Tell It What to Know
Review of Search

6.871 - Lecture 2

A Reminder

- Checkbook balancing vs.
  getting out of the supermarket
- Character of task
- Character of solution
- Go past image to technical ideas and concepts

Purposes of This Lecture

- Explain the mindset of knowledge engineering
- Change your mind about what a program is
  - From a buncha bits to …
  - From code to …
- Change your mind about how to create them
  - Don't tell it what to do
  - Build it incrementally
- Change your mind about what to use a computer for
  - Many things…

Punchlines

- The issue is style and pragmatics, not theory
- A program can be much more than just code.
  It can be a repository of knowledge,
  an environment for the development of knowledge
- Embody the reasoning, not (just) the calculation
- Don't tell it what to do, tell it what to know, and how to use what it knows (often many different ways)
  - Task changes from writing a program to specifying the knowledge.
  - Task becomes debugging knowledge, not code.

Punchlines

- One payoff: multiple uses of the same knowledge.
- Performance is only the beginning
  Solving the problem is only (a small) part of the job
  - Explanation
  - Learning
  - Tutoring
- Suppressing detail helps
- Build a custom language

Punchlines

- Nothing is ever right the first time
  - Nature of the task
  - Nature of the knowledge
  - Evolutionary development
    - » Build a little
    - » Test a little
    - » Redesign a little

What's a Good Representation?

- Consider: 1996 vs. MCMXCVI
- Which would you rather use in arithmetic? Why?

What's a Good Representation?

- Consider: 1996 vs. 11111001100
- Which would the *computer* rather use in arithmetic? Why?

The Power of A Good Representation

The proportional ownership of the first party shall be equal to a ratio, the numerator of which is: a ratio, the numerator of which is the holding period of the first party multiplied by the capital contributed by the first party, and the denominator of which is a sum, the first term of which is the holding period of the first party and the second term of which is the holding period of the second party; and a denominator which is the sum of two terms; the first term of which is a ratio, the numerator of which is the holding period of the first party multiplied by the capital contributed by the first party, and the denominator of which is a sum, the first term of which is the holding period of the first party, the second term of which is the holding period of the second party; and the second term of which is a ratio, the numerator of which is the holding period of the second party multiplied by the capital contributed by the second party, and the denominator of which is a sum, the first term of which is the holding period of the first party and the second term of which is the holding period of the second party.

What's a Program? The Minimal Number of Bits View

```
     DO 14 I = 1,N
     DO 14 J = 1,N
14   V(I,J) = (I/J)*(J/I)
```


Task: Symbolic Mathematics

How can we take a derivative of

$$3x^3 + 4x^2 + 5x + 7$$

to get

$$9x^2 + 8x + 5$$

Observations about the knowledge

- It's organized around the operators.
- It's organized around nested sub-expressions
- Top-down tree descent is the natural approach
- The representation should reflect that.
- The representation should facilitate that.

Use a Natural Representation

- Conventional mathematical notation

$$2y\sqrt{x^3 + xy(z+a)}$$

(* (* 2 y) sqrt(+ (^ x 3) (* x y (+ z a))))

- Use the pattern appropriate for the leading operator

A Small Language

- In effect we've built a *language* with the right *abstractions*:
  - Expression tree
  - Dispatching on leading operator
  - Recursive descent through the expression tree
- Operators are *independent, modular chunks* of "mathematical *knowledge*"
- Operators can be added *incrementally*
- There is an *indexing mechanism* for finding relevant operators given the structure of the current representational focus

Catchphrases and Punchlines

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Task: Balancing Your Checkbook

```
Read StatementBalance
AdjBalance = StatementBalance
until done do {read OutstandingCheck
               AdjBalance=- OutstandingCheck}
until done do {read OutstandingDeposits
               AdjBalance=+ OutstandingDeposits}
until done do {read Fee
               AdjBalance=- Fee}
until done do {read Interest
               AdjBalance=+ Interest}
if AdjBalance = CheckBookBalance
      {print (“It balances!”); return}
else if AdjBalance > CheckbookBalance
      {print “Hey, good news.”; return}
else {print “We’re scrod.”; return}
```

A Spreadsheet is Almost Right

- The right mindset: focus on the knowledge

The Checkbook Example

		Cleared Deposits	Cleared Checks	Uncleared Deposits	Uncleared Checks
Bank Balance	$1234.56	$100.00	$213.40	$250.00	$12.34
		$250.00	$874.30	$95.00	$19.99
Total uncleared deposits	725.00	$75.00	$19.00	$180.00	$25.00
		$90.00	$22.00	$200.00	$72.54
				$15.00	$105.00
					$14.00
Total uncleared checks	$248.87				$24.00
New Balance	$1,710.69				

A Spreadsheet is Almost Right

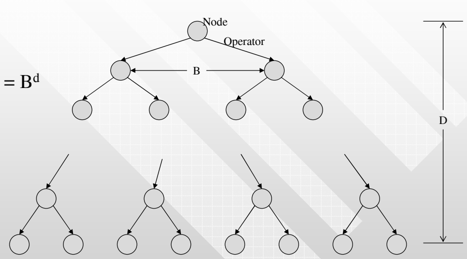
- The right mindset: focus on the knowledge
  But:
  - They are numeric and we want more
  - They have only one inference engine
- KBS as “conceptual spreadsheets”

Search Basics

- Lecture 2, Part 2.

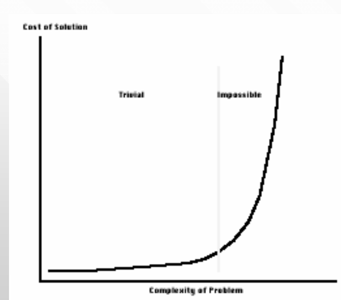
The Fundamental Problem: Search in a Problem Space

Size = B^d



- B = branching factor
- D = depth

Search Spaces Grow Exponentially

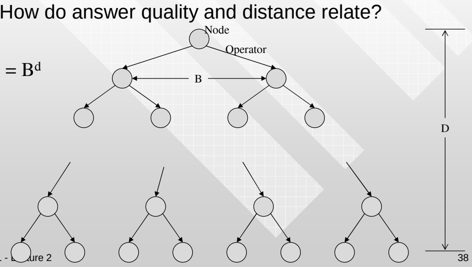


The marginal cost of slight improvement is prohibitive

The Shape of The Space

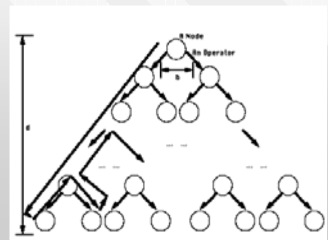
- How densely distributed are the answers?
- How uniformly distributed are the answers?
- How do answer quality and distance relate?

Size = B^d



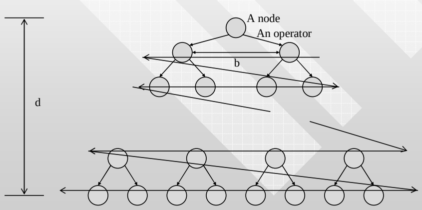
Depth First Search

- Go down before you go across
- Maintains focus
- Minimizes storage requirements
- Finds answer faster sometimes



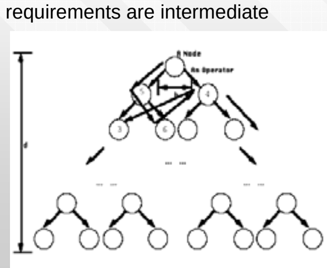
Breadth First Search

- Never gets lost on deep or infinite path
- Always finds answer if it's there
- Requires lots of storage



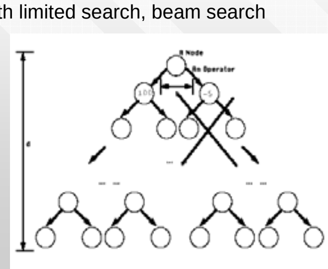
Best First Search

- Requires quality metric
- If metric is informed it's very quick
- Space requirements are intermediate



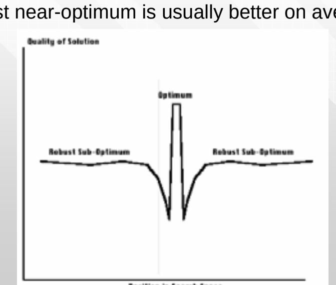
Pruning

- Throw away unpromising nodes
- Some risk that the answer is still there
- Great savings in time and space
- Breadth limited search, beam search

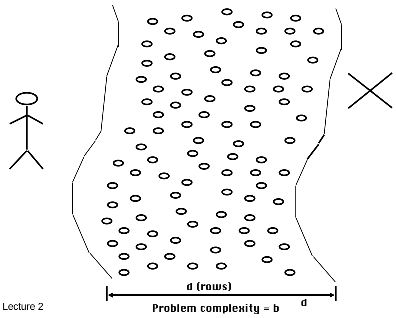


Optimum Often isn't Optimum

- In the real world things go wrong
- Robust near-optimum is usually better on average



Planning Islands: The Power of Recognition



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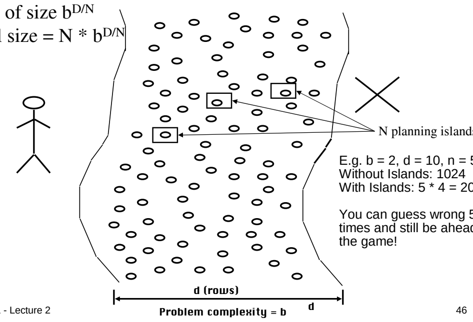
Recognizing the Form of the Problem

N subproblems
Each of depth D/N
Each of size $b^{D/N}$
Total size = N * $b^{D/N}$



E.g. b = 2, d = 10, n = 5
Without Islands: 1024
With Islands: 5 * 4 = 20

You can guess wrong 50 times and still be ahead of the game!

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Summary

- All problem solving problems involve search spaces
- Search space grow intractably
- Many common algorithms for search are known
- In the Knowledge Lies the Power
  - Knowledge of a heuristic metric
  - Knowledge of planning islands
  - Knowledge of relevant abstractions
- Build representations that capture these sources of power

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