Learning Automata
Chapter 1~1.2

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2016/10/06
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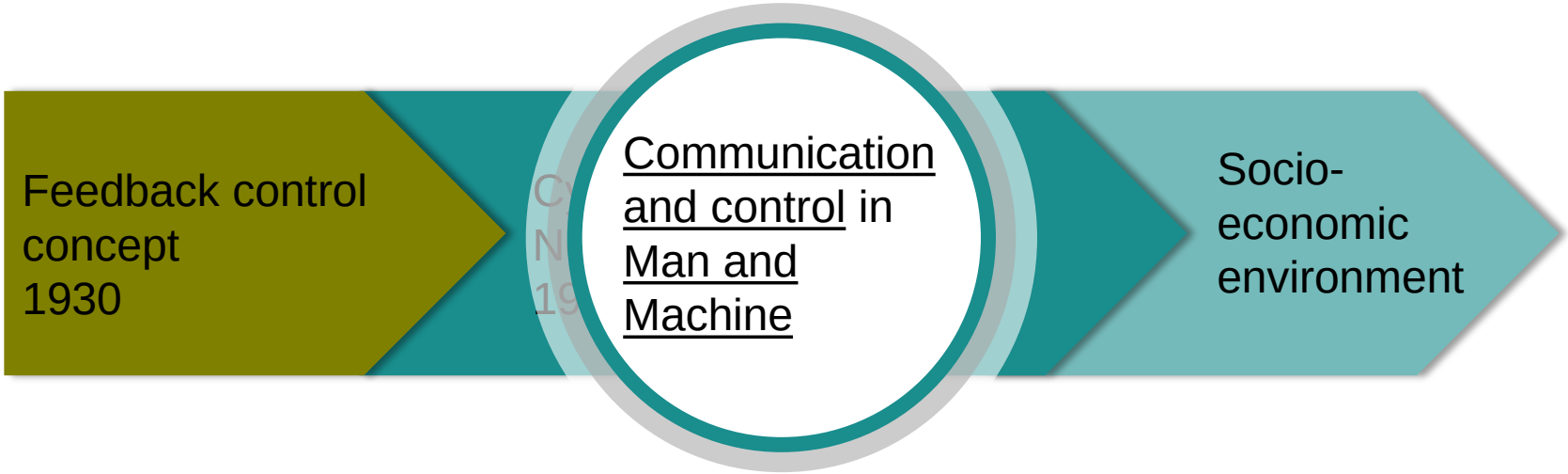
Contents

Introduction

- System theory



Introduction

- Systems Theory
  - The identification and control of well defined deterministic and stochastic systems
  - Interest gradually shifted to substantial amount of uncertainty
    - Adaptation
    - Learning
    - Pattern recognition
    - Self-organization
  - Deterministic and Stochastic approach

Introduction

- In more Complex Systems
  - Highly Uncertainty
  - Lack of parameter information
  - Hard to find dynamic relation
- Distributed processing
  - Due to distributed databases
    - Collecting, processing, accessing data
- Learning Automata
  - Input output searching under the influence of reinforcement feedback
  - Collective behavior of a number of automata operating in a distributed fashion can be described

Pattern recognition

Adaptive control

Self-organization

Learning

- Learning in Psychology
  - Empiricism
    - Experience is the only source of knowledge
    - All complex ideas are made up of simpler ideas
    - Complex ideas are connected together through the association of experience
  - Rationalism
    - The interrelations among elementary ideas are just as fundamental as the ideas themselves

Learning

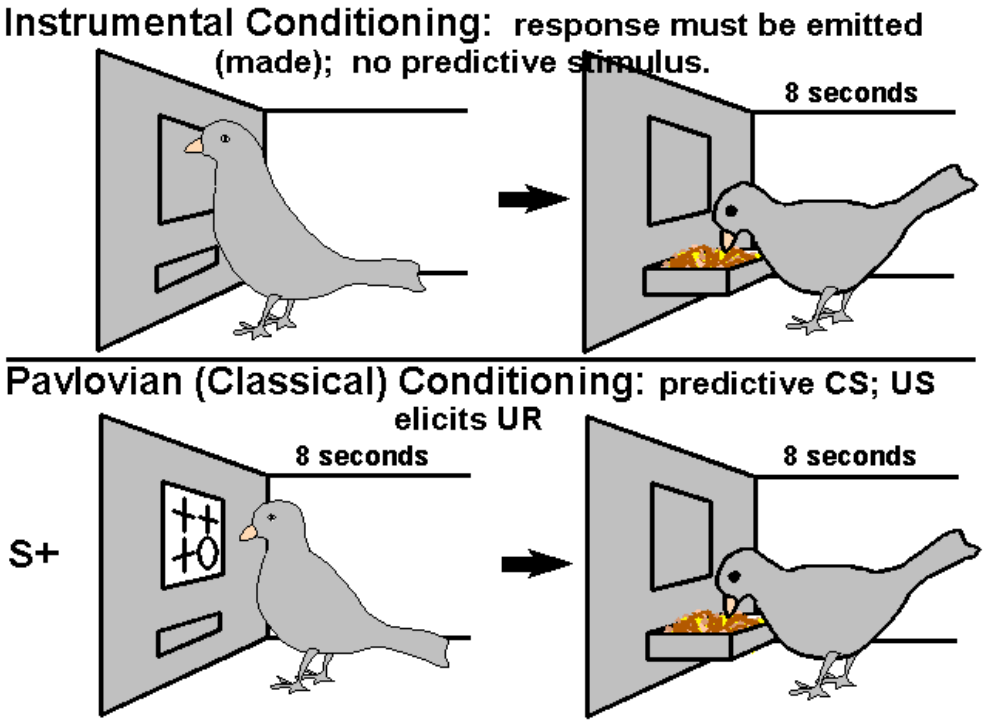
- Learning in Psychology
  - Stimulus-response theories
    - Importance of motivations, reward, punishment
    - Behaviorist
      - A detailed understanding of the internal workings of an organism is not necessary for developing a theory of behavior
  - Cognitive theories
    - Collection, transmission, storage, retrieval of information

Learning in Psychology

- Expectancy learning
- Classical learning
- Instrumental conditioning
- Operant conditioning

Learning in Psychology

- Expectancy conditioning → inductive inference
- Instrumental conditioning
- Classical conditioning



Learning in Psychology

- Expectancy conditioning → inductive inference
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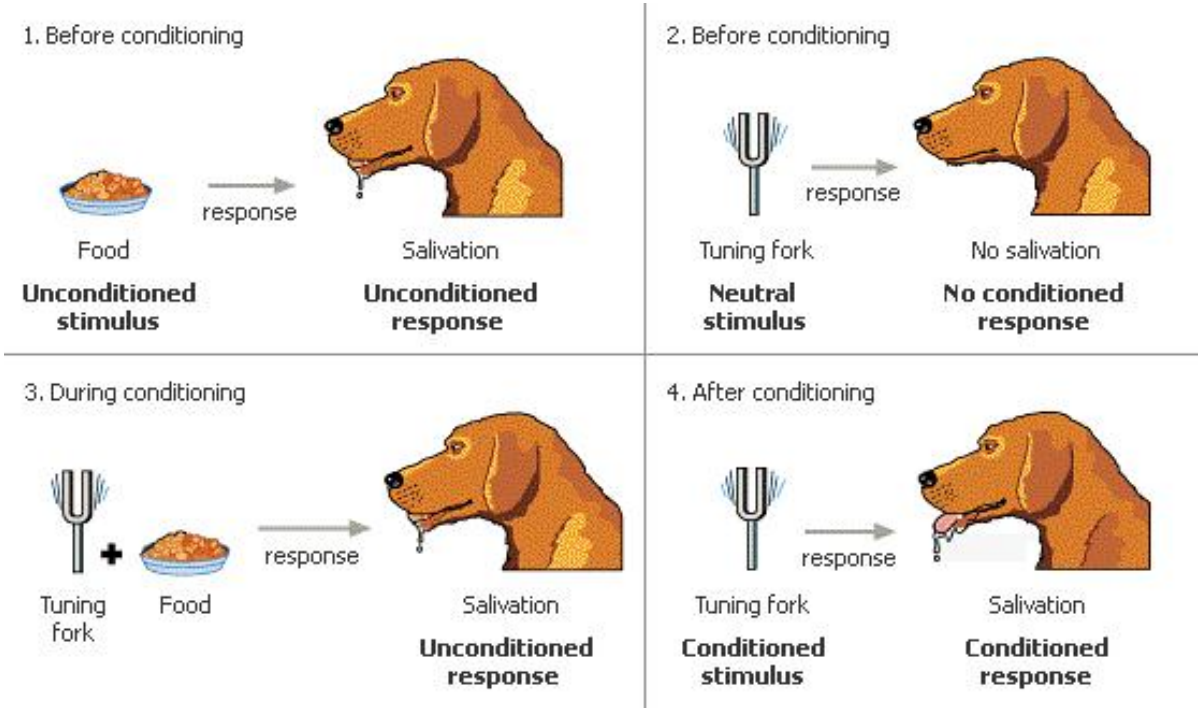
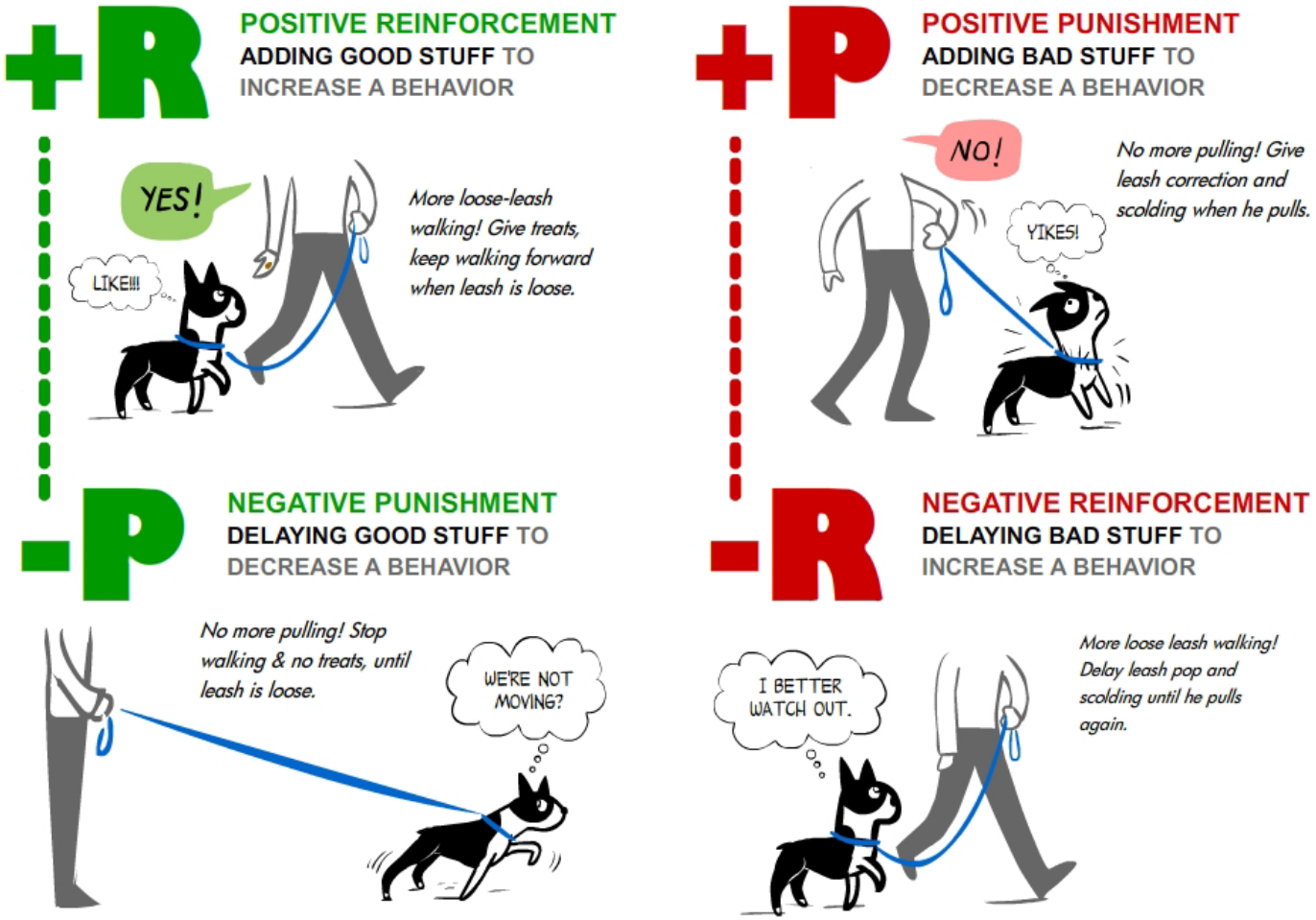


Learning in Psychology

- Operant conditioning



Mathematical Learning Theory

- Hull (1943)
  - Argued for the development of quantitative theories in learning
- Estes (1959)
  - The development of learning theory for individual organisms is an elaboration of association theory
  - Association theory
    - Complex stimulus and response patterns at higher levels of learning

Deterministic, Stochastic, and Adaptive Process

- Adaptive Control Processes - A Guided Tour

  (Bellman , 1961)

  - Deterministic
  - Stochastic
  - Adaptive Processes

Prior information

Less Prior information

Deterministic, Stochastic, and Adaptive Process

- Deterministic Processes
  - The controller is designed
  - To satisfy either a set of performance criteria
  - To optimize a given index of performance

  - The design of practical estimators and controllers may be difficult due to analytical and computational reasons

Deterministic, Stochastic, and Adaptive Process

- Stochastic Control Processes
  - Probability characteristic
  - Relevant distributions
  - Optimization of linear system with quadratic performance
  - The optimization problems as well as the numerical procedures used to solve them are same

    (deterministic process)

Deterministic, Stochastic, and Adaptive Process

- Adaptive Processes
  - Prior information is considerably less
    - Ex. economics, biology, engineering, psychology, operations research, and AI
  - So, information needed for their estimation by off-line experiment

E

- Evolutionary algorithm
- Evolutionary programming
- Expectation–maximization algorithm
- Extremal optimization

F

- Fernandez's method
- Fourier–Motzkin elimination
- Frank–Wolfe algorithm

G

- Gauss–Newton algorithm
- General Subpopulation Framework
- Generalized iterative scaling
- Genetic algorithm
- Genetic algorithms in economics
- Genetic improvement (computer science)
- Golden section search
- Gradient descent
- Gradient method
- Graduated optimization
- Great Deluge algorithm
- Greedy algorithm
    - CMA-ES
- Quasi-Newton inverse Least Squares Metho
- Quasi-Newton Least Squares Method
- Quasi-Newton method

R

- Random optimization
- Random search
- Revised simplex method
- Rosenbrock methods

S

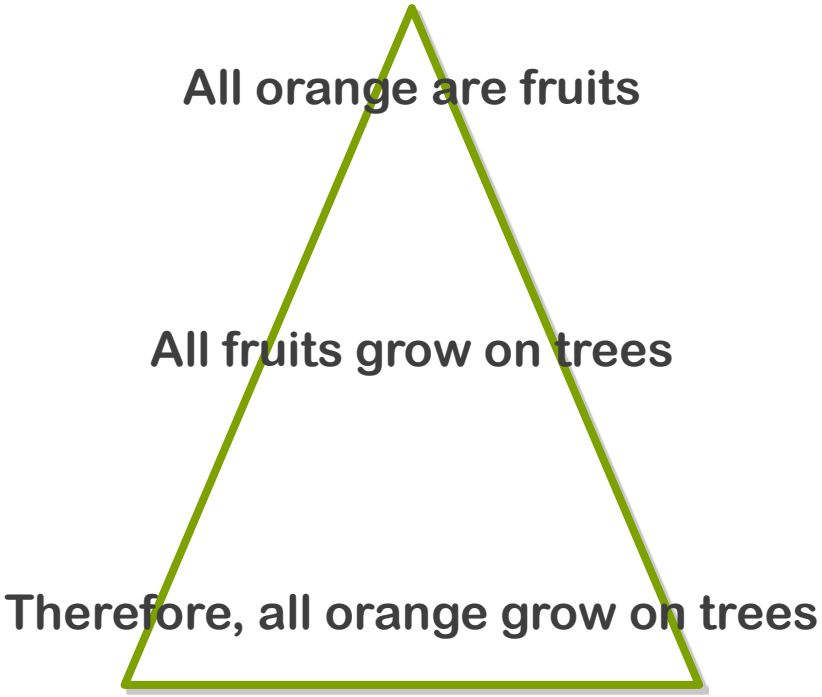
- Search-based software engineering
- Sequential minimal optimization
- Sequential quadratic programming
- Simplex algorithm
- Simulated annealing
- Simultaneous perturbation stochastic appro
- Social cognitive optimization
- Space allocation problem
- Space mapping
- Special ordered set
- Stochastic hill climbing
- Successive parabolic interpolation
- Symmetric rank-one

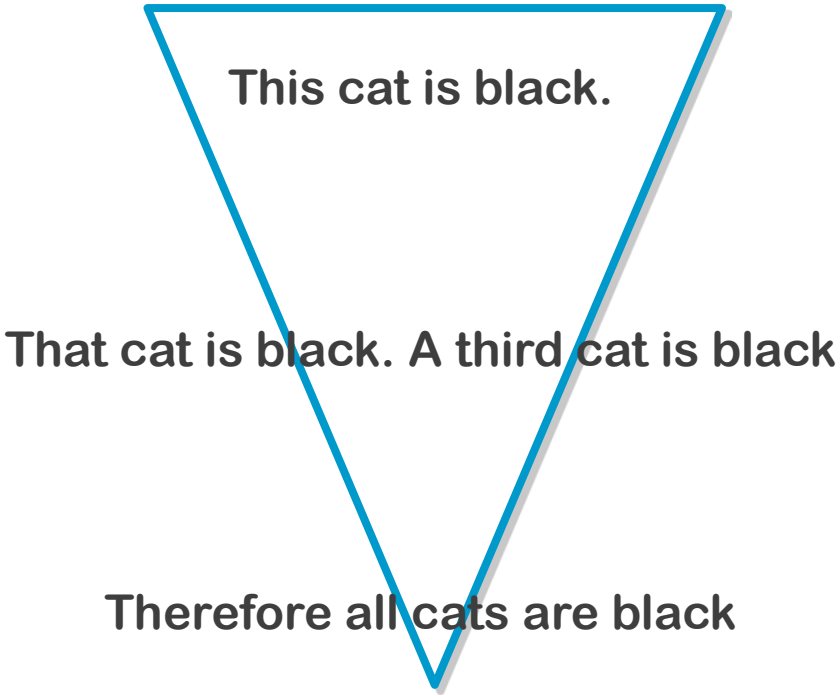
T

- Network simplex algorithm

Deductive and Inductive Inference

- Inference reasoning





Inductive and deductive inference do not contradict but merely complement each other and both are found to be essential for the learning.

Deductive and Inductive Inference

- Credibility and Induction
  - Inductive probability : “credibility”

    Measure of confidence we place in a hypothesis on the basis of observed data

$$q(H_i) \geq 0, \sum_i q(H_i) = 1$$

Identification and Control

- Identification vs Control
  - Decide better action in the future, or taking the best action on the basis of past experience
  - Feldbaum (1965) – Dual control problem

    Contains uncertainty
    - New inputs it has to improve its knowledge of the characteristics of the system
    - New knowledge, it has to determine what actions are necessary for successful control

Pattern Recognition

- Definition
  - Deals with the issue of building a machine or a program that will display some capability of living organisms for *classifying* or *discriminating* sensory signals
- Object
  - To sort patterns into different classes so that those patterns which belong to a class share some common properties
    - Medical diagnosis, speech recognition, and scene analysis

Pattern Recognition

- Pattern recognition process
  - Collect raw data
  - Raw data of the patterns is converted into n-dimensional feature vectors
    - Feature : contain the essential attributes of the given patterns
      - Preprocessing (Data Transformation, Smoothing, Normalize, Balancing etc)
      - Filtering (FFT, DWT, CWT, etc.),
      - Feature extraction(PCA)
      - Feature selection (ICA)
  - Classification

$$p(x|w^1) > p(x|w^2) \Rightarrow x \in w^1$$ X is the pattern, w is class

Pattern Recognition

- Limitation
  - Unknown parameters
  - Non linear separable case, complex pattern
    - Image, speech, natural language etc.

Bayesian Learning

- Frequentist vs Bayesian **(Degree of Belief)**
  - Frequentist
    - Parameters – quantities whose values are fixed but unknown
    - The best estimate of their values – the one that maximizes the probability of obtaining the observed samples
  - Bayesian
    - Parameters – random variables having some known prior distribution
    - Observation of the samples converts to a posterior density; revising our opinion about the true values of the parameters

Bayesian Learning

- Bayesian approach
  - Extract information regarding the unknown parameter θ from observation $x_1, x_2, x_3, \ldots, x_N$ on the system

Posterior

$$p(\theta|x_i) = \frac{p(x_i|\theta)p(\theta)}{p(x_i)}$$

The probability that the hypothesis $(\theta, parameter)$ is true given the evidence

Likelihood

The probability of getting this evidence if this hypothesis were true

Prior

The probability of θ being true, before gathering evidence

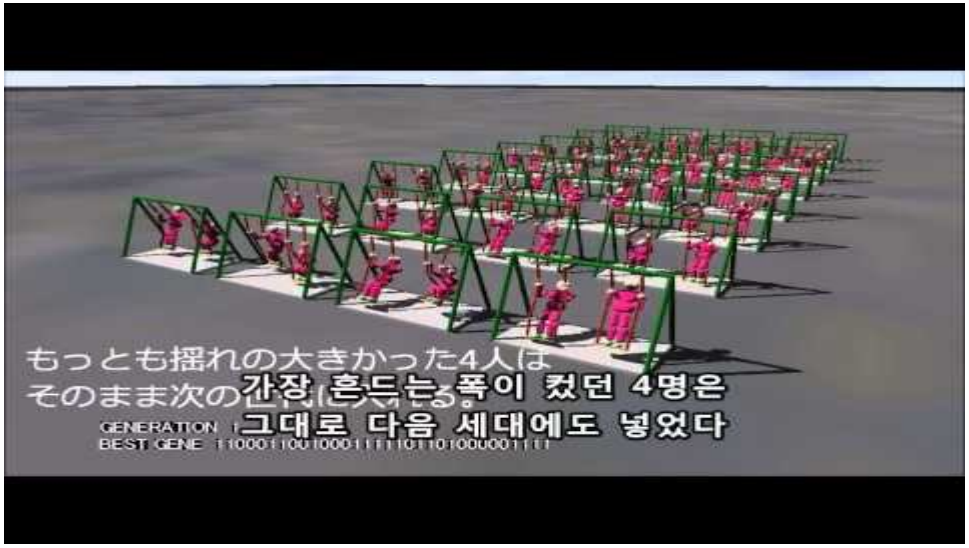
Evidence

The marginal probability of the evidence

Further discussion

Learning automata

- Example



Hill Climbing

- Optimization problems