INTRODUCTION
What is Artificial Intelligence?
Historical Overview

Cse537

Lecture Notes (1)

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Introduction

- AI is a broad field. It means different things to different people.
- AI is concerned with getting computers to do tasks that require human intelligence.
  - Example 1 : Complex Arithmetic −Computers can do this very easily.
  - Example 2: Recognizing a face − People do easily, but it **<u>was (historically!)</u>** very difficult to automate.

Definition Attempt

- AI is concerned with difficult tasks, which require complex and sophisticated reasoning process and knowledge

Why to automate Human Intelligence?

(and to which degree is it possible?)

Why to automate Human Intelligence ?

- Reason 1: To understand human intelligence better: We may be able to test and refine theories of Human Intelligence by writing programs which attempt to **simulate** aspects of human behavior

- Reason 2: To have smarter programs and machines; by studying human reasoning we may develop useful techniques for solving difficult problems

Science Fiction

Science Fiction Human-like Robots -

whether such a **goal** is possible

or even desirable − belongs to science fiction

But it **does have impact** on the practical work and research towards developing **better models** of human reasoning

The progress in modern day ROBOTICS

and its scope is **very interesting – even fascinating**

AI as a branch of Science and Engineering

- AI – for us is a **technical subject**; we put emphasis on computational techniques and **less** on psychological modeling and philosophical issues

- AI - is both a branch of science and a branch of engineering

  - As engineering, AI is concerned with the concepts, **theory** and **practice** of building intelligent machines

Knowledge in Intelligent Entities

"Intelligent entities seem to **anticipate their environments** and the consequences of **their actions**"

We **assume** that the Intelligent entities posses knowledge of their environments

Knowledge in Intelligent Entities

Basic QUESTIONS

- What is **knowledge**?
- What **forms** can it take?
- How do **entities use** knowledge?
- How is **knowledge acquired**?

Knowledge in Intelligent Entities

We have:

- Procedural Knowledge
- Declarative Knowledge

We talk about and define:

- Knowledge Representation
- Knowledge Base

Forms of Knowledge

There are **two major ways** we can think about machine having knowledge about its world:

- IMPLICIT – Procedural
- EXPLICIT – Declarative

Forms of Knowledge

The knowledge represented by the actual running or execution of a **program** is **procedural**;

Spider knowledge about spinning the web and **tennis** knowledge used by a **player** are both **procedural**

Tennis knowledge as TAUGHT by the instructor is a **declarative**

Intelligent Machines need both:

procedural and declarative knowledge

Declarative Knowledge

- **AI** focuses strongly on the declarative knowledge
- One of classic books

  Logical Foundations of Artificial Intelligence

  Michael R.Genesereth, Nils j. Nilsson (Stanford University)

  is concerned with and based on declarative knowledge

Reasons for preferring Declarative Knowledge

- Here are some reasons for AI researchers to prefer declaratively represented knowledge :

  Can be changed easily.

  Can be used for several different purposes.

  The knowledge base itself does not have to be repeated or designed for different applications

  Can be extended by reasoning process that **derive** additional knowledge

Requirements for Knowledge Representation Languages

- Representational adequacy:
  It should allow to represent all knowledge that one needs to reason with

- Inferential Adequacy:
  It should allow new knowledge to be **inferred** from basic set of facts

- Inferential Efficiency:
  Inferences should be made **efficiently**

- Naturalness:
  The language should be **reasonably natural** and easy to use

Syntax and Semantics

- Clear Syntax and Semantics:
  We should clearly **define**
- the language,
- allowable formulas,
- and their meaning

- Syntax (symbols):
  Formal Language = Set of Symbols

- Semantics (meaning):
  semantics is the assignment of well defined **meaning** to all symbols of the language

Classical Propositional Logic Representation

- Syntax
- If light goes on, then bring a towel.
- p : light goes on,
  q: bring a towel
- $(p \Rightarrow q)$
- Semantics :
- p is True or False.
  q is True or False.

$\Rightarrow$	T	F
T	T	F
F	T	T

Classical Propositional Logic Representation

- We say:

  A is **tautologically true**

  iff A is a propositional tautology

- NOTATION for "A is a propositional tautology " is

$$\models A$$

First Order Logic Representation

- Representation Example:

Red(Allison, Car) ≡ Allison's car is red

(Intended Interpretation)

  - Red – Two argument predicate symbol.
  - Alison – Constant
  - Car – Constant.

$P(C_1, C_2)$

Example

- Question:
  Is Red (as a color) always a 2−argument predicate?
- What about "Red (flower)" with intended interpretation
- Red here now **one argument** predicate- **more intuitive**
- **But** using Red as a 2−argument predicate may be OK in your particular represenation, if well defined and **used consistently**
-
- PRINCIPLE: Always define your syntax and semantics in a formal and not intuitive way

Knowledge Representations

- We can have **two** Knowledge Representations for a statement "Alison's car is Red"

- Knowledge Representation 1:
  - Red(Allison, Car)
  - Here we have a predicate of the form: P (C_1, C_2), i.e., two argument predicate

  - Intuitive meaning:
  - Red(x,y) iff x has a Red y

Knowledge Representations

Knowledge Representation 2:

Syntax: Red(Allisons−car)

Intuitive meaning

Red(x) iff x is red (Different semantics !)

where Allisons−car is a constant

- Pure Logic: P(c)
  - P is one argument predicate, c is a constant
  - $P_{\underline{r}}$: Red **Intended Interpretation**

Knowledge Representations

- **Different** knowledge representations should not appear together !

1. $\exists$ **x** Red (x, house)
   There is x, such that Red(x, house) is **true** under intended interpretation

   means that some people have a red house

2. $\exists$ **x** Red (x)
   This means some x (object) is Red **under intended interpretation**

Naturalness

- A Knowledge Representation language should allow us to represent adequately complex facts in a clear, precise and natural way
- This is a reason why we use Intended Semantics

- Some facts are **hard to represent** in a way that we can also correctly reason with them
- Example:
  John believes no-one likes brussel sprouts.
  - Believes - ??
  - Syntax: Bel (x,y)
    Intuition: x believes in y

  - What are rules that govern our **believe system**?
  - Believe Logics, Modal Logics, etc.
  - **We are out of classical logic**

Clear Syntax and Semantics

$$\begin{tikzcd} \boxed{\text{SYNTAX}} \arrow[r, leftrightarrow] & \boxed{\text{SEMANTICS}} \end{tikzcd}$$

- A precise syntax and semantics are particularly important given that an AI program will be reasoning with the **knowledge** and drawing new **conclusions**

Clear Syntax and Semantics

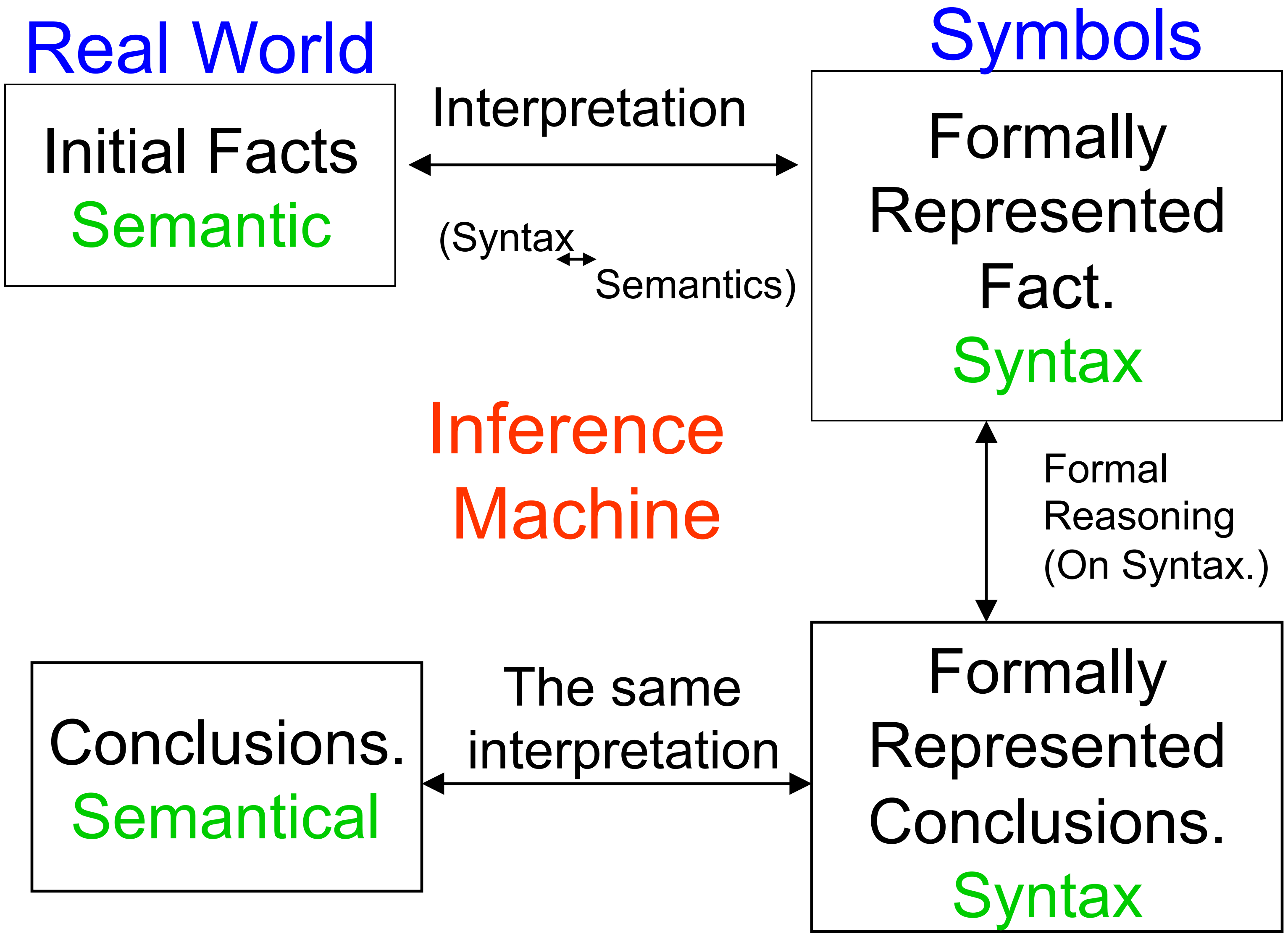
- Example:
  If system concludes:
  Interest (Alison, high)
  we need to know what it mean !

  Does it mean:
  - Allison's Mortgage interest is high
  - I am interested highly in Allison
  - Or maybe... Allison is interested in high mountains climbing….

  And all this under **Intended Interpretation**

  Interest(x,y) iff "x is interested in y" (defined intuitively)

Syntax – Semantics Picture



Inferential Adequacy

We have to be able to **deduce** new facts from existing knowledge

- Knowledge Representation Language must support **inference**

- We can't represent explicitly everything that the system might ever need to know;
- Some things must be left implicit to be **deduced** when **needed**

Main Approaches to Knowledge Representation

- Logics:
- Propositional, Predicate, Classical, Non-classical
- Frames and Semantic Networks (Nets)
- Rule – Based Systems

Main Approaches to Knowledge Representation

- Logic:
  represents declarative approach and often classical reasoning
- There are many logics:
- Classical logic, non-classical logics: temporal, modal, belief, fuzzy, intuitionistic and many others

Main Approaches to Knowledge Representation

- Frames and Semantic Networks (Nets):
  - Natural way to represent **factual knowledge** about classes of objects and their properties
  - **Knowledge** is represented as a collection of objects and relations.
    The special relations are: Subclass and Instance, and we define the property of Inheritance.

Conceptualization

The **formalization** of knowledge in **declarative** form begins with a notion of conceptualization

- The **language** of conceptualization is often **predicate calculus**
- Definition presented here is from

Nils Nilsson’s book

Logical Foundations of AI

Conceptualization

- Conceptualization – **step one** of formalization of knowledge in declarative form
- **Definition**
- $C = (\mathcal{U}, \mathbf{F}, \mathbf{R})$
- $\mathcal{U}$ – **Universe** of discourse; it is a finite set of **objects**

- **F** – **Functional Basis Set**; finite set of functions (defined on $\mathcal{U}$). Functions may be partial
- **R** – **Relational Basis Set**; finite set of relations defined on $\mathcal{U}$

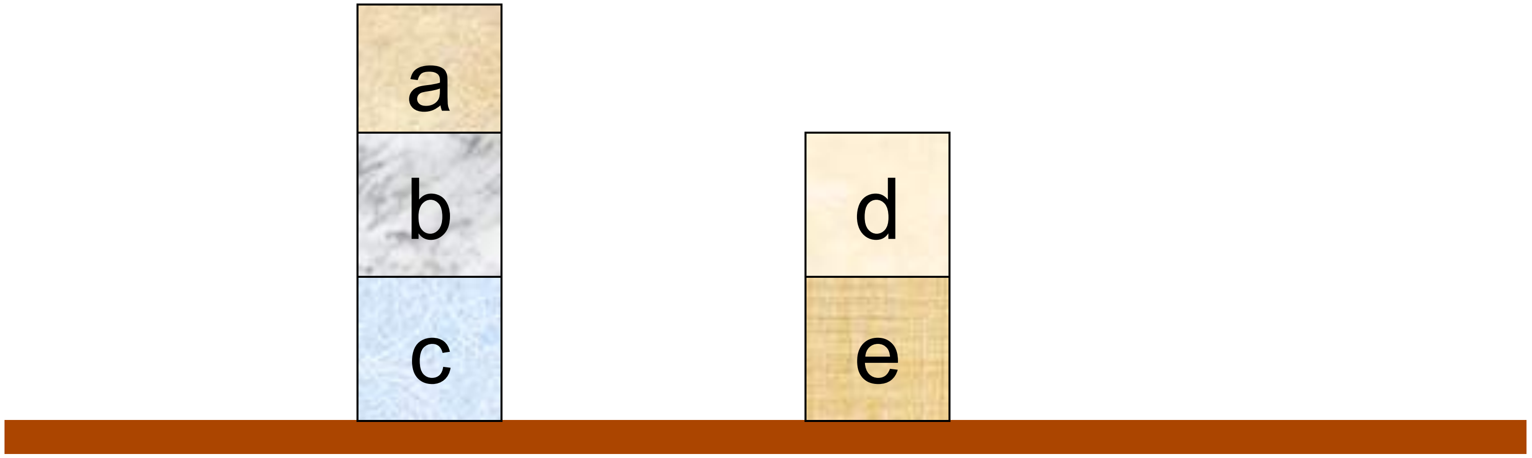
- Remark: sets $\mathcal{U}$, **R**, **F** are finite

Conceptualization

- **R** – **Relational Basis Set**; Set of relations defined on $\mathcal{U}$, i.e.
- $R \in \mathbf{R}, \quad R \subseteq \mathcal{U}^n, \quad \# R = n$

This is like in predicate logic:
We define
$M = (\mathcal{U}, \mathbf{F}, \mathbf{R})$ is a Model
Where $\mathcal{U} \neq \varnothing$ is the Universe,
$f \in \mathbf{F}, \quad f \in \mathbf{F}, \quad f_I$ –interpretation, $f_I : \mathcal{U}^n \rightarrow \mathcal{U}$, etc.,
$R \in \mathbf{R}, \quad R \subseteq \mathcal{U}^n, \; \# R = n$

Example: Block World



(Example is continued on next slide.)

Example: Block World

- $\mathcal{U}$ = { a, b, c, d, e}
- **F** – set of functions; here **F** = {h}
- Intuitively: h maps a block into a block on the top of it
- We use **intended interpretation** and write h = Top
- **Formally:** h = {(b,a) , (c,b), (e,d)}, i.e
- h(b) = a; h(c) = b; h(e) = d
- h is a **partial function** and h : $\mathcal{U} \rightarrow \mathcal{U}$
- Domain of h = {b,c,e} $\subseteq \mathcal{U}$

Example: Block World

R – Set of Relations (always finite)

- We **define** here 4 relations, i.e.

  R = {Above, On, Table, Clear}

where

Above $\subseteq \mathcal{U} \times \mathcal{U}$, On $\subseteq \mathcal{U} \times \mathcal{U}$

- Table $\subseteq \mathcal{U}$, Clear $\subseteq \mathcal{U}$

- Observe that Above, On are **two** argument relations and Table, Clear are **one** argument relations

Example: Block World

We define intuitively:

Above (x,y) iff x is anywhere above y

We define formally:

Above = {(a,b), (b,c), (a,c), (d,e)}

Above is a two argument relation

We define intuitively:

On (x,y) iff x is immediately above y

We define formally:

On = {(a,b), (b,c), (d,e)} On $\subseteq \mathcal{U} \times \mathcal{U}$

On is a two argument **partial function**

Example: Block World

We define intuitively:

Clear(x) iff there is no block on top of x

- **We define formally:**

  $\text{Clear} = \{a, d\} \subseteq \mathcal{U}$

-

  Clear is one argument **relation**

- **We define intuitively:**

  Table(x) iff x is resting directly on the table

  We define formally:

  $\text{Table} = \{c,e\} \subseteq \mathcal{U}$

- Table is one **argument relation**

Example: Block World

- Observe that
-

$On \subseteq Above; \quad Clear \cap Table = \emptyset$

We have chosen in our conceptualization to define some particular **relations** and **functions**

But depending on what we want to tell about our world – we can define less or more of them, or some totally different sets of **relations** and **functions**

Example: Block World

- On $\subseteq \mathcal{U} \times \mathcal{U}$
  On = {(a,b), (b,c), (d,e)} (Math. Definition)
- This is **Prolog** like statements:
  $\boxed{\text{On(a,b) , On(b,c) and On(d,e)}}$ ← Facts in Prolog
  It is equivalent to your definition as a **declaration** of what "On" means, i.e.
- We write On(a,b) for (a,b) Є On
- Prolog is called a **declarative** programing language

Intended Interpretation

- We defined

  On = {(a,b), (b,c), (d,e)}
- We can also use other symbols, e.g. :
  ◘ = {(a,b), (b,c), (d,e)} (Math. model)
- This is the same as:
  ◘(a,b) , ◘(b,c) and ◘(d,e)
- **Intended Interpretation** of the symbol ◘ is as is the intuitive meaning of the word On in our definition, i.e. "x is immediately above y"

Representation in Predicate Logic

- **Facts** about our Universe:

On(a,b)	Above(a,b)	Clear(a)
On(b,c)	Above(b,c)	Clear(d)
On(d,e)	Above(a,c)	Table(c)
Top(b,a)	Above(d,e)	Table(e)
Top(c,b)	Top(e,d)	

Representation in Predicate Logic

We can also add some Rules (general properties) about our Universe (Axioms of our Universe)

For example

- $\forall x \forall y\, (On(x,y) \Rightarrow Above(x,y))$
- $\forall x \forall y ((Above(x,y)$ □ $Above(y,z)) \Rightarrow Above(x,z))$
- etc

Reasoning in Prolog : Resolution

- To be able to use Prolog we have to convert all statement into a "non quantifier" form
-
- This process is called Skolemization
- Good Prolog compiler does it for us
- Resolution is the Inference Engine of Prolog

Plan for Logic Part

1. Short **Introduction** and **Overview** to Predicate Logic
2. Laws of Quantifiers
3. Skolemization
4. Propositional Resolution

(Proof of Correctness =
Completeness Theorem.)

5. Resolution Strategies (to go faster!)
6. Predicate Resolution- introduction

History: Major AI Areas

1. Game Playing:
   In early 1950 Claude Shannon (1950) and Alan Turing (1953) were writing **chess programs** for von Neumann computers

But, in fact Shannon **had no real computer** to work with, and

Turing **was denied access** to his own team's computers by the British government on the grounds that

research into AI was frivolous !

History: Search as AI

- **Search** as a Major AI Technique
- Search is a problem solving technique that systematically explores a space of problem states, i.e., stages of problem solving process
  - Example: Different board configurations in a game form a space of alternative solutions. The space is then searched to find a final answer.

History: Search as AI

- Much of early research in State Space Search was done using common board games: checkers, chess, 16-puzzle
- Games have well defined rules, and hence it is easy to generate the search space
- Large space – Heuristic Search
- 1984 book by Pearl , "Heuristics" – First Comprehensive Mathematical treatment of heuristic search
- **Heuristic Search** is widely used now in Theorem Proving, Machine Learning, Data Mining and Big Data

Heuristic Search became now a newly vibrant area of research

History: Major AI Areas

2. Automated Reasoning and Theorem Proving:

Origin: Foundations of Mathematics.

Mathematics can be considered as "axiomatic theory."

- Hilbert Program (1910) – to formalize all of mathematics in such a way that a proof of any theorem can be found automatically.
- Gentzen(1934) – positive answer for Propositional Logic

  Partial (semi-decidable) answer for

  First Order Logic

History: Major AI Areas

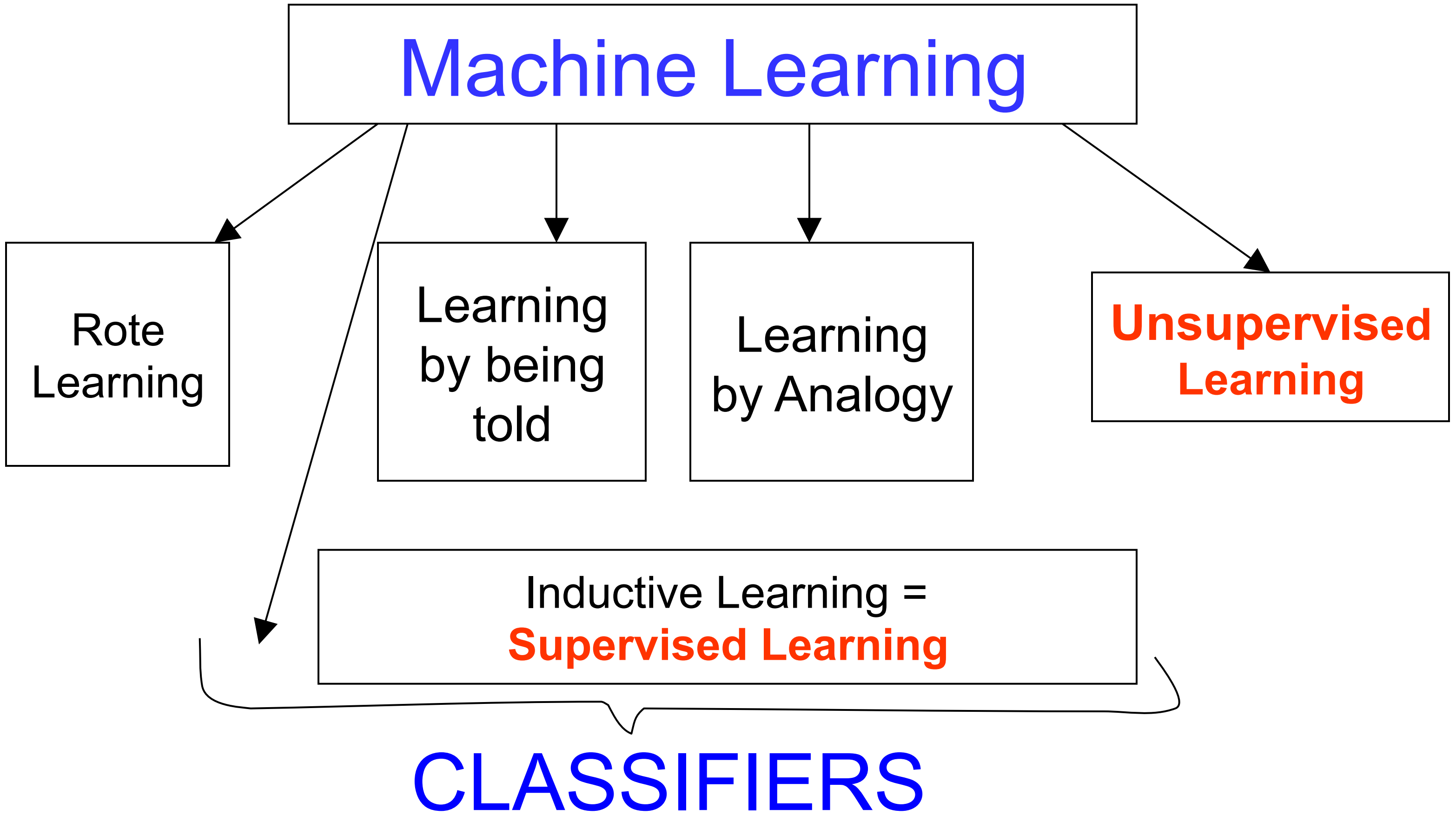
Automated Reasoning and Theorem Proving

- Gödel (1933) – negative answer for **arithmetic;** incompleteness theorem
- Robinson (1965) – Resolution
- Program Verification – uses theorem proving techniques

History: Major AI Areas

3. Expert Systems:
   - Obtaining knowledge from human experts, or databases (automated rules generators) and representing it in a form that computer may apply to similar problems
   - Rule Based Systems.
   - **Expert Systems** grew into information systems
   - **Expert Systems are always** developed for a specific domain

History: Major AI Areas



History: Other AI Areas

- Natural Language Processing
- Natural Language Understanding
- Robotics
- Intelligent Visualization
- etc
- etc…

Short History: Expert Systems

- First Expert Systems Examples:
  - Dendral, Stanford 1960:
    built to infer the structure of organic molecules from their chemical formulas.
  - MYCIN, Stanford 1970:
    diagnostic system, plus prescribes treatment for Spinal Meningitis and bacterial infection in the blood. It was the first program to address the problem of reasoning with uncertain and/or incomplete information.
    Still on the Web ! (Medical Information Systems)

Expert Systems – Modern Approach

Managing Uncertainty in Expert Systems
(Jerzy Busse, Kluwer)

Knowledge acquisition by using Machine Learning:

Rule Induction from databases –
Rough Sets approach

Managing Uncertainty in E.S.

Uncertainties – Set Valued, Quantitative Approaches

- Fuzzy Sets (Zadek, 1965)
- Rough Sets (Pawlak, 1985)
- Various Machine learning techniques

Uncertainties – Qualitative Approaches:

- Modal Logics
- Non-monotonic logics
- Default logic
- Plausible Reasoning

History: Expert Systems

MYCIN Story:

MYCIN asked if the patient was pregnant even though it has been told that the patient was male

Expert Systems

- **Modern Expert Systems** always have a **Machine Learning** Components
- Supervised Learning = Classification

- Major **Supervised Learning** Techniques are:

  1) Genetic Algorithms. (Evolutionary)
  2) Neural Networks
  3) Decision Tree
  4) Rough Sets
  5) Classification by Association

AI: Very Short History

- **The name, "AI"** , was suggested in 1956 by McCarthy (at Dartmouth at that time, and then at Stanford, Yale) during a **two month long** workshop at Dartmouth

- The Workshop was devoted to programs that could perform:
  - Elementary Reasoning Tasks
  - Proving Simple Theorems.
  - Answering Simple Questions.
  - Playing Board Games.

  - ALL Non computational (in a sense of numbers) tasks
  - -revolutionary at that time

Very Short History

- All together there were 10 people
- For the next 20+ years the field would be dominated by them, their students and colleagues at MIT, CMU (Carnegie-Mellon University), Stanford and IBM

- Allen Newell and Herbert Simon from CMU stole the show with Logic Theorist (LT) – first program to think non-numerically

Very Short History

- LT proved most of the theorems in Chapter 2 of Russell and Whitehead's "Principia Mathematica"
- Herb Gelernter (Stony Brook) constructed **first** (1959) Geometry Theorem Prover
-
- Anita Wasilewska (now Stony Brook) invented and wrote
- **first** theorem prover (in LISP-ALGOL) for MODAL LOGIC in 1967 at Warsaw University, Poland
- Now Theorem Proving is a separate field of Computer Science
-

Very Short History

- 1952-1969 : Time of **Early Enthusiasm** and **Great Expectations**
- 1952 :

  Arthur Samuel wrote a tournament level checkers program
- In February 1956 the program was demonstrated on National TV
- A. Samuel, like Alan Turing had a hard

  time to obtain computer time; worked only at night

Short History

- 1958 :
  McCarthy moved from Dartmouth to MIT and invented LISP - Second **oldest** programming language still in use; Which is the Oldest?
- LISP is now being replaced by Prolog as a dominant AI language (in many areas)
- McCarthy and his group also invented Timesharing and formed Digital Equipment Corporation (DEC) to produce **time sharing** computers

Very Short History

- 1958 :
  - Marvin Minsky moved to MIT - hee represented Anti-logic outlook.
  - McCarthy was Pro-logic and moved to Stanford
  - McCarthy' s **Logic agenda** was busted by Robinson' s discovery of Resolution and Kowalski's work on Prolog - Logic Programming"
  - McCarthy founded SRI - Stanford Research Institution – still main place for research in

general purpose methods for logical reasoning

Very Short History

- 1963:
  J. Slagle' s program SAINT was able to solve closed form integration problems. (first year calculus)
- 1969:
  - Green' s Question – Answering and Planning Systems.
  - Shakey's Robotics Projects; first integration of logical reasoning and physical activity

- 1971:
  D. Huffman' s "vision" project - rearrangement of the blocks, put on top of the table, using a robot hand that picked one block at a time

- 1970:
  P. Winston – first **learning theory**

Very Short History

- 1972:
  T. Winograd – first natural language understanding theory
- 1974:
  Planner of Scott Fahlman

- **1966 – 1974:**
  A Dose of Reality
- 1966:
  All **American** Governmental funding for machine translations were **cancelled**
- 1973:
  British Government **stopped** AI support to all but 2 universities

Very Short History

- Genetic Algorithms were formulated in 1958-59, but computers were not yet up to it

- The same happened to Neural Networks – mathematical model and theoretical research was rampant, but for years computers were not strong and fast enough to give meaningful results

- 1980 – back propagation (NN) algorithm was invented and **first applications** followed

AI becomes an Industry

1982:

First successful Expert System RI at Digital Equipment Corporation (DEC) was made (McDermot)

RI helped configure orders for new Computer Systems and by1986 was saving the company $40 million a year

1988:

DEC's AI group had **40 Expert systems**

Du Pont had **100 E.S.** in use and 500 in development saving $10 million a year

Information Systems Departments were crated in Industries and at Universities

Industry went from a few million in **sales** in 1980
to 2 Billion in 1988

History: AI becomes an Industry

- 1981:

  Japan announced Fifth Generation project

  The Fifth Generation Project was created to use **Prolog** to achieve full-scale natural language understanding

  USA **formed** a company MCC (Microelectic and Computer Technology Corporation) **to compete** with Japan
  ALSO: Cornegie Group, Inference, Intellicop,Lisp Machines

- Fifth Generation Project generated a progress but the **project failed**

- Prolog is just one of many programming languages

- Prolog is still prominent in Linguistics and Natural Language processing and translation

History: AI Philosophical Issues

- AI research makes the assumption that human intelligence can :

1) be reduced to the (complex) manipulations of symbols, and

2) It does not matter what Medium is used to manipulate these symbols. (It does not have to be a biological brain)

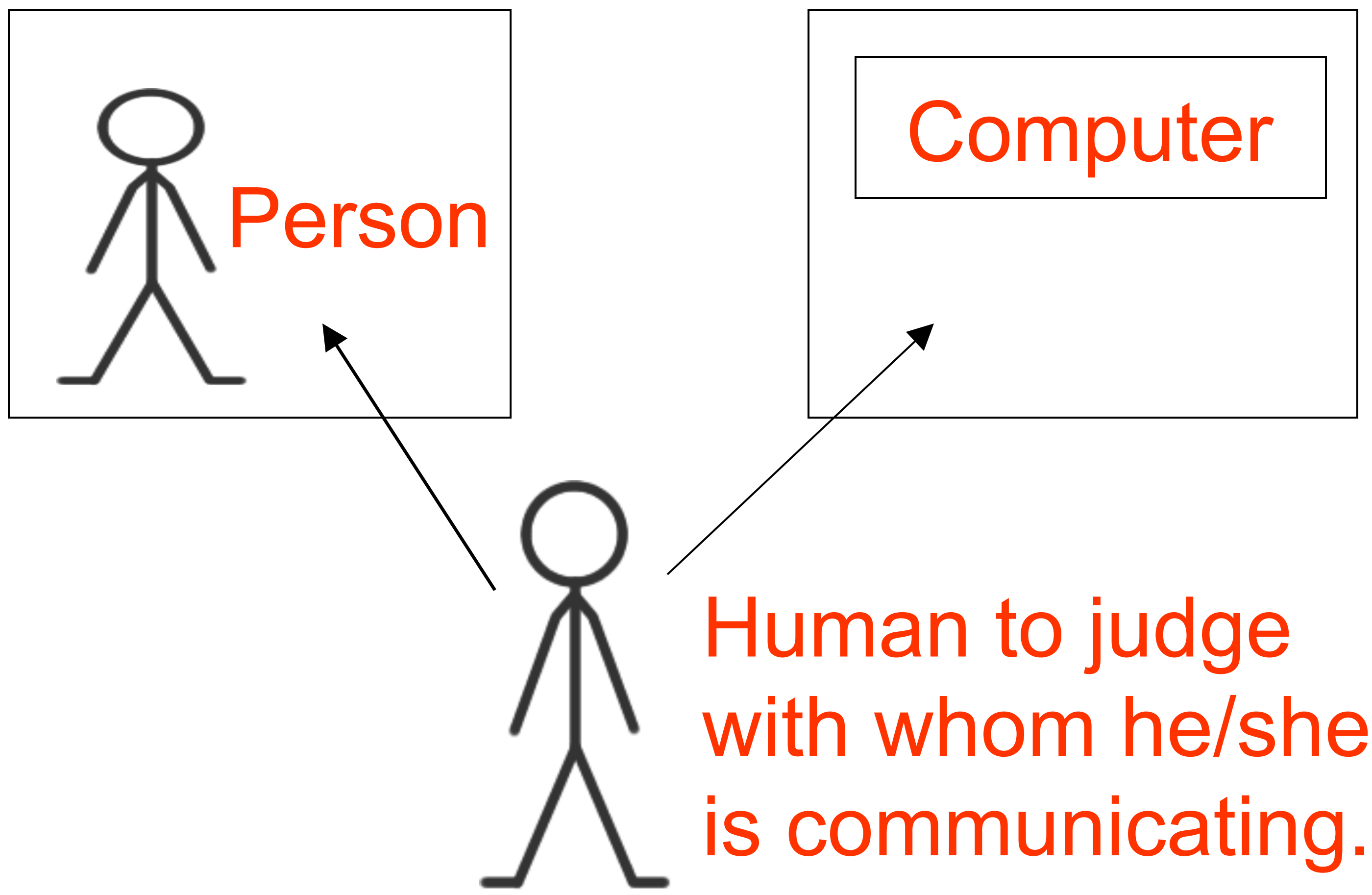
History: Philosophical Issues

- Turing’s test (1950) and Charles Searle’s Chinese room (1980) are the **most known** contributions to the philosophical debate

- Loebner Prize Contest – competition started in 1991 & inspired by Turing test
  - Best program – $2,000.
  - Grand Prize - $100,000
  - No one claimed yet

History: Philosophical Issues

- Turing Test:



History: Philosophical Issues

- Turing test:
  - The human can ask the other person/ computer any question; including very subjective questions, like:
    - "What is your favorite color?" and
    - "What do you think of the privatization of the British Rail" ?

  - Computer is Intelligent – If it answers so well that the judge cannot distinguish it from a person.

History: Philosophical Issues

- Searle “Chinese Room” critique:

  If you have a huge rule book on Chinese you can “talk” Chinese even if you do not understand it;

  so, Turing Test **does not** measure the Intelligence

Questions – Answers Systems
The Loebner Prize Contest

- 10 judges type questions at a computer which are responded by a person or a program.
- The best program receives $2000
- The Winning program : $100,000
- No one won yet and the Contest is still going on!

The Loebner Prize Contest

- 1996 Winning Fragment:

- P: No worries ! Hey! I did not come here to be subjected to bad language! How rude.

J2: Sorry, sorry. Did not mean to offend. How old are you?

P: That is ok. Just don't do it again. Well, should my age really matter? Just for the record, I am 24. How old are you then?

J2: I am 21.

P: If you are 21, it is your business! Would you like to hear a joke? Knock, knock