Tiger in a Cage: The Applications of Knowledge-Based Systems

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Infrastructure Barriers were Daunting

- Infrastructure not under control of AI/KS people
- Workstations or desktop power, large memories, GUIs, OOP, networks, rapid prototyping methodology, etc. are just now becoming part of MIS/DP infrastructure
Time Must Pass

- Some technologies take 25 years to make it
- RDB was invented early 70s. Made it in late 80s
- OOP was invented 1967. Hasn’t quite “made it” yet
The Logic of this Talk

- Knowledge systems technology is powerful and fits well with important economic and organizational goals.
- The documented benefits from most deployed systems are large, sometimes remarkable—the KS technology is a tiger.
- Where is the growth, the demand, to match the observed payoff?
- Why is the tiger in a cage? What kind of a cage is it?
No Standards were Adopted

- Standards were shunned by AI academics (as usual) and by overcompetitive small firms, inhibiting users, developers, managers
- No standard methodology for developing and testing evolved
Tiger of a Technology
Real or Paper Tiger?
Success Stories in the Government (1): NASA

- Flying as we speak (or nearly so)
- June, 1993; first KS flown in space: SHOOT-Superfluid Helium On-Orbit Transfer, assists astronauts in setting up, running, diagnosing, etc. the transfer in space of helium between dewers
- Sept., 1993 (scheduled for 9/8/93): PI-in-a-Box, assists astronauts in carrying out in-flight life science experiment, diagnosing trouble, dealing with surprise events, etc.
Mass Customization: the Configuration Task Revisited (cont’d.)

- Launching “knowledge service”: customer accesses CONQUER for configuration, quote and ordering of a PC
- Trilogy says that last year it was the fastest growing software company in the USA (% growth in revenues)
Configuration Tasks are Surprisingly Omnipresent and Important

- Many problems fit this task model
- To enable "mass customization" inevitably to arrive in a highly competitive world, this technology is crucial
- Constraint-based methods are central to system design
- Sekisui Heim’s application is example of EXCELLENT ROIs seen with KSs. Payback of system costs often comes in months
Tiger, not Paper Tiger!

- Ten thousand operational KSs deployed worldwide (order of magnitude estimate)
  - Millions if Tax Cut, Grammatik, other KP products are counted
- The applications show important benefits; economic, organizational, professional, and social
  - Transfer of expertise from expert to technician and across the organization
  - Order of magnitude speedup of human problem solving and decision making when assisted by KS
Tiger, not Paper Tiger!
(cont’d.)

- Significant reduction in error when KS assists person; improved quality has large economic and other payoffs
- Impressive ROI percentages and cost savings, at the outer edge for a new technology
- Creation of new knowledge products and services and a major new way to deliver knowledge
- Empowering of people vs complex rules, regulations, laws, procedures, forms, instructions, etc.
Knowledge, Knowledge, Knowledge!

- The field forgot its battle plan
  - The Knowledge Principle
- Sold knowledge-free shells, not solution-programs
- Sold reasoning, not answers
Inference Process Acquisition

- Heuristic and hidden—difficult to acquire
- Not a problem for conventional algorithmic programs
A Knowledge System’s Narrow Niche

- IF too broad a domain, THEN not powerful enough
- IF appropriately narrow, THEN user group too small?
- No knowledge reuse outside the narrow niche
- In DB systems, data is often subject to intense reuse
- Needed to amortize the cost of KA over bigger base
Ease of Use of KS Software

- Users have little patience with complex, quirky, slow-acting software
- The average MIS/DP programmer is not a rocket scientist, or MS/CS grad student
  - MS-CS?: the first few years were unique, misleading

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K.I.S.S. (Keep It Simple, Stupid)

- Surprise: cost, speed, memory size mattered to users
- The goal was world-class problem solving behavior
  - Forgotten were society’s simpler “rule-systems”
    -- forms, procedure manuals, government regulations, etc.

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K.I.S.S. (Keep It Simple, Stupid) (cont’d.)

• These simpler systems are much cheaper and EASIER to build
  – Not much KA and no PS method acquisition
• Fuzzy logic ideas are easy to understand and apply; hence, fuzzy systems had explosive growth!
Knowledge “Rot” and the Maintenance Problem

- Since knowledge changes over time, the power of KSs decays with time
- Must be routinely updated
- Maintenance personnel, tools, were rarely institutionalized
- Result: many good systems simply faded away
Knowledge Systems: From Birth to Adulthood

- The mother was AI
  - Heuristic search, problem solving methods, knowledge representation
- The father was Chemistry (or Mathematics)
  - The power of domain-specific knowledge
• 1965-79: Will the ideas work on “real” problems?
• 1981: IJCAI at Vancouver
• 1982-89: The REAL world tests the technology
  – “AI boom” in industrial and commercial exploration
  – DARPA supports further work in its Strategic Computing Initiative; also UK and EC in other initiatives

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Knowledge Acquisition—the Bottleneck was not Broken

- “It has been too difficult to get the knowledge.” (S. Sato, Director, Fujitsu Labs)
- Note: data acquisition not a problem for DB Systems!
- Not enough KA tools (because our KA ideas have been too weak)
- Task oriented tools (e.g. diagnostic shells) not good enough yet to impact the problem
1993: Several thousand applications deployed worldwide

- Remarkable diversity in end-user task performed
- Large payoffs of various types reported
- Growth is slow or negative; computer industry, its media, and users skeptical
NASA Operations on the Ground:
GPSS (Ground Processing Scheduling System)

- Schedules Kennedy Space Center operations for the recycling of space shuttle from one flight to next
- Constraint-based reasoning using heuristic iterative improvement search (not backtracking algorithm); rich temporal modeling language
NASA Operations on the Ground (cont’d.)

- Order of magnitude gains in SPEED of scheduling and ACCURACY
- Saves half to one million dollars per flight
- System cost 1.5 to 2 million dollars (over 3 years to build). Hence LARGE RETURN on investment (ROI)
Mass Customization: the Configuration Task Revisited (cont’d.)

- Trilogy Development Group’s SalesBuilder
  - KSs to make “build to order” possible and efficient
  - Constraint-based reasoner with object oriented framework for defining products
  - SalesBuilder application for ATT (complex PBXs) reduced configuration time from days to minutes
  - Other applications to PC configuration (Dell, IBM, DEC, NEC), medical equipment configuration (GE), networks, much more

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Mass Customization: the Configuration Task Revisited (cont’d.)

- Configurer reduces steady-state error rate from 5% to zero; reduces errors early in introduction of new line by 30%.
- Saves Sekisui Heim 1 billion yen per year ($9 million); cost a fraction of that to write the system, so big ROI.
Mass Customization: the Configuration Task Revisited (cont’d.)

- Sekisui Heim: makes factory-built modular homes: 25,000/year
  - Customer designs her own home within specific architectural design constraints (the “line”)
  - Of 300,000 different parts, about 5000 are used in any particular home—but which 5000 parts should be picked?
  - Configurer works out parts-picking plan, inventory to factory floor for assembly

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Mass Customization: the Configuration Task Revisited (cont’d.)

- The first industrial application of KS was a configuration application, XCON by DEC, followed by a sales aid, XSEL
  - Enormously successful, saving DEC hundreds of millions of dollars to date
  - IBM, UNISYS, ICL, and others followed
Mass Customization: the Configuration Task Revisited

- Configuration problems are ubiquitous because most engineered and manufactured objects are made from subassemblies
- Semi-custom ordering, design, manufacturing leads to great knowledge demands and combinatorial complexity
Knowledge Publishing will be an Important New Industry (cont’d.)

- As PCs become almost universal in home and business, companies will prefer to distribute procedure manuals in “active” form, rather than traditional (and unread) paper.
- Companies are doing this for internal publication now.
Knowledge Publishing will be an Important New Industry

- NEW PRODUCTS added to the economy as result of KS technology. Maybe this is the largest field for future KS application.
- The first wave of KP “active books” will be easy to implement.
- Many will be compliance advisers, like Tax Cut.
Knowledge Publishing—KSs as “Active Books”

- Delivering knowledge specifically in the context of a user need or request
- Andrew Tobias’ Tax Cut—ask Dan Caine and his tax lawyers for advice
  - Rule-based KS
  - Sold 250,000 copies last tax season
- Grammatik—your English teacher is checking your grammar
  - Sold more than one million copies
- Compaq—the KS that comes with your printer

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Observations about Compliance Advisers ("Rule Helpers")

- A class of KS that "diffuses" well to large bodies of people, because everyone has to comply with rules, regulations, laws
- Easy to implement, least expensive of all classes to program
- The space of applications appears to be endless
- Government and corporate bureaucracies can become HELPFUL
Tiger in a Cage

- Thanks to A. Barr and H. Schorr for ideas and discussions
- What kind of growth might have been expected that did NOT happen to KSs?
  - The story of Oracle and other relational database companies
- The reasons the tiger is caged are many and various, from strategic to very tactical
Success Stories in the Government (3): Welfare and Social Security

- The laws that men (and women) make are too complex for men (and women) to understand
- Welfare: Tulare Touch System (CLEAN)
- British Social Security System
Accuracy is Beautiful Also

- KSs often increase accuracy and lower error rate vs unassisted people doing the job
- Sometimes this is the crucial success factor (e.g. configuration systems, financial systems, etc.)
- Constraint-based reasoning methods have broad applicability to scheduling, planning, configuration
Fast is Beautiful

- Use of KS gives major SPEEDUP to "thinking work"
  - Often factors of ten to hundreds (!)
  - Speedup gain can be crucial success factor
- Experience and AI knowledge enable success
  - NASA, DARPA and its contractors had knowledge and experience
Success Stories in the Government (2): 
DARPA + Contractors (cont’d.)

- Major gain in speed of planning: “what-if” replanning reduced from weeks to hours
- Discovered logistics bottlenecks in time for planners to deal effectively with problem
- Director of DARPA, Victor Reis, in talk at Stanford said this one application paid back DARPA’s entire investment over the years in AI research
Success Stories in the Government (2): DARPA + Contractors

- DART: logistics planning for the Desert War. Moving soldiers and materiel to Saudi Arabia
- Assisted officers in planning what and how to send
- Constraint propagation and maintenance techniques
- Blackboard-type architecture with RDB as blackboard
Uncaging the Tiger--

“BE BOLD”
Actions Companies Can Take
(just a few of many)

- Sell knowledge-FULL systems, not empty shells
  - In other words, sell systems that give answers
- Make application and development software much easier to use; spreadsheets can be role model for ease of use
  - Focus on making the KR and KA tasks much easier
- Get together to agree on standards
- Make software cheaper, faster, smaller

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What the AI Research Community Can Do

- Develop the technology and content of large knowledge bases, so new developers don’t have to start from scratch
  - Proposed big Japanese national project focuses AI research effort in this direction
- Develop the technology of knowledge base reuse and sharing
  - Small American national project is doing this
What the AI Research Community Can Do (cont’d.)

- More research on practical (!) machine learning methods
  - Breakthrough(s) needed to put an end to KA bottleneck
Actions Government Can Take

- Use Knowledge Systems widely to improve efficiency, assist compliance, help citizens understand rules, laws, fill out forms; and also to solve complex problems.
- Organize and support the development of a second-generation of knowledge systems science and technology, including the underlying AI basic research.
  - As part of the National Information Infrastructure activity.

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Government support nurtured the tiger;
Now help remove the bars of its cage!