

Decision making data from games and their integration with individual-based modelling

21 February 2023

Human decision-making and SDGs

Need to understand how people make decisions in complex social-ecological systems (SDGs 3, 7, 13, 15, & 16)

- ▶ ecosystem management¹
- ▶ biodiversity loss²
- ▶ food security³
- ▶ energy management⁴

Integrate ecological, environmental, and social dynamics



¹Defries, R & H Nagendra. 2017. *Science* 356:265-270.

²Mason, T. H. et al. 2018. *Conserv. Lett.* 11:1-9.

³Gould, F, et al. 2018. *Science* 360:728-732.

⁴Thollander, P, et al. 2019. *Sustainability* 11:1-11.

Social-ecological systems

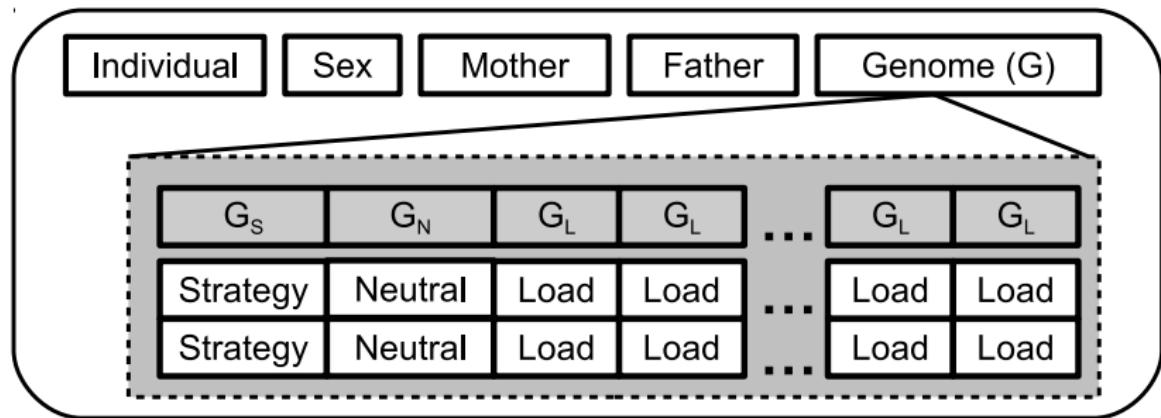
- ▶ Include individual, goal-oriented, decision-making agents¹
- ▶ Complex feedbacks between social and ecological components
- ▶ Can be simulated using Agent-Based Modelling (ABM) approach^{1,2}

¹Shulze, J, et al. 2017. *J. Artif. Soc. Soc. Simul.* 20:8.

²Duthie, AB, et al. 2018. *Meth. Ecol. Evol.* 9:2396-2401.

Agent-based modelling: a general overview

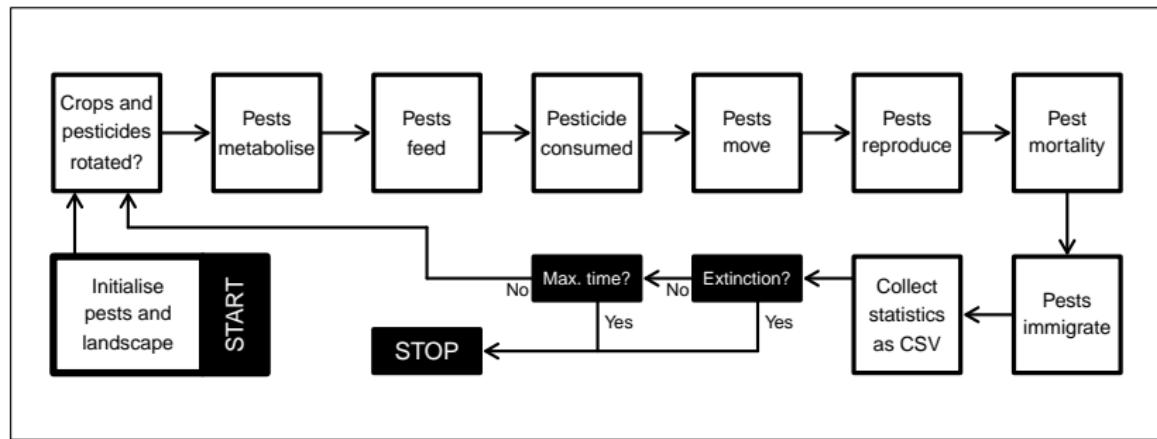
- ▶ Simulate a system *in silico*, using computer code
- ▶ Individuals are represented as discrete entities



¹Duthie, A. B., & Reid, J. M. (2016). *Am. Nat.* 186, 651-667.

Agent-based modelling: a general overview

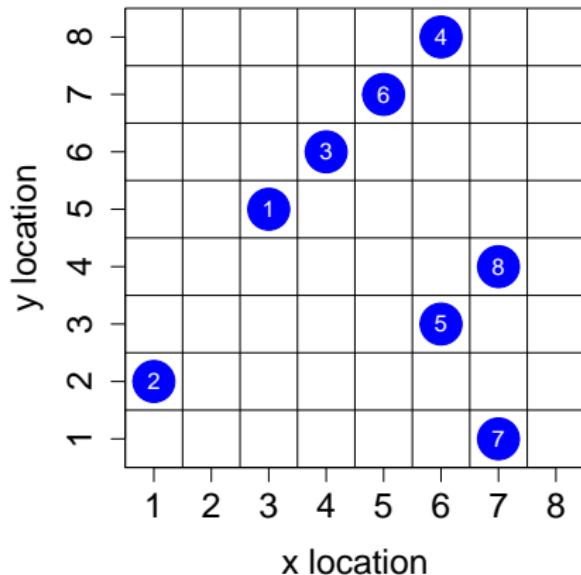
- ▶ Processes are often stochastic (events probabilistic)
- ▶ Highly mechanistic models are possible
- ▶ Can test ideas by simulating across many parameters



¹Duthie, AB, et al. 2022. *bioRxiv*. DOI: 10.1101/2022.08.22.504740.

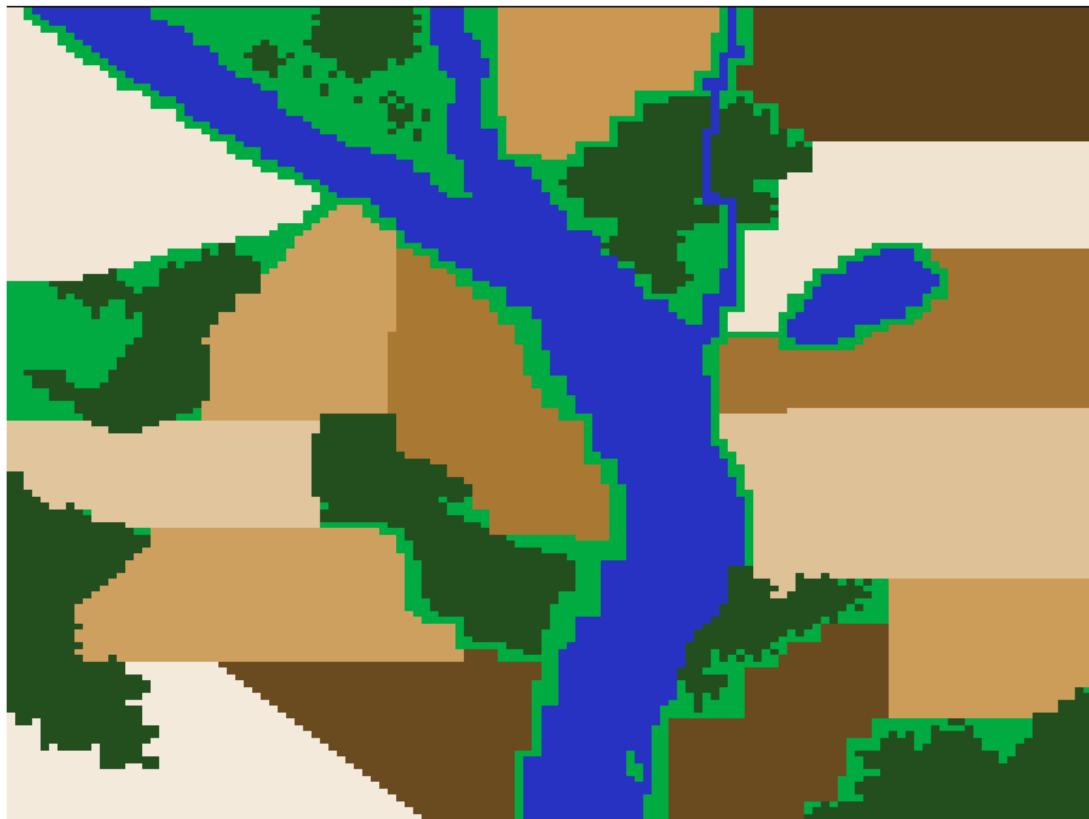
<https://bradduthie.github.io/resevol/>

Agent-based models are often spatially explicit



- ▶ Agent locations can be mapped to a landscape, with rules for movement
- ▶ Landscape can include complex properties and spatial autocorrelation

Complex landscapes in agent-based models



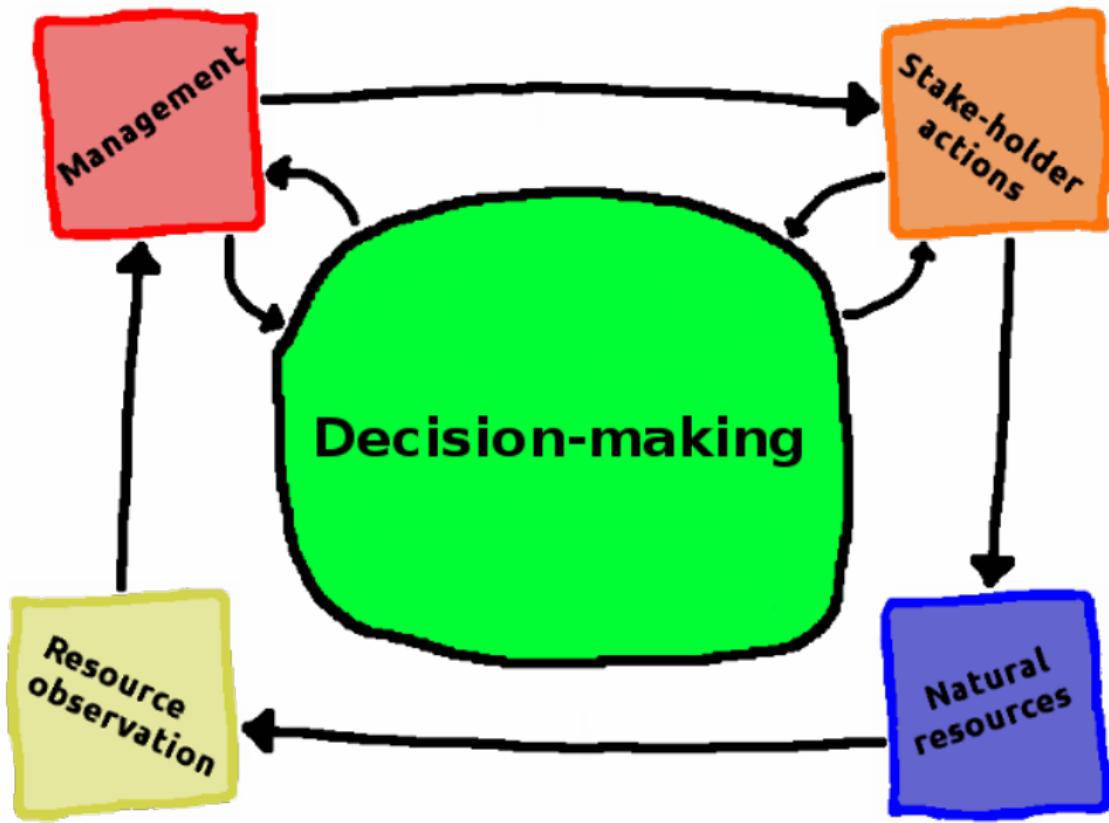
¹Duthie, AB, et al. 2022. *bioRxiv*. DOI: 10.1101/2022.08.22.504740.

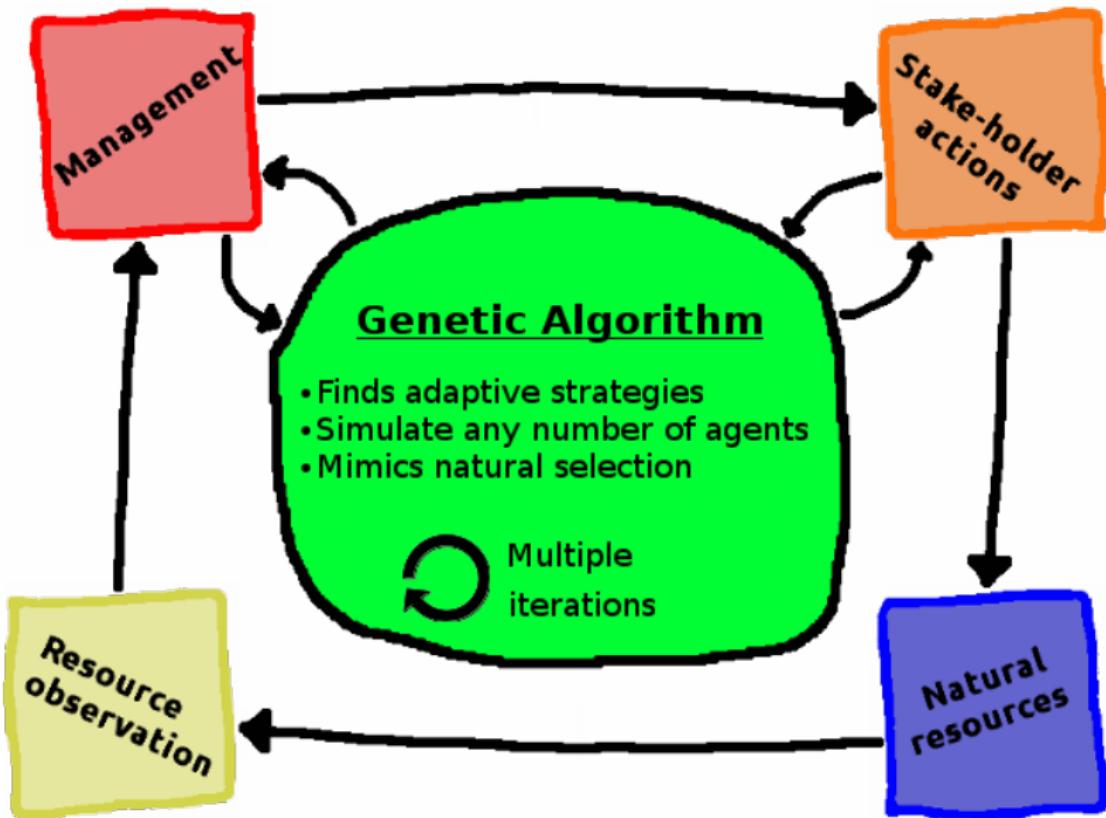
<https://bradduthie.github.io/resevol/>

Generalised Management Strategy Evaluation (GMSE)

- ▶ Model biodiversity dynamics & realistic human decision-making
- ▶ Predict resource & land-use changes in social-ecological systems
- ▶ Open-source on [CRAN](#) & [GitHub](#)

¹Duthie, A. B. et al. 2018. *Method. Ecol. Evol.*, **9**: 2396-2401.

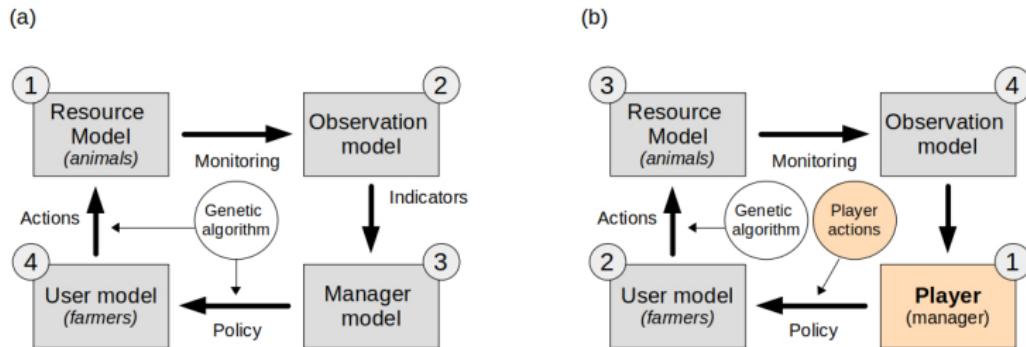




Gamifying GMSE (Animal and Farm)

Create a game using the GMSE package

Substitute genetic algorithm with player decision-making¹

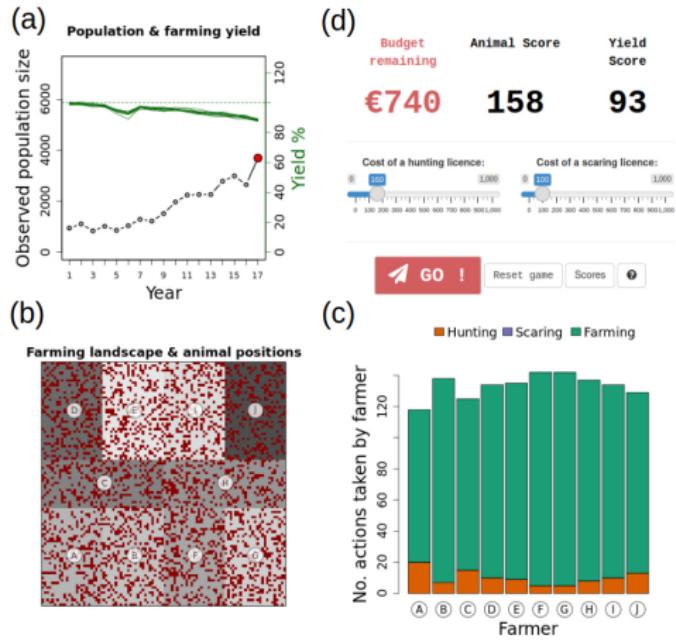


Collect data to see how people play

¹Minderman, J, et al. 2021. *bioRxiv*. DOI: 10.1101/2021.09.23.461497

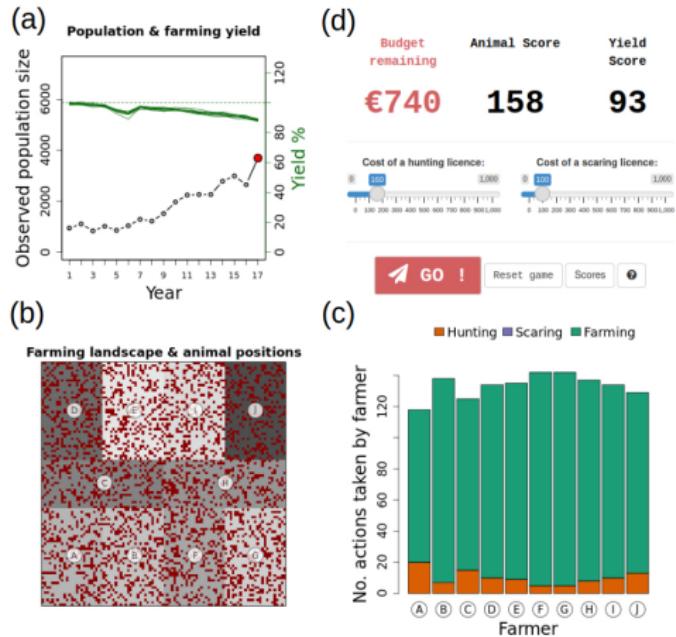
Gamifying GMSE (Animal and Farm)

- ▶ Players use sliders to set policy
- ▶ Players gave feedback on game



Gamifying GMSE (Animal and Farm)

- ▶ Players use sliders to set policy
- ▶ Players gave feedback on game

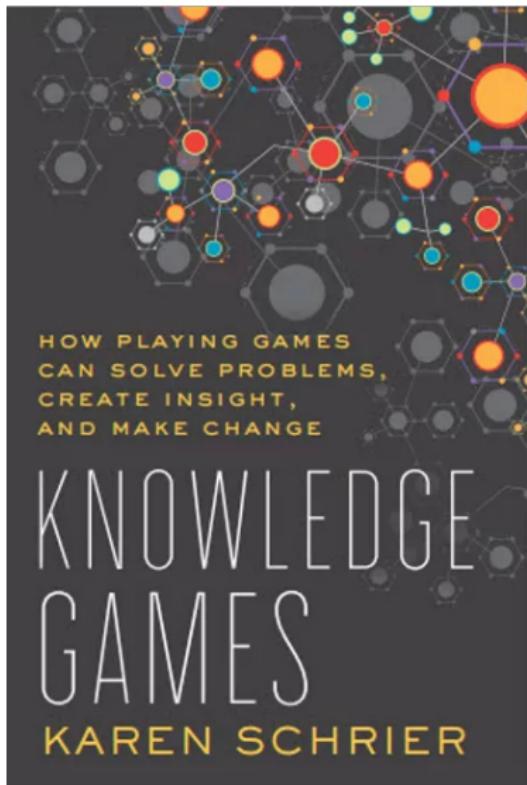


Game feedback is model feedback¹

¹Minderman, J, et al. 2021. *bioRxiv*. DOI: 10.1101/2021.09.23.461497

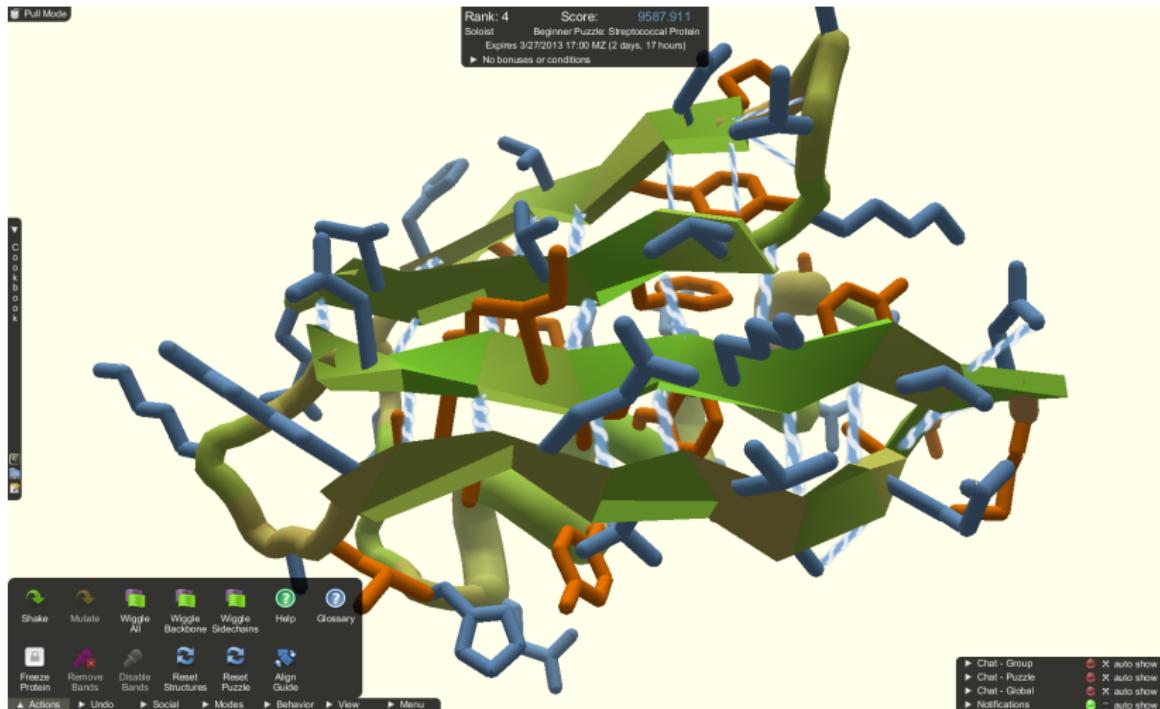
Knowledge games

Knowledge games “seek to invent, create, and synthesise new understandings of the world, solve real-world problems big and small, and help us reconsider, reframe, and reflect on humanity and our universe.” [1]



¹Schrier, K. 2016. *Knowledge games: How playing games can solve problems, create insight, and make change*. John Hopkins University Press.

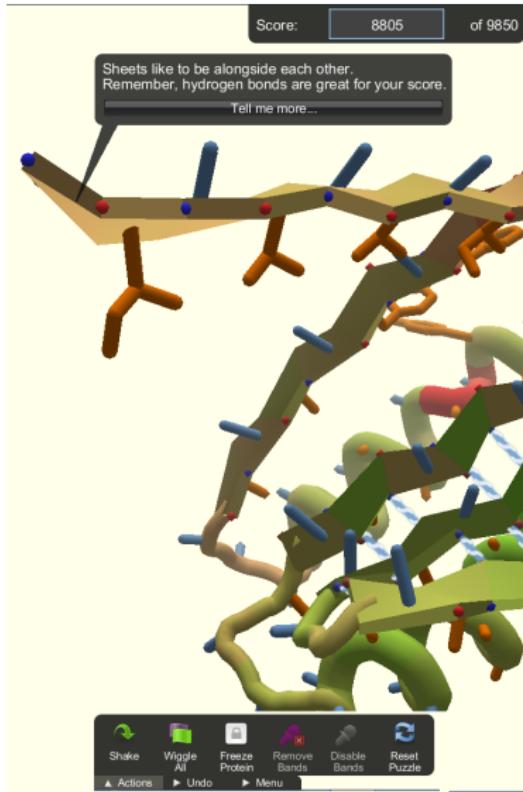
FoldIt: A game for biochemistry research



¹Image: <https://fold.it/portal/info/science>

FoldIt: A game for biochemistry research

- ▶ 50000+ players
- ▶ Support from DARPA, NSF, NIH, HHMI, Microsoft, Adobe, and RosettaCommons
- ▶ 21 papers since 2010



¹Image: <https://fold.it/portal/info/science>

LETTER

<https://doi.org/10.1038/v41586-019-1274-4>

nature
structural &
molecular biology

De novo protein design by citizen scientists

Brian Koepnick^{1,2}, Jeff Flatten³, Tamir Husain³, Alex Ford^{1,2}, Daniel Adriano Silva^{1,2}, Matthew J. Blick^{1,2}, Aaron Bauer¹, Gaohua Liu^{1,2}, Yojoji Ishida⁴, Alexander Boykov^{1,1}, Roger D. Estep¹, Susan Kleinfein^{1,1}, Toke Nørgråd-Sølano⁵, Linda Weil¹, Foldit Players^{1,2}, Francisco T. Montalvao^{1,2}, Frank DiMaio^{1,3}, Zoran Popović¹, Eliezer Khatib¹, Seth Cooper¹ & David Baker^{1,2,5,6}

Online citizen science and protein recognition game Foldit presents Watson-C, however, it represents three-dimensional design in presented as a folded protein.



Algorithm discovery by protein folding game players

Firas Khatib¹, Seth Cooper¹, Michael D. Tyka¹, Kefan Xu¹, Ilya Makedon⁶, Zoran Popović¹, David Baker^{1,2,5}, and Foldit Players

¹Department of Biochemistry, ²Department of Computer Science and Engineering, and ³Howard Hughes Medical Institute, University of Washington, Box 357370, Seattle, WA 98195

Contributed by David Baker, October 5, 2011 (sent for review June 29, 2011)

Foldit is a multiplayer online game in which players collaborate and compete to create accurate protein structure models. For specific hard problems, Foldit player solutions can in some cases outperform state-of-the-art computational methods. However, very little is known about how collaborative gameplay produces these results and whether Foldit player strategies can be formalized and

As the players themselves understand their strategies better than anyone, we decided to allow them to codify their algorithms directly, rather than attempting to automatically learn approximations. We augmented standard Foldit play with the ability to create, edit, share, and rate gameplay macros, referred to as "recipes" within the Foldit game (10). In the game each player



nature

Vol 466 | 5 August 2010 doi:10.1038/natur

DOI: 10.1038/nature

LETTERS

Predicting protein structures with a multiplayer online game

Seth Cooper¹, Firas Khatib¹, Adrien Treuille^{1,3}, Janos Barbero¹, Jeehyung Lee¹, Michael Beenen¹, Andrew Leaver-Fay^{2,4}, David Baker^{2,4}, Zoran Popović¹ & Foldit players

People exert large amounts of problem-solving effort playing computer games. Simple image- and text-recognition tasks have been successfully "crowd-sourced" through games^{1–3}, but it is not clear if more complex scientific problems can be solved with human-directed computing. Protein structure prediction is one such

retaining the deterministic Rosetta algorithms as user tool developed a multiplayer online game, Foldit, with the goal of producing accurate protein structure models through gameplay. Improperly folded protein conformations are posted online sites for a fixed amount of time, during which players inter-

ARTICLE

Received 18 Apr 2016 | Accepted 12 Jul 2016 | Published 16 Sep 2016 | Updated 25 Oct 2016

Determining crystal structures through crowdsourcing and coursework

Scott Horowitz^{1,2,*}, Brian Koepnick^{3,*}, Raoul Martin^{1,4,*}, Agnes Tyminiecki^{1,2}, Amandi Seth Cooper⁷, Jeff Flatten⁸, David S. Rogawski⁹, Nicole M. Koropatkin¹⁰, Tsinatkeab T Philipp Koldewey^{1,2}, Logan S. Ahlstrom^{1,2}, Matthew R. Chapman¹, Andrew P. Sikkelma¹, Finn P. Maloney¹³, Felix R.M. Beinlich^{11,14}, Foldit Players¹, University of Michigan study David Baker^{1,3,15,16}, Firas Khatib¹⁷ & James C.A. Bardwell^{1,2}

Social simulation games are very popular

Decision-making in complex social-ecological systems is the focus of many highly popular games¹.

- ▶ **Farmville**

- ▶ 80 million players
- ▶ Diverse player base^{2,3}

- ▶ **SimCity**

- ▶ 1989 to present
- ▶ Millions of copies sold

People invest a lot in these games and take their decisions seriously^{1,4}.



¹Duthie et al. 2021. *Conserv. Biol.* 35:1051-1053.

²ESA. Essential Facts 2019. *Entertainment Software Association*.

³Berry, N. Facebook Casual Game Demographics.

(<http://www.datagenetics.com/blog/december12010/>), accessed 2020-11-17.

⁴Yee, N. 2006. *Avatars at work and play*. Pp 187-207. Springer.

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¹Lane, R. 2018. The Guardian
(<https://www.theguardian.com/games/2018/jul/24/meet-the-real-life-farmers-who-play-farming-simulator>), accessed 2020-10-25.

Overlap between games and agent-based models

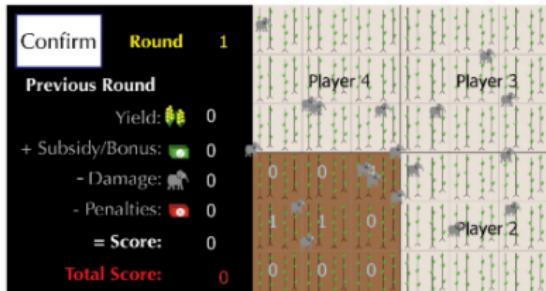


¹Duthie, AB, et al. 2022. *bioRxiv*. DOI: 10.1101/2022.08.22.504740.

<https://bradduthie.github.io/resevol/>

ConFooBio games (tablet-based and face-to-face)

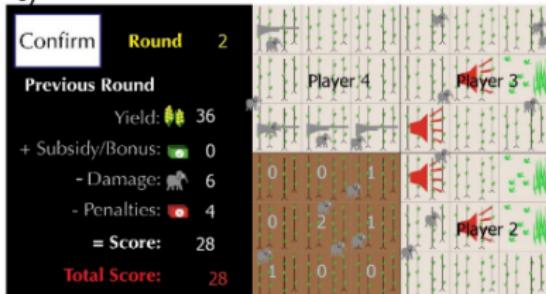
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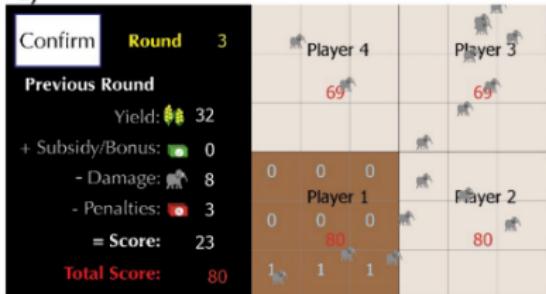
b)



c)



d)



¹Rakotonarivo, OS, et al. 2021. *Ecol. Soc.* 26:8.

²Rakotonarivo, OS, et al. 2021. *People & Nature* 3:162-175.

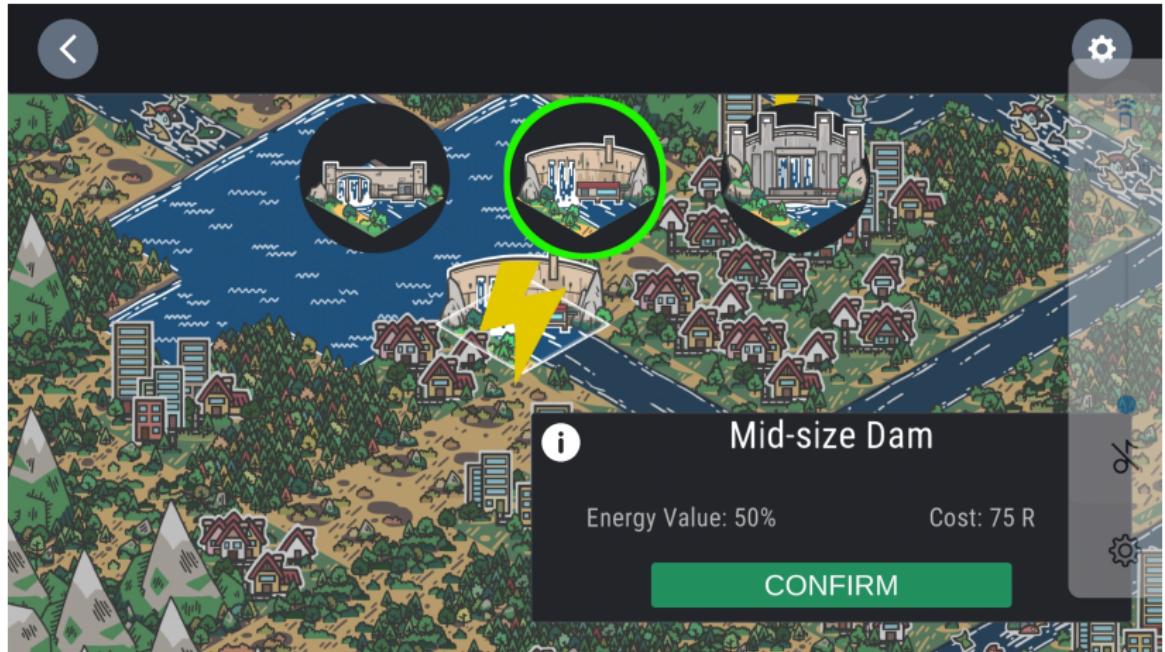
³Rakotonarivo, OS, et al. 2021. *Front. Environ. Sci.* 2:661987.

BEACON project (mobile app game)



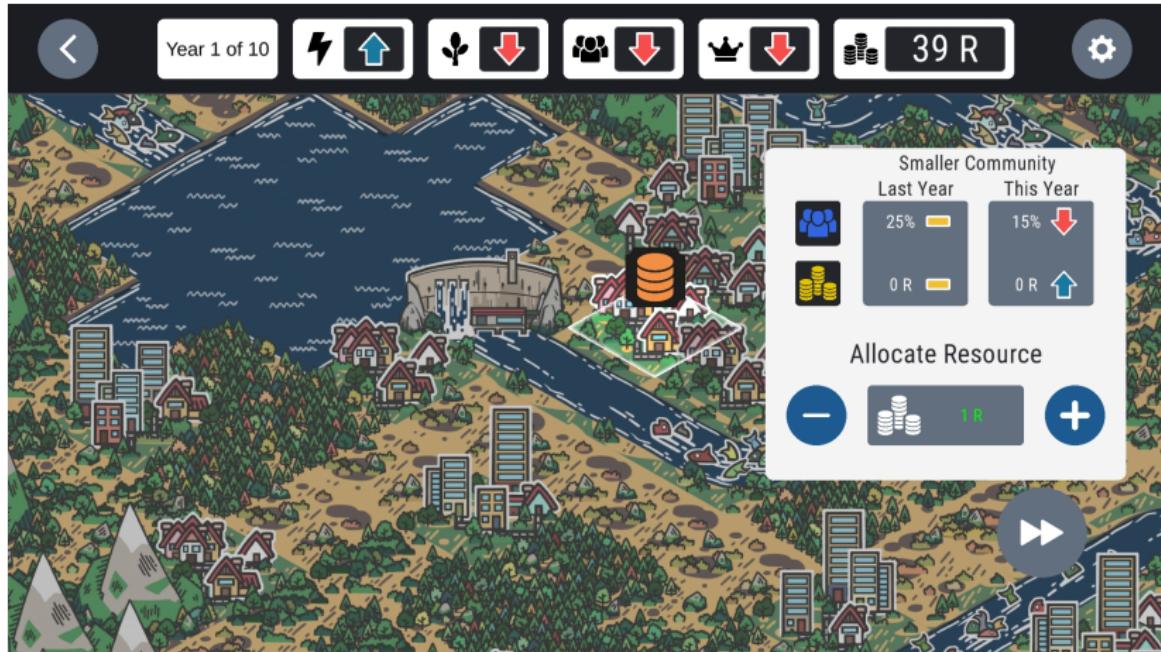
<https://play.google.com/store/apps/details?id=com.hyperluminal.stirlinguniversity.sustainabledevelopmentgame&gl=GB>

BEACON project (mobile app game)



<https://play.google.com/store/apps/details?id=com.hyperluminal.stirlinguniversity.sustainabledevelopmentgame&gl=GB>

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<https://play.google.com/store/apps/details?id=com.hyperluminal.stirlinguniversity.sustainabledevelopmentgame&gl=GB>

Power up data collection

How to best collect game data?

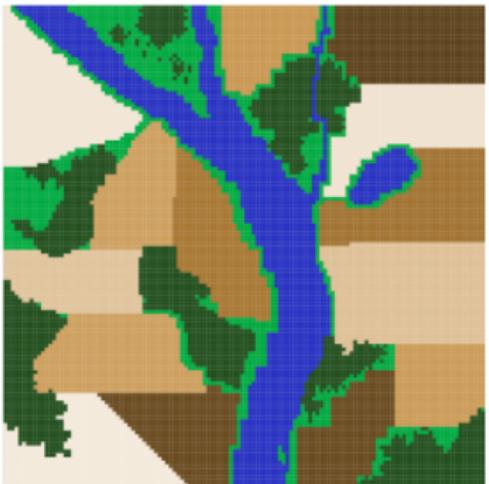
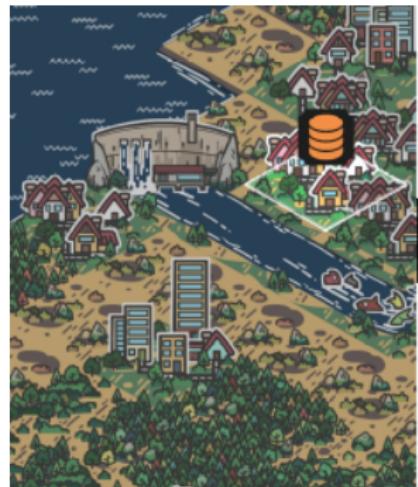
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Power up data collection

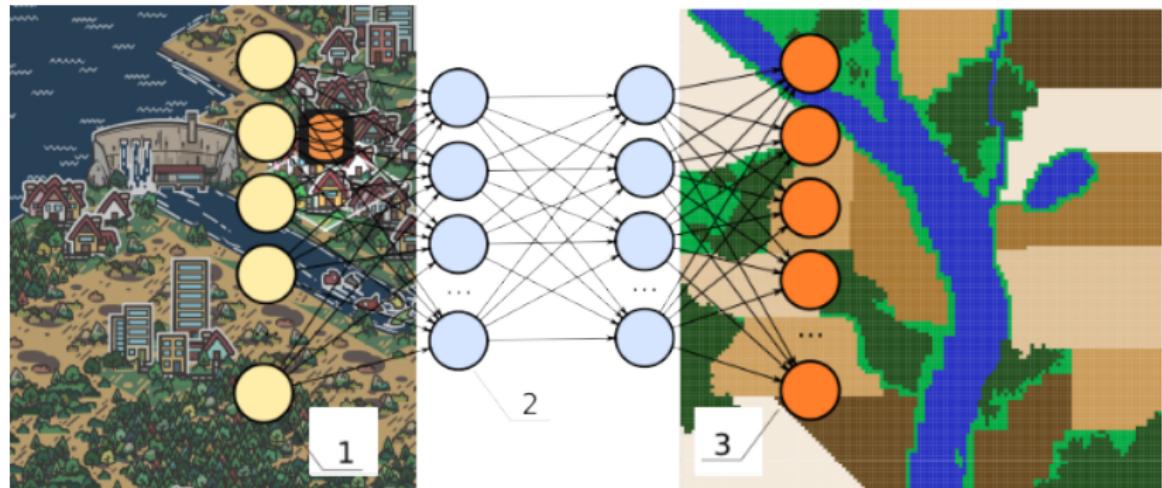
Over 11k rows since January 2023

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73	ResourceChanged	e4e0ce4c-62ec-428b-a4ca-50fe70	1672058156282	0743c3c1	BIOU9CP_GR	16	

Game data to agent-based models



Game data to agent-based models



Knowledge games for model parameterisation

Knowledge games as a free and open tool for data collection¹.

- ▶ Test hypotheses under simulated conditions
- ▶ Long-term natural experiments *in silico*
- ▶ Big data for agent-based model development



¹Duthie, AB, et al. 2022. *Conserv. Biol.* 35:1051-1053.