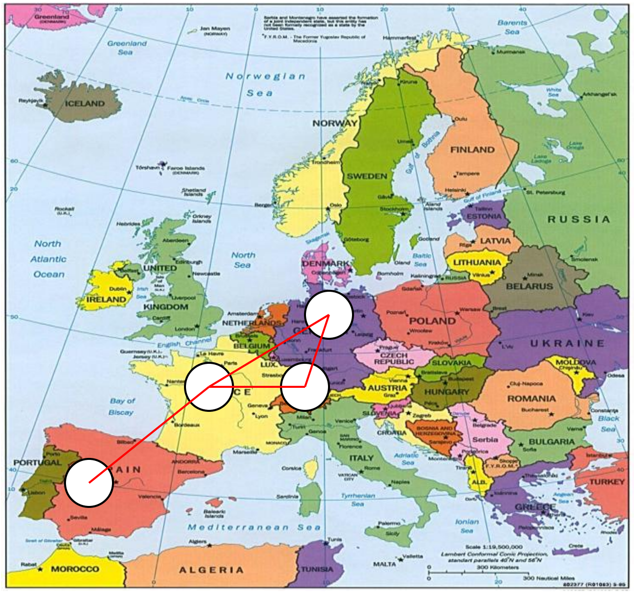
based on reducing all problems to constraint satisfaction solved on a quantum computer

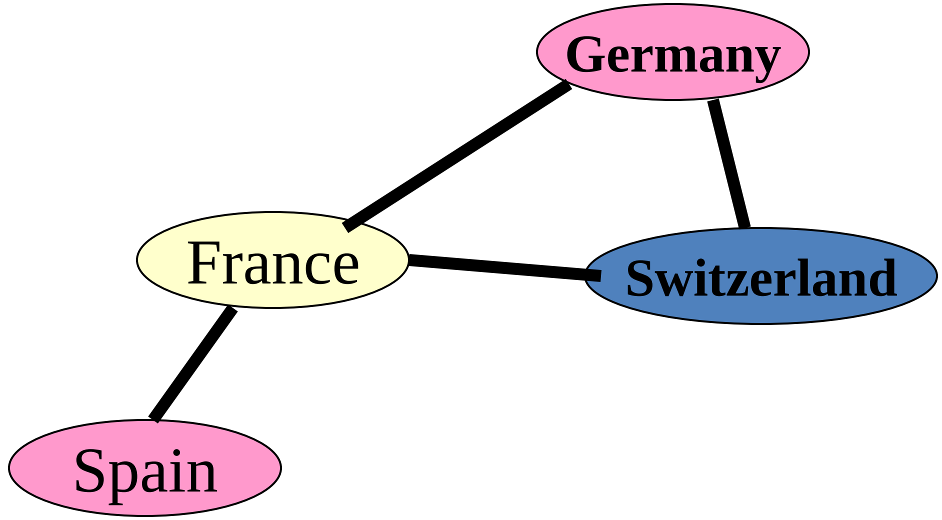


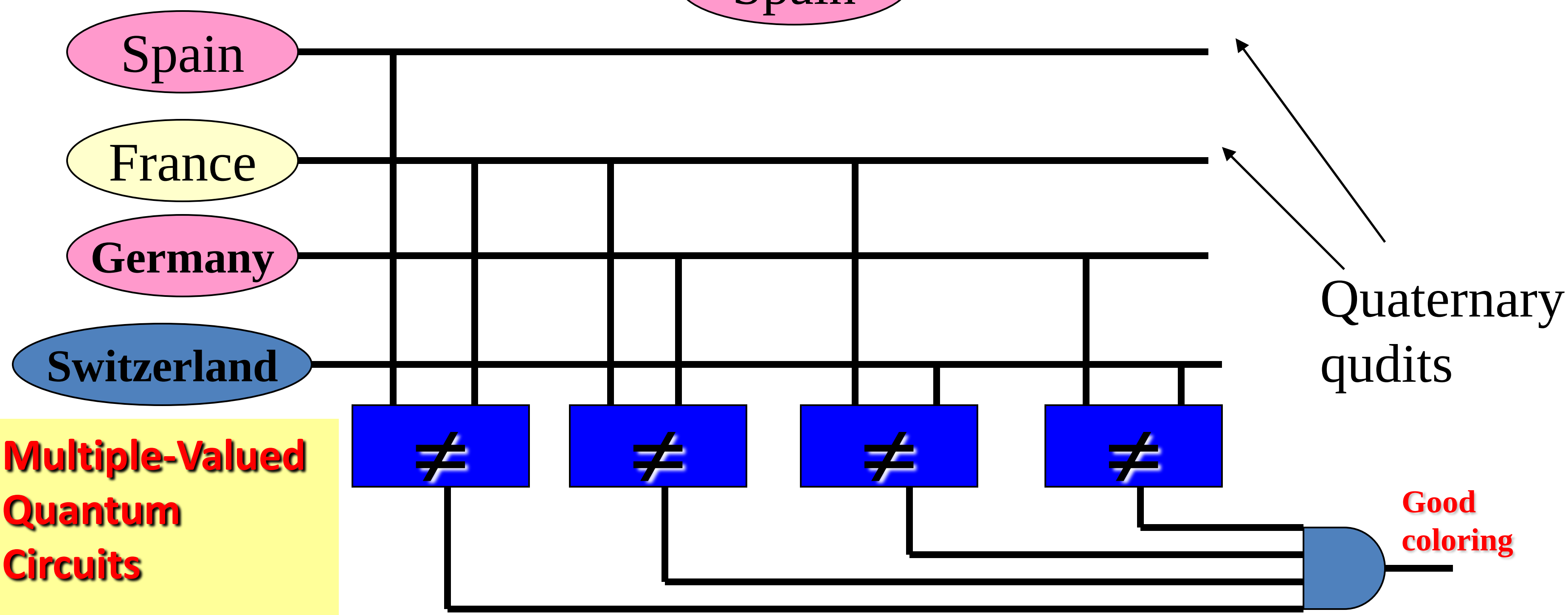
The whole proposed PSU Quantum Robot system

QUBOT-1 – the world’s first quantum robot

Oracle for Quantum Map of Europe Coloring

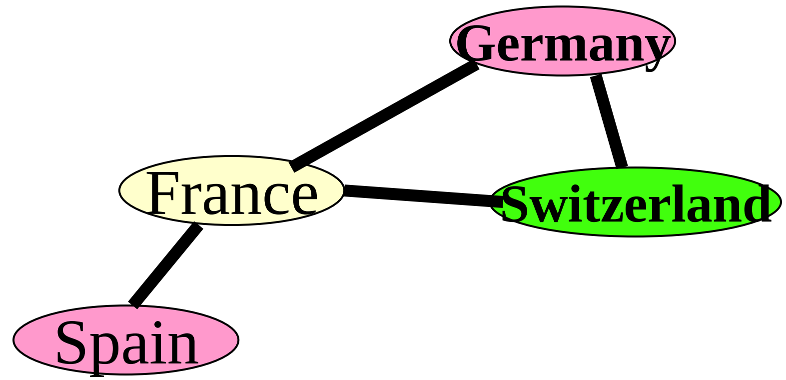


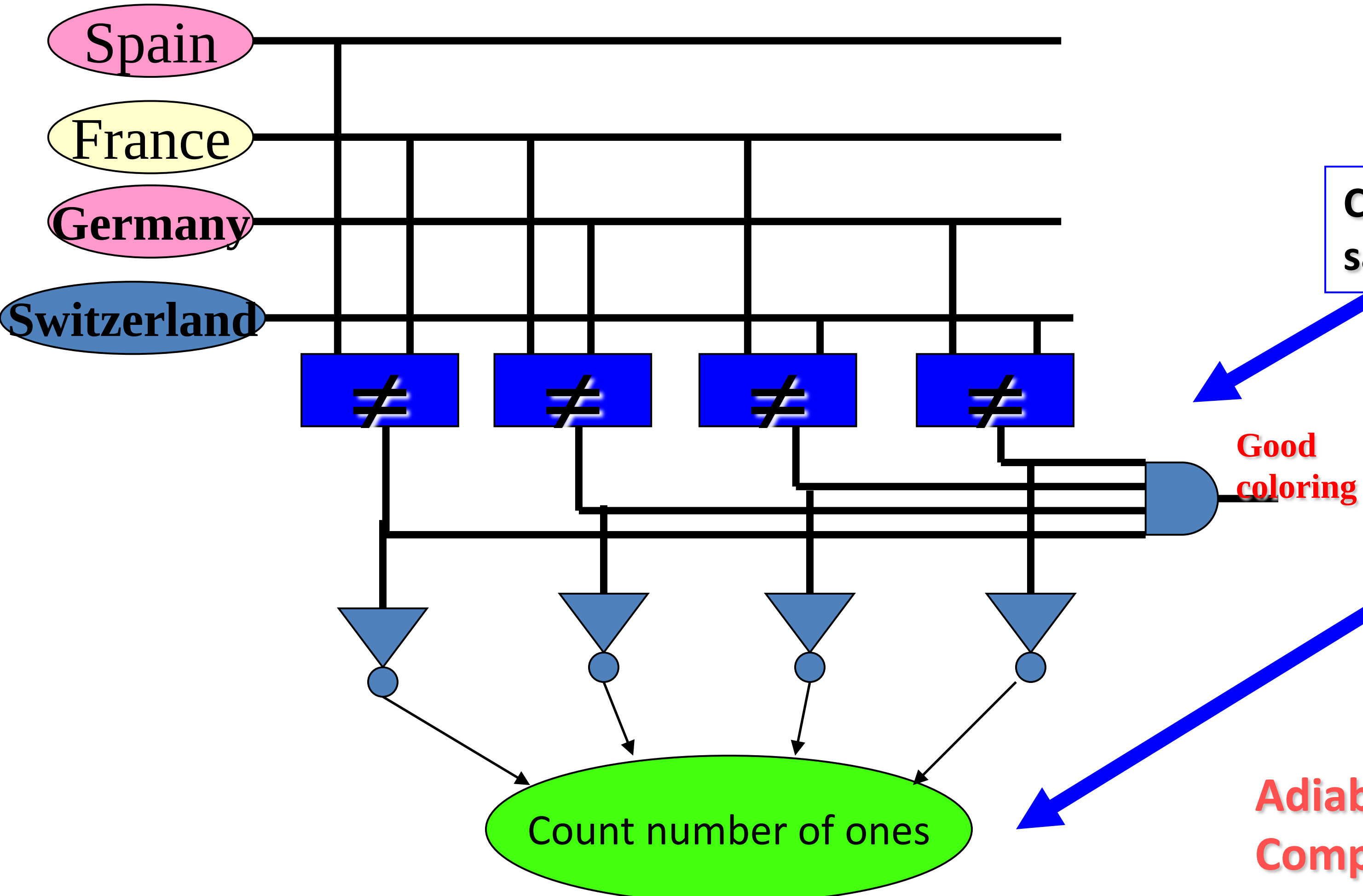




Multiple-Valued Quantum Circuits

Constraint Satisfaction Problem is to satisfy the constraints and **minimize the energy**



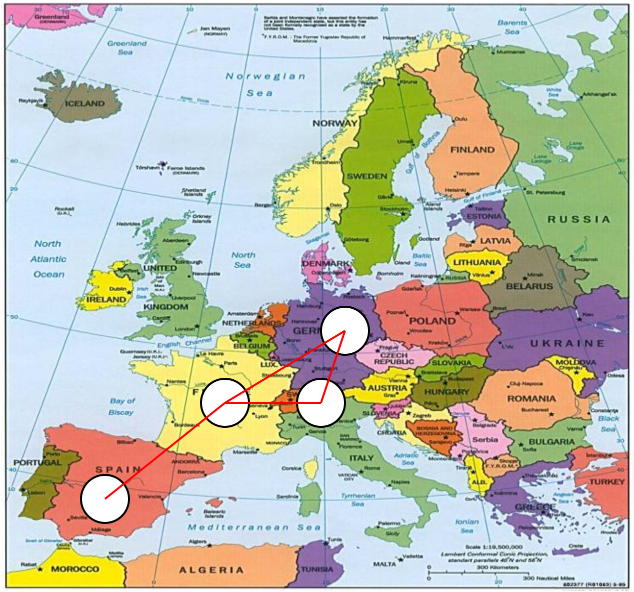


Constraints to be satisfied

Energy to be minimized

Adiabatic Quantum Computer

Constraints Satisfaction Problems



Graph coloring

$$
\begin{array}{r}
\text{S E N D} \\
+\ \text{M O R E} \\
\hline
\text{M O N E Y}
\end{array}
$$

Cryptographic Problems

Constraint Satisfaction for Robotics

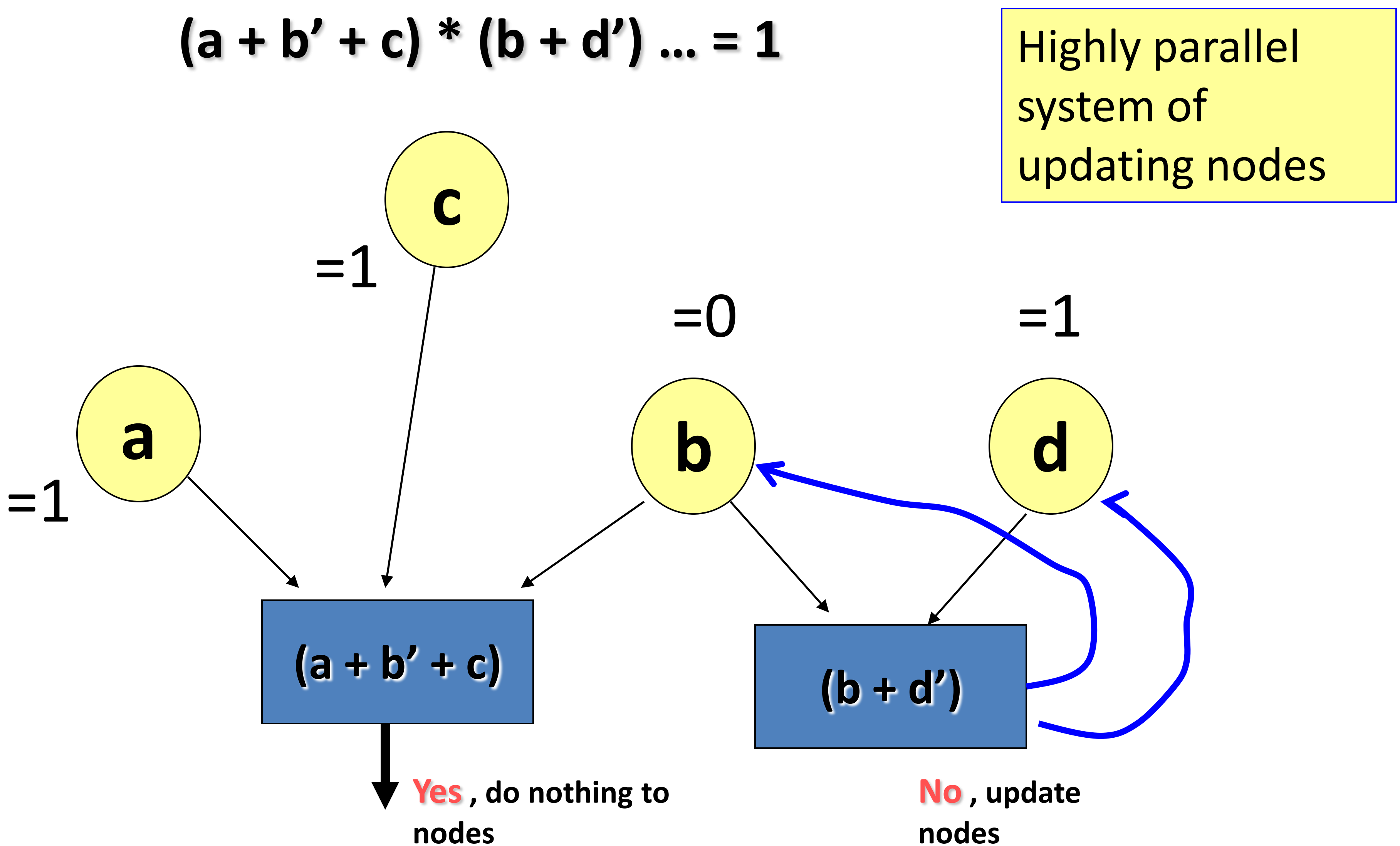
- Insufficient speed of robot image processing and pattern recognition.
  - This can be solved by special processors, DSP processors, FPGA architectures and parallel computing.

- Prolog allows to write CSP programs very quickly.

- An interesting approach is to formulate many problems using the same general model.

- This model may be predicate calculus, Satisfiability, Artificial Neural Nets or **Constraints Satisfaction Model**.
  - Constraints to be satisfied (complex formulas in general)
  - Energies to be minimized (complex formulas)

SAT as a constraint satisfaction problem



SAT as a constraint satisfaction problem

(a + b' + c) * (b + d') … = 1

Constraints:

(a + b' + c) = 1

(b + d') = 1

…..

Energy optimization:

(a + b' + c) = f1

(b + d') = f2

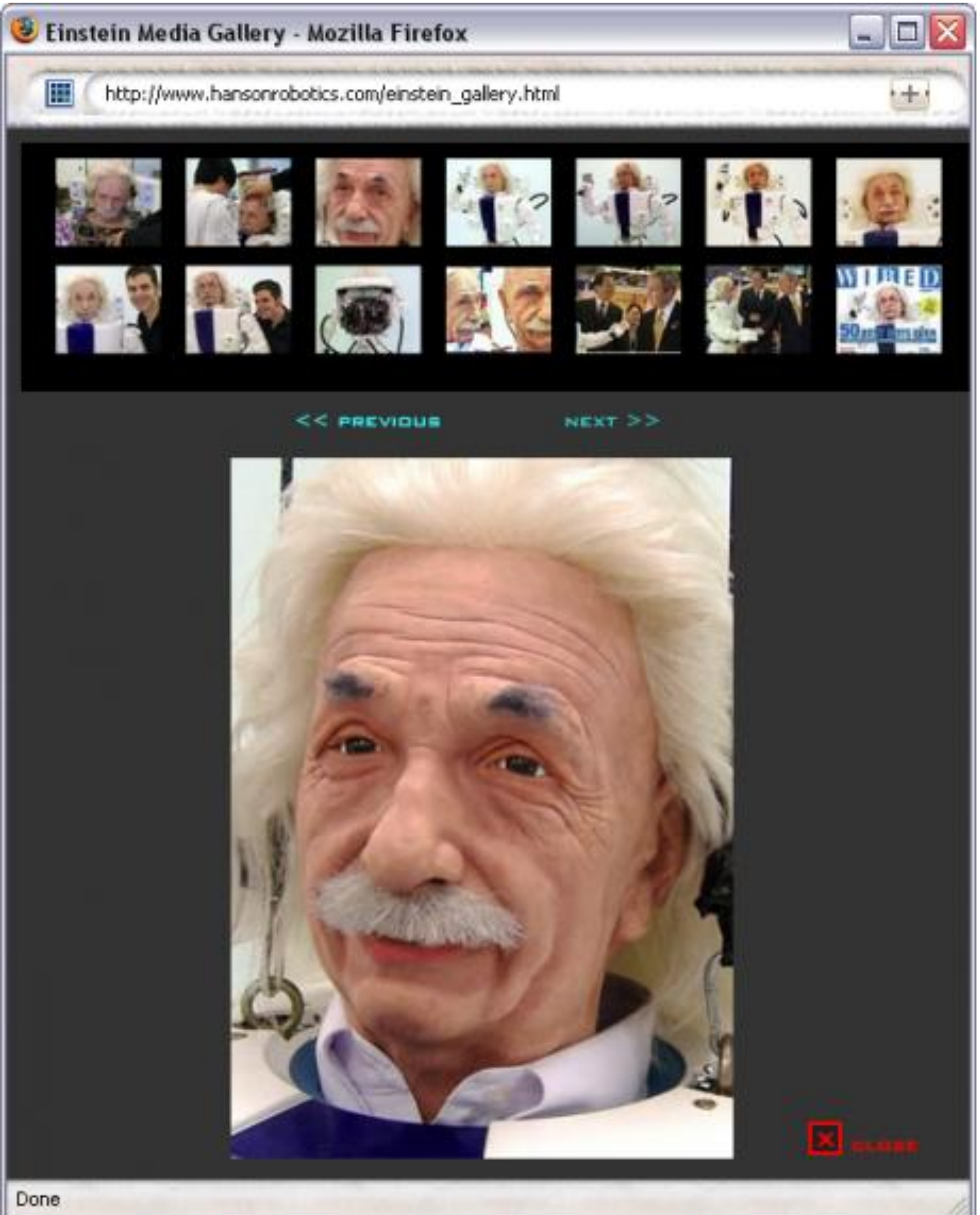
….

Min (f1' + f2' + …..)

Orion programming is just writing equations for constraints and equations for energy

Conditional robot response based on camera input

- This one is really cool.
- At a high level the way it works is as follows.
- You have a camera trained on a human. The data taken by the camera is processed so as to detect features, which are generalized patterns of behavior.
- For example, a feature detector could be configured to detect the presence of anger in the human, for example by learning-based methods.
- In addition, there is a robot, which is connected to the data processing system connected to the camera.
- This robot has effectors which control its actions.
- In this application, the effector controls are functions of the processed input from the camera, where the rules connecting the two are user-determined.



• This generic situation, where the robot's behavior is conditioned upon the input from the feature detectors connected to the camera, maps to a constraint satisfaction problem as described here.

• The way this would work is that the human / camera / robot system would generate optimization and satisfiability problems, to determine how the robot's effectors should fire, and these problems can be remotely solved using Orion.

• For example, you could acquire a Hansen Robotics Einstein, sit ~~it~~ him on your desk, train a camera on your face, use an anger feature detector that causes the Einstein robot to laugh harder the angrier you get.

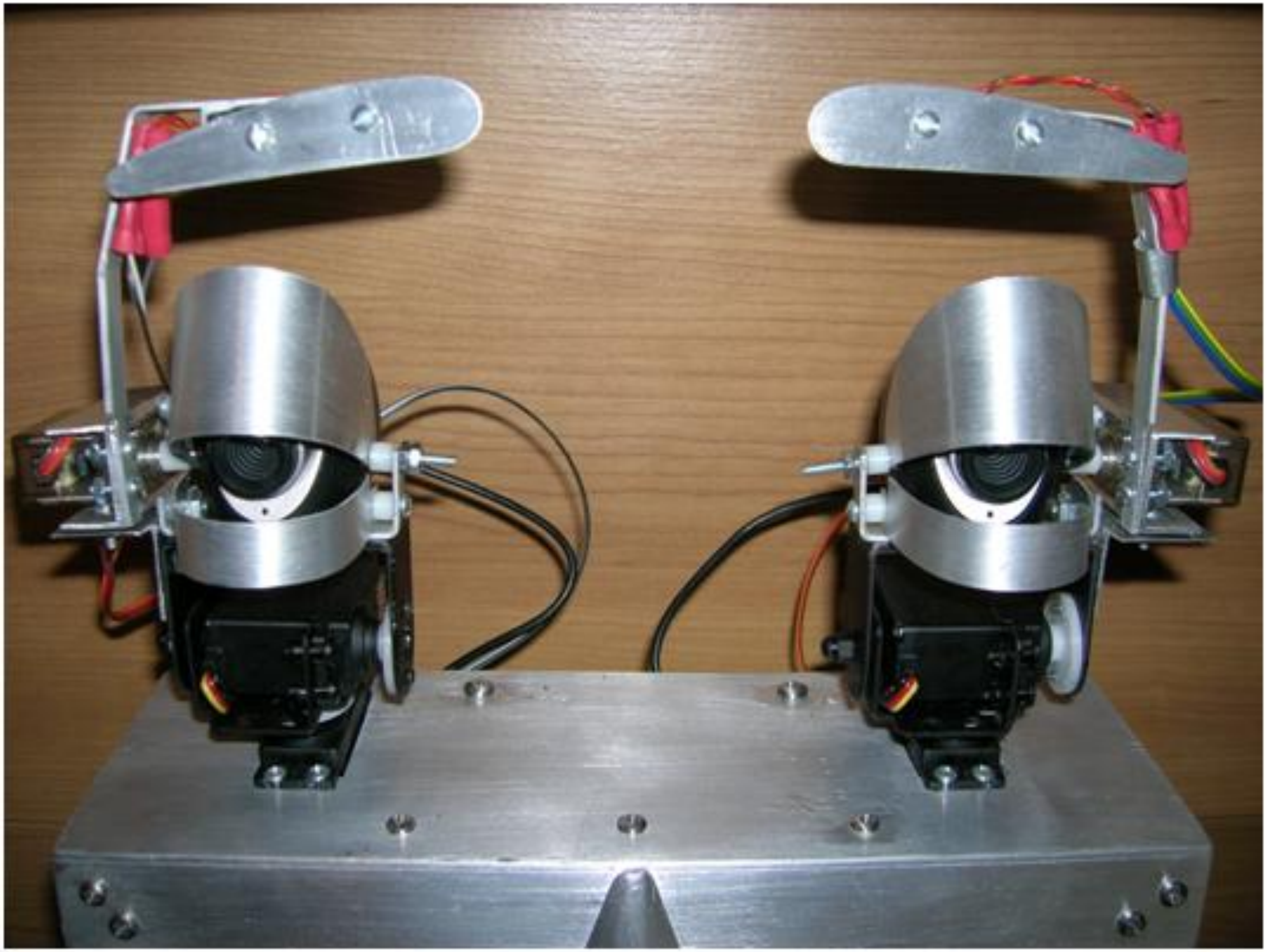


Figure 8.9 – DIM Eye Design.

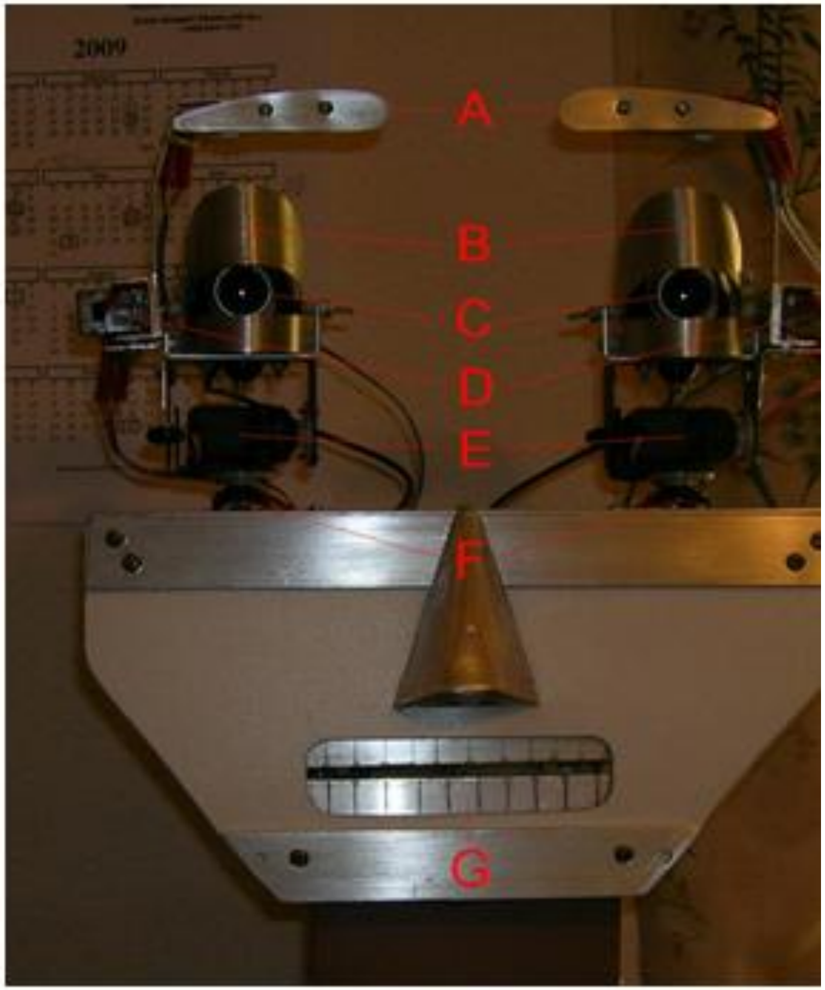


Figure 8.6 – Frontal Face Close-up.

Description

A) Controllable Eyebrows.
B) Controllable Upper-Eyelids.
C) USB Cameras Used for Image Capture.
D) Servos which Drive the Eyelids.
E) Servo's which Control the UP-DOWN Eye Motion.
F) Servo's which Control the LEFT-RIGH Eye Motion.
G) Controllable Upper Jaw of Mouth.

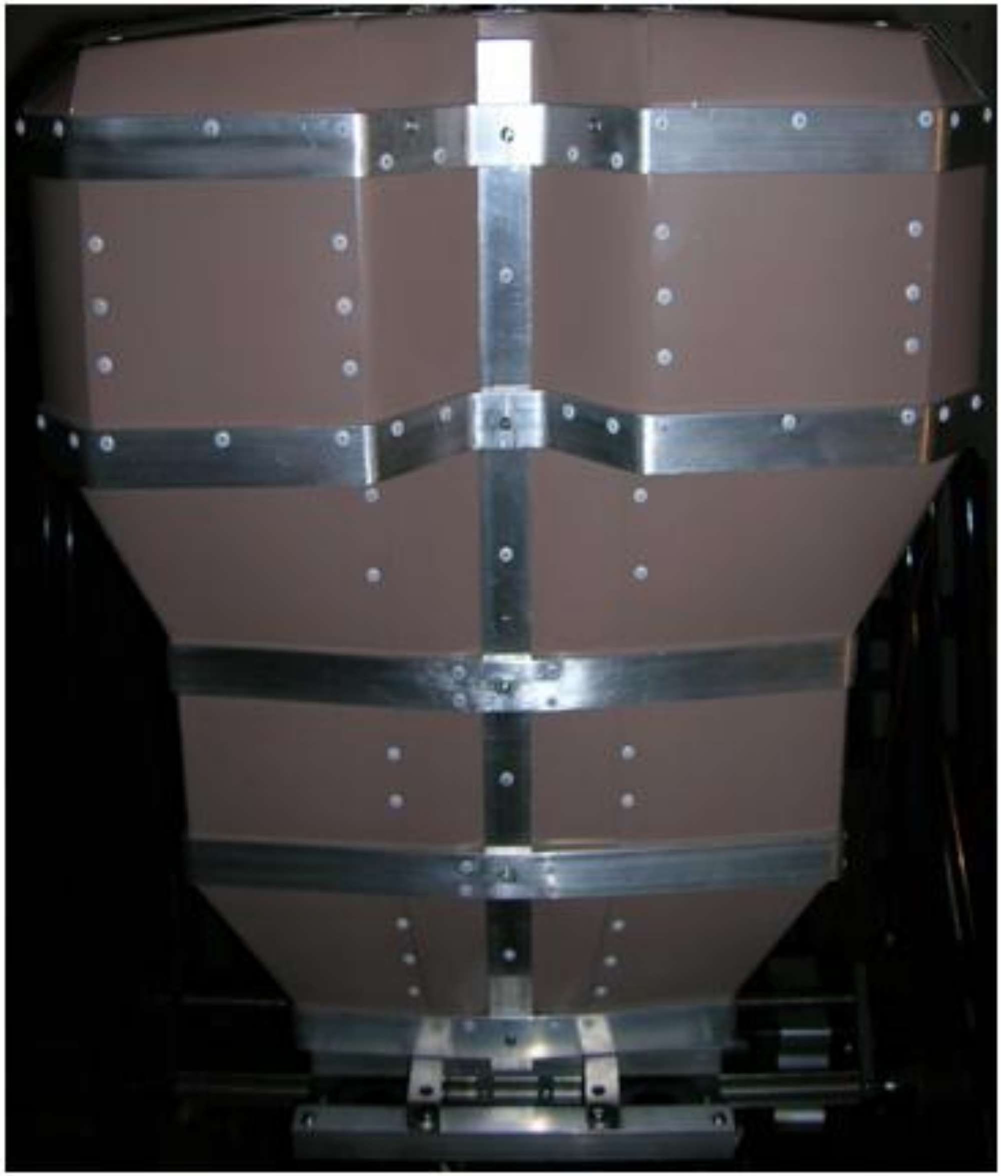


Figure 8.2 – DIM Body Design.

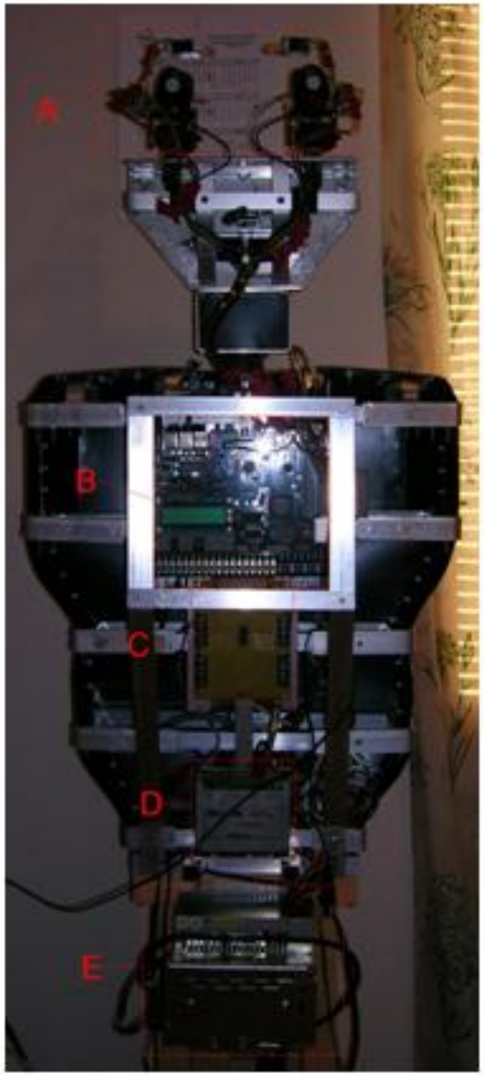
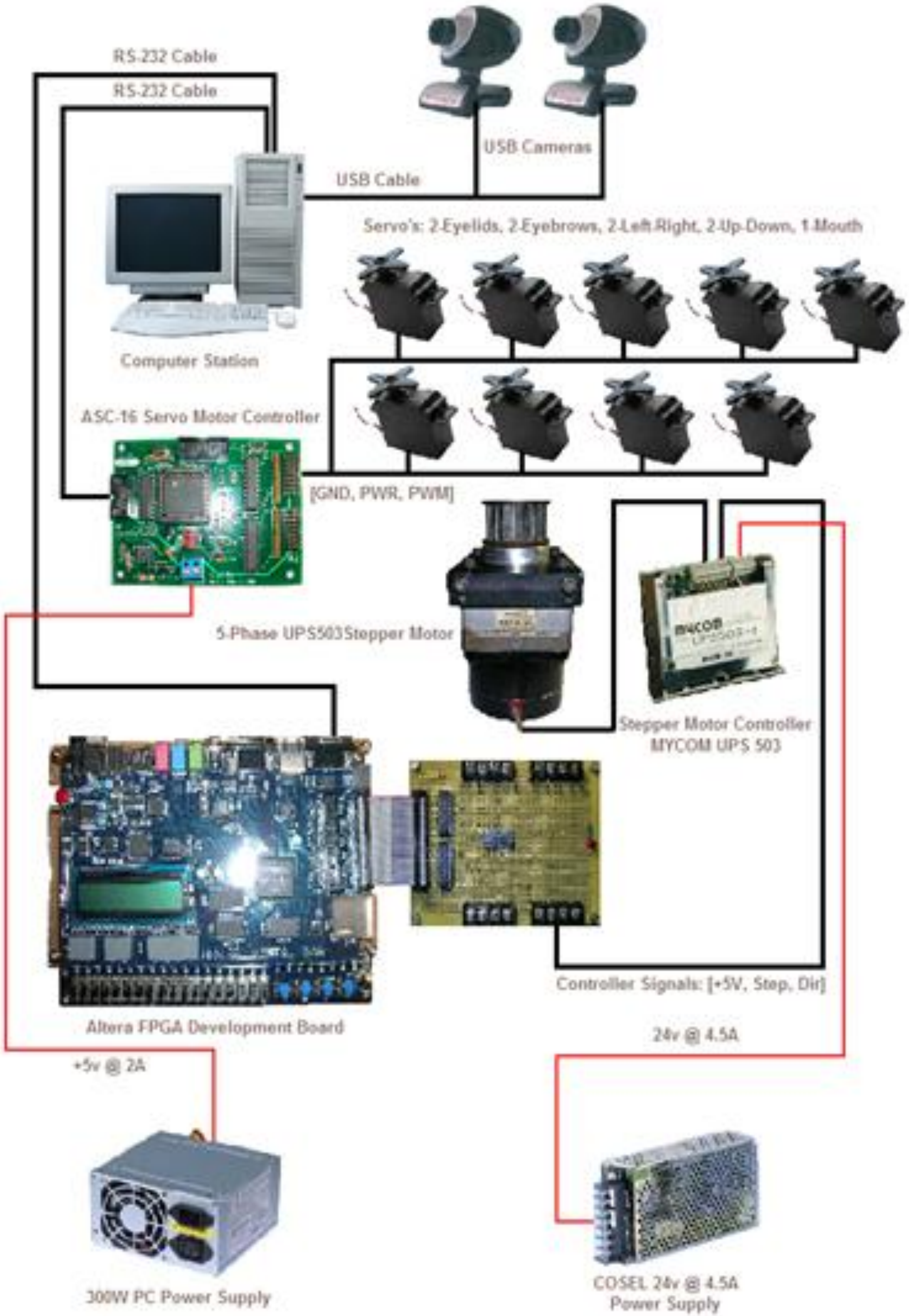



Figure 8.7 – Back View of Robots Hardware.

Description

A) USB Cameras Adapted to Function as Robot Eyes.
B) Altera FPGA Board Used to Drive Stepper Motor Controller.
C) FPGA Board to Stepper Motor Interface Card.
D) Stepper Motor Controller.
E) Power Supply System.

High Level Schematic of DIM robot



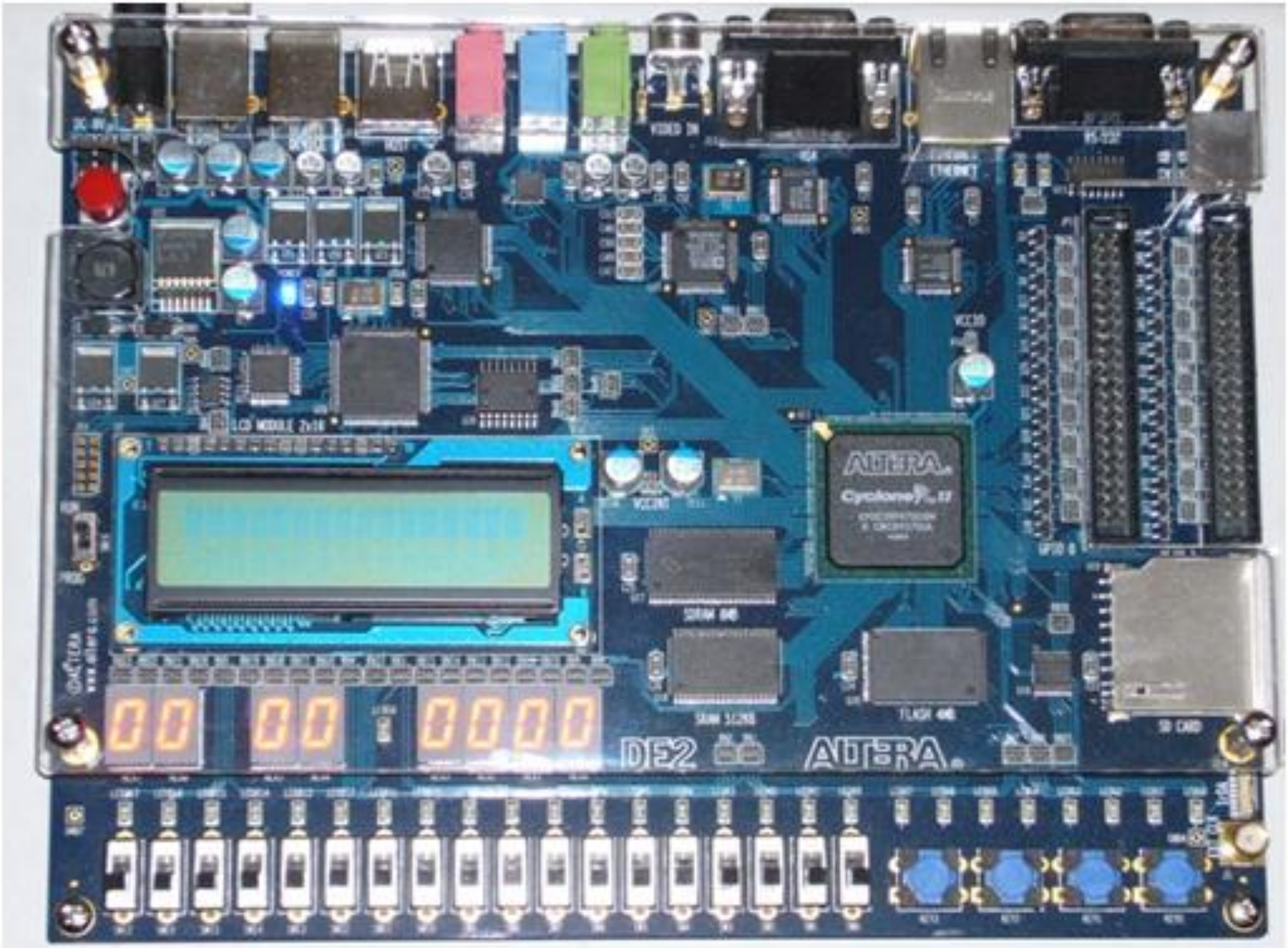


Figure 8.3 – Altera FPGA Development Board.

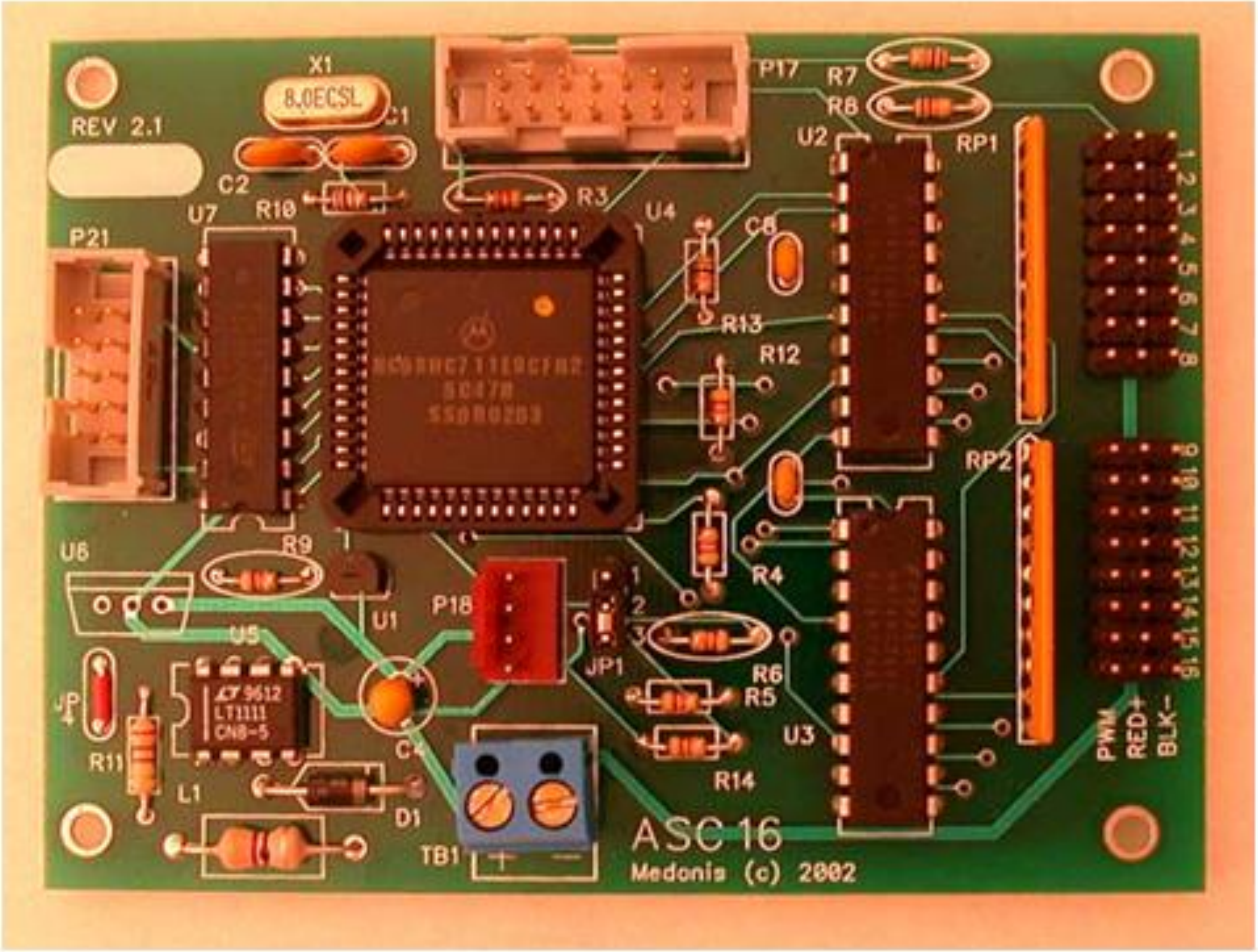


Figure 8.4 – AS16 Servo Controller Board.

Many research and teaching areas

My robotics classes and topics of theses are much broader than in other universities:

1. Classical Robotics
2. Speech synthesis and analysis
3. Robot vision
    1. Face recognition and tracking,
    2. gesture recognition, etc.
4. Motion generation
5. Dialog and natural language
6. Scripts and agents.
7. Search and Machine Learning.
    1. Search theory
    2. Decision trees and constructive induction (AC decomposition)
    3. CSP
    4. Pattern Recognition
8. New models:
    1. Probabilistic robotics,
    2. Quantum Robotics,
    3. Developmental Robotics.

Many partial practical projects, broad range of technical knowledge

1. Controllers and processors
2. FPGA and PLD, VHDL and Verilog.
3. CUDA and GPU
4. Motors and sensors
5. RobotC, C, C++, Prolog, LISP, PYTHON, etc.
6. Writing requirements
7. Creativity and invention.
8. Integration of engineering, science and art.
9. Many awards for high school students.

Conclusions

1. Our goals are to both **create a model innovative robot theatre** and a theory of robot theatre that would be similar to the theory of film or theory of interactive computer games.
2. We believe that robot theatre will become a new art form and we are interested what are the basic questions related to the art of performing robots.
3. We hope to have an interesting feedback to our ideas from the System Science oriented researchers.

Questions:

1. Will Robot theatre be ever as popular art form as film or theatre?
2. Will robots be popularly used in theatres?
3. Will we see robot theatre toys?
4. Will home robots be also entertainers?

New Research Area or only application?

1. What is Robot Theatre Theory?
2. What are its main methods?
3. How to evaluate Robot Theatres.
4. Is robot theatre only an application of robotics or is it more? What ?

- We see that humans can laugh looking at our theatre.
- *Will we ever experience humans crying at robot performances?*
- **<u>What can we learn from robot theatre that is not a standard robotics problem?</u>**