Bioinformatics CSM17
Week 8: Simulations (part 2):

- plant morphology
- fractals
- virtual reality
  - *Lindenmayer* systems

Plant Morphology

- ‘shape study’
- stems, leaves and flowers

Stems

- can bear leaves and/or flowers
- can branch
- usually indeterminate
  - Can grow and/or branch ‘forever’

Leaves

- never bear flowers
- can appear to branch (fern)
- simple or compound
- vary a lot in size and shape
- can have straight veins (grasses)
- or branching veins (linden/lime tree)

Flowers

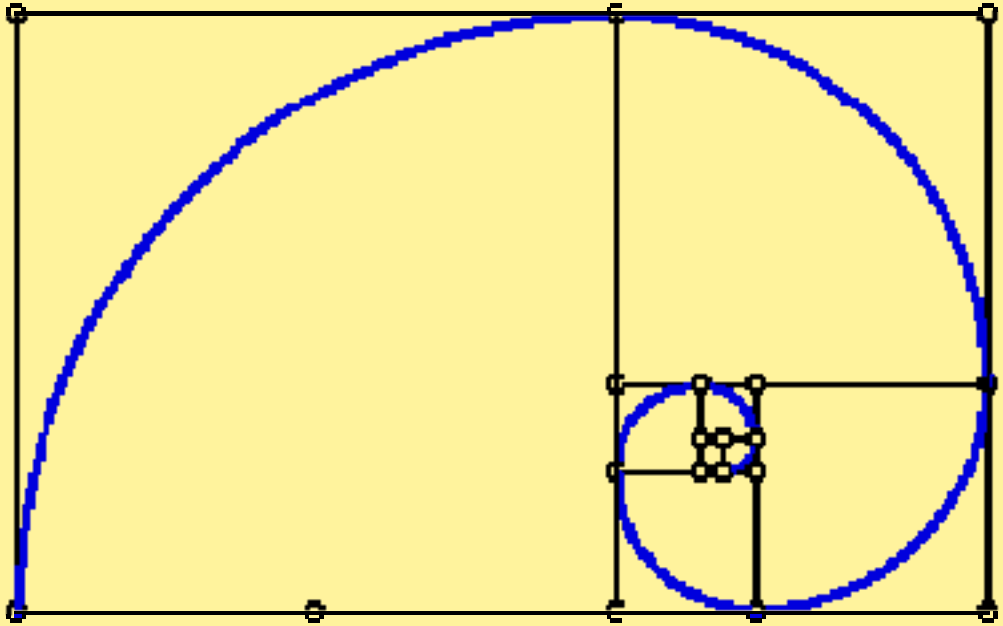
- can be simple or compound
- a compound flower (group) is called an *inflorescence*

Inflorescences

- can be a flower spike or *raceme*
- or a branching structure called a *cyme*
- racemes themselves can have racemes
- daisies and sunflowers have lots of flowers in a *capitulum* or head
  - outer ones are petal-like *ray* florets
  - inner ones are *disc* florets
  - the disc florets are arranged in a spiral

Fractals are...

- self-similar structures



Nautilus

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Lindenmayer Systems

- A. Lindenmayer : Theoretical Biology unit at the University of Utrecht
- P. Prusinkiewicz : Computer Graphics group at the University of Regina
- *Lindenmayer Systems* are
  - *rewriting* systems
  - also known as *L-Systems*
- Ref: Lindenmayer, A. (1968). Mathematical models for cellular interaction in development, Parts I and II. *Journal of Theoretical Biology* 18, pp. 280-315

Rewriting Systems

- techniques for defining *complex* objects
- by successively *replacing* parts of a *simple* initial object
- using a series of *rewriting rules* or *productions*

Koch Snowflake

- von Koch (1905)
- start with 2 shapes
  - an *initiator* and a *generator*
- replace each straight line with a copy of the generator
- that copy should be reduced in size and displaced to have the same end points as the line being replaced

Array Rewriting

- e.g. Conway's game of Life
- Ref: M. Gardner (1970). Mathematical games: the fantastic combination of John Conway's new solitaire game "life". *Scientific American* 223(4), pp. 120-123 (October)

DOL-Systems

- the simplest class of L-Systems
- consider strings (words) built up of two letters a & b
- each letter is associated with a rule
  - a → ab means *replace* letter *a* with *ab*
  - b → a means *replace* letter *b* with *a*
- this process starts with a string called an *axiom*

Turtle graphics

- Prusinkiewicz (1986) used a LOGO-style turtle interpretation
- the state of a turtle is a triploid (x, y, α)
  - x & y are cartesian coordinates (*position*)
  - α is the heading (*direction* pointing or facing)
- there can also be
  - d used for *step* size
  - δ used for the *angle* increment

Tree OL-Systems

- turtle graphics extended to *3-Dimensions*
- a *rewriting system* that operates on *axial trees*

Tree OL-Systems

- a rewriting rule (tree production) *replaces* a predecessor *edge* by a successor axial tree
- the *starting* node of the predecessor is matched with the successor's *base*
- the *end* node of the predecessor is matched with the *top* of the successor

Stochastic L-Systems

- *randomness* and *probability* are added
- produces a more *realistic* model more closely resembling real plants

Summary

- plant morphology: leaves, stems,flowers
- fractals in nature
- Lindenmayer systems (L-Systems)
  - art, computer graphics
  - virtual reality models e.g. in museums
  - computer games
  - biological growth models

Useful Websites

- Algorithmic Beauty of Plants + others
  http://algorithmicbotany.org/
- L-System4:
  http://www.geocities.com/tperz/L4Home.htm
- Tree Generator (Nicolas Boneel):
  http://www.treegenerator.com/

More References & Bibliography

- P. Prusinkiewicz & A. Lindenmayer (1990), *The Algorithmic Beauty of Plants*, Springer-Verlag. ISBN 0387946764 (softback) (out-of-print, but is in UniS library, and available as pdf from http://algorithmicbotany.org/).
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- Kaandorp, J. A. (1994). *Fractal modelling : growth and form in biology*, Springer-Verlag, Berlin. ISBN 3540566856
- Pickover, C. (1990). *Computers, pattern, chaos and beauty*, Alan Sutton Publishing, Stroud, UK. ISBN 0862997925 (not in UniS library)
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