Artificial Intelligence: An Introduction

Byoung-Tak Zhang

School of Computer Science and Engineering
Seoul National University

E-mail: btzhang@cse.snu.ac.kr
http://bi.snu.ac.kr/

Can Machines Think?

The Turing Test

Computing Machinery and Intelligence [Turing, 1950]
Chess Playing

Garry Kasparov and Deep Blue. © 1997

화성탐사 로봇 소저너
자연 언어 처리

- 다의성 (Polysemy)
  - I keep the money in the bank.
  - I walk along the bank of the river.

- 중의성 (Ambiguity)
  - Time flies like an arrow.
  - I saw a man with a telescope.

- 다양성 (Diversity)
  - She sold him a book for five dollars.
  - He bought a book for five dollars from her.

- 관련 지식
  - 어휘적 지식, 문법적 지식, 상황, 문맥 지식

전문가 시스템

Figure 18-2 An expert system on the job. The expert system helps find mechanical and fix engine problems.
History of AI

- Early enthusiasm (1950’s & 1960’s)
  - Turing test (1950)
  - 1956 Dartmouth conference
  - Emphasis on intelligent general problem solving
- Emphasis on knowledge (1970’s)
  - Domain specific knowledge
  - DENDRAL, MYCIN
- AI became an industry (late 1970’s & 1980’s)
  - Knowledge-based systems or expert systems
  - Wide applications in various domains
- Searching for alternative paradigms (late 1980’s - early 1990’s)
  - AI’s Winter: limitations of symbolic/logical approaches
  - New paradigms: neural networks, fuzzy logic, genetic algorithms, artificial life
- Resurge of AI (mid 1990’s – present)
  - Internet, Information retrieval, data mining, bioinformatics
  - Intelligent agents, autonomous robots
- Recent trends:
  - Probabilistic computation
  - Biological bases of intelligence
  - Brain research, cognitive science
Artificial Intelligence (AI)

Symbolic AI
Rule-Based Systems

Connectionist AI
Neural Networks

Evolutionary AI
Genetic Algorithms

Molecular AI:
DNA Computing

Research Areas and Approaches

Artificial Intelligence

Research

Application

Paradigm

Learning Algorithms
Inference Mechanisms
Knowledge Representation
Intelligent System Architecture

Intelligent Agents
Information Retrieval
Electronic Commerce
Data Mining
Bioinformatics
Natural Language Proc.
Expert Systems

Rationalism (Logical)
Empiricism (Statistical)
Connectionism (Neural)
Evolutionary (Genetic)
Biological (Molecular)
Applications of Intelligent Agents (1)

- E-mail Agents
  - Beyond Mail, Lotus Notes, Maxims
- Scheduling Agents
  - ContactFinder
- Desktop Agents
  - Office 2000 Help, Open Sesame
- Web-Browsing Assistants
  - WebWatcher, Letizia
- Information Filtering Agents
  - Amalthea, Jester, InfoFinders, Remembrance agent, PHOAKS, SiteSeer
Applications of Intelligent Agents (2)

- News-service Agents
  - NewsHound, GroupLens, FireFly, Fab, ReferralWeb, NewT
- Comparison Shopping Agents
  - Mysimon, BargainFinder, Bazzar, Shopbor, Fido
- Brokering Agents
  - PersonalLogic, Barnes, Kasbah, Jango, Yenta
- Auction Agents
  - AuctionBot, AuctionWeb
- Negotiation Agents
  - DataDetector, T@T

Computers Meet Biosciences

Bioinformation Technology (BIT)
AI in Life Sciences

Sequence analysis
- Sequence alignment
- Structure and function prediction
- Gene finding

Structure analysis
- Protein structure comparison
- Protein structure prediction
- RNA structure modeling

Expression analysis
- Gene expression analysis
- Gene clustering

Pathway analysis
- Metabolic pathway
- Regulatory networks

Evolutionary Computation:
Nature as Computer

“Owing to this struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring.”

Origin of Species “Charles Darwin (1859)"
Genetic Algorithms

- **Encoding**
  - Chromosomes
  - Solutions
- **Selection**
  - Roulette wheel
- **Evaluation**
  - Fitness computation
- **Crossover**
  - Solutions
- **Mutation**
  - New population

Application Example 1

**Hot Water Flashing Nozzle (1)**

- **Start**
  - Hot water entering
- **Hans-Paul Schwefel** performed the original experiments
- **Steam and droplet at exit**
- **At throat: Mach 1 and onset of flashing**
Application Example 3

Concrete Shell Roof

under own and outer load (snow and wind)

Spherical shape

Height 1.34m

Optimal shape

Half span 5.00m

max $|\mathbf{m}| \rightarrow$ min Orthogonal bending strength

Savings: 36% shell thickness
27% armation

Application Example 13

Cooperating Robots (3)

Cooperating Autonomous Robots
At RoboCup there are two "leagues": the "real" robot league and the "virtual" softbot league

How do you do this with GP?

- GP breeding strategies: homogeneous and heterogeneous
- Decision of the basic set of function with which to evolve players
- Creation of an evaluation environment for our GP individuals

Co-evolving Soccer Softbots (2)

- Initial Random Population
Application Example 14
Co-evolving Soccer Softbots (3)

- Kiddie Soccer

Application Example 14
Co-evolving Soccer Softbots (4)

- Learning to Block the Goal
Application Example 14
Co-evolving Soccer Softbots (5)

- Becoming Territorial

1000-Pentium Beowulf-Style Cluster Computer for Parallel GP
Von Neumann’s *The Computer and the Brain* (1958)
The Computer and the Brain

- Less than 1 million processors (10^{-9} sec each, neuron: 10^{-3} sec)
- Central processing
- Arithmetic operation (linearity)
- Sequential processing
- Silicon-based (dry)

- 10 billion neurons (100 trillion synapses)
- Distributed processing
- Nonlinear processing
- Parallel processing
- Carbon-based (wet)

From Biological Neurons to Artificial Neurons
Multilayer Perceptron (MLP)

- **Activation Function**
- **Scaling Function**
- **Output Comparison**
- **Information Propagation**
- **Error Backpropagation**

$$w_i' \leftarrow w_i + \Delta w_i, \quad \Delta w_i = -\eta \frac{\partial E}{\partial w_i}$$

$$E_d(w) \equiv \frac{1}{2} \sum_{k=outputs} (t_k - o_k)^2$$

Application Example: Autonomous Land Vehicle (ALV)

- NN learns to steer an autonomous vehicle.
- 960 input units, 4 hidden units, 30 output units
- Driving at speeds up to 70 miles per hour
Neural Nets for Face Recognition

A 960 x 3 x 4 network is trained on gray-level images of faces to predict whether a person is looking to their left, right, ahead, or up.

Humans and Computers

The Entire Problem Space

Human Computers

Current Computers

What Kind of Computers?
What is the information processing principle underlying human intelligence?
Molecular Basis of Learning and Memory in the Brain

1. Strong stimulation depolarizes the cell membrane.
2. Depolarization causes the cell to fire an action potential.
4. Calcium ions enter the cell, activating CREB.
5. CREB activates the genes for synapse strengthening proteins.
6. The proteins diffuse throughout the cell, affecting only the synapses that are temporarily strengthened.

Principles of Information Processing in the Brain

- **The Principle of Uncertainty**
  - Precision vs. prediction
- **The Principle of Nonseparability**
  - Processor vs. memory
- **The Principle of Infinity**
  - Limited matter vs. unbounded memory
- **The Principle of “Big Numbers Count”**
  - Hyperinteraction of $10^{11}$ neurons (or > $10^{17}$ molecules)
- **The Principle of “Matter Matters”**
  - Material basis of “consciousness” [Zhang, 2005]
Unconventional Computing

- Quantum Computing
  - Atoms
  - Superposition, quantum entanglements
- Chemical Computing
  - Chemicals
  - Reaction-diffusion computing
- Molecular Computing
  - Molecules
  - "Self-organizing hardware"

Molecular Computing: BioMolecules as Computer

011001101010001
ATGCTCGAAGCT
DNA Molecules for Information Storage and Processing

Writing: make DNA sequences

Reading: hybridization and readout

Bio-Lab Procedure

1. Sequence Design and Synthesis
2. Hybridization
3. Ligation
4. Learning (Affinity Separation)
5. Classification
Benchmark Problem: Digit Images

- 8x8 = 64 bit images (made from 64x64 scanned gray images)
- Training set: 3823 images
- Test set: 1797 images
Pattern Information Processing

Effect of Memory-Chunk Size

The diagrams show the effect of memory-chunk size on the classification rate and average error (number of mismatches) with varying corruption intensity. The classifications include Order 1, Order 2, Cardinality 2, Cardinality 3, and Cardinality 4. The graphs illustrate how these metrics change with different chunk sizes and corruption intensities.
Effect of the Error Tolerance Level

- Correlation intensity
- Average error (# of mismatches)
- \( \tau_0 \), \( \tau_1 \), \( \tau_2 \), \( \tau_3 \), \( \tau_4 \)

Biological Application

- 120 samples from 60 leukemia patients
- Gene expression data
- Class: ALL/AML
- Training with 6-fold validation
- Diagnosis

Da Vinci’s Dream of Flying Machines

Engines of Flight

- Piston Engine
- Jet Engine
- Rocket Engine
Turing’s Dream of Intelligent Machines

Alan Turing
(1912-1954)

Computing Machinery and Intelligence (1950)

Computers and Intelligence
Future Technology Enablers

- True neural computing
- Bio-electric computers
- 1e6-1e7 x lower power for lifetime batteries
- Quantum computers, molecular electronics
- Smart lab-on-chip, plastic printed ICs, self-assembly
- Vertical/3D CMOS, Micro-wireless nets, integrated optics
- Wearable communications, wireless remote medicine, hardware over internet!
- Pervasive voice recognition, “smart” transportation
- Metal gates, Hi-k/metal oxides, Lo-k with Cu, SOI
- Full motion mobile video/office

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- Connectionist AI: Neural Networks
- Evolutionary AI: Genetic Algorithms
- Molecular AI: DNA Computing