Last time: Introduction to Data Science and Artificial Intelligence

- Data Science – using data as key part in the process of creating knowledge.
- Artificial Intelligence – the science of engineering systems that fulfill some criteria of intelligence.
  - Thinking, acting, rationally, humanly
  - Learning from experience: An entity's capability to adapt behaviour in a changing environment in order to achieve goals.
- Three key capabilities of intelligent systems: Perceive, think, act

2 – Boolean logic, Rules

Institute of Interactive Systems and Data Science

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Learning Goals

- Understand assumptions underlying rules as KR and rule-based systems
- Understand the basic components of a rule (antecedent, consequent)
- Understand the main components of an (interactive, expert) rule-based system.

- Apply forward chaining
- Apply backward chaining

EMCYN framework for identifying causes for blood clotting problems

RULE025

IF: 1) Bleeding-history is one of the reasons for this consultation,
2) There is an episode of significant bleeding in the patient,
3) Coagulation-defect is one of the bleeding disorders in the patient,
4) The defective coagulation pathway of the patient is intrinsic, and
5) There are not factors which interfere with the patient's normal bleeding

THEN: It is definite (1.0) that the following is one of the bleeding diagnoses of the patient: The patient has one or more of the following conditions: Hemophilia A, von Willebrand's syndrome, an IX, XI, or XII deficiency, or a high molecular weight Kallikrein defect.

```
PREMISE:  ($AND (SAME CNTXT REASON BLEEDING-HISTORY)
                (SAME CNTXT SIGBLD)
                (SAME CNTXT FINALDEF COAGULATION-DEFECT)
                (SAME CNTXT DEFPATH INTRINSIC)
                (NOTSAME CNTXT INTERFERENCE))
ACTION:  (CONCLUDETEXT CNTXT DX (TEXT DXHEMOPHILIA) TALLY 1000)
```

FIGURE 16-4 A sample rule from CLOT. RULE025 partly determines the final diagnosis.

Source: Buchanan & Shortcliffe, Chapter 16.

--------PATIENT-110--------
1) Name:
** **Pt110**
2) Age:
** **90 YEARS**
3) Sex:
** **FEMALE**
4) Race:
** **CAUCASIAN**
5) Please indicate your reason(s) for requesting this consultation:
** **BLEEDING-HISTORY**
6) What type of bleeding describes Pt110's most recent episode of bleeding?
** **HEMARTHROSIS**
7) Is there a history of a genetic bleeding disorder in Pt110's family?
** **YES**
8) Was the onset of the bleed immediate or delayed?
** **DELAYED**
9) BT:
** **5 MINUTES**
10) PT:
** **13**
11) PTT:
** **50**
12) TT:
** **15**
13) FSF:
** **NORMAL**
14) Has Pt110 recently exercised?
** **NO**
15) Is Pt110 currently receiving any of the following drugs: ASA, Heparin, Coumarin, oral-contraceptives, Ephedrine, Epinephrine, ADH?
** **NO**
16) Is Pt110 diagnosed as having cirrhosis, collagen disease, cancer, or any chronic disease?
** **NO**

Conclusions: the blood disorders of Pt110 are as follows:
COAGULATION-DEFECT (.97)
Conclusions: the statements about the consistency of the case data and CLOT's interpretation are as follows:

Both clinical and lab data are internally consistent and there is overall, consistent interpretation of the blood disorder.

Conclusions: the bleeding diagnoses of Pt110 are as follows:

The patient has one or more of the following conditions:

Hemophilia A, von Willebrand's syndrome, an IX, XI, or XII deficiency, or a high molecular weight Kallikrein defect. (.97)

FIGURE 16-6 Transcript of a CLOT consultation.

Source: Buchanan & Shortcliffe, Chapter 16.

Knowledge representation approach: Symbolic

- Computer „thinks“ in terms of states or concepts that apply or don‘t – symbolic, traditional Boolean logic
  - Extensions: fuzzy logic, probabilistic logic – states or concepts apply to different degrees (fuzzy) or with a given probability (probabilistic)
- … and links these together logically to derive more complex implications.

- Underlying assumption
  - The cognition we are aware of as humans is symbolic; symbolic KR is therefore natural to humans (-> schema theory)
  - Logic formalisms are well developed, though computability characteristics are sometimes not good (-> logic and computability)

Basics: Boolean logic

Boolean variable: Variable that can take a binary value (true/false; 0/1)

Boolean expression: A composite expression that evaluates to a binary value (true/false; 0/1)

- *A Boolean expression can contain elements from other formalisms, it just needs overall to evaluate to true/false!*

Boolean operators:

AND &&, OR ||, NOT ~, IMPLIES →

Variable assignment: Variables can get values assigned, e.g. x=5; x=TRUE.

Components of a Rule

IF **antecedent** THEN **consequent**.

Examples

- IF (sunny && hot) THEN (good-weather)
- IF (customer-age < 18 && desired-withdrawal > 1000) THEN (parental-signature-required).
- IF (12 < age(x) < 20) THEN (teenager(x))

- IF (wind-speed > 40km/h) THEN (draw-in-window-shutter).
- IF (sim(a,b)<threshold && c=recently-bought-books(b)) THEN recommend(a,c)).

Rules update knowledge and lead to action

Infer facts

- IF (sunny && hot) THEN (good-weather)
- IF (customer-age < 18 and desired-withdrawal > 1000) THEN (parental-signature-required).
- IF (12 < age(?x) < 20) THEN (teenager(?x))

Act

- IF (wind-speed > 40km/h) THEN (draw-in-window-shutter).
- IF (sim(a,b)>threshold && c=recently-bought-books(b)) THEN recommend(a,c)).

Reasoning

Which questions can be asked of a rule-based systems?

1. **Infer**: What are all the known facts? What can be inferred from the given knowledge (facts, rules)?
   - **Depending on the consequent:** The inference could be an action: What should be done under the given knowledge (facts, rules)?
2. **Validate**: Is X known under the given knowledge (facts, rules)?

Different question – different reasoning mechanism

- Infer -> Forward chaining – derive all facts that can be inferred from given facts and rules; act according to given rules and facts.

- Validate -> Backward chaining – test whether a hypothesis is true under the given facts and rules.

Forward Chaining: Steps

Input: set of facts & set of rules

1. Go through all rules and for every rule:
   a) Check whether the antecedent is true given the known facts: The antecedent needs to **match** a fact[1] in the database; then the rule **fires**.
   b) If yes (=the rule fires): Check whether the consequent is already known (matches the database)
      i. If not: Add consequent to the set of known facts
2. Repeat 1 (go through all rules again) until no more new facts are added in one cycle.

[1] Simplification for forward + backward chaining: We only have Boolean *variables* and operators in the antecedent + consequent, so all Boolean *expressions* are already evaluated.

Forward Chaining Example in Propositional Logic

Facts: A,B,C,D,E

Rules:

R1: Y & D $\rightarrow$ Z

R2: X & B & E $\rightarrow$ Y

R3: A $\rightarrow$ X

R4: C $\rightarrow$ L

R5: L & M $\rightarrow$ N

Cycle	Fired rules	Added facts
1	R3 R4	X L
2	R2	Y
3	R1	Z
4		

Backward Chaining: Steps

Input: Goal, set of rules, set of facts.

1. Check whether the goal is met (known) by the given facts. If yes, return TRUE.
2. For each rule
   a) Check whether goal matches a consequent.
   b) Recursion: If yes, set all sub-clauses in the antecedent as sub-goals and start recursion - Repeat from 1 for each sub-goal.
      i. Return TRUE when the combination of recursive results leads to positive evaluation of (sub-)goal.
3. Return FALSE - no explanation has been found, the goal has not been met

Backward Chaining Example in Propositional Logic

Facts: A,B,C,D,E

Rules:

R1: Y & D $\rightarrow$ Z

R2: X & B & E $\rightarrow$ Y

R3: A $\rightarrow$ X

R4: C $\rightarrow$ L

R5: L & M $\rightarrow$ N

Goal:

Z

Database: A, B, C, D, E X, Y, Z
Goal: Z

R1

True

Database: A, B, C, D, E X, Y
Sub-goal: Y

&

True

Database: A, B, C, D, E
Sub-Goal: D

R2

True

Database: A, B, C, D, E X
Goal: X

&

True

Database: A, B, C, D, E
Goal: B

&

True

Database: A, B, C, D, E
Goal: E

R3

Database: A, B, C, D, E
Goal: A

True

Exercise 2

Exercise 2

Boolean Variables - Vocabulary:

A: croaks
B: eats-flies
C: Frog
D: chirps
E: sings
F: Canary
G: Green
H: Yellow

Knowledge Base:

R1: $A \land B \rightarrow C$
R2: $D \land E \rightarrow F$
R3: $C \rightarrow G$
R4: $F \rightarrow H$

Database – what we know about Fritz

A=TRUE; B=TRUE;

Is Fritz green? What else do we know?

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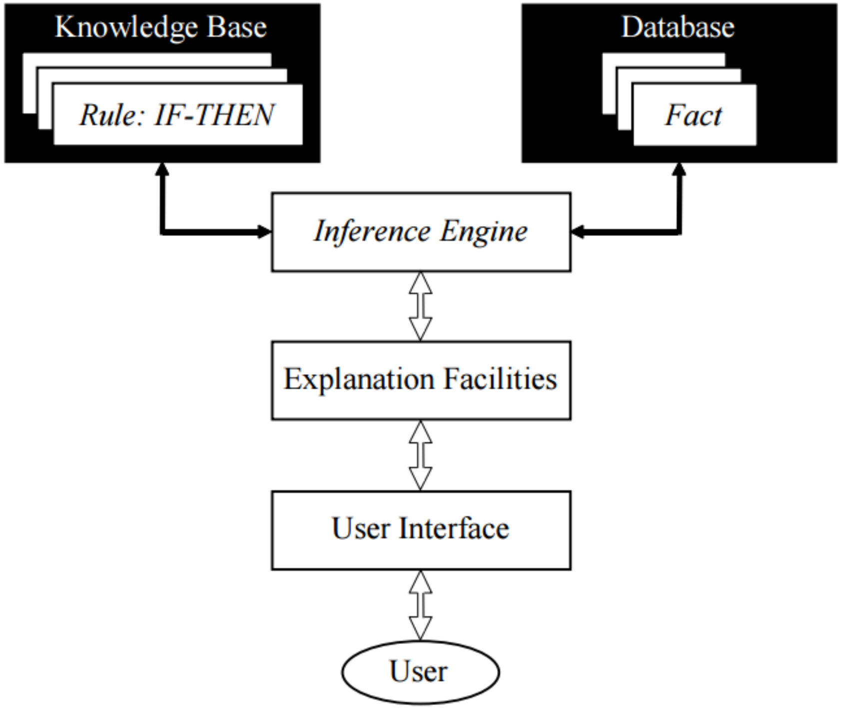
Rule-Based Systems - Architecture

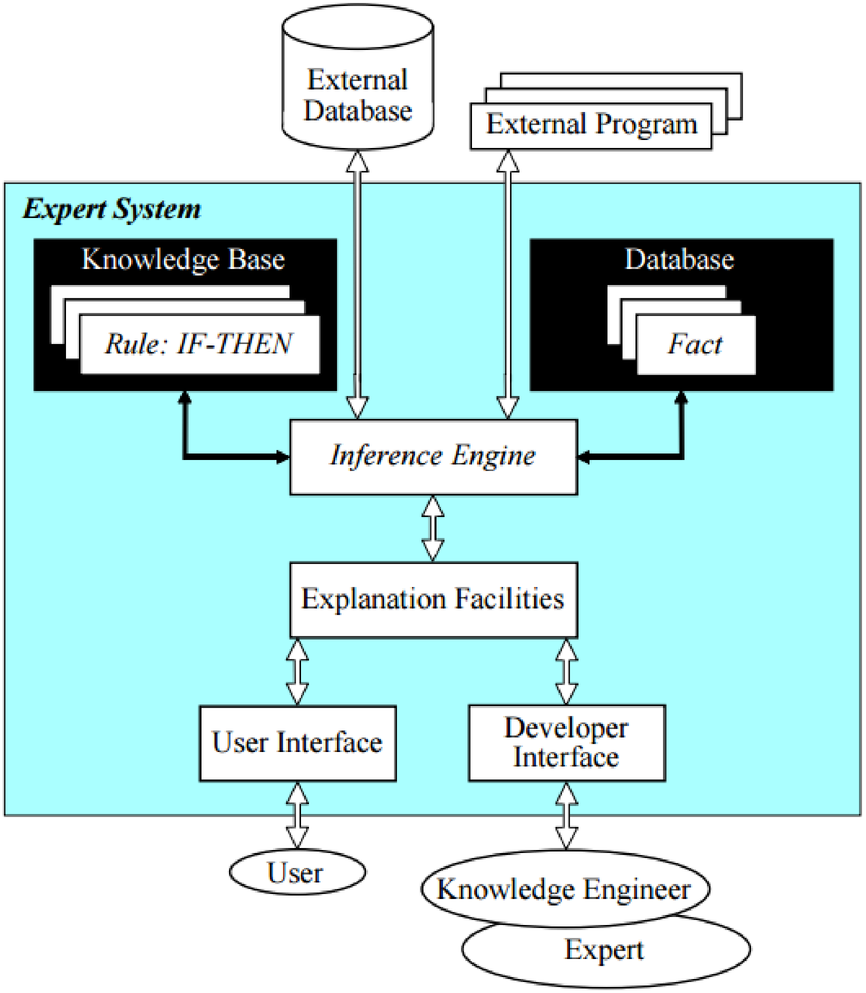
Main components of a Rule-Based System

- Set of rules
  - contains the general domain knowledge useful for problem solving
- Set of facts
- Inference Engine (carries out the reasoning, answers questions)
- Explanation Facilities (explains the reasoning - optional)
- User Interface



Source: Negnevitsky, Pearson Education, 2005

Complete Structure of a Rule-Based Expert System



Source: Negnevitsky, Pearson Education, 2005

Main components of an Interactive Rule-Based Expert Systems in Relation to Key Capabilities of an Intelligent System

Perceive

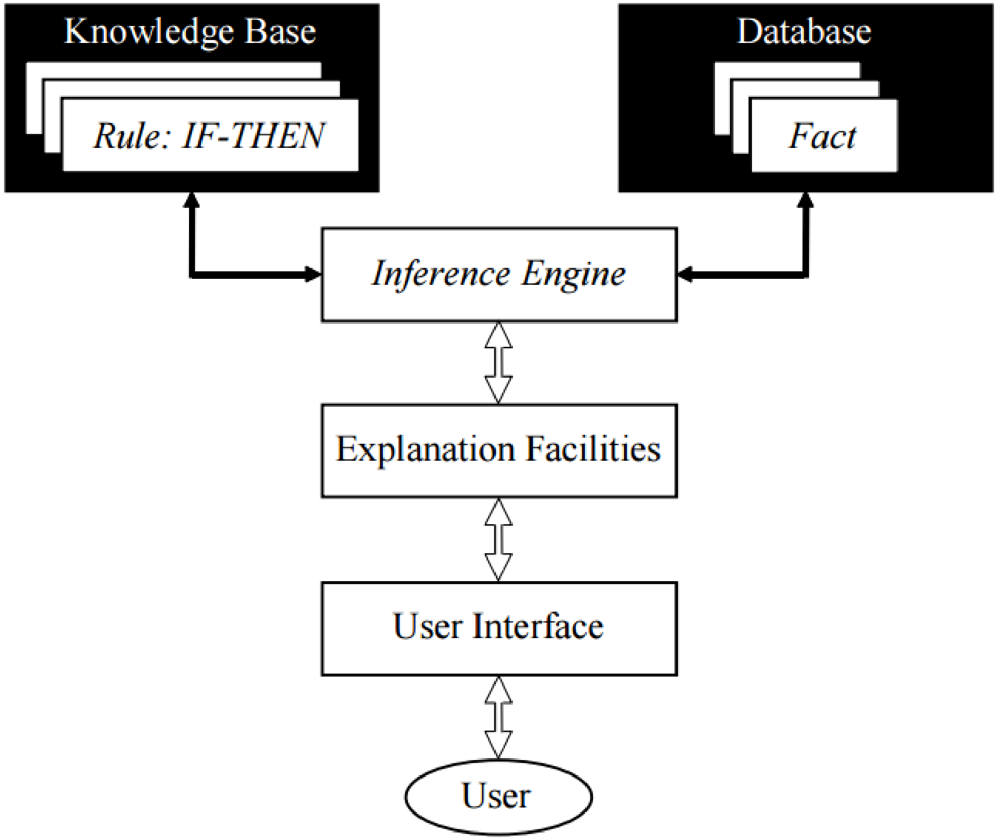
- User Interface
- Programmatic interfaces to external systems

Think

- Two types of memory:
  - Set of rules
  - Set of facts
- Inference Engine
- *Explanation Engine*

Act

- *User Interface*
- *Programmatic interfaces to external systems*



Source: Negnevitsky, Pearson Education, 2005

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Discussion

Discussion

Knowledge representation and reasoning

- Knowledge representation and reasoning are clearly separated
- Antecedents and evaluation of antecedents can in principle be arbitrary other knowledge representations and reasoning mechanisms

- Complex knowledge, including procedural knowledge ("how to ride a bike") can only be expressed to a limited degree in logic formalisms

Discussion

Knowledge engineering

- Rules are relatively easy to formulate and understand for humans – helpful when domain experts need to be involved in systems design and evaluation
  - But not all human is explicit – many experts are good at being experts, but not about explaining their knowledge and expertise
- Knowledge engineering may require a huge effort, the more complex the domain (“knowledge acquisition bottleneck”).

References

- Michael Creen and Simon Kendal. An Introduction to Knowledge Engineering. 2007.
- Michael Negnevitsky. Artificial Intelligence: A Guide to Intelligent Systems. 2004.
- Buchanan, B.B. & Shortcliffe, E.H. Rule-based Expert Systems. The MYCIN Experiments of the Stanford Heuristic Programming Experiment. http://people.dbmi.columbia.edu/~ehs7001/Buchanan-Shortliffe-1984/MYCIN%20Book.htm