OREGON CYBER THEATRE

Marek Perkowski

Main Ideas

(for those in a hurry)

- ***MAIN THESES***

All existing Brain/Robot/Human theories such as symbol manipulation or evolutionary computing are no more than **powerful metaphors**.

New Metaphors for Intelligent Robotics

- New metaphors may be more appropriate to develop **intelligent humanoid robots**.
- It is more scientifically interesting and fruitful to **evolve a society of robots** rather than to program a robot.
- ***Powerful metaphors*** that can be used to build robots and their societies:
  - the high-technology industry,
  - the internet,
  - the quantum computer,
  - the earth's ecology, and
  - the theater

What is proposed

- **Combine ideas** from logic synthesis, system theory, game theory, autonomous agents, tele-presence, virtual reality, robotics, video-directing/computer animation, and puppet theater,
- to create a WWW theater:
  - robot-puppets located in our laboratory,
  - human participants - animators and observers located worldwide on Internet.

Oregon Cyber Theatre

- Robots, tele-operated by humans and/or fully autonomous,
- Equipped with sensors and cameras, radio-controlled and often mobile:
  - Play Shakespeare,
  - Dance and sing,
  - Play games,
  - Live their autonomous lifes; reproduce, compete and cooperate,
  - Personify "The Prisoner's Dilemma" as a "game of morality" with emergent behaviors,
  - Teach students.

Humans and Robots

- Humans will teach robots about human emotions and behaviors.
- This will be a permanent Turing test online for all its human participants and observers.

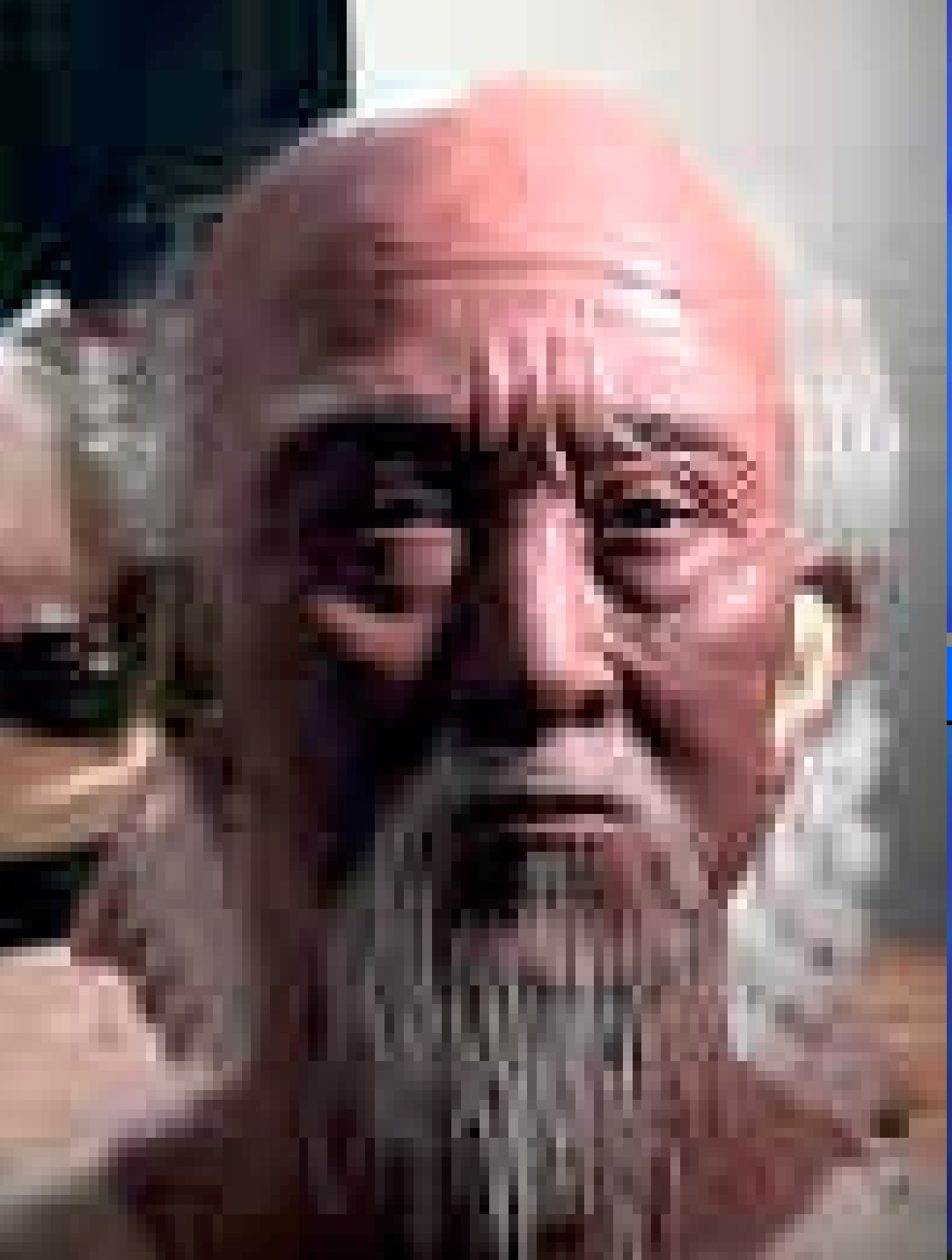
1999
A Breakthrough Year
In Robotics


This system
can be
constructed

A man with a child ?

- This is not a child
- This is a robot
- It comes from Brook’s Company


REAL WORLD INTERFACE
ROBOT SALES
Interactive TOYS
RESEARCH in Robotics
Creative TECHNOLOGIES
Robots for COMMERCE & INDUSTRY
IS ROBOTICS
Robots for ENERGY & UTILITIES
People
@Robot



- Head of Japanese Robot

- And What About these?

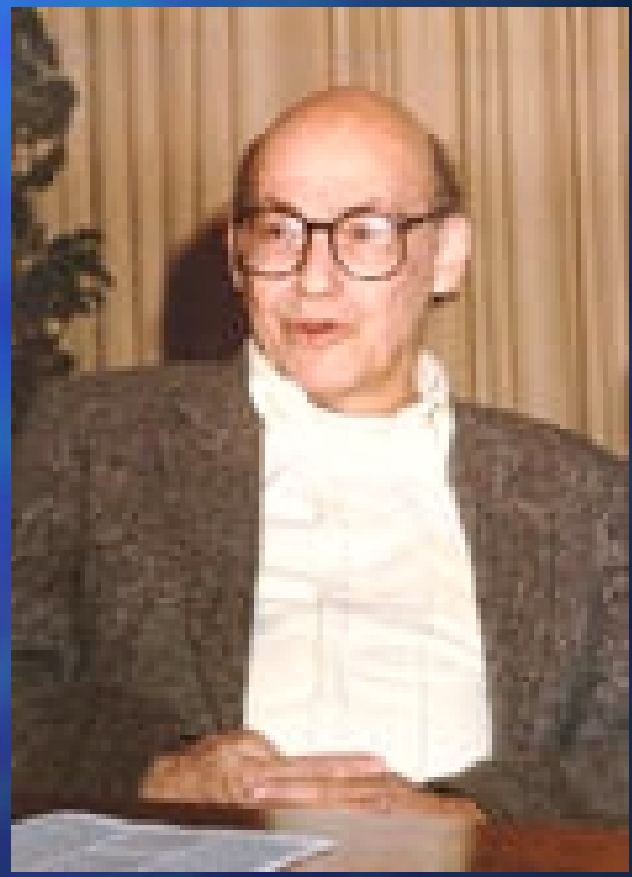
- Marylin Monroe without cloths ...and skin, with her creator

- There exist several companies that build entertainment robots

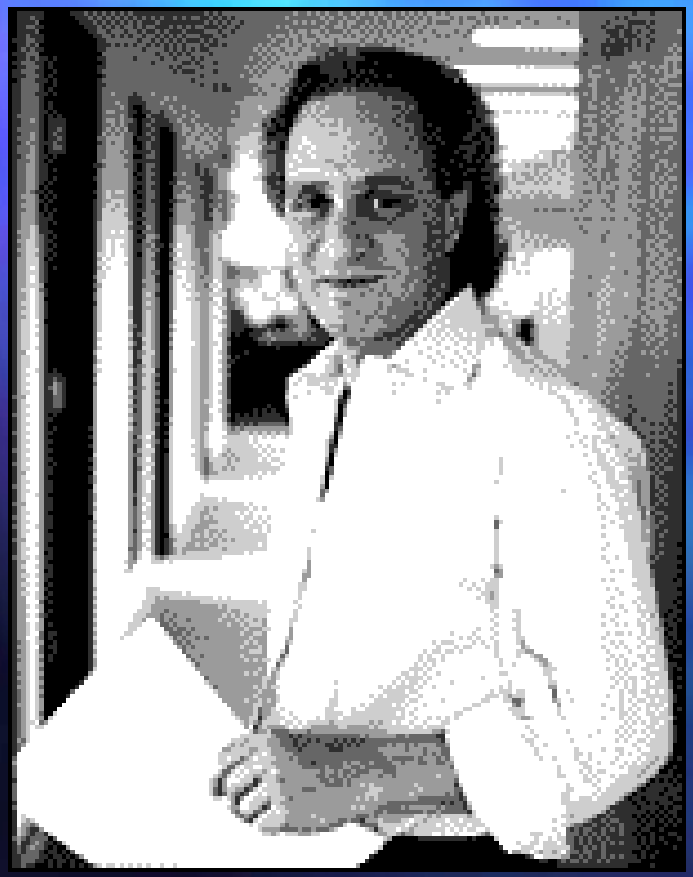
Will Year 1999 go to the history of Robotics?

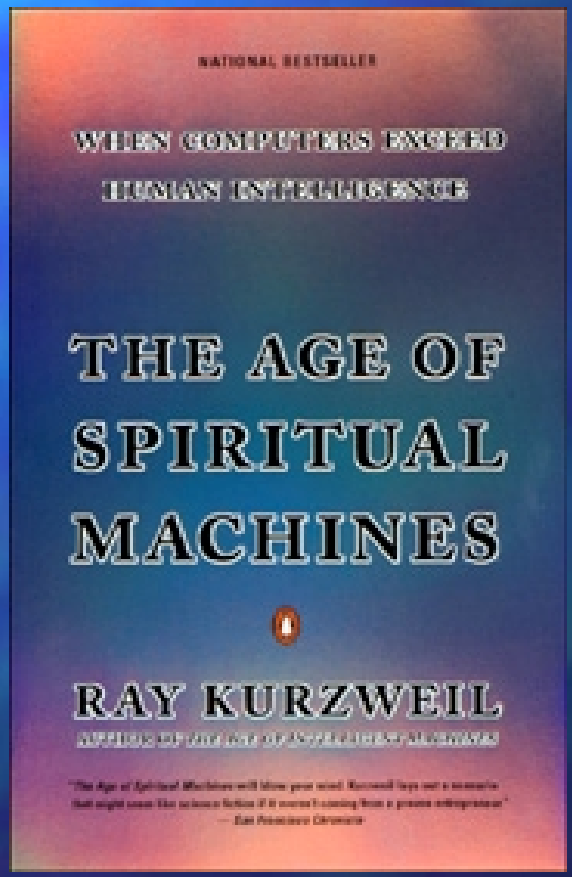
Marvin Minsky

- The author of (in)famous statement that “brain is computer from meat”
- Pioneer of the idea of “the society of brain” that influenced Rodney Brooks robotics research and modern robotics
- One of main metaphors of Oregon Cyber Theatre

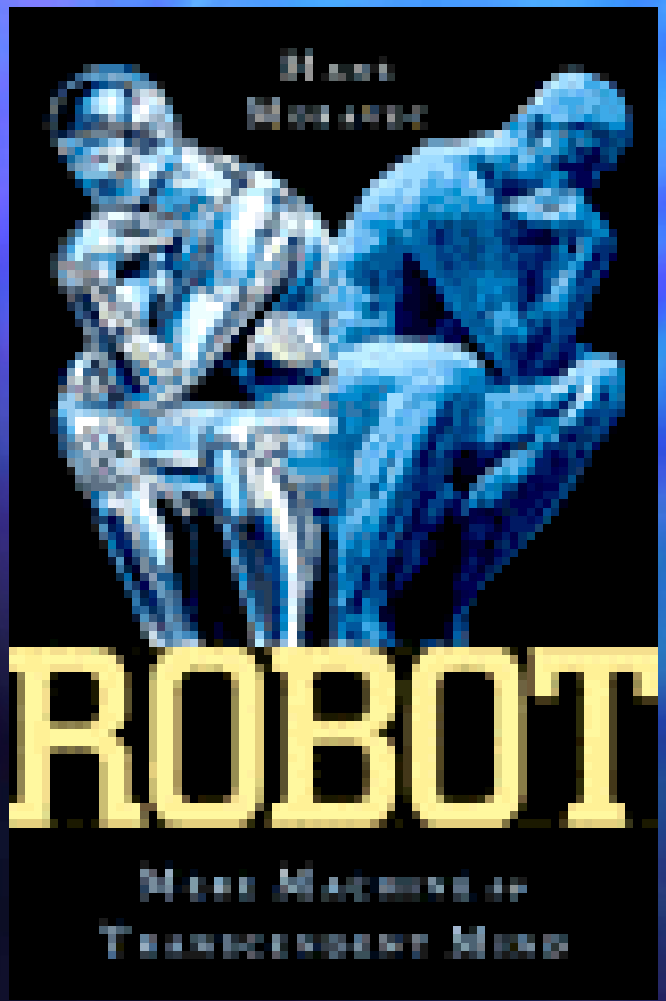


Two Prominent Scientists Announced the coming era of Spiritual Robots





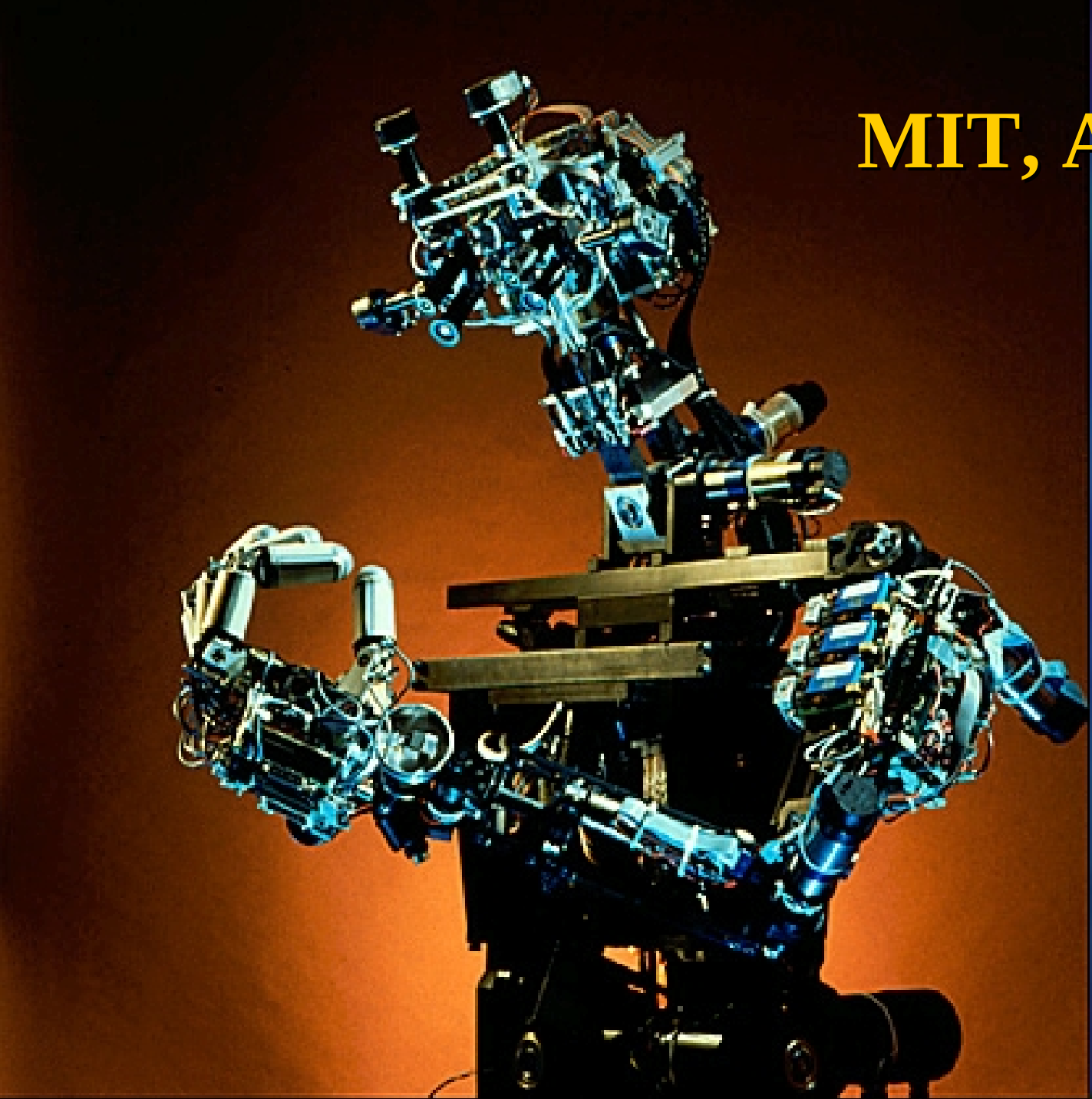
Kurzweil, Moravec, Brooks, Minsky, Papert, Simon, De Garis



Are they crazy?


COG system has been demonstrated
Photo © Sam Ogden

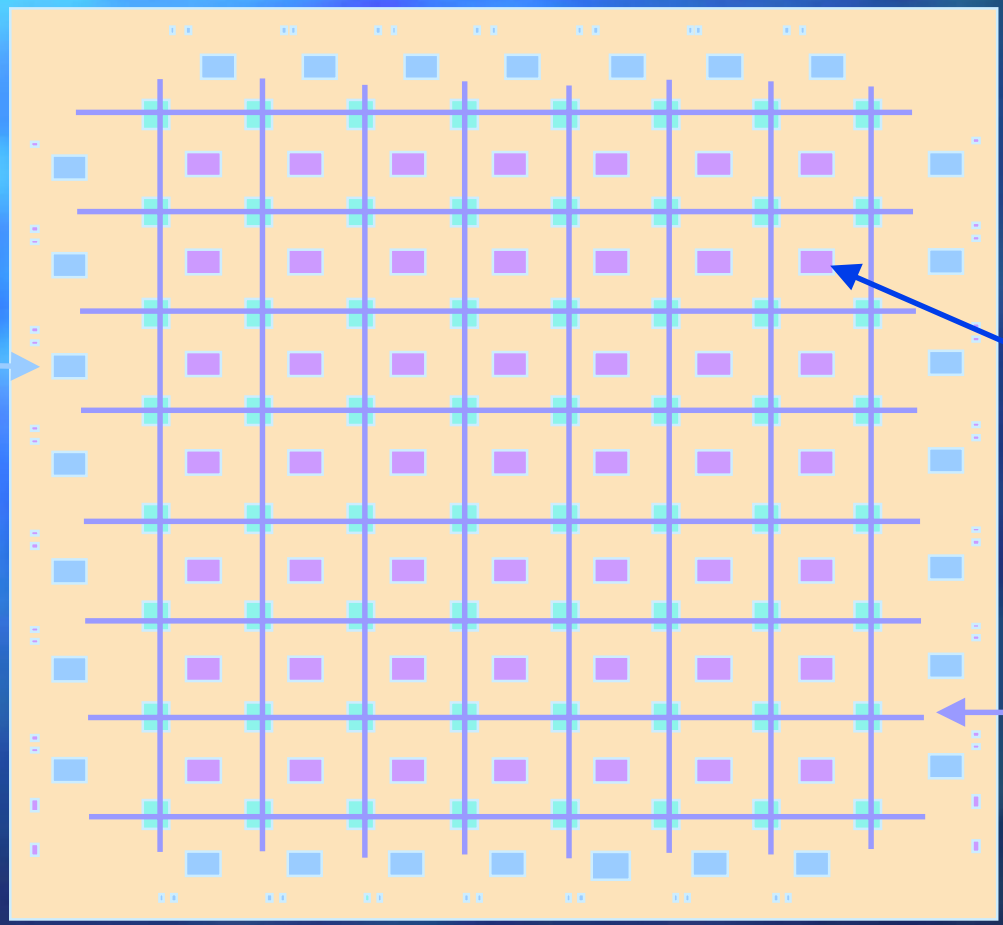
MIT, AI LAB



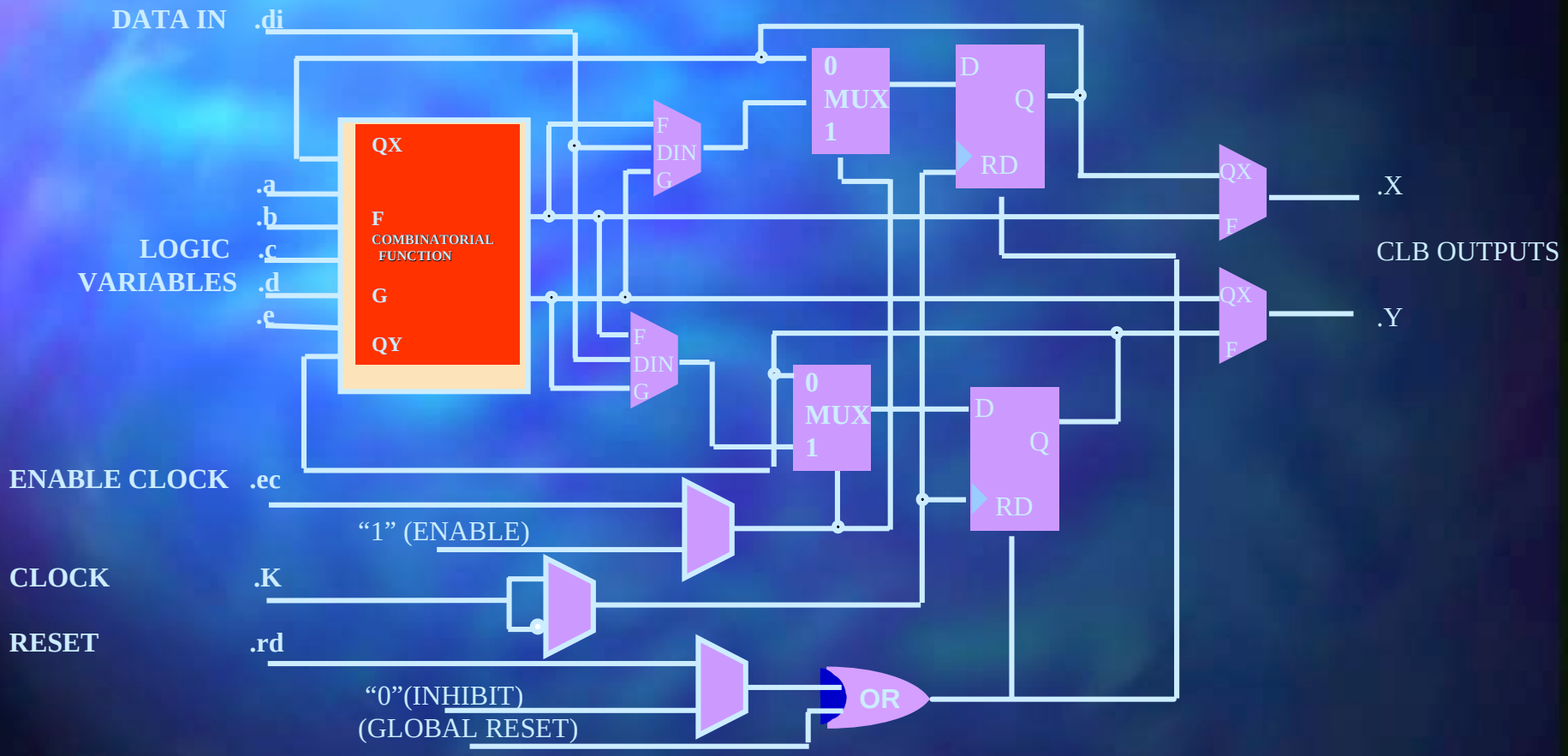
Evolvable Hardware for Intelligent Robots

Hugo De Garis announced the BrainBuilding and Robokoneko

XILINX Field Programmable Gate Array



Configurable Logic Block



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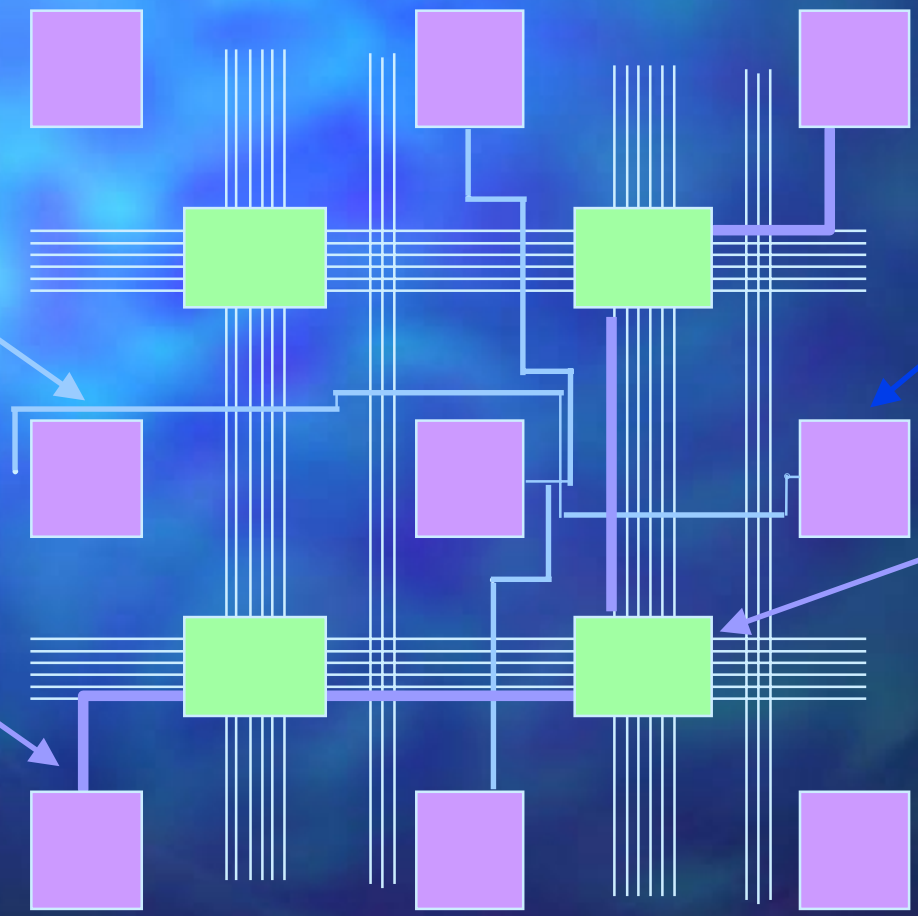
Interconnections



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CAM-BRAIN MACHINE (CBM)

- The CAM-Brain Machine (CBM) is a piece of specialized **"evolvable hardware"**
- It grows and evolves cellular automata-based neural network circuit modules in about a second.

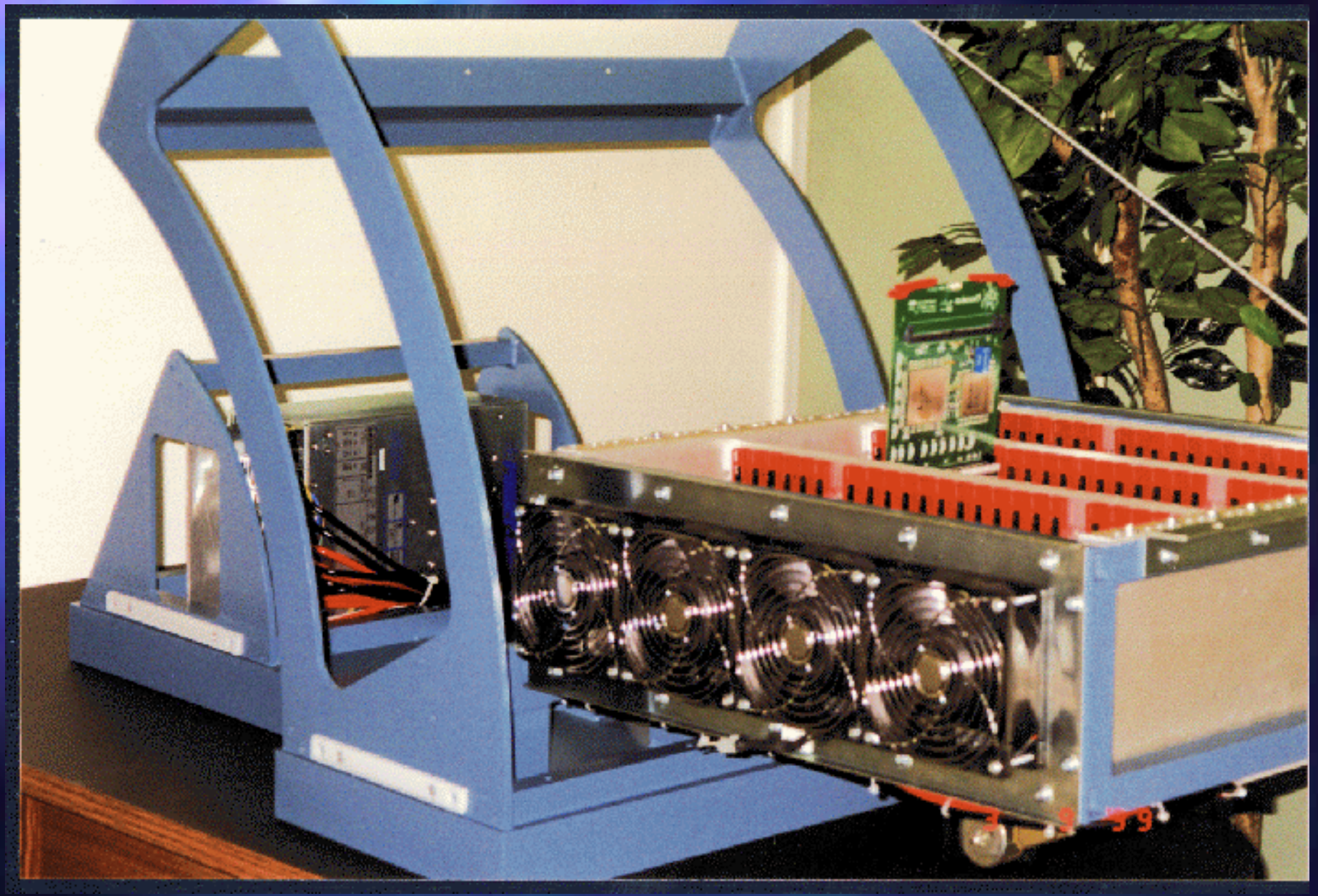
- De Garis: This is so fast that from now on it will be practical to build **“artificial brains”** by assembling tens of thousands of these quickly evolved modules

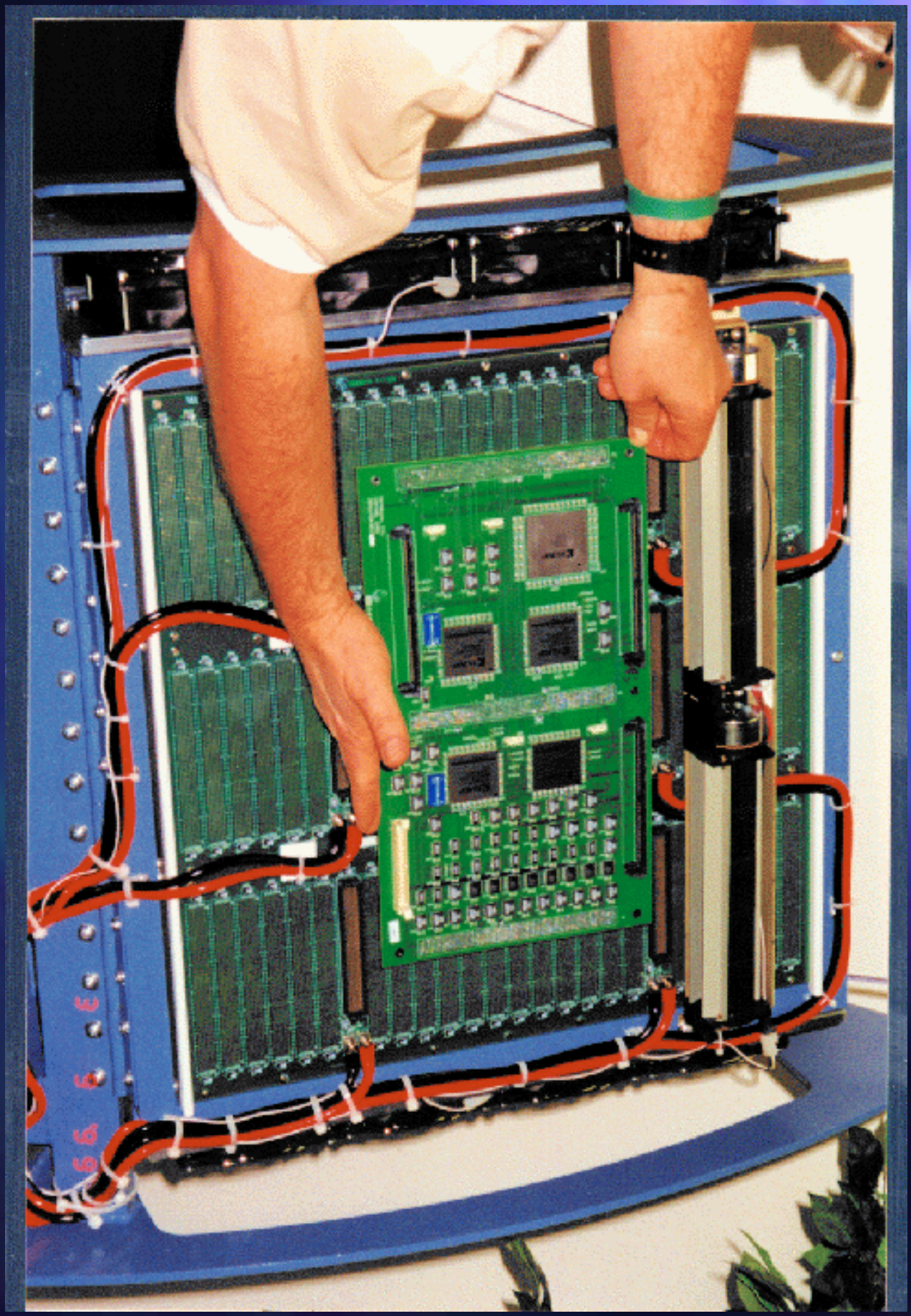
- The CBM can then update the 3D cellular automata cells in the RAM at a rate of 150 Billion a second, updating an artificial brain consisting of 32000 modules (40 million neurons) at a rate of 300 times a second.

- Fast enough for real time control of the life-sized kitten robot "Robokoneko".

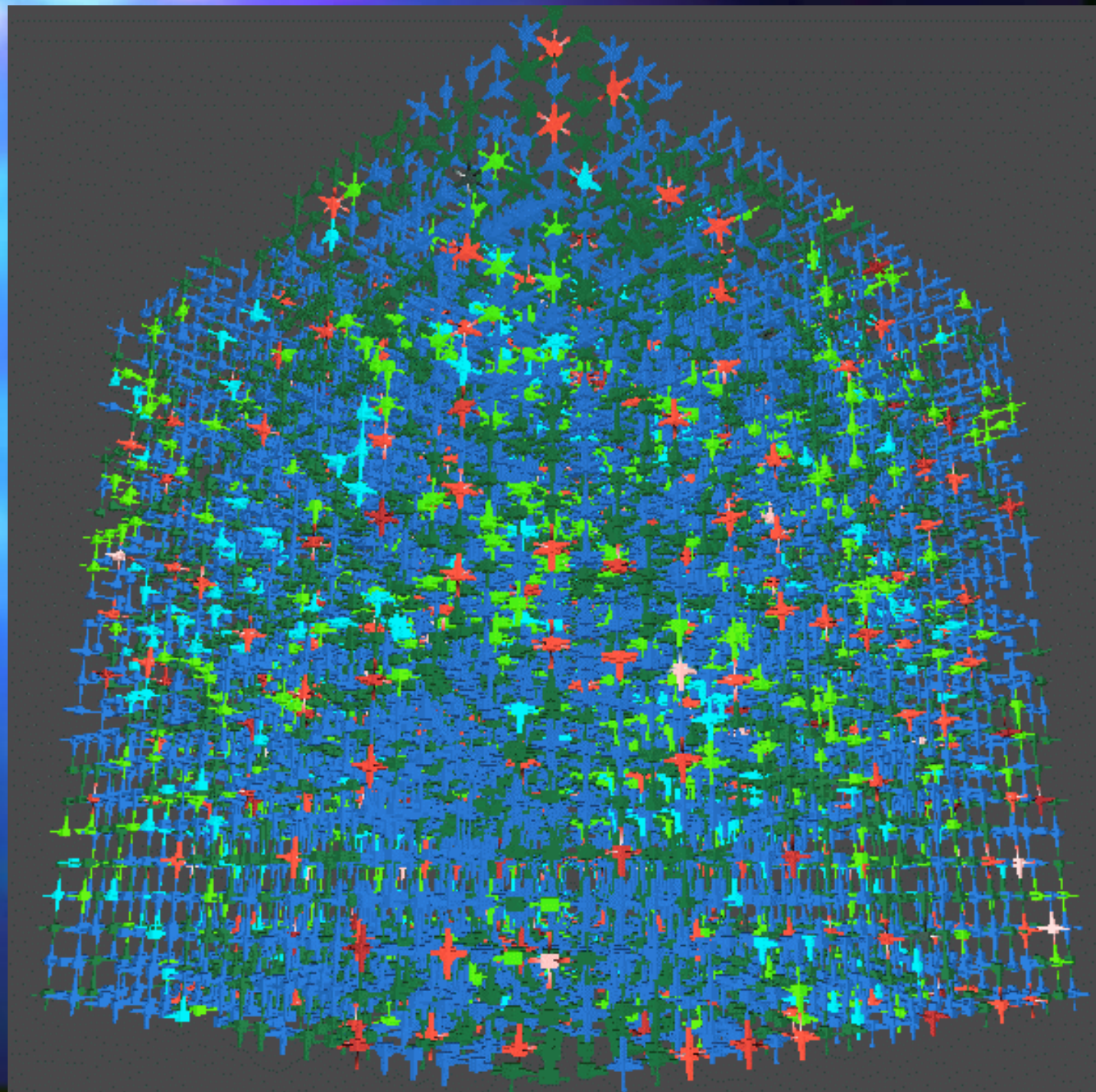
Evolvable Neural Net Supercomputer of De Garis

- Information Flow Rate, Neuronal Level (max.): 12 Gbytes/s.
- Number of FPGA Reconfigurable Function Units: 1,179,648.
- Phenotype/Genotype Memory: 1.18 Gbytes.
- Computational power (estimated): 10,000 Pentium II 400 MHz computers.

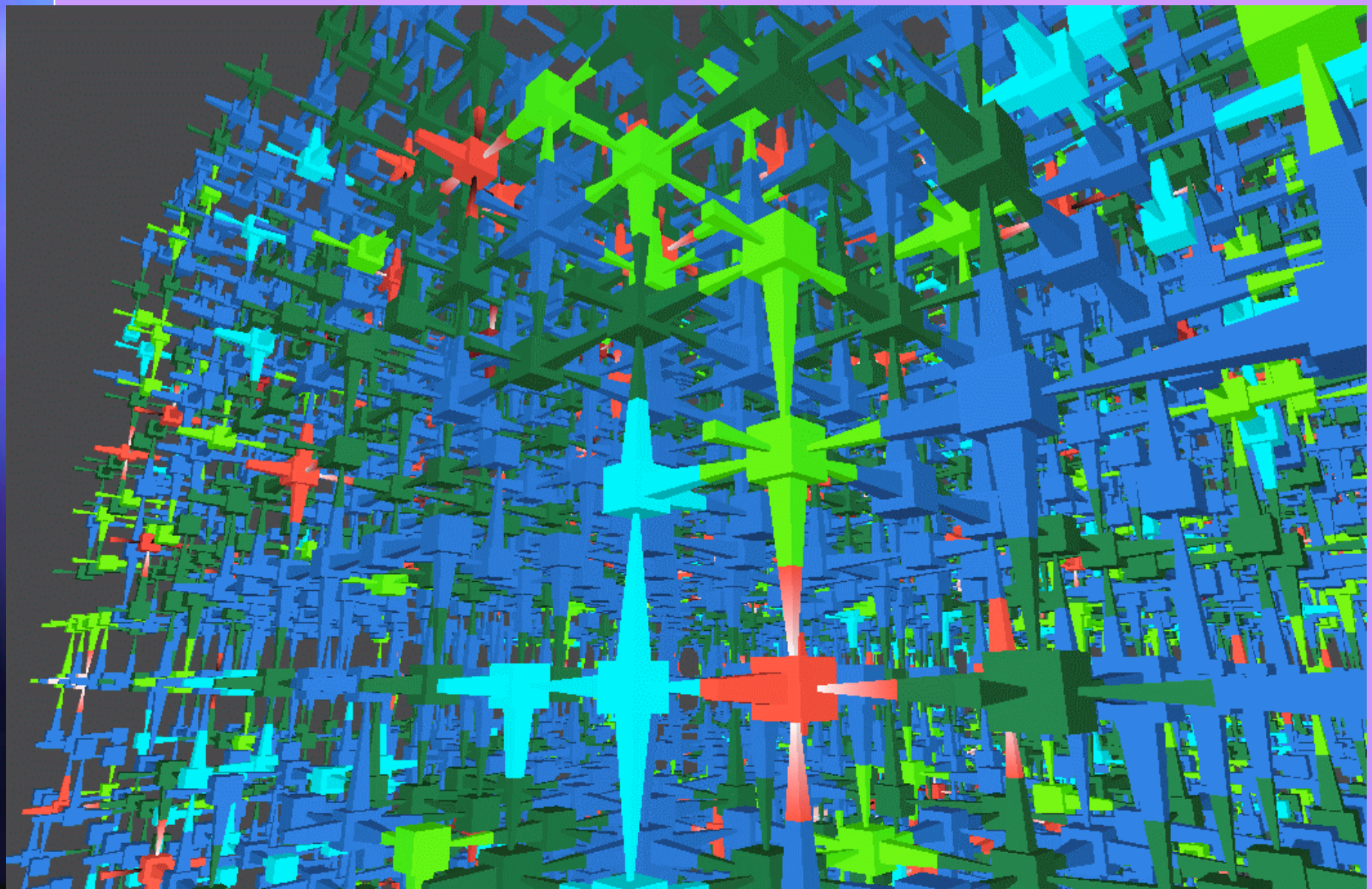


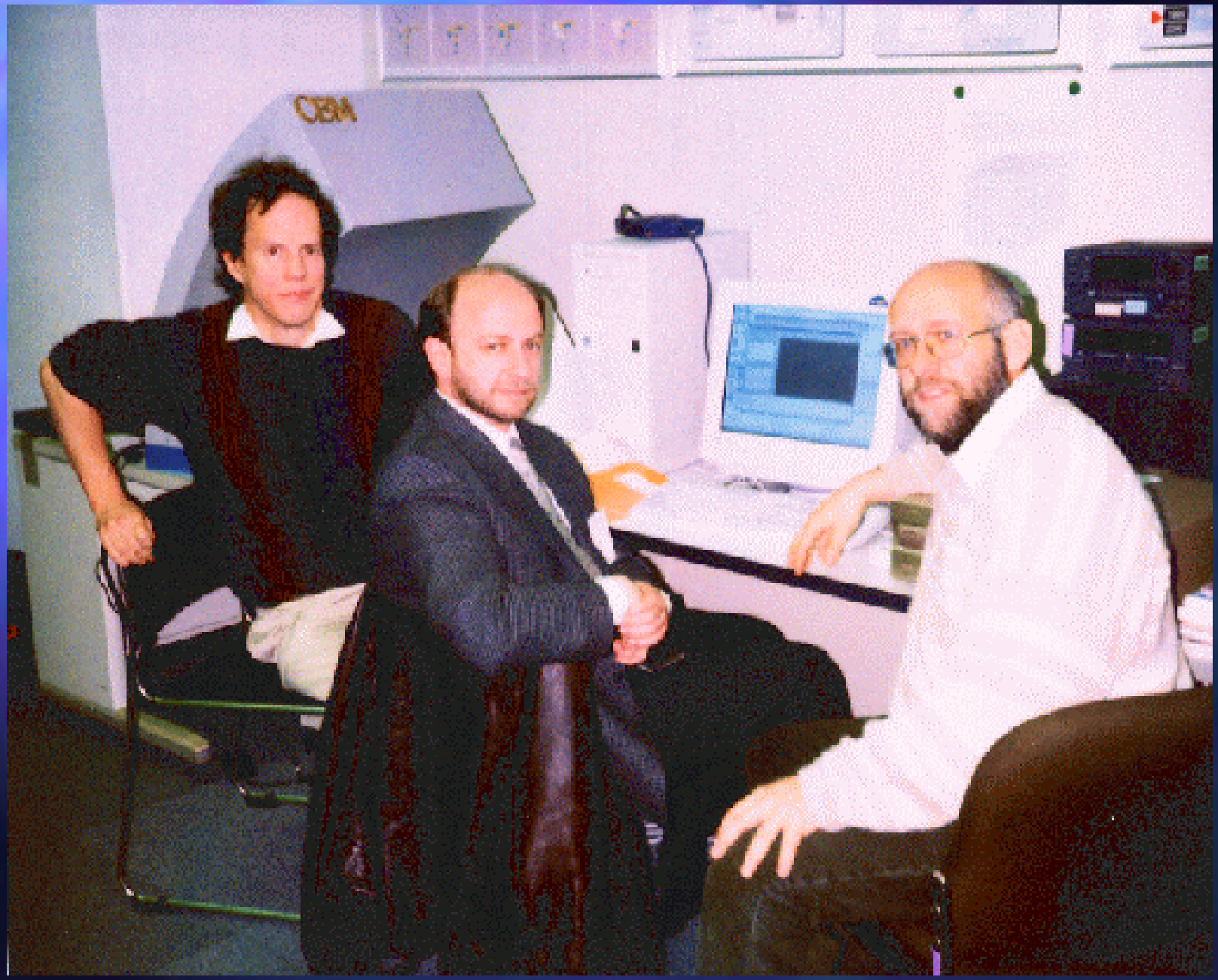


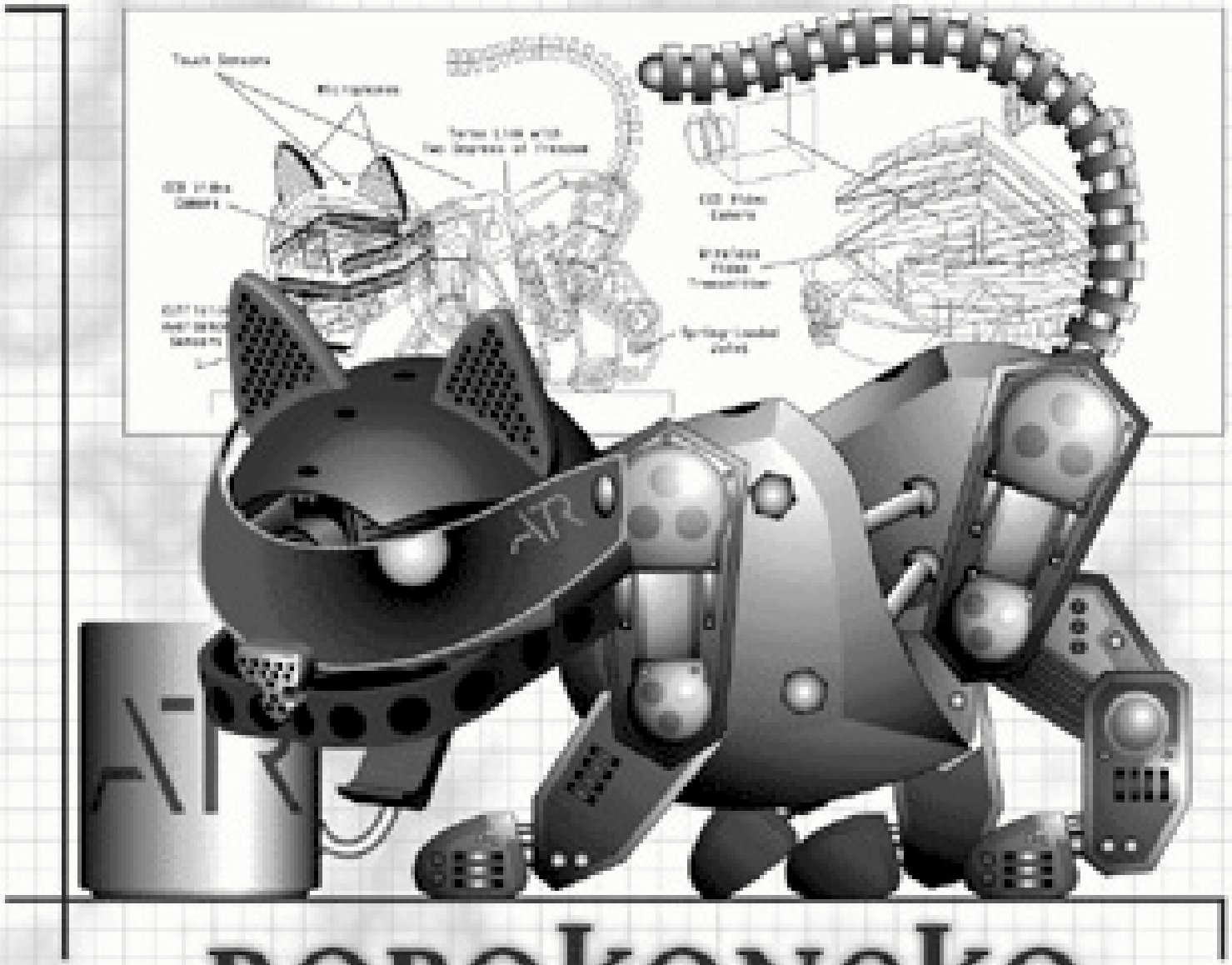
A module is a 24*24*24 cube of 3D CA (cellular automata) cells, which contain up to about 1000 neurons (red). From these neurons grow axons (blue) and dendrites (green).



- Lighter blue and green cells contain a signal (1 bit).
- Whitened tapered connections to a neuron are excitatory neural inputs, i.e. the signal adds to the neurons' binary counter.

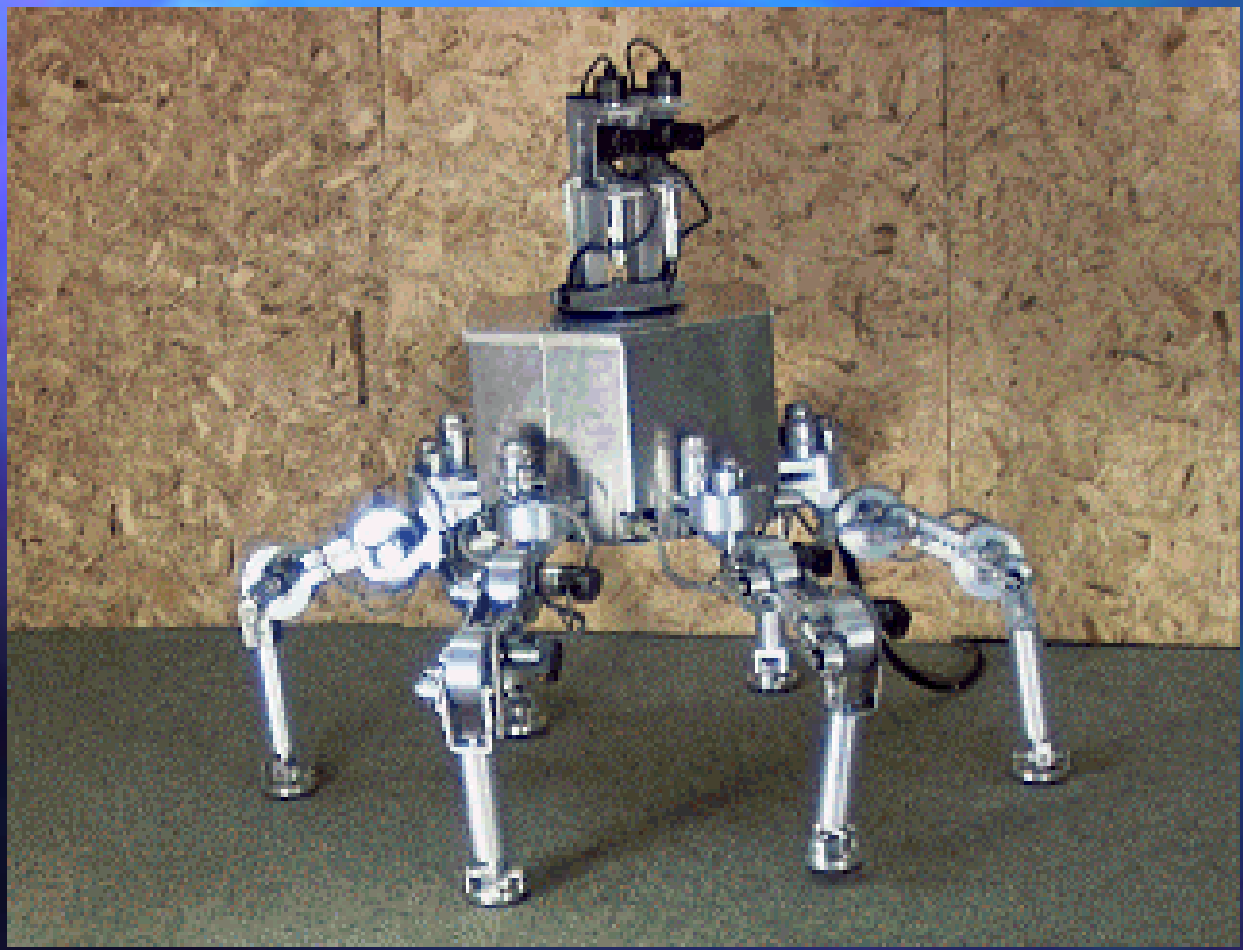


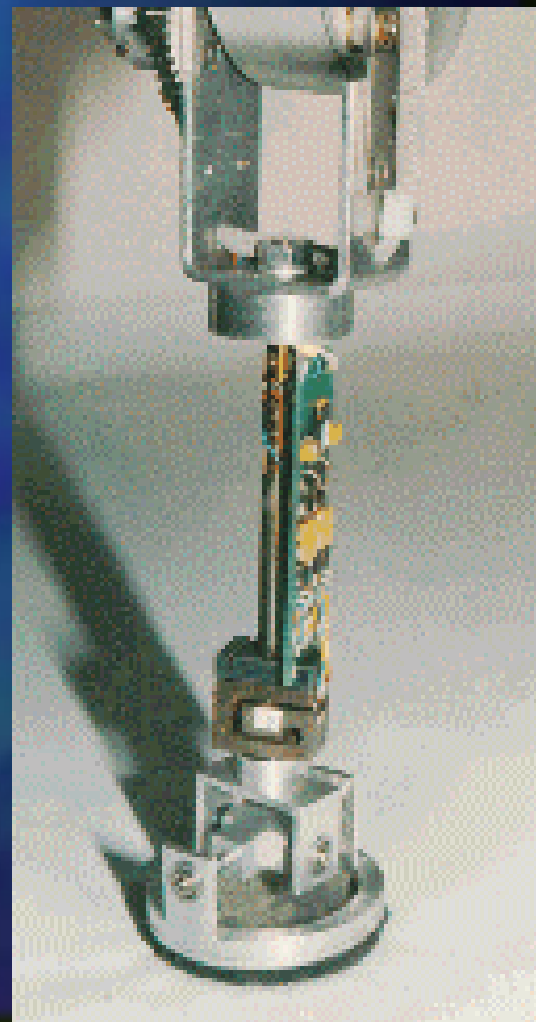



Touch Sensors
Mic Speakers
CCD Video Camera
CCD Video Camera
Wireless Video Transmitter
Spring Loaded Arms
ATR
ATR

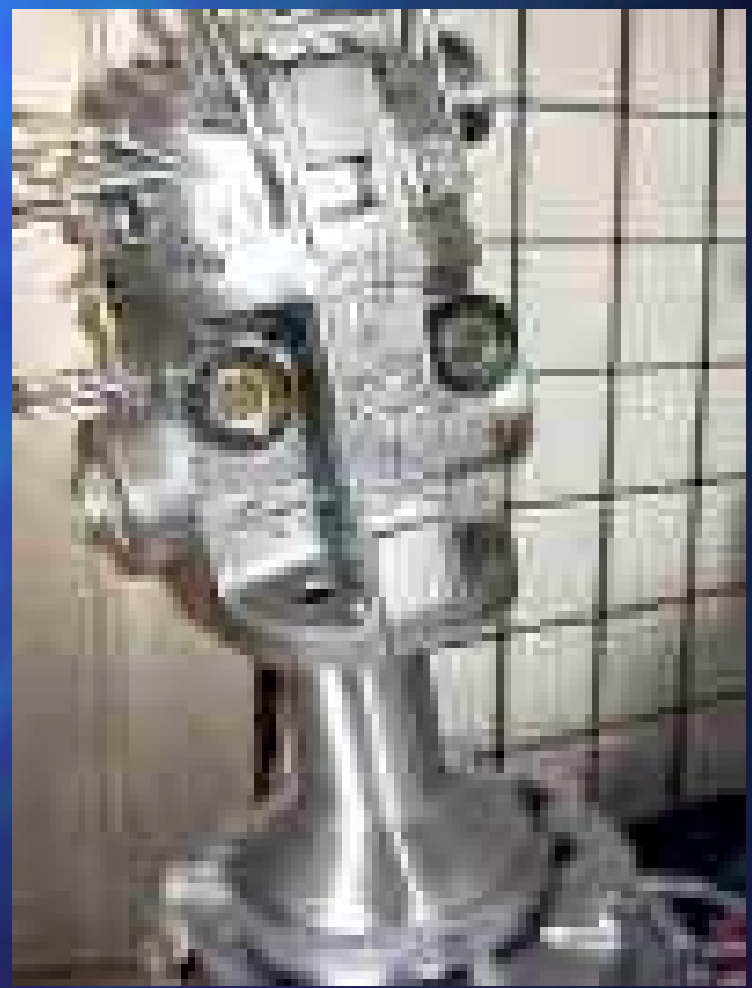
ROBOKONEKO

Several walking robots have been developed





…. And several new will come



World's First Cyber Theatre at PSU

Background: Robotics Theatres and Internet Robots

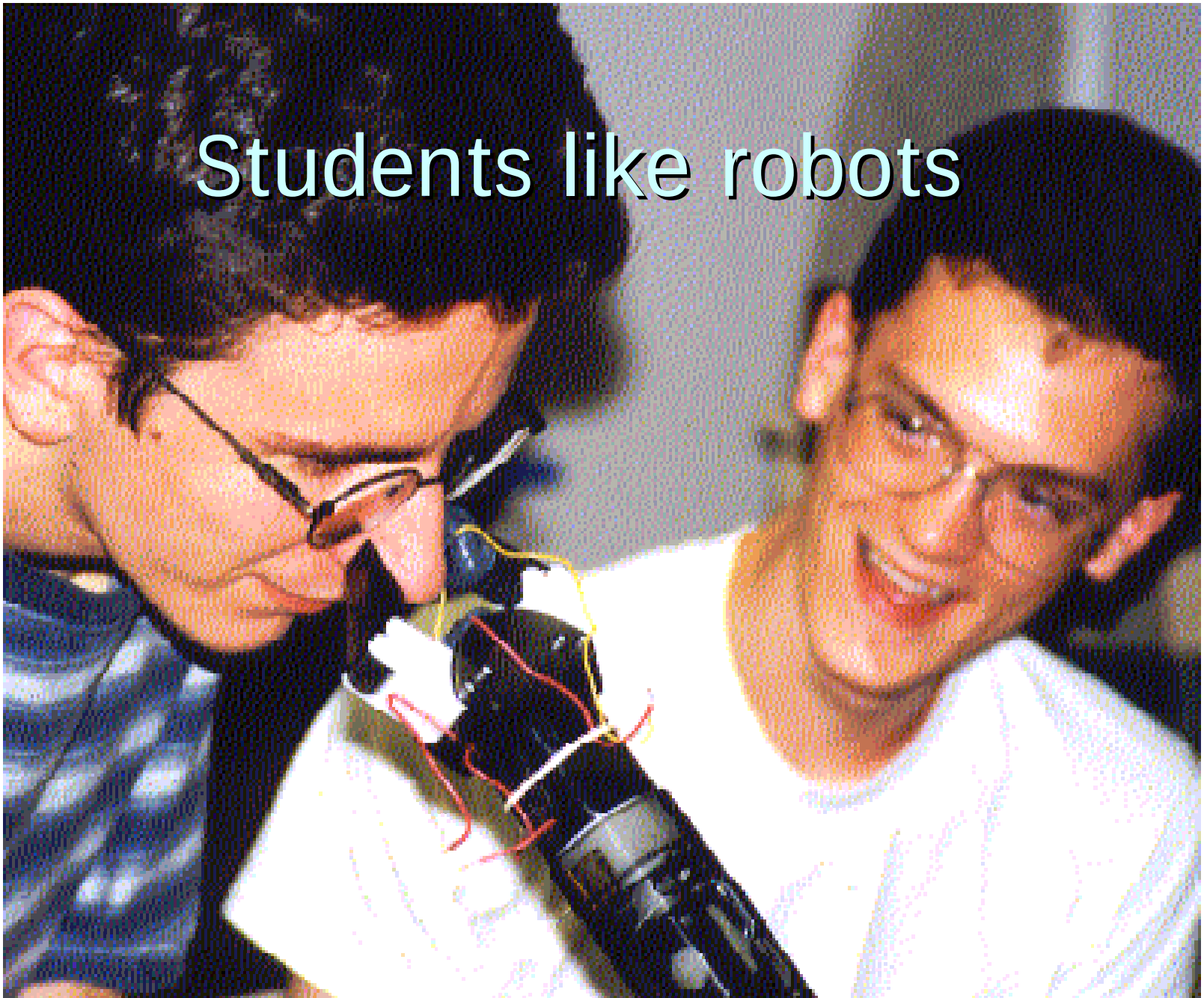
- There exist few "***puppet theaters"*** with robots as puppets [Ullanta00, MUSEUM].
- There are single *robots connected to WWW* [USC].

- Nobody yet proposed to create a ***ROBOTIC THEATER on WWW.***
- Let us be brave enough to try this new idea - and observe ***what will emerge***.
- We will call it the **OREGON CYBER THEATRE**.

... and what about PSU?

Poor Man's Robotics.....

Students like robots



Oregon Cyber Theatre : Lab space in Suite FAB 70

Oregon Cyber Theatre

- In our theatre, robots will be taught and introduced to movements/behaviors by humans who will tele-remotely act as these robots playing roles.
- Humans will **teach** robots to speak, pronounce, move, perform, act, behave and learn.
- The **Machine Learning** and evolutionary techniques of both supervised and unsupervised learning will be used.
- **Emergence and evolution** through evolutionary, logic and game-theoretic approaches

Machine Learning in Hardware

- Machine Learning will be partially realized in hardware for speed.
- Evolvable Hardware - FPGAs, microcontrollers, parallel systems.
- Various learning paradigms will be used.
- Logic methods emphasized in MVL lecture this morning will dominate.

Main Ideas

- Humans-operators will ***play roles*** in plays performed in the robot theater :
  - researchers ,
  - graduate and undergraduate students,
  - high-school students,
  - actors and acting students.
- Operators in Laboratory.
- Tele-operators from all over the world.
- Observers through Internet.

Theater as a Myth

- Role of theatre in history, religion and culture
- Classical tragedies and comedies
  - For instance, we will try to adapt the **Myth of Prometheus** to our environment.

The theatre plays

- Plays will be ***partially organized***, like playing Shakespeare, but:
  - the actors/agents *may deviate* from the text,
  - something *non-expected* can happen, or
  - some tele-agents will be *missing*, so they will be replaced by automated software robotic-agents.

Repertoire

- Not every play can be realistically played in the coming few years.
- We need to find a writer to write a play for the "actors" shown here and others that we have.
- On the other hand, it may be interesting to play the “Romeo and Juliet” with spiders and dogs, or human-like-robot-actors in wheelchairs or on tricycles.

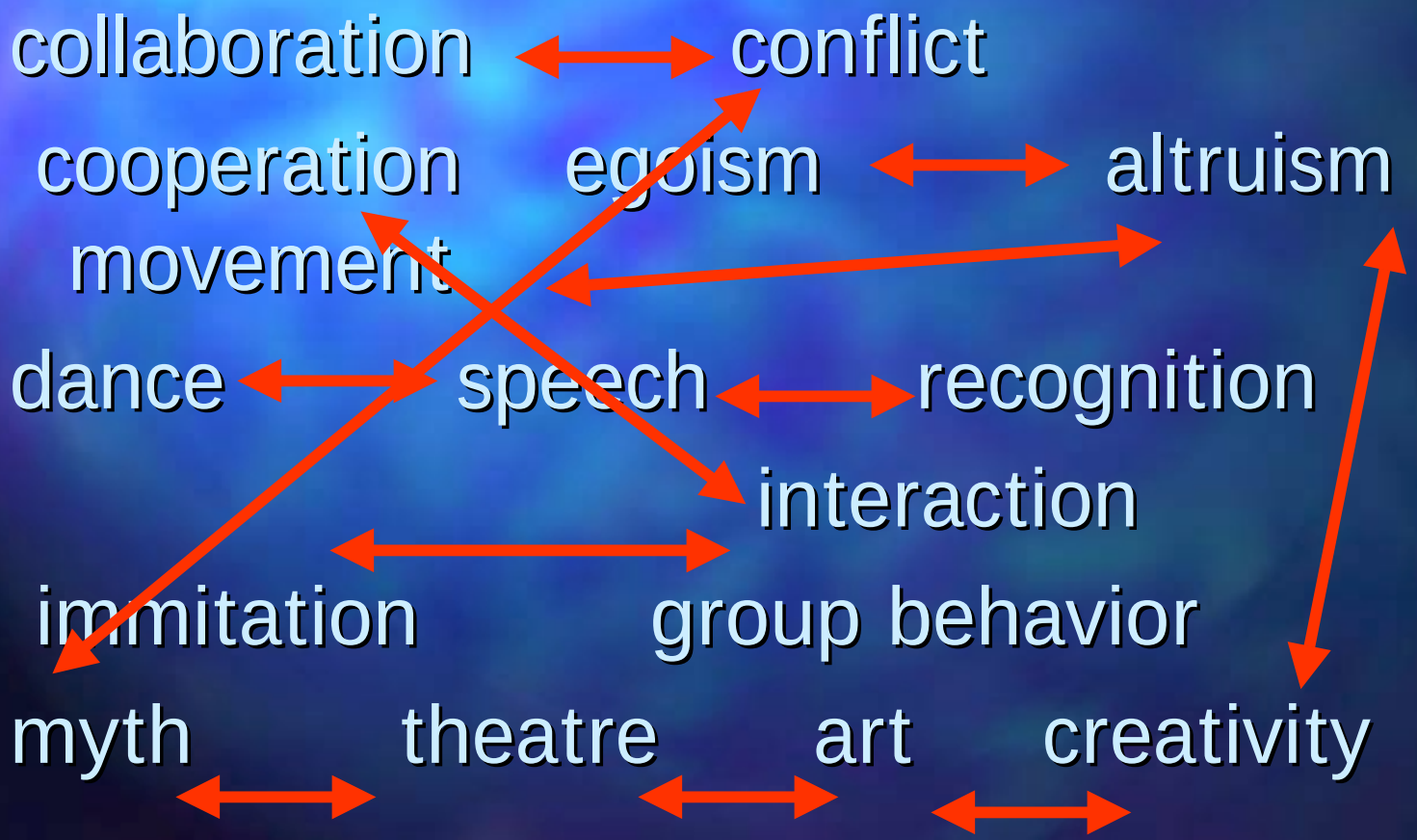
The theatre plays

- In the future plays, you, the tele-operator, can be a human-robot, an animal-robot, an alien, a mushroom, a plant, a dragon, an angel, a machine.
- True big industrial robots will be next incorporated to change the scene and play the roles of giants.
- In addition to dramas and comedies, dances and vocal performances by robots, we will organize educational performances.
  - For instance, Figure presents a setup with a Professor's Head, who explains the robot test technology to students.

RHINO: Setup for automatic test and fault location with self-repair.
In the first plan you see the conveyor belt with the board for test/self-repair.
On the right there is the Professor's Head that will explain the project to students in English

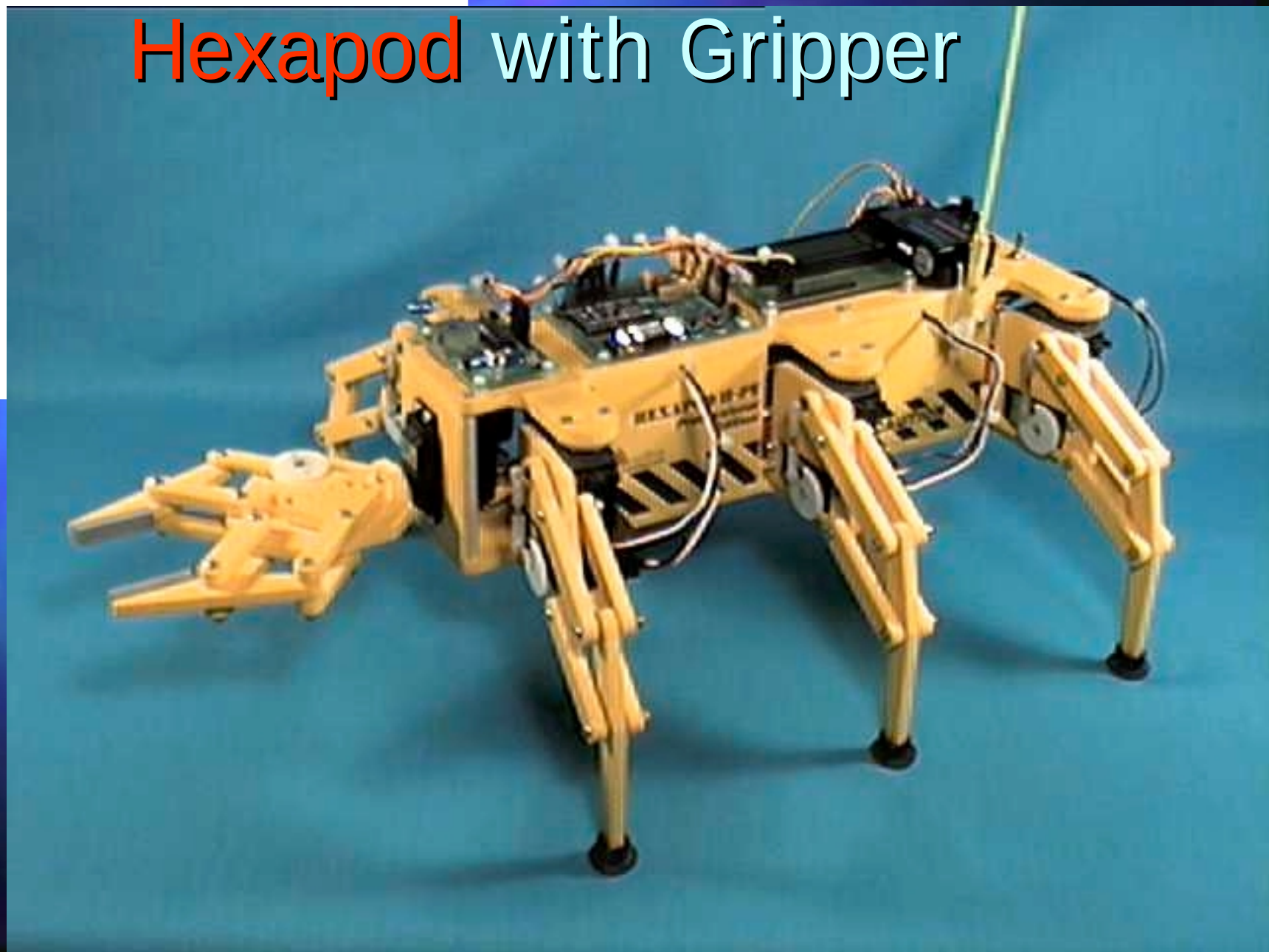
The goal....

- **....will be to involve people around the world to think about the fundaments of**



presenting our actors

Basic Radio-Controlled Spider Hexapod with Gripper



Spider with a camera

First Stage - Spiders

- To build 8 radio-controlled spiders with grippers and cameras.
- Observe and demonstrate some simple ***emerging societal phenomena***.

- Having eight spiders will allow us to designate four of them as males and four as females, two couples in a "country".

Robot Behaviors

- 8 spiders will allow to perform the plays and observe emerging phenomena such as:
  - Duel, war, love, sexual reproduction,
  - Creation of families (polygamistic and monogamistic),
  - Collaboration, competition, emergence of hierarchy, belief and morality.
  - Truth telling and lying robots.
  - Cheating and honest workers.
  - *Ten Commandments* adapted to the robot-spiders mini-world, versus the *Three Robotics Laws of Asimov.*

OREGON CYBER THEATRE

- Oregon Cyber Theatre will be composed of:
  - A. **Robots-puppets** located in interdisciplinary Intelligent Robotics Laboratory at Portland State University (Suite FAB 70).
  - B. **Cameras and sensors** located on the puppets (for instance in their eyes)
  - C. **Computer controlled cameras**, for passive observers will be located in various locations in the room.

Camera for birds, angels and Internet observers

Under $100

in 2000 money

Sonar for control of a robotic wheelchair

OREGON CYBER THEATRE

- D. **Microphones and other sensors** in the physical theatre.
- E. **Computers** in the lab controlling the robots by radio, tethered or directly.
  - They will range from laptops to special-purpose FPGA-based supercomputers.
  - Movement control, learning, image processing, natural language/speech software, and AI software will be installed on these computers.

OREGON CYBER THEATRE

- This software will come from Portland State University (PSU), Oregon Graduate Institute (OGI) and our external collaborators.
- All computers will be **linked to WWW**.
- F. **Global recording mechanisms** of what happens on the scene.
  - All control decisions, events, images, sounds, sensor readings, etc. will be recorded as a base for further protocol analysis and learning processes.

OREGON CYBER THEATRE

- G. Computers linked to WWW in **Internet tele-sites.**
- H. **Role-playing software** at tele-sites, WWW-linked to our software controlling the puppets and the scene (lights, scene rotations, etc).
- I. In the next phase, **cameras located in tele-sites.**
  - Thus such camera can look at a person in Honolulu and replicate her movements to our spider or dog puppet (the "**avatar concept**" well-known from multimedia and video-animation systems).

OREGON CYBER THEATRE

- K. Microphones and sensors located at tele-sites.
  - Persons will use their own body movements and voice to act,
  - this will be transformed to the movements and voices of robotic puppets.

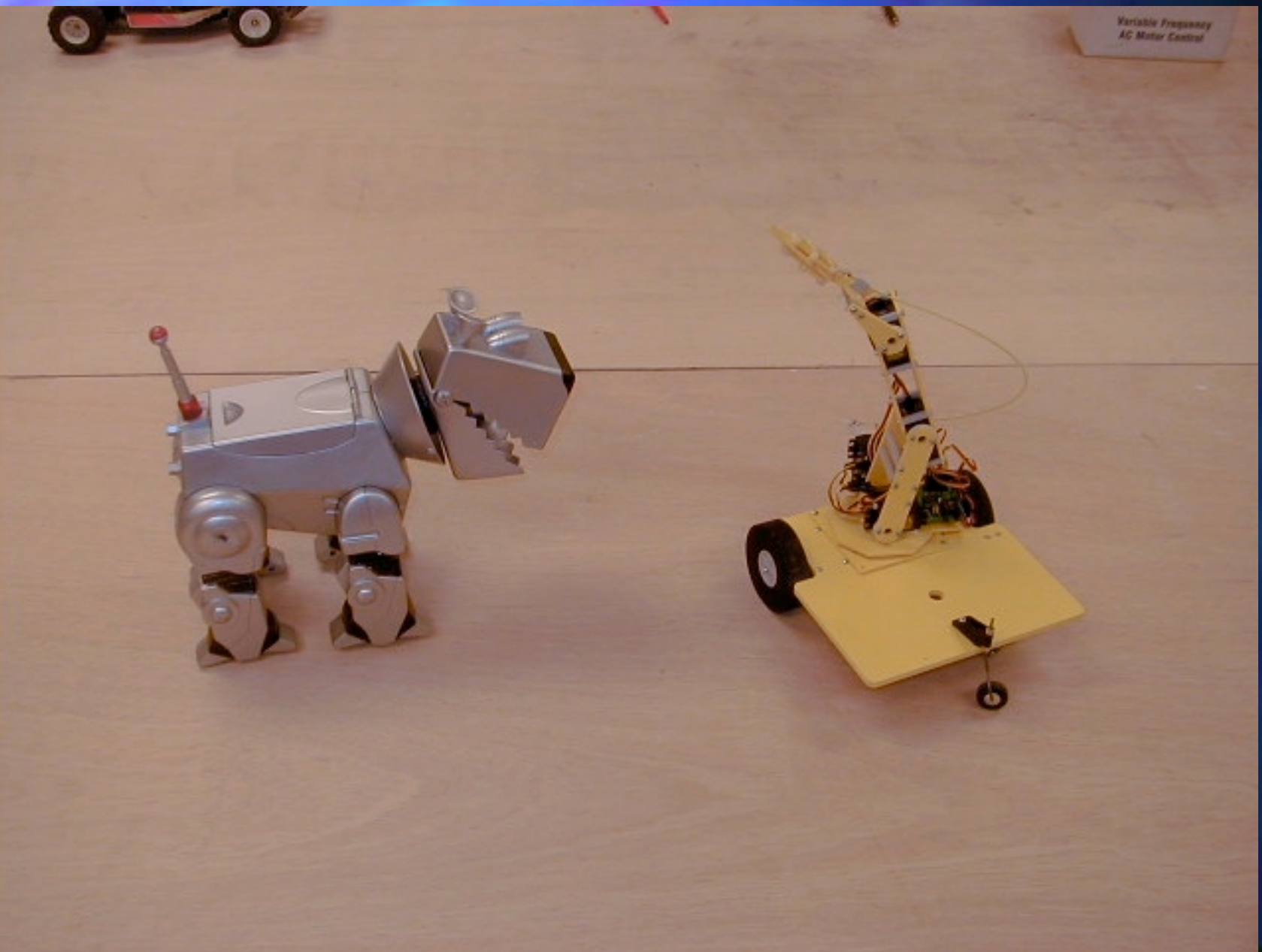
Robot Puppets

- Physically, most puppets-robots will be rather small.
- Our tallest puppet, a walking human, is about 1/2 meter high.
- Small size allows to control the robots from inexpensive servo motors:
  - used in radio-controlled airplane and car models, keeping the cost of a single robot below 1000 $ in year 2000 money.

Robot Puppets

- A puppet walking on **6 legs** is simpler to build and control , than one walking on four.
- Walking bipeds are the most challenging to build and we do not plan to build them in the first phase.
- On the other hand, robot technology gives us the freedom to design **new "life forms**" such as "intelligent snakes" or **three-legged insects**.

The Dog does not like the mobile arm



Robot Puppets in 2005

- We expect that in few years the price of a robot with about **30 degrees of freedom** will drop to about **100 dollars**.

- We will be able to have about 20 robots in the theatre in year 2005, and thus to have full scale performances with many actors.

"Hexapod Centaurs"

- Next generation of robots
- Build in scale 4:1,
- With six legs for better stability and strength,
- But with "human-like" upper body - head and hands.
- This will allow to extend the repertoire of plays and games

Future robots

- **Walking**
  - spiders
  - insects, ants, turtles
  - snakes and other easy animals.
  - Hexapod Centaurs
  - dogs, cats, horses,
  - monkeys
  - humans and mythological figures
- **Situated** (big humans, giant, mythical)
- **Wheeled** (walk simulation, in wheelchairs, on wheels)

Re-Use Technology for inexpensive robots

- **Halloween items**, **mannequins** and other existing items.
  - After-holiday sales provide opportunity to purchase such items at a fraction of their original price.
- Some other are built from commercially available **kits** and upgraded.
- **Toys** are fabricated in China and Japan, they will be also used after computer interfacing and mechanical modifications.

Future Cyber-Theatre dance group

Halloween Skeletons. This 10$ (on sale) toy can be converted to a talking and moving robot.

- A variety of heads that can be converted to talk arbitrary text by replacement of their EPROMs with parallel port interface to PC

Our permanent competition for the best MUVAL's Head

Characteristics of robots

- Robots will have certain degree of **autonomy** and certain degree of **tele-operation**.
- The autonomy will include the non-deterministic rule-based systems and emergent behaviors based on **Finite State Machine** Distributed agents.
- **Random number generators** will be used in them.
- Autonomous behavior will be **not predictable**, although it will be **constrained** to a certain degree.
  - You do not know which path the robot will take to omit an obstacle, but you can predict that it will try to do this and will not fly above.
  - This way, for instance, additional conflicts or funny situations may emerge in plays.

Brain as a society of agents

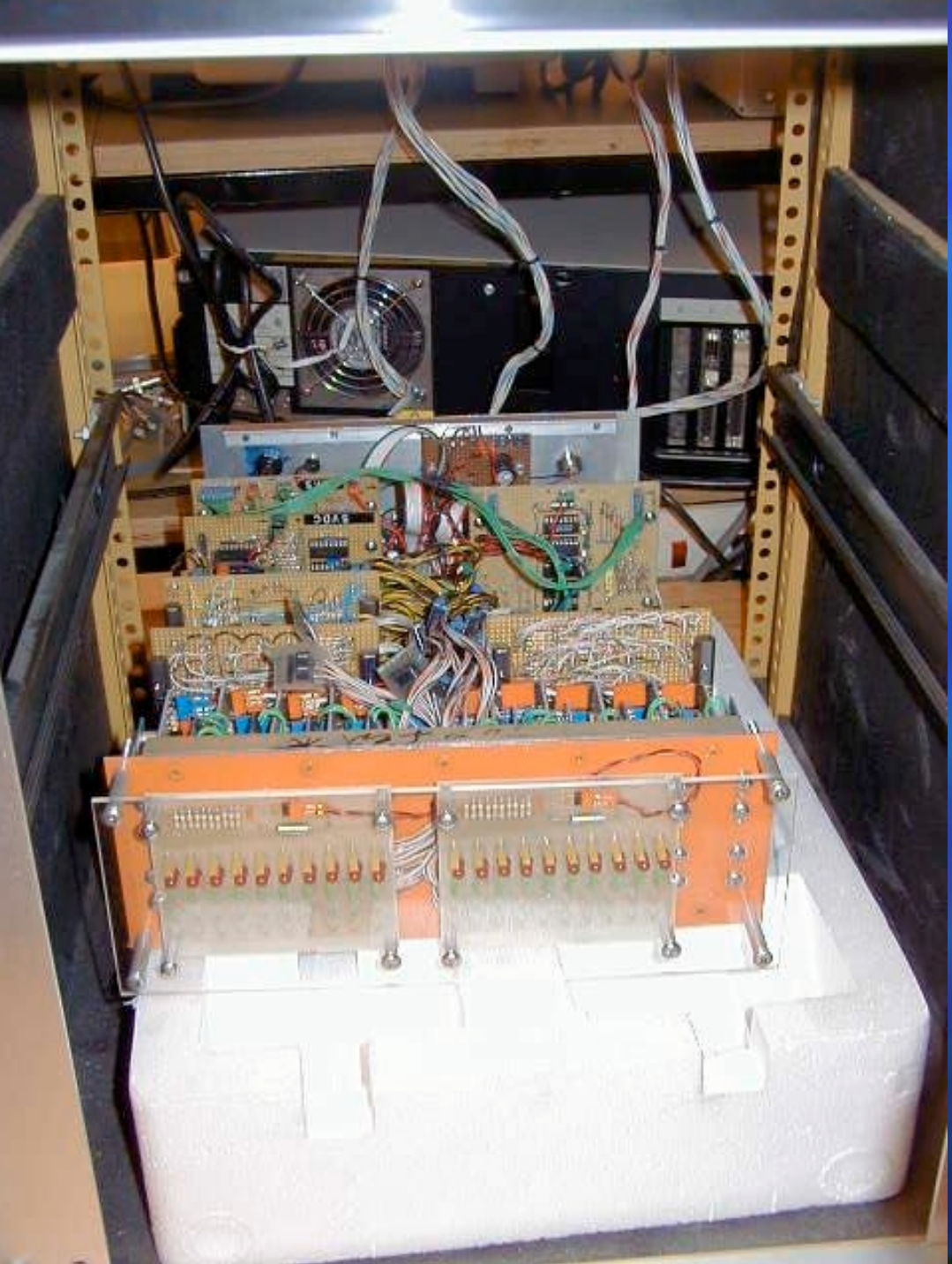
- MUVAL (MUltiple-VAued Logic robot, reasoning in multiple-valued logic).

- "Brains" of more complex robots, such as MUVAL will be constructed as **"societies of agents".**

MUVAL ROBOT

- Would you like to work on improving his appearance and intelligence?

MUVAL will have pneumatic body, so it will become fat and red when angry



- Electronics build by a student from freshmen class
- Robotic Theater exposes students to a variety of experiences

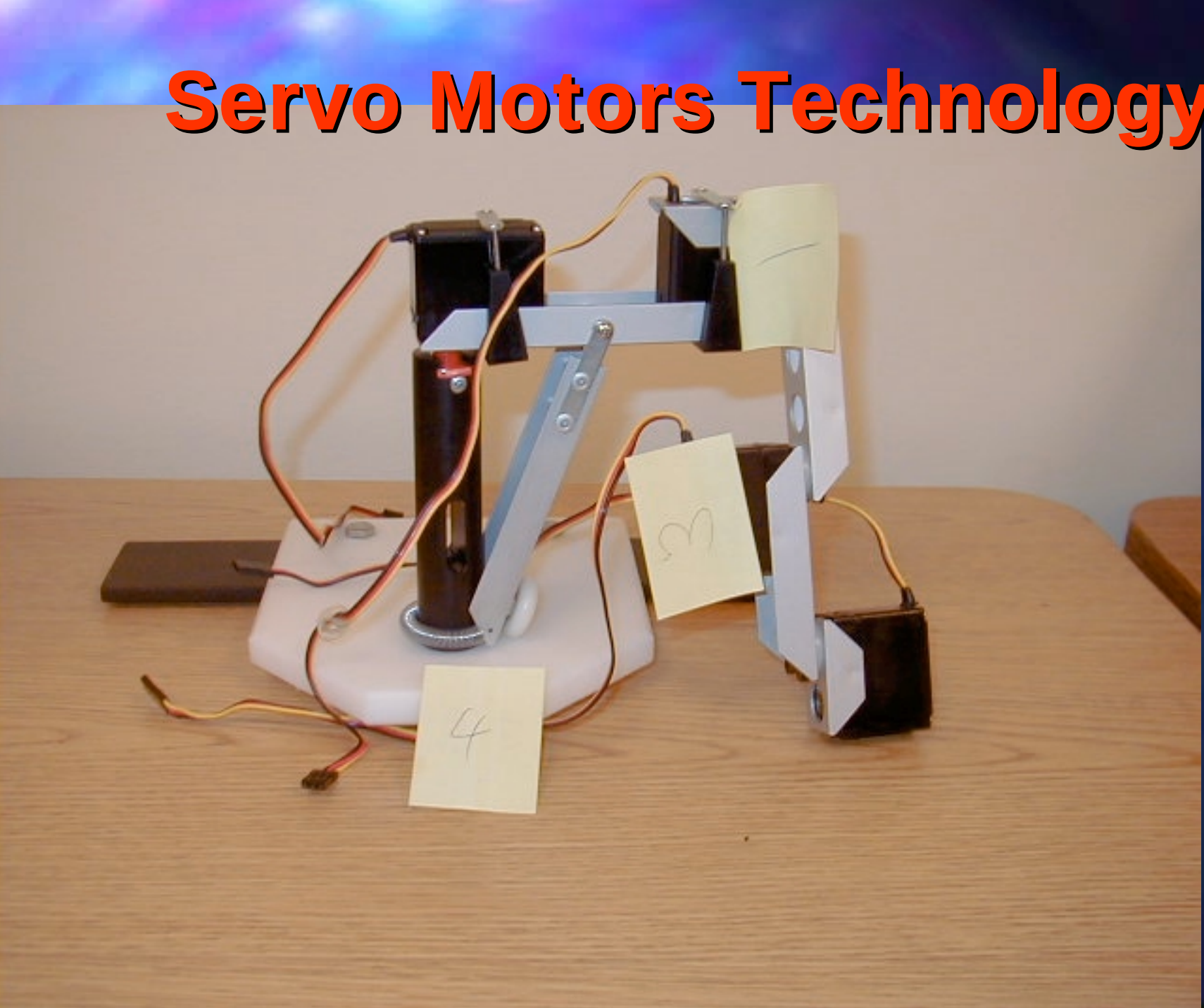
The tele-operation

- Robots will be radio-connected to the control/transmission computer linked to Internet.
- Each agent will be either autonomous or controlled by a human located somewhere on the Internet.
  - A person from Singapore could control the right hand and a person from Hawaii the walking gaits.
  - The voice will come from the memory or it will come, say, from Hungary.

The tele-operation

- Thanks to Internet technology, all the software for recognition, processing and voice-generation can be distributed world-wide

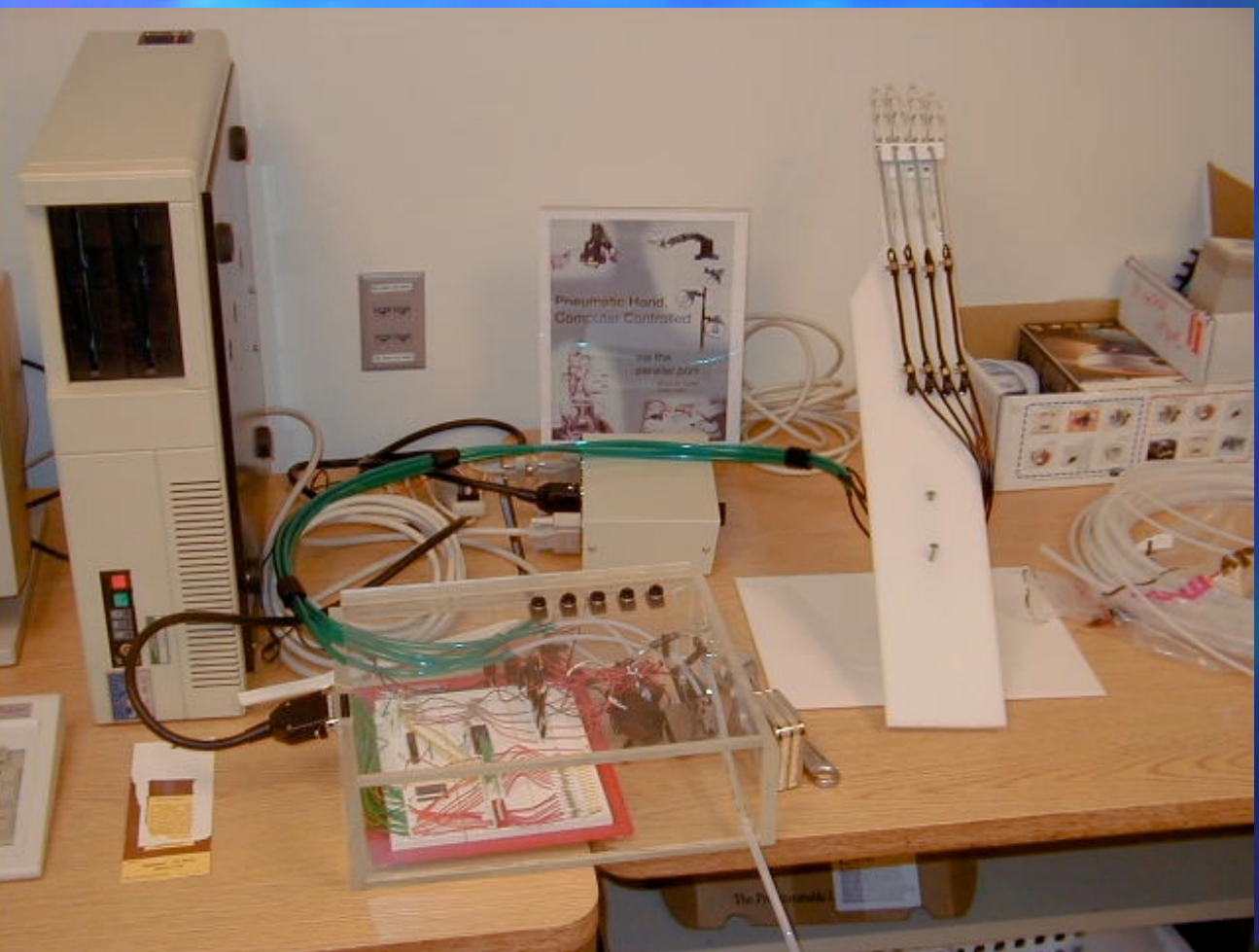
Servo Motors Technology



This is inside the Furby, ... new control in GAL

Pneumatic Technology

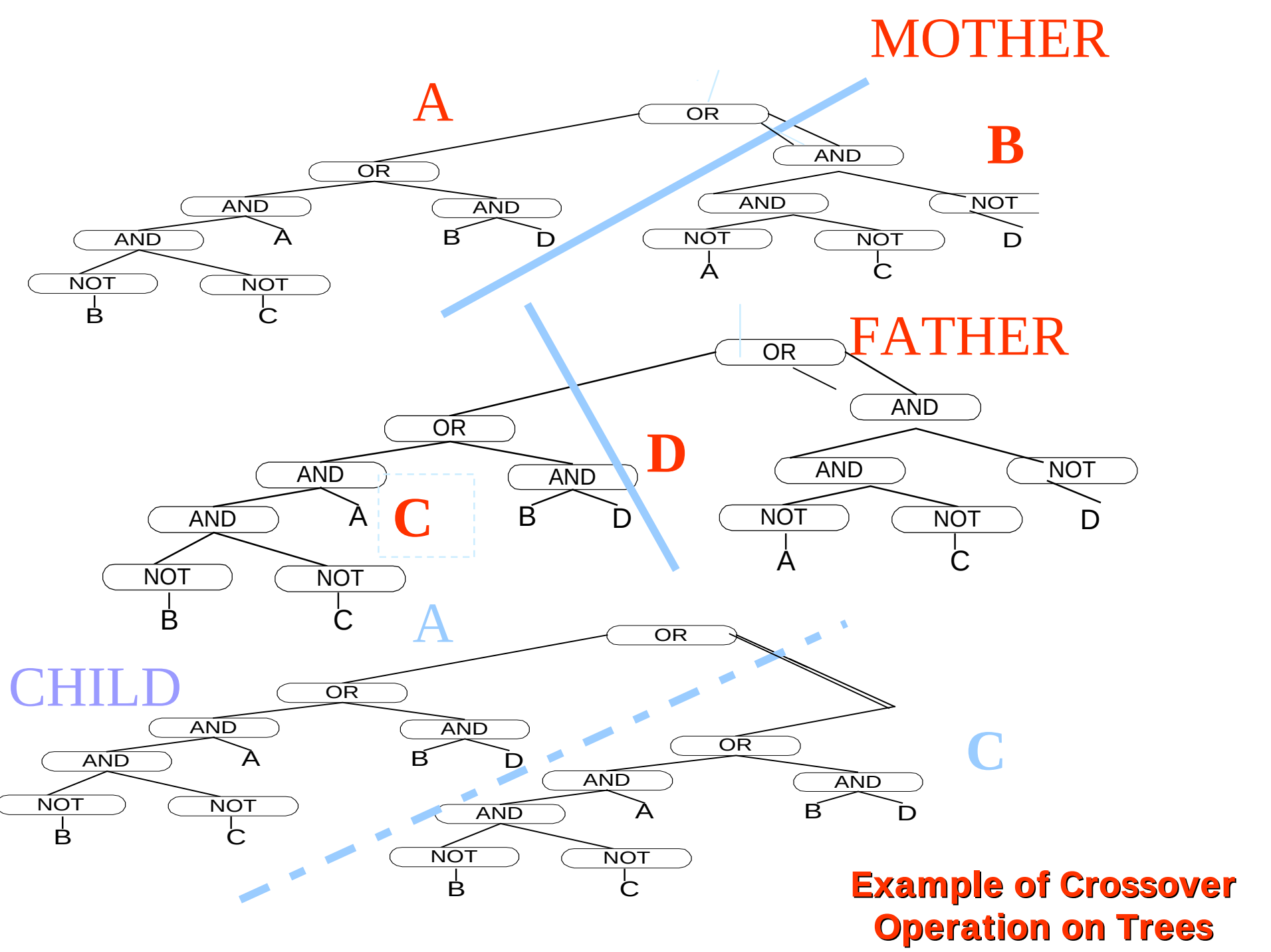
- You can see the artificial muscles at the right and PC interface with valves at left.



Electric, Pneumatic, Hydraulic,.....?

- Electric control.
- Pneumatic control based on inexpensive artificial pneumatic muscles, a new inexpensive technology developed in last few years.
- We experiment also with inexpensive hydraulic technologies based on pistons and syringes.


and now to the serious business


MOTHER
A
B
FATHER
C
D
CHILD
A
C
OR
AND
NOT
A
B
C
D
Example of Crossover Operation on Trees

Evolving or Learning in Hardware?

Machine Learning becomes a new and most general system design paradigm

It starts to become a new hardware construction paradigm as well

- Evolvable Hardware is Genetic Algorithm PLUS reconfigurable hardware
- We propose Learning Hardware as any learning algorithm PLUS reconfigurable hardware
- Learning algorithm can be realized in software or in hardware.

What is most important in robotics?

- **Speed of processing data in real time**
- **Understanding what is going on, rather than using black boxes**
- **Building model of the world around**

Our algorithms proved to be useful and give very good quality solutions in

--- FPGA synthesis

--- Data Mining

So now let us try the challenge of ROBOTICS

Universal Logic Machine

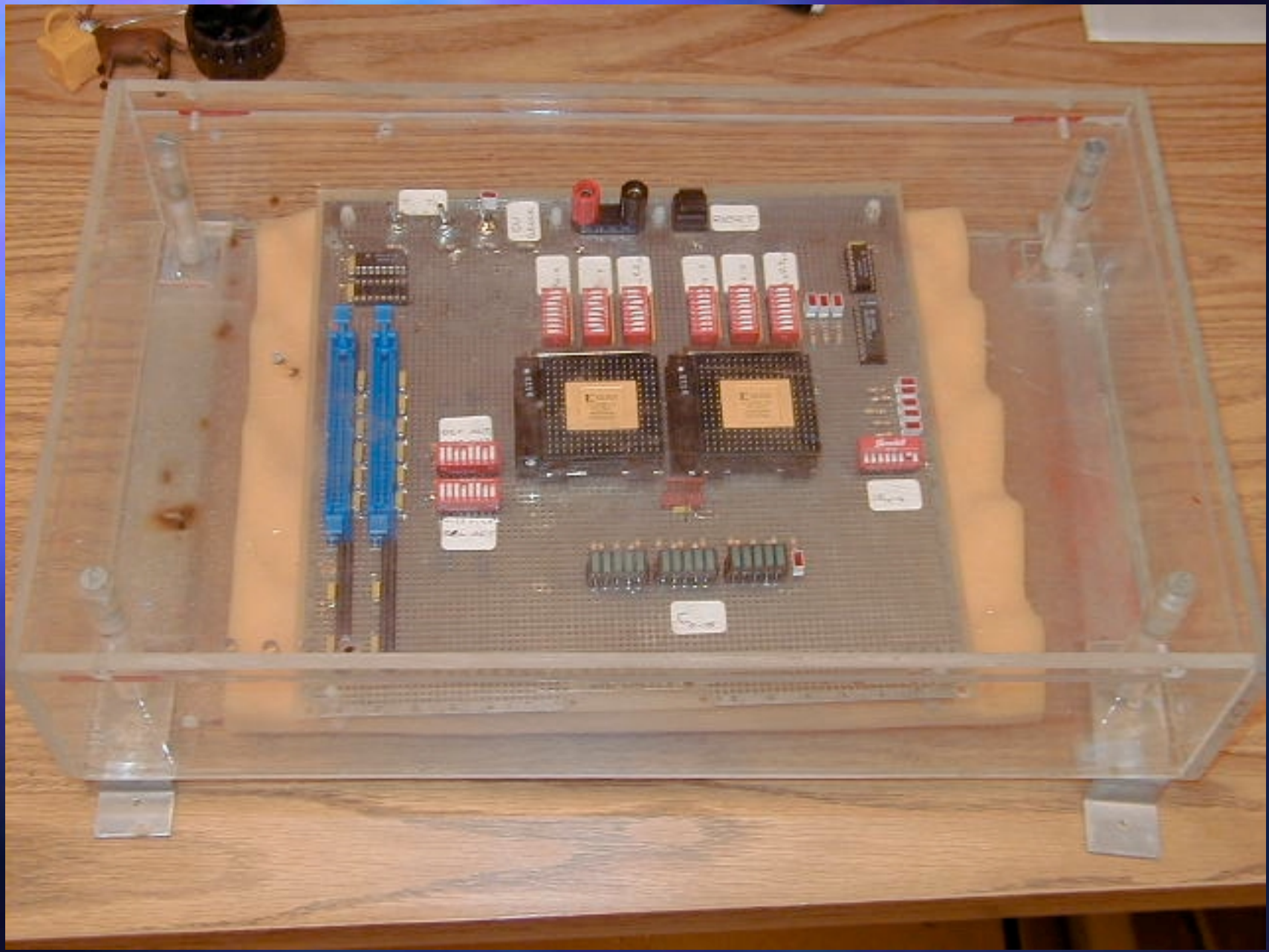
Synthesis and Decision problems reduced to NP-hard combinational problems

- Combinational problems reduced to simple combinational problems such as graph coloring, set covering, binate covering, clique partitioning, satisfiability or multi-valued relation/function manipulation

Cube Calculus Machine (CCM) operates on multiple-valued cubes (terms of MV literals).

First variant uses two FPGA 3090 chips and **second** the DEC-PERLE-1 board with 23 chips

General Special-Purpose computer for Cube Calculus



- DECstation and the DEC PERLE 1 board

Universal Logic Machine

- The high quality of decompositional techniques in Machine Learning, Data Mining and Knowledge Discovery areas was demonstrated by several authors; Ross (Wright Labs),Bohanec, Bratko/Zupan, Perkowski/Grygiel,Perkowski/Luba/Sadowska, Jozwiak, Luba, Goldman, Axtel.
- Small learning errors. Natural problem representation

We compared the same problems using several methods: decomposition, decision trees, neural nets, and genetic algorithms

Decomposition is clearly the winner but it is slow because the NP-complete problem of graph creation and coloring is repeated very many times.

Partial Automata for Robot Behavior

- Partial automata will be of two types:
  - Some will correspond to characteristic behaviors that are highly automated in animals, such as walking or eating.
  - The other will be various learning engines realized in hardware.

Hardware Learning Engines

- So far, we realized the Cube Calculus Machine [Sendai92], the Functional Decomposition Machine and the Rough Set Machine [Euro-Micro99].
- We know of course that there is no Cube Calculus Machine in our brain, but we realize it for our robot's brain as an efficient method to solve combinatorial problems that occur in robot's vision and learning (such as graph coloring or matching.)
- Whether actual brain works like this or not, is irrelevant:
  - Actual brain does also not work using GA or NN metaphors, either.
  - No model can claim to be any "more true" than the other. Let the best metaphor win a stage.

Autonomous Agents and The Games they play

Voting and agent-like behaviors

- Will be used to combine the machines.
- We believe in our technology's hardware speed, and also in our implementation of new ideas taken from game theory.
- The construction of the "brain" will be hierarchical and heterarchical, based on many levels of voting and competing behaviors.

Voting and agent-like behaviors

- Lower levels will be highly automated for speed and efficiency.
- The lowest level, the Movement Control, will relate to spider's ability to:
  - walk straight forward, backward, turn left, right, sit on its back, to bend the knees, to "lay dead", walk, dance, avoid small obstacles, climb the stairs, hobble along, etc.
- All these behaviors will be pre-specified and pre-programmed, but their combinations and variants will be emergent.

Voting and agent-like behaviors

- Part of the lowest level control will be in the **microcontroller** on robot's body, part in **FPGA boards** of the radio-connected PC, and part in its **software**.
- In our ***solipsistic approach***, all sensors, switches and effectors will be **doubled** by software data structures which will create and receive symbolic information for the robot's brain.
- Thus going from real to simulated worlds and vice versa will be easy, and **internal models** that robot may have about its environment may be compared with the real data during interaction with the environment.

Higher-level behavior layer

- will include the basic behaviors and scenarios in the world of robots, that can however be highly unstructured.
- They will include:
  - avoidance of large obstacles requiring planning,
  - path and movement planning (also in the presence of unfriendly moving obstacles),
  - duels and fights,
  - copulation and love scenes,
  - food collection (batteries) and eating,
  - child raising, sleeping and rest, entertainment.

Higher-level behavior layer

- The first variant of a program that combines ready search scenarios with Genetic Algorithm used to select the best program in the space of programs is described in [Dill00].

Social behaviors of the spider society

- will include the mechanisms that are the fundament of animal kingdom:
  - fight for survival,
  - seeking for food,
  - sexual reproduction.
- Food will be simulated by batteries for which the robots will be seeking when hungry.
- Robots may choose to fight for the batteries or **cooperate** in providing themselves with batteries.

Social behaviors of the spider society

- Similarly, monogamic or polygamic families may emerge.
- Sexual reproduction will be simulated by crossover algorithm;
  - the closely located and positioned robots of opposite sexes will exchange the electrical codes of their chromosomes, modeling the Genetic Algorithm.
- This will create a chromosome for a new robot mind, which will be radio-transmitted to one of the previously idle robots.

Social behaviors of the spider society

- This robot will know its parents and will be now subject to their education.
- The WWW observers will be able at any time to
  - perform software vivisection,
  - to learn and visualize on their computer screens the emotion vectors and the chromosomes of any robot.

Social behaviors of the spider society

- **Aging process** will be simulated by decreasing energy levels with time and battle injuries as seen by sensors.
- When the energy level decreases below some threshold, the robot dies, it means it is send physically to the pool of idle robots, waiting for its reincarnation after a following sex act of some of the surviving robots.
- Only robots with certain values of energy level and other parameter levels are allowed to reproduce.
- The emergent behaviors will include duels and fights, structured or not, between the spiders.
- Some kind of ritual behaviors typically associated with war, marriage and family may emerge.

Game Theory

- The robots will be able to create coalitions to achieve goals,
  - these coalitions will include food seeking, families, countries, and armies.
- Our research will require adapting the known **theories of coalition and conflict**, mostly based on game theory, to the programming of the spider society.

Game Theory

- Both zero-sum and non-zero sum games will be programmed
- The interesting phenomena that happen on their borders and their interplay will be simulated and analyzed.
- The weights in the game matrices will be permanently updated to reflect changing emotions of spiders.

Game Theory

- The role of communication between partners of non-zero games will be investigated [Wright99].
- We expect that many phenomena such as coalition forming, cooperation and competition will be observable.
- We expect also to be pleasantly surprised by what may happen and we cannot predict now.

Moral and Immoral Robots

Axiomatic Morality and Game Playing Robots

- Recent research on axiomatic morality uses models from game theory, automatic theorem proving, knowledge-based reasoning, higher-order logic, and constraints programming [Danielson92].
- We will program all the known models, in Prolog, Fuzzy Prolog and new constrained-programming and inductive programming languages, as the highest level of spiders' society control.

Asimov's Laws and Ten Commandments for Robot Spiders

- The moral codes will first include Asimov's Three Laws of Robotics,
- We will enhance them by simplified Ten Commandments or other highly abstract laws - higher order logic rule sets, adapted to spiders' conditions.
- The laws will be taken from books on ethics, temporal logic, multivalued logic, verification theory and various continuous and modal logics [Hajnicz].

Asimov's Laws and Ten Commandments for Robot Spiders

- No attempt at consistency of the global logic system of any of the robotic agents or societies will be taken.
- Let the emergence decide if logical spiders have higher chance of survival.

The role of Internet and controlling humans

- Important, especially in the first phase.
- The **collection of data** about robot movements, behaviors and interactions.
- It will come from **human-controlled keyboards**, joysticks and microphones
- Stored for reuse.
- Modified

The role of Internet and controlling humans

- The system will automatically create the ***ever-growing repertoire*** of future theater plays, robot interactions, games and life in form of stored assemblies of control signals and associated sounds.
- The users will also send through the WWW ready **controlling scenarios** of plays.
- The WWW technology to be used in the theatre will be quite similar to the one used in **WWW chat rooms.**

What people expect from Robot Theatre?

- So far, I found that people want to construct and see **"robot sex and violence"** as well as competitive behaviors such as **battles and sport** competitions, rather than robot intellectual behaviors.
- Let us remember that "Romeo and Juliet" or "King Lear" can be also characterized as "sex and violence".
- As it is in the true art, let us use the vehicle of theater to emerge the angelic parts of spiders' souls above their animal natures.

Emotional Robots

- Our robots will be highly emotional.
  - It means, the emotion modeling system will be central in their brains and will globally affect operation of all subsystems.
- **Rational and irrational behaviors** will be competing on the free-market of the society of mind; the black-board architecture.
- The state of the character of each agent will be described by a vector:

[energy level, **maturity level**, hunger satisfaction, sexual instinct satisfaction, social acceptance satisfaction, power satisfaction, moral self-satisfaction, intellectual satisfaction]

Complex Dynamics

- Highly complex equations, partially human-created, partially evolved, will use
  - **cellular automata**,
  - **fuzzy dynamic logic** [Buller00]
  - **game theory models**

  leading to dynamics of chaos, immediate mood changes and other emergent phenomena.
- The ***state of the society*** is described by the Cartesian product of states of its members.

Complex Dynamics

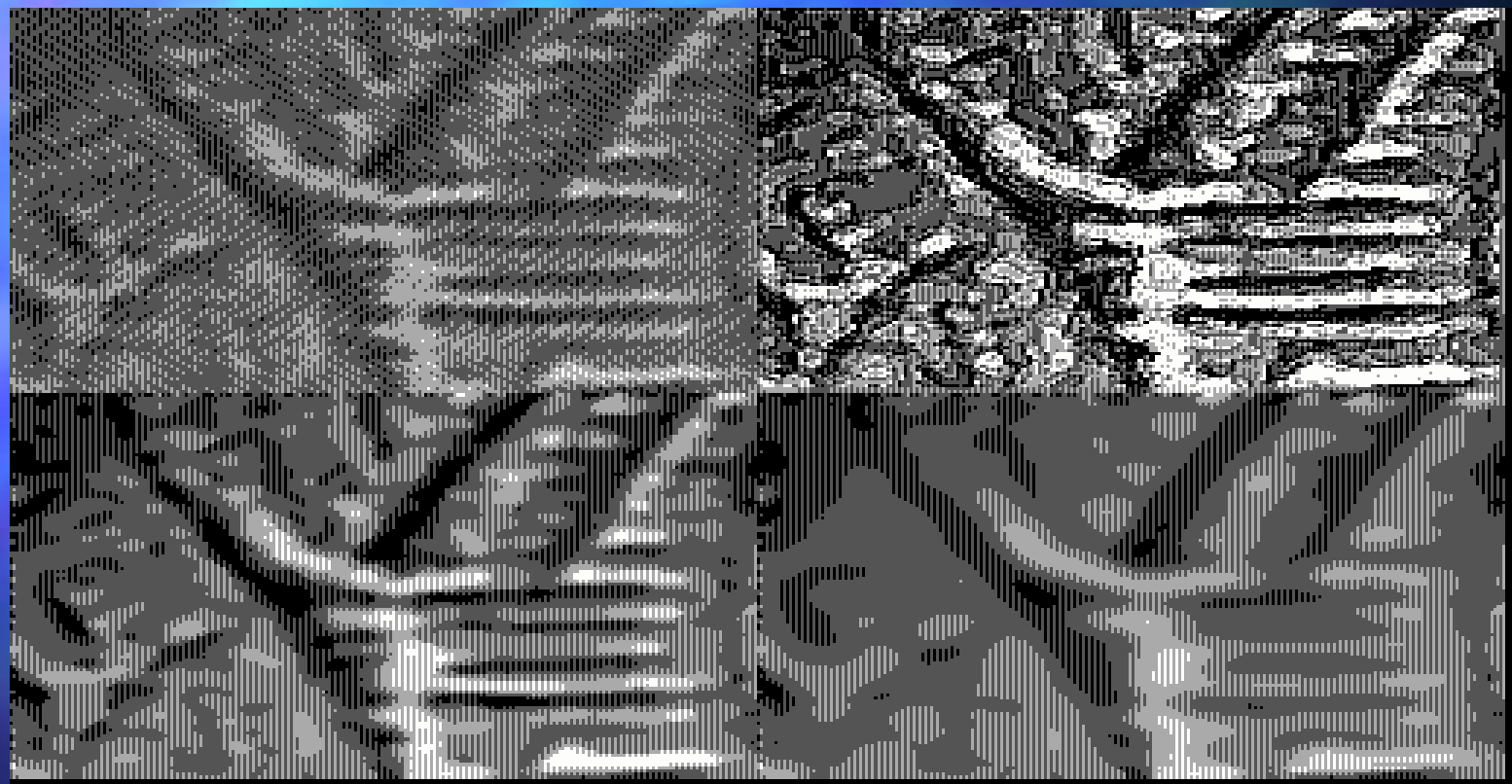
- The highest-level controlling computer can play the role of **God of Spider's World**,
  - analyzing **the dynamics of the general vector** and
  - **globally broadcasting** some parameters such as behavior-releasing thresholds.

- These phenomena are known to control ***societies of ants or termites***.

Image processing and robot vision.

- It will use the developed by us previously standard image processing software, based on
  - line detection and
  - shape recognition using various Hough and other Transforms.
- The typical applications include
  - ball recognition for "soccer-like" games,
  - sword recognition for duels,
  - other robot recognition for all social behaviors,
  - and human face recognition for demos

Images are processed and converted to MV relations



Acquire
Display
Load
Save

Histogram
Plot hist
Print hist

Add areas
Binarize
Brighten
Burn
Clear area
Contrast stretch
Copy area
Grid

Lable
Median
Negate
Rotate
Stretch

Blur
Horiz egde
Vert egde
Laplacian
Sharpen
Sobel
Prewitt
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Thin Image
FIR Fltr

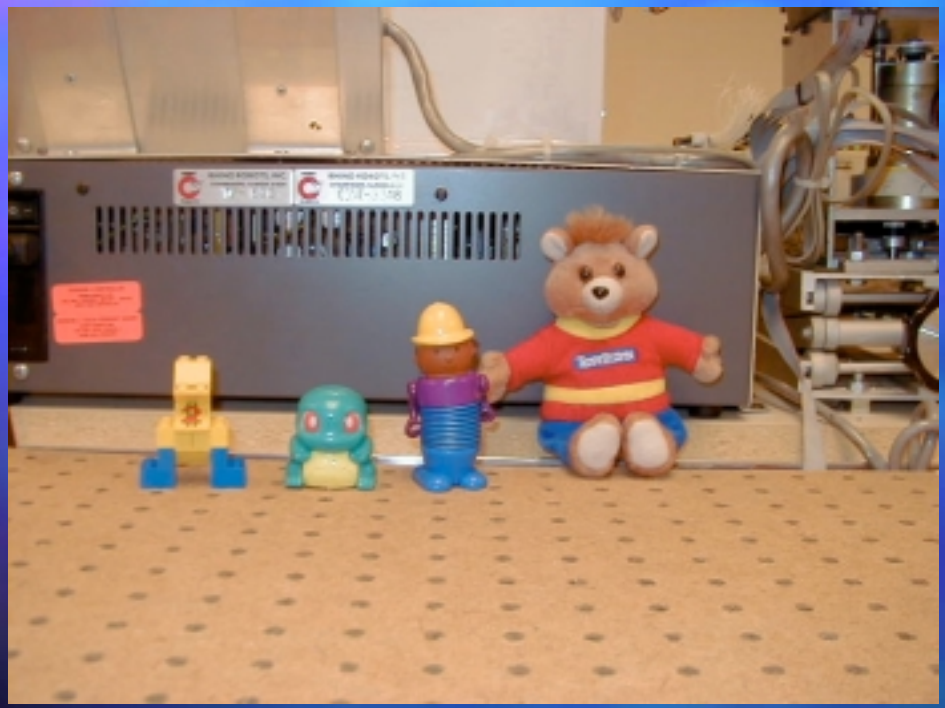
HPprint
PSprint
TIFFprint

UNDO

Test all
Quit

Command :

Image Processing for Rhino



- Convolution methods
- Binary Decision Diagrams
- Decomposition of Multi-valued Relations
- Reduction of Data
- Pattern Recognition
- Hough Transform
- Linearly Independent Transforms

Robot development stages

MUVAL architecture

Human teacher

World Model

Dual

Learning Loop

Trace

Syntha

Image Processing

Mvgud

Image Acquisition

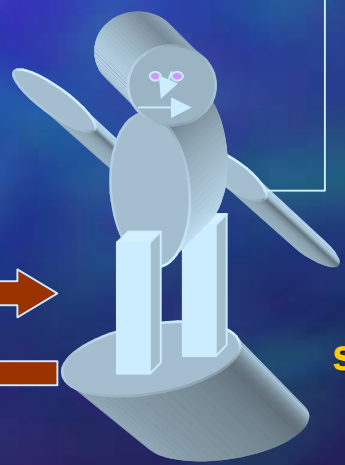
Lotus

camera

FPGA programming

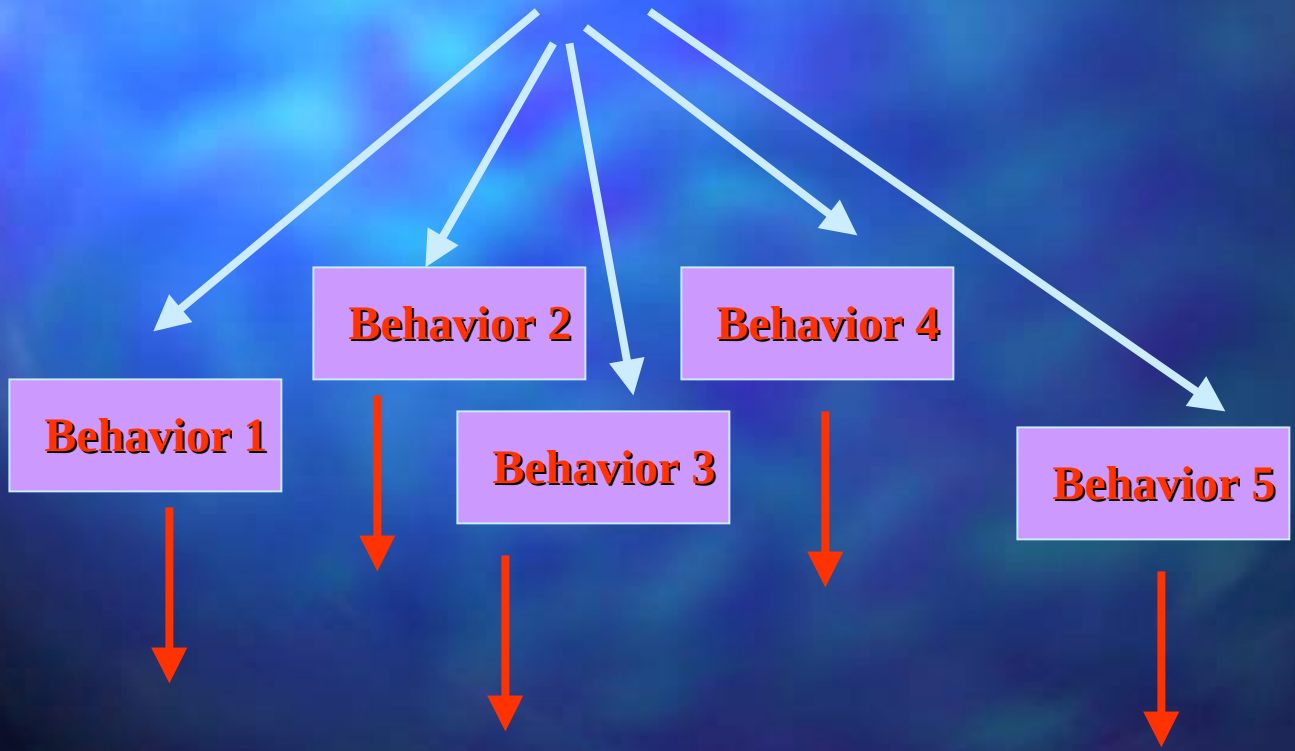
State machines

Robot knowledge

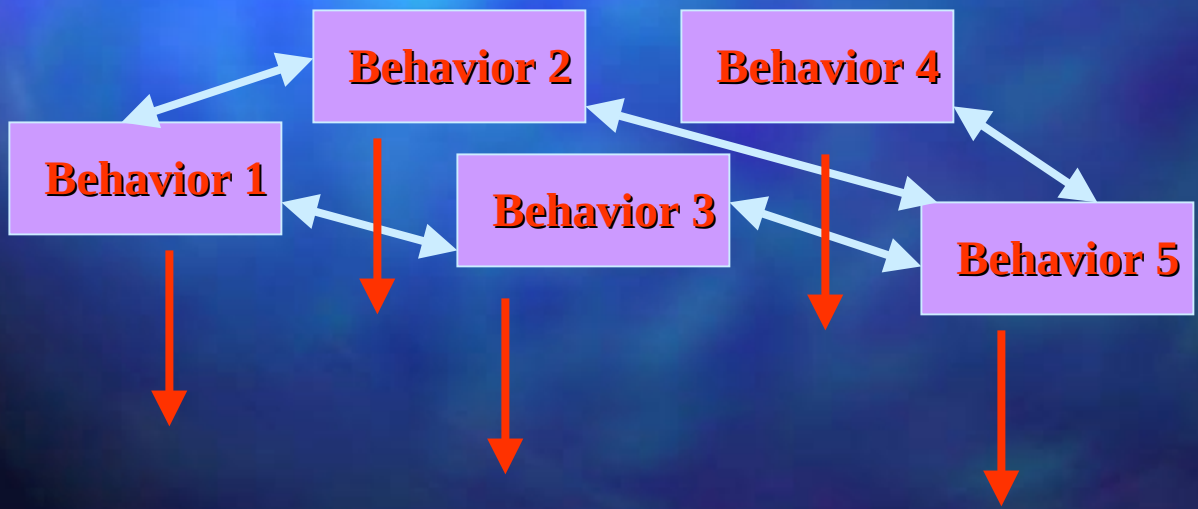


sensors

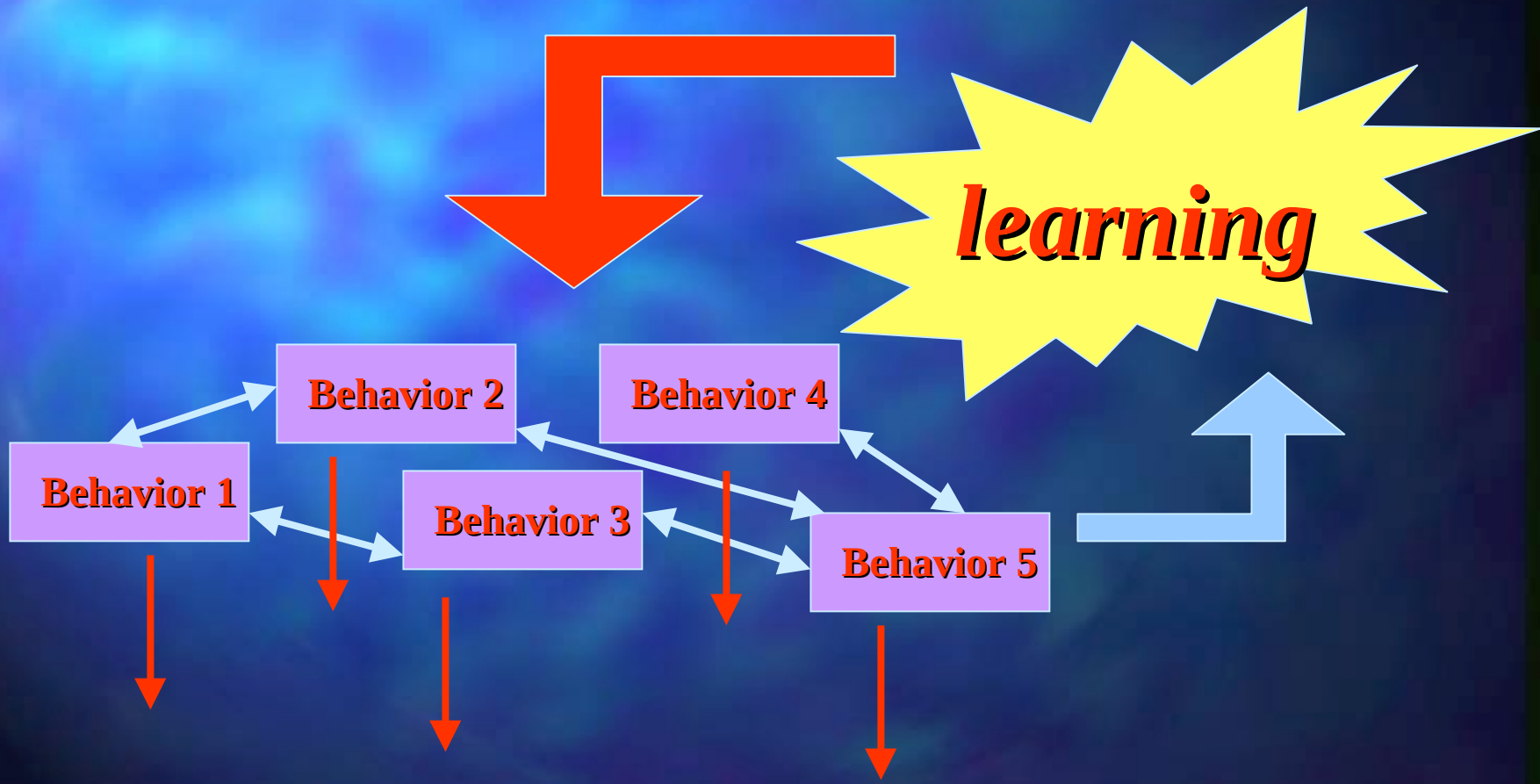
Software Architecture 1



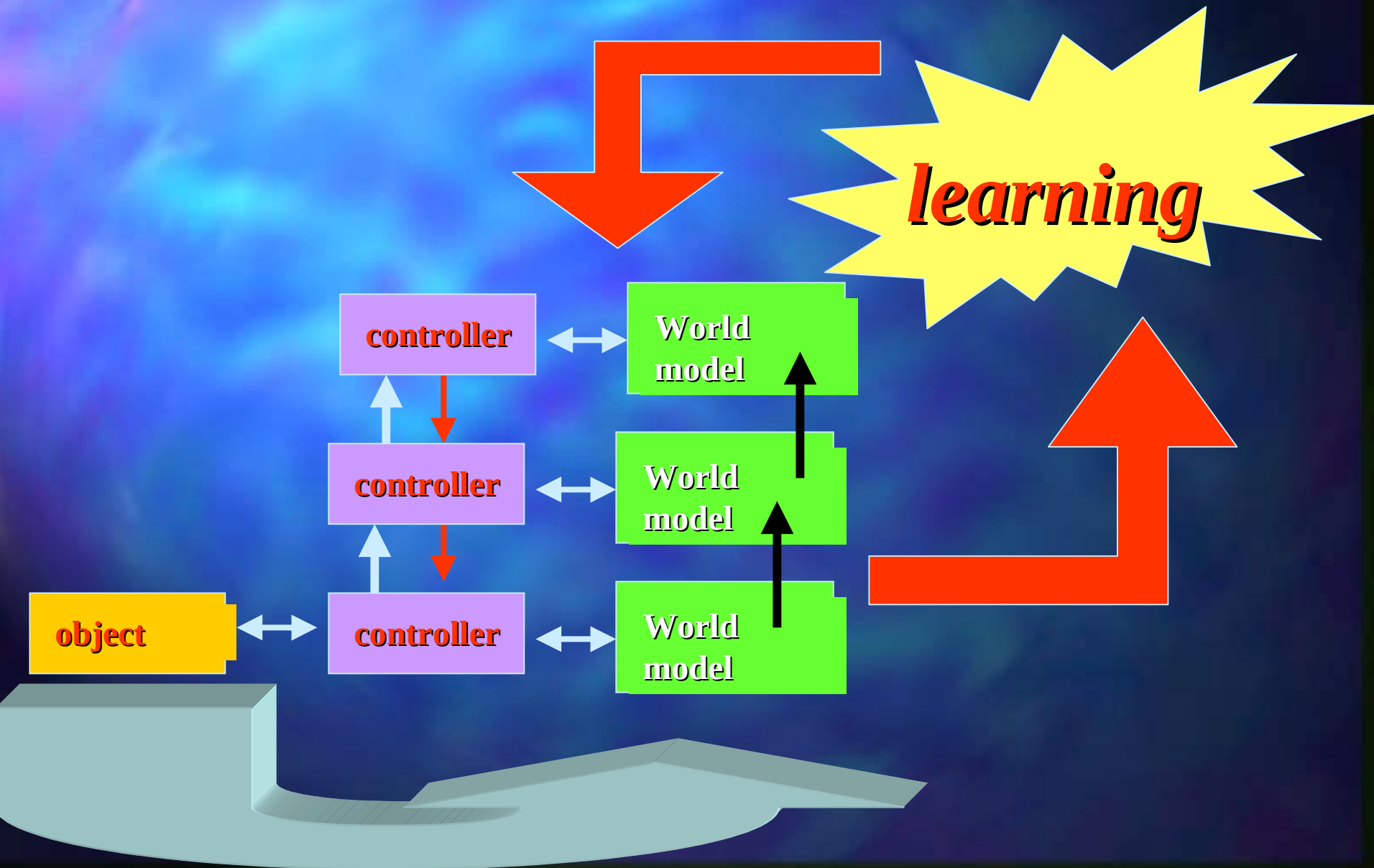
Software Architecture 2



Software Architecture 3



Software Architecture 4



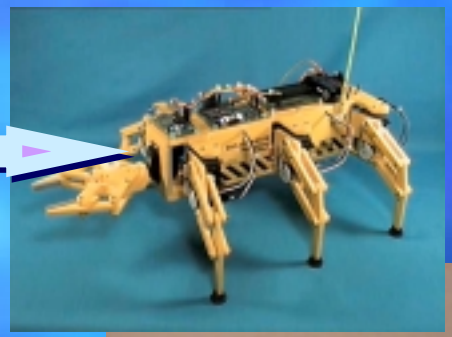
Undergraduate Projects

XILINX

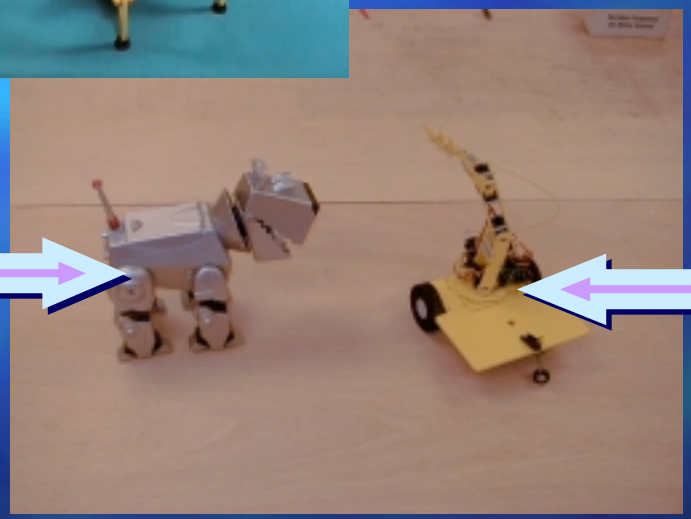
ALTERA

CYPRESS

EPLD



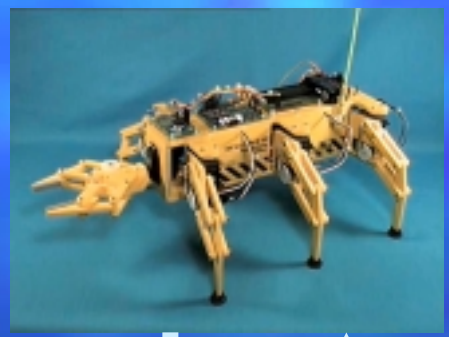
EPLD



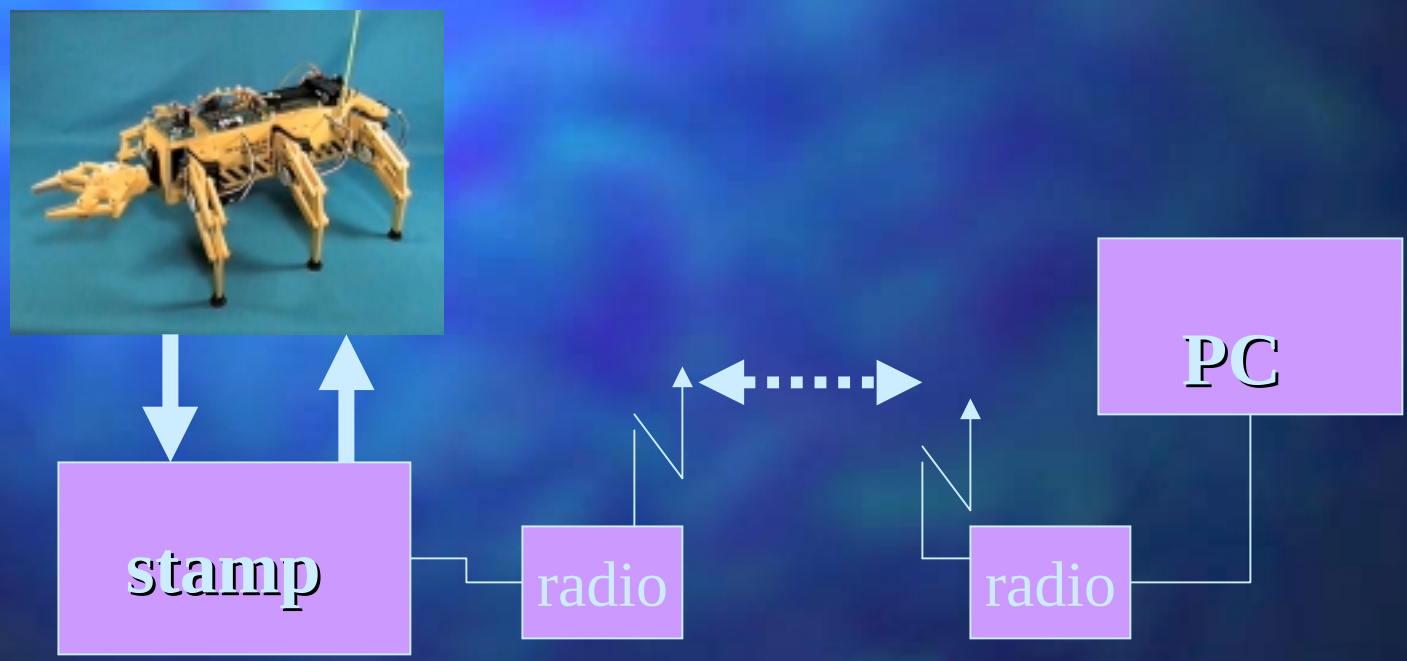
FPGA

Group Learning behaviors

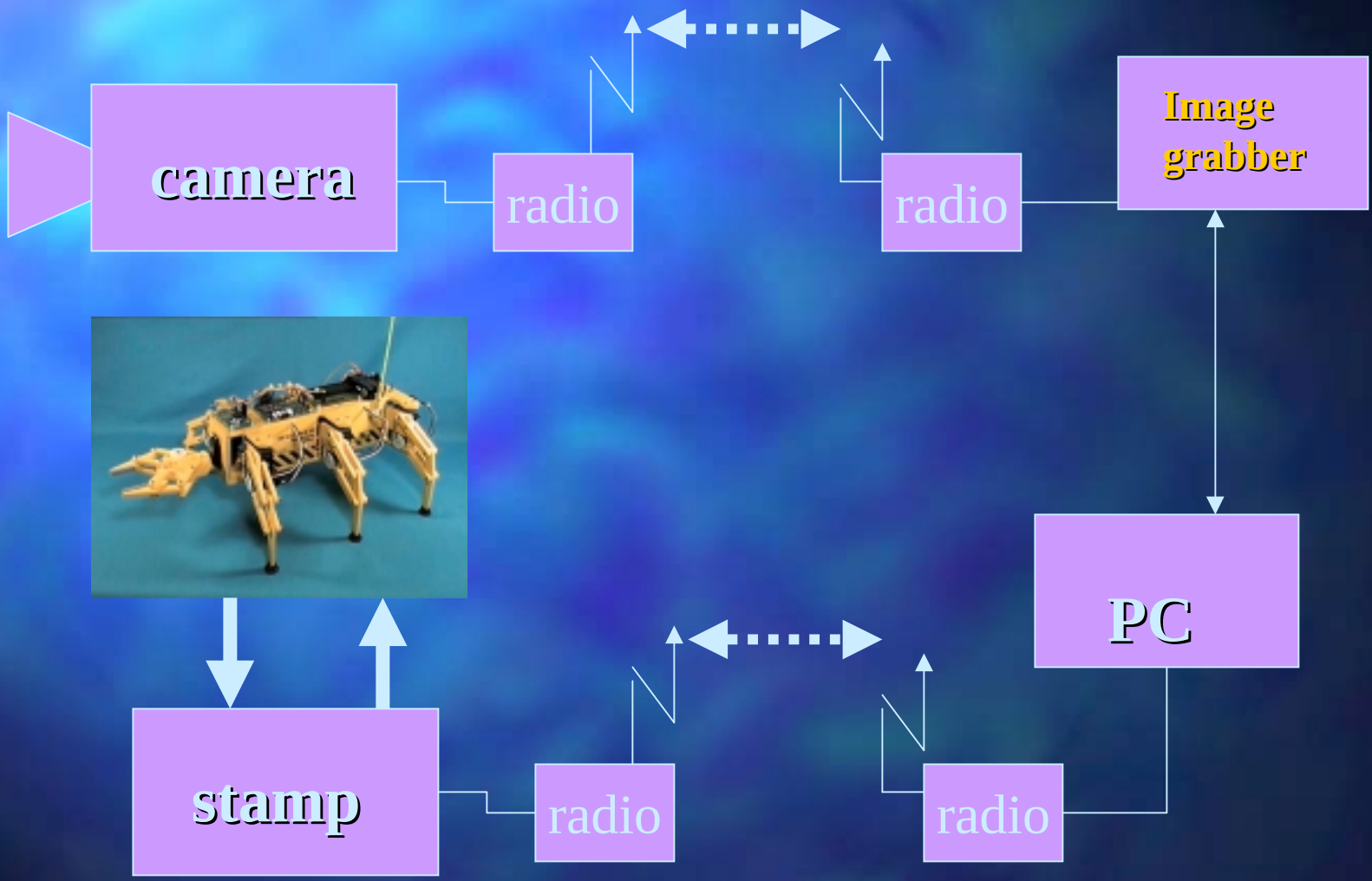
Spider I control - phase one



Spider I control - phase two



Spider I control - phase three



Spider I control - phase five: ***supercomputer***

camera

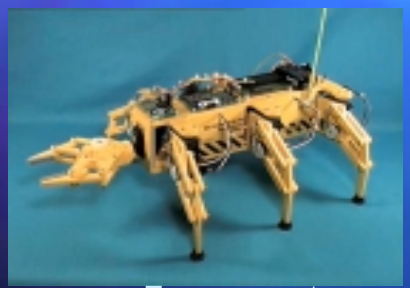
camera

radio

radio

DEC PERLE

Universal Logic Machine



DecStation

stamp

radio

radio

Turbochannel

Modes of Operation

- Programmed (theater, demos)
- Learning
- Interactive (interactive theater, society of robots, human-robot interaction)

Long-term Research

- This presentation is a proposal of long-term research project being a continuation of long-term research project.
- We further extended the ideas of robot as a data-mining evolvable hardware system, outlined in:
  - **[Perkowski99 - invited paper - Sendai]**
  - **[Perkowski,Chebotarev,Mishchenko 99 - First NASA/DOD Workshop on Evolvable Hardware].**

Invitation to Collaboration

- We plan to **find people** with all kinds of skills, talents and interests;
  - people with writing/directing,
  - robot-building,
  - psychology,
  - biology and many other backgrounds.

- For instance, we look for somebody who ***understands behaviors and movements of spiders***, or social behaviors of insects.

Standarized Robotic Puppets for Oregon Cyber Theatre

- Servo Motors, from small to large, same control
- Mechanical materials and components
- Design procedures for students
- Electronic interfaces
- Low - level software
- Image processing software
- Machine Learning software
- Radio communication and cameras
- Internet protocols

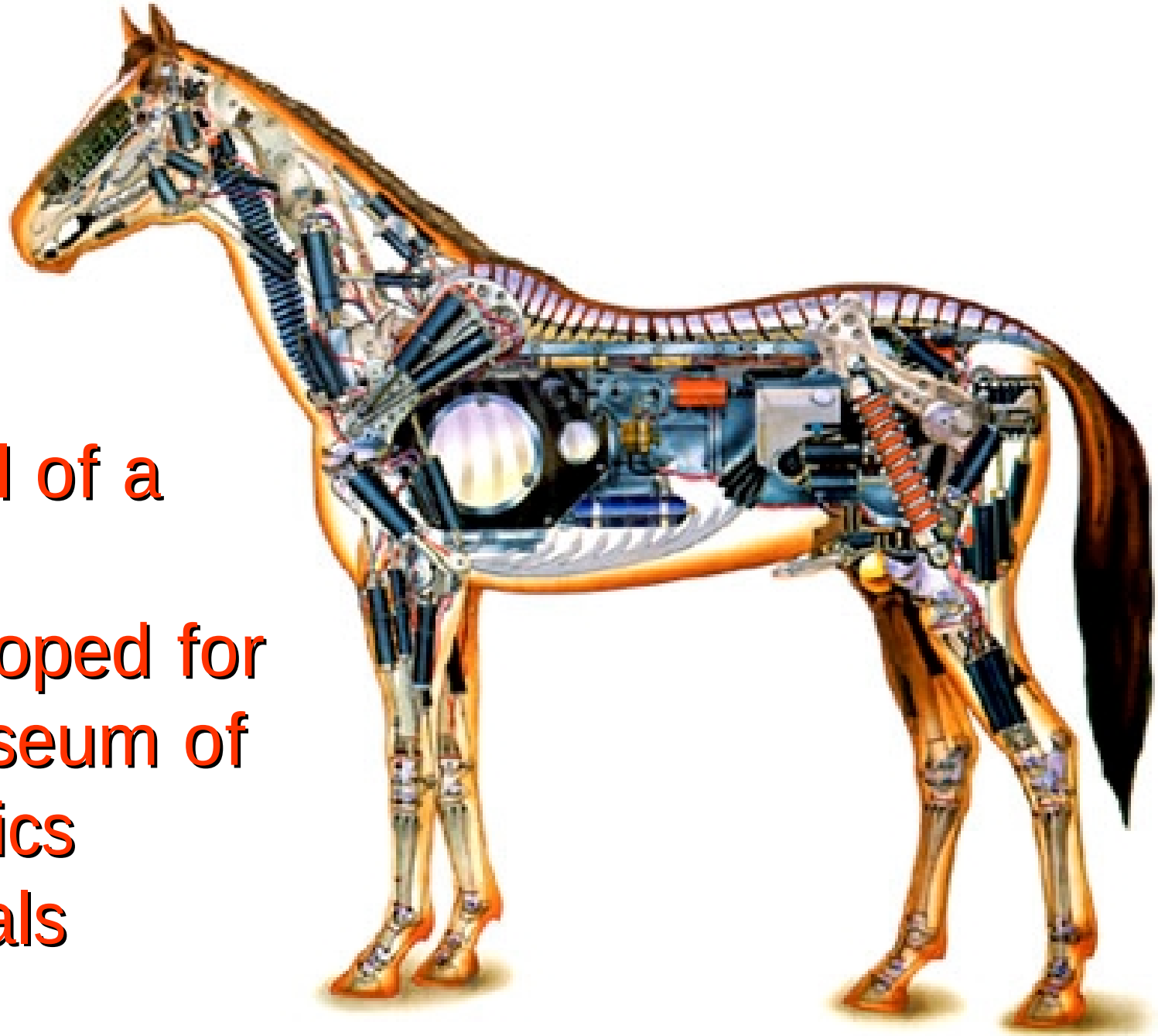
Conclusion

- **Robot Theatre** is a Powerful Metaphor
- **Internet Robot Theatre** is a world-wide initiative
- Intelligent robot can be build under $2000 of Year 2000 money
- Please bring ***your robot-puppet*** to LDL symposium 2001.
  - Please bring your robot-puppet to Boolean Problems Symposium 2002
  - Please bring your robot-puppet to LDL 2003
  - …….

ACKNOWLEDGMENTS

- Martin Zwick, Alan Mishchenko, Craig Files, Stanislaw Grygiel, Karen Dill, Michael Levy, Anas Al-Rabadi, Rahul Malvi, Kevin Stanton, Tu Dinh,
- Robo-Club and Electric Horse groups,
- Bryce Tucker, Jeff Ratcliffe, Intel Corporation, Portland State University Foundation, Deans Office, and Provost funds, Tektronix Inc., Seiko Robots, Xilinx, Altera, and private donors. Doug Hall.

- Model of a horse developed for a museum of robotics animals




Thank you