LECTURER: Nghia Duong-Trung

ARTIFICIAL INTELLIGENCE

TOPIC OUTLINE

UNIT 2

EARLY SYSTEMS IN ARTIFICIAL INTELLIGENCE

STUDY GOALS

On completion of this unit, you will have learned …

- … about important approaches that have defined the field of artificial intelligence in the past and that continue to influence it today.
- … why expert systems are important and how they have contributed to artificial intelligence and computer science.
- … about advances brought about in the Prolog programming language.
- … the definition of machine learning and how it contributes to artificial intelligence.

EXPLAIN SIMPLY

1. List the three types of machine learning and explain them using your own words.
2. What are the main components of expert systems?
3. Explain the declarative programming paradigm.

Expert systems

Knowledge representation

Case-based systems

– storage of problems and successful solutions

Rule-based systems

– description of relations between facts

Decision tree

– representation in form of decisions

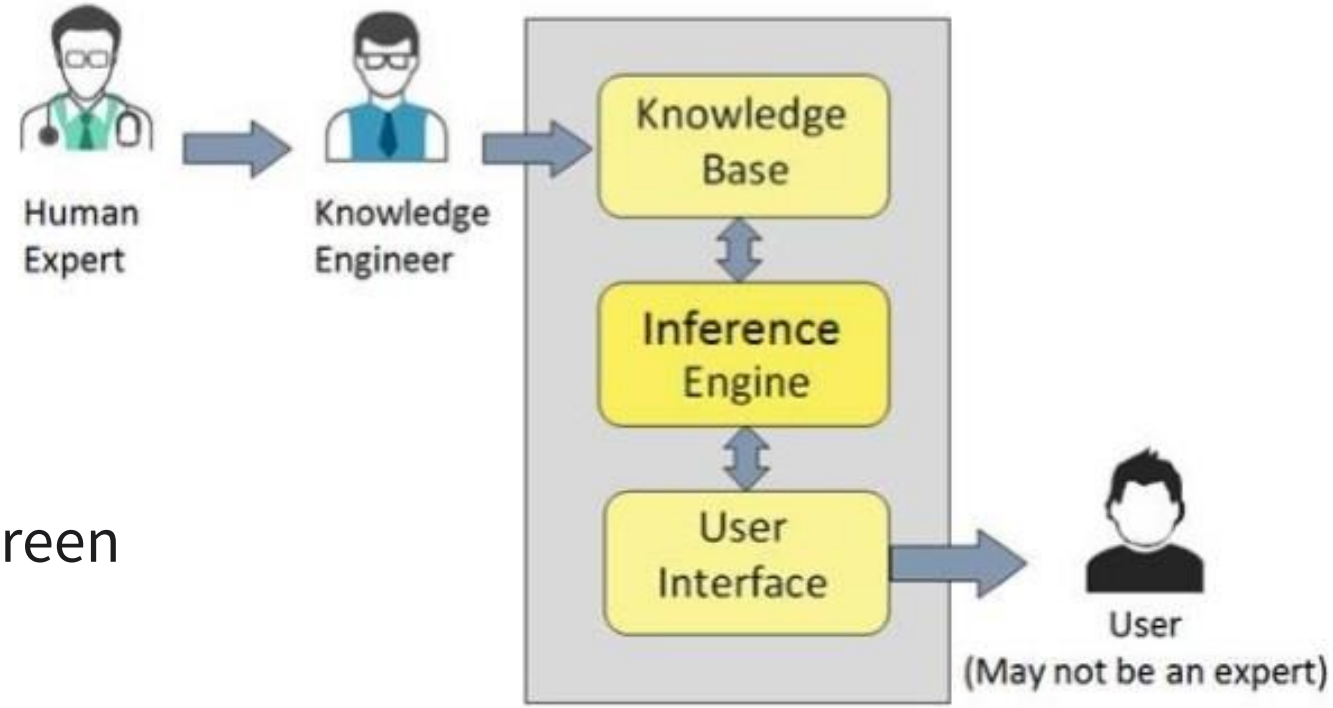
Inference engine

Inference engine

– implements rules of logical reasoning to derive new facts

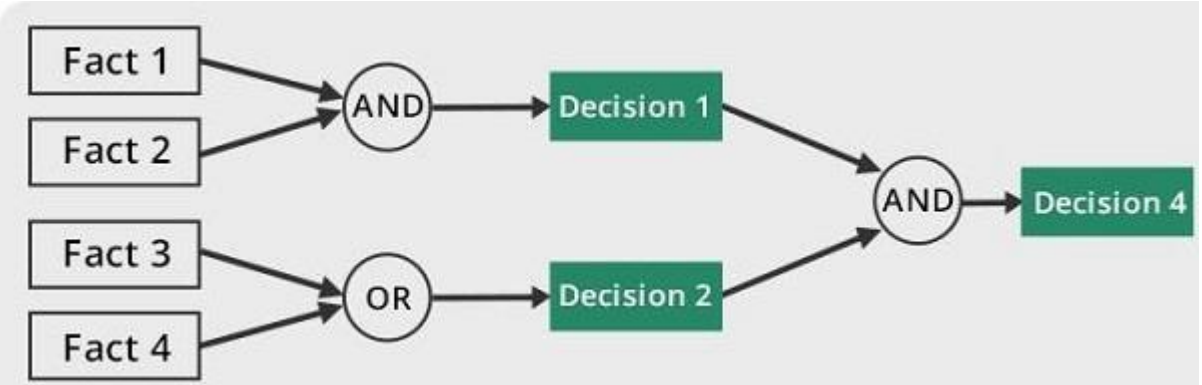
BASIC COMPONENTS OF EXPERT SYSTEMS

- Knowledge base
  - Data is collection of facts, experience
  - factual and heuristic knowledge
  - The form of IF-ELSE rules
- Inference engine
  - Forward and backward chaining
- User interface
  - Natural language displayed on the screen
  - Verbal narrations via speaker

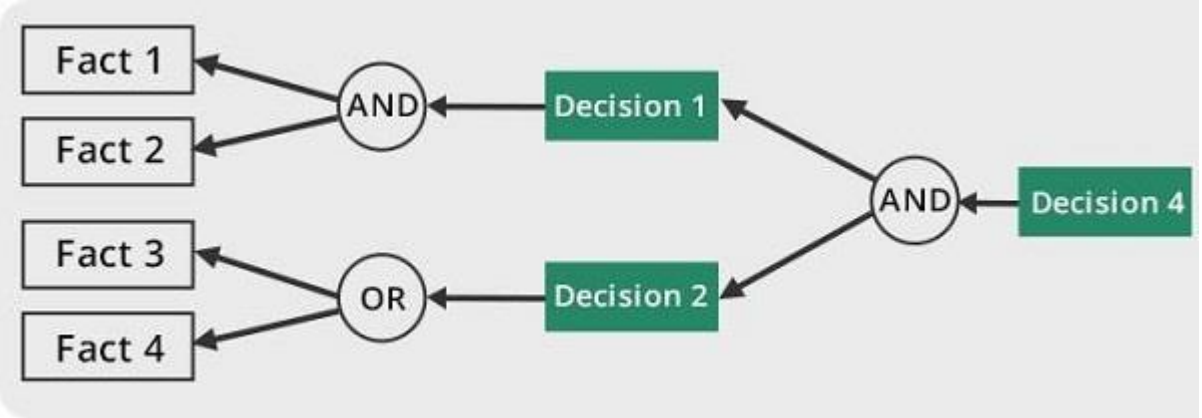


BASIC COMPONENTS OF EXPERT SYSTEMS

- Forward chaining
  - To answer the question „what can happen next?“
  - Follows the chain of conditions, derivations and finally deduces the outcome



- Backward chaining
  - To answer the question „why this happened?“
  - Finds out which conditions could have happened in the past for the current result

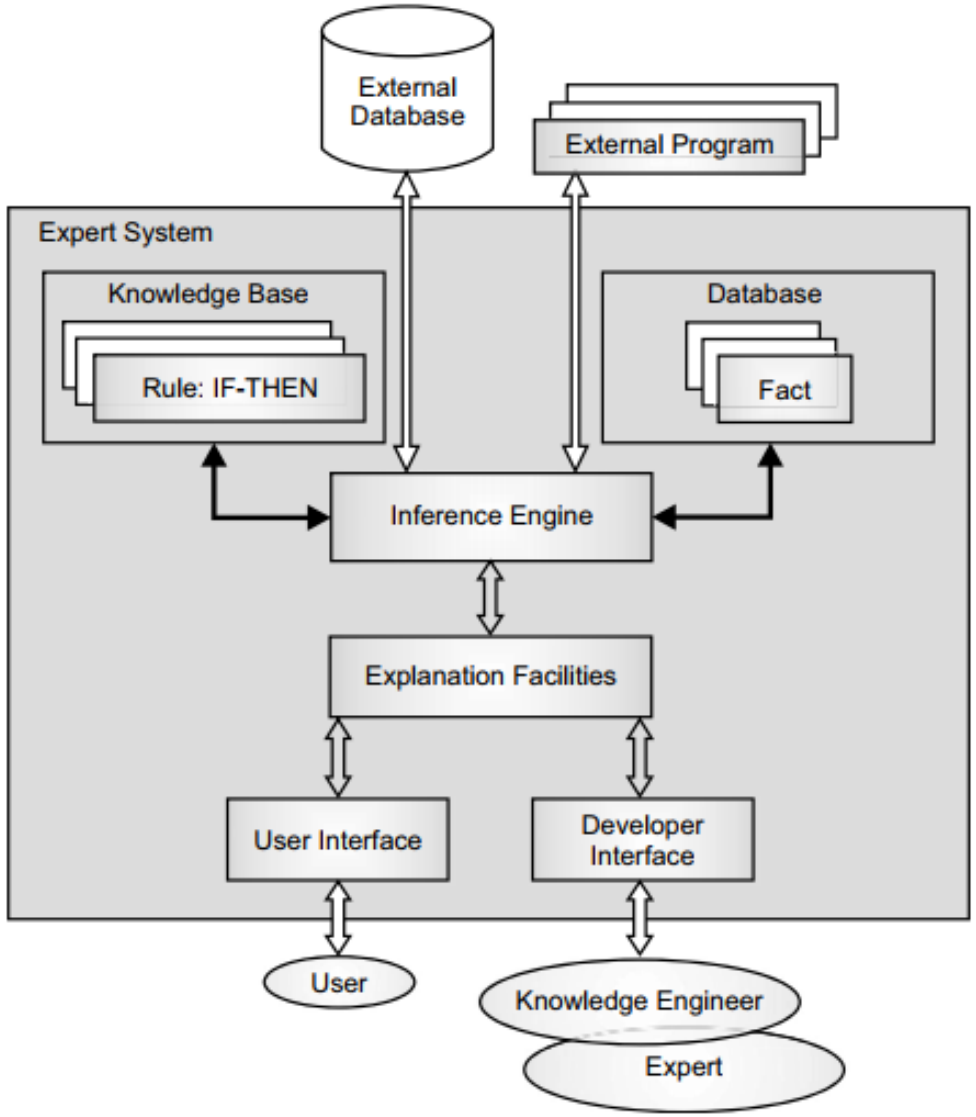


ADVANCED COMPONENTS OF EXPERT SYSTEMS

Krishnamoorthy, C. S., & Rajeev, S. (2018). *Artificial Intelligence and Expert Systems for Artificial Intelligence Engineers*. CRC press.

Gupta, I., & Nagpal, G. (2020). Artificial Intelligence and Expert Systems. Mercury Learning and Information.

In short: expert system = knowledge base + inference engine



HISTORY OF EXPERT SYSTEMS

- Historically, expert systems are an outgrowth of earlier attempts at implementing a so-called general problem solver to solve arbitrary problems by successive reduction to simpler problems in the late 1950s.
- Systems that combined domain specific knowledge with domain dependent apposite reasoning patterns
- Expert systems introduced the idea of **rapid prototyping** since the fixed inference engine enabled the creation of programs for entirely different purposes simply by changing the set of underlying rules in the knowledge base

FEATURES OF GOOD EXPERT SYSTEMS

- Useful: meet a specific need
- Usable: even a notice computer user finds them easy to use
- Educational: an expert system may be used by non-experts who can then increase their own expertise by using it
- Able to explain the given advice: explain the reasoning process
- Able to learn new knowlege: ask questions to gain additional knowledge
- Exhibit a high performance: high quality output -> satisfy users
- Make timely decisions: able to produce decisions on time

New use cases require a larger knowledge base

- Increased computational complexity during inference
- Challenge of consistency without contradictions

→ Lead to development of logical programming to formulate rules and reasoning processes

Declarative programming

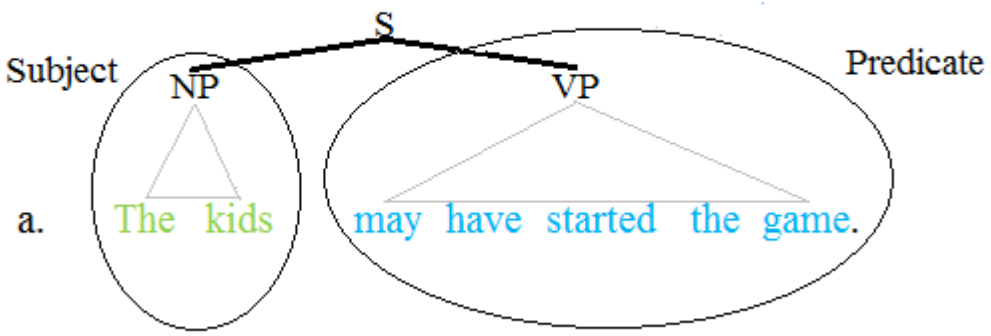
- programming style with specified properties of the sought solution but not the algorithm

→ sequence of operations that lead to a solution (= logic)

INTRODUCTION TO PROLOG

- Prolog was created by French computer scientists Alain Colmerauer and Philippe Roussel, with the logician Robert Kowalski further developing the language
- It was first implemented in the early 1970s.
- The main motivation for creating Prolog was to use it in the development of systems for natural language processing and artificial intelligence.
- Prolog is based on a **declarative programming** paradigm.
  - The programmer specifies characteristics of the desired solution and the programming language interpreter then constructs a sequence of processing steps to reach the given goal.

- Prolog is designed to formalize these processes in the form of **first order logic**
  - Objects: DLMAIAI01, fred, BER 4.02,
  - Relations/Predicates: is_Man(fred), Located(DLMAIAI01, BER 4.02), is_kind_of(apple, fruit)
    - Note: Relations typically correspond to verbs
  - Functions: Best_friend(), beginning_of() : Returns object(s)
  - Logical Connectives:
    - ∧ for conjunction, ∨ for disjunction, → for implication, ↔ for biconditional, ¬ for negation.
  - Quantifiers:
    - Universal: ∀x: (is_Man(x)) is_Mortal(x))
    - Existential: ∃y: (is_Father(y, fred))



https://www.cs.cornell.edu/courses/cs4700/2011fa/lectures/16_FirstOrderLogic.pdf
https://simple.wikipedia.org/wiki/Predicate_%28grammar%29

PROgramming in LOGic (Prolog): Consists of predicates and clauses

Example of the Prolog Language		
Prolog language construct	**Prolog syntax**	**Meaning and output**
Fact	lectures (Smith, DLMAIAI01)	Establishes the fact that Dr. Smith teaches the course DLMAIAI01. It is an exmple of a Prolog clause.
Predicate	professor(Smith). professor(Jones). professor(Meyer).	Defines the one argument predicate professor by three facts. Drs. Smith, Jones, and Meyer are professors.
Rule	technicalCourse(X) :- engineeringCourse(X)	All engineering courses are technical courses. Note the use of variable X!
Query	? – lectures(Smith, DLMAIAI01)	Does Dr. Smith teach DLMAIAI01?
Goal	? – lectures(Smith, X)	What courses does Dr. Smith teach? Note the use of the variable X!

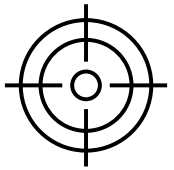
Source of the table: Course Book DLMAIAI01, 33-34

TYPES OF MACHINE LEARNING

Machine learning

Supervised learning

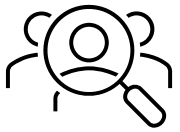
(predict a target variable)



House Price Prediction

Unsupervised learning

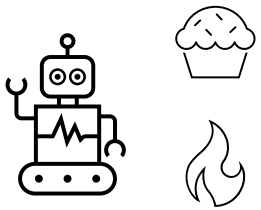
(discover hidden patterns)



Customer Segmentation

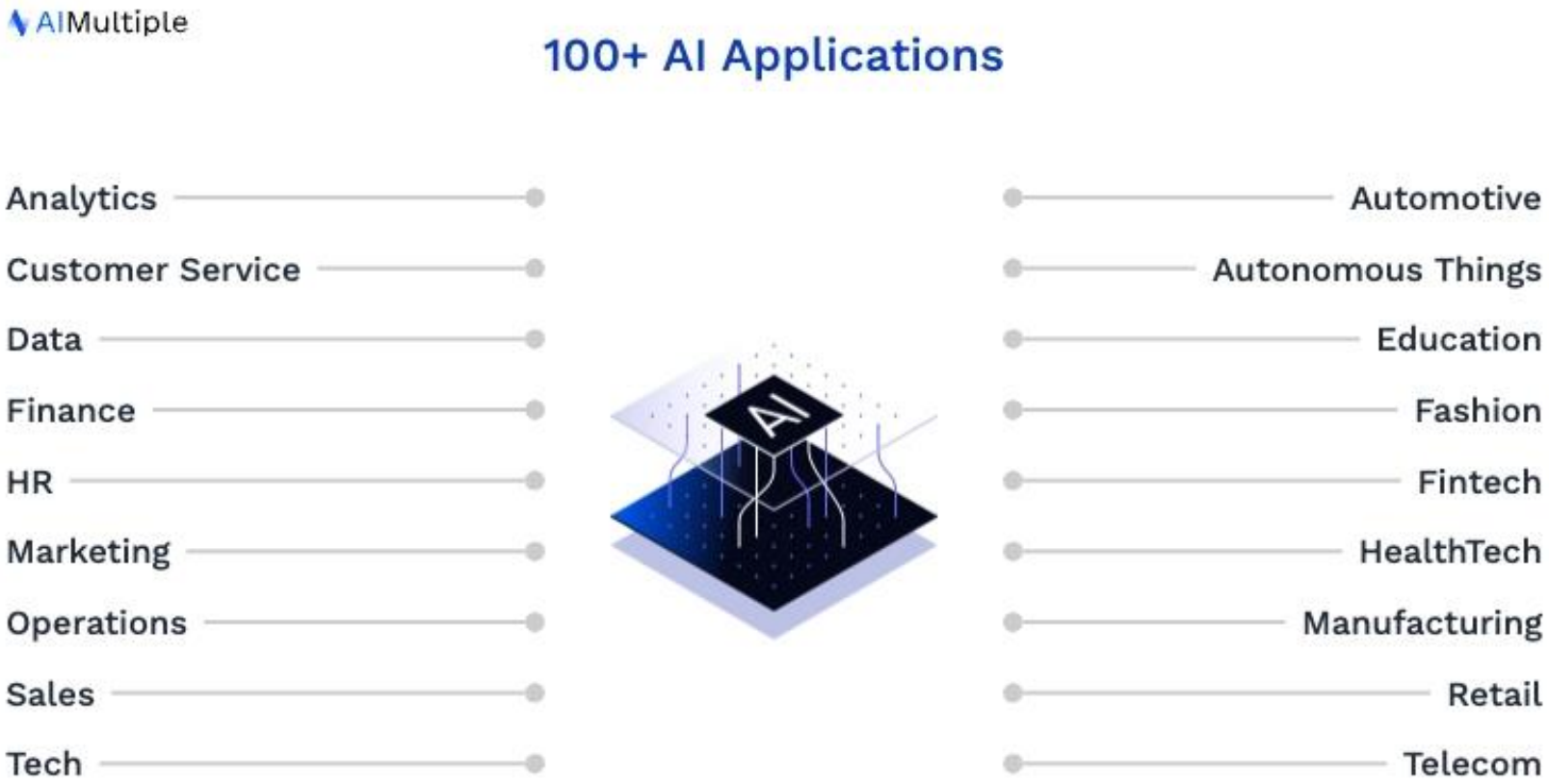
Reinforcement learning

(agent learns how to act)



Gaming agent for chess

USE CASE EXAMPLES IN DIFFERENT INDUSTRIES



https://research.aimultiple.com/ai-usecases/

REVIEW STUDY GOALS

You have learned …

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- … about advances brought about in the Prolog programming language.
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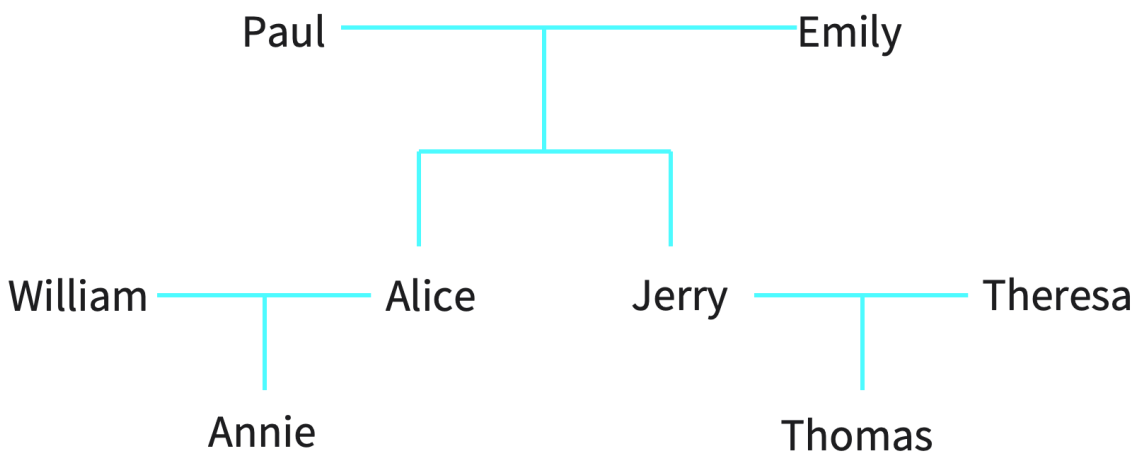
SESSION 2

TRANSFER TASK

TRANSFER TASK

Use Prolog to develop rules for the following family relations:



Write the following queries:

- *Does Annie have an uncle? Who?*
- *Who are the grandparents of Thomas?*

→ Use this virtual environment: SWI Prolog, using **Create a Program** function.

TRANSFER TASK
PRESENTATION OF THE RESULTS

Please present your results.

The results will be discussed in plenary.

TRANSFER TASK SAMPLE SOLUTION

```
female(annie).
female(theresa).
female(alice).
female(emily).

male(thomas).
male(jerry).
male(william).
male(paul).

parent_of(paul,alice).
parent_of(emily,alice).
parent_of(paul,jerry).
parent_of(emily,jerry).
parent_of(alice,annie).
parent_of(william,annie).
parent_of(jerry,thomas).
parent_of(theresa,thomas).
```

```
father_of(X,Y) :- male(X),
                  parent_of(X,Y).
mother_of(X,Y) :- female(X),
                  parent_of(X,Y).

grandfather_of(X,Y) :- father_of(X,Z),
                       parent_of(Z,Y).
grandmother_of(X,Y) :- mother_of(X,Z),
                       parent_of(Z,Y).

sister_of(X,Y) :- female(X),
                  parent_of(Z,X),
                  parent_of(Z,Y).
brother_of(X,Y) :- male(X),
                   parent_of(Z,X),
                   parent_of(Z,Y).

aunt_of(X,Y) :- sister_of(X,Z),
                parent_of(Z,Y).
uncle_of(X,Y) :- brother_of(X,Z),
                 parent_of(Z,Y).
```

Does Annie have an uncle?

- *uncle_of*(_,annie).

Who?

- *uncle_of*(X,annie).

Who are the grandparents of Thomas?

- *grandmother_of*(X,thomas).
- *grandfather_of*(X,thomas).

1. In Prolog, the sequence of concrete steps to arrive at a desired program outcome is:

   a) specified by the program user.
   b) generated by the Prolog system.
   c) specified by the programmer.
   d) not determined at all

2. Supervised learning, unsupervised learning, and reinforcement learning

   a) define the full range of the field of artificial intelligence.
   b) are concepts still being tested in laboratories. They are not yet being applied.
   c) have no relation to machine learning or artificial intelligence.
   d) are subfields of machine learning.

3. The main lasting contribution of expert systems to artificial intelligence and/or computer science were

   a) explicit formal representation of knowledge, declarative programming style, and rapid prototyping.
   b) the popularization of imperative programming and probabilistic reasoning.
   c) list processing and procedural programming.
   d) object-oriented programming and the implementation of systems without prototyping.

SOLUTIONS

- 1b, 2d, 3a

DISCLAIMER

- This is the modified version of the IU slides.
- I used it for my lectures at IU only.