ICFP Programming Contest 2010

International Cars and Fuels Production

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June 18–21, 2010

About the ICFP Programming Contest

- programming, problem solving, fun
- annual contest, since 1998
- sponsored by ICFP conference/ACM
- 2010 contest hosted by HTWK Leipzig, Germany
- contest format
  - 72 hours (June 18, 12:00 – June 21, 12:00 GMT)
  - participation online, international
  - teams allowed
  - no fixed programming language
  - lightning division (first 24 hours)

Contest Task

storyline:
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  - cars (= problem instance) (public)
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  - or creating instances (with solution, which is hard to find)

  income tax (devaluates earnings by 1/2 per day)

Contest Web GUI (Team Status)

pgflastimage

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- ternary stream encoding of structured data
  (= format used for published instances)

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obfuscation:
- ternary stream encoding of structured data
  (= format used for published instances)
- ternary circuits (with state) to produce streams
  (= format used for submitted solutions)

Contest Web GUI (Submission Page)

pgflastimage

The Difference Engine that Moves Cars

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- air: contains several ingredients:
  vector over $\mathbb{N}$, first component positive
- fuel component:
  (linearly) transforms incoming air in reaction chamber:
  square matrix over $\mathbb{N}$, top left entry positive
- difference engine compares upper and lower pipe's outputs: $(\geq)$ everywhere, $(>)$ in first component.

Example Car and Fuel

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In other words,

$\mathbb{M}$:= square matrices over $\mathbb{N}$ with top left entry ≥ 1
Find $A, B \in \mathbb{M}$ with $AA - ABA \in \mathbb{M}$.

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$$[\![\text{fuel } 0]\!] = \begin{pmatrix} 1 & 1 \\ 1 & 0 \end{pmatrix}, [\![\text{fuel } 1]\!] = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

$$[\![\text{output}]\!] = \begin{pmatrix} 2 & 1 \\ 1 & 1 \end{pmatrix} - \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}$$

Ternary Encoding: Definition

221022000022010112201010022001122011110220010

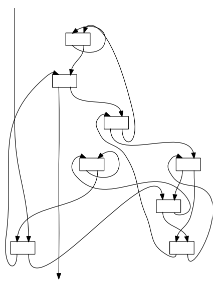
- types: car = $[([\mathbb{N}], \mathbb{N}, [\mathbb{N}])]$, fuel = $[[[\mathbb{N}]]]$
- tuples: $[\![(a, b)]\!] = [\![a]\!][\![b]\!]$
- lists:
  - $[\![\text{nil}]\!] = 0$, $[\![x : \text{nil}]\!] = 1[\![x]\!]$
  - $[\![x]\!] = 22[\![\text{len}(x) - 2]\!][\![x_1]\!] \ldots [\![x_{\text{len}(x)}]\!]$
- natural numbers: $[\![n]\!] = [\![raw(n)]\!]$
  - $raw(0) = \text{nil}$
  - $raw(n) = (n-1) \bmod 3 : raw((n-1) \operatorname{div} 3)$
  - 0, 10, 11, 12, 2 0 00. . . 2 0 22, 2 10 000. . . 2 10 222, . . .
- contestants had to reverse engineer the encoding (from parser's error messages) (the 22 gives some redundancy)

Ternary Encoding: Implementation

- use Parsec (of course)
- use Printer/Parser pairs

```
data PrinterParser t a =
    PrinterParser
       { printer :: a -> Maybe [t]
       , parser  :: Text.Parsec.Parsec [t] () a
       }
or :: PrinterParser t a
   -> PrinterParser t b
   -> PrinterParser t (Either a b)
...
```


obfuscation: circuits



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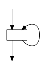

```
code:   0L:X0R0#X0R:0L

input:  01202101210201202...
output: 02120112100002120...
```

- one external input, one external output
- each gate has left and right inputs and outputs
- every output is connected to exactly one input
- backwards wires are delayed
- contestants had to deduce the circuit synatx (from example and error messages) and gate semantics (from our simulator's output)
- then build their own simulator, and circuit compiler.
- semantics:

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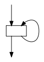

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- semantics: left: $(l - r) \bmod 3$, right: $(l \cdot r - 1) \bmod 3$

Participation

- 871 teams
- 214 teams figured out the circuit
- 146 teams submitted valid fuels
- 3,746 submitted cars
- 257,901 fuels (i.e. correct solutions)
- 350,344 bytes: max fuel (circuit description)
- 22,889 bytes: max car (ternary string)

Statistical Data

Country Language (average) Age

Statistical Data

Country		Language	(average) Age
29	USA		
28	Japan		
25	Russia		
12	Germany		
11	Ukraine		
8	France		
7	UK		
5	Hungary		
4	Australia		
4	Canada		

Statistical Data

Country		Language		(average) Age
29	USA			
28	Japan	29	Haskell	
25	Russia	17	C++	
12	Germany	16	Python	
11	Ukraine	12	Java	
8	France	7	OCaml	
7	UK	6	Ruby	
5	Hungary	5	C#	
4	Australia	3	Common Lisp	
4	Canada			

Statistical Data

Country		Language		(average) Age
				81734636191301391914215762649510094645
29	USA			24.333333333333
28	Japan	29	Haskell	grad student
25	Russia	17	C++	DRINKING AGE
12	Germany	16	Python	grey-beard
11	Ukraine	12	Java	22 sucks!
8	France	7	OCaml	54.043189
7	UK	6	Ruby	below 30
5	Hungary	5	C#	unknown
4	Australia	3	Common Lisp	22,23
4	Canada			0x20
				31.3
				15.5

People

- Web server programming and maintenance:
  Daniel Borkmann, Tobias Kalbitz, Christopher Schädlich, Michael Schmeißer
- Web design, Brute force solver:
  Johannes Erber
- Log file evaluation:
  Christian Reichmann
- Contest task design, semantics server programming:
  Bertram Felgenhauer, Johannes Waldmann
- external testers:
  Alexander Kiel (Univ. Leipzig), Georg Martius (Univ. Göttingen), Henning Thielemann (Univ. Halle)
- external advisor:
  Robby Findler (Northwestern Univ.)

Hard- and Software

specs:

- Cluster of 5 $\times$ Intel(R) Xeon(R) CPU X5365 @ 3.00GHz
- Debian GNU/Linux OS
- Web server (1 node):
  apache2, tomcat, Spring(Roo)/Java, postgresql
- Semantics server (4 nodes):
  haskell (xmlrpc, parsec, haskelldb, autolib)

load:

- 115,760 submissions per hour: peak server load
- 20 GB: total incoming traffic
- 768,049,967 bytes: size of gzipped contest database

References/Reverences

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```
let f 0 = [0,1,2] ; f 1 = [0,2] ; f 2 = [1]
    rest = 1 : 2 : ( rest >>= f )
in  0 : rest
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  `required_prefix = [1,1,0,2,1,2,1,0,1,1,2,1,0,1,2,2,1]`

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  is `"ICFP"` in morse code
- *cars*: cf. racing track of 2003 contest (Chalmers)
- *circuits*: cf. 2D (ASCII) programming in 2006 (CMU)
- *prefix*: cf. 2007 contest (Utrecht)

Comments from Participants

- I really enjoyed this problem set and our team had a ton of fun.
- Again, thanks for the fun competition! You did a great job with the problem this year. It was fun to unravel layer after layer of it!
- I enjoyed the contest very much; while the server problems were frustrating and discouraging, we think the task was very well crafted and interesting.
- I was utterly crushed after 2 minutes of reading the problem description.

Background Story: Cars and Rewriting

- chambers of engine = rules

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- upper, lower pipe = lhs, rhs of rewriting rule: $00 \to 010$
- *fuel* = matrix interpretation, a method of proving termination

Termination of Rewriting

…is undecidable, but important for software verification

automated termination provers:

- Termination Competition (termcomp) (yearly, since 2004)
- Termination Problem Data Base (TPDB)

methods for automated termination analysis:

- syntactic, e.g.,
  - recursive path orders (Dershowitz, 1982)
- semantic (interpretation), e.g.,
  - polynomial functions over $\mathbb{N}$ (Lankford, 1979)
  - linear functions (= matrices) over vectors over $\mathbb{N}$ (Hofbauer, Waldmann, 2006)

How to Find Matrix Interpretations

$\mathbb{M} :=$ square matrices over $\mathbb{N}$ with top left entry ≥ 1

- Find $A, B \in \mathbb{M}$ with $AA - ABA \in \mathbb{M}$.
- Find $A, B \in \mathbb{M}$ with $A^2B^2 - B^3A^3 \in \mathbb{M}$.
- ...

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- brute force (complete or random enumeration)

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- (SMT solvers? SAT encoding?)

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  (but: no easy way to enforce the intended shape/semantics)
- take set of random sparse matrices (fuel), then generate matching cars. prefer length increasing rules.
  $5305453 \succeq 5510450343, 5412501 \succ 3343403001$

After the Contest

- selection of ICFP contest problems was submitted to TPDB,
- were used in Termination Competition 2010 (July): termination provers performed badly (only very few were solved)

ICFP contest problems in Termcomp

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- were used in Termination Competition 2010 (July): termination provers performed badly (only very few were solved)
- contest participants should consider entering their matrix solver into next termination competition
  (use one of the open-sourced termination tools and plug in your solver)

`http://termination-portal.org/`

After the Contest

solve this puzzle:

- $\mathbb{M} :=$ square matrices over $\mathbb{N}$ with top left entry ≥ 1
  Find $A, B \in \mathbb{M}$ with $A^2B^2 - B^3A^3 \in \mathbb{M}$.

prove (or disprove and repair) this theorem

- If a string rewriting system has a compatible $\mathbb{M}$-interpretation as used in the ICFP contest, then its derivational complexity is linear.

and submit paper to

- Intl. Workshop on Termination (next: February 2012, near Innsbruck, Austria)
- Conf. Rewriting Techniques and Applications (RTA)
  (next: July 2011, Novi Sad; May 2012, Nagoya)
  `http://rewriting.loria.fr/rta/`

and the ICFP 2010 programming contest winners are ...

Judges' Prize

for their very efficient circuit encoding (one gate per trit)

Cult of the Bound Variable

... are an extremely cool bunch of hackers.

Languages: SML, C++

The guy who figured out our final circuit encoding in a fit of brilliance at 2am Saturday morning (and finished implementing it in C++ before anyone who knew SML woke up, which ended up being fine) posted a write-up of how it worked:

Winner of the Lightning Division

best score after 24 hours (second best after 72 hours)
produced very hard problem instances

Carl Witty

Language: Sage (`http://www.sagemath.org/`),
a computer algebra system that runs under Python.

Sage is very suitable for rapid prototyping.

Winner of the Main Division

best score after 72 hours

Pure Pure Code ++

Languages: C++, Python, Haskell

. . . are the programming languages of choice for discriminating hackers.

The Future

- (Tell your students to) Take part in the ICFP programming contest!
- Submit your proposal for running the next ICFP programming contest to the ICFP PC chair/steering committee.
  (E.g., you have a super nifty Haskell Web Server framework and want to showcase it.)

all information via

- `http://icfpcontest.org/`
- `http://www.icfpconference.org/`