Evolving Structures in Mathematics

Seminar at Charles University, Prague

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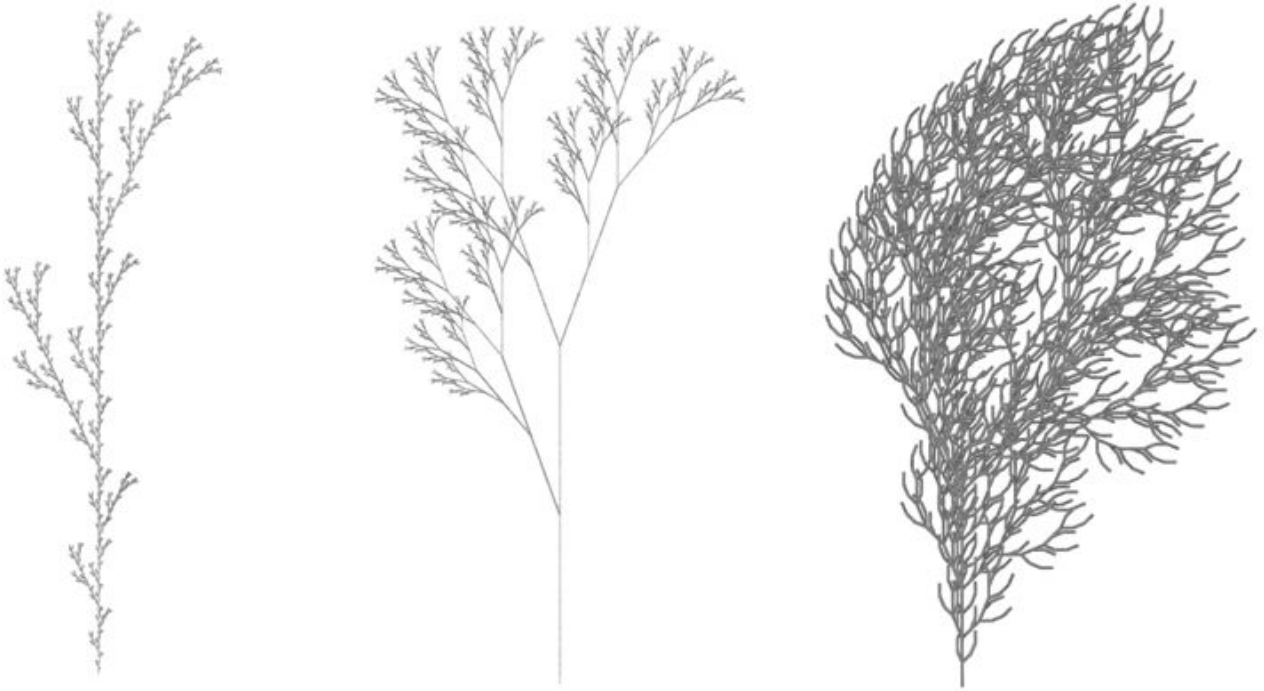
The Goal

Certain mathematical structures, such as cellular automata, can apparently develop complex patterns when starting from simple conditions.

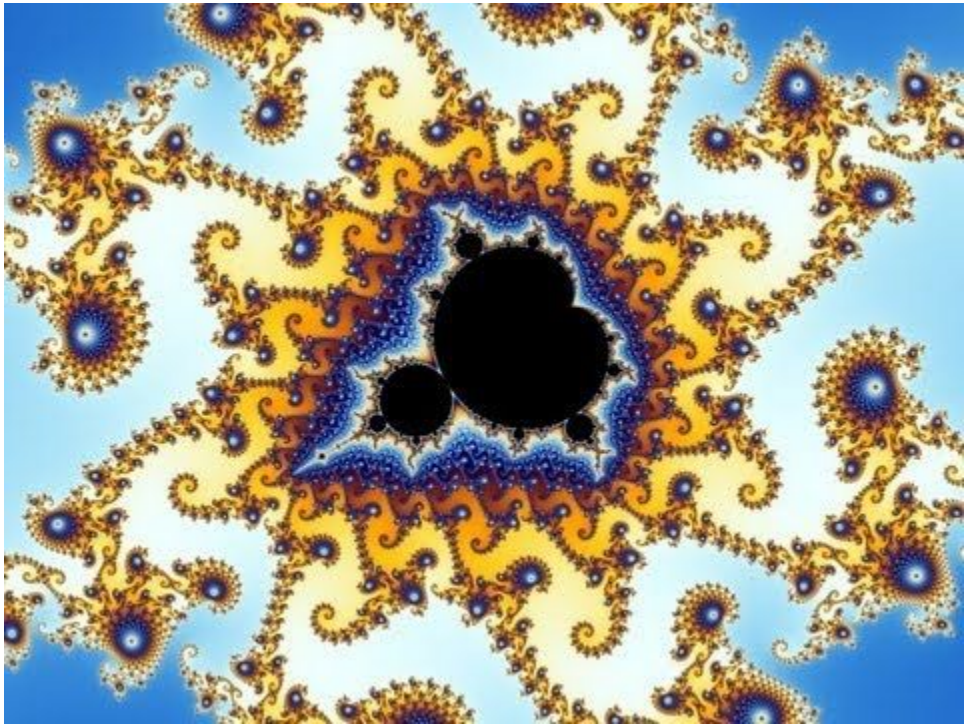
What if life, intelligence, culture, languages all arise from a simple system, and the complexity we observe is only illusionary?

In this seminar, we aim to understand better the concept of evolution in mathematical structures.

Example: L-system



Example: Mandelbrot’s fractals



Seminar Overview

- Computing Machinery and Intelligence, A. Turing
- Society of Mind, Marvin Minsky
- The Quark and The Jaguar, Murray Gell-Mann
- L-systems: Mathematical Models for Cellular Interactions in Development, A. Lindenmayer
- Fractals: The fractal geometry of nature, B. Mandelbrot
- Von Neumann's Self-Reproducing Automata, A. W. Burks
- Studying Artificial Life with Cellular Automata, C. G. Langton
- Genetic Algorithms, J. Holland
- Neuroevolution
- Proving Darwin, Gregory Chaitin

Today’s talk and discussion

On Creativity, I. Asimov: to help set the style of the seminar

Computing Machinery and Intelligence, A. Turing: classic paper on AI where evolution is discussed

On Creativity

- many great new ideas are obvious in the hindsight, but are rejected at first: don’t be afraid to ask “stupid questions”

- to create novel ideas, we may need diverse backgrounds and experiences

- it takes a lot of time to develop simple and general ideas, and we should not be worried if the first ideas are messy and incomplete

Computing Machinery and Intelligence, A. Turing

- Imitation game
- Turing’s opinions on how to develop “intelligent machines”
- Turing machine, halting problem and how do these relate to evolution

Imitation game

- replaces question “Can machines think?” with “Can we construct machine that acts as an intelligent person?”

- Imitation game: a committee of experts is supposed to decide if it communicates with a machine or a person

- besides some loopholes (naive experts, limited communication) Turing test remains unsolved

Imitation game objections

- Theological objection: missing soul
- “Heads in the Sand”: better if machines cannot be intelligent
- Mathematical Objection: Halting problem shows limitations of machines
- Missing consciousness
- Various disabilities: missing sense of humour, make mistakes, …
- Ada Lovelace’s objection: "The Analytical Engine has no pretensions to originate anything. It can do whatever we know how to order it to perform"
- ...

Learning machines

- Can the machine generate novel ideas?

- How much information can the brain hold? Turing’s estimate: 10^9 bits

Turing’s idea of the solution to AI

“At my present rate of working I produce about a thousand digits of programme a day, so that about sixty workers, working steadily through the fifty years might accomplish the job, if nothing went into the wastepaper basket.“

-- it appears Turing did think the intelligent machine could be all programmed manually

Second idea: Child machine

- instead of programming the AI machine that can play the game, one could program a Child machine that can learn

- the complexity of programming is substantially lower, and the game can be played be the child machine after “education period”

- “Presumably the child brain is something like a notebook as one buys it from the stationer's. Rather little mechanism, and lots of blank sheets.”

Evolution of the child machine

“Structure of the child machine = hereditary material

Changes of the child machine = mutation,

Natural selection = judgment of the experimenter”

Reinforcement learning and language channels

- Turing discusses rewards & punishments for speeding up the learning beyond random mutations
- Communication through language seems to be crucial for fast learning without excessive need for punishments

“... I have done some experiments with one such child machine, and succeeded in teaching it a few things, but the teaching method was too unorthodox for the experiment to be considered really successful.“

Further discussion

- Turing machine, Turing completeness

- Halting problem