

Prolog Concluded

February 15–16, 2012

CS 60: Principles of Computer Science

Assignment 4 due Monday February 20: Prolog Puzzles

Also on Monday, February 20: Guest Lecture by Paul Ruvolo (HMC '03)

HOMEWORK: THE (GENERALIZED) 24 PROBLEM

Given:

1. A list of possible operators (usually $[+, -, *, /]$)
2. A list of integers (e.g., $[3, 4, 2]$)
3. A goal value

is there some arithmetic tree such that

- ✓ The leaves are the given integers (exactly once each)
- ✓ The interior nodes are from our possible operators
- ✓ The “value” of the tree is our goal value

?- solve([+,*,/], [2,3,4,6], 24, T).

T = [+ , 2 , [+ , 4 , [* , 3 , 6]]] ;

T = [+ , 2 , [+ , 4 , [* , 6 , 3]]] ;

...

T = [+ , [/ , 2 , 3] , [* , 4 , 6]] ;

...

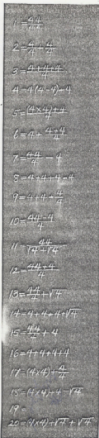
T = [+ , [* , 3 , [+ , 4 , 2]] , 6] ;

...

RELATED PUZZLE: FOUR 4'S

Martin Gardner

2 4 6 8 10 12 14 16 18 20



The page of four 4's

in the *Mathematical Courier* for May, 1912, and there have been scores of subsequent articles, including titles that go above 1,000. Even now the month will suddenly sense the employment of an office or laboratory, examination causing a work stoppage that lasts for days.

"It is possible," I asked Dr. Martin, "to square 1964 with four 4's and the traditional symbols?"

"He should be kind rigorously. Of course many important dates are possible, 1776 is 4 times 441. But 1964 is not one of them. With five 4's, yes." He patted on my note pad:

$$444^4 + 4/4$$

"But four 4's, no."

"How about 49?"

"That," said Dr. Martin, "is not difficult. Oddly enough, 44 can also be expressed under traditional restrictions, of course—with three 4's and also with two."

The reader is invited to try his skill on all three problems; that is, to express 44 with four 4's, with three 4's and with two 4's. No symbols may be used other than those that have been mentioned. The trick is scribbling hand with four 4's, miraculously easy with three, extremely difficult with two. Next month I shall give the best solutions known to Dr. Martin.

Dr. Martin gazed softly off into space when I spoke to him about the coming election campaign. In an interview that I reported in January, 1951, he had called attention to the grim pattern of death to office for every president who had been elected in a new ending to men, beginning with 1801: Lincoln (elected 1800), Garfield (1880), McKinley (1896) and now Kennedy (1960) had been killed by an assassin. Roosevelt (1882), Harding (1920) and Eisenhower (1952) had died in office.

"Yes," he said finally, "the names and birth dates of the leading candidates deserve careful scrutiny. In the past 23 elections, beginning in 1876, the only shorter list names was the popular vote in 1968, when Tall deflated Byrne. This gives four Bushidoes an edge over all his competitors. Of course Nixon, Roosevelt and Johnson are eliminated because their names lack a double letter, such as the two 4's in Bushidoes." (Dr. Martin was being cheeky to the name, well-known law that all U.S. presidents of the 20th century must have a double letter in their name. So far Eliza-

hower has been the only exception, but because his "apostrophe," Adlai Ewing Stevenson, also lacked the double letter, there was no real impediment.)

I was scribbling furiously. "That makes Bushy a strong candidate for Goldwater, I suppose. Both men have the double letter, but Bushy's last name is longer."

"In that respect, yes. Bushy's height, of course, is a liability. In the past 12 elections, beginning in 1904, the only time the shorter candidate was the popular vote was in 1948, when Dewey, at an inch two inches, defeated Wallace, six feet two and a half. By the way, did you know that both Bushidoes and Roosevelt, the two 8-oval men, were born on July 19?"

I shook my head.

"In fact, all five leading Republican candidates—Roosevelts, Hoover, Goldwater, Nixon and Eisenhower—were born in months that begin with I. Goldwater and Nixon were born in January, Eisenhower in July; I is the 19th letter of the alphabet. Note that "Republican" has 10 letters and that the digit of 94 was to 10."

"Is that a good omen?"

"To a certain degree. The digit of 1964, however, was to 10. The only candidate with twenty 20 letters in his full name is Barry Morris Goldwater. On the other hand, the president will not be inaugurated until 1969, which sums to 15, the number of letters in the name of William Weaver Stevenson."

"Your summation is confusing," I said.

"No more than politics. I expect to report that Bushidoes, the governor of Pennsylvania, was not born to Stevenson, Jr., or to an unambiguous month, November, 11. He was born in Madison, Conn. But Madison is a presidential name, so that should be considered a favorable sign."

"Nonsense but suggested," I remarked, "that Bushidoes should open a campaign speech by saying 'I come to Barry Goldwater, not by grace here.'"

Dr. Martin looked so solemn as I scribbled. "It is possible to devise many appropriate puns on the candidates' names. On Nixon, for example, although Roosevelt reminds the 'old rich only father,' and one might say that his 'sweet' or 'sacred' lines are enough to end a life. Nixon's straightforward Republicanism is indicated by the fact that the first and last letters of 'Republican' are his initials, the same letters backward are Bushidoes'. The governor's full initials, backward, may be prophetic: the

MORE LOCALLY...

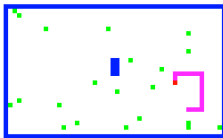
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1	$\frac{4!}{4}$	34	$4! + \frac{4!}{4} + 4$	67	$\frac{4! + 4!}{4} + \sqrt{4}$
2	$\frac{4!}{4} + \frac{4!}{4}$	35	$4! + \frac{4!}{4}$	68	$4 \cdot 4 \cdot 4 + 4$
3	$\frac{4! + 4!}{4}$	36	$4! + 4(4) - 4$	69	$\frac{4! \sqrt{4} - \sqrt{4}}{\sqrt{4}}$
4	$4! - 4(4) - 4$	37	$4! + \frac{4!}{4} + 4$	70	$4! - 4! - \sqrt{4}$
5	$\frac{4!}{4} - \frac{4!}{4}$	38	$44 - \frac{4!}{4}$	71	$(4! + 4 \cdot 4) / 4$
6	$4 + \frac{4! + 4!}{4}$	39	$4! + 4! - \frac{4!}{4}$	72	$4! \sqrt{4} / \sqrt{4}$
7	$\frac{4!}{4} + \frac{4!}{4}$	40	$4 \cdot 4 \cdot 4 - 4!$	73	$(4! \sqrt{4} + \sqrt{4}) / \sqrt{4}$
8	$4 + \frac{4(4)}{4}$	41	$44 - \sqrt{\frac{4!}{4}}$	74	$4! - 4! + \sqrt{4}$
9	$4 + 4 + \frac{4!}{4}$	42	$44 - \frac{4!}{4}$	75	$(4! + 4 + \sqrt{4}) / 4$
10	$4(4) - \frac{4!}{4}$	43	$44 - \frac{4!}{4}$	76	$4! - 4! + 4$
11	$(4! + 4) / 4 + 4$	44	$44 / \frac{4!}{4}$	77	$(\frac{4!}{4})^2 - 4$
12	$4! - (4! + 4)$	45	$44 + \frac{4!}{4}$	78	$(4! - 4)4 - \sqrt{4}$
13	$4! - \frac{4!}{4}$	46	$44 + \frac{4!}{4}$	79	$(\frac{4!}{4})^2 - \sqrt{4}$
14	$\frac{4!}{4} + 4 + 4$	47	$4! + 4! - \frac{4!}{4}$	80	$4! - 4(4)$

MORE LOCALLY...

15	$4(4) - \frac{4}{4}$	48	$(4!+4!)/\frac{4}{4}$	81	$(\frac{4!4}{4})^{\frac{4}{4}}$
16	$4(4)/\frac{4}{4}$	49	$4!+4!+\frac{4}{4}$	82	$(4!-4)4+\sqrt{4}$
17	$4(4)+\frac{4}{4}$	50	$4!+4!+\frac{4}{\sqrt{4}}$	83	$(\frac{4}{4})^{4!}+\sqrt{4}$
18	$(4.4)4+.4$	51	$4!+4!+\sqrt{\frac{4}{4}}$	84	$44\sqrt{4}-4$
19	$4!-4-\frac{4}{4}$	52	$4!+4!+\sqrt{4}+\sqrt{4}$	85	$(\frac{4}{4})^{4!}+4$
20	$(4+\frac{4}{4})4$	53	$44+\frac{4}{4}$	86	$44\sqrt{4}=\sqrt{\frac{4}{4}}$
21	$4!-4+\frac{4}{4}$	54	$4!+4!+4+\sqrt{4}$	87	$4!4-\frac{4}{4}$
22	$\frac{4}{4}+4(4)$	55	$\frac{4!}{\sqrt{4}}/4$	88	$4!4-4-4$
23	$4!-\sqrt{4}+\frac{4}{4}$	56	$4!+4!+4+4$	89	$\frac{4!+\sqrt{4}}{4}+4!$
24	$4(4)+4+4$	57	$4!+4!+\frac{4}{4}$	90	$4!4-4-\sqrt{4}$
25	$4!+\sqrt{4}-\frac{4}{4}$	58	$(4!-4-4)/4$	91	$4!4-\frac{\sqrt{4}}{4}$
26	$4!+\frac{4!4}{4}$	59	$[(4!4)!-4]/4$	92	$4!4-\sqrt{4}\sqrt{4}$
27	$4!+4-\frac{4}{4}$	60	$4.4.4-4$	93	$4!4-\sqrt{\frac{4}{4}}$
28	$44-4(4)$	61	$[(4!4)!+.4]/4$	94	$4!4-\frac{4}{\sqrt{4}}$
29	$4!+4+\frac{4}{4}$	62	$4.4.4-\sqrt{4}$	95	$4!4-\frac{4}{4}$
30	$4!+\sqrt{4}\sqrt{4}+\sqrt{4}$	63	$(4^4-4)/4$	96	$4!4/\frac{4}{4}$
31	$4!+\frac{4!4}{4}$	64	$4.4.\sqrt{4}.\sqrt{4}$	97	$4!4+\frac{4}{4}$
32	$4!+\sqrt{4}\sqrt{4}+4$	65	$(4^4+4)/4$	98	$4!4+\frac{4}{\sqrt{4}}$
33	$4!+\frac{\sqrt{4}\sqrt{4}}{4}$	66	$4.4.4+\sqrt{4}$	99	$4!4+\sqrt{\frac{4}{4}}$
				100	$4!4+\sqrt{4}\sqrt{4}$

HOMEWORK: THE ALIEN, SPAM, SPAMPEDE, AND MUDDER



Goal: The Mudder gets the alien, spam, and spampede from the west end of campus to the east end.

Constraints:

- ✓ *The Mudder can carry one item at a time.*
- ✓ *The spampede cannot be left alone with the spam.*
- ✓ *The alien cannot be left alone with the spampede.*

Solution? Prolog solution?

THE BIG IDEA

Find a *sequence* of legal moves leading from start to goal:

```
[ [alien, mudder, spam, spampede], [] ]
      ↓      mudder_takes_spampede_east
[ [alien, spam], [mudder, spampede] ]
      ↓      mudder_goes_west
[ [alien, mudder, spam], [spampede] ]
      ⋮
[ [], [alien, mudder, spam, spampede] ]
```

What constraints are there on legal configurations?

GENERAL PURPOSE PROBLEM SOLVING!

```
solve(C, []) :- winning(C).      %% Done (base case)
                                %%   Assumes we defined a
                                %%   rule recognizing winning
                                %%   configurations

solve(C, [Move | RoM]) :-
    validmove(C, Move, NewC),    %% Move to configuration NewC
    solve(NewC, RoM).           %% solve the resulting puzzle
```

WHEN IS A MOVE VALID?

```
validmove( [Wb,Eb], mudder_goes_east, [Wa,Ea] ) :-  
    %% For this specific move, before and after  
    %% are same except for mudder  
    perm( Eb, [mudder|Ea] ),  
    perm( Wb, [mudder|Wa] ),  
    %% Configuration afterwards must still be legal  
    %% (Assumes the "ok" predicate has been defined.)  
    ok( Wa ),  
    ok( Ea ).
```

ONE PROBLEM: IT DOESN'T WORK!

```
[ [alien, mudder, spam, spampede], [] ]
```

```
      ↓      mudder_takes_spampede_east
```

```
[ [alien, spam], [mudder, spampede] ]
```

```
      ↓      mudder_takes_spampede_west
```

```
[ [alien, mudder, spam, spampede], [] ]
```

```
      ↓      mudder_takes_spampede_east
```

```
[ [alien, spam], [mudder, spampede] ]
```

```
      ↓      mudder_takes_spampede_west
```

```
      ⋮
```

dynamic PREDICATES IN PROLOG

`:- dynamic marked/1.`

- ✓ Declares the 1-argument predicate `marked` to be “dynamic.”
- ✓ We can now add and remove `marked` facts in the middle of our search!

`assert(marked(42))`

- ✓ Adds `marked(42)` to the program's database of facts.

`retract(marked(42))`

- ✓ Deletes `marked(42)` from the program's database of facts.

`retractall(marked(_))`

- ✓ Deletes all `marked` rules from the program's database of facts.

dynamic ACTION

Assume `foo/1` has been declared `dynamic`.

```
?- foo(X).  
false.
```

```
?- assert( foo(42) ).  
true.
```

```
?- foo(X).  
X = 42.
```

```
?- assert( foo(spam) ).  
true.
```

```
?- foo(X).  
X = 42 ;  
X = spam.
```

```
?- retract ( foo(42) ).  
true.
```

```
?- foo(X).  
X = spam.
```

WORKING GENERAL PURPOSE PROBLEM SOLVING!

```
:- dynamic marked/1.
```

```
solve(C, []) :- winning(C).    %% Done (base case)
```

```
solve(C, [Move | RoM]) :-
```

```
    \+ marked(C),
```

```
    assert( marked(C) ),
```

```
    validmove(C, Move, NewC), %% Move to configuration NewC
```

```
    solve(NewC, RoM).        %% solve the resulting puzzle
```

```
Afterwards: retractall(marked(_)).
```