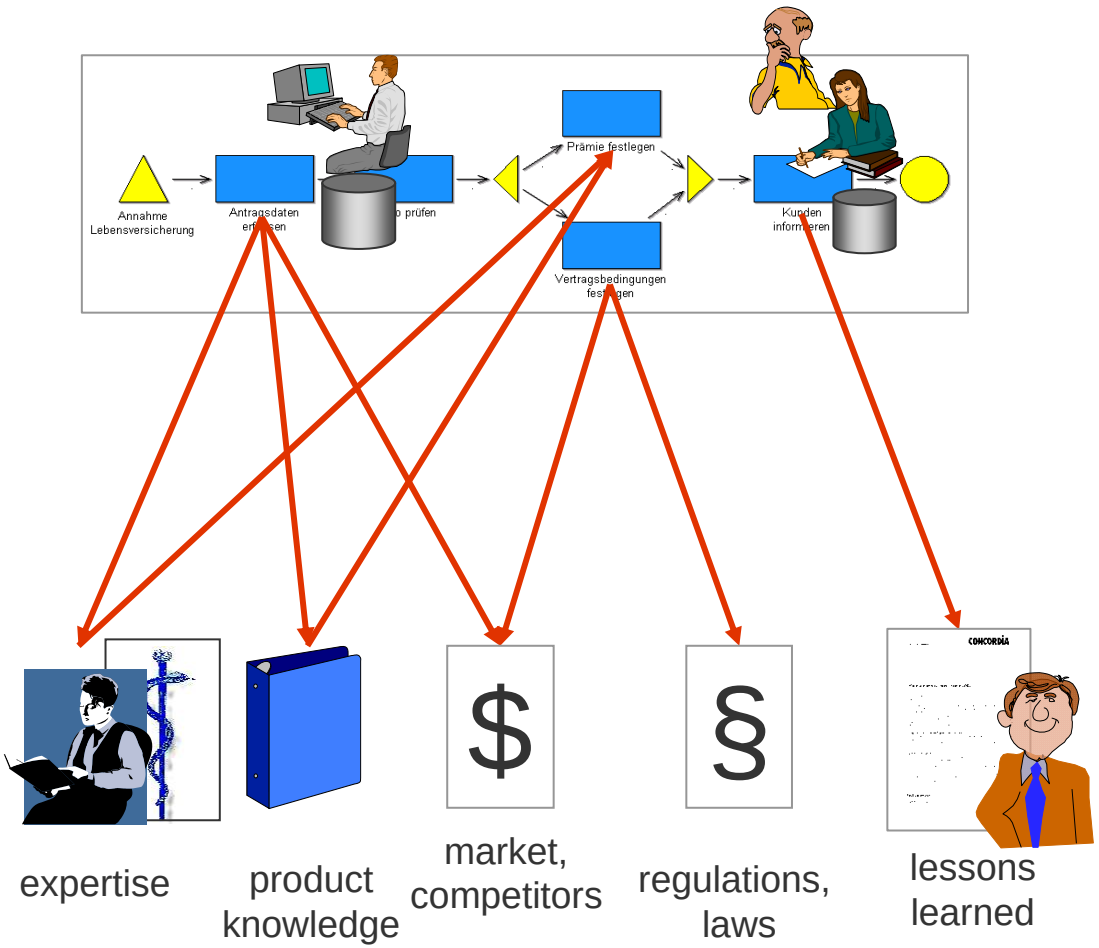
University of Applied Sciences Northwestern Switzerland
School of Business

Knowlege in Processes - Introduction to Knowledge-Based Systems

Starting Point: Knowledge and Processes



process knowledge

knowledge *about* processes:

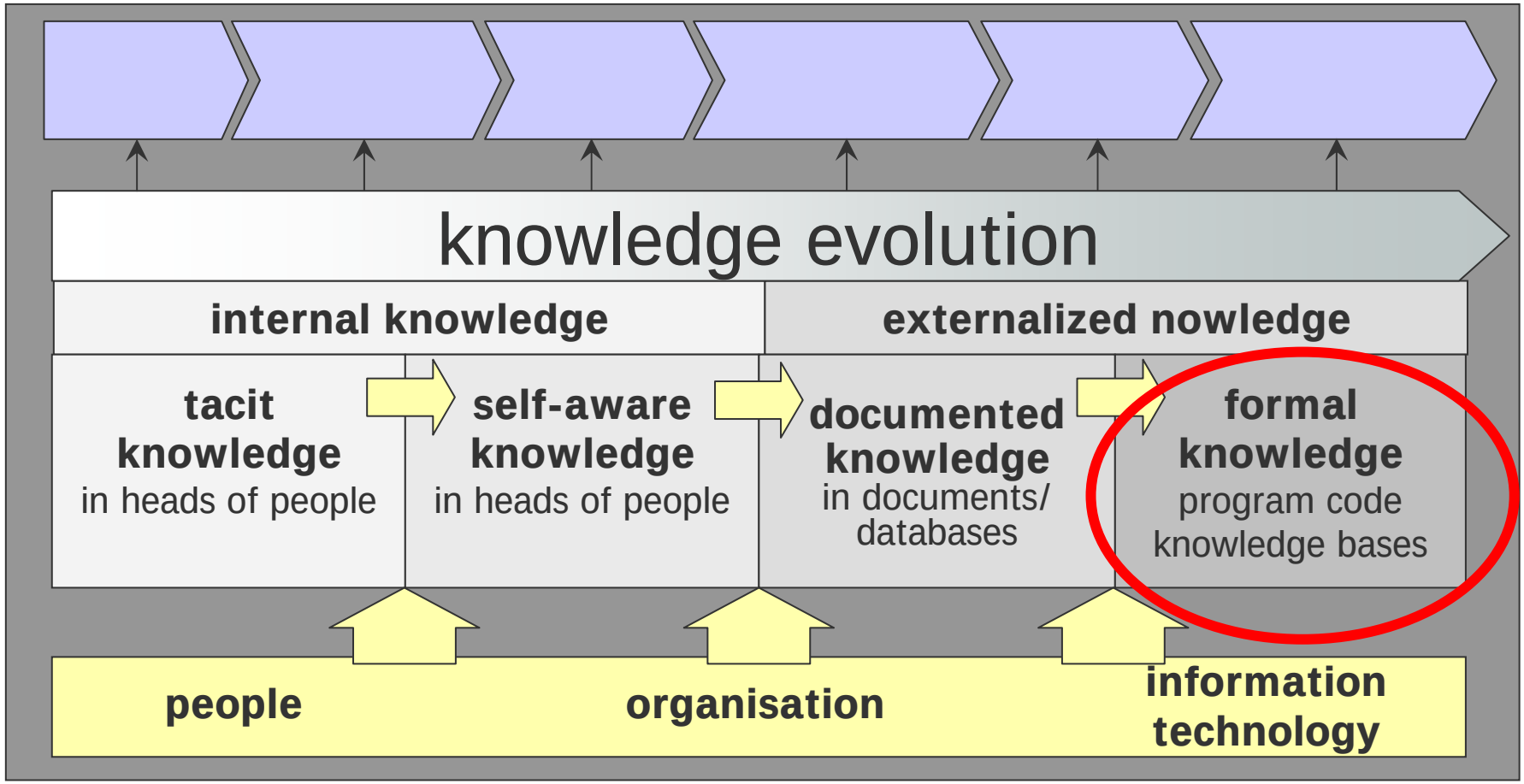
- workflow
- participants
- ressources

functional knowledge

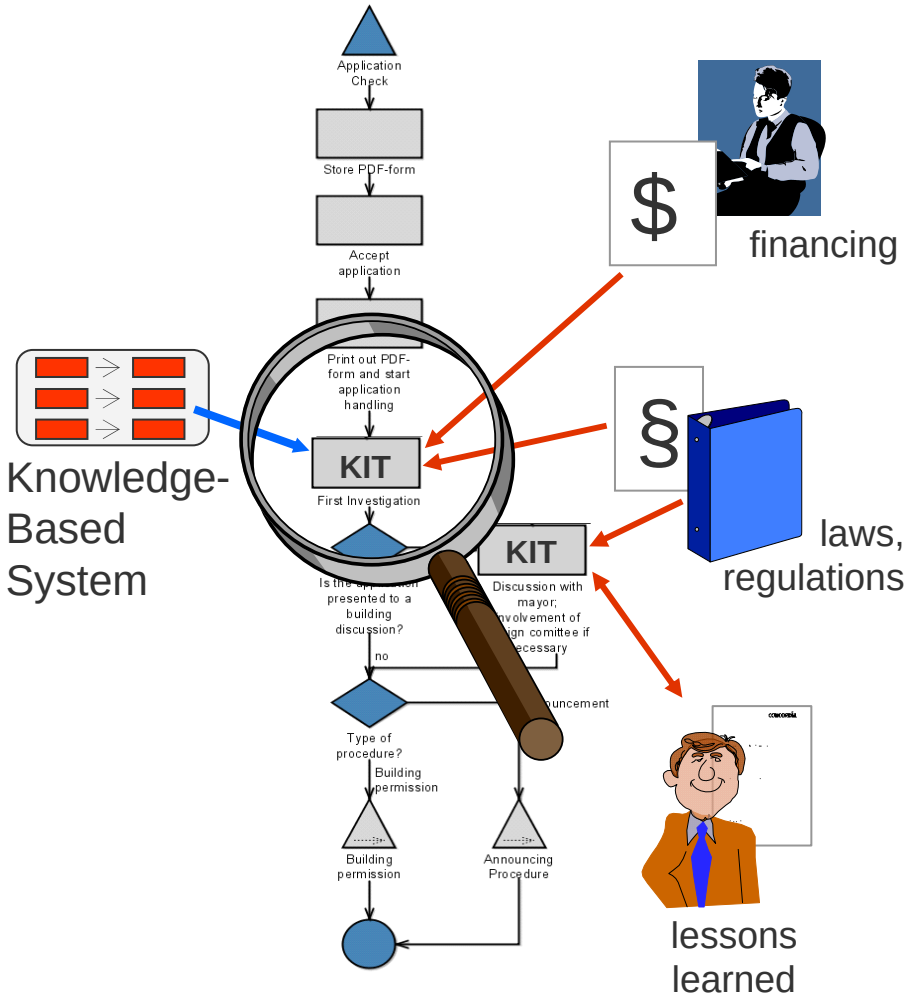
knowledge *in* processes:

- skills
- domain knowledge
- strategies

Knowledge in Enterprises



Knowledge Support of Processes



- Structured processes can contain knowledge work
- Support of Knowledge-Intensive Tasks (KIT) by …
  - … Identifying knowledgable people
    - Assign the task to employee with appropriate skills
  - … Intelligent Information Provision
    - Find documentation
  - … Knowledge-Based System (expert system) for
    - Decision making
    - Planning
    - Diagnosis
    - Problem solving

Application of Knowledge

Examples from the Car Rental Company

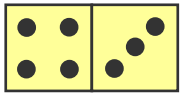
- Decision-Making
  - Choose between different offers for new cars
- Diagnosis/Problem Solving
  - Find the failure if the engine of the car does not start
- Configuration
  - Select equipment for new cars
- Planning
  - Scheduling of cars so that they are at the branch
- Information Retrieval
  - Find all documents with regulations about international drivers licences

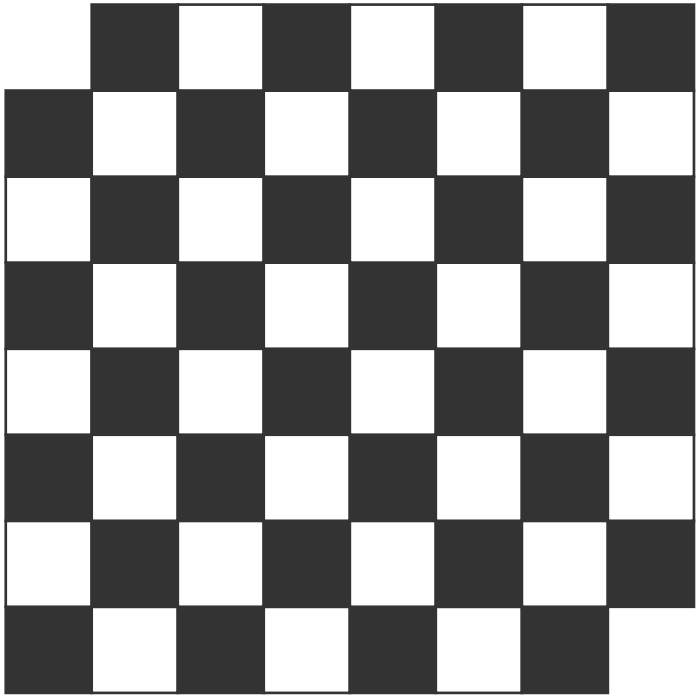
Expert Systems

- *„An Expert System is an intelligent computer program that uses knowledge and inference procedures to solve problem that are difficult enough to require human expertise for their solutions.“*
  (Feigenbaum 1982)
- The term „knowledge-based systems“ is often used synonym for „expert systems“. It makes clear that the system has an explicit knowledge base.

The Role of Knowledge in Problem Solving: Example

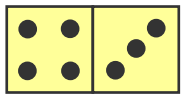
Placing a domino on a chess board

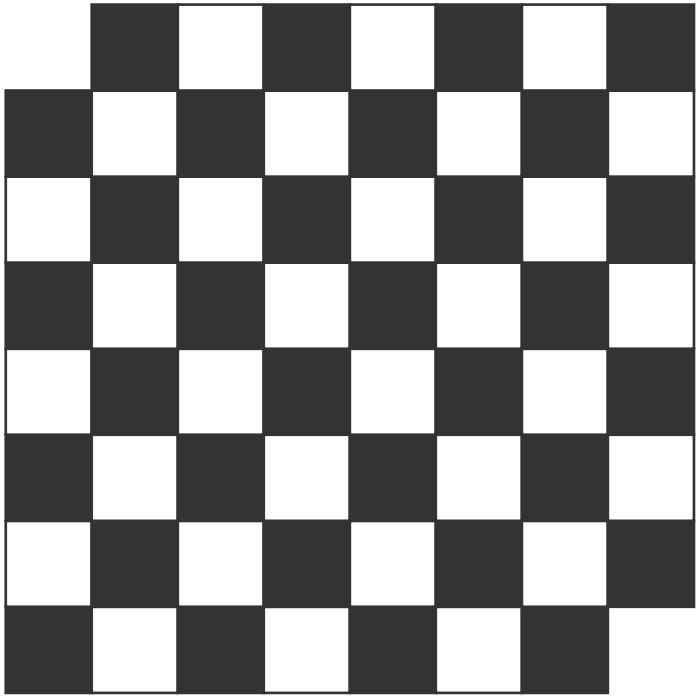




- Given a chess board where two opposite corners are missing
- A domino covers two adjacent field
- Is it possible to cover all fields of the board with dominos?

Possible Solution Approaches





- Solution 1: Exhaustive Search

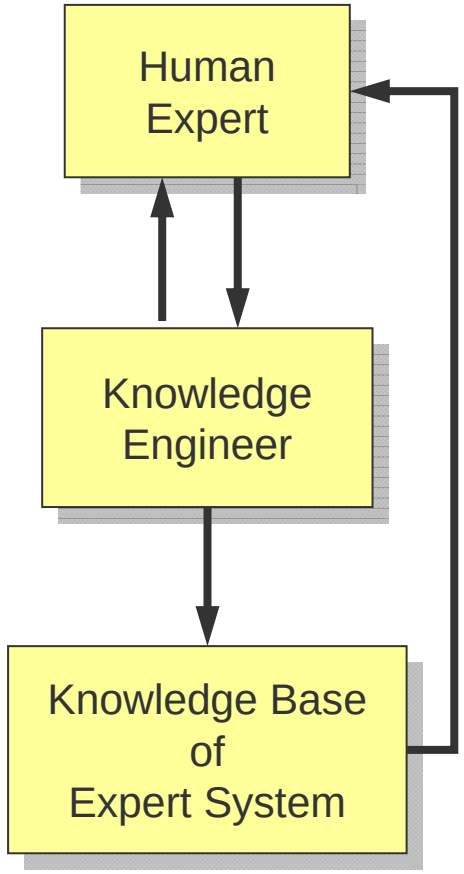
  Check all possibilities to put dominos on the board. Stop when all fields are covered or all possibilities failed.

- Solution 2: Heuristics

  Prune the search: Try only promising paths which seem to lead to a (good) solution.

- Solution 3: Knowledge

Knowledge Engineering



- Knowledge Engineering is the process of
  - building and
  - maintaining

  knowledge-based systems or intelligent agents
- *"Knowledge Engineering is an engineering discipline that involves integrating knowledge into computer systems in order to solve complex problems normally requiring a high level of human expertise."*[1)]
- Sources of knowledge
  - Human experts
  - Documentation

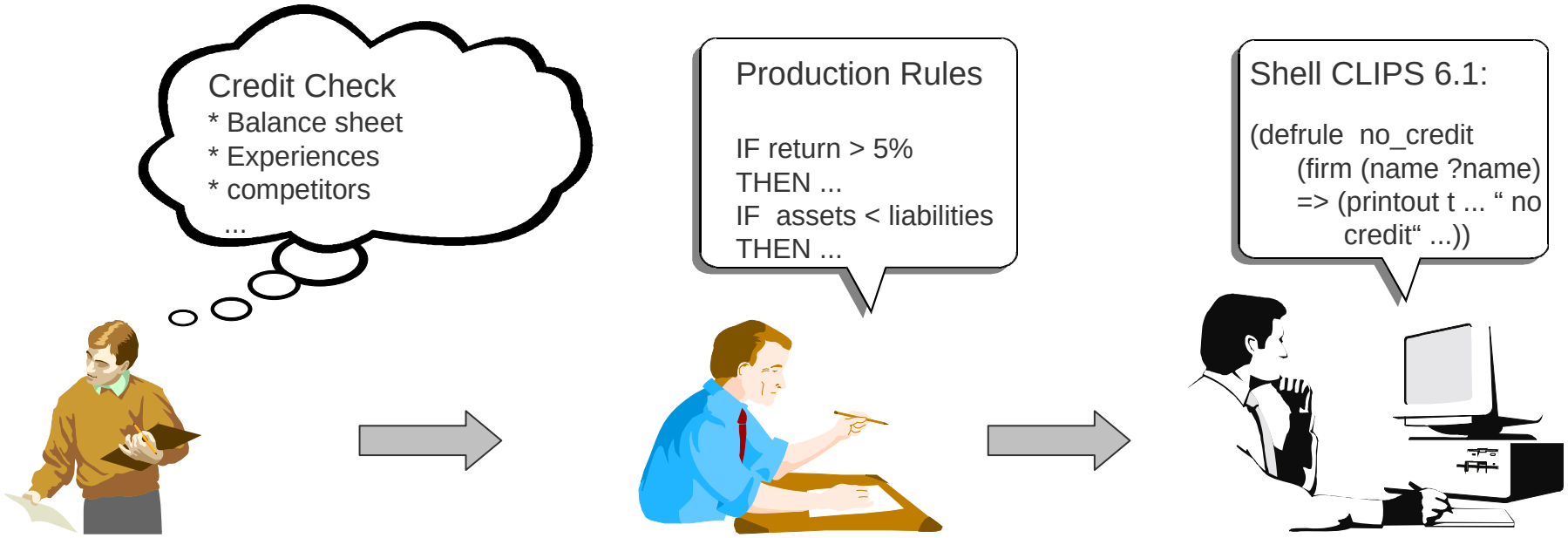
1) Feigenbaum, E., and P. McCorduck. (1983). The Fifth Generation. Reading, MA: Addison-Wesley

Knowledge Layers

Knowledge can exist on different layers:

- Cognitive layer:
  colloquial statement of thoughts; problems are getting modelled, but still not formalised.
- Representation layer:
  Formalisation of thoughts in a representation formalism (e.g. production rules, logic, ontologies)
- Implementation layer:
  Formalisation has progressed so much, that the reasoning is possible on a computer (e.g. realisation of a Prolog programme).

Layers of Knowledge-Based Systems



Cognitive Layer

Formulation of thoughts - Not formally modelled

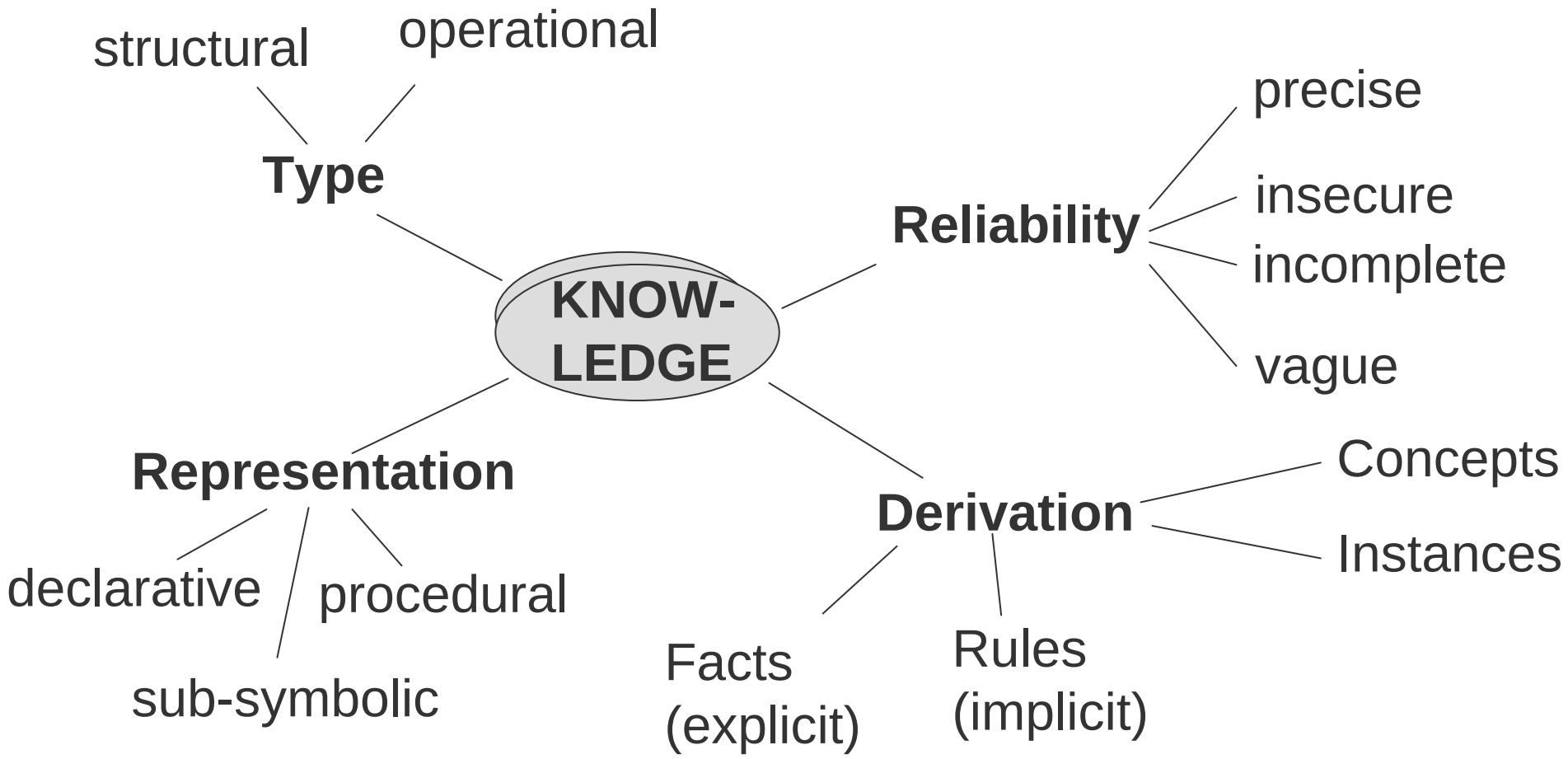
Representation Layer

Selection of a representation formalism

Implementation Layer

Selection of a software tool

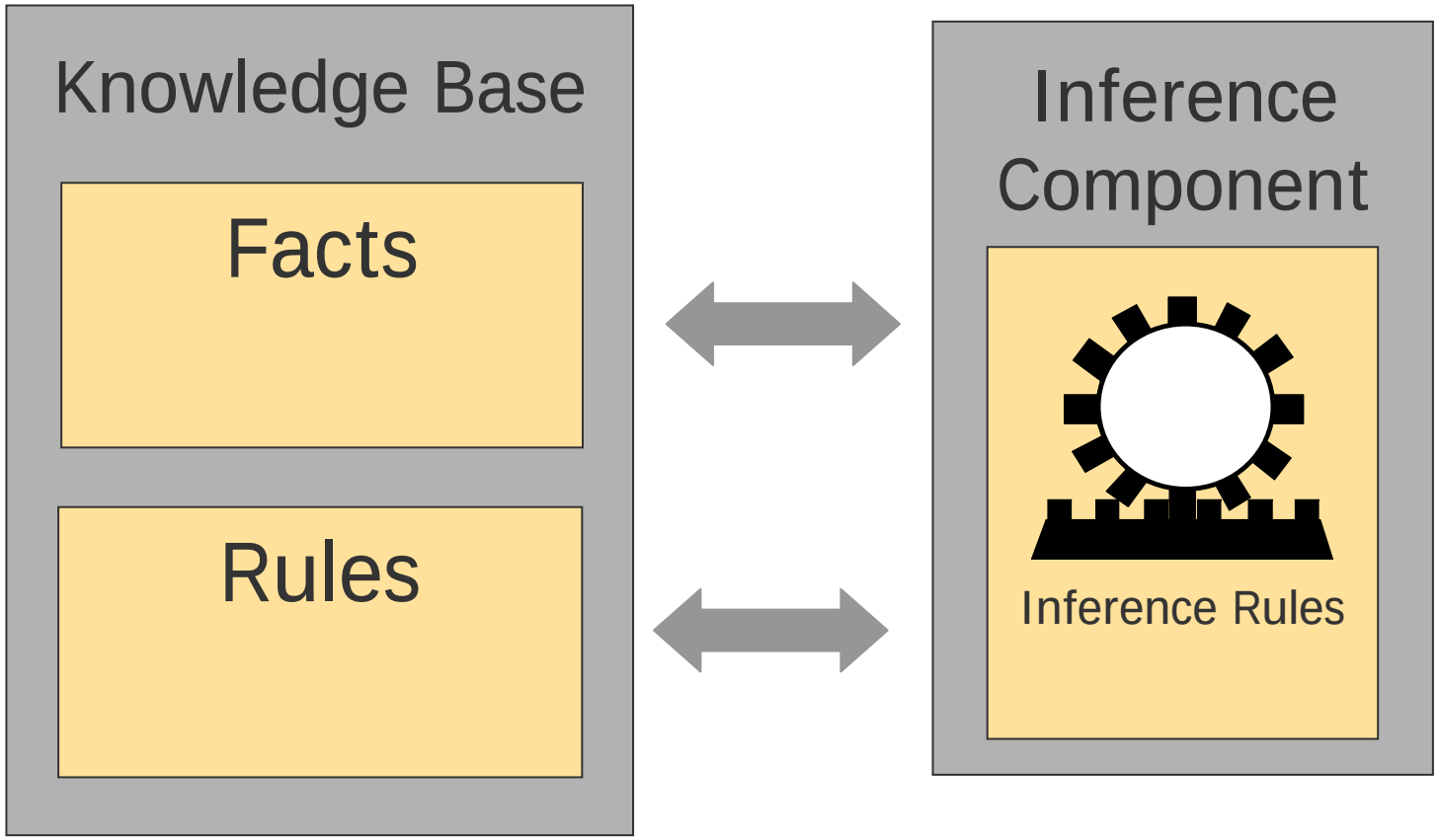
Classification of Knowledge



Reliability of Knowledge

- Exact knowledge:
  - „It is raining."
- Uncertain knowledge:
  - „I believe it will not rain tomorrow.“
- Incomplete knowledge (knowledge not complete, but strongly delimitated):
  - „The temperature ist between 10 and 15 degree Celsius“
- Vague knowledge (interpretation-dependent knowledge):
  - „The weather is good."

Knowledge-Based Systems



Facts and Rules

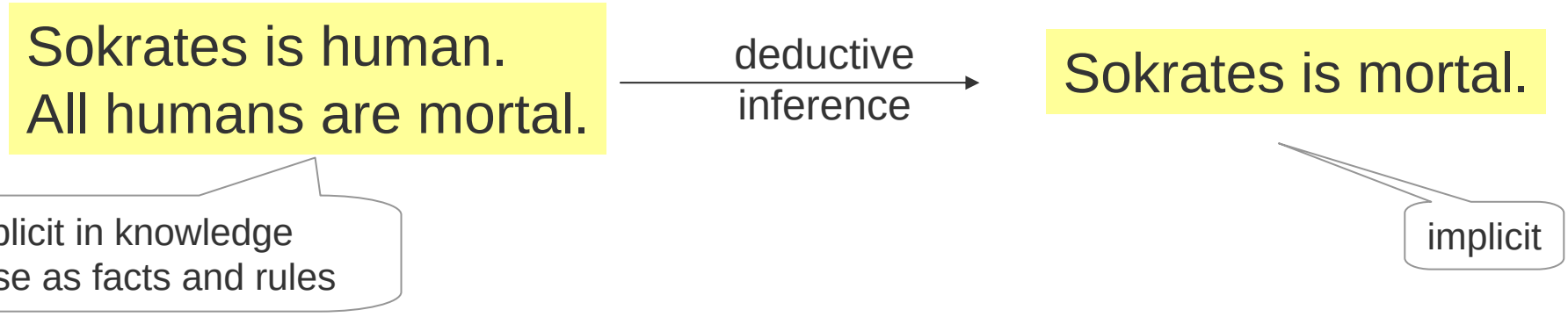
- Facts: statements about reality (explicit knowledge)
- Rules: General proposition about relations or procedure that are valid under specific conditions (e.g. in an „if ... then“-form“)

Examples:

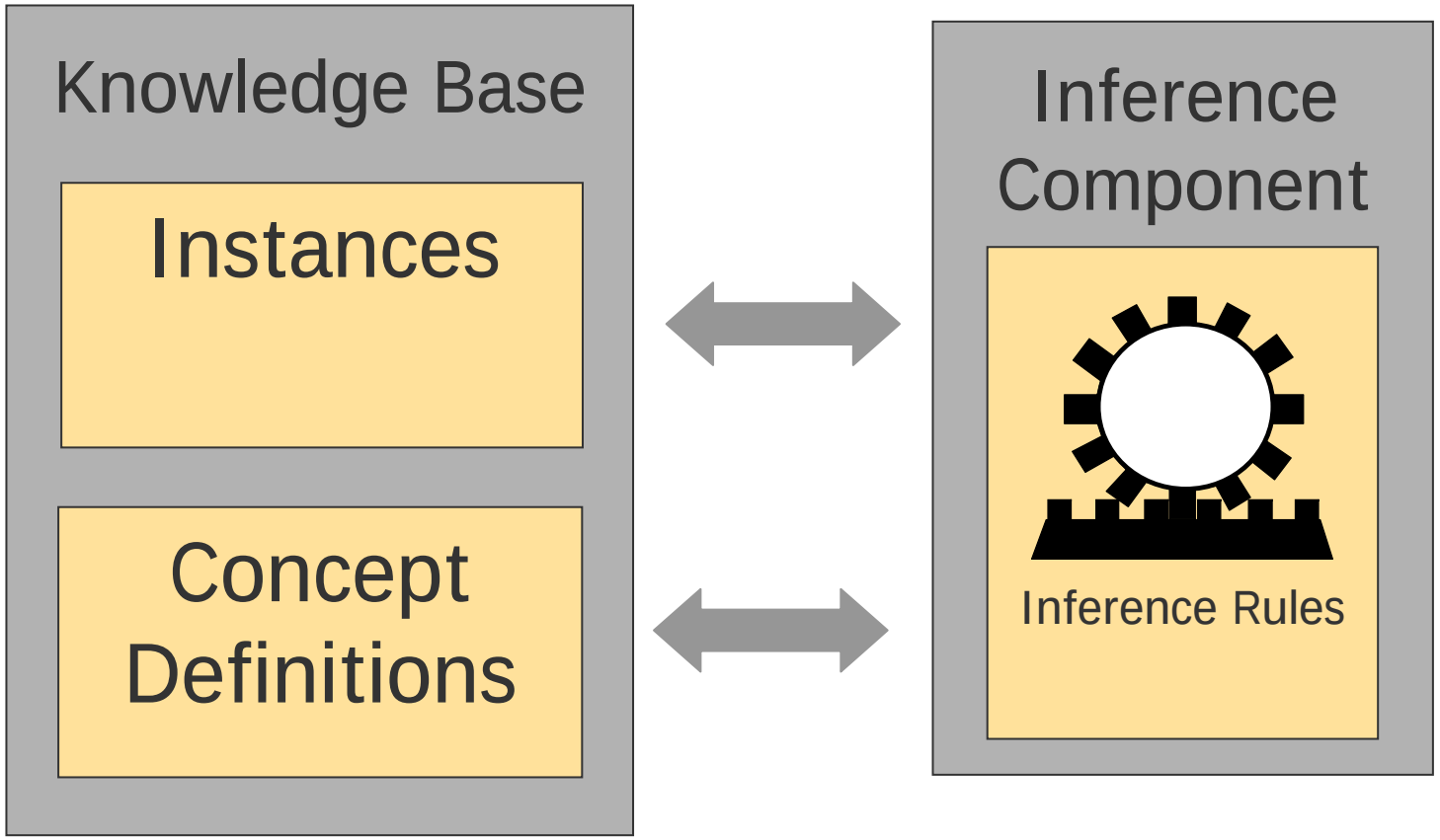
- Fact:
  - Socrates is human
- Rule:
  - All humans are mortal

Derivation

- Explicit knowledge:
  - knowledge which is filled away in the knowledge base
- Implicit knowledge:
  - not explicitly stated in the knowledge base
  - is determined from facts by application of rules
- *Derivation = Inference = Reasoning*
  - New knowledge is generated from existing one: Making implicit knowledge explicit



Knowledge-Based Systems (Concepts and Instances)



Types of Knowledge

- Instances: statements about reality
- Concepts: General proposition about relations that are valid under specific conditions

Examples:

- Instance:
  - Socrates is human
- Concept:
  - Humans are specialisations (is-a) of Mortal Beings

Derivation

- Explicit knowledge:
  - knowledge which is filled away in the knowledge base
- Implicit knowledge:
  - not explicitly stated in the knowledge base
  - is determined from facts by application of rules
- *Derivation = Inference = Reasoning*
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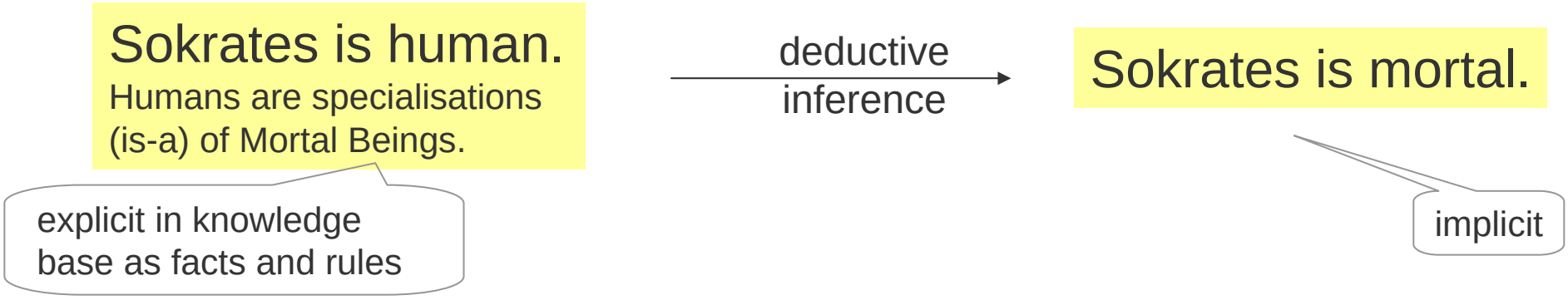


Structural vs. Operational Rules

- Rules can represent structural and operational knowledge (in the sense of SBVR)
  - Structural: True by definition
    - It is necessary that …
    - It is impossible that …
    - It is possible that … only if …
    - Example: **It is necessary that an Employee is a person**
  - Operational: govern what the business does
    - It is obligatory that …
    - It is prohibited that ….
    - It is permitted that … if …
    - Example: **It is obligatory that an Employee who is a manager gets a bonus**

Example of a Knowledge Base

Facts

Employee(john_smith)
Employee(mary_baker)
Manager(mary_baker)

Rules

Employee(X) → Person(X)
Employee(X) AND Manager(X) → GetBonus(X)

- The facts represent explicit knowledge
- The rules can be used to derive knowledge that is implicit in the facts and rules:
  - All persons that get a bonus
- The second rule represents operational knowledge because bonus is not given by definition (remember SBVR: operative rules, enforcement)
- The facts and rules are declarative: simply logic

Predicate Logic: $\forall x\ \text{Employee}(x) \rightarrow \text{Person}(x)$
$\forall x\ \text{Employee}(x) \wedge \text{Manager}(x) \rightarrow \text{Bonus}(x)$

Example of a Knowledge Base

Facts

Father(peter)

Mother(mary)

isFatherOf(peter,mary)
isFatherOf(peter,john)
isMotherOf(mary,mark)
isMotherOf(jane,mary)

Rules

isFatherOf(X,Y) AND isFatherOf(Y,Z) → isGrandfatherOf(X,Z)
isFatherOf(X,Y) AND isMotherOf(Y,Z) → isGrandfatherOf(X,Z)
isMotherOf(X,Y) AND isFatherOf(Y,Z) → isGrandmotherOf(X,Z)
isMotherOf(X,Y) AND isMotherOf(Y,Z) → isGrandmotherOf(X,Z)
isFatherOf(X,Y) AND isFatherOf(X,Z) → isSiblingOf(Y,Z)
isMotherOf(X,Y) AND isMotherOf(X,Z) → isSiblingOf(Y,Z)

The rules can be used to derive information that is implicit in the facts and rules:

- Derive all grandparent and sibling relationships (forward chaining)
- Answer questions about relationships (backward chaining)

These rules are structural (in the sense of SBVR): true by definition

Alternative Representation of a Knowledge Base

Instances

Father(peter)	isFatherOf(peter,mary)
	isFatherOf(peter,john)
Mother(mary)	isMotherOf(mary,mark)
	isMotherOf(jane,mary)

Concept Definitions

Parent $\subseteq$ Father OR Mother

Grandfather $\subseteq \exists$isFatherOf.($\exists$isFatherOf)

Grandfather $\subseteq \exists$isFatherOf.($\exists$isMotherOf)

Grandmother $\subseteq \exists$isMotherOf.($\exists$isFatherOf)

Grandmother $\subseteq \exists$isMotherOf.($\exists$isMotherOf)

Declarative vs. Procedural Knowledge

- *Declarative knowledge*: The semantics of the knowledge is independent of an inference engine
- *Procedural knowledge*: The representation of knowledge has non-logic elements, e.g. representing actions, updating knowledge

if a car reaches a traffic light
and the traffic light has switched to red
then hold at the stop line

if account balance is X
and deposit is Y
then account balance = X + Y

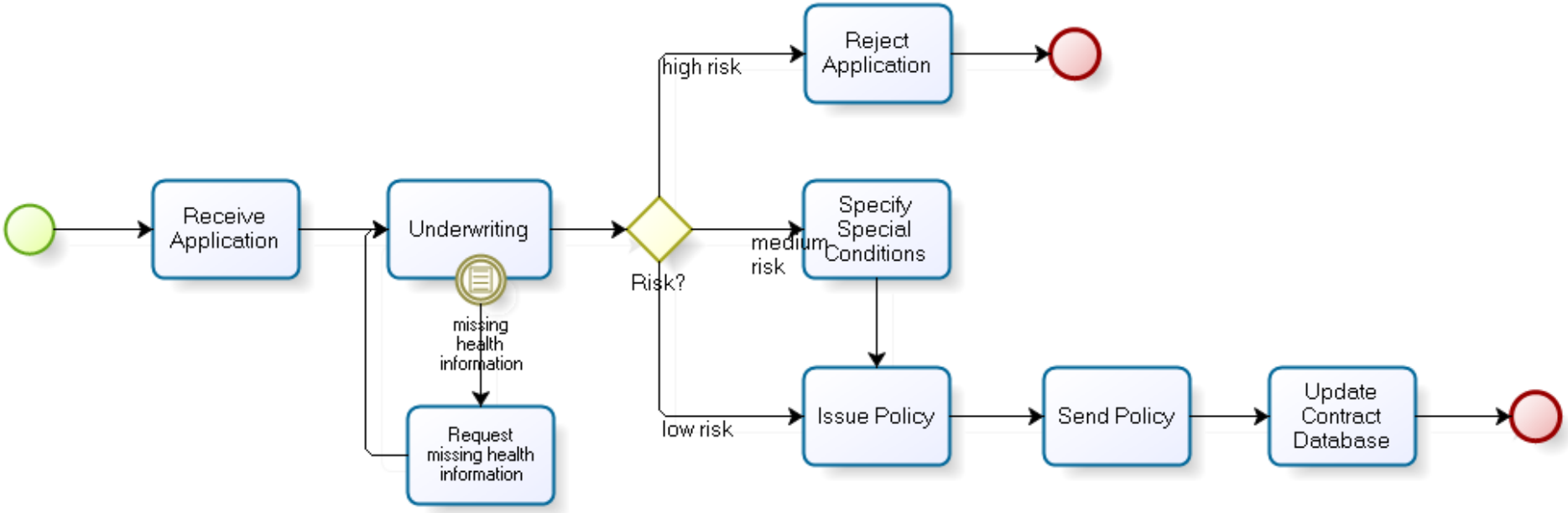
if X is employee of company Y
and X quits jog
then delete (X is employee of company Y)

Paradigms of Knowledge Processing

- Symbolic Systems:
  - Logic Systems:
    - Representations: logical formulas
    - Derivation of knowledge: Inference (Deduction)
  - Non-Logic Systems:
    - Representations: condition-action rules
    - Derivation of knowledge: Inference
  - Fuzzy Systems:
    - Representation: linguistic formulated knowledge
    - Derivation of knowledge: Approximate conclusion
- Subsymbolic Systems:
  - Neural Networks
    - Representation: units, weights between units
    - Derivation of knowledge: Connotation

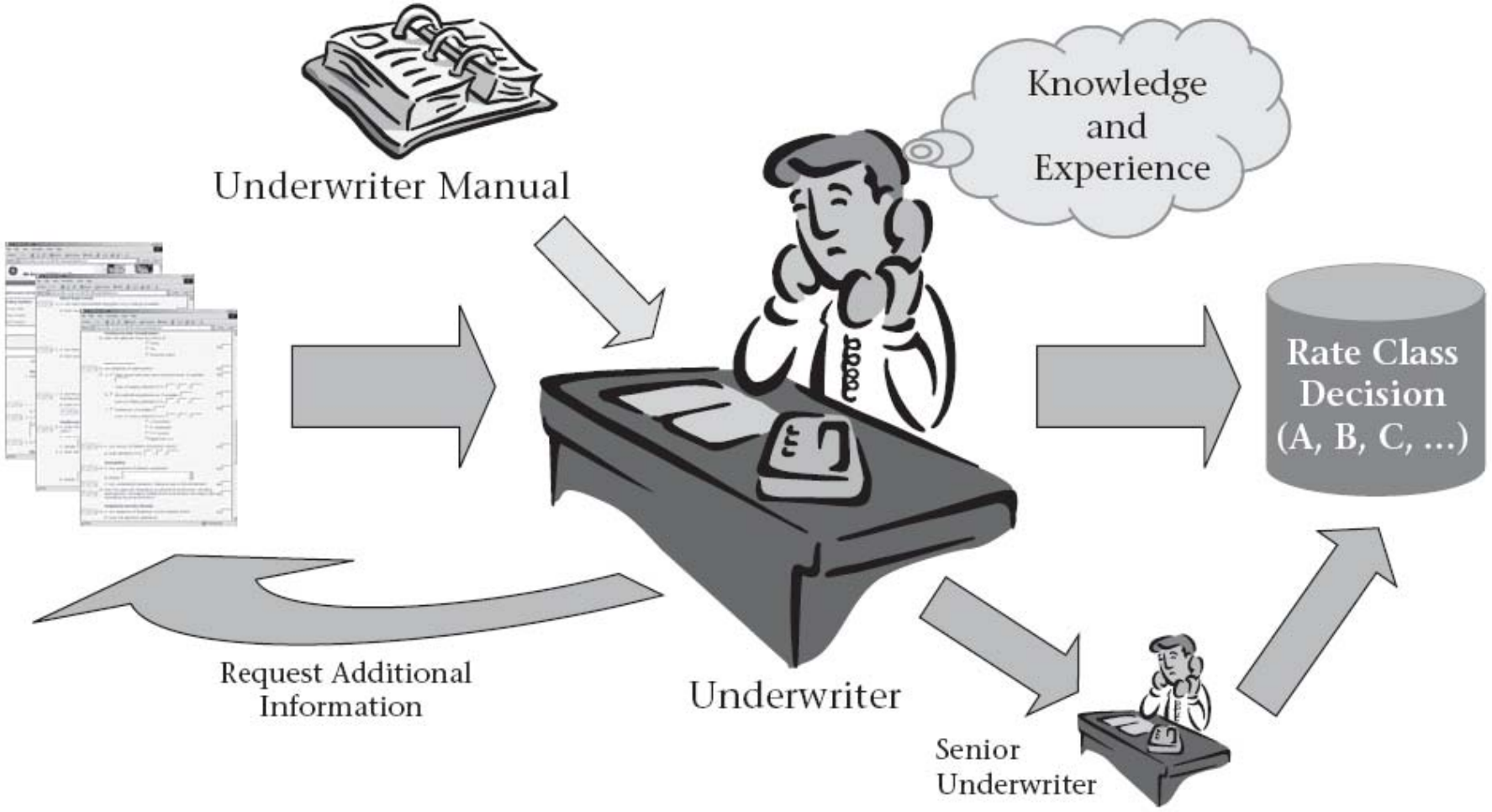
Example: Application for Health Insurance

- Medical Underwriting for Life Insurance is a knowledge-intensive tasks in a structured process of dealing with applications for health insurance



Example: Underwriting of Insurance Applications

Manual Underwriting Process



Manual Underwriting Process

- The LTC underwriting process begins when a paper application (APP)
- The APP is scanned into an electronic data warehouse.
- Underwriters located throughout the country view these scanned documents online, and then rate the risk of insuring each person.
- If the underwriter has any concerns, he can request additional information from the applicant via a Phone Health Interview (PHI) and/or a Face-to-Face (F2F) interview, resulting in the submission of additional paper forms
- An underwriter can also request a copy of the applicant's medical history from their primary physician (Attending Physician Summary APS)
- An underwriter can make a decision at any point they feel they have sufficient information.
- If they have any questions or concerns, they can refer cases to a senior underwriter.

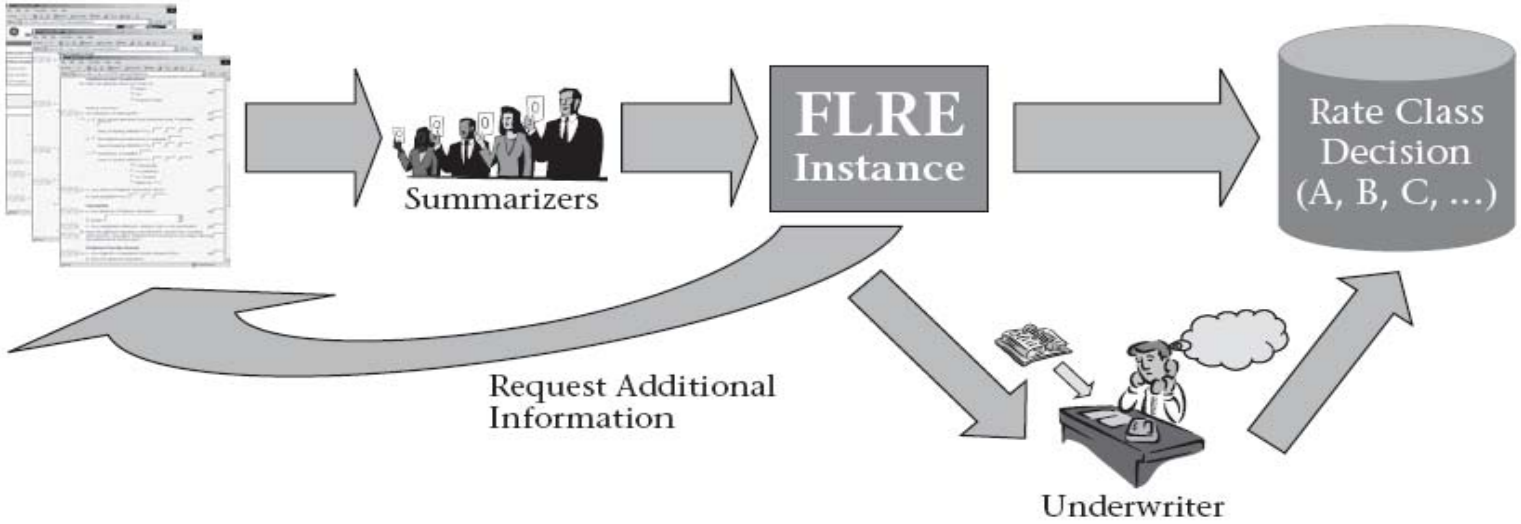
Decision Making in Underwriting

- Underwriters make decisions following guidelines specified in an underwriter manual.
- They also rely upon extensive medical knowledge and personal experience when underwriting cases.
- Problem:
- The reliance upon their own experience and judgment causes inconsistency across the underwriters, resulting in inaccurate rate classifications.

Automated Underwriting

- Supporting Underwriting has been an application for knowledge-based systems for many years
- In the following we look at an example to automate underwriting of Long Term Care and Life Insurance applications
- The system has been in production since December 2002
- In 2005 it completely automated 19.2% of the LTC applications
- Source:
  Aggour, K. S., Bonissone, P. P., Cheetham, W. E., & Messmer, R. P. (2006). Automating the Underwriting of Insurance Applications. *AI Magazine*, *27*(3), 36-50

Automated Underwriting Process



- Medical Summarizers view applications and fill web-based forms
- FLRE (Fuzzy Logic Rule Engine) = Digital Underwriter
  - Codification of unterwriter rules
- Three decisions done by the FLRE
  - Rate class of the application
  - Whether or not to order additional information
  - Whether or not to send the case to a human underwriter for review

Challenges for Automating Unterwriting

- Use of personal knowledge and experience to make decisions automatically
  - Knowledge elicitation
- Input to the process (application, attending physician summary APP, summaries) contains free text
  - Natural Language Understanding

Excursion: Natural Language Understanding

- Problems with natural Language Understanding:
  - There can be multiple expressions for the same statement
    - Word level: Synonyms
    - Sentence level: different formulations
  - A sentence can have multiple

    „Time flies like an eagle"

    „John saw the boy in the park with a telescope"

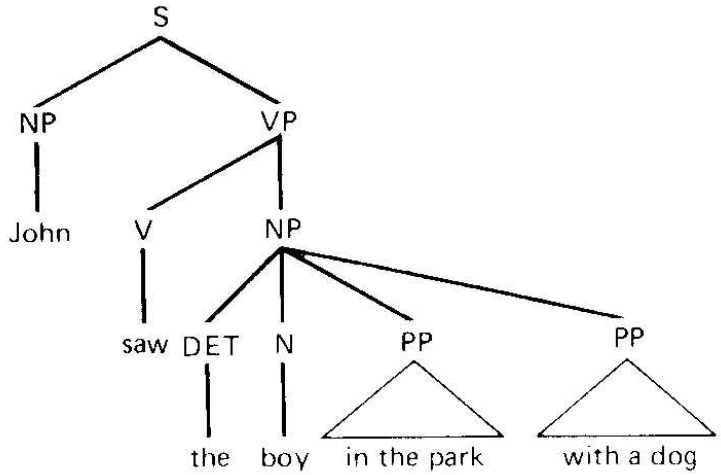
    „John saw the boy in the park with a statue"
- Understanding natural language requires knowlege about
  - language (**Syntax** – grammar rules)
  - domain (**Semantics -** knowledge about the meaning of terms)
  - conventions about language use (**Pragmatics**)

    " Do you know the time?“ → request to tell the time

Excursion: Example

Same sentence structure but different interpretations:

John saw the boy in the park with a dog.



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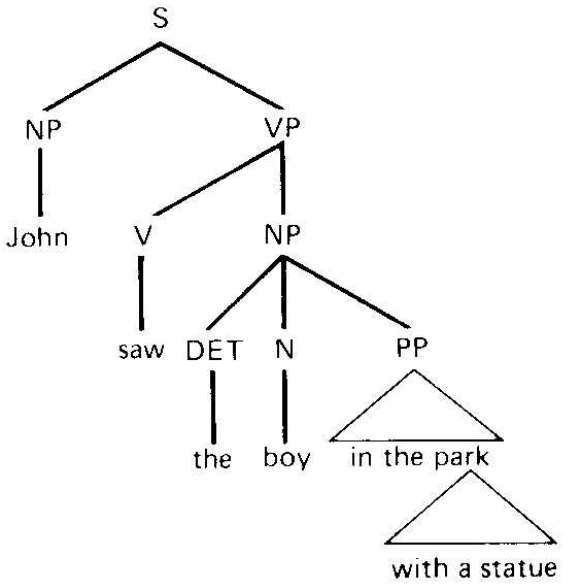

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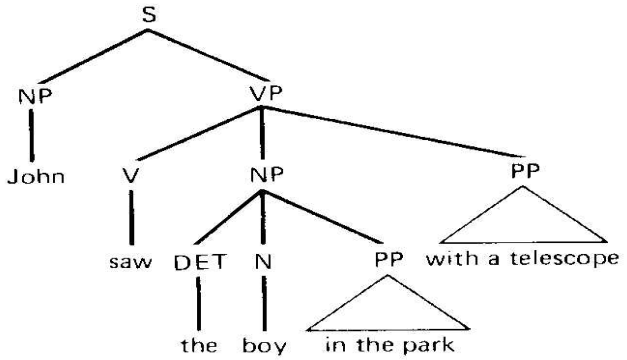


Natural Language Processing

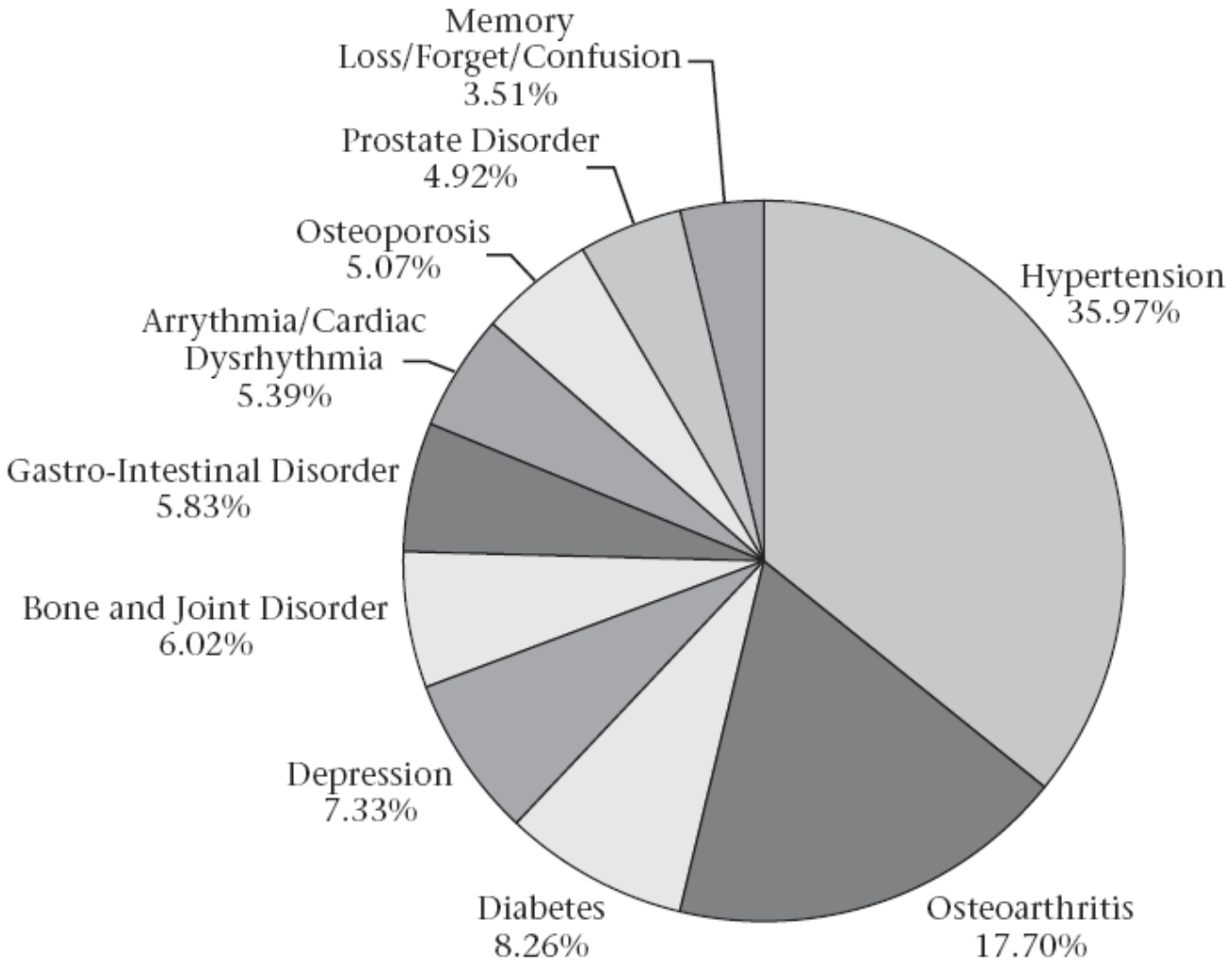
- Objective: determine if the text entered by the summarizers is benign
  - If text entries could be interpreted and classified as benign, the level of automation could be increased.
- A grammar was constructed for benign text and lists were created for:
  - Noise words and in-phrase characters (Noise)
  - Phrase separators (Separator)
  - Benign words or synonyms (Benign)
  - Dates in various formats (Date)
- Statistical Approach: Learn benign words and phrases
- The current grammar for benign text is:
  - **BenignText:**
    - BenignPhrase [Separator [BenignPhrase]]*
  - **BenignPhrase:**
    - [Noise]* [Benign [Noise]* [Date [Noise]*]

Part of an APP Summarization Form

Yes	No		
○ Y	○ N	1. Are you covered by Medicaid (not Medicare)?	
○ Y	○ N	2. Do you use a Walker or Wheel chair; Oxygen; Respirator; or Kidney Dialysis; or need assistance or supervision by another person in performing any of the following: Moving in/out of bed or chair; Bathing; Dressing; Eating;Toileting;Bowel/Bladder control; Walking?	
○ Y	○ N	3. Have you had, do you currently have, or have you ever been medically diagnosed as having any of the following:	
		☐ Acquired Immune Deficiency Syndrome (AIDS)	☐ Emphysema/COPD in combination with any of the following: current smoking, Congestive Heart Failure (CHF), Asthma, or Chronic Bronchitis
		☐ AIDS Related Complex (ARC)	☐ Frequent or persistent Forgetfulness
		☐ ALS (Lou Gehrig's Disease)	☐ Memory Loss
		☐ Alzheimer's Disease	☐ Metastatic Cancer (Spread from original site/location)
		☐ Congestive Heart Failure (CHF) in combination with any of the following: Heart Attack or Angina;	☐ Multiple Sclerosis (MS)

☐ Positive HIV test
☐ Senility
☐ Stroke
☐ Transient Ischemic Attack (TIA) within the past 5 years
☐ TIA in combination with Diabetes or Heart Surgery

Relative Frequency of Impairments



Underwriter Assist Screen

Applicant Information Exit

Policy Number		**PI/SP :**	**SP**		
Name :		**Age :**	47		
Application Type:	Preferred	**Employment Status:**	Does Not Work	**Smoking Status:**	Non-Smoker
App Height:	5 ft. 10 in.	**Weight:**	175 lb.		
PHI Height:	NA	**Weight:**	NA	**DWR:**	09
MRR Height:	NA	**Weight:**	NA	**Date:**	03/22/2004

Engine Results Summary

Date/Time	Engine	Recommendation	Routing	Requirements
03/22/2004 12:20:54	APP	PREFERRED	UW	NA
0	PHI	NA	NA	NA
0	HTN	NA	NA	NA
0	DM	NA	NA	NA
03/23/2004 05:23:05	OA	STANDARD	UW	NA
0	OP	NA	NA	NA
0	GENERAL	NA	NA	NA
03/23/2004 10:12:02	Finals	STANDARD	UW	NA

Recommendations made by different engines (one line per FLRE instance)

Underwriter Assist Screen

Details about rules that caused the rate class recommendation

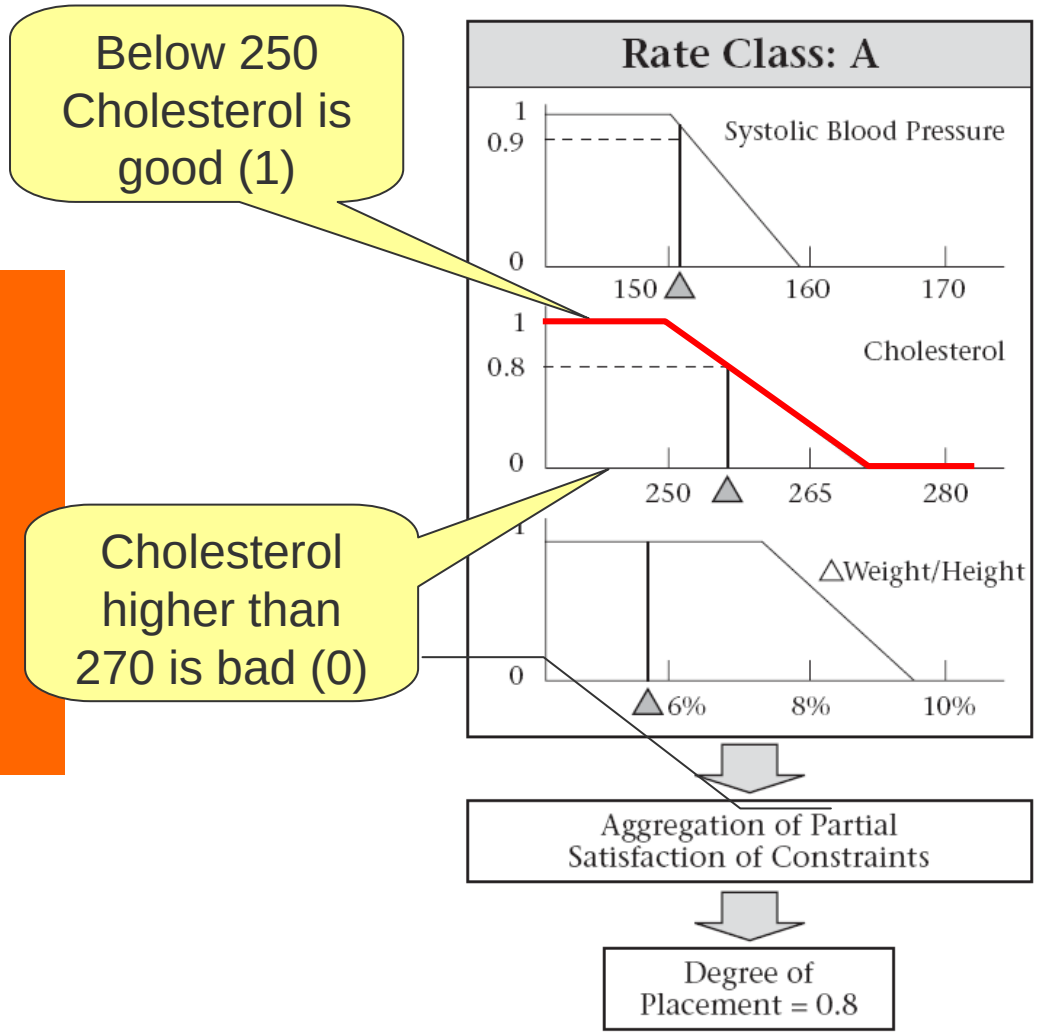
APP

Underwriting Reason	Value	English Rule	Guideline	Source
Prescription_1	NA	Applicant takes a prescription	PDF	pg 2
Speciality_Not_Stated	NA	Speciality not stated	PDF	pg 10
Other_Dr_Reason_Visit_1	NA	Unknown reason for a doctor's visit	PDF	pg 1

Osteoarthritis

Rate Class Reason	Value	English Rule	Guideline	Source
Prescription_Use	NA	Applicant takes a non-narcotic prescription for OA	PDF	pg 7
Joint_Replacement_Discussed	NA	Doctor discussed joint replacement surgery with applicant	PDF	pg 7
COX2_Use	NA	Applicant takes a COX2 inhibitor	PDF	pg 8

Vague Knowledge: Fuzzy Logic Rule for Classification



- Underwriting relies on vague knowledge
  - when is cholesterol good or bad
  - what is a high blood pressure
- Fuzzy logic rules are used to encode underwriting standards.
- Fuzzy logic is a superset of conventional Boolean logic for vague knowledge:
  - Instead of have only two values (true/false) it can express intermediate truth values