AN ANECDOTE FROM THE DENDRAL EXPERIMENTS

FOR STRUCTURES OF C2ON ACYCLIC AMINES

WITH CHEMICAL KNOWLEDGE (VALENCE) ONLY...15 MILLION

ADDING MASS SPECTRUM FRAGMENTATION KNOWLEDGE...1.25 MILLION

ADDING NUCLEAR MAGNETIC RESONANCE KNOWLEDGE (SIMPLEST POSSIBLE)

...1 THE CORRECT ANSWER!
THUS

KNOWLEDGE IS POWER

(THE KNOWLEDGE PRINCIPLE)
KNOWLEDGE IS (ALMOST) ALL THERE IS

- THERE ARE NO "MAGIC BULLETS" IN THE FORM OF REASONING PROCESSES.
- WE NEED TO GET TO WORK CODIFYING LARGE BODIES OF KNOWLEDGE.
- KNOWLEDGE REPRESENTATION RESEARCH IS INDICATED.
  - REPRESENTING OBJECT STRUCTURE AND FUNCTION AND MAPPING BETWEEN S & F
  - REPRESENTING TIME, ACTIONS, CAUSES, OUTCOMES, AND MANY OTHER CONCEPTS
- AND RESEARCH ON NEW REASONING METHODS THAT HIGHLIGHT KNOWLEDGE
WHAT NEXT?

THE BETTER QUESTION IS:

WHAT SCOPE?
LARGE KNOWLEDGE BASES AS CORPORATE AND NATIONAL INFRASTRUCTURE RESOURCES

MCC: "CYC", ENCYCLOPEDIC COMMON SENSE KNOWLEDGE

ELECTRONIC DICTIONARY RESEARCH LTD. (JAPAN): COMMON SENSE KNOWLEDGE

STANFORD AND UNIV. OF ILLINOIS: TECHNICAL KNOWLEDGE

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MOTIVATION

Problems with 1st generation expert systems:

1. Britteness - only a narrow range of expert behavior exhibited

2. Over-specialization - only a single task supported
**HYPOTHESIS:** Problems originate with the specialized form and content of expert system knowledge bases:

- Contents dictated by minimal task requirements -- "Irrelevant" knowledge omitted
  - First principles knowledge
  - Causal knowledge
  - Common sense knowledge
- "Compiled", heuristic form of rules is engineered specifically for one task

**RESULT:** Britteness + Over-specialization
Contents of Proposed LMKB

LMKB would contain knowledge about:

- **Devices**: valve, switch, motor, ...
- **Physics and Engineering Constructs**: rigid-body, contained-fluid, pulley-system, ...
- **Physical Quantities**: force, mass, length, ...
- **Physics Principles**: Newton's laws, Ohm's law, ...
- **Materials**: metal, rubber, ...
- **Shapes**: sphere, rod, ...
Contrast with Traditional Expert System KB

Typical expert system diagnostic rule:

**IF:** ACTUAL-SPEED of AUDIO-TURNTABLE < DESIRED-SPEED of AUDIO-TURNTABLE

**THEN:** POSSIBLE-DIAGNOSIS of AUDIO-TURNTABLE is SLIPPING-BELT

**Difficulties**

1. Brittleness:
   - Suppose the turntable is *direct*-drive, rather than *belt*-drive
   - Suppose the belt is *not* slipping and no other diagnosis rules pinpoint the problem
   - Suppose ACTUAL-SPEED > DESIRED-SPEED

2. Over-specialization: Suppose we want to *redesign* the belt so it doesn't slip
LMKB Solutions

1. **Overcome brittleness:**
   By carrying out diagnosis at a "deeper" level

2. **Overcome over-specialization:**
   By using knowledge of design alternatives
Traditional Simulation

Device-specific computational model

Simulation engine

Behavior description

Human

Human
Research Areas

- **Knowledge representation**
  How to represent useful knowledge about physical devices: how they are put together, how they work, why they designed the way they are.

- **Model formulation**
  How general knowledge of physics and special knowledge about modeling can be used to construct device models for particular purposes.

- **Knowledge-based simulation**
  How to use explicit symbolic knowledge about devices to analyze and predict their behavior in given situations.

- **Machine-generated explanation**
  How can programs generate human-scale explanations of how devices work and why they are designed as they are.
MOVING AWAY FROM ARISTOTLE

MOST REASONING DONE BY EXPERT SYSTEMS TODAY IS BASED ON ARISTOTELIAN LOGIC (FORWARD AND BACKWARD CHAINING)

SOMETIMES BASED ON BAYES THEOREM OR VARIANTS

NEEDED: A LESS RIGOROUS FORM OF REASONING, CLOSER TO METAPHOR AND ANALOGY

- BASED ON PARTIAL MATCHING OF NEW SITUATION WITH STORED KNOWLEDGE

- LIMITED ROLE FOR LOGIC, IN "TUNING" SOLUTIONS

USE OF ANALOGIZING IN PROBLEM SOLVING AND LEARNING

WATCH "CASE-BASED" OR "MEMORY-BASED" REASONING METHODS

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THE NATURAL INTERFACE (I)

NATURAL LANGUAGE UNDERSTANDING IS IMPORTANT

- IS COMING. PROGRESS DEPENDS ON HAVING LARGE KNOWLEDGE BASES

- WORKS MINIMALLY TODAY, IN NARROW AREAS NEEDS USE OF METAPHOR FOR FLUIDITY AND NATURALNESS
THE NATURAL INTERFACE (II)

PICTURES: MEDIocre TODAY BUT GETTING BETTER FAST

- SOME EXPERT SYSTEM TOOLS HAVE SYSTEM-LEVEL SUPPORT FOR BUILDING DYNAMIC PICTURES (E.G. ACTIVE IMAGES)

- OFTEN THE PICTURE IS WHAT "SELLS" THE SYSTEM TO USERS

- LESSON: GO FOR GREAT GRAPHICS AT THE INTERFACE
THE NATURAL INTERFACE (III)

Speech: Not good today but coming fast

- Continuous natural speech is the goal, but slightly discontinuous "connected" speech is useful

- Like natural language understanding, depends on knowledge
  
  - Hence, likely to work best in narrow knowledge domains, i.e. expert systems

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THE KNOWLEDGE SERVER OF THE FUTURE

AS COLLEAGUE NOT SERVANT

- A RECONCEPTUALIZATION OF THE EXPERT SYSTEM

AS AN EXAMPLE, A VISION OF THE LIBRARY OF THE FUTURE

(SEE PAPER: "KNOWLEDGE PROCESSING: FROM FILE SERVERS TO KNOWLEDGE SERVERS")