# Chapter 1. Introduction

## in Self-modifying Systems in Biology and Cognitive Science by Kampis, G. (1991)

## Course: Autonomous Machine Learning

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# Contents

# Models of Life and Mind

- The Closer Subject: Dynamical Processes
  - A few major ideas are needed to model life and mind
  - Model classes: structures, empirical data, and **processes**
  - “Nothing in biology makes sense except in the light of **evolution**” Th. Dobzhansky (1973)
  - **Models of living and mental processes**
  - We will discuss dynamical processes, with its implications and justifications.

# Models of Life and Mind

- Model Schemes of Dynamics

$$\frac{dx_i}{dt} = f_i(x, p, t), \qquad i = 1, \ldots, n$$

  - x={x_i} := situation in the system
  - p := individual identity
  - Updating of the variables x according to f

# Models of Life and Mind

- Model Schemes of Dynamics – Automata theory

$$A = (U, Y, \Omega, \tau, \delta)$$

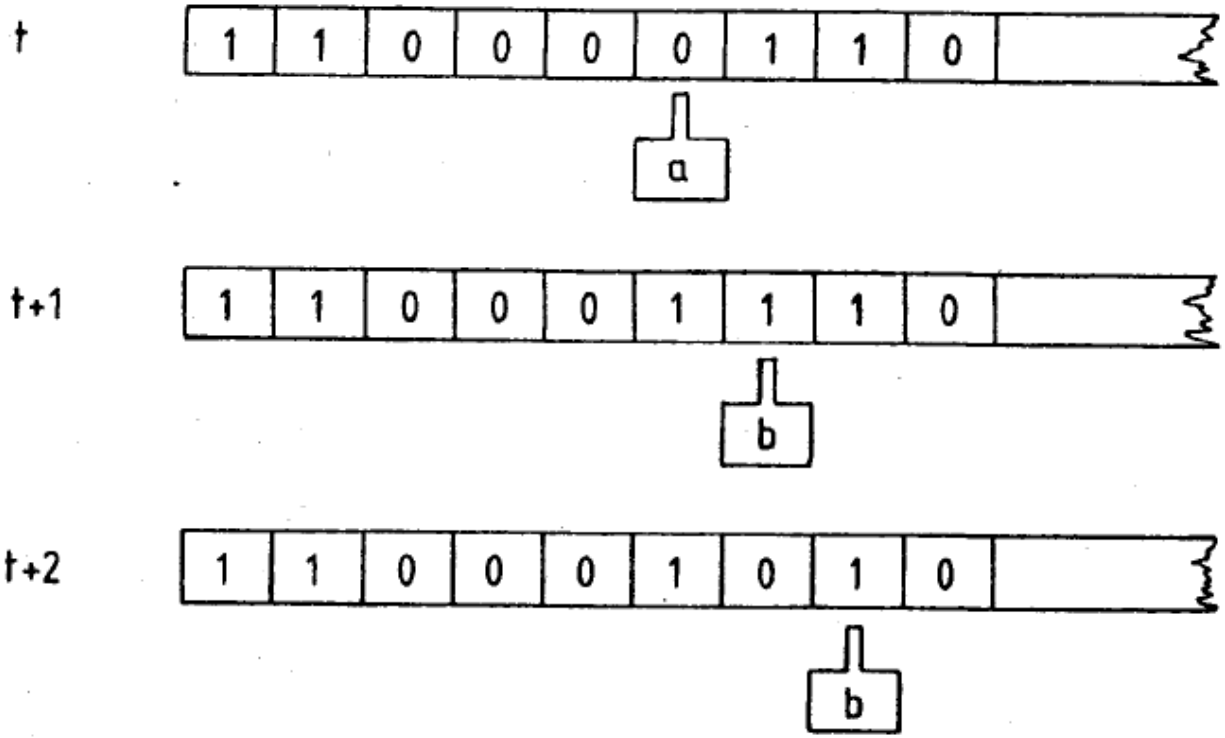
  - U,Y := input and output signs, respectively
  - $\Omega$ := set of internal states
  - $\tau : \Omega \times U \rightarrow \Omega$, next-state mapping
  - $\delta$: $\Omega \times U \rightarrow$ Y, next-output mapping

# Models of Life and Mind

- Model Schemes of Dynamics – Turing Machine

$$A = (U, Y, \Omega, \tau, \delta)$$

  - Realization of the automaton scheme with three parts:
  - Tape: instructions and the data are stored
  - Read/Write Head: interacts with the tape
  - Finite control unit: tells how to operate the head and the tape
  - $\mathrm{Y} = \mathrm{M} \times U$, M := the set of possible moves of the head over the tape containing sets of symbols taken from U




transition function

(0,a) ⟶ (1,R,b)
(0,b) ⟶ (STOP)
(1,a) ⟶ (0,L,a)

states: a,b,STOP

symbols: 0,1

moves: L(eft),R(ight)

**Figure 1.1. Example for a Turing Machine**

# Models of Life and Mind

- Model Schemes of Dynamics – Turing Machine
  - Symbols to express how the variables change
  - Variables to represent conditions or states
  - Current state and the mathematical functions
  - Independent external factors
  - **State-determined systems**

# Models of Life and Mind

- Examples for Dynamical Models
  - Simplest models of ecology: binary predator-prey interactions
  - Classical population genetics (Lewontin, 1974)
  - Dynamic models of evolutionary processes (Holland, 1975; Eigen and Schuster, 1979; Rada, 1981)
  - J. von Neumann (1958), W. R. Ashby (1954), and Alan Turing (1950) envision thinking machines based on the automaton conception.
  - Neural Networks (McCulloch and Pitts, 1943; Arbib, 1964)
  - Perceptrons (Rosenblatt, 1958)
  - **Evolutionary learning**

# Pitfalls of Dynamical Models

- **Behaviorism** vs. Cognitive Science
  - Watson and Skinner's behaviorism favors a view of environmental stimuli (S) and organismic responses (R), setting aside 'mind', for the brain as an **input-output machine**.
  - The basic situation of **associative learning**

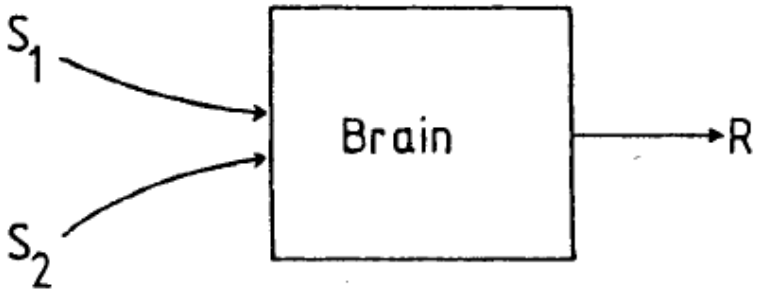



Figure 1.2. Stimulus-response model of the brain.
$S_1, S_2$: stimuli, R: response

# Pitfalls of Dynamical Models

- Behaviorism vs. **Cognitive Science**
  - Behavior is controlled by **internal manipulation of mental representations of the environment**
  - Mind as **an active agent**

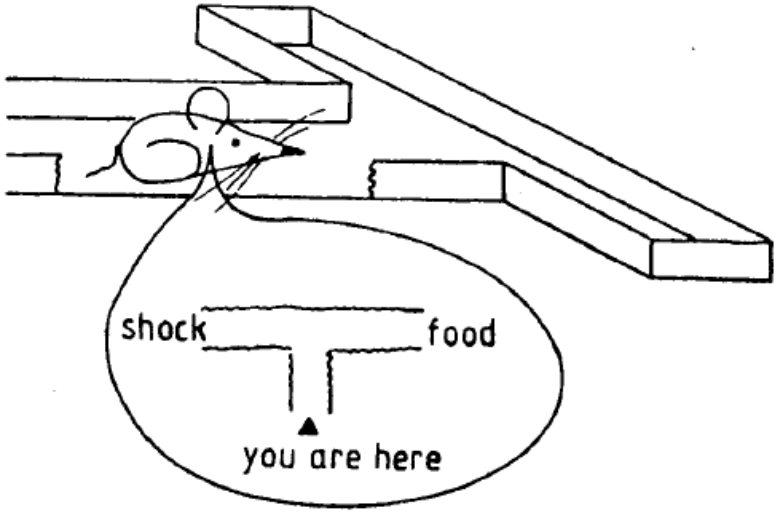



Figure 1.3. Cognitive map as a model of reality

# Pitfalls of Dynamical Models

- Behaviorism vs. Cognitive Science
  - In a model perspective, the difference between behaviorism and cognitivism disappears.
  - B=(u(t),y(t)), t=0,1,2,…
  - An internal structure Σ=(X,g,h) such that x(t+1)=g(x(t),u(t)), x(0)=$x_0$, y(t)=h(x(t))

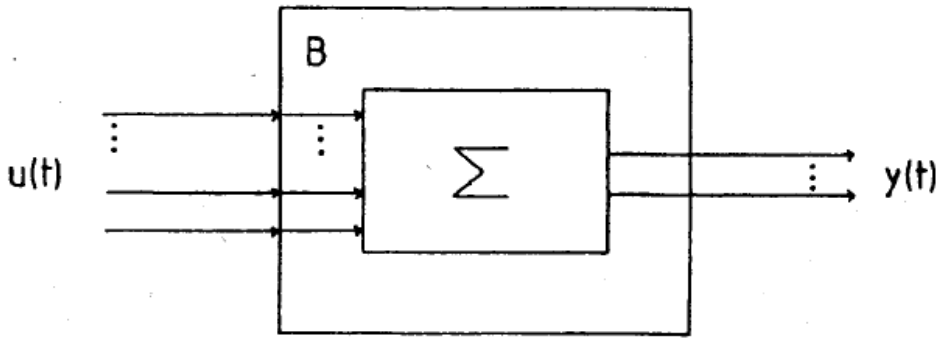



Figure 1.4. Behaviourism to cognition: are they equivalent?
**u(t)**: input, **y(t)**: output, **B**: input/output structure,
**Σ**: generative structure

# Pitfalls of Dynamical Models

- Behaviorism vs. Cognitive Science
  - Internal structure of Σ is similar with I/O system.
  - Automaton is a common ground for both groups.
  - Internal model of the environment

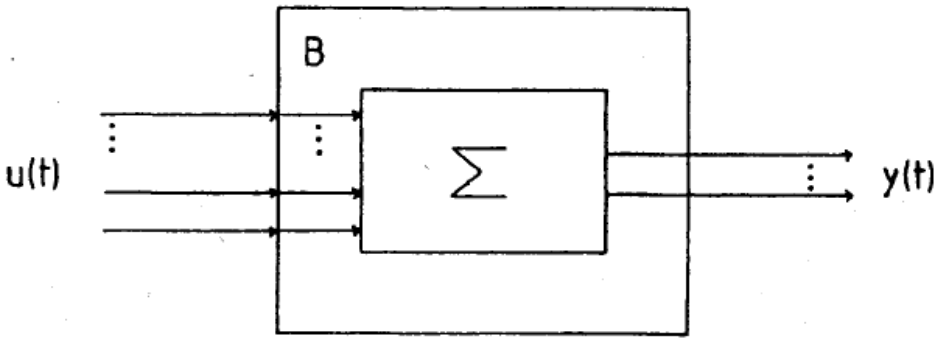



Figure 1.4. Behaviourism to cognition: are they equivalent?
**u(t)**: input, **y(t)**: output, **B**: input/output structure,
**Σ**: generative structure

# Pitfalls of Dynamical Models

- Evolution and Coevolution
  - Natural selection
  - External force induces a differential reproduction of genetic variants in the population
  - Coevolutionary theories (Csanyi, 1982; Csanyi and Kampis, 1985; Csanyi, 1988; Kampis and Casanyi, 1990) suggest that causes for evolution are internal to life (**autonomous**)

# Pitfalls of Dynamical Models

- **Evolution (Roughgarden, 1979)**

$$\frac{dG_i}{dt} = f(G, W), \qquad i = 1, \ldots, n, \qquad W = W(E)$$
$$\frac{dE_j}{dt} = g(E, q), \qquad j = 1, \ldots, m$$

  - G: a set of genetic variables
  - E: a set of environmental variables
  - W: fitness (Darwinian selection)
  - q: ecological parameters (who eats who)

# Pitfalls of Dynamical Models

- **Coevolution (Stenseth, 1988)**

$$\frac{dG_i}{dt} = h(G, q), \qquad i = 1, \ldots, n$$

  - G: a set of genetic variables
  - q: a vector of parameters
  - h: a function expressing the evolutionary ‘force’
  - ‘fitness’ is excluded, directly deals with inter-populational cross-effects
  - h(G,q) = f(G, $\hat{g}$(q))

# Pitfalls of Dynamical Models

- **Discussion**
  - Transformationalism: systems undergo changes because **their existing components undergo changes**
  - **Neo-darwinism is essentially transformational**.
  - Life is itself's own environment and own creator
  - Coevolution refers to this self-determined development and denies the independent pre-existence of evolutionary factors
  - Dynamic models based on the principles of neo-Darwinism, transformationalism.

# Conclusions

- One possible solution to model life and mind is a dynamical model, which can be instantiated with Turing machine.
- Behaviorism and cognitive science can be analyzed via dynamical models.
- Coevolution assumes interactions between agents and self-determined actions, which may uncover the limit of dynamical models.

Thank you!