IGO MATH – Playing Go in an integrated Mathematics and Computing course

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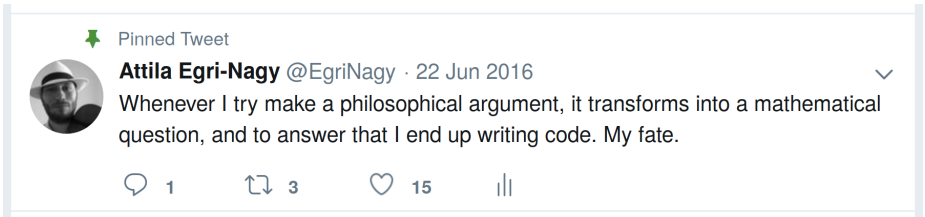
Who am I?



Software engineer disguised as a mathematician,

- research in applied computational abstract algebra,
- teaching traditional math classes (Algebra, Calculus, Discrete Math, Statistics) and programming.

Started to play Go in 2004 (due to the Hikaru No Go anime/manga).

Akita International University, Japan

- a liberal arts college
- teaching in English

Topic

Rationale for a course integrating Go into a Mathematics/Computing curriculum.

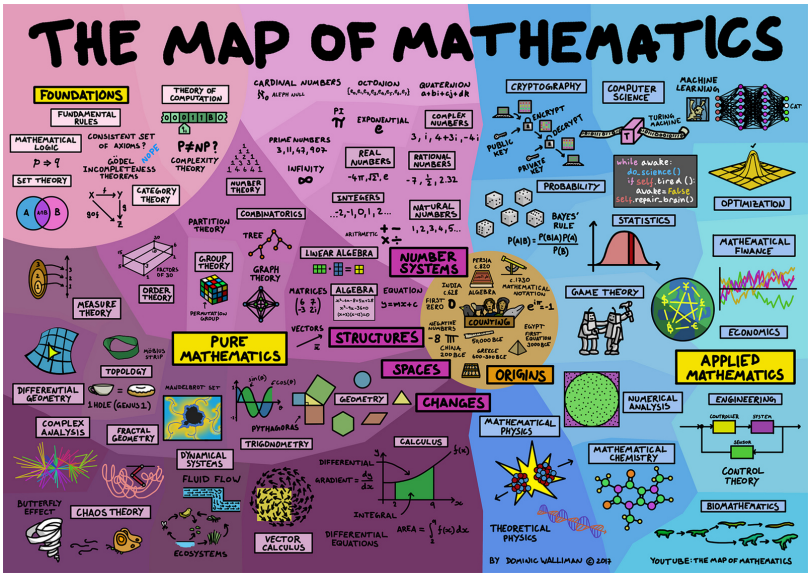
What is the ultimate goal?

Teaching students to think for themselves.

Best guess/attempt: Mathematics.

An artificial language for

- describing the world and our ideas precisely,
- making complex problems easier to handle.



Trouble with mathematics education

Most people simply don't like the subject.

A "cultural disaster", multifaceted issue.

One aspect:

We are giving solutions to problems that students don't have.

'Interest' in Mathematics courses:

- required: many students, but a course with the usual content cannot easily change the experience
- elective: few students, typically exchange or graduating students (after study abroad)

Traditional mathematics fails to attract students.

IT'S WEIRD HOW PROUD PEOPLE ARE OF NOT LEARNING MATH WHEN THE SAME ARGUMENTS APPLY TO LEARNING TO PLAY MUSIC, COOK, OR SPEAK A FOREIGN LANGUAGE.

Programming works to some extent

Computational problem solving can be compulsive.

MAT245 Poetry of Programming – Puzzle based introduction to Functional Programming `https://egri-nagy.github.io/popbook/`

Same time, thinking about a different problem.

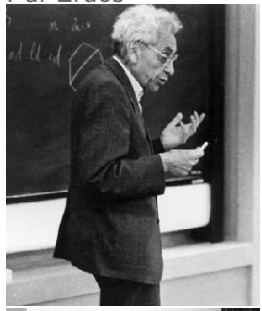
What are the benefits of teaching Go to small kids? e.g. my 4 years old son.

These two problems (math ed & raising kids) collided in my head, then the idea escalated quickly.

No, it didn't.

“Learning the game is worth taking an advanced mathematics course. ”

Pál Erdős



We tend to say this, but where is the evidence?

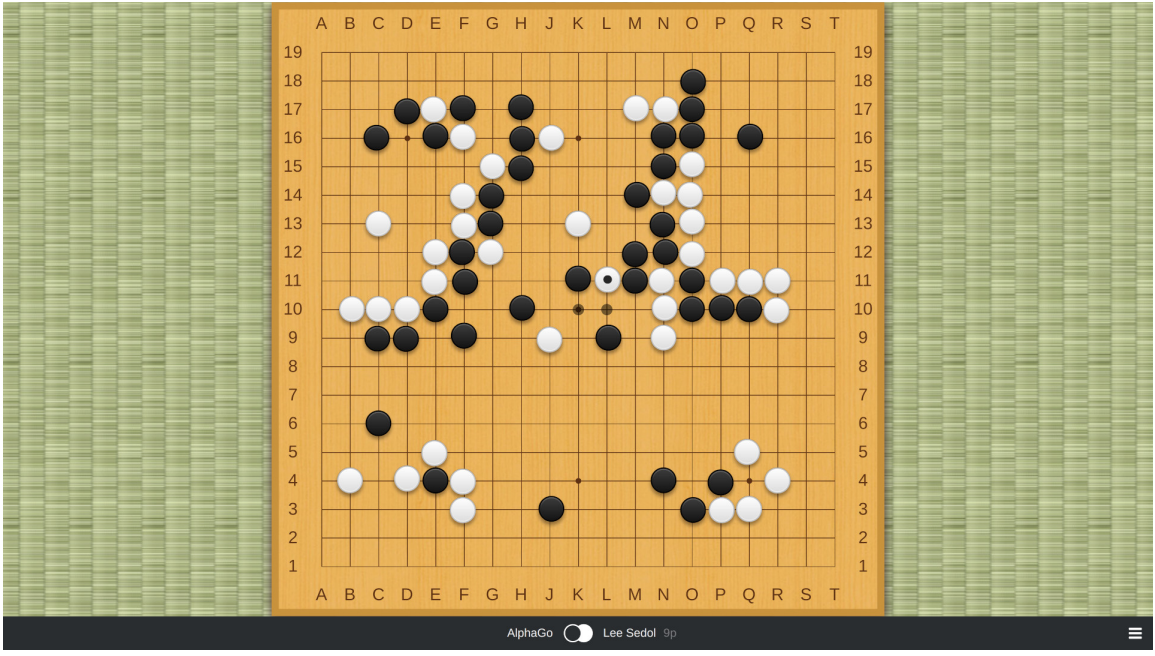
What does this mean?

Is it just the size of the mental effort, or could there be **knowledge transfer** between Go and Mathematics?

Mathematics is a symbolic language, Go is not.

Enter AI – another important topic

©AlphaGo movie


A B C D E F G H J K L M N O P Q R S T
19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
AlphaGo
Lee Sedol 9p

AI as a mirror for human intelligence

AI algorithms often follow our (partial) understanding of how natural intelligence works.

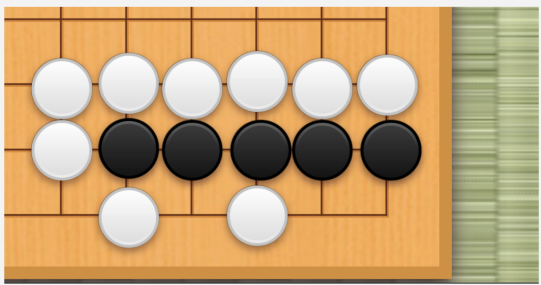
Therefore, by looking at AIs, we can improve our thinking too.

When there is no correspondence (e.g. Monte-Carlo tree search), we can learn something new.

Where Maths and Go meet

metacognition – thinking about thinking, understanding understanding

Tsumego (Go puzzle) black to play & live



A math problem

Simplify the expression

$$\frac{1}{2}\log_3(x-1) - \log_3 y - 3\log_3(z+1)$$

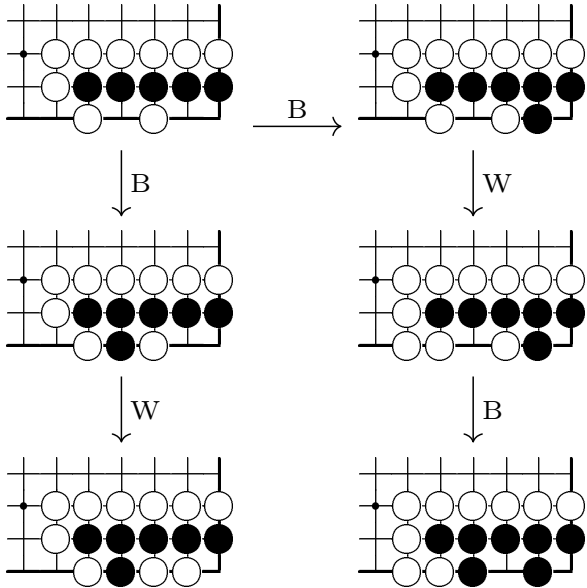
into a single logarithm by using the laws of logarithm

$$\text{(L1)}\quad \log_a(xy) = \log_a x + \log_a y,$$

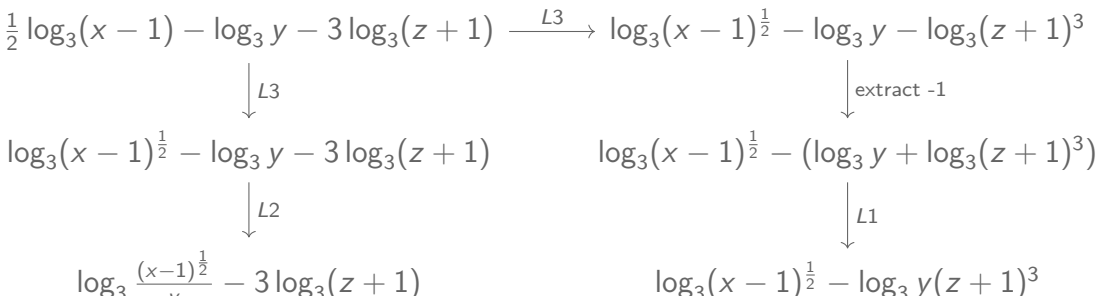
$$\text{(L2)}\quad \log_a\left(\frac{x}{y}\right) = \log_a x - \log_a y,$$

$$\text{(L3)}\quad \log_a x^y = y\log_a x.$$

Graph search



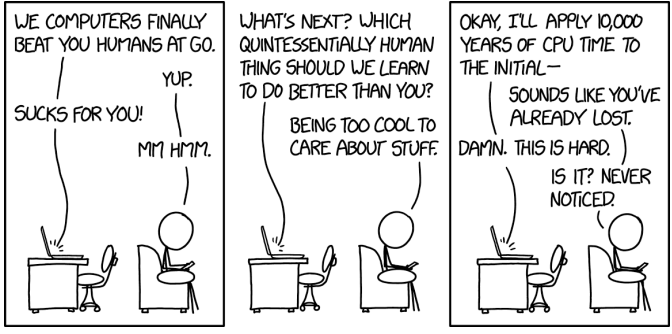
Graph search also



Natural – Artificial

Classical search algorithms. We choose from a finite set of operations repeatedly in order to get closer to a solution.
Systematic, conscious step-by-step thinking.

Deep learning and intuition. After practise, we just 'see' the right way to the solution, with no immediate explanation.



https://xkcd.com/1875/

Another source of ideas and inspiration

Go in a first year writing course.

Peter Schumer: Design of a College Go Course

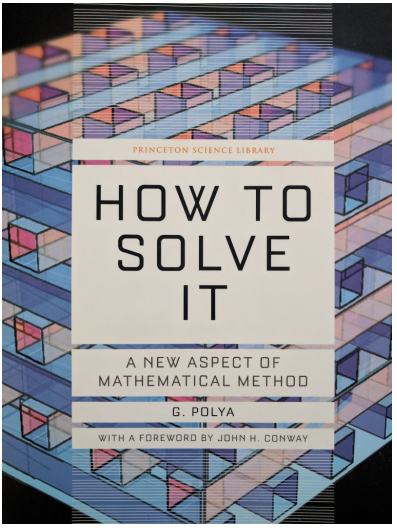
Talk given at 2012 International Go Symposium `http://www.gosymposium.org/`

Previous work

Recasting traditional mathematical heuristics in terms of tsumegos. Special session for selected high-school students in a talent-nurturing programme.

"How to solve it?" - The tsumego session
Annales Mathematicae et Informaticae, Vol 38 2011, pp 137-145
`http://ami.ektf.hu/uploads/papers/finalpdf/AMI_38_from137to145.pdf`

Conclusion: In Go it is easier to point to the cognitive processes, compared to Mathematics.



IGO MATH – Natural and Artificial Intelligence and the Game of Go

Course design: `https://egri-nagy.github.io/igomath/`

- proposal
- syllabus and assessment details
- draft paper and research poster

Course Schedule (tentative)

Week	Topics
1	**Introduction.** *What is Go?* The rules of Go. *How was it invented/discovered?* History. *How to play Go?* Tactics and strategy.
2	**Learning and improving.** *How can one become a better player? What do professional players do?* Go problems (tsumegos). Metacognition. Go proverbs.
3	**Go ratings.** *How to measure progress in learning? How to rank players?* Traditional kyu and dan system, winning probabilities and the handicap system. Élő rating. Elimination, ladder and all-play-all tournaments.
4	**Game tree representation.** *How to describe gameplays in a precise manner?* AI concepts: search space and evaluation function. Graph theory. Tree structure to linear text – the SGF file format.
5	**Minimax algorithm.** *How to solve a game?* Search algorithms in classical AI. Heuristics. Adversarial search.

Course Schedule (tentative)

Week	Topics
6	**Computational complexity.** *What makes a problem difficult for a computer? What are combinatorial explosions?* Polynomial and exponential growth rates of execution times of programs.
7	**Enumerative combinatorics.** *What is the size of the game tree? How many legal positions are there?*
8	**Symmetry as a compression tool.** Shapes on the board rotated and reflected, switching colors.
9	**MIDTERM TEST**
10	**Statistical methods and probabilistic sampling.** Randomness as a tool for dealing with hard problems. Monte Carlo simulations. Exploitation versus exploration. Multi armed bandit.

Course Schedule (tentative)

Week	Topics
11	**Architecture of a Go playing program.** *How to evaluate a board position? How the choose the next move?*
12	**Neural networks.** The inner workings of the AlphaGo system. AlphaGo Zero, reinforcement learning.
13	**The impact of AlphaGo.** *What happens next?* Responses by Go players. Parallels to the more general phenomenon of automation.
14	**Variants of Go.** *Why the rules of Go are so special?* The notion of emergence. Exploring the 'space' of games in the neighbourhood of Go. Irregular Go boards, Go in higher dimensions, more than two players.
15	**FINAL EXAM**

Summary

- automated thinking has to be understood, both its technical details and its impact,
- mathematics has to break out from the traditional lecturing style,
- knowledge gained from different areas of study have to be synthesized and integrated.

Go is in a unique position to facilitate these.

We expect IGO MATH to be an efficient and pleasant gateway course to the study of more serious topics in AI versus natural intelligence.

Conclusion

None yet, ask me again in March 2019!

Thank You!

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