

ARK-E3020 Sustainable Design Principles

Computational Cycle: Designed Form

Toni Kotnik

Professor of Design of Structures

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Animal architecture view from the outside

Observation I

from material multiplicity to geometric complexity
materials are expensive, form is cheap

Observation II

architecture is ecosystem engineering
architecture is prosthetic nature

Observation III

from static isolation to dynamic porosity
architecture as an open system of fluid exchange

Observation IV

from top-down control to bottom-up process
architecture as adaptive generation to environmental conditions



2

Feedback complex behavior

A SOURCE NEST

B SOURCE NEST

C SOURCE NEST

D SOURCE NEST

both ants start at same time

ant along shorter path will reach food first ...

... and will inform other ants about the food first ...

... which will attract more ants to follow the shorter path

... and reinforce the path with more pheromone

after some time only the shortest path will be used

Ant Colony Optimization (ACO) Algorithm
search for shortest path in networks

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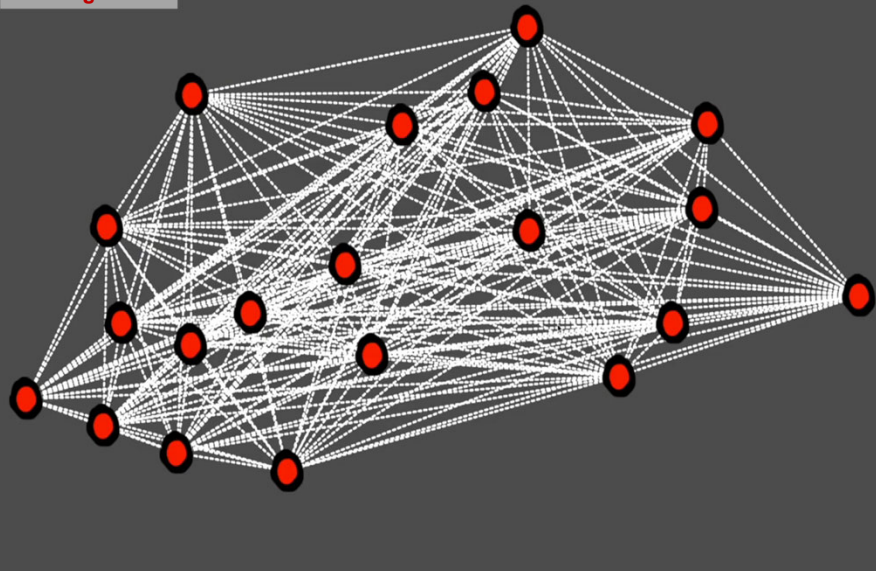
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ACO Algorithm



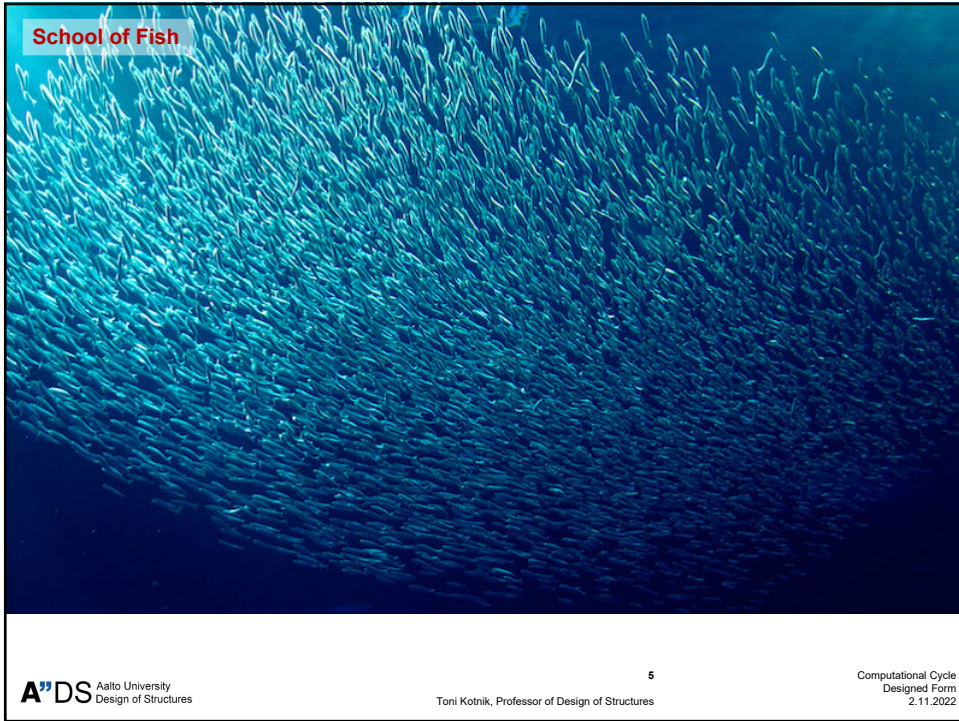
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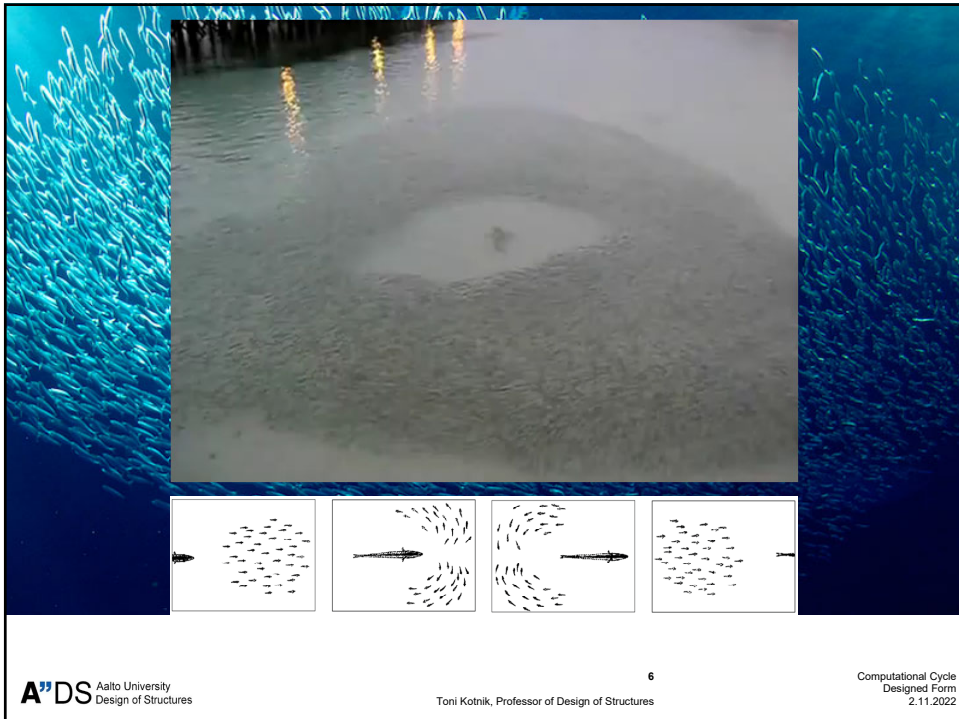
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Computation as Formalization School of Fish

internal logic
interacting network of basic elements

external adaptation
interaction of network with context

Separation
steer away to avoid local congestion

Alignment
orient towards average direction

Cohesion
steer towards center of gravity

Predator Avoidance
Swarm Attraction/Repulsion

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Computation as Formalization Agent System

basic element

transformation of basic element

application of fixed set of rules

description of systemic behaviour of swarm as computational process

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**Computation as Formalization
Agent System**

BOIDS

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**Agent System
Human Behavior**

Local attractor
Attractor that is in field of vision

Global attractor
Agent has prior knowledge of the position of the point of interest

Separation
Steer to avoid local neighbours

Collision avoidance
Avoid obstacles and other agents

Tina Čerpnjak
Formal Diffusions: Agent-Based Systems in the context of architectural space making
Master Thesis, Aalto university, 2021

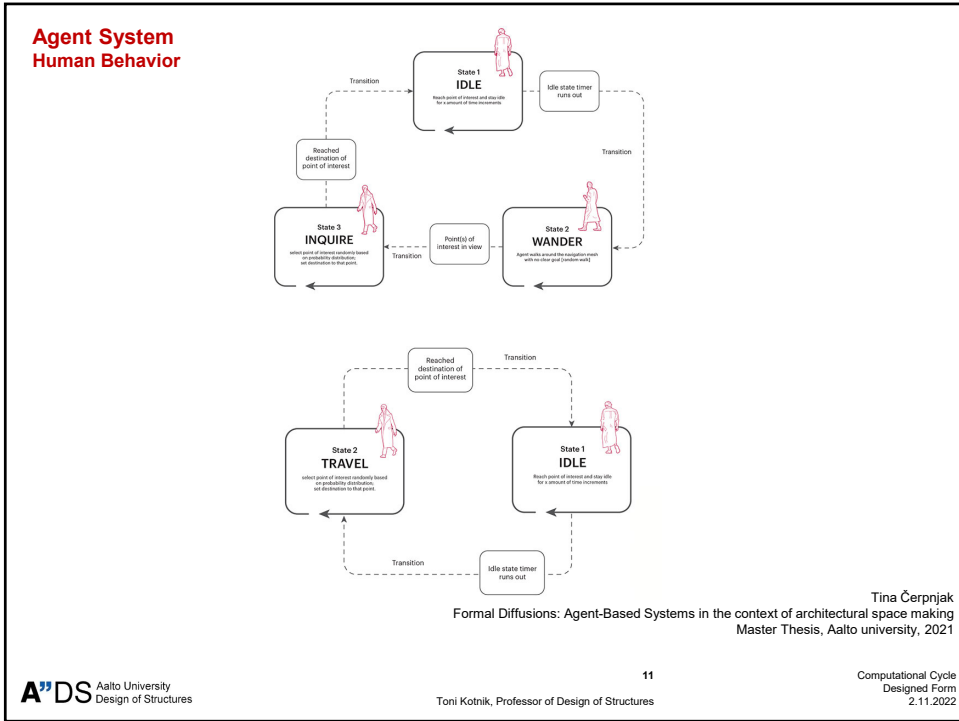
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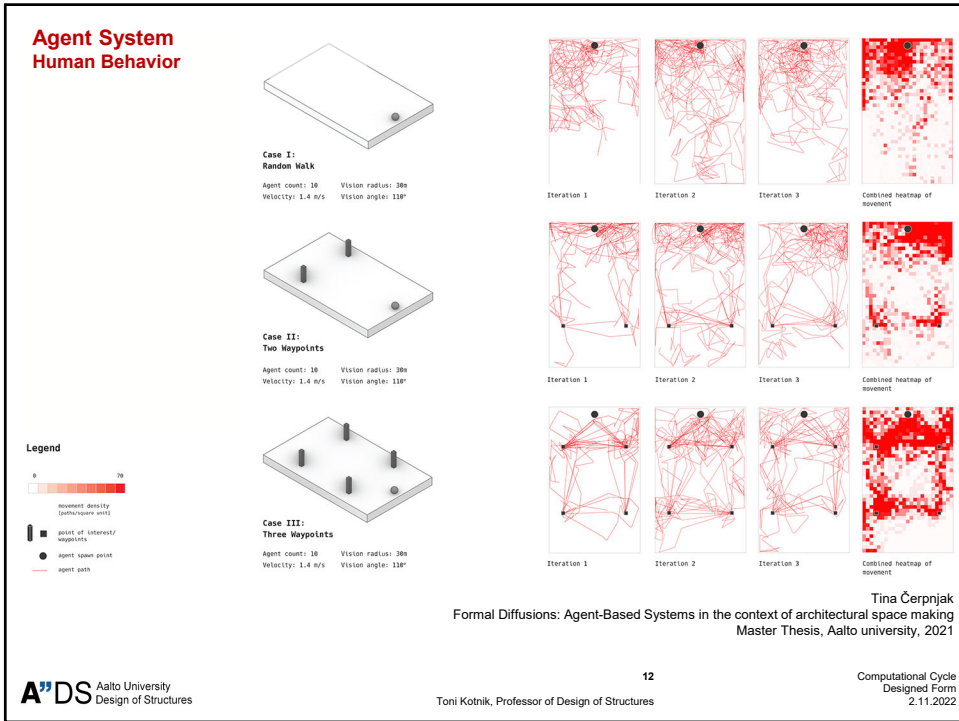
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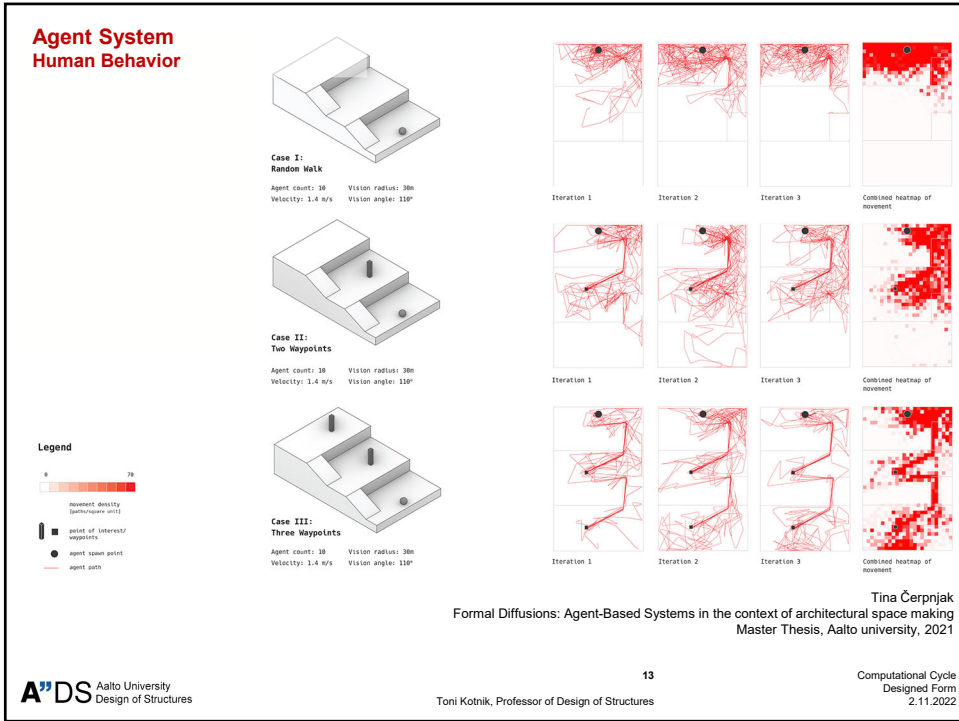
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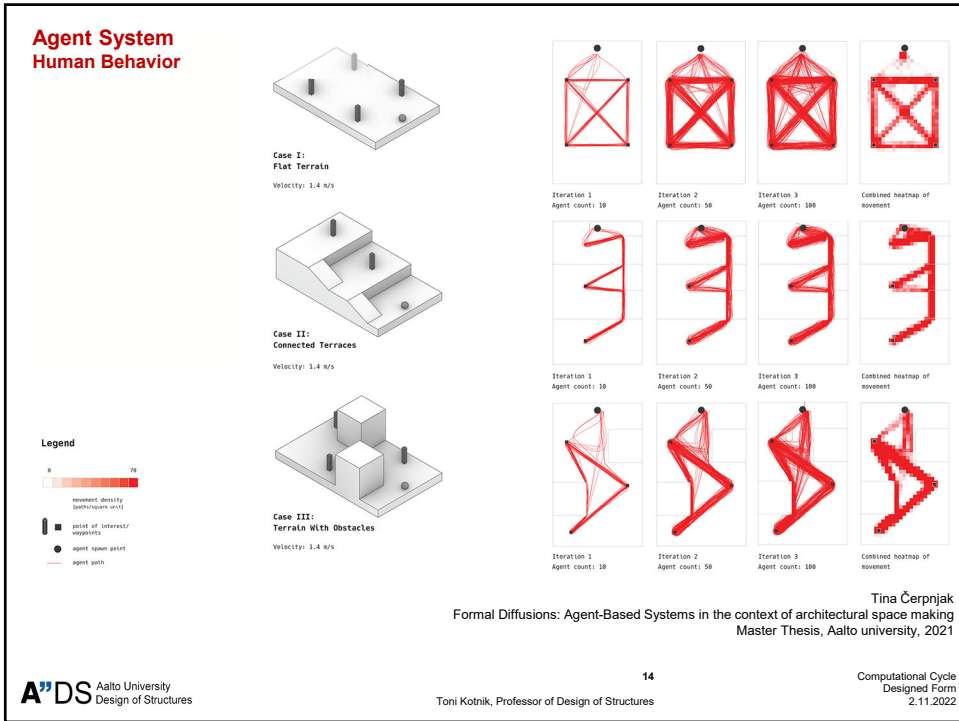
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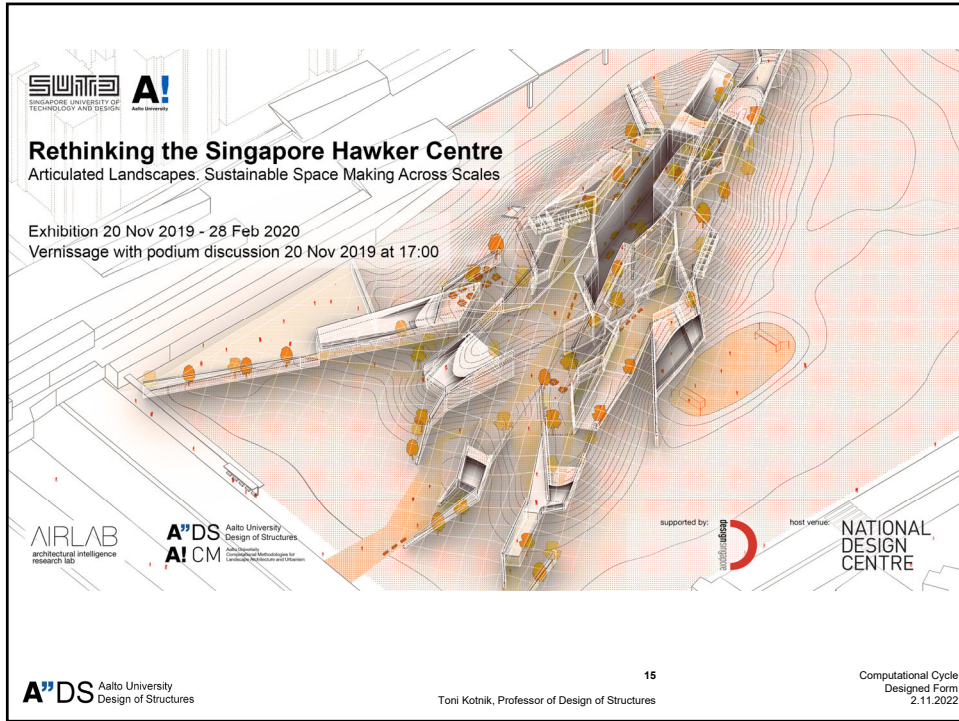
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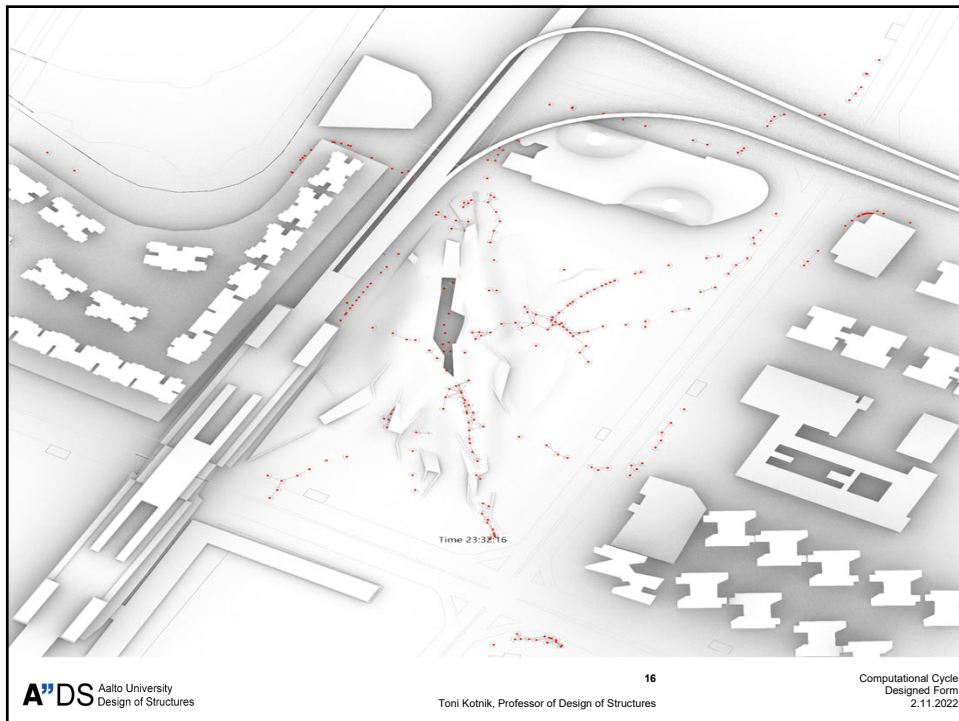
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Digital Revolution

"An intellectual revolution is happening all around us, but few people are remarking on it. Computational thinking is influencing research in nearly all disciplines, both in the sciences and the humanities. ... [The Computer] is changing the way we think. ... If you want to understand the 21th century then you must first understand computation."

Alan Bundy

Natural Computation
new methods of composition of form

- Cellular Automata**
inspired by intercellular communication
- Neural Computation**
inspired by the functioning of the brain
- Evolutionary Computation**
inspired by Darwinian evolution of species
- Nature-Inspired Algorithms**
inspired by behavior of groups of organism

Modernity
scientific revolution → reductionism → paradigmatic shift in science → systemic

computer

context-free dynamics

context-sensitive dynamics

systemic complexity

bifurcation

strange attractors

catastrophic folding

deterministic chaos

nonlinearity

fractal geometry

L-systems

reaction-diffusion equation

vectorfields

cellular automata

self-organization

genetic algorithm

genotype

phenotype

adaptation

multi-agents

hierarchy

swarm systems

1960 1970 1980 1990 2000 t

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How much area can be fenced in with a 1000m long wall?

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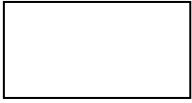
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Optimization
best possible output

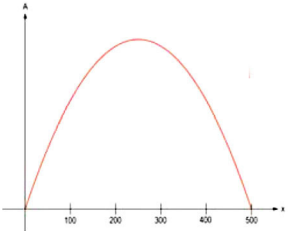
Formalization

How much area can be fenced in with a 1000m long wall?
 $\max A = x \cdot y$ under the condition $1000 = 2 \cdot x + 2 \cdot y$



$A = x \cdot (500 - x)$

fitness function
measure for quality of solution



fitness landscape
field of all possible solutions

x = y = 250
square

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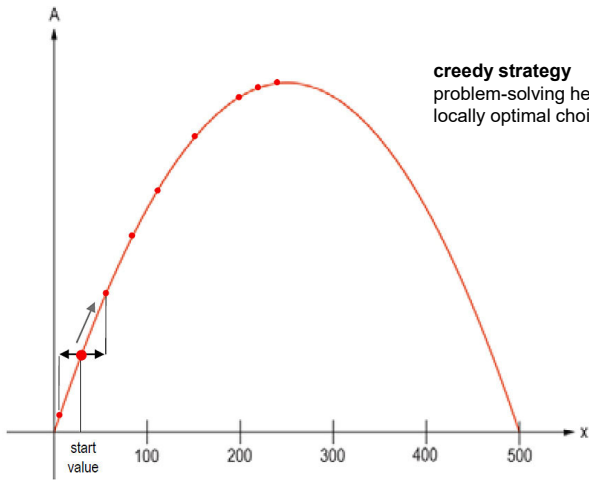
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Optimization
best possible output

fitness landscape
field of all possible solutions

basic intention in optimization process
stepwise improvement of solution by variation of parameter



creedy strategy
problem-solving heuristic of making the locally optimal choice at each stage

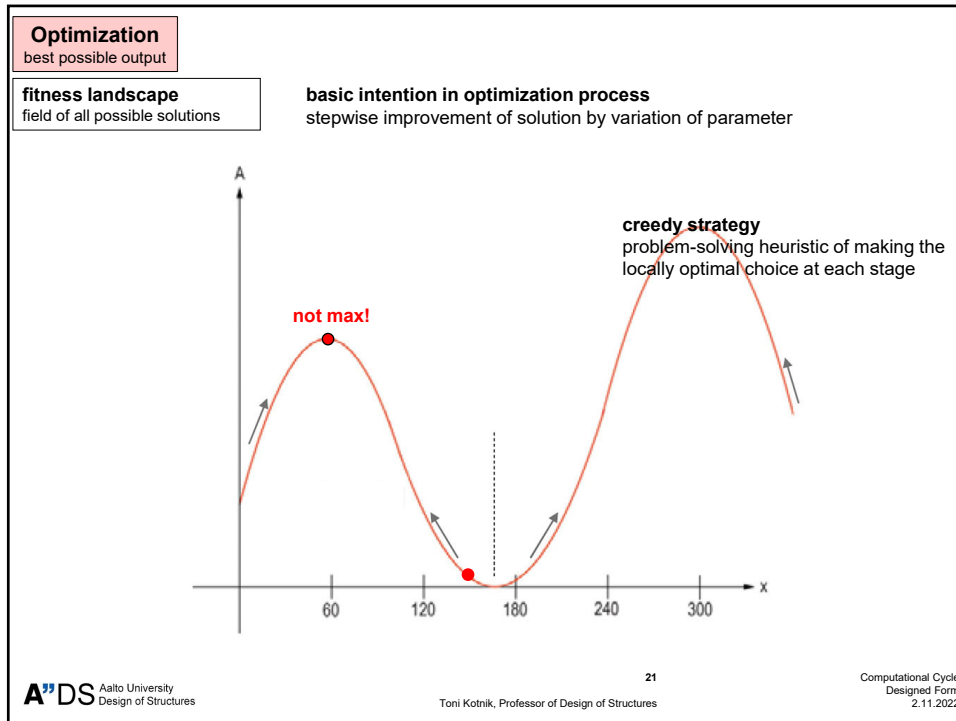
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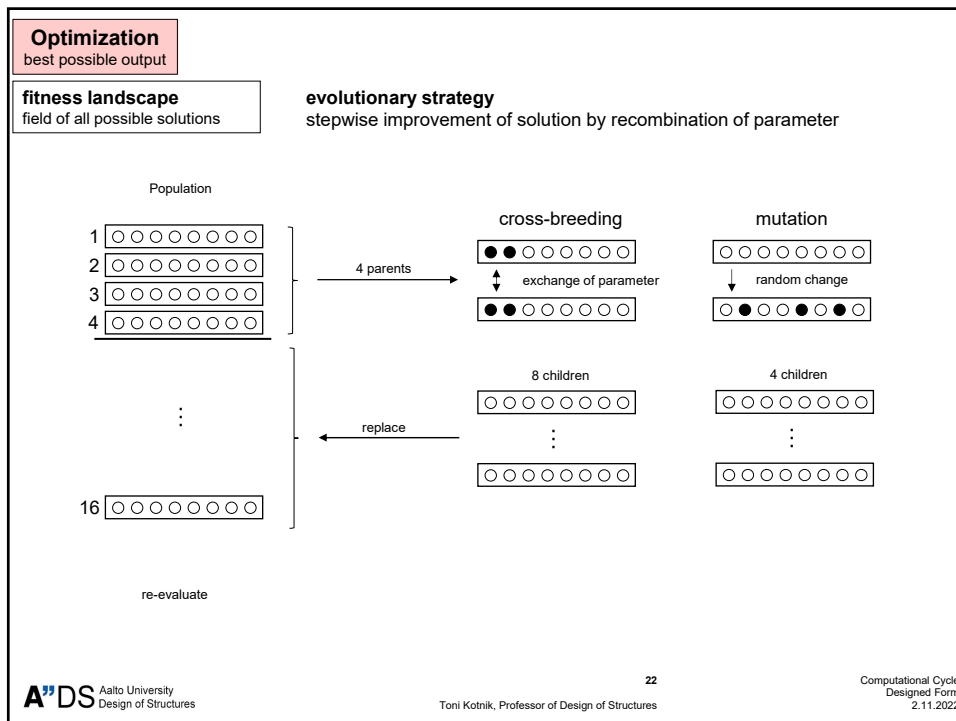
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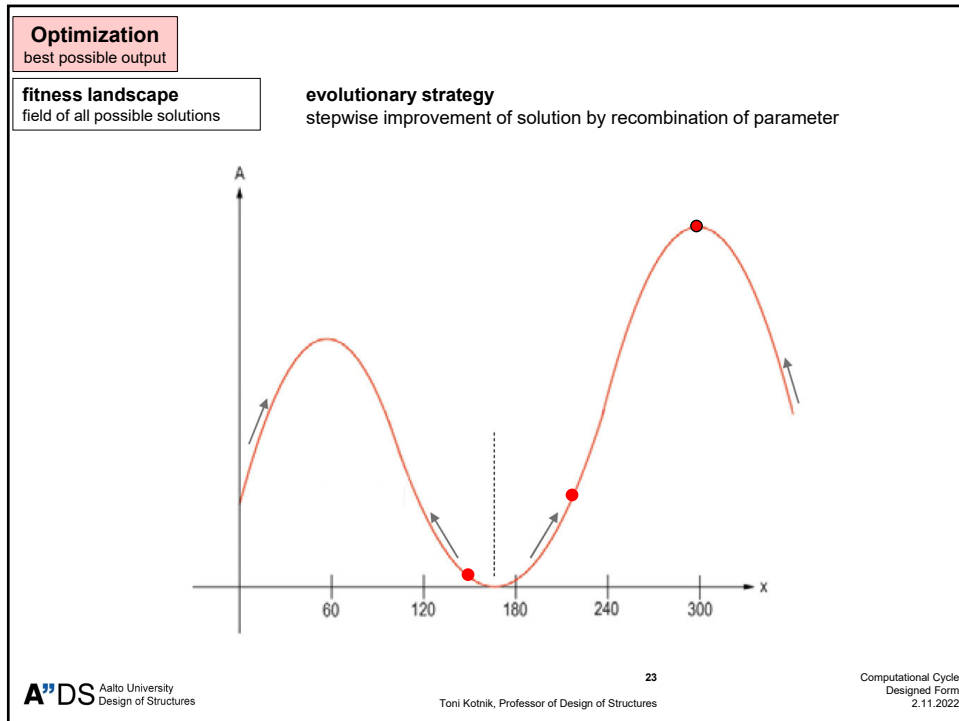
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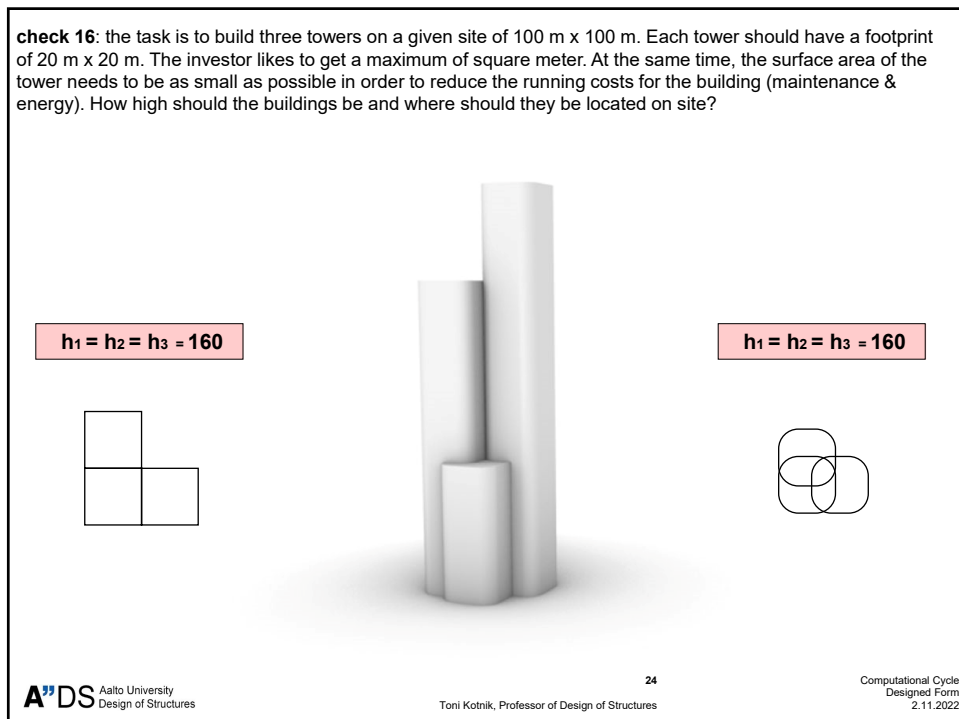
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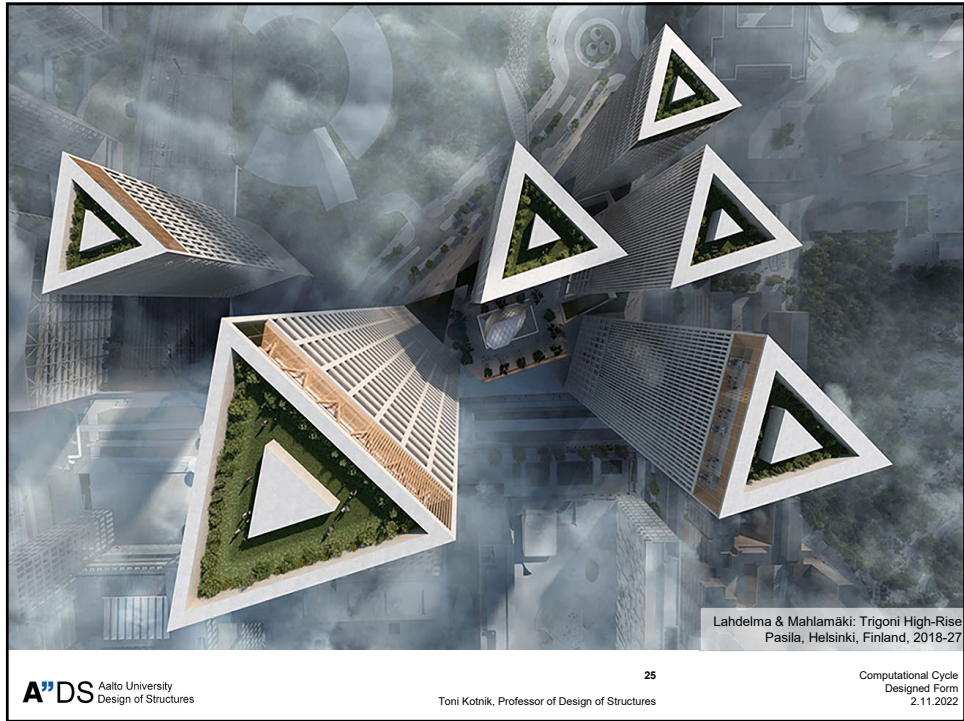
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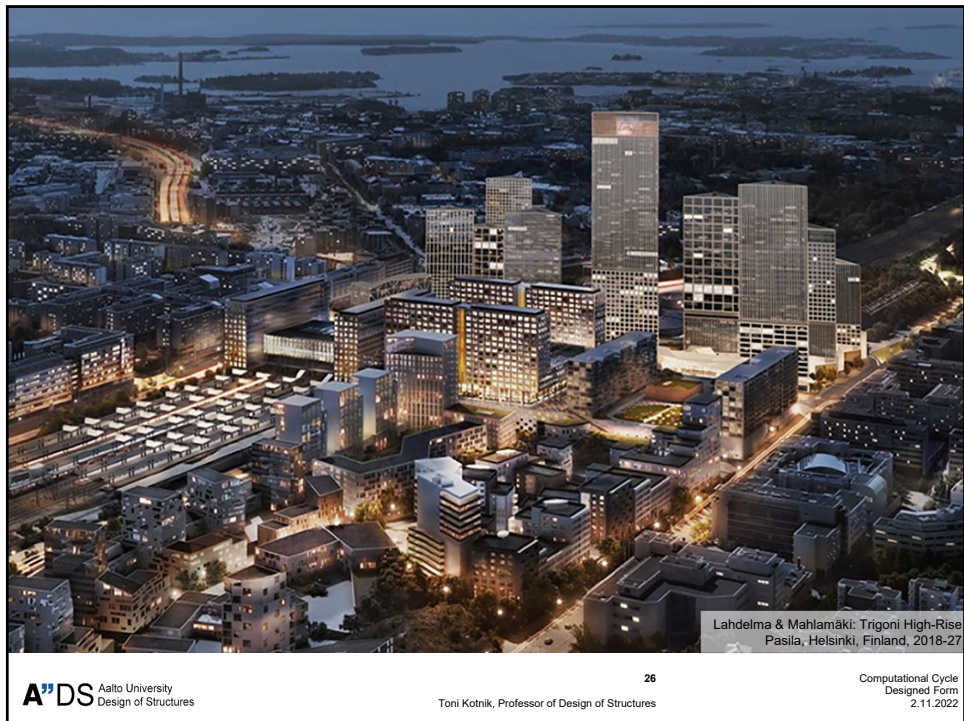
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Lahdelma & Mahlamäki Trigoni High-Rise Pasila, Helsinki, Finland, 2018-27

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An evolutionary climate-responsive urban model

What is the best possible neighborhood?

combinations of these variations of the basic building type are combined on an urban patch using cellular automata

environmental principles are used for the generation of variations of the basic building type of a courtyard house

Patch generation

- The aim is to cluster those blocks whose volumes in total would represent similar values, maintaining the same density;
- Mutation(1-a): this 4 by 4 arrangement (of 4 chosen blocks) is subjected to the random height/depth variations and at the same time avoiding the same blocks being adjacent together.
- Mutation (1-b): General strategy - randomly height increase and decrease within the patch
- the random floor addition and reduction, set within a certain range would balance out the total volume, resulting in height variation which will contribute to produce complex climatic relations between the blocks.

Mutation (1-k): Floor Addition Floor Reduction

volume(1) = volume(2)

Fatehah Nasser, Yasaman Mousavi
Metabolism and Culture: An evolutionary climate-responsive urban model
Master Thesis, Architectural Association, 2011

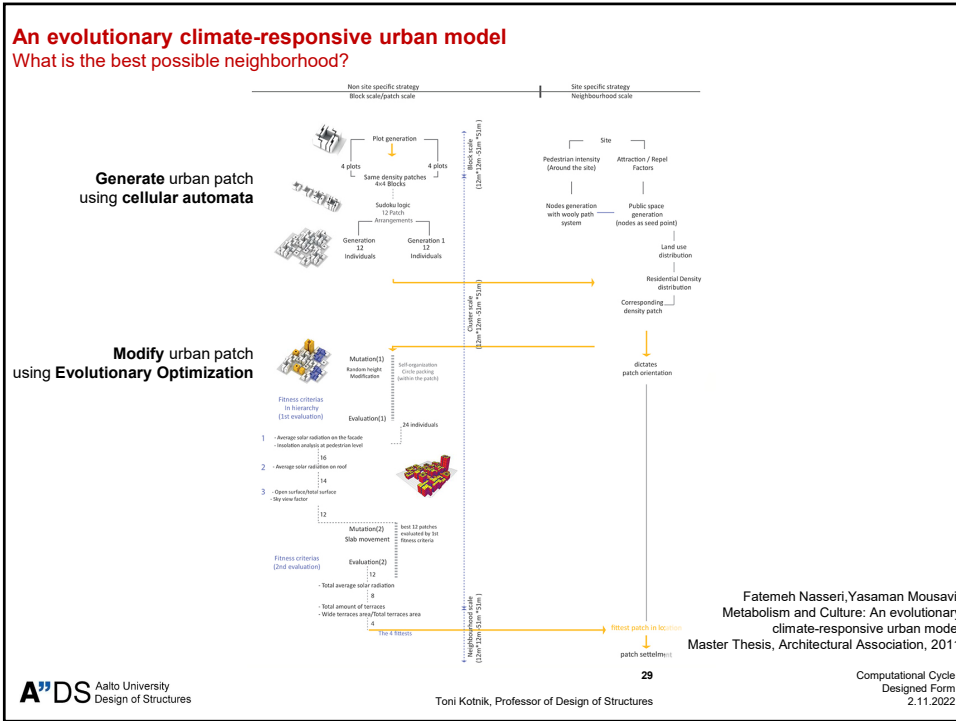
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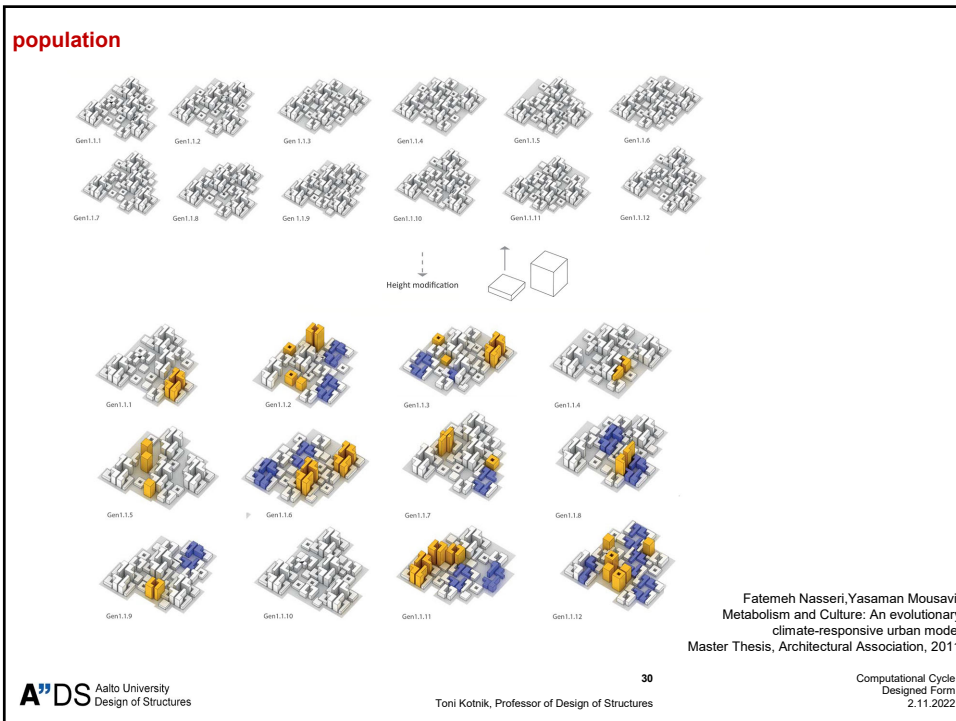
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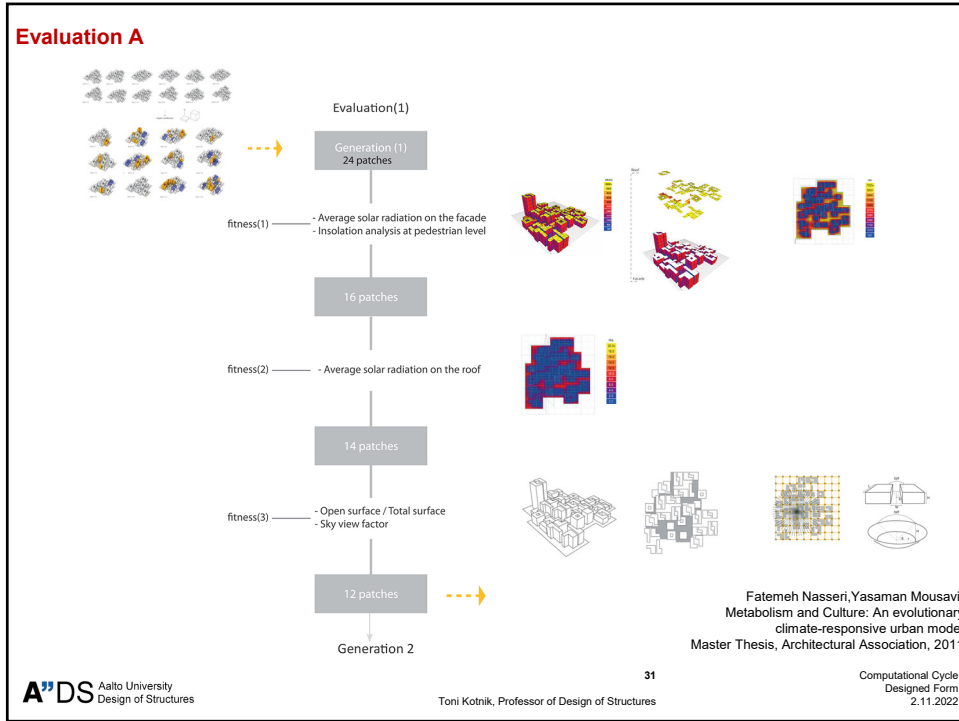
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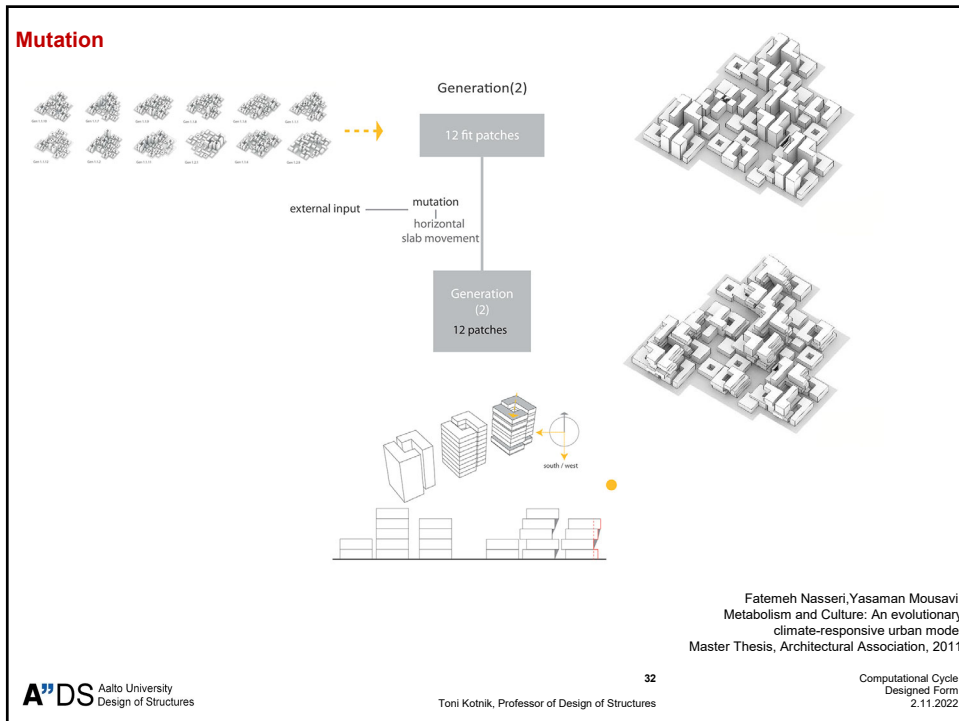
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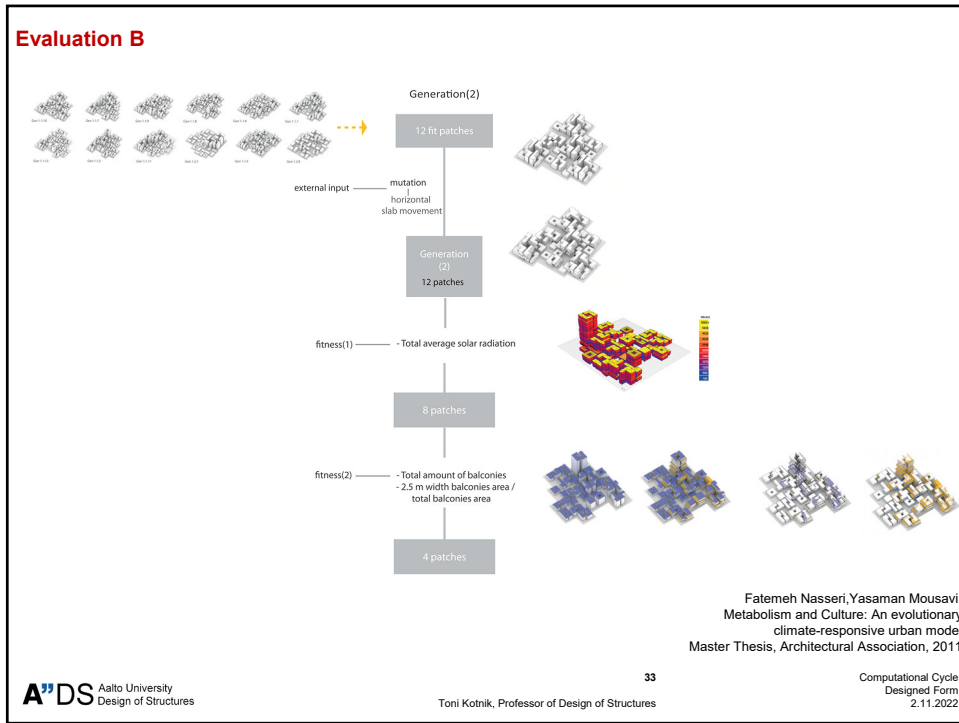
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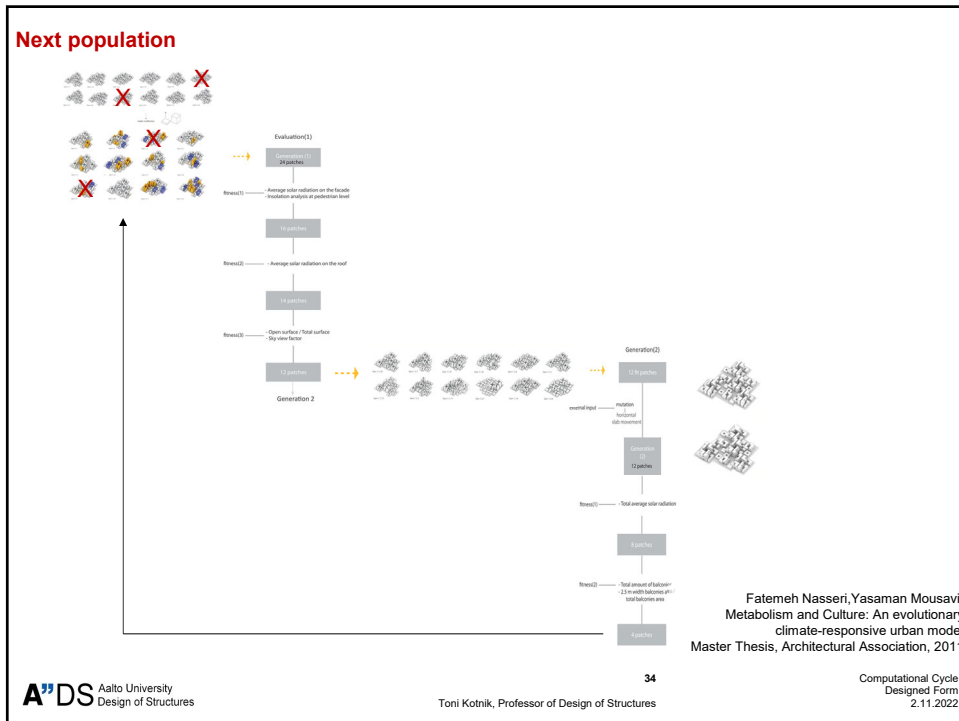
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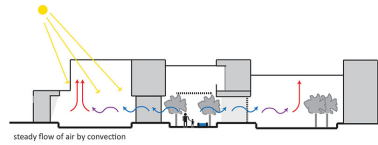
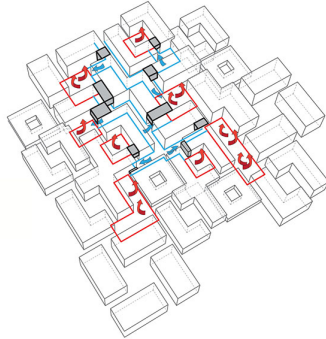


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An evolutionary climate-responsive urban model
What is the best possible neighborhood?



The emergent porosity within the fabric results in environmental comfort at the scale of a patch. Hierarchical scale of routes within the tissues acts as a regulator through convection.



Fatemeh Nasser, Yasaman Mousavi
Metabolism and Culture: An evolutionary climate-responsive urban model
Master Thesis, Architectural Association, 2011

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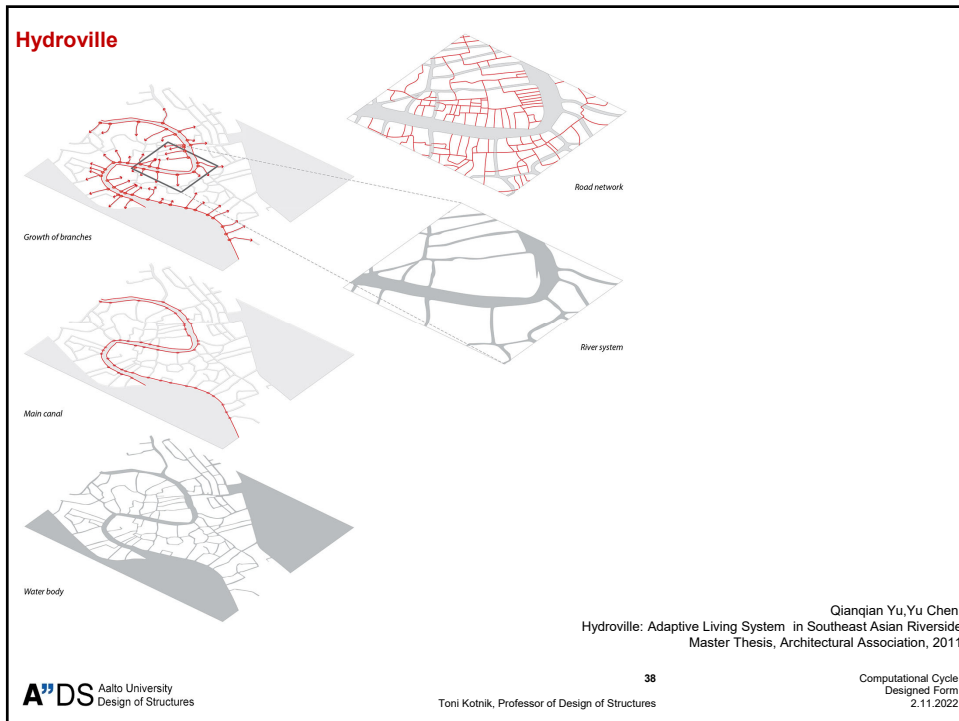


Masdar City, United Arab Emirates, 2008-2030

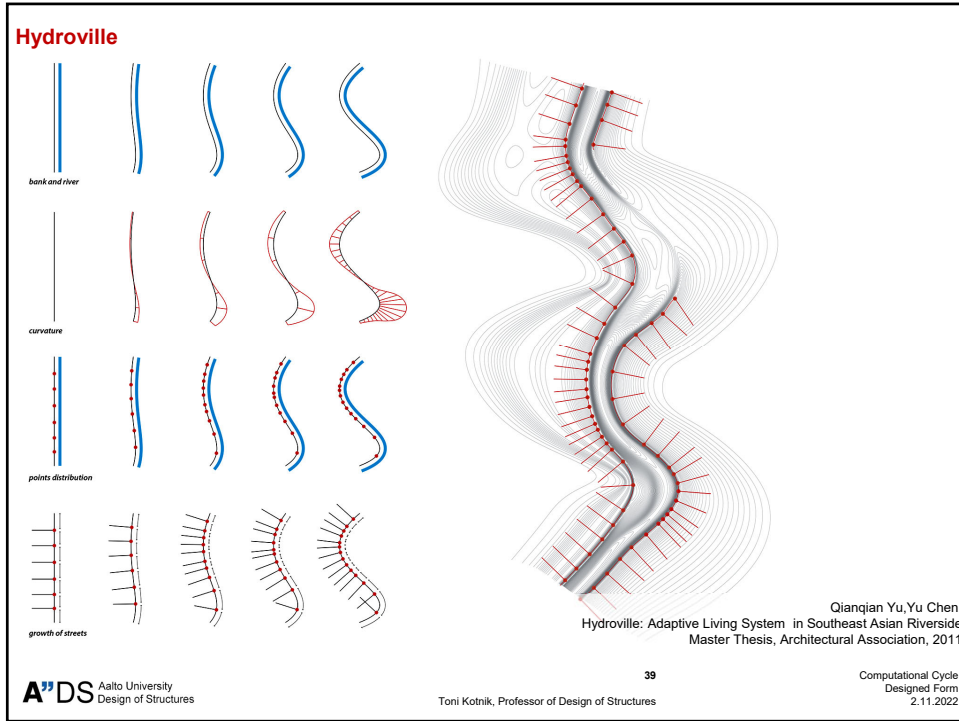
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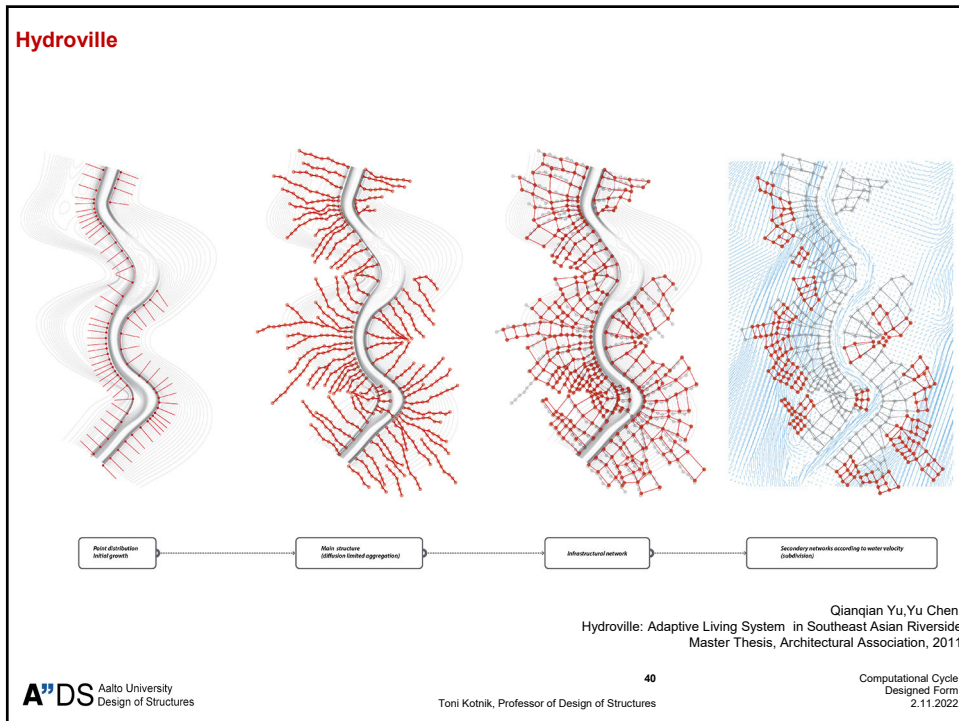
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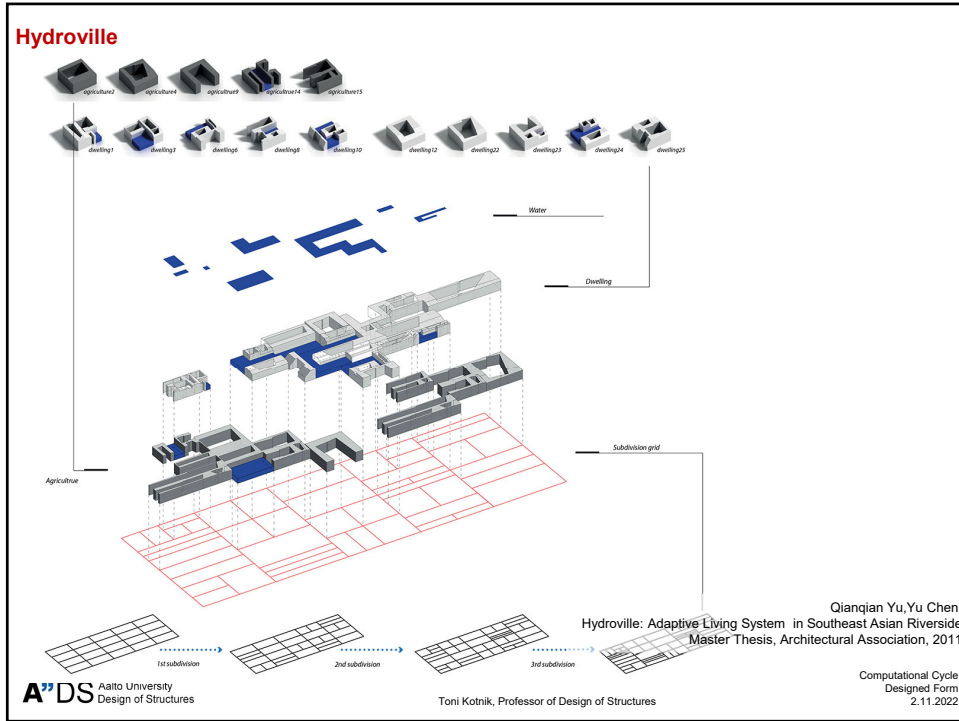
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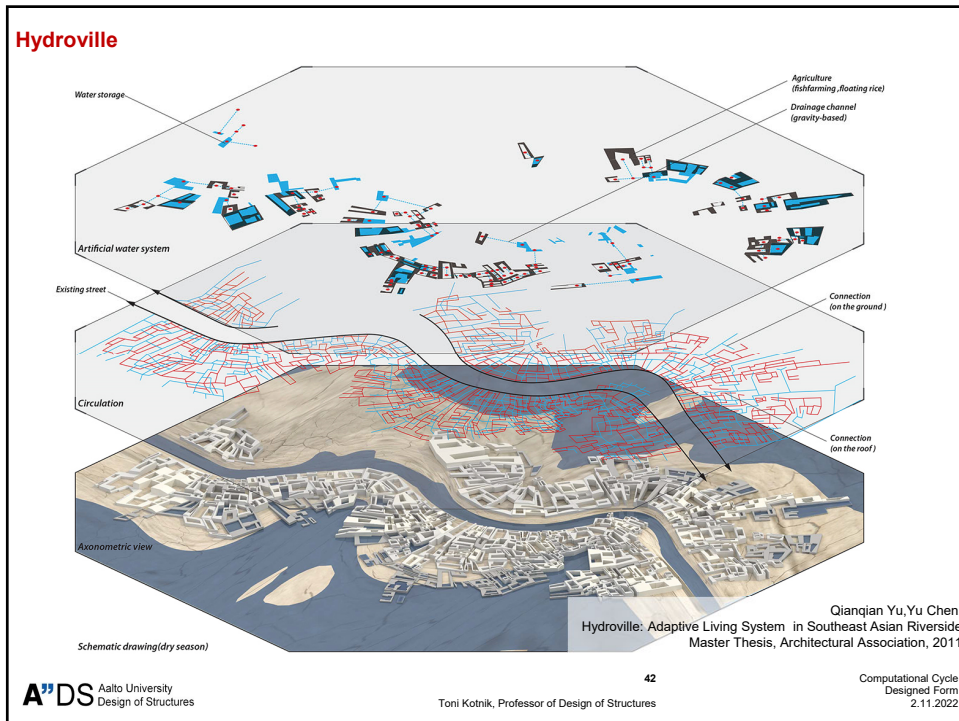
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Hydroville

Water storage
Semi-waterdefence
Waterdefence
Artificial water system
Existing street
Boat route
Circulation
Connection (on the roof)
Axonometric view
Schematic drawing (wet season)

Qianqian Yu, Yu Chen:
Hydroville: Adaptive Living System in Southeast Asian Riverside
Master Thesis, Architectural Association, 2011

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Computational Cycle

Performative Form

equilibrium

BODY

$\Delta H = M - E \pm C \pm R$

SURROUNDING

Regionality
local conditions

Science of Energy

ENG

ARCH

stable

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Computational Cycle

Performative Form
Found Form

Observation I
from material multiplicity to geometric complexity
materials are expensive, form is cheap

Observation II
architecture is ecosystem engineering
architecture is prosthetic nature

Observation III
from static isolation to dynamic porosity
architecture as an open system of fluid exchange

Observation IV
from top-down control to bottom-up process
architecture as adaptive generation to environmental conditions

material & form for microclimatic modulation

Regionality local conditions

stable

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Computational Cycle

Performative Form
Found Form
Designed Form

**computational design thinking
is of central importance for a
sustainable future**

Natural Computation
new methods of composition of form

Cellular Automata
inspired by intercellular communication

Neural Computation
inspired by the functioning of the brain

Evolutionary Computation
inspired by Darwinian evolution of species

Nature-Inspired Algorithms
inspired by behavior of groups of organism

material & form for microclimatic modulation

Regionality local conditions

stable

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