Intelligent Systems: Reasoning and Recognition

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Intelligence, Knowledge, Reasoning and Recognition

Outline

Class notes on the web :

http://www-prima.inrialpes.fr/Prima/Homepages/jlc/Courses/2010/ENSI2.SIRR/ENSI2.SIRR.html

Intelligence, Knowledge and Reasoning

What do we mean by Intelligence?

INTELLIGENCE :

(Petit Robert) "La faculté de connaître et comprendre,
incluant la perception, l'apprentissage, l'intuition, le jugement et la conception."

(Dictionnaire American Heritage) "The ability to know and to reason"

In this course we are concerned with technologies for Knowledge, Reason and Understanding.

The term "Artificial Intelligence" emerged from a pioneering workshop at Dartmouth University in 1956. Pioneers attending this workshop included Alan Newell, Herb Simon, John McCarthy, Marvin Minsky, Nils Nilsson, and Ed Feigenbaum.

Intelligence as the Ability to Solve Problems

A. Newell and H. Simon defined Intelligence as the Application of Knowledge to Problem Solving"

Newell, A.; Shaw, J.C.; Simon, H.A. (1959). Report on a general problem-solving program. *Proceedings of the International Conference on Information Processing*. pp. 256-264.

Nilsson: STRIPS, A* GraphSearch
R. Fikes and N. Nilsson (1971), "STRIPS: A new approach to the application of theorem proving to problem solving", Artificial Intelligence 2: 189–208

This view allows us to define knowledge and reasoning.

What is Knowledge?

What is knowledge? - Competence
Whatever enables the solution of problems.

Knowledge is defined by function and not by representation.

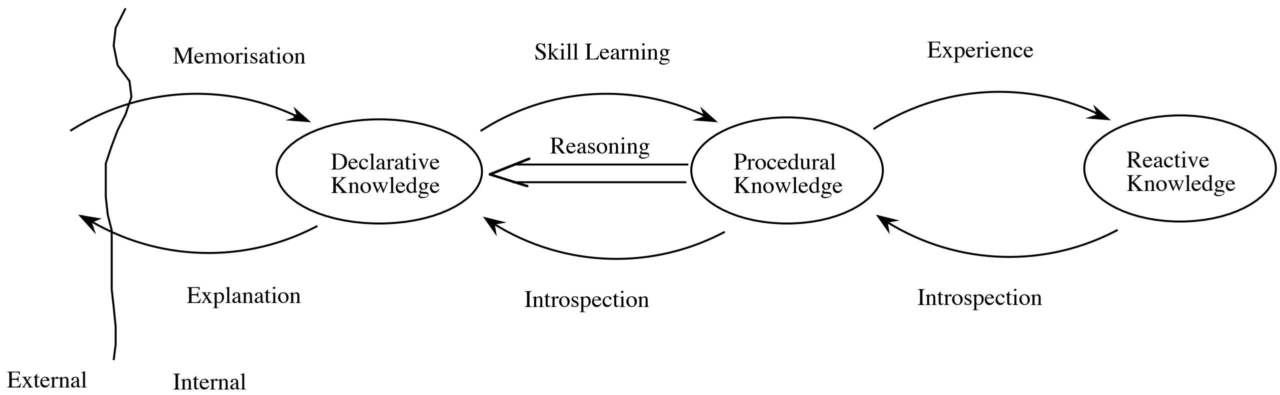
Kinds of Knowledge

Cognitive Psychologists identify different categories of knowledge:

Declarative: A symbolic expression of competence.
Declarative knowledge is abstract
Declarative knowledge is used to communicate and to reason.

Procedural: A series of steps to solve a problem.
A compiled expression of knowledge

Reactive: stimulus - response.



Newell proposes the distinction between "superficial" knowledge and "deep" knowledge.

Superficial knowledge provides reasoning without understanding. A common example of **superficial** reasoning is reasoning by symbol manipulation, without regard to the meaning of the symbols.

Deep knowledge requires the ability to predict and explain, and requires some form of model.

What is Reasoning?

Generation of new knowledge by inference.
Examples of types of inference:

Deduction : $(p \wedge (p \rightarrow q)) \Rightarrow (q)$
Abduction : $(q \wedge (p \rightarrow q)) \Rightarrow \text{Maybe}(p)$
Induction: $p(A) \rightarrow q,\ p(B) \rightarrow q,\ \ldots \Rightarrow \forall x\ (p(x) \rightarrow q)$

The Physical Symbol System hypothesis

In 1980, Alan Newell proposed that Intelligence REQUIRED the manipulation of symbols by a physical system. Newell's was based on a linguistic view of intelligence dating back to the 19th century.

What is a symbol?
A symbol is a 3rd order relation between
    A sign
    A thing
    An interpreter

There are two problems with Newell's hypothesis
1) It confuses "What intelligence is" with "How intelligence is achieved".
Newell claimed that only symbol manipulation system could be intelligent.
2) It restricts intelligence to symbol manipulation. Intelligence is more general.

Expert Systems

In 1980, the commercial successes of expert systems brought a great interest in Artificial Intelligence. In the early 1980, AI was presented as the future of informatics.

For expert systems technology, reasoning is accomplished by manipulation symbols.

The technologies for "Expert Systems" are based on symbol manipulation, without regard for the meaning of the symbols. Thus Expert Systems are based on superficial knowledge.

The knowledge acquisition barrier

While Expert Systems technologies provide useful solutions for many applications, there is a fundamental problem: Hand-crafting a knowledge base is generally a very expensive and difficult process.

By the late 1980's this led to a strong growth in interest in machine learning techniques for knowledge acquisition.

Machine Learning for Recognition

Historical Roots

Symbolic Learning vs Statistical Learning

In the 1990s, there were TWO machine learning communities:
Symbolic learning and Statistical learning.

The Symbolic Learning community attempted to program methods to manipulate declarative knowledge representation to infer new knowledge

Probability, Statistics, and Bayesian Methods.

While pattern analysis has long been a part of probability and statistics, Pattern Recognition has emerged as an engineering discipline in the 1950s, as part of the overall trend to automated machinery.

While pattern recognition was initially concerned with hand-crafting recognition machines, the availability of programmable computers raised interest in automatic algorithms for learning for recognition.

In the early 1960's, Rosenblatt demonstrated the Perceptron learning machine [Rosenblat 62], with an implementation as a large analog computer. Nilsson, among others, published a treatise on learning machines [Nilsson 65] grounded on Bayesian probability theory.

The textbook by Duda and Hart summarized the state of the art [Duda-Hart 73] in Bayesian pattern recognition in a remarkably modern and accessible form. While Minsky and Papert's critique of perceptrons [Minsky 69] led the field of machine learning away from probabilistic approaches in favor of linguistic approaches based in Boolean logic, lack of progress on symbolic learning in the 1980s and 1990s eventually renewed interest in Bayesian probabilistic methods.

Connectionist movement

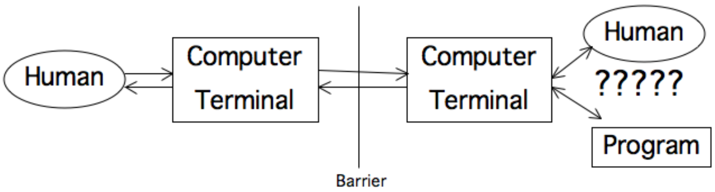
In the 1980's, Rummelhart, Hinton, McClelland and other [Rummelhart 86a] led a counter movement leading to the emergence of Neural Networks as an alternative approach to machine learning. Initial successes with the use of back-propagation for learning two layer neural networks [Rumelhart 86b], led to increasing attention and attempts at mathematical formulation. Bayesian approaches have gradually supplanted non-linear neural networks, both because of the tractability of formal analysis, and the consistently superior results in performance evaluation experiments. Vapnik's proposal for Support Vector Machines [Vapnik 98], and the emergence of Kernel methods [Poser 92], let to a rise in interest to high dimensional feature spaces, yielding solutions to a variety of previously intractable problems in learning and recognition [Shawe-Taylor 04].

Chris Bishop's 2006 textboook [Bishop 06] provides an authoritative review of modern approach pattern recognition and machine learning. Combined with access to the massive amounts of data available on the internet, such methods provide powerful tool for building systems that learn.

While current machine learning is focused on recognition, a more generally class of learning problems is receiving increasing attention in robotics: The problem of learning for interaction. On-line learning of actions and interactions is fundamental to human centered systems and services.

Intelligence as a Description of Behaviour

The Turing Test: an imitation game



In 1936, Alan Turing claimed that a machine would exhibit intelligence if it exhibited behaviour that could not be distinguished from a person.

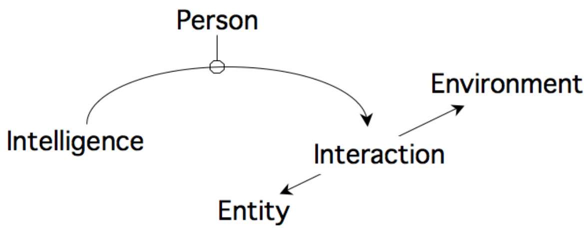
Limits: 1) Assumes that only humans are intelligent
2) Reduced intelligence to human linguistic interaction

Turing posed the problem in terms of linguistic and social interaction, ignoring many other forms of intelligence.

However, Turing gave an important insight: Intelligence is NOT an intrinsic property of an agent. Intelligence is a "DESCRIPTION".

Modern View of Intelligence

In the 1990's, research in robotics and perception, combined with insights from Cognitive science to bring about a new view of intelligence as a description of interaction.



Intelligence <u>describes</u> the <u>interaction</u> of an <u>entity</u> with its <u>environment</u>.*
Intelligence is a <u>description</u> (an ascribed property)
Intelligence describes an <u>entity</u> that <u>interacts</u>.

To be considered "intelligent", a system must be embodied, autonomous, and situated [Breazeal 02], [Brooks 94].

Embodied: Possessing a body (sensory/motor components)

Autonomous: Self-governing;
Have independent existence
Situated: Behaviour determined by the environment

[Breazeal 02] C. Breazeal, Designing Sociable Robots, MIT Press, 2002.
[Steels and Brooks 94] L. Steels, and R. Brooks, The artificial life route to artificial intelligence: Building Situated Embodied Agents. New Haven: Lawrence Erlbaum Ass., 1994.

Embodied: Incarnated. Possessing a body.

Body: A sensori-motor system for tightly coupled interaction with an environment.

Examples of Bodies:
Natural: Human, mammal, insects, bacteria, plants,
Artificial: Humanoid Robot, AIBO, mobile robots, roomba?

Environment: A system composed of multiple interacting entities.

Examples of Environments:
Natural: Jungle, desert, sea floor….
Artificial: Office, home, family, social network, computer games…
Abstract: Chess, mathematics, any academic discipline…

What does it mean to Understand?

Understanding can be described as the ability to predict and explain. Understanding typically relies on some form of model that can be used to predict the outcome of a process or phenomena. Decomposing the model into components and interactions between components provides a means to explain a process or phenomena.

Course Overview

Part 1 – Reasoning

1) Expert Systems
2) Planning
3) Rule Based Systems
4) Structured Knowledge Representations

Part 2 – Recognition

1) Bayes Rule
2) Non-parametric methods
3) Quadratic Recognition
4) Linear Discrimination

Programming exercise: Using CLIPS. – C Language Integrated Production Systems.

Exercises are NOT graded.
Feedback and corrections will be provided for COMPLETED exercises.
Completed exercises should be COPIED INTO AN EMAIL including the names of all persons who contributed to the solution. Feedback will be returned by email. Please allow at least 2 weeks for feedback.
Note: DO NOT Send a file named file.clips or Exerise.clips, etc.