Chapter 1
Evolving Processes and Evolving Connectionist Systems

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Overview

- Evolving Processes
- Working classification scheme for connectionist learning systems
- Artificial Intelligence (AI) vs. Emerging Intelligence (EI)
- Introduction to ECOS

Evolving Process

- Process that is “revealing, developing” (Oxford English Dictionary, 1983);
- Process that is developing over time in a continuous manner
- Process that may interact with other processes in its environment
- Difficult to model due to:
  - » Unknown parameters
  - » Unexpected changes during development
- Most obvious example – LIFE.

Evolving Processes

5. Evolutionary development
Function examples: genome evolution, creation of new individuals and species

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4. Brain level
Function examples: *cognition, speech and language, consciousness*

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3. Neural network level
Function examples: *sound perception, signal processing*

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2. Whole cell, neuronal level
Function examples**:** *neuron activation*

1**. Molecular level**
Function examples: DNA translation into RNA, RNA and gene transcription into proteins

Five levels of evolving processes in a higher order living organism (Fig 1.1)

Working Classification Scheme for Learning in Connectionist Systems

- Most NN training algorithms are influenced by a model where the weight increases when the source and destination neurons are activated.
- Connectionist System Components {S,W,P,F,L,J}
  - S – structure
  - W – weight
  - P – parameter
  - F – function
  - L – learning procedure
  - J – goal function
- Through learning, system improves its reaction to observed events and captures information that may later be represented as knowledge

Classification Scheme for connectionist learning models

(1) What space has the learning system developed in?

(a) (a)The learning system has developed in the original data space Z

(b) The learning system has developed in its own machine space M

(2) Is the space open?

(a) An open data space

(b) A closed space that has a fixed dimensionality

(3) Is learning on-line?

(a) Batch-mode, off-line learning

(b) On-line, pattern mode, incremental learning

(c) Combined on-line and off-line learning

(4) Is learning life-long?

(a) Single session learning

(b) Life-long learning

Classification scheme…

(5) Are there desired output data and in what form?

- (a) Unsupervised learning
- (b) Supervised learning
- (c) Reinforcement learning
- (d) Combined learning

(6) Is evolution of populations of individuals involved in the learning process?

- (a) Individual, development-based learning
- (b) Evolutionary learning, (population-based learning over generations)
- (c) © Combined

(7) Is the structure of the learning system of a fixed size, or it is evolving?

- (a) Fixed- size structure
- (b) Dynamically changing structure

(8) How structural modifications in the learning system partition the problem space?

- (a) Global partitioning (global learning)
- (b) Local partitioning (local learning)

Classification Scheme…

(9) What knowledge representation is facilitated in the learning system?

(a) No explicit knowledge representation is facilitated in the system

(b) Memory-based knowledge

(c) Statistical knowledge

(d) Analytical knowledge

(e) Symbolic knowledge

(f) Combined knowledge

(g)Meta-knowledge

(h) “Consciousness” (the system knows about itself)

(i) “Creativity” (e.g., generating new knowledge)

……

(12) Is learning active?

(a) Active learning in terms of data selection, filtering and searching for relevant data;

(b) Passive learning – the system accepts all incoming data

Major Problems with Learning Systems

- Systems – NNs, fuzzy systems, GA, hybrid systems
- Difficult to pre-select architecture
- Catastrophic forgetting
- Excessive training time required
- Lack of knowledge representation facilities

=> New connectionist and hybrid methods are required for learning algorithms and system development

Intelligence

- Constant/continuous adaptation
- “the faculty of adapting oneself to the circumstances” (Newell & Simon, 1972)
- “the human capacity to acquire knowledge, to acquire a set of adaptations and to achieve adaptation” (Plotkyn, 1994)
- Characteristics – knowledge representation, concept formation, reasoning and adaptation
- Implementing intelligence in a computer model – main objective of AI

Artificial Intelligence

- Soft definition – Development of methods, tools, techniques and systems to enable computer modelling of intelligence
- Hard definition (by A.Turing) – AI test is to implement natural language communication in a computer model (to be indistinguishable from human communication)
- Not yet fully achieved

Emerging Intelligence

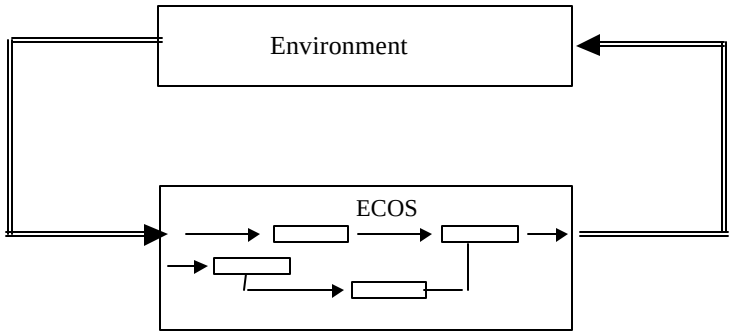
- Subset of AI
- Enabling of systems to “understand” dynamics of intelligence process by extracting “rules”
- A feature of an information system that develops its structure and functionality in a continuous, self-organised, adaptive and interactive way from incoming information possibly from many sources, and performs intelligent tasks typical of humans; the systems acquires intelligence.
- EI represented in this presentation as ECOS and their applications

Introduction to ECOS

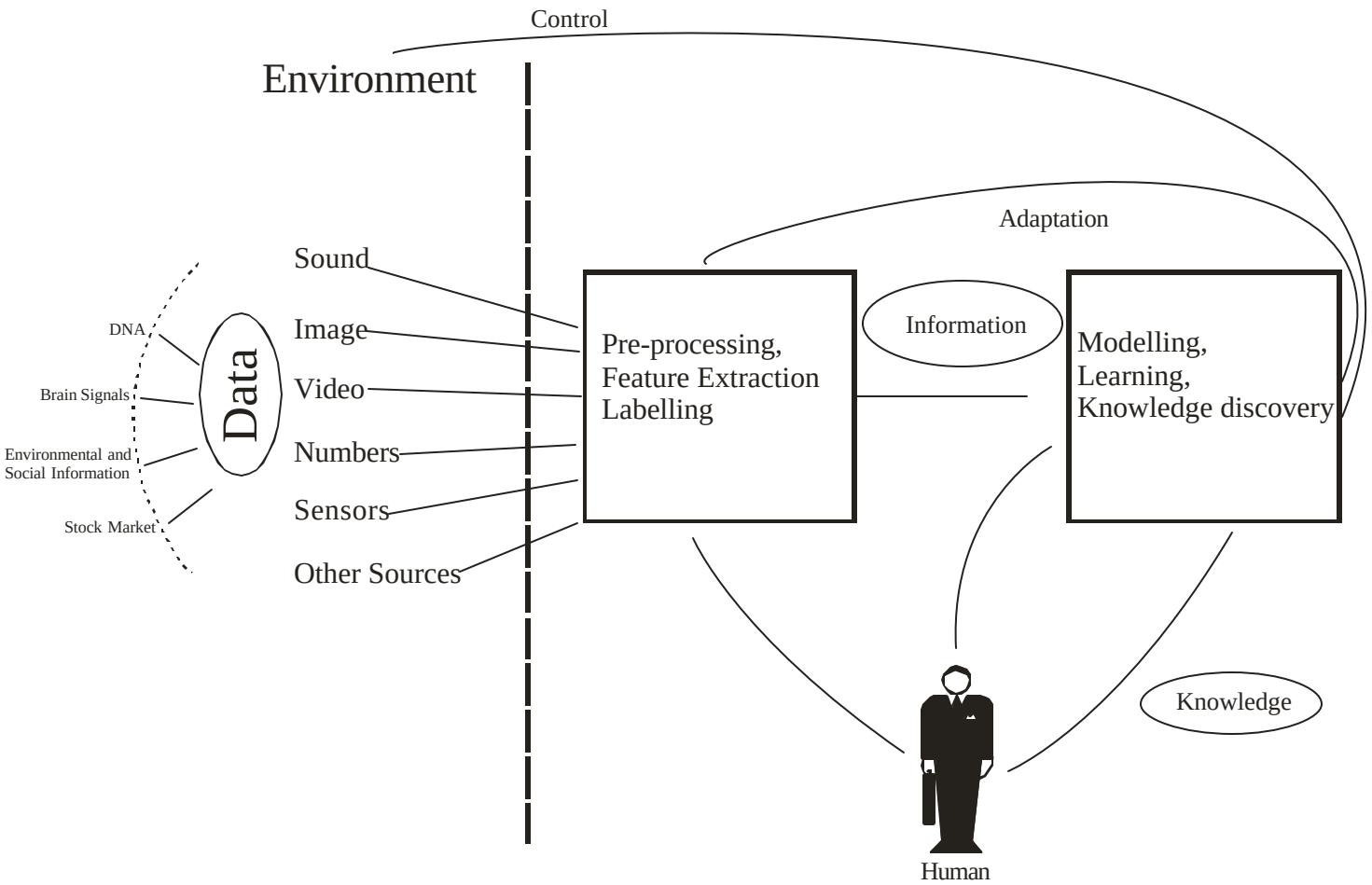
- Multi-modular connectionist architectures that facilitate modelling of evolving processes and knowledge discovery.
- Parts – data acquisition, pre-processing and feature evaluation, connectionist modelling, knowledge acquisition
- A NN that operates continuously in time and adapts its structure and functionality through a continuous interaction with the environment and other systems.
- Methods of learning in ECOS – on-line, adaptive, life-long, supervised/unsupervised, prototype-based, knowledge-based, and more…

ECOS Characteristics

- Evolve in an open space
- Learn in an on-line mode
- Learn in a life-long mode
- Learn as an individual and as evolutionary population systems
- Have evolving structures
- Learn and partition space locally
- Facilitate different types of knowledge (memory-based, statistical and symbolic)



ECOS


Control
Environment
Adaptation
DNA
Brain Signals
Environmental and
Social Information
Stock Market
Data
Sound
Image
Video
Numbers
Sensors
Other Sources
Pre-processing,
Feature Extraction
Labelling
Information
Modelling,
Learning,
Knowledge discovery
Knowledge
Human

Summary

- Modelling evolving processes is a difficult task
- Most existing techniques may not be appropriate to model evolving processes.
- Variety of methods need to be developed to be applied to a number of challenging real-world applications

Further Reading

- The Nature of Knowledge (Plotkyn, 1994).
- Cognition and Categorization (Rosch and Lloyd, 1978).
- Emergence and evolutionary processes (Holland, 1998).
- Alan Turing's test for AI (see Hoffstadter, 1978 and Fogel, 2002).
- Introduction to the principles of artificial neural networks (Amari, 1967, 1977, 1990; Arbib, 1972, 87,95, 2002; Werbos, P. 1990; Hertz et al, 1991; Rumelhart et al, 1986; Haykin, 1994; Bishop,1995; Hassoun, 1995; Aleksander, 1989; Aleksander and Morton, 1990; Zurada, 1992; Hech-Nilesen, 1987; Hopfield, 1922; Kasabov, 1996; Feldman, 1989).
- Principles and classification of on-line learning connectionist models (Murata et al, 1997; Saad, 1999).
- NN and MLP for data analysis (Gallinari et al, 1988).
- Emerging intelligence (EI) (Fogel, 2002).
- Integrating NN with AI and expert systems (Touretzky and Hinton, 1985 and 1988; Hinton, 1990; Kasabov, 1990; Hendler and Dickens, 1991; Barnden and Shrinivas, 1991; Giacometti et al, 1992; Medsker, 1994; Morasso et al, 1992; Towel and Shavlik, 1993, 1994; Tresp et al, 1995).
- Integrating NN with fuzzy logic (Yamakawa et al, 1989; Takagi, 1990; Hayashi, 1991; Kosko,1992; Furuhashi et al, 1993; Kasabov, 1996).
- Evolving connectionist systems as evolving intelligence (Kasabov, 1998-2001).