

Universal Biological Motions for Educational Robot Theatre and Games

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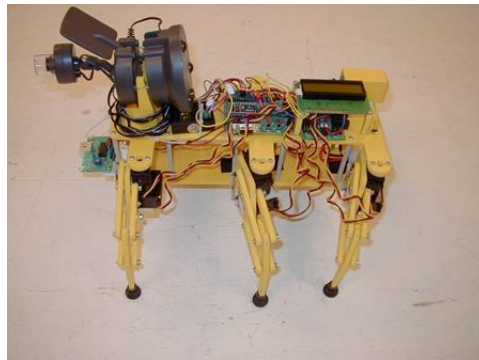
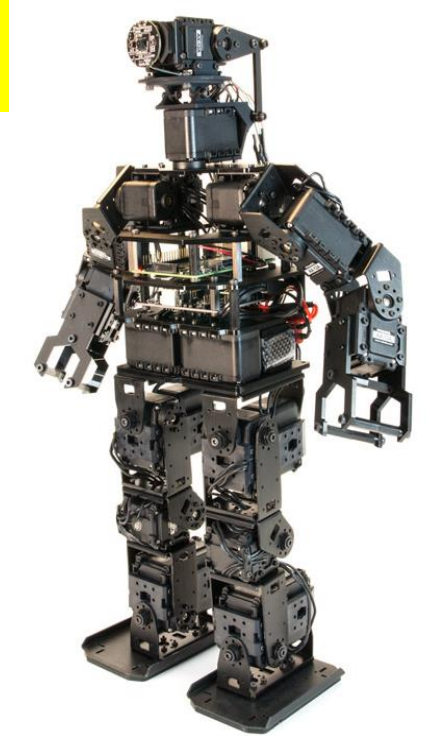
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Presented by Marek Perkowski

Portland Cyber Theatre Project

2000 - 2021

1. Portland Cyber Theatre is a research educational project.
2. Graduate research:
 - Emotions
 - Quantum control of motion
 - Theory of motion and emotion
3. Undergraduate research
 - Building robots, stages, plays, performances and games
4. Research with high-school students
 - Building robots, stages, plays, performances and games
5. Plays
6. Games.



Educational Robot Theatre

- Uncanny Valley?
- Sesame Street?
- Realism?
- Puppet Theatre?
- Disney World?

Theories

**Practical
Realizations**

Scenarios

Games

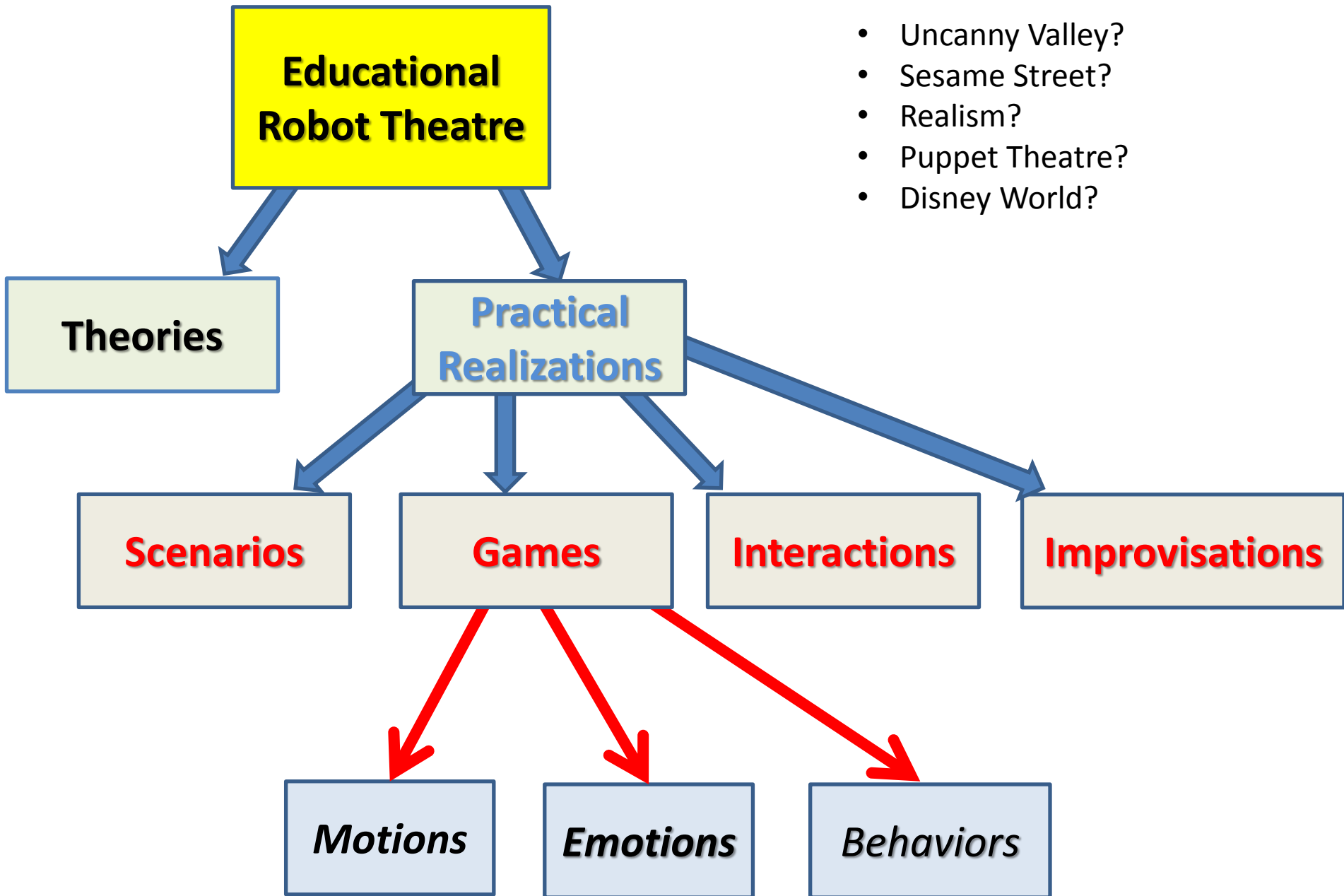
Interactions

Improvisations

Motions

Emotions

Behaviors



Animation is difficult

- The “robotic” motion is usually bad
- The repeated motion is bad
- Motions should be similar, but **every time different.**
- Motions should be “**biological**”, “organic”
- What is the **nature of motions** of humans and animals?

Most general motions that exist

- Chasing, tracking, escaping, attacking, eating, foraging.
- Diffusion processes
- Brownian motions
- Schroedinger and Fokker-Planck.
- Particles, molecules, nano-world, physiology, biology, animal social behavior.
- Sociology, psychology, social groups.

Markets and Applications

- Humanoid and animatronic robots are already used in several areas of human-robot interaction:
 - (1) to interact with **elderly** and **autistic** children,
 - (2) as robot museum **guides** and **receptionists**,
 - (3) as **home robots** and popular **toys**,
 - (4) as robot **entertainers**.



Designing the motions of the robot that would be natural

1. Art of animation in puppet theatre, movies and computer games.
2. Motions can be not necessarily human-like but must be “*characteristic and believable*” or “*biological*”.
3. How to program an inexpensive robot built from an internet kit
 - to “run like a dog”?
 - to “eat like a nutria”?

Previous research on “artistic robot motion”

1. robot programming **languages** based on elementary motions and algebraic operators to combine them.
2. low-level robot **motion editors** to design motions (gestures) as sequences of postures (similar to graphic animations).
3. methods based on **feedback** from position **sensors**.
4. **human motion acquisition** and transformation to robot kinematics and dynamics.
5. heuristic systems for **converting music** to motions.
6. **random number** generators.
7. **Machine Learning** approaches.
8. methods based **on spectral analysis** of individual motion waves from sensors.
9. Perlin **noise**.
10. several others.

New Model of motions

1. realistic (“biological”) motion generation problem, based on **general principles of motions in Nature**.
2. We present an interesting issue for robot theatre: “**designing new motions** for animatronic, humanoid and other theatrical and social robots”.
 - Should they have motions similar to humans?
 - Similar to machines?
 - To animals?
 - To Fairy Tale Characters?
 - To electrons in an atom?
3. Attempt to design motions that are **new** and unexpected, interesting, symbolic, information-carrying and characteristic are important for **improvisational** robot theatre.

New Model of motions

We create a model of motions for **robots playing motion-behavior games**, like policemen chasing a thief or an airplane battle.

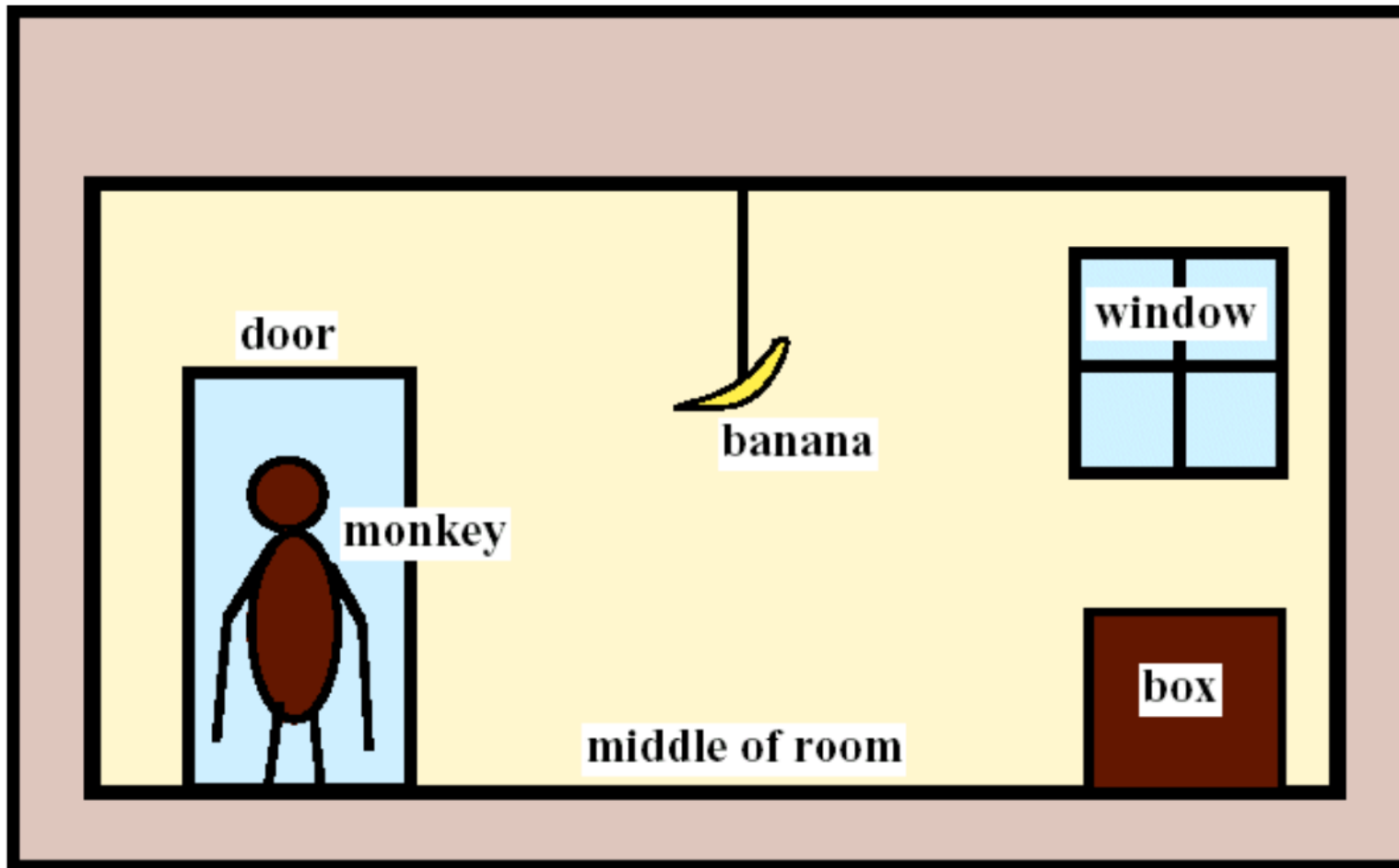
- The motions may be:
 - **influenced by noise**,
 - have controllable errors or some other parameters
 - so that the motions are not predictable by opponents
 - but are interesting to watch by the game audience.
- Our games are a kind of **interactive, improvisational theatres**, like a *cheese escaping from hungry mice* and asking verbally for mercy.

Noise on top of deterministic motion

- Noise-like processes (like Perlin or Diffusion Drift) can **be added on top of any deterministic motion generations.**
 1. For instance, Fokker-Planck model has parameters like **D** , **v** and **w** of equations, and the animator or the supervising software can experiment with their values.
 2. Natural noise or mechanical disturbances are simulated with **w** .
- We found this “general motion transfer” property to be useful in several robot theatre applications.
 - In an example, in one of experiments with another robot a motion was developed for a golf-playing robot arm but next applied to the neck-moving behavior of a humanoid - interesting and unexpected gesture was thus created.
- It was observed that the motions transferred from area to area and from robot to robot can be unexpected, interesting and innovative.

Logic Puzzles and Advanced Planning

Monkey and Banana Problem



Logic Puzzles and Advanced Planning



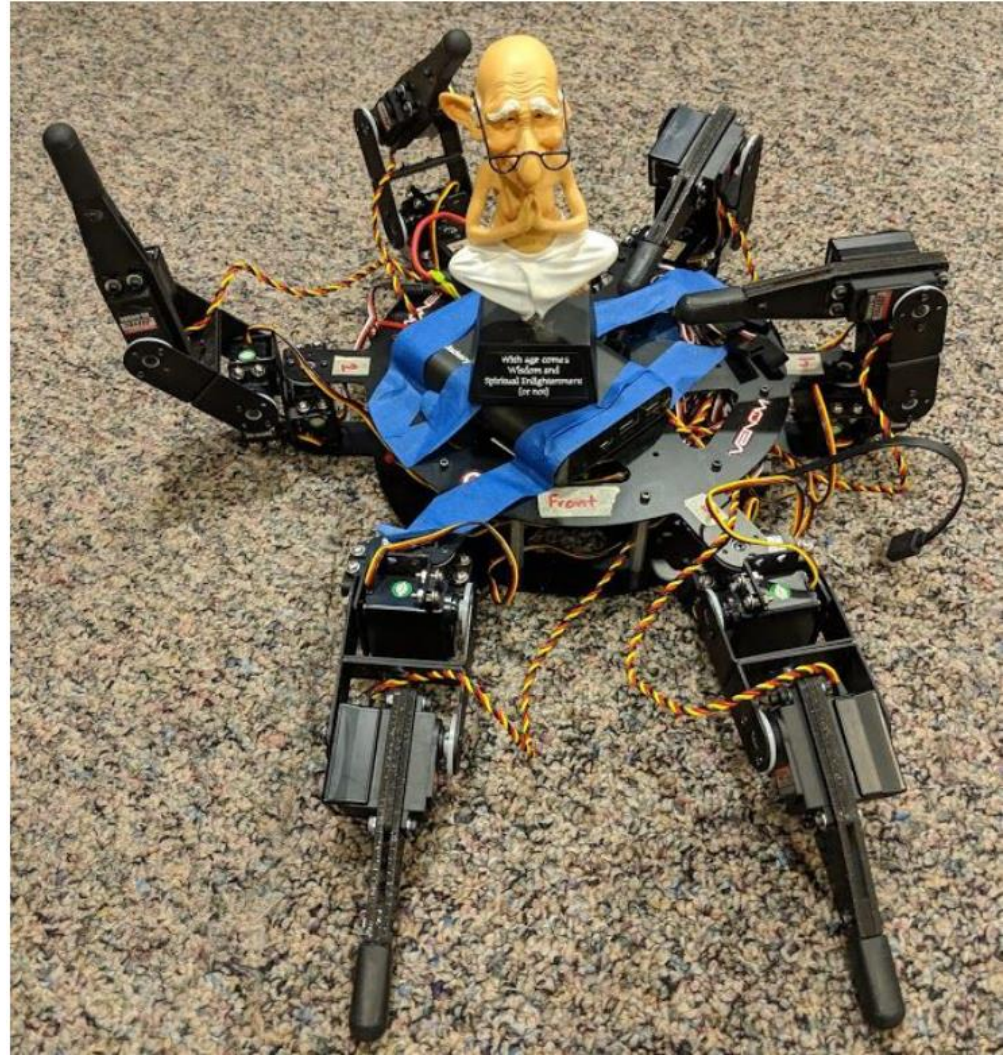
Theatre + Games = Education

- Robot improvisations.
- Interaction of humans and robots.
 - Future home robots
 - Robot toys
 - Social robots
 - Robots for autism
 - Games played by robots, by robots and humans.



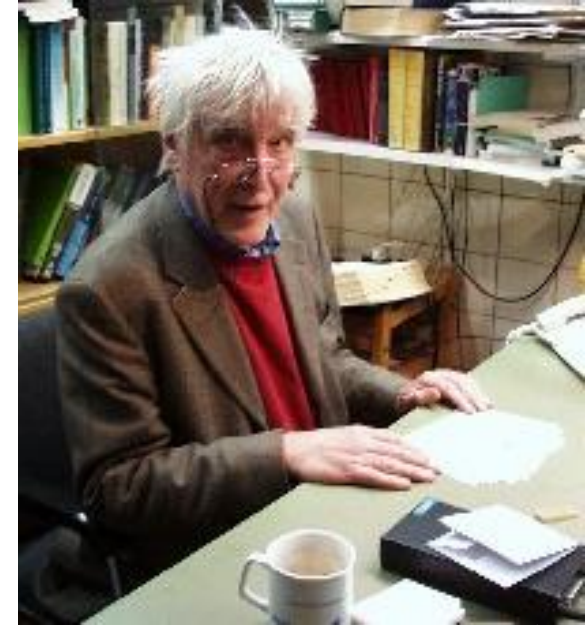
Games

- Board games
 - Tic-Tac-Toe
 - Go
 - Chess
- Computer games
 - Sum-of-Products minimization
 - Quantum Circuit minimization
 - Quantum games
- Games played by mobile robots
 - Devil and Angel
 - Romeo and Juliet
 - Policemen and Thief
 - Mice and Cheese



Braitenberg Vehicles

- Valentino Braitenberg
 - *Vehicles: Experiments in Synthetic Psychology*
 - Neuro-psychologist interested in how primitive neural structures can give rise to complex behavior
 - He developed a simple model of robots with sensors and motors to show how complex behavior can arise from simple mechanisms
- We're interested in his vehicles as a simple autonomous agent framework we can play with
 - Build ecosystems of interacting agents and sensory sources



Braitenberg Vehicles – Simple Mobile robots with two wheels

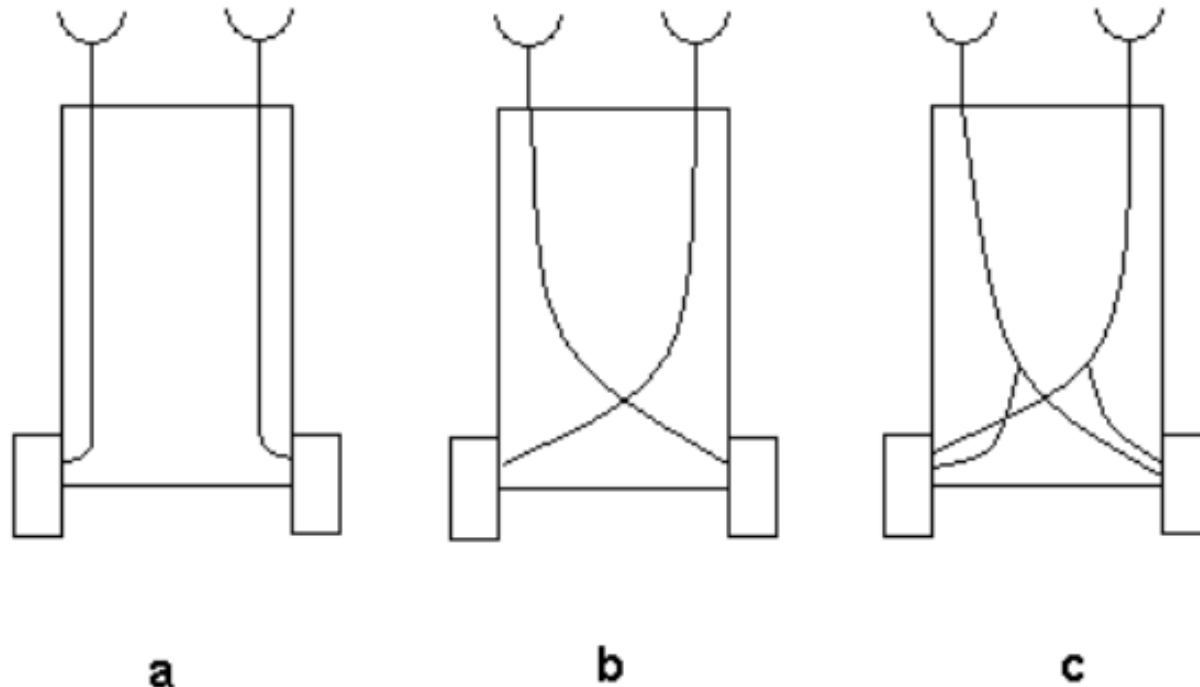
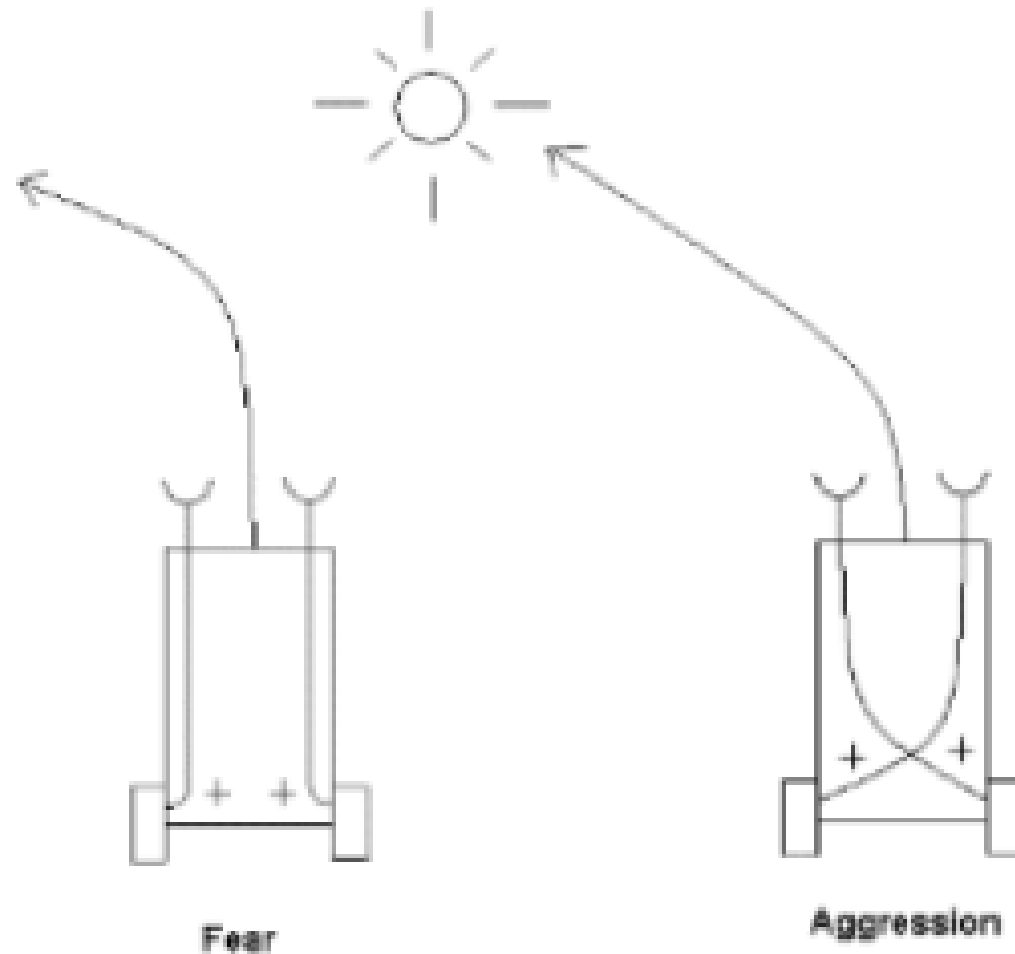
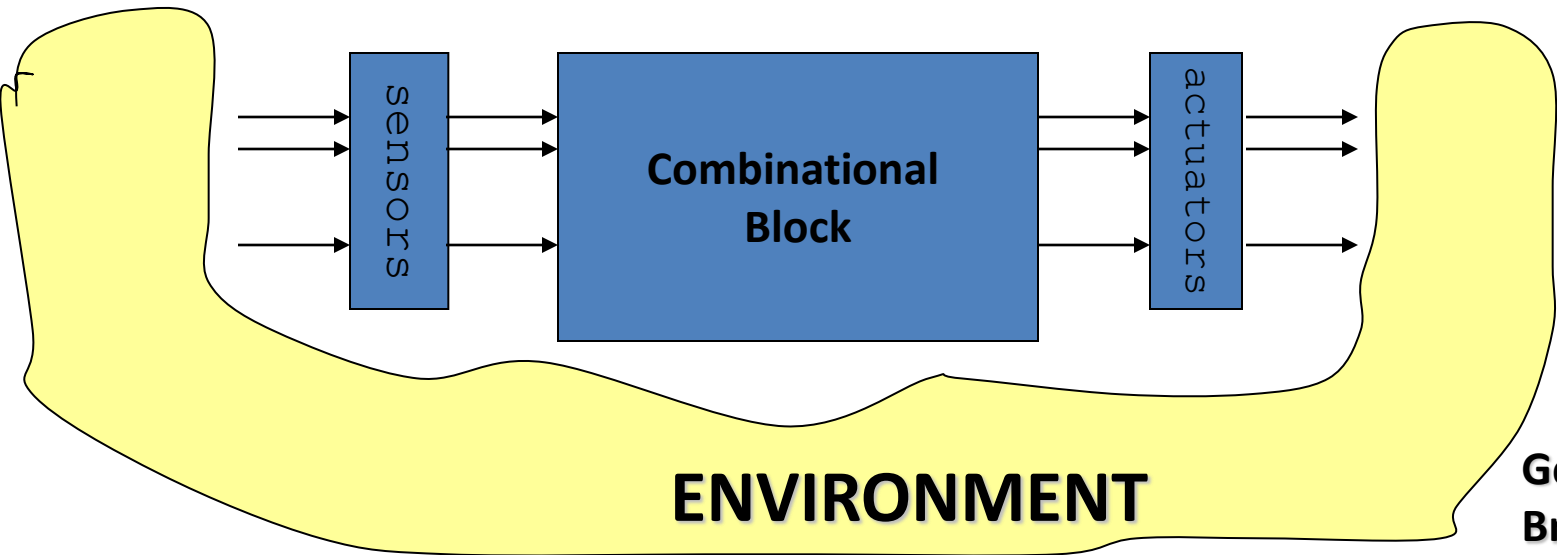


Fig. 1. The simplest Braitenberg Vehicles with analog control, (a) each sensor is connected to the motor on the same side, (b) each sensor connected to the motor on opposite side, (c) both sensors connected to both the motors.

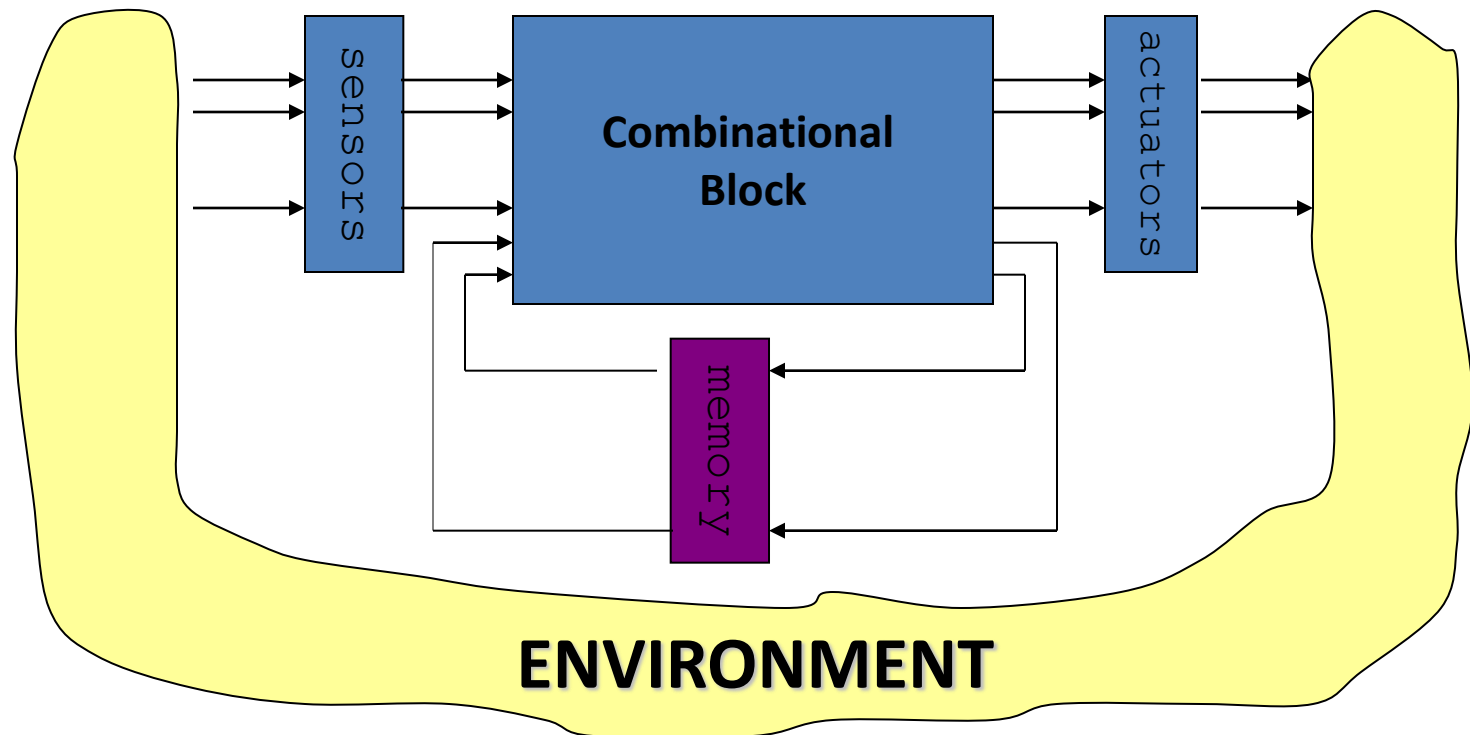
Autonomous Behaviors of Braitenberg Vehicles



Left Vehicle avoids light while right vehicle follows light.



**Generalized
Braitenberg Robot**

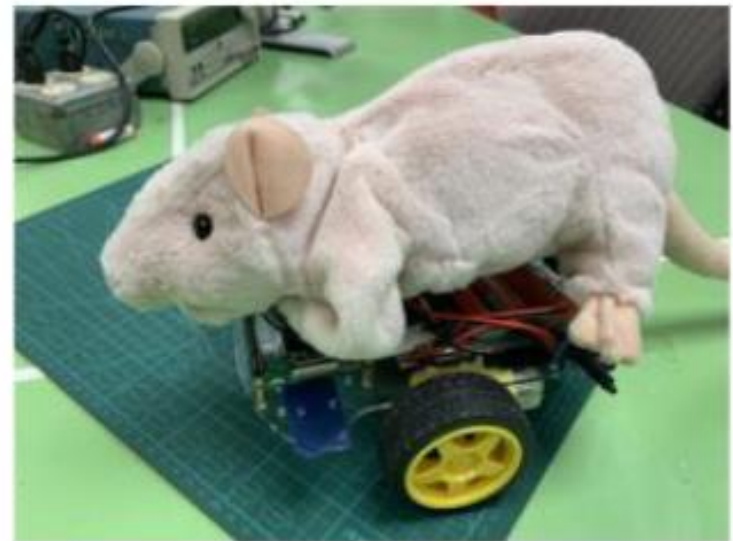


**Braitenberg
Automaton Robot**

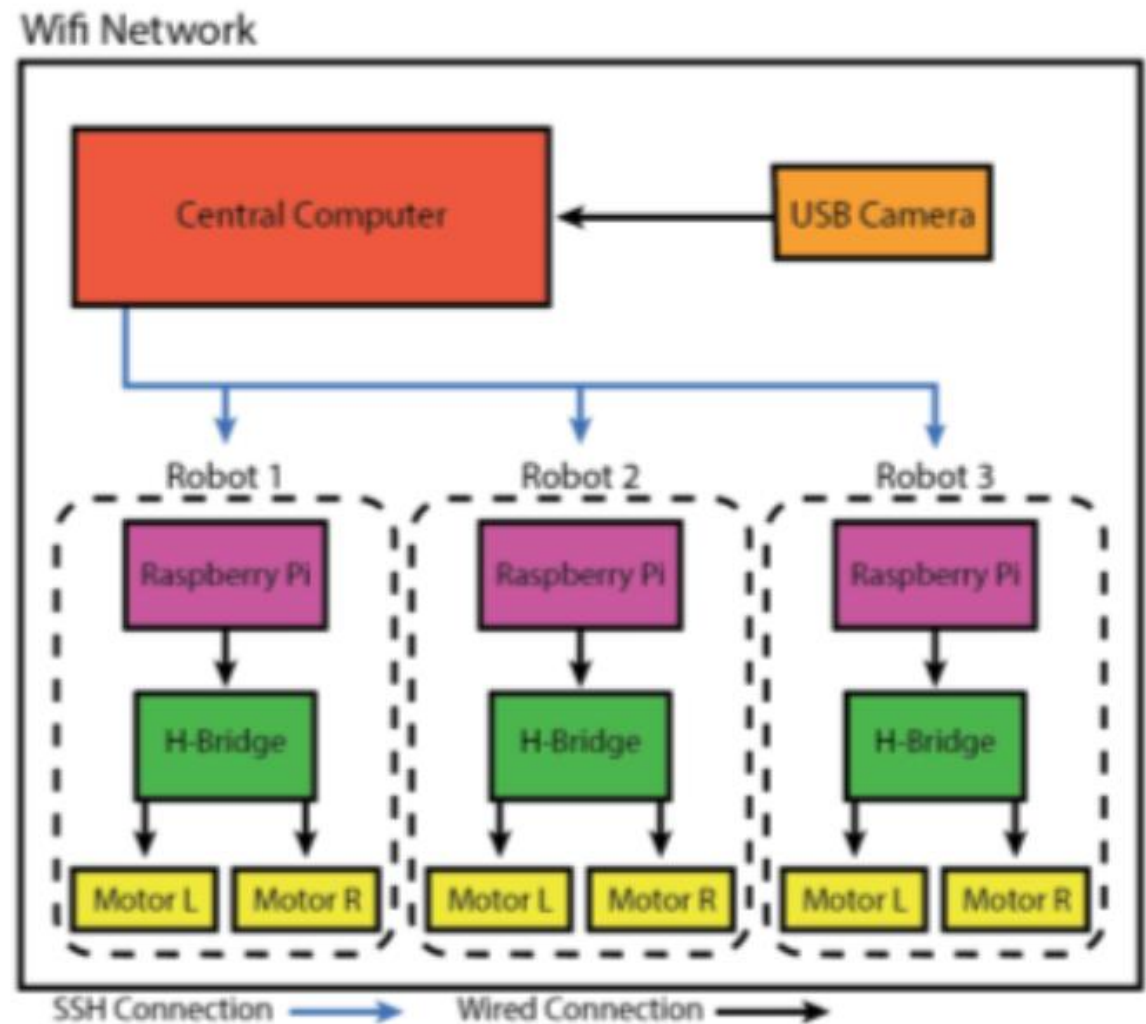
Example of Robot Game/Theatre – Mice and Cheese



Figure 6: Robot kit fully assembled with H-Bridge module



Stage System with WIFI and Ceiling Cameras



- Human is a Cheese
- Robots are Mice

Figure 3. The Mice and Cheese System with ceiling camera and Wifi Network.

Fokker-Planck Stochastic Dynamics

- For simple state spaces like state spaces on real line \mathbf{R} and line segment $[0, 1]$, it is equivalent to the following ***partial differential equations (PDE)*** below.
- Equation below is an example of PDE defined by Fokker-Planck operators.

$$\frac{\partial c(x, t)}{\partial t} + v \frac{\partial c(x, t)}{\partial x} = D \frac{\partial^2 c(x, t)}{\partial x^2}$$

where $c(x, t)$ is the probability density of finding the system in state \mathbf{x} at time \mathbf{t} .

- Note that this PDE is deterministic, even though the underlying system is stochastic.
- This equation is the classic ***diffusion equation*** originally constructed to model evolution of heat conduction in extended finite temperature materials and is identical to ***Schrödinger's equation*** known from Quantum Mechanics.

Fokker-Planck Stochastic Dynamics

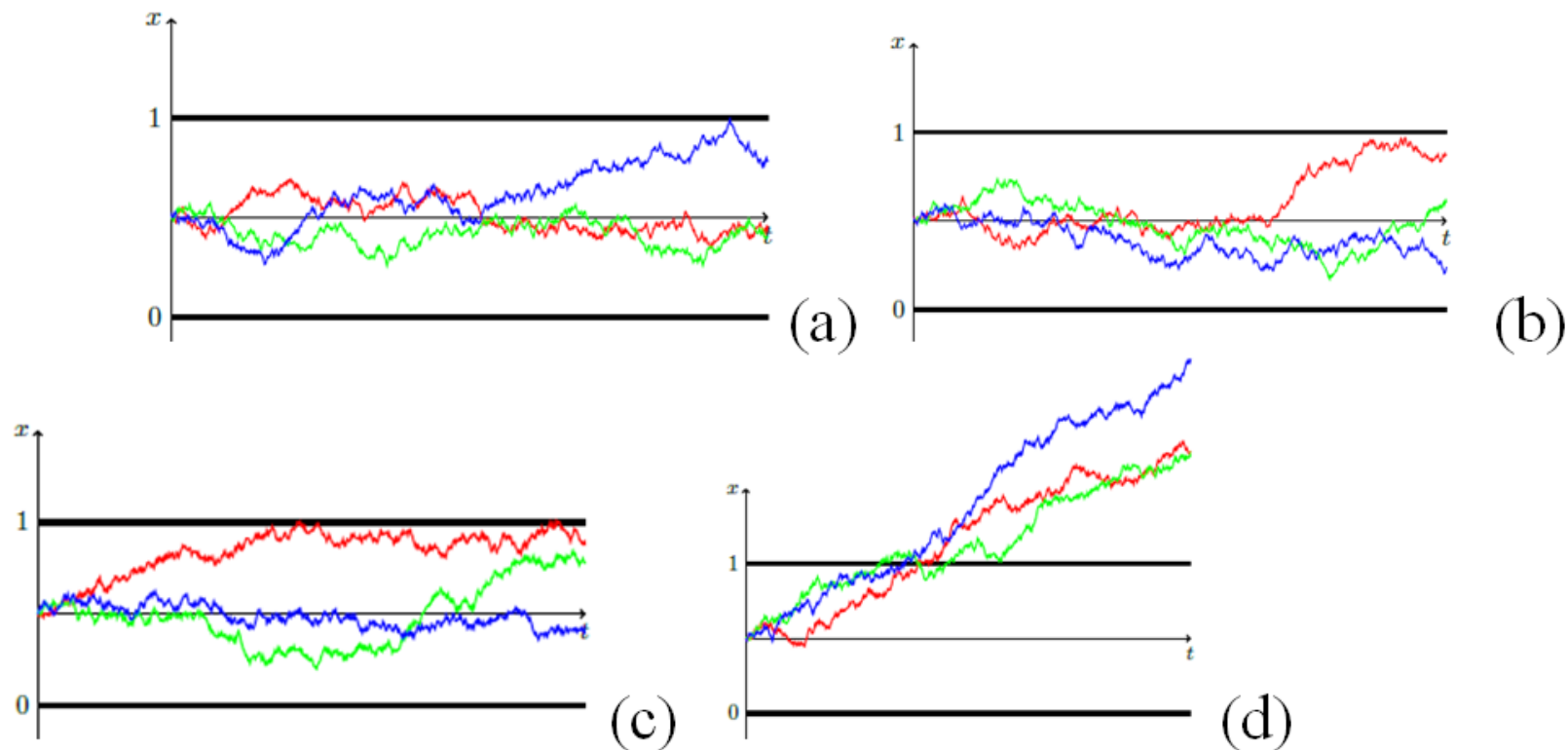


Fig.4. (a) Drift Diffusion Model (DDM) with no drift and small diffusion constant (b) DDM with very small drift and small diffusion constant, (c) DDM with small drift and larger diffusion constant, (d) DDM with large drift

Where will be the drunken man after one hour? After two?

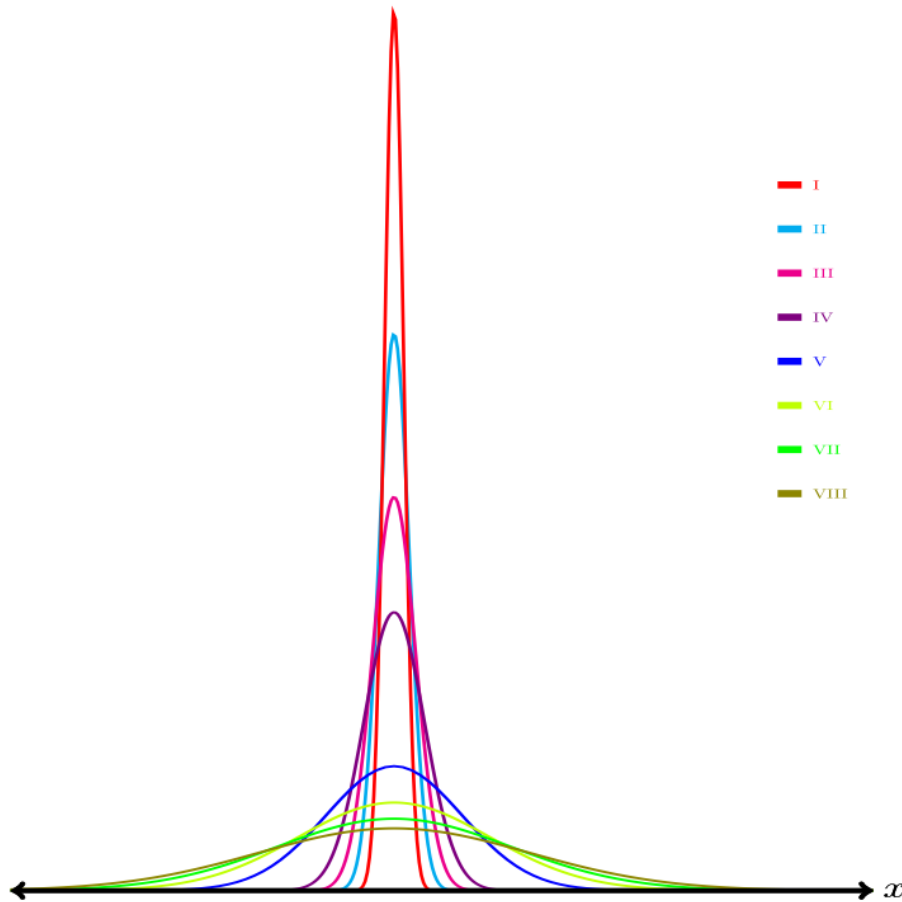


Figure 1: Diffusion on an infinite line
Roman numerals are numbered in the direction of increasing time. The x axis is the state space and y axis is the probability density.

Where will be a “drunken car” after some time?

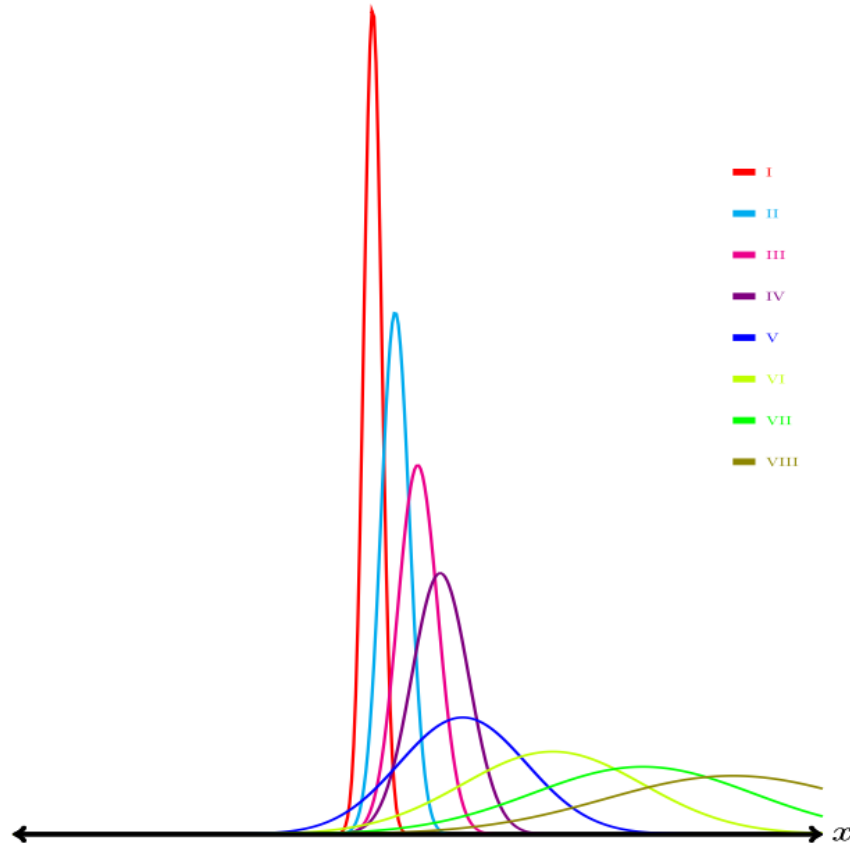


Figure 2: Diffusion with drift on an infinite line
Roman numerals are numbered in the direction of increasing time. The x axis is the state space and y axis is the probability density.

First-passage – reaching to grab a fruit or escaping from poverty?

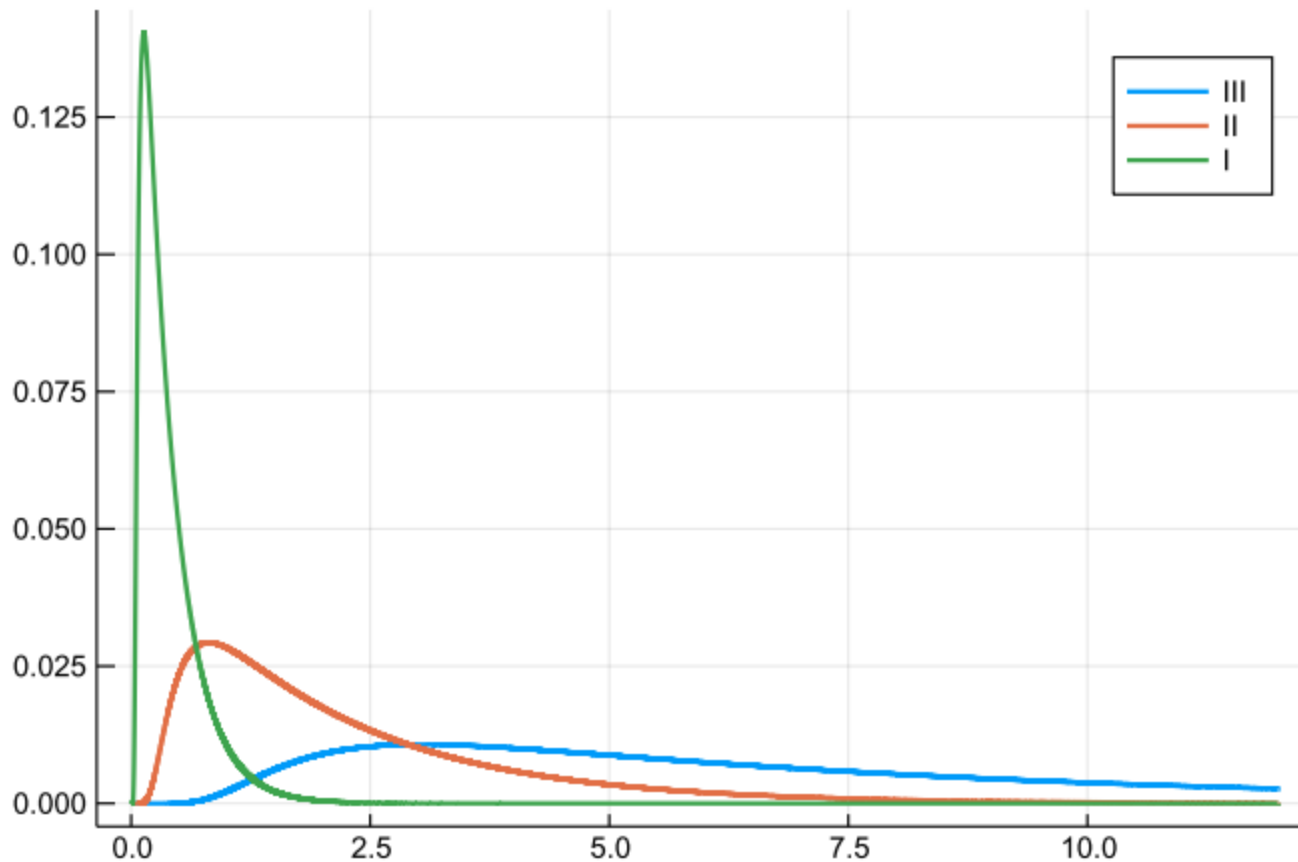


Figure 3: First passage time density for varying diffusion constants
Roman numerals are numbered in the direction of increasing diffusion.

Examples of hybrid automata.....

EXAMPLE 2: Thermostat

A thermostat model

Off

$$\dot{X} = -k_r X$$

$$X < 15; X' = X$$

If $X < 15$ turn heater on

On

$$\dot{X} = k_h - k_r X$$

$$X \geq 20; X' = X$$

If $X \geq 20$ turn heater off

SYSTEM
DYNAMICS

Derivative in time
of continuous
variable X

Firefox

http://bncap...=486&score=453

Google

popcorn my pinboard

Bookmarks

Bottsy: Robot art Fight!

Winner and Loser

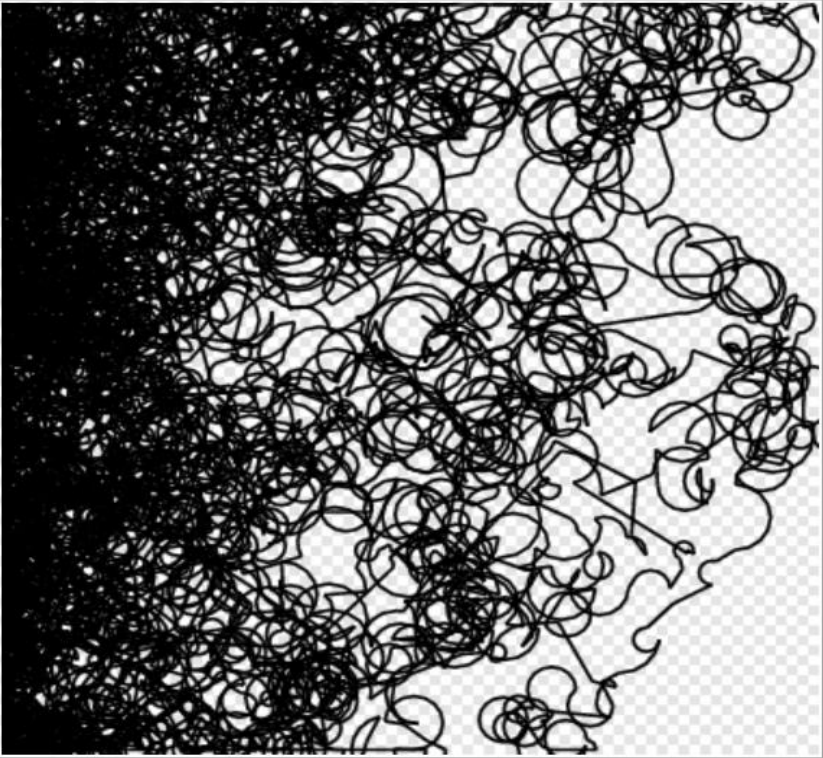
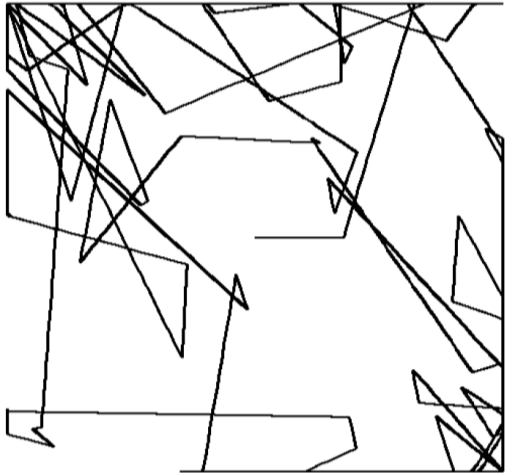
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[Ranking](#)
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CONCLUSION

1. Part of a larger project “teaching by games and improvisational robot theatres”.
2. Innovative **general methodology to create motions for all kinds** of assistive and theatrical robots.
3. Based on the concept of **universal motion processes** that exist in Nature
 - Described by **Fokker-Planck** differential equations.
4. Introduced robot motions **generalize physiology** and lift it to the systems level.
5. The surprisingly deterministic behavior of physiological processes the concept of reliable behavior is generalized and the models of nano- and micro- physiology, as well as atomic forces, are lifted to the systems level.
6. Applied to “fairy-tale” robot

Future Works

1. **Quantum robot** – Perkowski, Kumar, Lukac – replace Fokker-Planck with Schroedinger Equations
2. **Quantum Automata** – Hybrid Automata
3. **Evolution of automata** – new types of quantum motions and emotions.
4. How to make a **science of artistic robots** – research on evaluation of Human-Robot Interaction systems – art of animation.

Appreciation

- National Science Foundation
- Portland State University Research Grants
- PSU Foundation
- Portland School District
- **Many private donors**