Solving Hard Problems with Games

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Solving Hard Problems with Human-Computer Symbiosis

Coadaptation:
1. People → Experts
2. Programs/Games → Optimal problem tools

Games are an ideal vehicle of coadaptation
Center for Game Science

• Over 35 PhD, ugrads, SDEs, designers, artists
• 6 games currently in development
The Challenge:

1. hard to make an entertaining game
2. even harder do it and solve a hard problem
   – constraints on game design
   – make real discovery, really learn something
   – Long term involvement
• cannot separate the two objectives
Secondary Award Effect

% of players

Time
% of players

Time

Secondary Awards Considered Harmful

100

0
Proteins
Proteins

Sequence: MQIFVKTLTGKTILEVEPSDTIE...

Sequence: MGKYDKQIDLSVTDLKKLRVKEL...

Sequence: KPVSLSYRCPRFFESHVARANV...

3D Structure
Challenges

• Solve difficult problem
• By people who know nothing about it
• while ensuring they have fun

But at the beginning...

• Don’t know how to teach the rules
• Don’t know appropriate problem visualization
• Don’t know appropriate human-centered tools
Approach it as science
Foldit
Challenges

visualization
interaction
scoring
training
Training refinement
Training refinement

![Graph showing level completion percentage over dates for various tasks. The graph includes lines for tasks such as One Small Clash, Swing It Around, Hide the Hydrophobic, Shake It Off, Close the Gap, and When Backbones Collide, among others. The legend also includes options like Twin Pack, Nudge It Along, Triple Packed, Sheets Together, Lonely Sheets, Sheets and Ladders, Lock and Lower, Turn It Down, The Right Rotation, Flippin' Sheets, Rubber Band Reversal, and Linear trend (R.B.R. only).]
Training refinement

[Graph showing level completion percentage over dates with various game elements represented.]

- One Small Clash
- Swing It Around
- Hide the Hydrophobic
- Shake It Off
- Close the Gap
- When Backbones Collide
- Twin Pack
- Nudge It Along
- Triple Packed
- Sheets Together
- Lonely Sheets
- Sheets and Ladders
- Lock and Lower
- Turn It Down
- The Right Rotation
- Flippin' Sheets
- Rubber Band Reversal
- Linear trend (R.B.R. only)
Training refinement
Training refinement
Training refinement
Training refinement
Training refinement
Biochemistry not just for experts...

Prior knowledge of biochemistry

- None
- High school / Basic
- One undergraduate course
- Majored in biology or similar
- PhD in chemistry or organic chemistry
- PhD in biochemistry 30 years ago
- Professionally involved
Players search over strategies

Band
Lock
Global minimize
Local minimize
Repack
Backbone pull
Sidechain pull
Rebuild
Secondary structure
Tweak
Players search over strategies

- Player A
- Player B
- Player C
- Player D

Refinement puzzles:
- Band
- Lock
- Global minimize
- Local minimize
- Repack

Freestyle puzzles:
- Backbone pull
- Sidechain pull
- Rebuild
- Secondary structure
- Tweak
Players search over strategies

Refinement puzzles

Freestyle puzzles

- Band
- Lock
- Global minimize
- Local minimize
- Repack
- Backbone pull
- Sidechain pull
- Rebuild
- Secondary structure
- Tweak
Players search over strategies

- Player A
- Player B
- Player C
- Player D

Refinement puzzles

Freestyle puzzles

Rosetta rebuild and refine

Band
Lock
Global minimize
Local minimize
Repack
Backbone pull
Sidechain pull
Rebuild
Secondary structure
Tweak

Entire job
First day
First hour
Entire job
Comparison to Algorithm

Better energy

Closer to native

Player solutions
Top player path
Algorithm solutions
Comparison to Algorithm

Player solutions
Top player path
Algorithm solutions

Swapped Strands

Buried residues full-atom RMSD to native 2kpo NMR model
Comparison to Algorithm

Player solutions
Top player path
Algorithm solutions
Protein Structure Prediction

Problem Solving

MQIFVKTLTGKTLVEPSDTIE...
nature

Heading
Interesting subtitle

Heading
Type some cool information that entices you to read this magazine
Experimental Structure Solved

- Mason-Pfizer Monkey Virus Retroviral Protease (MPMV PR)
- Plays a role in AIDS in monkeys
- Experimentalists worked on for ~15 years
- Computational methods failed to solve
- Gave to players for 3 weeks
players are taking and modifying shared recipes
Algorithm Comparison

- Independent discovery of scientists’ algorithmic techniques

- Adjust repulsive force
- Discrete optimization
- Continuous optimization
Protein Design Changes

New tutorial levels
Experimental Validation
Fibronectin Design
Diels-Alder Design

• Useful chemical reaction
• Potential drug applications
• Improve enzyme for reaction
Diels-Alder Design

Puzzle Rounds:
1. Ligand moved
2. Helix binding ligand
3. Supporting helix
4. Refine/confirm helices

Starting scaffold
Diels-Alder Design

Starting scaffold
Player/scientist design
Biofuel Process Discovery
Nanotechnology
DNA game

Main Developers: Rich Snider, Dmitri Danilov
Domain Expertise: Georg Seelig
Novice to Experts
“Difficulty with fractions… is pervasive and is a major obstacle to further progress in mathematics.”

We cannot make an effective fractions game

We do not know

optimal pathways

student-specific adaptations
Games for STEM Learning
Games for Massive Data-gathering to Optimize Learning Pathways
In-game assessment and intelligent tutor refinement
100K students

100K students
Textbooks -> games
Game For Software Verification
CSFV New Capabilities

Source: University of Washington
Chip Layout Design
Thank you

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