# Evolutionary Design of FreeCell Solvers

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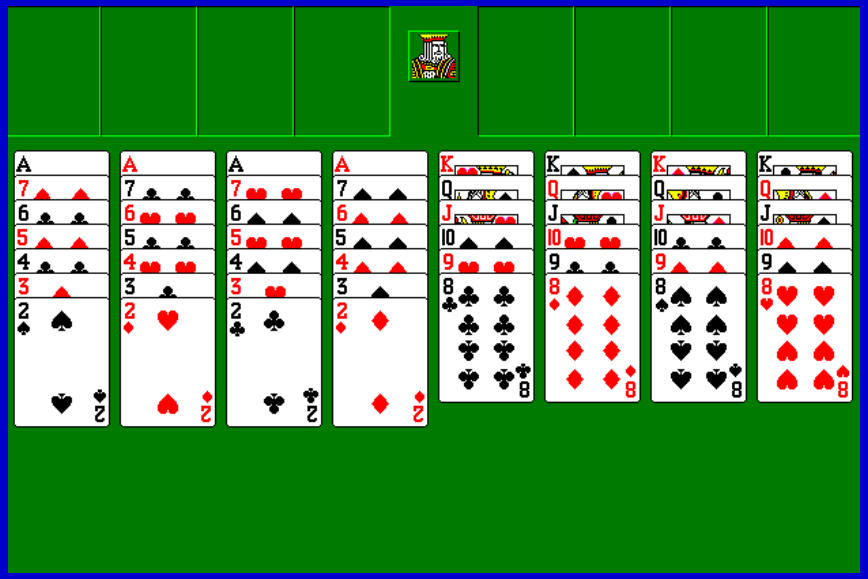
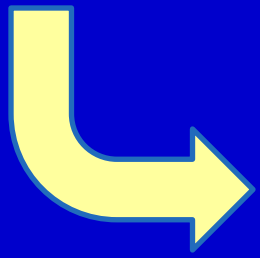
**2013 "HUMIES" AWARDS FOR HUMAN-COMPETITIVE RESULTS**

# The Game of FreeCell





EASY TO LEARN

HARD TO PLAY

HARD FOR Aler

# Humans

freecell.net

solitaire | jezzball | cinco | travel

...draining workplace productivity since 1996

Proceeds go to charity

home
play
scores
game stats
tournament
instructions
discussion
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**Do you just totally love Freecell?** Many consider Freecell the best solitaire game ever invented. It's fun, sometimes even addictive, and winning depends on strategy and skill, not just luck. Here at Freecell.net you can play Freecell online right now, learn more about Freecell, join in a discussion of the finer points of Freecell, compete in Freecell tournaments, and heck, even chat about Freecell. Plus we have massive lists of scores for the best Freecell players on the 'net, all updated continuously. Think you've got a big streak? Check out some of the streaks folks have going here! Oh yeah, almost forgot: supports iPad too.



**Spreadsheet look!** OK, so it's a fact that a large number of you out there are playing a few games of Freecell while at work, during lunch hour to be sure. But to avoid those awkward moments when someone walks past your desk and catches a glimpse of your monitor, we now provide Freecell in a convenient spreadsheet-like view. You look

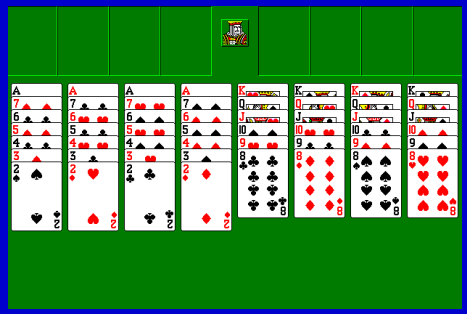
**Masters Tournament**
Sun Jun 24
Congrats, dr.calicoki...

**Standard Current**
11750 PudongPete
1147 WillWeBeFree
1120 huffy
768 Topgun
729 R2G2
664 rgk12
607 jules12
514 JohnWF
500 wasjun
486 theburger622

**Daily Today**
45 tstark
42 coloman
40 Joelma2012
35 doctorx
35 tonymacaroni
33 treb
33 blederer
33 ginom
31 moni64
30 kapra

# Top AI Solvers to Date

- **Second best: Heineman's Staged Deepening, able to solve 96% of Microsoft 32K**
- **Best: Our GA-FreeCell, 98.36% of Microsoft 32K**
- **Microsoft 32K: Standard problem suite comprising 32000 deals (initial configurations)**



# But that was way back in the past…

- As in, two years ago…

From our GECCO 2011 paper:

"The site statistics… included results for 76 humans who met the minimal-game requirement… If the statistics are sorted according to win rate then our player assumes the no. 9 position."

# Darn, some humans can still beat us…

**Can we do better?**

**Can we beat all humans?**


YES
WE
CAN

# Easier said than done…

- Tweaking our GA did not work, try as we did
- The gap between GA-FreeCell and the very best humans turned out to be significant
- An entirely new method was needed
- Standard GP? Tried it, didn't work
- We've invented a new method called policy-based genetic programming
- We used it to evolve a new solver: Policy-FreeCell
- Is it any good?

# Policy-FreeCell vs. Top Humans

| Rank | Name | Deals played | Time | Solved |
|---|---|---|---|---|
| 1 | Policy-FreeCell | 32,000 | 3 | 99.65% |
| 2 | JonnieBoy | 39,102 | 270 | 99.33% |
| 3 | time.waster | 37,286 | 191 | 99.20% |
| 4 | Nat_King_C. | 54,599 | 207 | 98.97% |
| ... | | | | |
| 11 | GA-FreeCell | 32,000 | 3 | 98.36% |
| ... | | | | |
| 66 | HSDH | 32,000 | 44 | 96.43% |

# Result is Human-Competitive (1)

**(B) equal to / better than new scientific result**

**We were able to evolve a killer application for the game of FreeCell, a highly challenging game for humans. Our evolved strategy is faster and better than ALL humans at a major FreeCell website.**

# Result is Human-Competitive (2)

(D) publishable in own right as new scientific result

(F) equal to / better than achievement in its field

(G) solves problem of indisputable difficulty in field


FreeCell is considered to be one of the most difficult domains for classical planning. Our evolved solvers are the most successful reported ones to solve this difficult problem with search.

Our solvers are evolved using policy-based GP and are publishable in their own right.

Our policy-based GP is better than other methods both in terms of scalability and performance.

# Result is Human-Competitive (3)

**(H) holds its own / wins competition vs. human**

**Victory over humans is two-fold:**

**(1) Our evolved solver's performance far surpasses that of ALL human players.**

**(2) We have developed the best algorithm for the hard FreeCell game, better than any algorithm designed by humans (including us!).**

# Why is Result Best? (1)

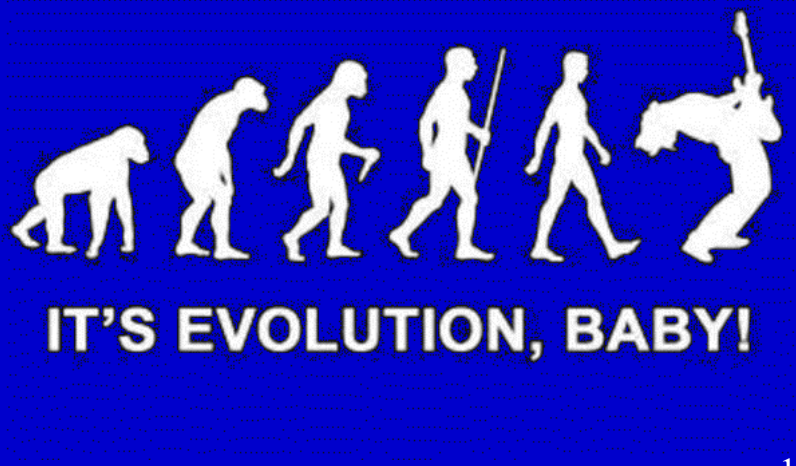

**SOLVES DIFFICULT PROBLEM WITH LONG HISTORY**

- Difficult puzzles (involving search and planning problems) have a longstanding tradition in the AI community
- FreeCell tackled in several International Planning Competitions (IPCs) and in numerous attempts to construct state-of-the-art planners
- Yet, in all competitions, all of the general-purpose planners performed poorly on this domain
- We have the best solver, able to beat both other algorithms and all humans

# Why is Result Best? (2)

**PUSHING EVOLUTION FURTHER**

- **FreeCell is the most difficult single-player search (i.e., planning) problem solved (so successfully) with evolution so far, as FreeCell requires an enormous amount of search, due both to long solutions and to large branching factors**



# Why is Result Best? (3)

**SEVERAL DEGREES (AND MODALITIES) OF IMPROVEMENT:**

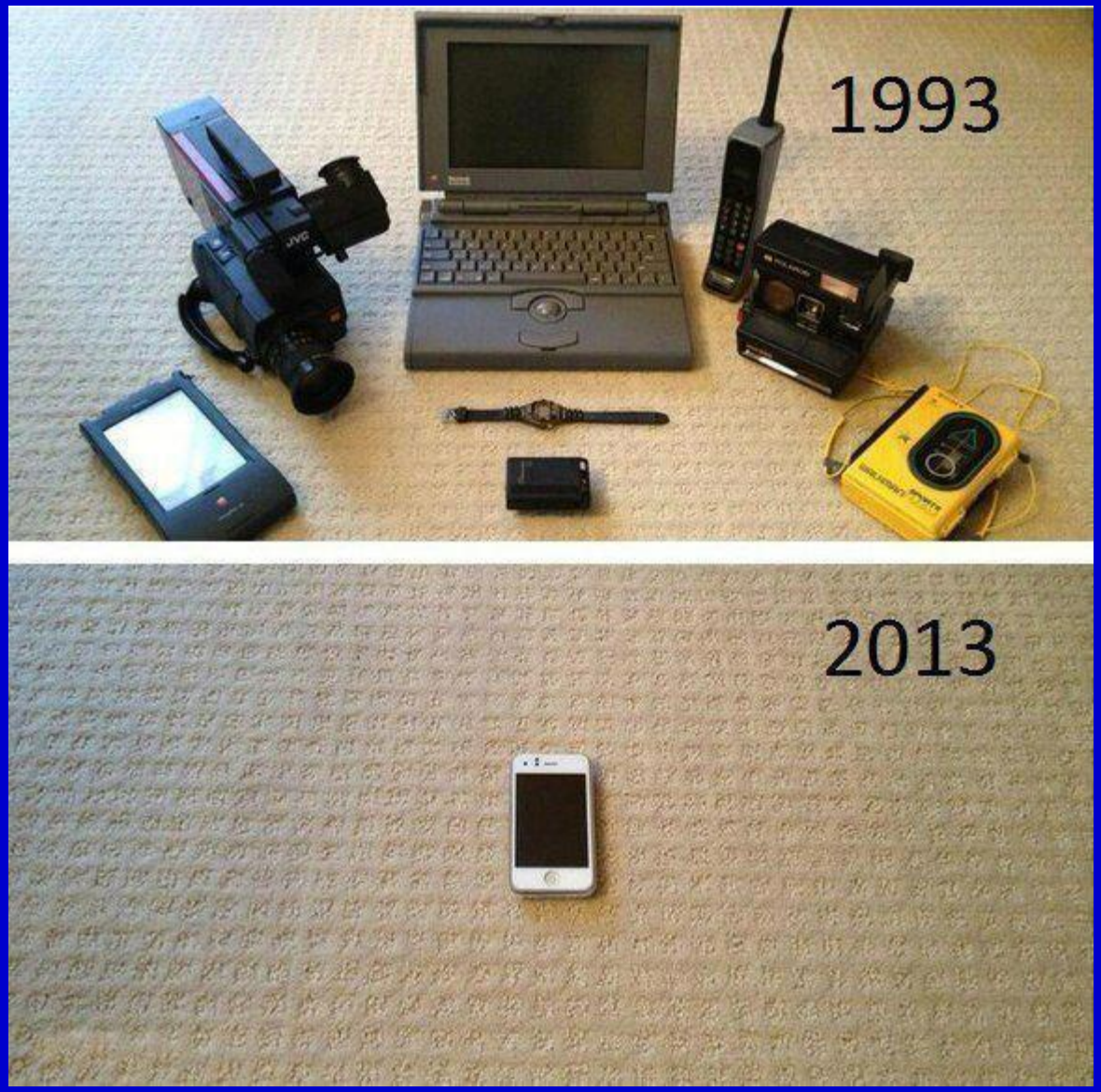
- **The popular Enhanced Iterative Deepening algorithm was outperformed by the HSD algorithm, all of which were beaten by our evolved solvers**
- **Evolution managed to take our best designed ingredients of limited performance and transform them into HIGHLY successful strategies**
- **Policy-FreeCell not only beat human AI researchers but also all human players of FreeCell on record**

# Why is Result Best? (4)

**PUBLISHED IN TOP JOURNAL**

# Take-Home (Take-Prize?) Message

- **We have designed a machine player of FreeCell through evolution (GP)**
- **This machine player is better than ALL humans**


1993
2013

# 1992

**Koza evolves strategies for very simple games**

**(“Simple discrete game”, “Game of simple pursuit”)**

# 2012

**We evolve strategies for highly complex, real-world game**