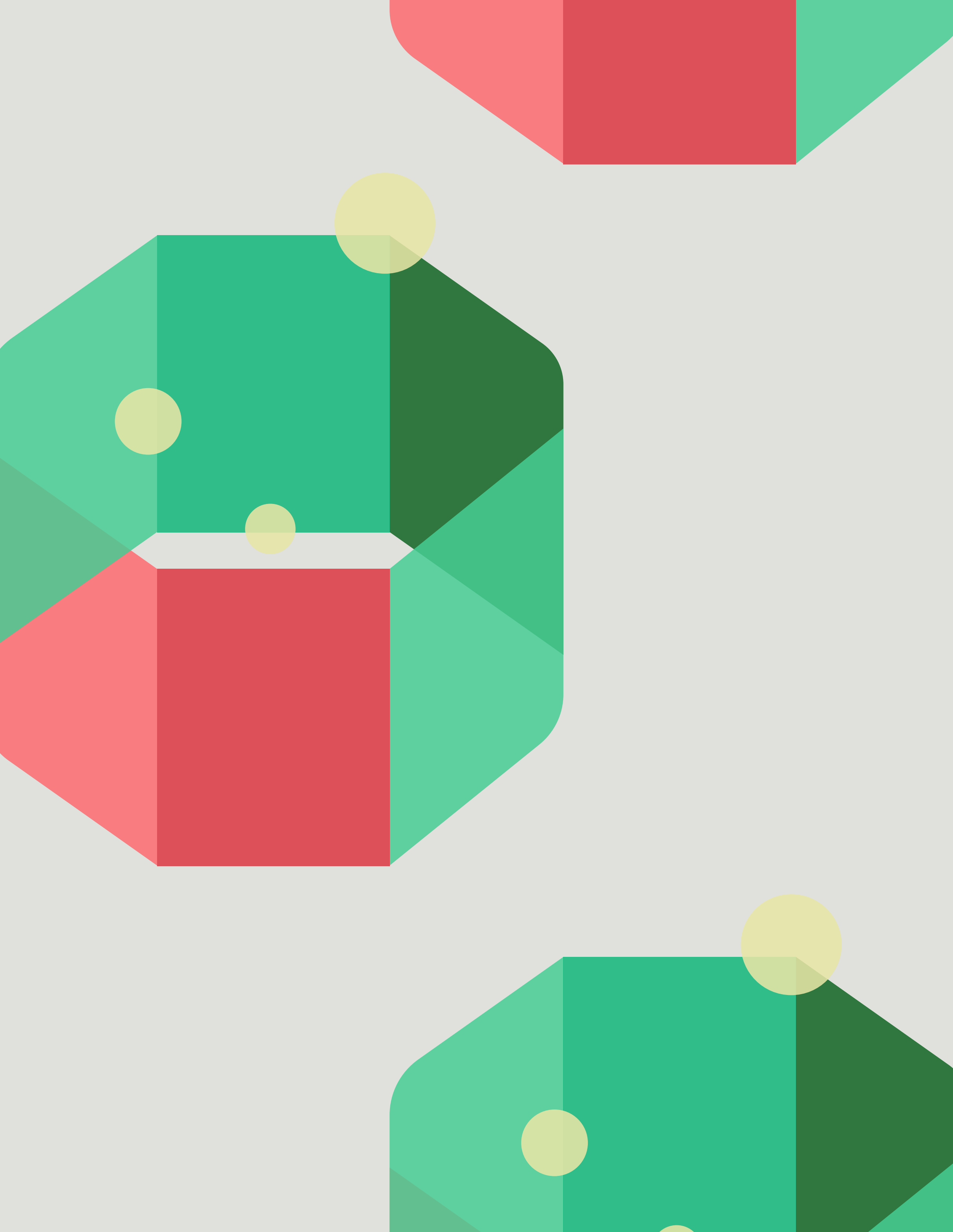


Lecture 1 15.09.2022

Introduction

Mathematical & Simulation Modelling:

formulae/equations — algorithms of behavior

Goals:

- What-if analysis
- Reduce costly experiments
- Reasoning when experiments are impossible

real system → make a model → model system

real system ↓ perform experiments ↓ experimental results

model system ↓ perform simulations ↓ simulation results

model system ↓ construct approximate theories ↓ theoretical predictions

experimental results, simulation results → review & improve model

simulation results, theoretical predictions → compare & improve theory

Lecture 2 22.09.2022

Malthusian growth model: $\frac{dP}{dt} = kP$

- no death rate
- death rate should depend on population size

Verhulst model

$$\frac{dP}{dt} = (B-D)t$$

$P(t)$ - population at time t

$B(t)$ and $D(t)$ - birth and death rates

$$\frac{dP}{dt} = (B_0 - D_0 P)P$$

$B_0, D_0 > 0$ const

Assumptions:

- birth rate is constant
- death rate is proportional to the size of the population

$$Pt = \frac{CP_0}{P_0 + (C - P_0)\exp(-rt)}$$

$$\frac{dP}{dt} = r\left(1 - \frac{P}{C}\right)P$$

$$r = B_0 \quad C = B_0/D_0$$

$$f(x) = \frac{L}{1 + e^{-k(x-x_0)}}$$

Sigmoid function

Predator-Prey Simulations

Assumptions:

- prey have unlimited food supply, Malthusian
- In the absence of predator: $\frac{dx}{dt} = ax$, a-autoincrease, $x_t = x_0 \exp(at)$ proportional growth
- In the absence of prey: $\frac{dy}{dt} = -\gamma y$ $\quad y(t) = y_0 \exp(-\gamma t)$ extinction of predator
- when both are present: decline of prey, increase of predator

rates of growth are proportional to rates of encounters

$$\begin{cases} \text{prey} & \frac{dx}{dt} = \alpha x - \beta xy \\ \text{predators} & \frac{dy}{dt} = -\gamma y + \delta xy \end{cases} \qquad \alpha, \beta, \gamma, \delta > 0$$

Equilibrium

$D\left(\frac{\gamma}{\delta}, \frac{\alpha}{\beta}\right)$ $\quad \frac{dx}{dt} = 0 \quad \frac{dy}{dt} = 0$

Application: Cloud computing

$\frac{dP}{dt} = \alpha P - \beta PQ \qquad \frac{dQ}{dt} = \delta PQ - \gamma Q$

P – число VMs
Q – число задач

Лекция 3 29.09.2022

Cellular Automata

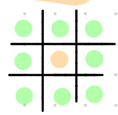
NetLogo – framework for agent-based modelling

Game of Life:

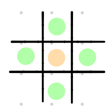
- zero-player
- rules for life, birth & death
- some stable dispositions & some that lead to extinction

Neighborhoods

- Moore



- Von Neumann



Лекция 4 06.10.2022

Cellular automata. Cars

Nagel-Schreckenberg rules for motion

Manhattan grid

- predictions
- what-if scenarios
- traffic simulation
- changes

Лекция 5 13.10.2022

Firespread

many parameters like: type of growth, landscape, wind, direction of fire

Лекция 6 03.11.2022

Modelling of firespread

Лекция 7

Agent-Based Modelling

Agents' properties

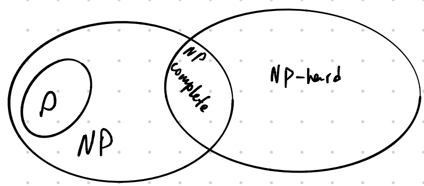
- adaptability
- autonomy
- collaboration
- knowledge-level communication
- inferential capability
- temporal continuity
- personality
- mobility

NP completeness

P - polynomial problems
* pleasant problems
* can be solved in $O(n^k)$

NP - complete, NP - hard problems
* most real-world problems
* cannot be solved in $O(n^k)$

- estimations of solution time, verification of correctness, but no proof of global optimum in polynomial time
- repositories of good-enough solutions & their updates
- problem reduction



Example

- minimal spanning tree

Лекция 8

Heuristics

find good-enough solutions by somehow limiting the solution space

metaheuristic - 1 solution algorithm for N problems

New metaheuristics are developed to:

- better solve existing problems
- solve new problems
- existing problems with increased size

Swarm Intelligence

mathematical modelling of swarm behaviour

Лекция 9 23.11.2022

Swarm intelligence

Ants & pheromones, behaviour based on "signs"

used for clustering

Лекция 10 01.12.2022

Genetic algorithms

- parallel & simple

Идеи:

- популяция хромосом
- макс. число итераций
- кроссинговер в парах хромосом
- мутации
- новые хромосомы заменяют старые