EE 656
Robotics & Control

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I strongly feel that the title of the course should be:

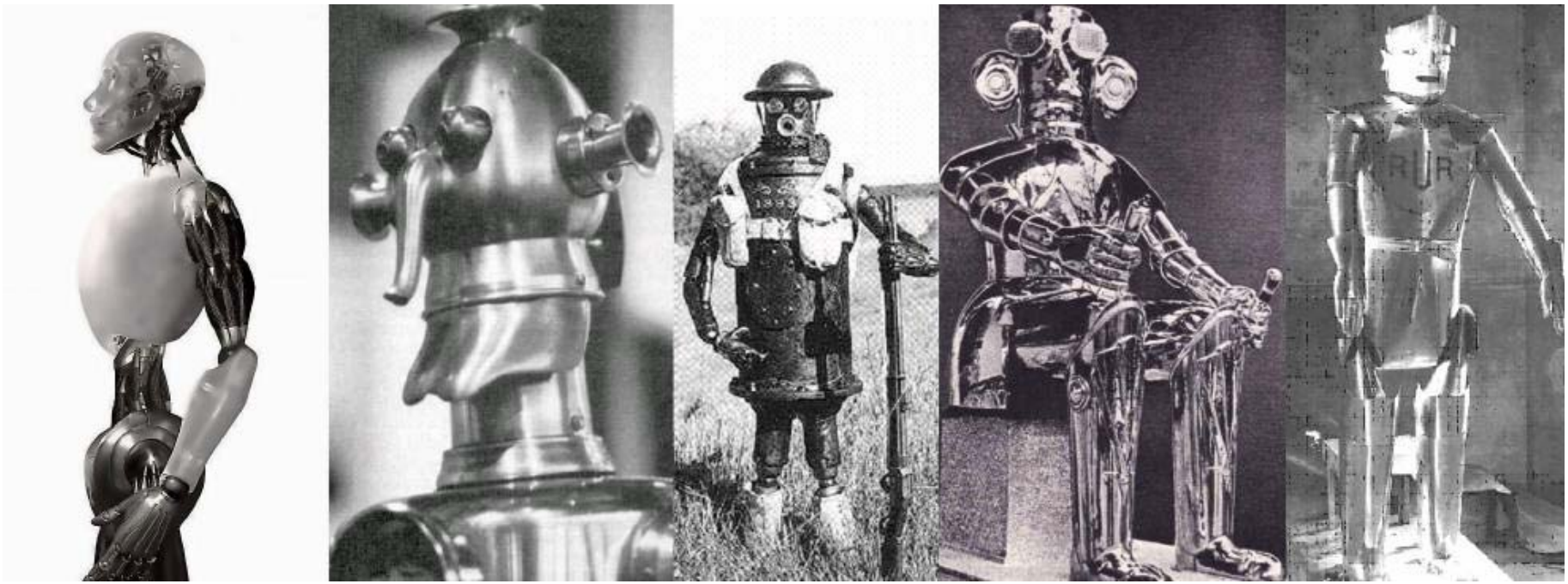
Robotics,
Guidance
& Control

Whatever

Informally,

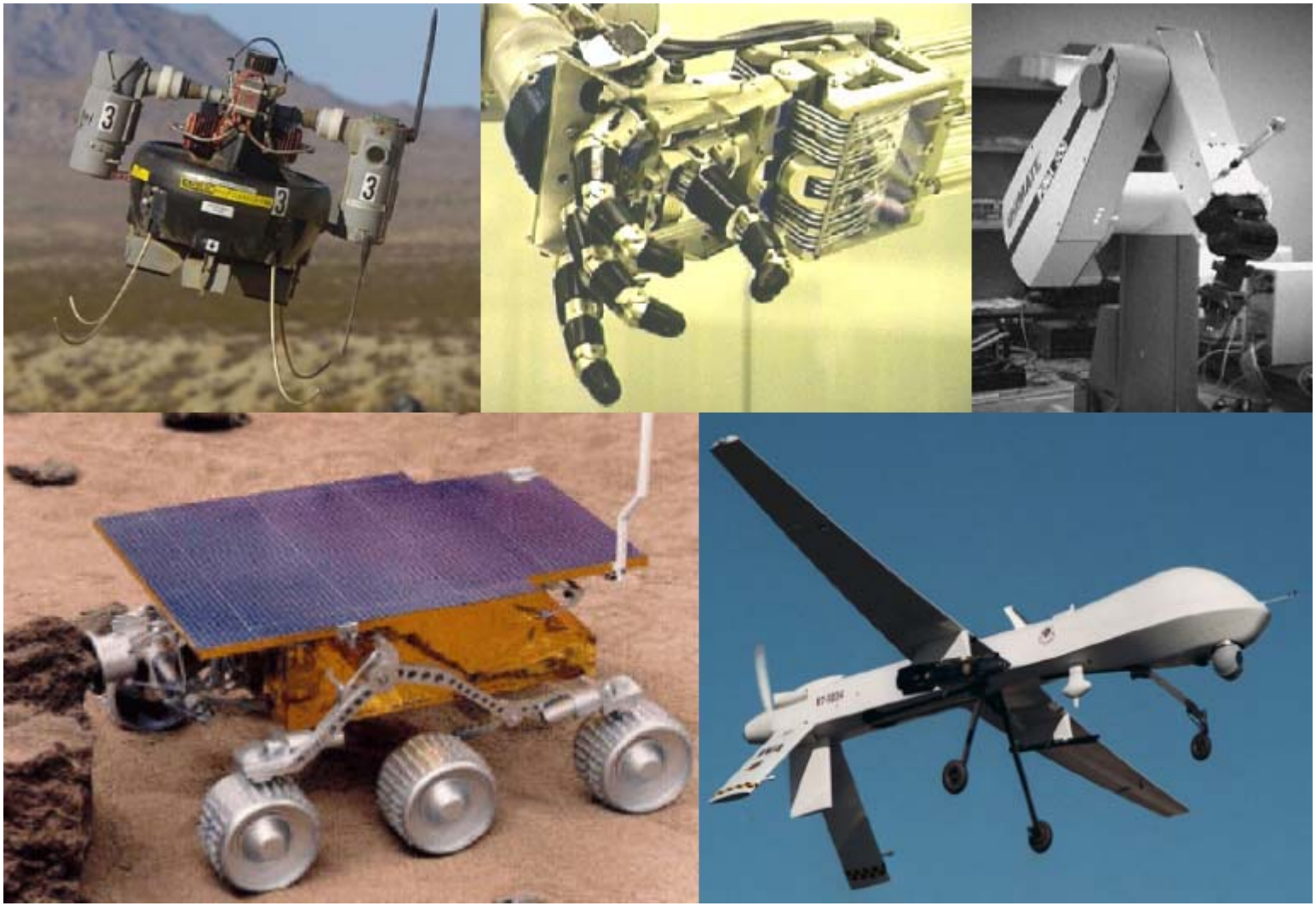
What is a Robot ?

What may first come to mind are these images



Anthropomorphic structures

You may have a more progressive view of robotics and envisage these images instead:

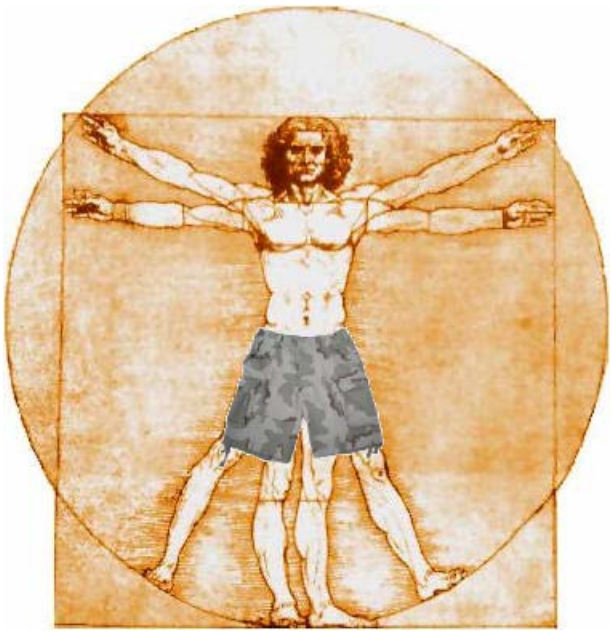


In both cases

your view may not be accurate.

So, what is a Robot ?

Let’s start by comparing



Humans to Bees

Let the comparison be based on a simplistic, chronological, external view of the structures both humans and bees have been building over time.

No attention is given to the function such structures are required to host nor to the manner in which they were planned and built.

Humans

Bees

100,000 BC

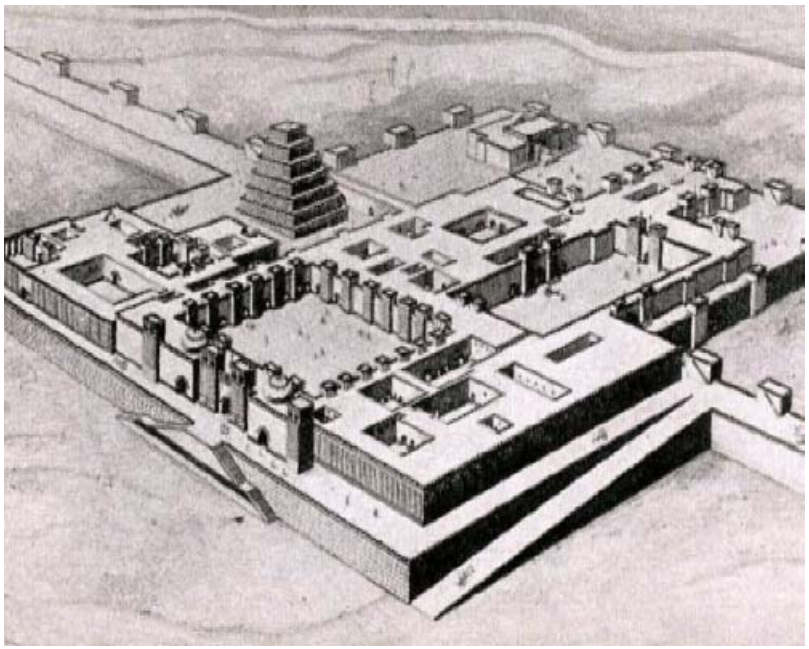
Humans

Bees

8,000 BC

Humans

Bees



2,000 BC

Humans

Bees

1,600 AD

Humans

Bees

2008 AD

Obviously there is a difference in behavior between the two.

While the form of the behavior, as well as the outcome of that behavior remained constant for the bees, there was a change in the behavior of humans both in terms of format and outcome.

Sociologists and anthropologists attribute that to humans , at lest some, being **self-steered** entities while other entities being **environmentally-steered**.

- **Environmentally-steered behavior**: the context or the environment of the entity is the sole determinant of the outcome.
- **Self-steered behavior**: the entity itself is a factor along with the environment in determining what the outcome is.

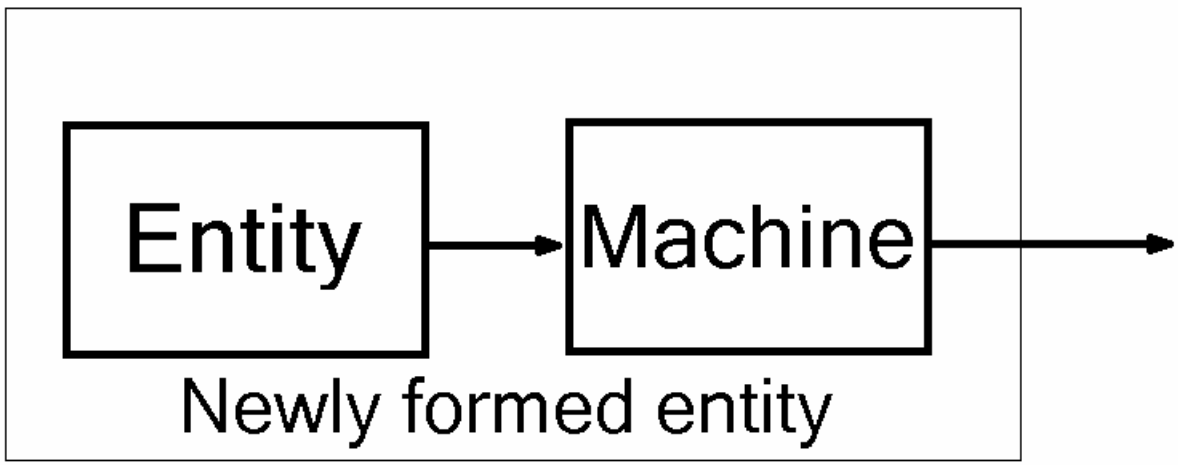
How does that work?

Simply, the environment relative to the entity determines a whole potential field of possible outcomes. The means (physical & intellectual) the entity possess enables it to actualize one of these possibilities.

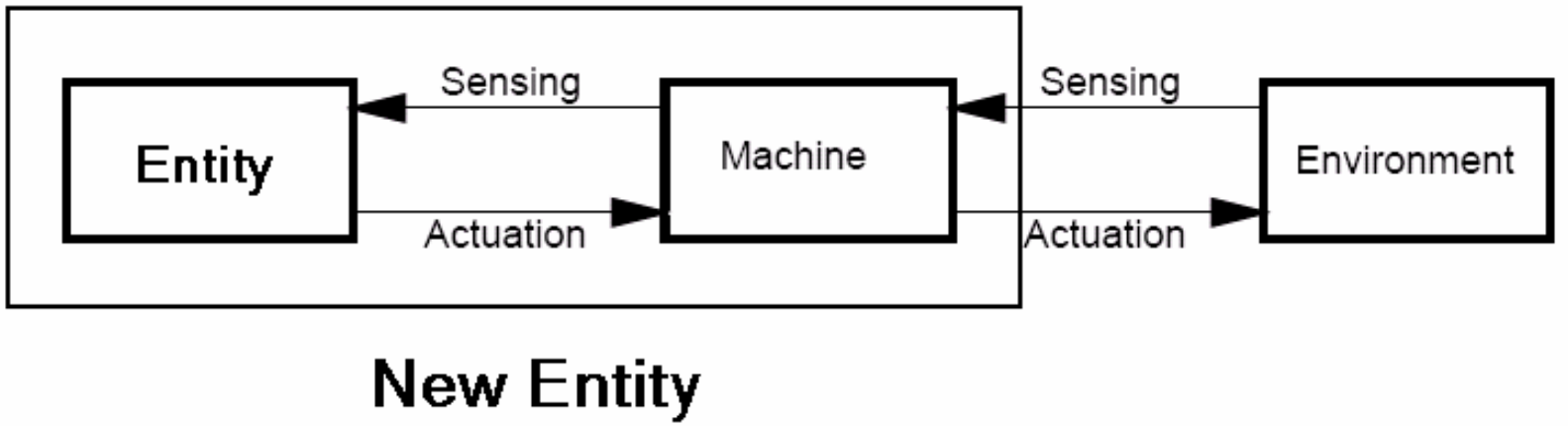
An environmentally-steered entity actualizes one and only one possibility given a situation.

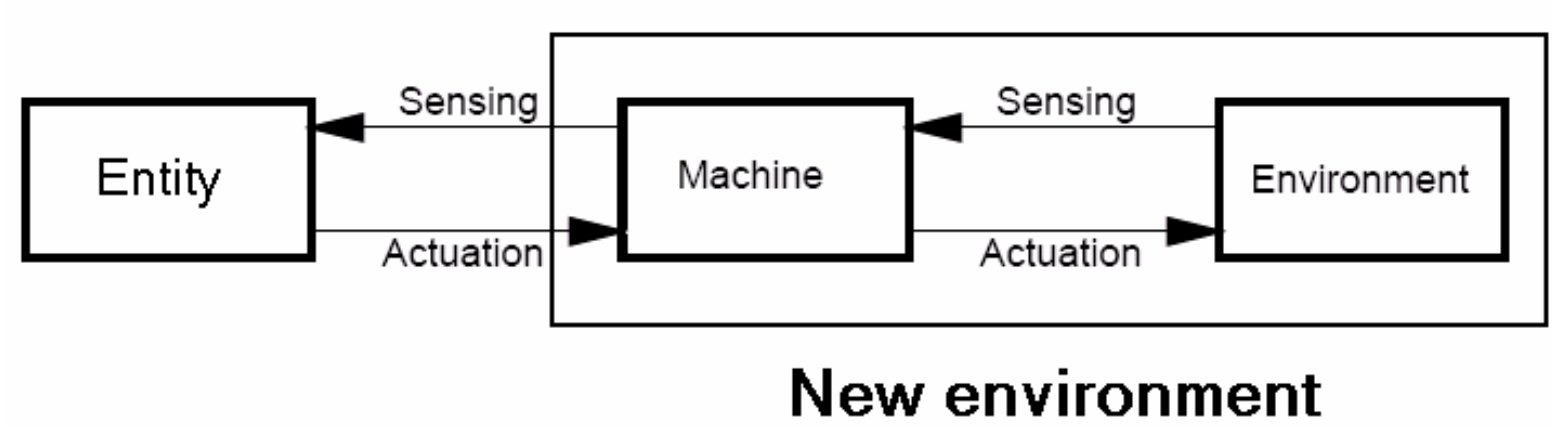
A Self-steered entity may **choose** from a whole ensample of potential events a possibility to actualize.

- In other words: Some humans can build and employ **machines** at will, other entities cannot,
- What is a machine?
- For now let us define it as an enabler that augments the ability of the entity and prevents failure in achieving a task

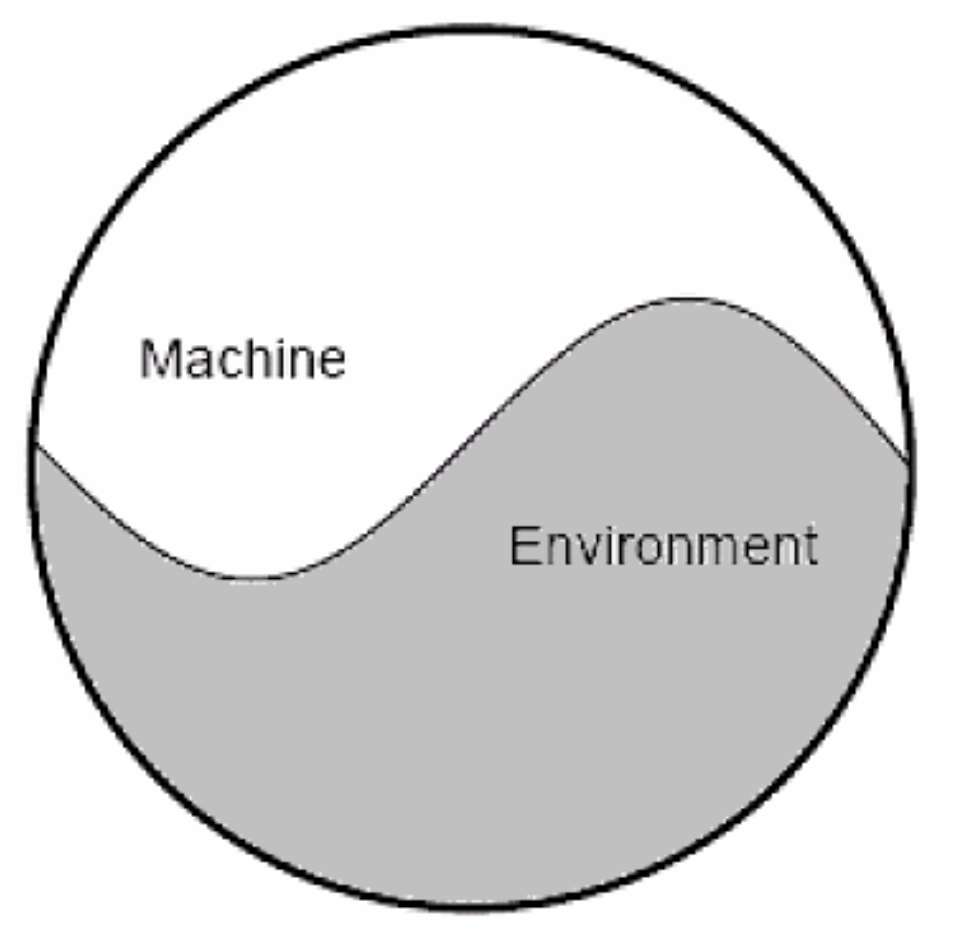


The machine becomes a proxy through which the entity can indirectly affect its environment.





One must also notice that the border between a machine and an environment can get a little blurry



so

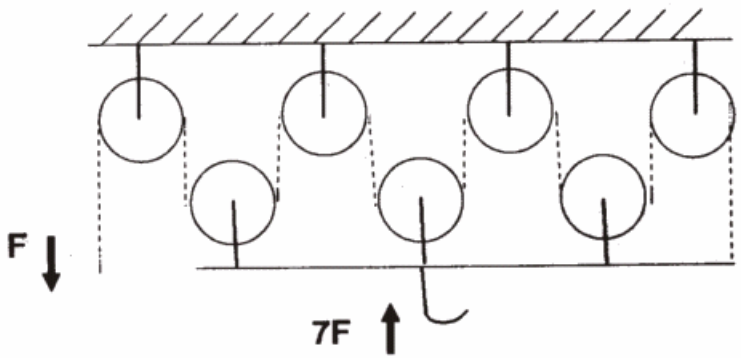
A machine may be looked at as a device that makes a goal attainable.

Or

A device that prevents failure in reaching a goal.

What are the causes of failure?

- Failure could result from the **quantity** of effort that is needed to perform a task,

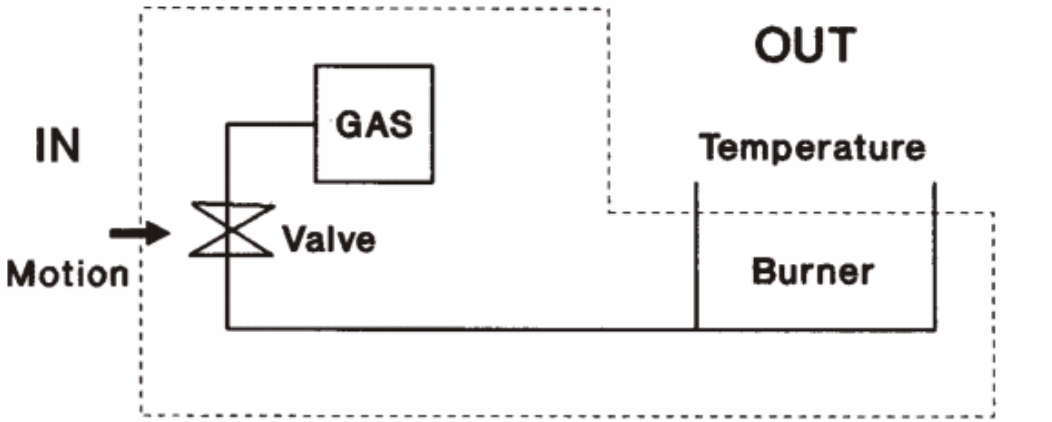


A simple Pulley System

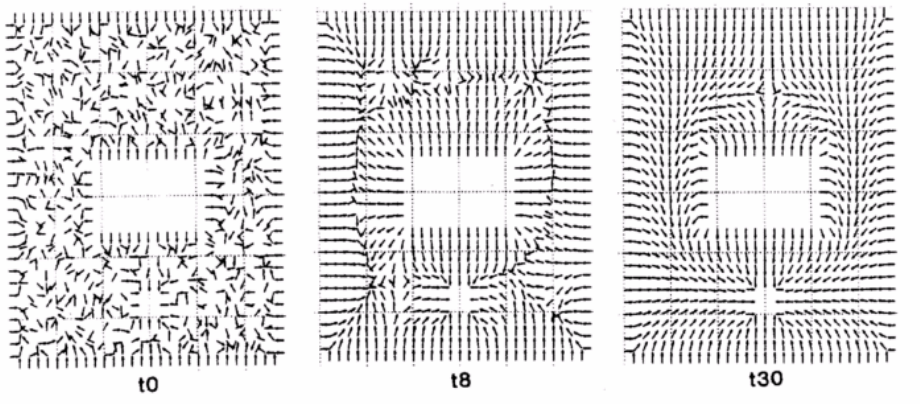
Archimedes Claw

A similar argument may be made about scale, speed, etc.

It could be the result of the **incompatibility** of the effort the entity is able to exert with the aspect of interest in the environment



Another reason is: the **lack of organizational** patterns governing behavior. An organizational pattern may be looked at as a non-physical instrument needed by the group to get a job done.



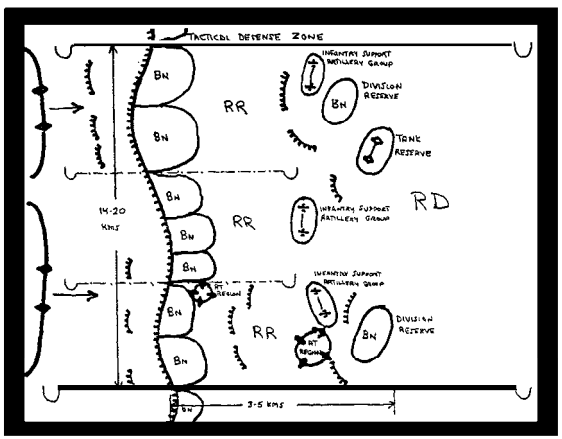
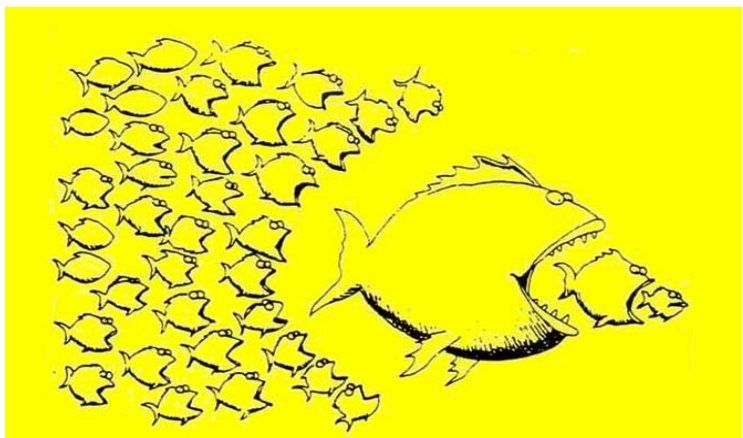
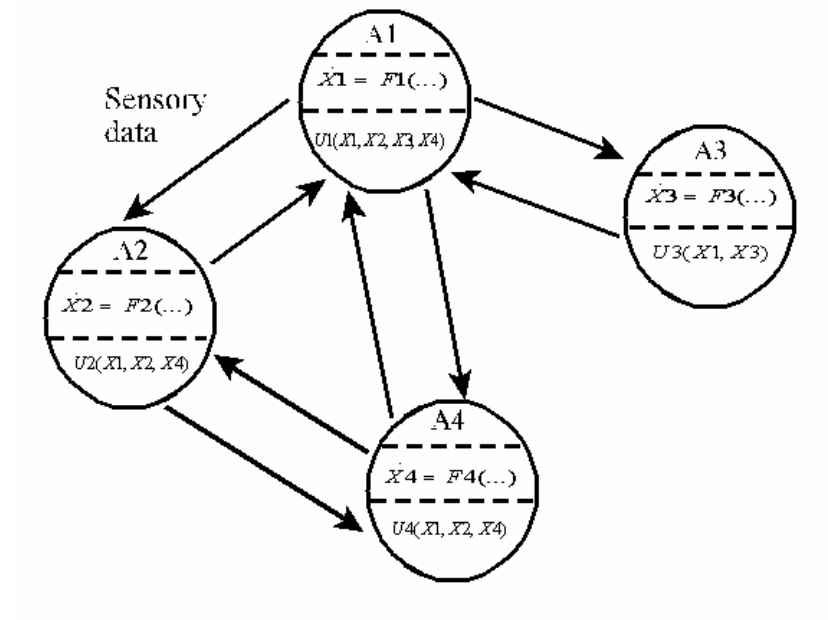


Figure 2. Rifle Division Combat Formation-Defense, 1941



The problem could be as deep as the availability of the **knowledge** needed for constructing organizational patterns.



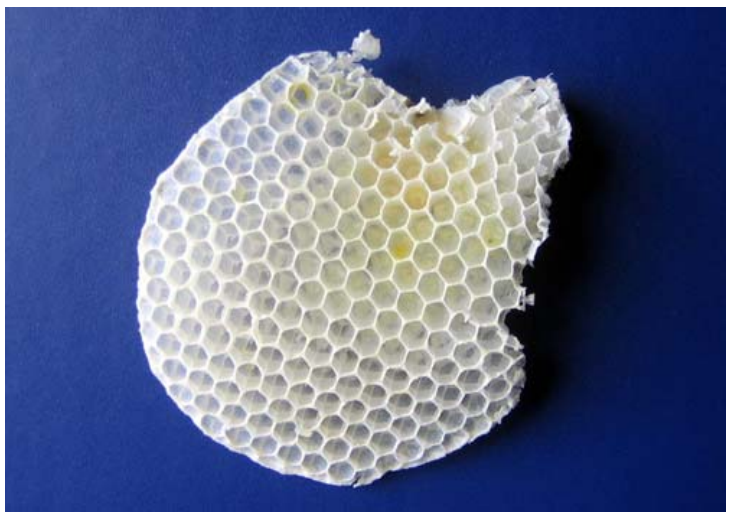
- So the ability of humans to construct machines or servant (servo-) processes is what made them the wonderful, evolutionary/ devolutionary creatures they are.

- On the other hand, bees, for some reason, lost their ability to evolve as well as devolve.

Just to be fair to Bees

Let’s take a close look at how they too build their homes.

- The material the bees use is WAX,
- They consume 8.5 KG of honey for each 1KG of wax they secrete
- The building block is a 3D hexagonal element known as a honeycomb
- They have to work in very large groups and fit their homes almost anywhere



- Fact #1: Hexagonal structures minimize the surface to volume ratio, i.e. bees can store the most honey using the least material

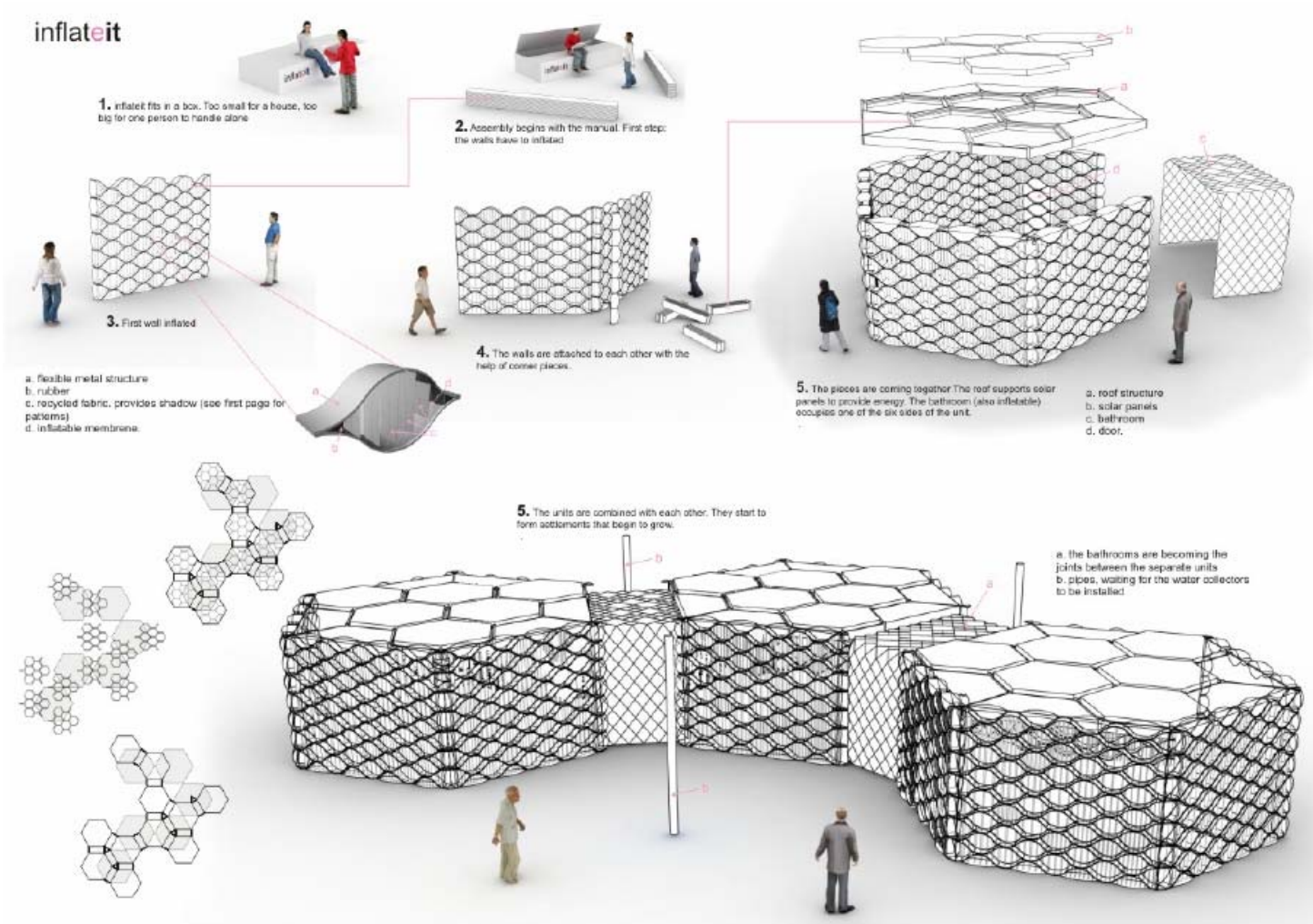
- Fact #2: honey comb structures allow bees to work individually yet collectively to build the hive, hence solving the serious coordination problem that arises from the massive size of the work-force

  (**local actions-global results**).

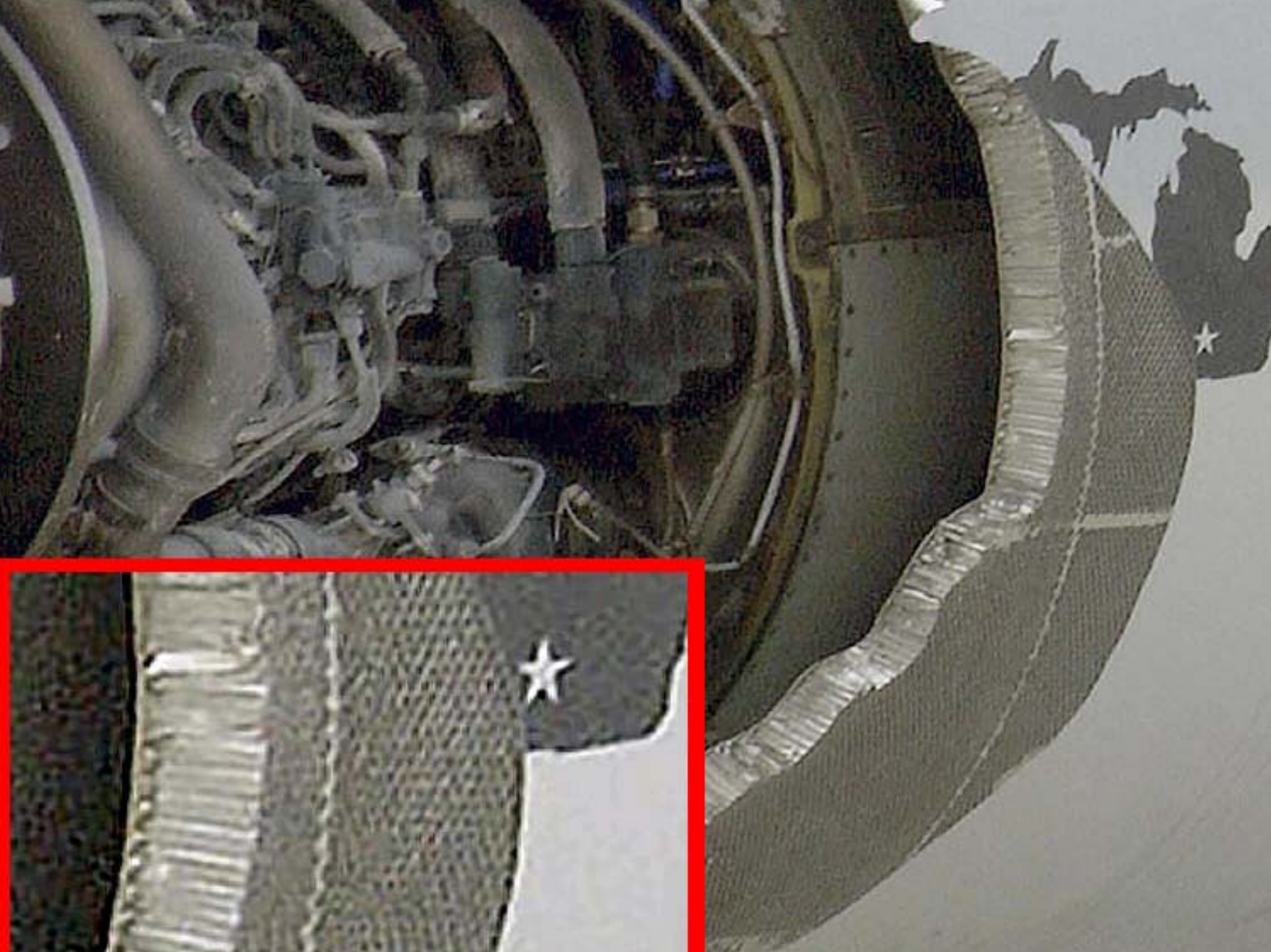
- Fact #3: the hexagonal building unit yields highly configurable honeycomb structures. This allows the bees to build a variety of structures and fit their hives almost anywhere.

You can even used them to make a vase.

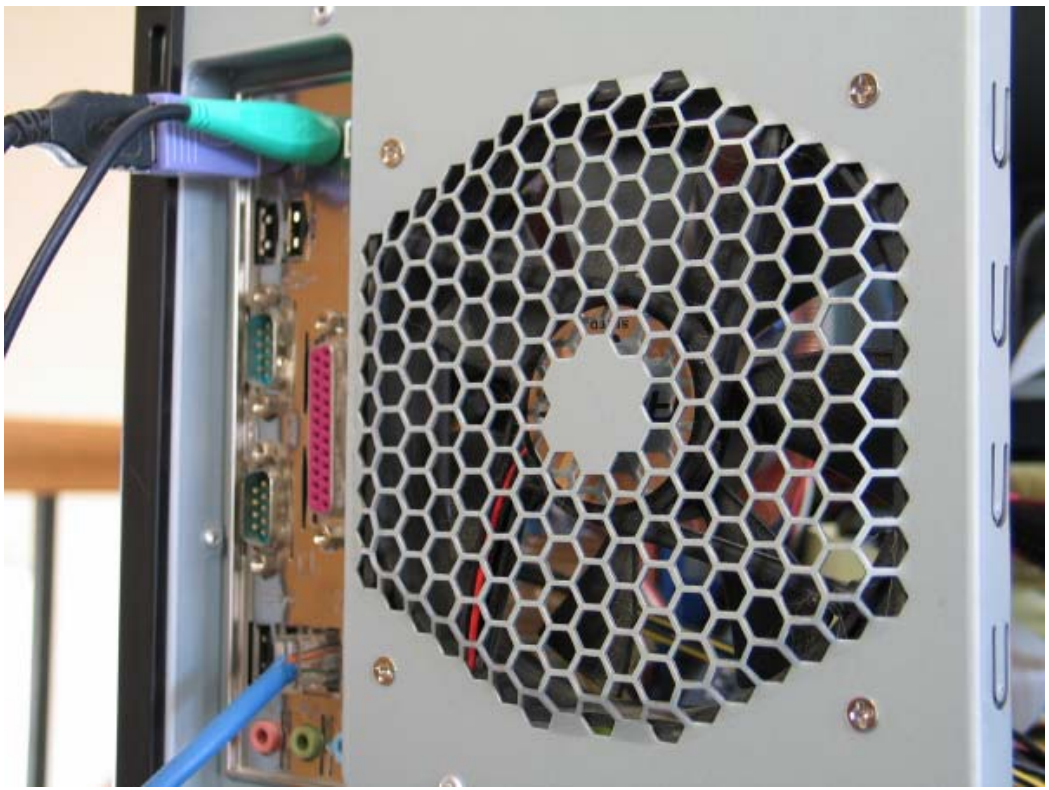
- It looks like this configurability impressed human architects,



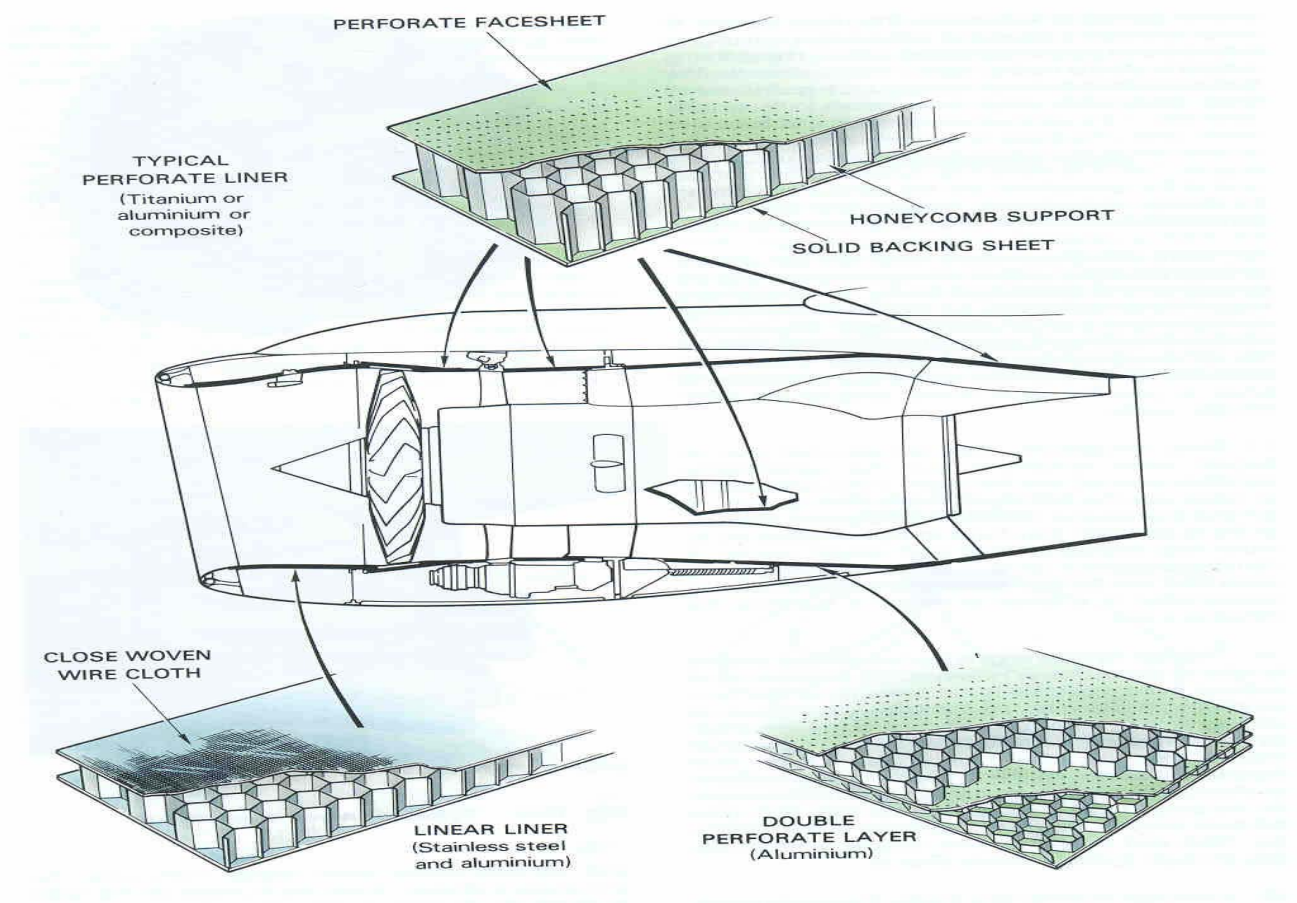
- Fact #4: honeycomb structures have a high strength-to-weight ratio. This motivated the use of such structures in building airplane frames and other light and strong building material.



- Fact #5: honeycomb structures reduce airflow noise and turbulence. This motivated their use in reducing noise, e.g. silent PCs



- The combination of noise reduction and high strength to weight ratio motivated the use of honeycomb structures in modern applications such as reducing the noise jet engines emit.

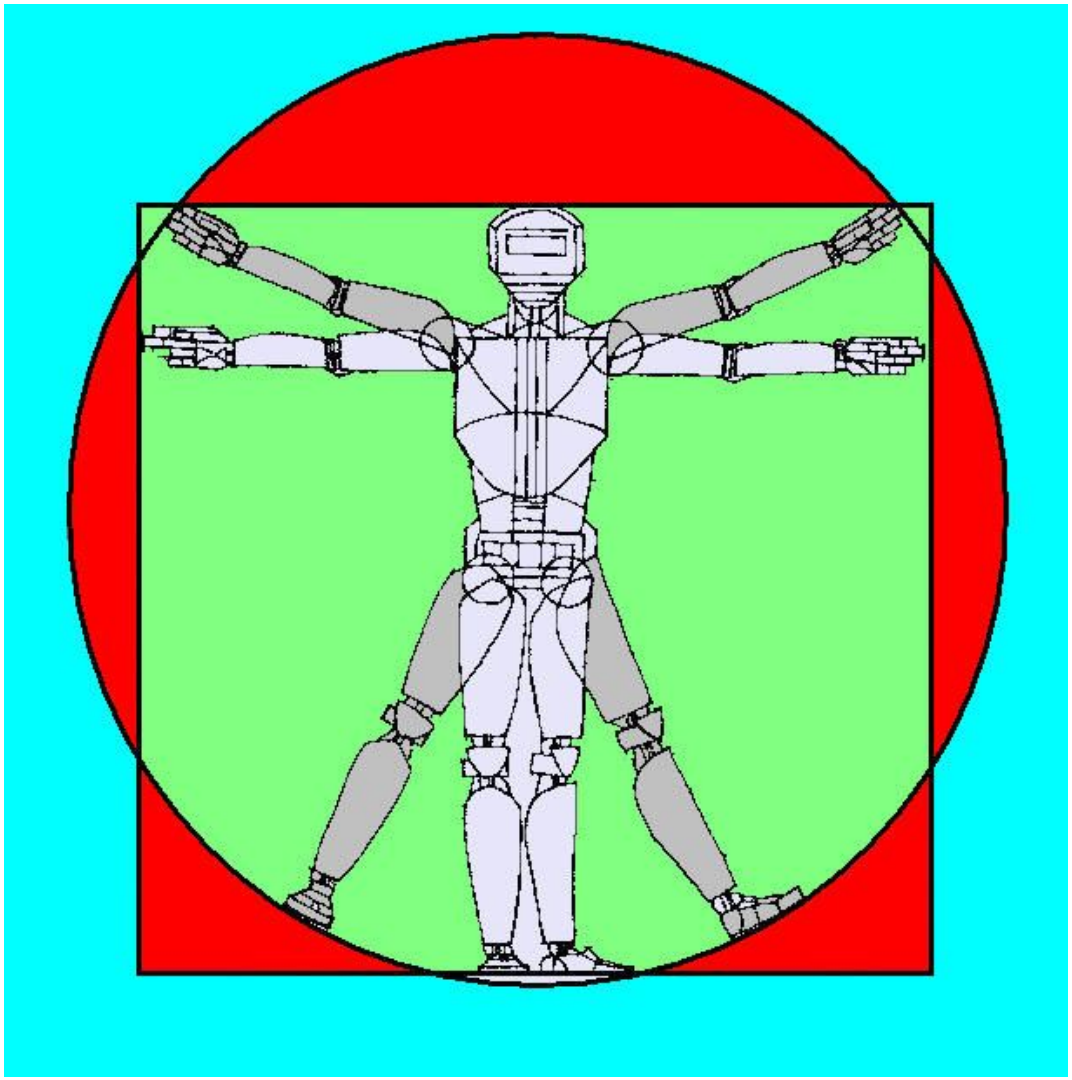


From what has been discovered Up-till-now, bees seem to be superb planners and builders.

Maybe that is the reason why bees no longer evolve or devolve:

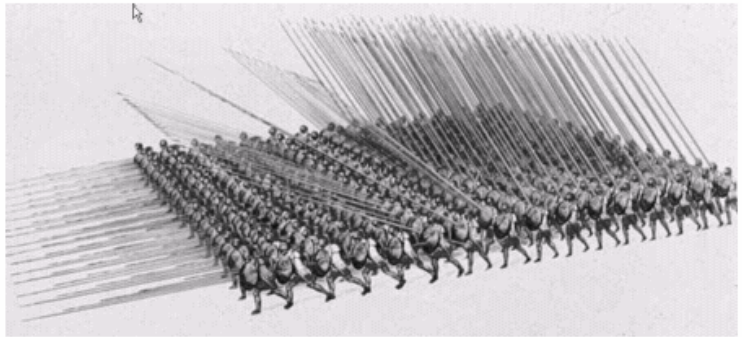
Somehow they found the best thing to do and they stayed with it.

Servant processes and the concept of a robot



Throughout history humans have used different Servant processes to achieve their goal.

An articulated mask with an air tube of the Egyptian god Anibu used by priests to talk to the faithful



A combat formation used by troops in battles

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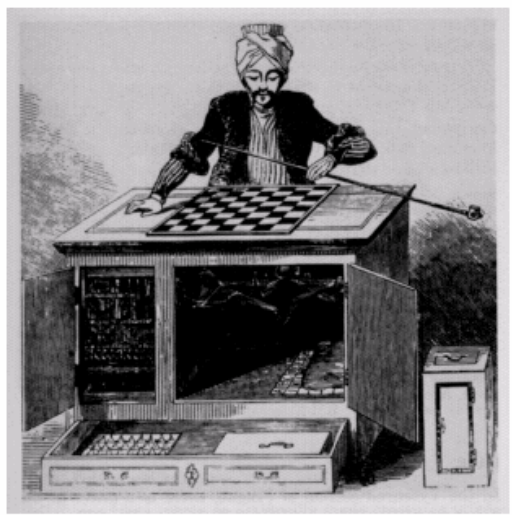
A robot created for nothing other than the amusement of others



A chess playing mechanism used to swindle people

The word ROBOT which is commonly used as a representative of a servant process was brought to the attention of the masses in 1921 through the play titled “Rossum’s Universal Robots” written by Karel Capek. In this play Capek described subservient entities whom he called RURs built to do drudge work of any sort. The word ROBOT which is derived from the Czech word ROBOTA, meaning **work** or **useful work**

A process or an entity may be defined as a robot if:

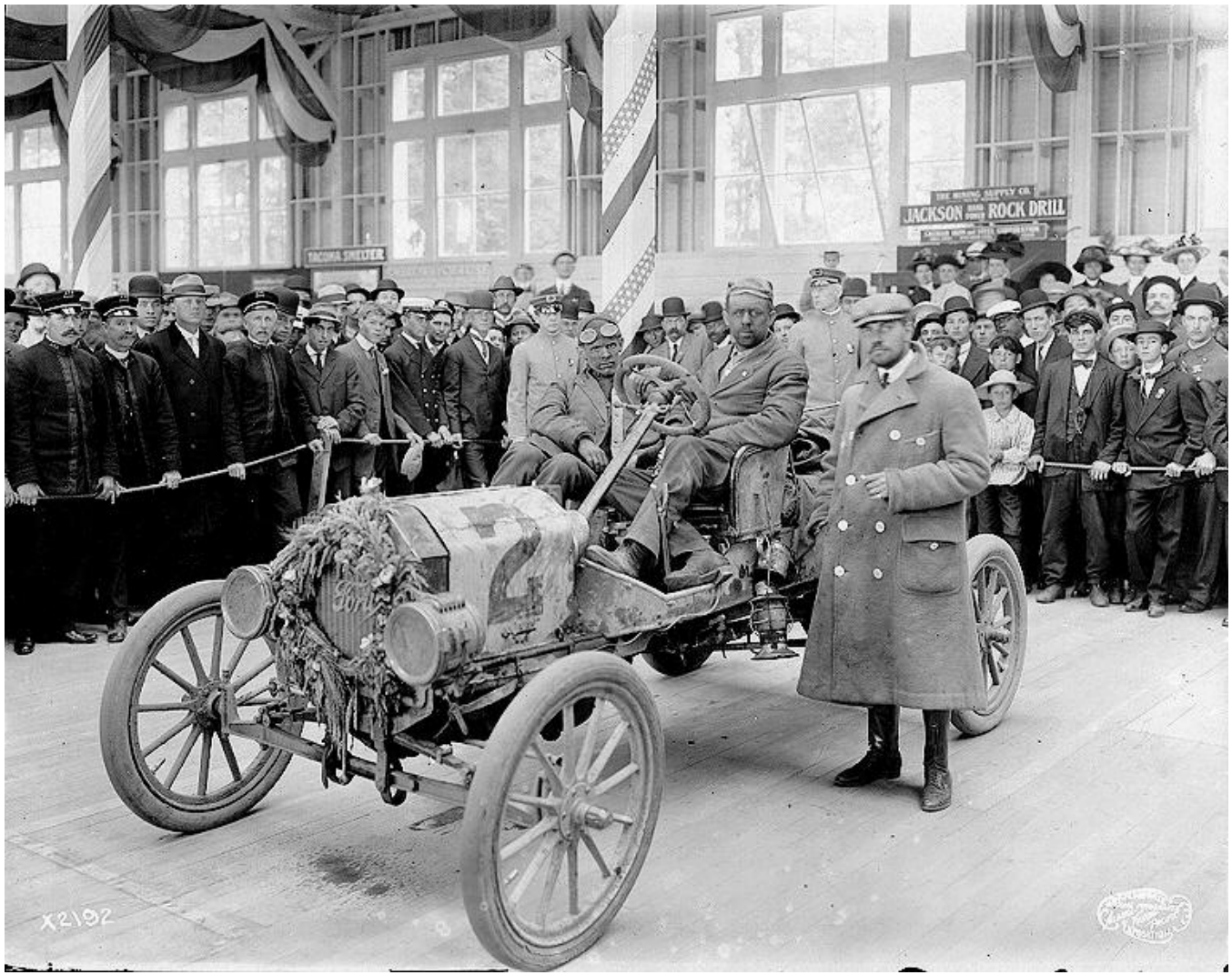
- it has a dual, interconnected nature: one that is responsive to the immediate actions of the operator, and the other that is compatible with the environment,
- it exhibits a yielding purposive behavior, or a behavior that can be made to yield, making it possible for the operator to set the robot's goal,
- the process or entity has the ability, both informational and physical, to actualize the goal set by the operator.

The above requirements set NO restrictions on the form or constituents of the entity or process that is being called a robot. It only places restrictions on its behavior.

Danger of disregarding those guidelines and following a stereotyped perception of what a robot is.

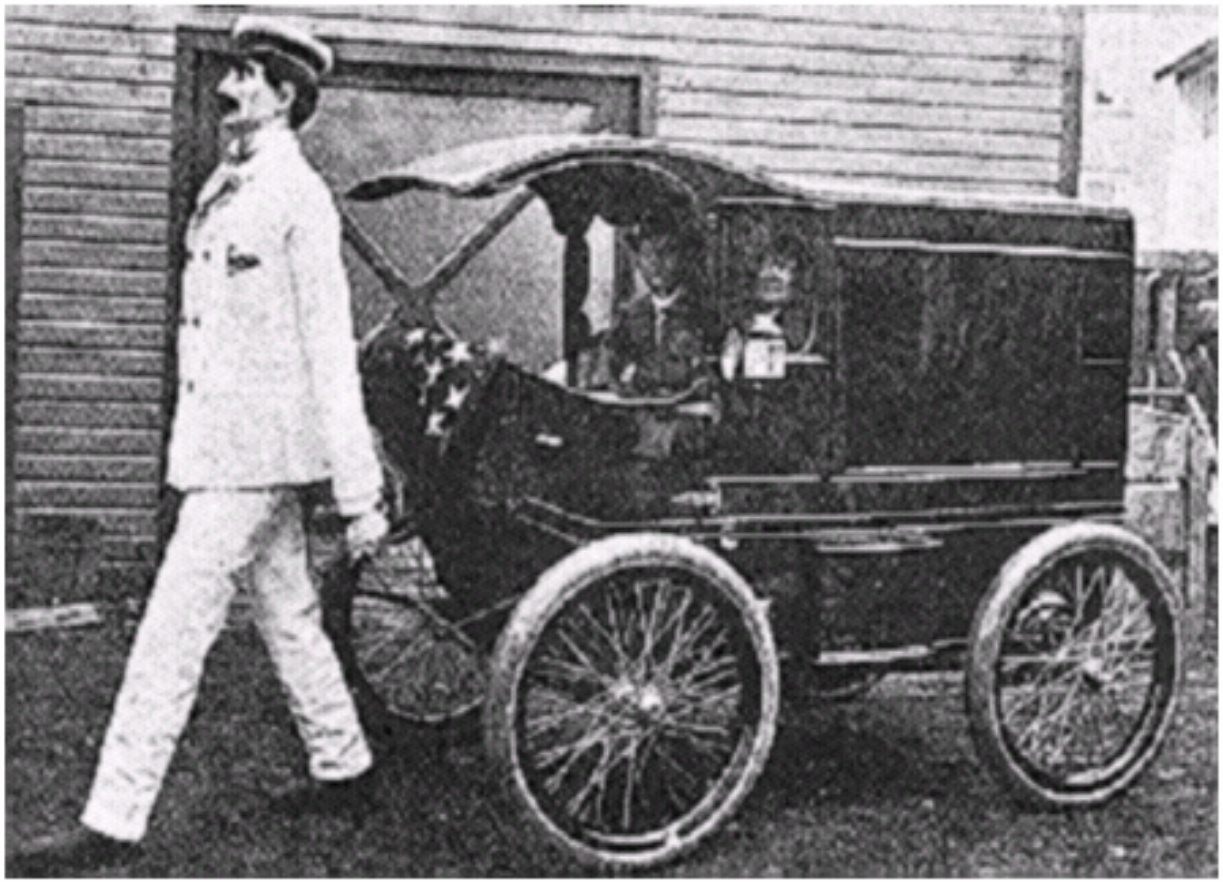
(An extreme example)

Before the model-T was invented



1909

A human-centered perception of what a robot is led to THIS

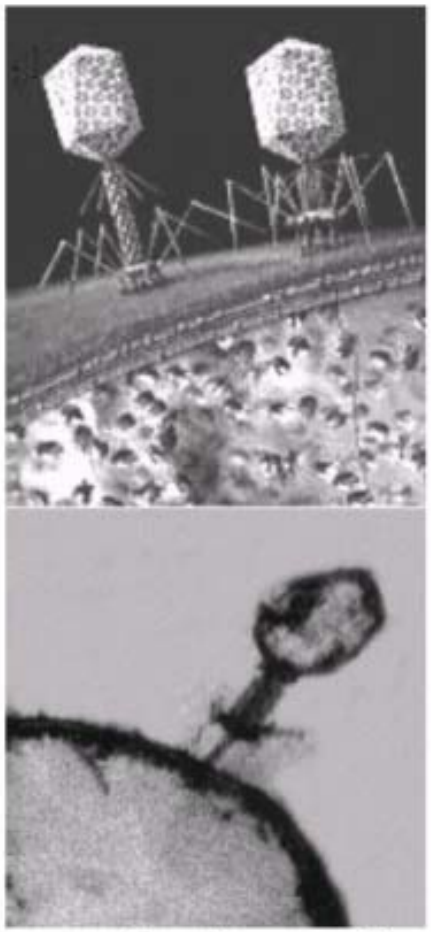


Here’s a modern version of that monstrosity.

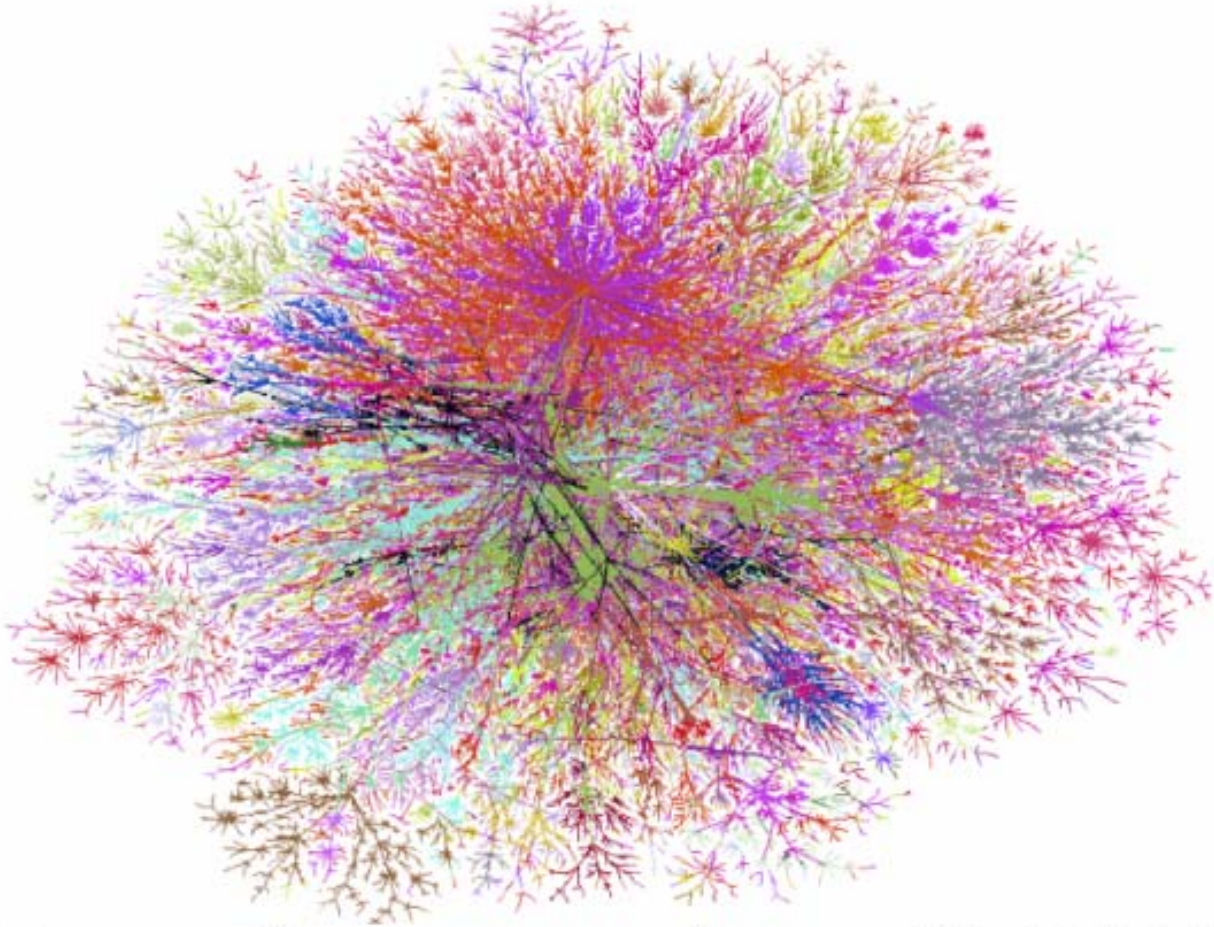
The moral is:

focus on **function** not **form**.

A robot could exist in any environment and at any scale.



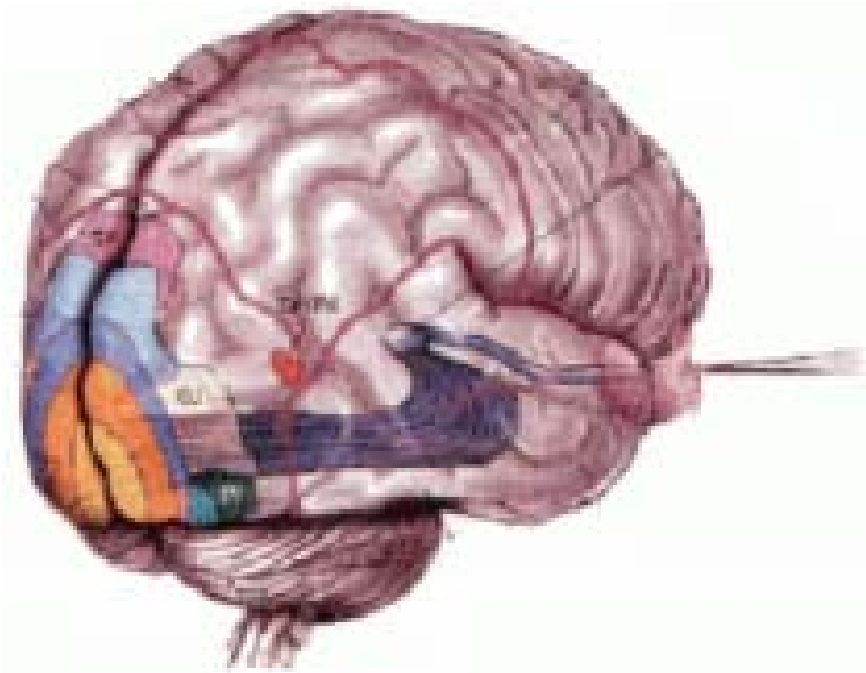
Bacterio-fage Virus



The tree of Internet as was discovered by Bell labs

What puts a robot together is a **B**ehavior **G**eneration **M**echanism **(BGM)**

(you may call it a brain)



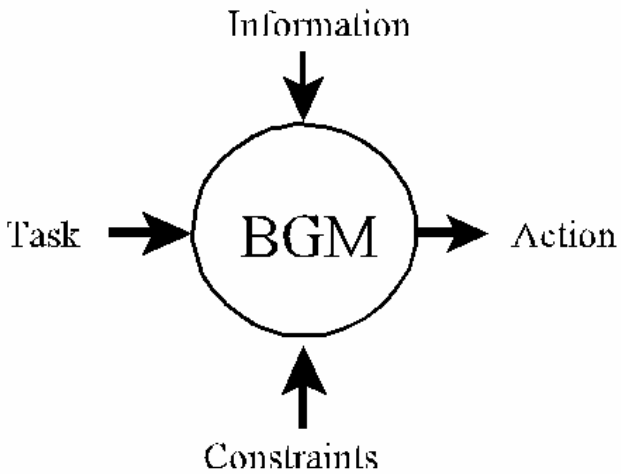
What does putting a robot together means?

It means making the activities of the basis systems the robot is utilizing :

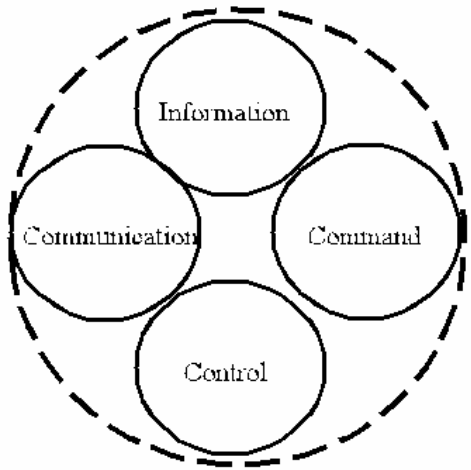
1- **data acquisition** system
2- **command** and guidance system
3- **communication** system
4- **control** system

coalesce to yield an integrated system that would serve as a machine used to make a user reach its goal.

- A BGM must be able to accept as inputs:
  - the task the operator wants the robot to carry-out
  - information about the robot and the environment
  - constraints on the manner the task should be carried out.
- As an output, the BGM should generate a stream of admissible action instructions



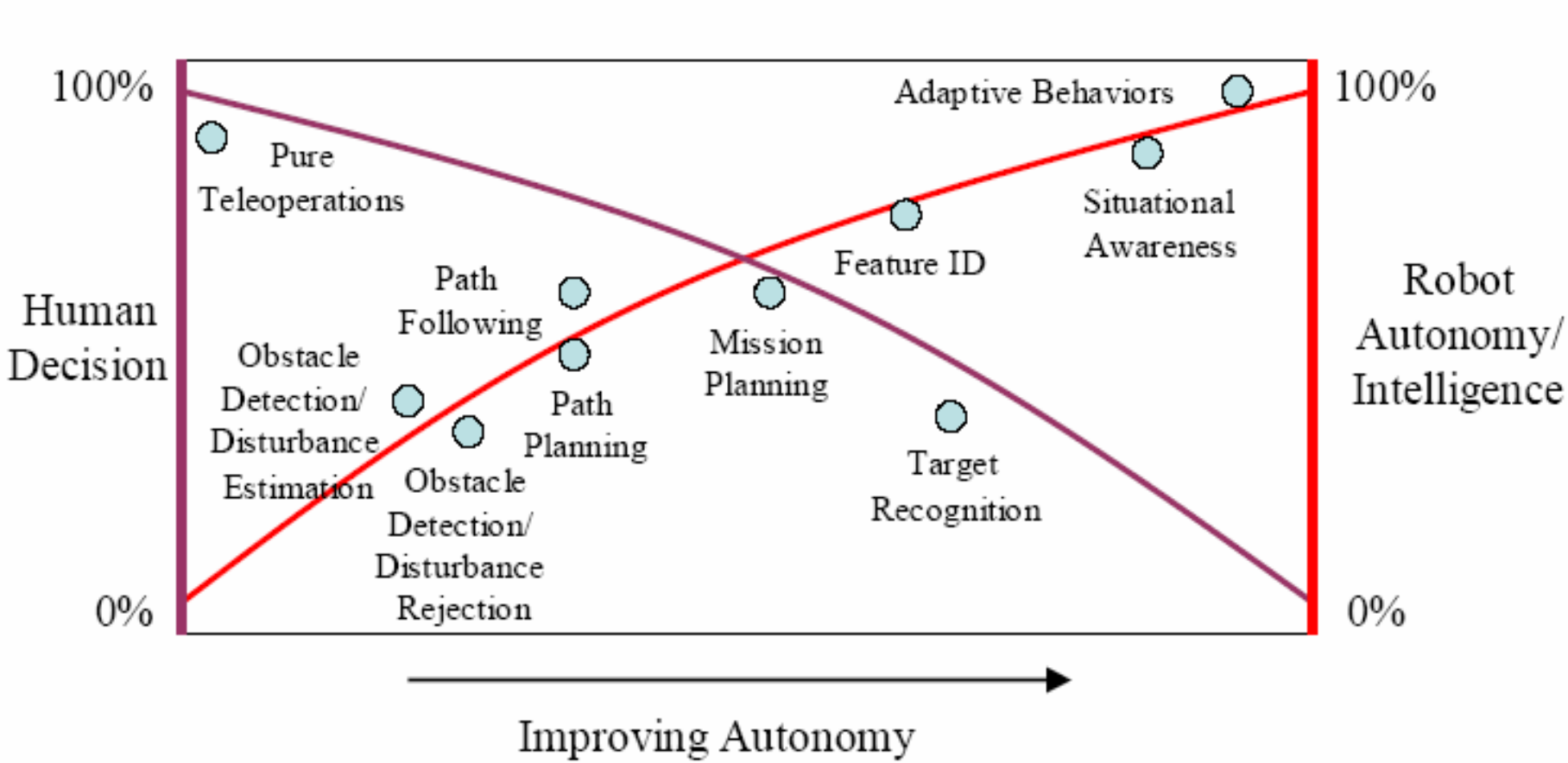
Behavior generation mechanism



C^3I kernels of a BGM.

How to classify robots.

A classification based on the degree of autonomy a robot does help In understanding the type of jobs a robot may be used for.



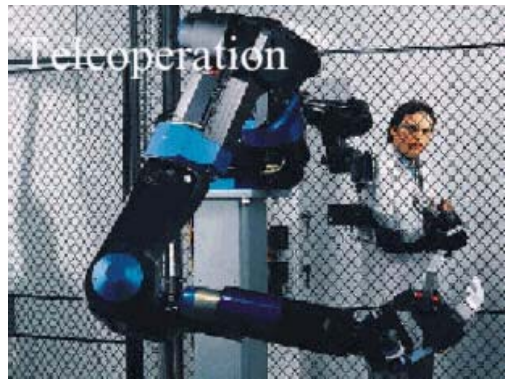
Autonomy may be defined as:

the ability of a robot to execute a high-level order given by an operator without receiving assistance (physical or intellectual) from an external entity.

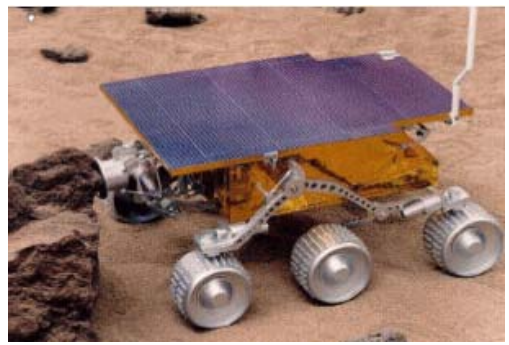
Based on this

A classification of robots

- Unintelligent robots



- Intelligent robots



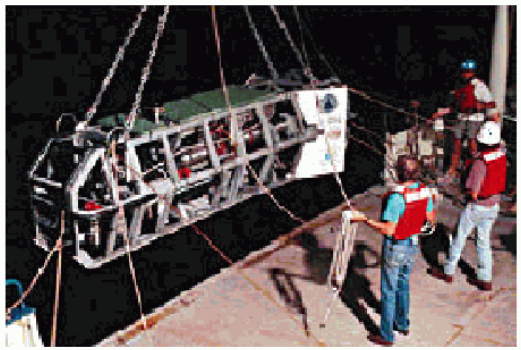
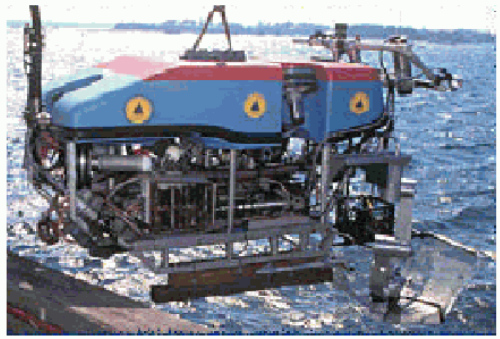
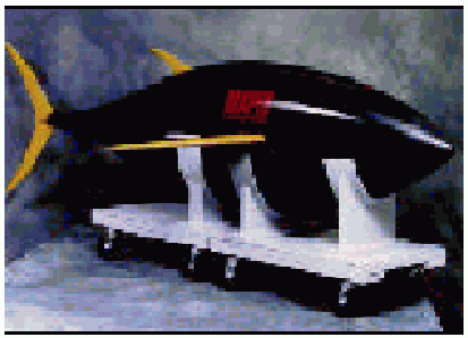
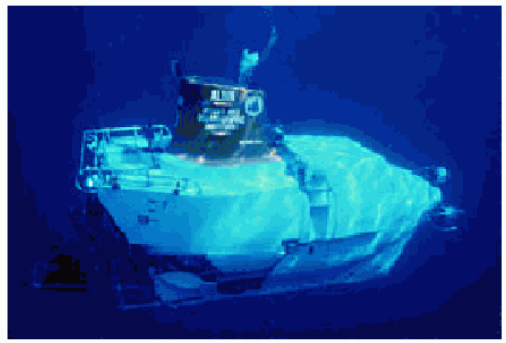
- Semi-intelligent robots
  (man-machine systems)

Applications of Robotics

Underwater Applications

- Inspection & maintenance
- cleaning & repair
- laying transoceanic cables
- exploration
- salvaging




Mining

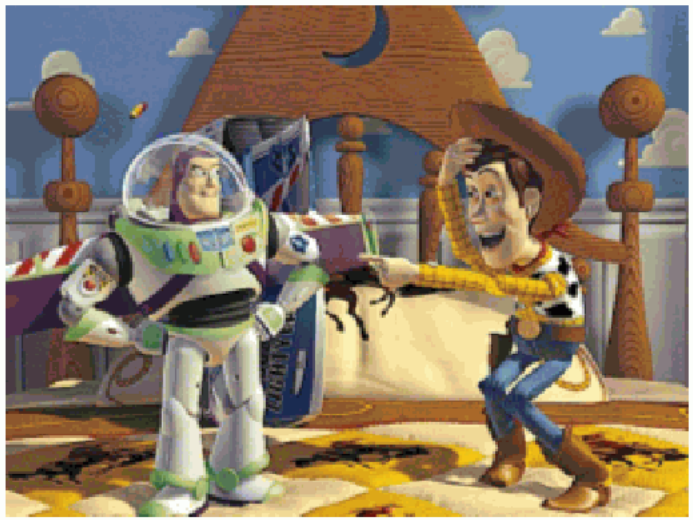
- Surface mining
- mine development
- underground coal transport
- coal preparation
- automated longwall system

Military

- Mine Clearing
- Ordnance Disposal
- Fire fighting onboard ships
- Cleaning
- Battlefield

Digital Actors

A Bug's Life (Pixar/Disney)



Toy Story (Pixar/Disney)

Antz (Dreamworks)

Tomb Raider 3 (Eidos Interactive)

The Legend of Zelda (Nintendo)

Final Fantasy VIII (SquareOne)

And many many more,

depending on how resourceful, skilled and imaginative one is.

How will this course be taught?

- Robotics is a multi-disciplinary area shared by computer science, electrical engineering, mechanical engineering, psychology, philosophy, mathematics,….
- An integrated rich view of robotics is needed in order to build a robot,
- Unfortunately, the aspects related to the background of who teaches the course seems to always get over emphasized,

- There are two popular forms in which robotics may be presented:
  - **Classical robotics:** stresses kinematics, dynamics, robot structure design, control,..
  - **AI robotics:** from a behavior or useful work generation point of view. Planning is the main focus of this area. A planner is what integrates all the assets a robot has in one unit capable of generating the behavior of interest.

- The course will cover both classical and AI robotics.
- The emphasis will be on AI robotics (55% - 65%) of the course
- Classical robotics will be presented in a manner that will aid the understanding of planning
- You should look at the course as a starter that will provide you with a general working view of robotics that will hopefully serve as a starting point for work in this area.

Simulated Research

(course project)

Robotics is a quickly changing area. What is standard today may not be so tomorrow. It may not take long for a modern text on the subject to become outdated assuming it was able to provide an objective view of the whole area to begin with. Therefore research journals are an important source in the learning process. In order to utilize this source one must be able to collect literature about the subject of interest, organize it and summarize it in a useful and clear manner. One should be able to focus on one point in his area of interest and understand it in-depth. This means being able to reproduce the results reported in the work that is being studied. Finally, one must be able to communicate in writing and verbally his findings. I opted to use the term: simulated research instead of: course project because you will be tested on each one of the three stages mentioned above.

Areas from which you may choose a topic:

1- non-holonomic motion planning for wheeled mobile robots,
2- energy-efficient motion control of mobile robots,
3- networked robotics,
4- decentralized traffic management and separation maintenance control,
5- SLAM (self localization and mapping),
6- probabilistic robotics, uncertainty and ambiguity in planning and sensory data interpretation,
7- sample-based motion planning,
8- visually-guided mobile robots (visual servoing)
9- pursuit-evasion in cluttered environments.

1- You must choose a SR topic during the first week of the class.

2- in about four weeks you will be asked to submit a report that summarizes the work in the area that you selected (i.e. a literature survey) and provide a presentation. The minimum number of distinct papers that you must survey is 10; the more the better. The report and presentation will carry a weight of 8 marks. You will also be required to select a specific paper, which I have to approve first, from the literature you surveyed.

3- About four weeks after first progress report you must hand-in a second progress report and a power point presentation showing your progress in studying and understanding the paper you selected along with the results you were able to reproduce or the examples based on the work in the paper that you simulated. This part will carry a weight of 4 marks.

4- The last week of the course will be reserved to presenting the total work. You must hand-in the report at least one week in advance. The final report and presentation will have a weight of 18 marks.

Grade distribution

Homework:	17%
Quizzes:	08%
Midterm Exam:	15%
Simulated research:	30%
Final:	30%

General Notes

1- the reading material consist of selected chapters from books, research papers, and handouts,

2- Homework should be treated as take-home exams. Students are expected to work **"individually".** Homework should be typed, graphs should be prepared using graphical packages, and programs should be fully documented,

3- students are required to have a CD-R available for the course. It will be used by the instructor to transfer electronic course material to them. It may also be used by students to submit homework, projects, and programs,

4- the project will be mainly based on the last part of the course (planning and navigation). However, many of the tools needed to proceed with the project are not dependant on the material at the end of the course.

5- all programming for the assignments and project should be written using MATLAB

Questions?