Knowledge in IT

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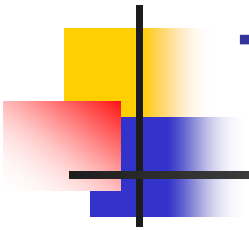
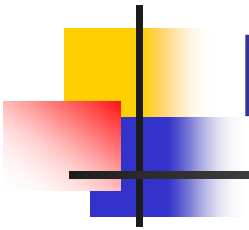


Three examples of KS‘s

- OTTER/EQN proves Robbins‘ conjecture
  - from 1930‘s, achieved in 1996
  - this knowledge system (KS) knows algebra and boasts an efficient reasoning engine
- Halo passes AP chemistry examination
  - in 2003, first step towards „Digital Aristotle“ for tutoring and research assistance
- GeneSim offers therapy against cancer



Plan of Talk

- Knowledge (K), representation, and operations
- Knowledge systems (KS) technology
- Potential of KSs for coping with complexity and for solving problems
  - modeling and theory formation from massive data
- Perspective for benefit of humankind

Knowledge (K): Cognitive View

- Concept of K difficult to define
  - in essence a psychological capacity
  - store, retrieve, relate, generalize, communicate information
  - my garden, birds fly, Pythagoras‘ theorem, scientific laws, web protocol, melodies
  - declarative vs. operative knowledge (skills)
- Evolutionary product for coping with complexity of the world

K, Representation, Reality

- Frege 1892: Sinn (sense) & Bedeutung (reference)
- Intensional & extensional semantics
- Melody: c‘, c“, g‘ (representation)
  - cognitive phenomena, physical signals
- Extensional semantics problematic:
  the cognitive phenomenon?
  the physical signals?

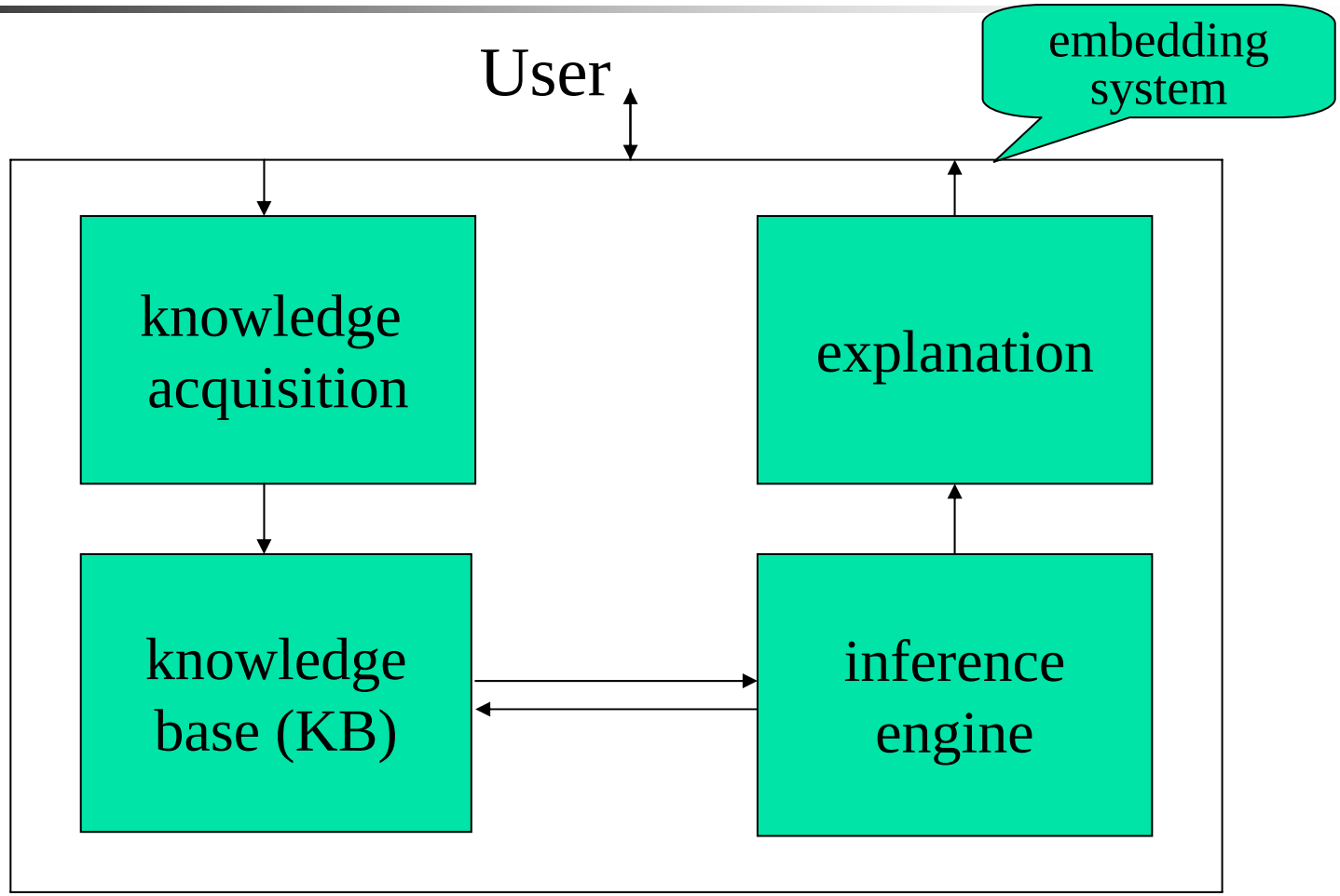
Knowledge Operations

- Storage and retrieval
- Logical reasoning, form of compression
  - cognitive – linguistic or formal
  - represented K based on ontology
  - semantic relation: $K_0 \models K_1$
  - syntactic relation (calculi): $K_0 \vdash K_1$
  - complications like imprecision, probabilism, state changes, etc:
    > *widely studied but not finally settled*

Evolution of Incorporating Knowledge in IT

- Knowledge buried in program code
- Knowledge management phase (KMS)
- Now entering meta-knowledge phase
  - reasoning, data-mining, learning, theory formation, discovery, problem solving, etc.
  - semantic web
- Modelling of human knowledge processing on language level

Knowledge Systems (KS) Architecture

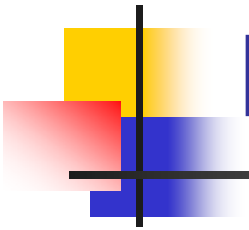


Components of KSs

- KB: CYC has millions of K chunks
  - humans about a hundred millions
- Modes of inference of the form $K_0 \models K_1$
  - deductive, inductive, and abductive reasoning, data-mining, learning, theory formation, discovery, imprecise and probabilistic reasoning, planning, problem solving, explanation, argumentation, self-reflection
- K-acquisition, eg. from natural language

Research Goals for KSs

- Compatibility of different KBs
- Ease of acquiring and collecting knowledge, efficiency of performance, enhanced comfort in using KSs
- Integration and possibly harmonization of different modes of reasoning
- Associating with knowledge chunks certain sensoric states (ext. semantics)



Role of Deduction

- Still fundamental for knowledge processing & hidden in many systems
- Progress slow but impressive (Robbins)
- Merging with other AI techniques required (vagueness, metaheuristics ...)
- Steps towards more compact, additive, declarative, understandable code as the following one partially illustrates:

Otten's theorem prover for Intuitionistic Logic: ileanCoP

```
(1) prove(Mat,PathLim) :-
(2) append(MatA,[FV:Cla|MatB],Mat), \+ member(-(_ ):_ ,Cla),
(3) append(MatA,MatB,Mat1),
(4) prove([!:[]],[FV:[-(!):(-[])|Cla]|Mat1],[],PathLim,[PreSet,FreeV]),
(5) check_addco(FreeV), prefix_ unify(PreSet).
(6) prove(Mat,PathLim) :-
(7) \+ ground(Mat), PathLim1 is PathLim+1, prove(Mat,PathLim1).
(8) prove([],_,_,_,[[],[]]).
(9) prove([Lit:Pre|Cla],Mat,Path,PathLim,[PreSet,FreeV]) :-
(10) (-NegLit=Lit;-Lit=NegLit) ->
(11) (member(NegL:PreN,Path), unify_with_occrs_chck(NegL,NegLit),
(12) \+ \+ prefix_ unify([Pre=PreN]), PreSet1=[], FreeV3=[]
(13) ;
(14) append(MatA,[Cla1|MatB],Mat), copy_term(Cla1,FV:Cla2),
(15) append(ClaA,[NegL:PreN|ClaB],Cla2),
```

Rest of ileanCoP without unification – leanCoP included

```
(16) unify_ with_ occurs_ check(NegL,NegLit),
(17) \+ \+ prefix_ unify([Pre=PreN]),
(18) append(ClaA,ClaB,Cla3),
(19) (Cla1==FV:Cla2 ->
(20) append(MatB,MatA,Mat1)
(21) ;
(22) length(Path,K), K<PathLim,
(23) append(MatB,[Cla1|MatA],Mat1)
(24) ),
(25) prove(Cla3,Mat1,[Lit:Pre|Path],PathLim,[PreSet1,FreeV1]),
(26) append(FreeV1,FV,FreeV3)
(27) ),
(28) prove(Cla,Mat,Path,PathLim,[PreSet2,FreeV2]),
(29) append([Pre=PreN|PreSet1],PreSet2,PreSet),
(30) append(FreeV2,FreeV3,FreeV).
```

The Fundamental Dichotomy of Global „Promise or Perish“

- Law of Accelerating Returns
  - Exponential increase computational powers
  - Synergies Converging technologies NBIC

„ITs are already deeply influential in every industry. … in a few decades, every area of human endeavor will essentially comprise ITs and thus will directly benefit from the law of accelerating returns.“

Ray Kurzweil, 2005

The Fundamental Dichotomy of Global „Promise or Perish“

- Law of Accelerating Returns
  - Exponential increase computational powers
  - Converging technologies NBIC
- Failures and risks of brinkmanship
  - Ongoing climate change, energy crisis
  - Complex governance on a global scale
  - Risks from global epidemics (H5N1 etc.)
  - Digital divide, social disintegration, etc.

The Promise of Artificial Intelligence (AI)

- Semantic Web (birthday date of friend)
- AI revolution in science (SCIENCE 2020)
- AI put into service of overcoming those failures and avoiding the risks
- AI technology for the needs of humans and the protection of the biosphere rather than meddling into the delicate and complex, subtle balance of nature
- Scientification of „soft“ sciences

Problem Solving with KBs

- Complex problems like coping with climate characterized by lack of problem specification (components? causal relationships and mechanisms? etc.)
- Theory formation by additive KB building and inductive generalization rather than just data collecting
- Anytime theory available for problem solving, explanation and prediction

Impediments for Prolific KSs

- Intellectual challenges in KS technology
  - demands on ability for abstract thinking as in all structural sciences
  - rare talent to be furthered from childhood
  - circumstances for concentration and ongoing commitment rarely available
- Sociological barriers and resistence
- Let‘s act before we are forced to act

Challenge Problems

- Integrated Hybrid Transportation System: door-to-door, competitive with car
- Semantic Law Support System
  - harmonization of 26+ legal systems in EU
  - compliance, optimization of regulation, etc.
- Automation of Programming
  - system autonomy: „integrate – automate“, ease of use, uniqueness

Underlying Papers

- W. Bibel, Knowledge in IT (2007).
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