Walking Membranes: Grid-exploring P Systems with Artificial Evolution for Multi-purpose Topological Optimisation of Cascaded Processes

for

17th International Conference on Membrane Computing

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Content

1. Introduction – *Self-Organisation in Nature*

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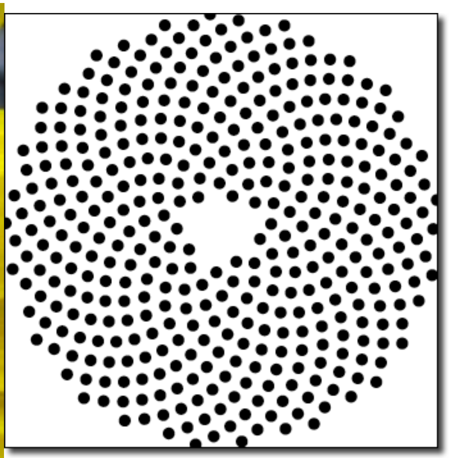

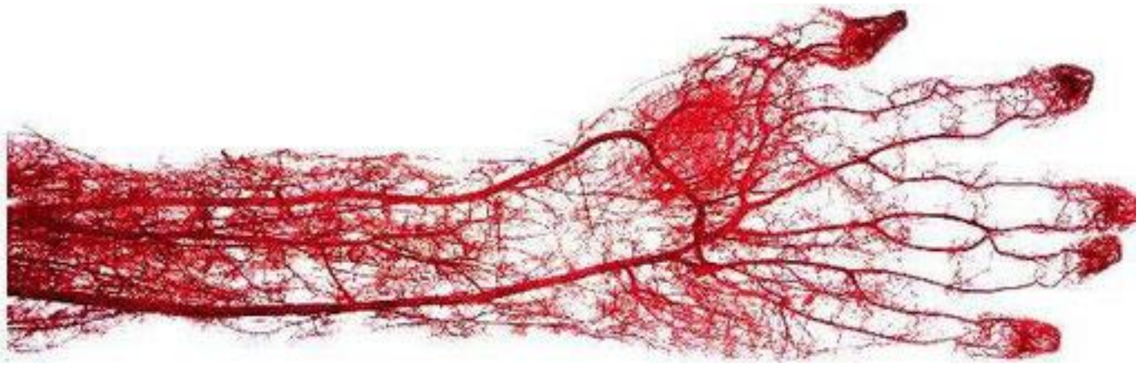

Sources:
sunflower: http://schoene-neue.medienwelten.org/wp-content/uploads/sonnenblume.jpg, 19/07/2016
fibonacci graphic: http://www.indesign-faq.de/files/2008/03/fibonacci1.png, 19/07/2016
blood vessels hand: https://image.jimcdn.com/app/cms/image/transf/dimension=510x10000:format=jpg/path/s259884baa86ce66f/image/id84fa9736a87a790/version/1280818164/image.jpg, 20/07/2016

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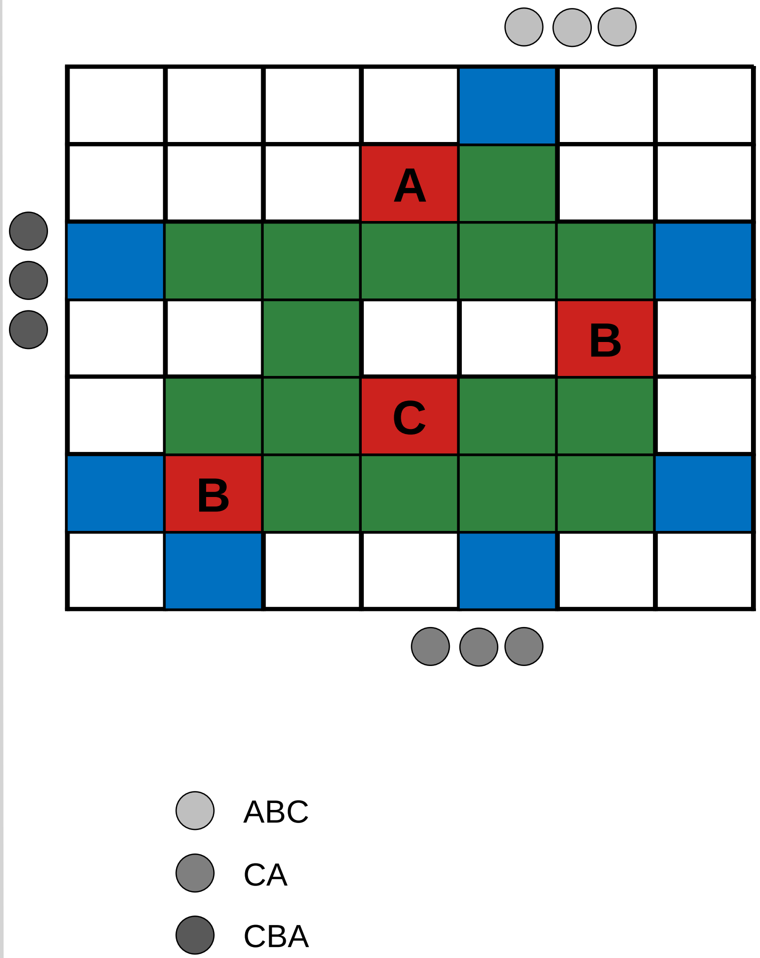
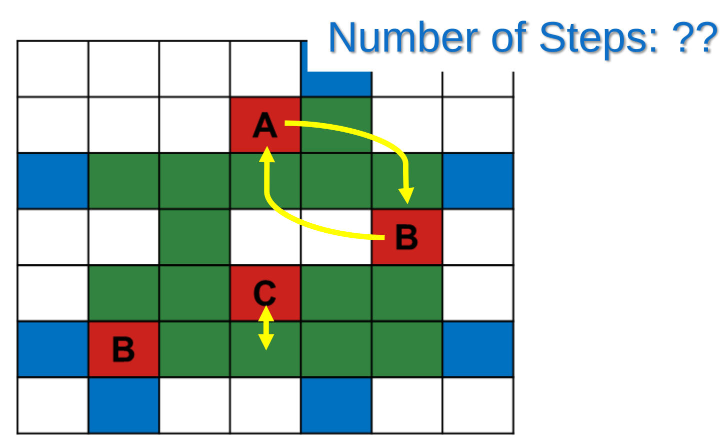
2. Model – *Specifications*

What do the examples have in common?



- spatial structure of adjacent membranes
- passed by particles
- particles move through designated areas
- particles are processed in certain locations (passage or assembly)

- particles follow a path
- paths consist of a sequence of destinations



- modifications through random mutation
- optimal topology leads to optimal fitness

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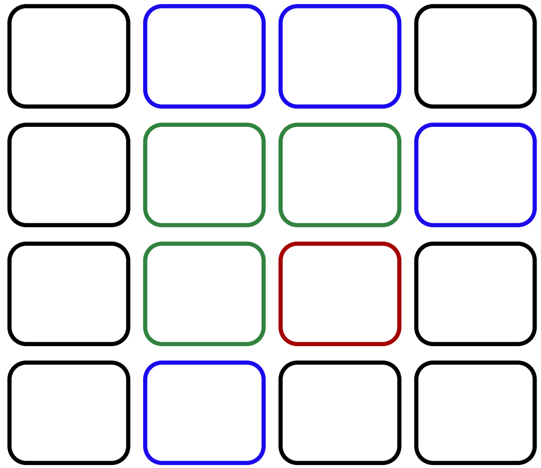
2. Model – *P System*



„Walking Membranes“

A *grid exploring P system* Π_{ge} is a construct

$$\Pi_{ge} = (m, n, \Sigma_F, \Sigma_P, G_{mbrns}, G_{capac}, G_{durat}, F, P)$$

with its components

$m \in N \setminus \{0\}$ . . . . number of grid columns
$n \in N \setminus \{0\}$ . . . . number of grid rows
Σ_F . . . . alphabet of processing unit types
Σ_P . . . . alphabet of particle categories

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2. Model – *P System*

$G_{mbrns} : \{1,\ldots,m\} \times \{1,\ldots,n\} \rightarrow \Sigma_F \cup \{\#\} \cup \{\perp\}$

grid of membranes, denoted by a matrix and represented by a function whose arguments identify column and row. Assigned function values provide the type of membrane at the corresponding grid position. Available types are processing units ($\in \Sigma_F$), paved areas (#), and blocked areas ($\perp$).

$G_{capac} : \{1,\ldots,m\} \times \{1,\ldots,n\} \rightarrow \mathbb{N}$

capacities of grid elements which define the maximum number of particles allowed to be present at the same grid membrane simultaneously. Blocked areas are assumed to have a capacity of 0. All other membranes should constitute individual capacities > 0.

$G_{durat} : \{1,\ldots,m\} \times \{1,\ldots,n\} \rightarrow \mathbb{N}\backslash\{0\}$

durations necessary for particle passage or processing individually assigned to each membrane within the grid. Each duration is expressed by a number of time steps.

$F : \Sigma_F \rightarrow \{*\} \cup \Sigma_P^3$

mode (kind of processing) for each processing unit type

$P : \{((i,j),p,f) \mid i \in \{1,\ldots,m\} \wedge j \in \{1,\ldots,n\} \wedge p \in \Sigma_P \wedge f \in \Sigma_F^* \} \rightarrow \mathbb{N}$

finite multiset of particles. Each particle comes with individual attributes such as its position (i, j) at the grid, its category p, and a finite sequence (word) f of processing unit types to be consecutively passed through.

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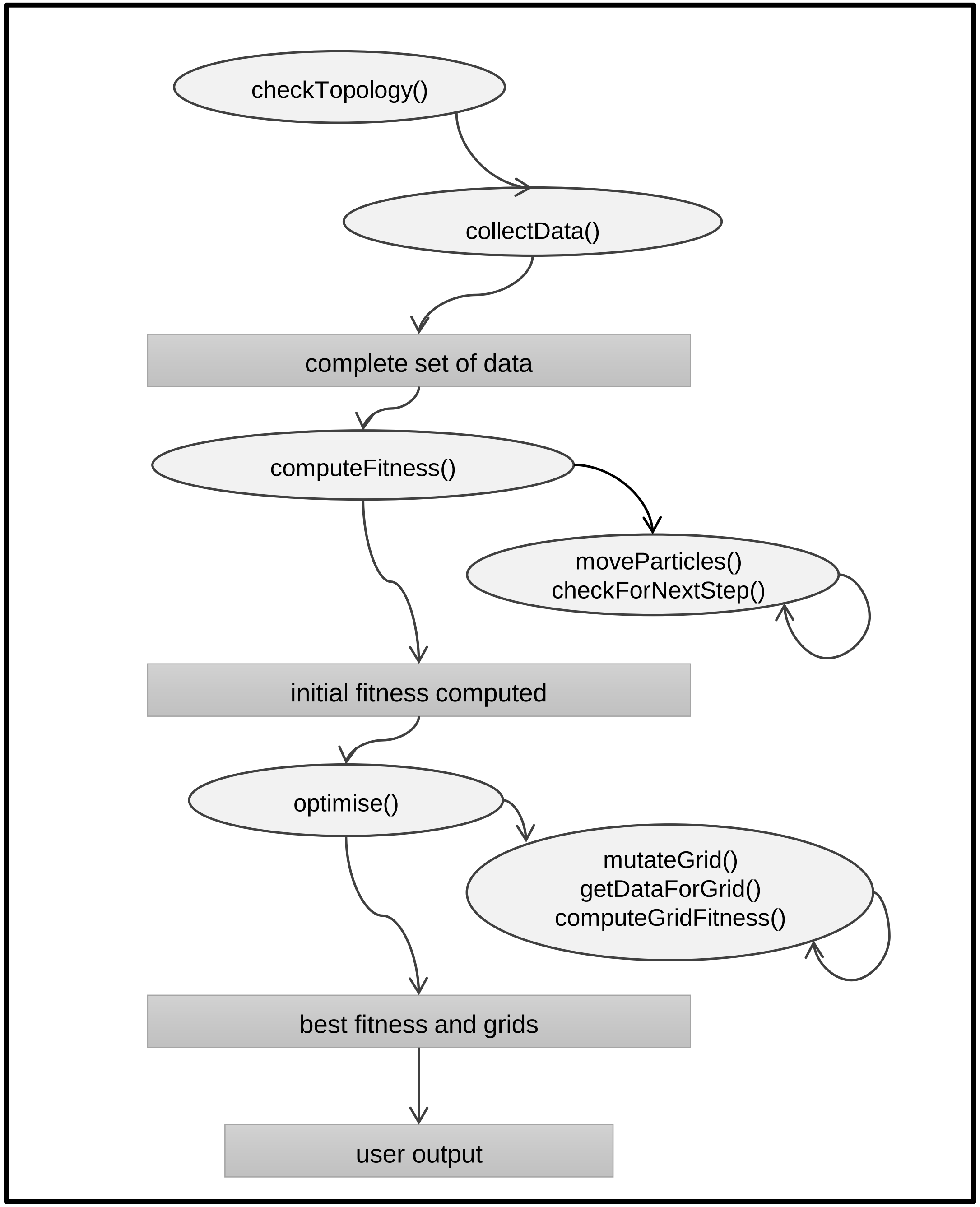
2. Model – *Related Research*

- modelling of swarm-based multi-agent systems using population P systems
  I. Stamatopoulou, P. Kefalas, M. Gheorghe. OPERASCC : An Instance of a Formal Framework for MAS Modeling Based on Population P Systems. *Lecture Notes in Computer Science* **4860**:438-452, 2007
- self-assembly by consecutive membrane division in population P systems
  F. Bernardini, M. Gheorghe, N. Krasnogor, J.L. Giavitto. On Self-assembly in Population P Systems. *Lecture Notes in Computer Science* **3699**:46-57, 2005
- minimising failure in network partitioning with self-adaptive and reconfigurable distributed computing systems
  S. Bagchi. Self-adaptive and reconfigurable distributed computing systems. *Applied Soft Computing* **12**:3023-3033, 2012
- 'on-the-fly' composition of self-modifiable sequences of instructions
  T. Hinze, K. Kirkici, Pa. Sauer, Pe. Sauer, J. Behre. Membrane Computing Meets Temperature: A Thermoreceptor Model as Molecular Slide Rule with Evolutionary Potential. *Lecture Notes in Computer Science* **9504**:215-235, 2015
- evaluation, accumulation, and categorised counting of particles initially positioned at a planar two-dimensional surface using blotting P systems
  T. Hinze, K. Grützmann, B. Höckner, Pe. Sauer, S. Hayat. Categorised Counting Mediated by Blotting Membrane Systems for Particle-based Data Mining and Numerical Algorithms. *Lecture Notes in Computer Science* **8961**:241-257, 2014

3. Software – *Algorithm*



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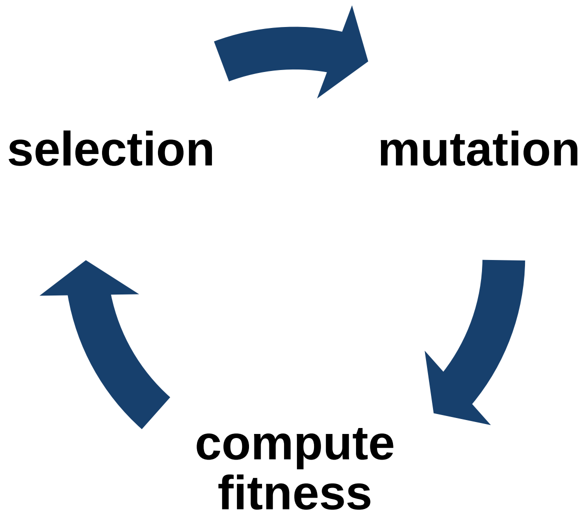
2. Model – *Artificial Evolution*

slowest 20% deleted
replaced by mutations of fastest 20%
(originals stay)

random
recombination or shift
(50% chance each)



number of time steps until all particles have finished their paths

population: 50 grids

termination: 100 generations without improvement

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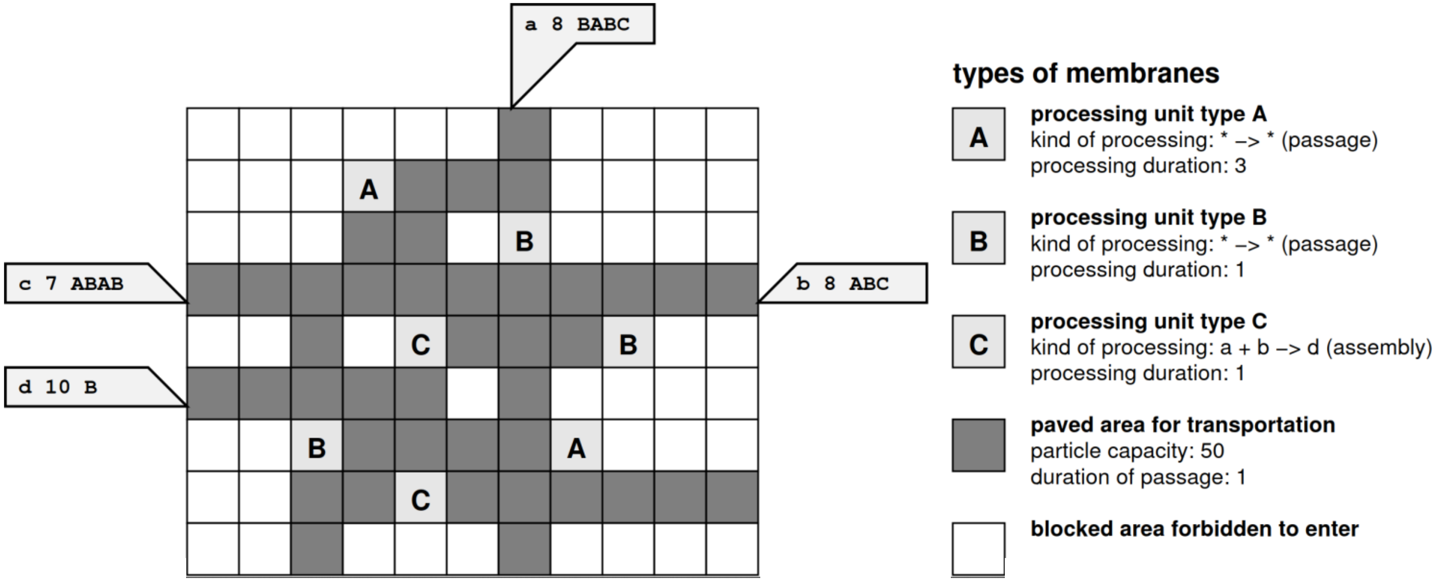
3. Software – *Demonstration*



→ online Grid Tool
www-user.tu-cottbus.de/~weberlea/gridtool

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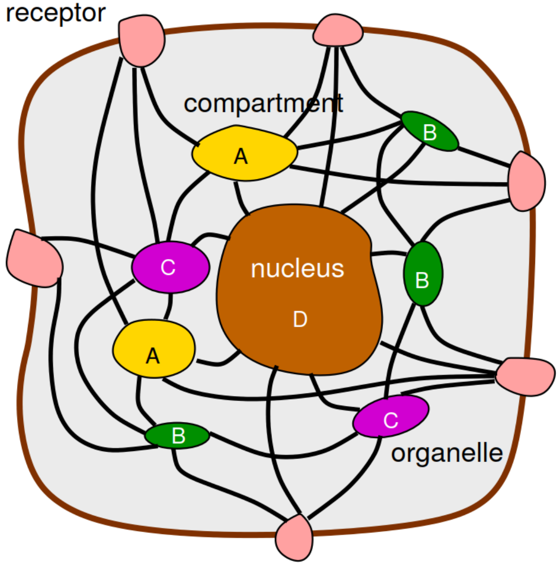
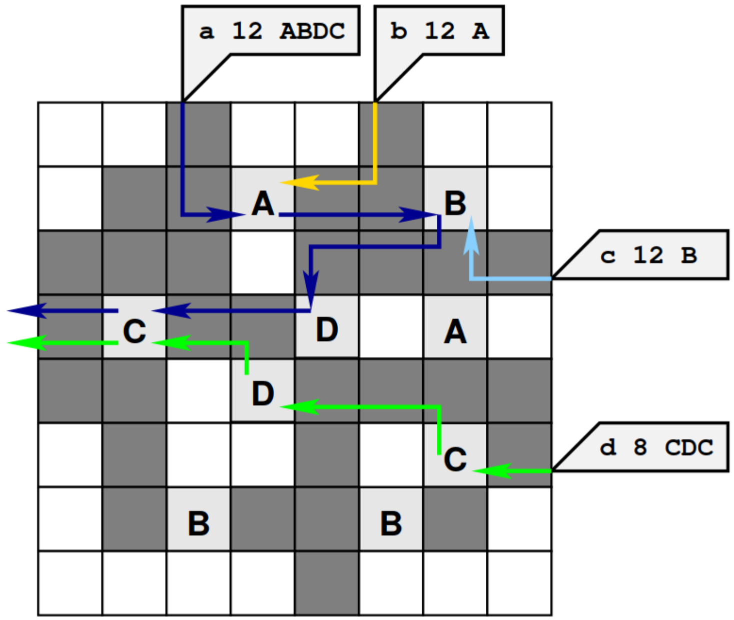
4. Case Study – *Biological Cell*





Number of Steps: 88

A a + b → a
processing duration: 1

B a + c → a
processing duration: 1

C * → *
processing duration: 1

D nucleus
* → *
processing duration: 1

microtubuli
particle capacity: 70
duration of passage: 1

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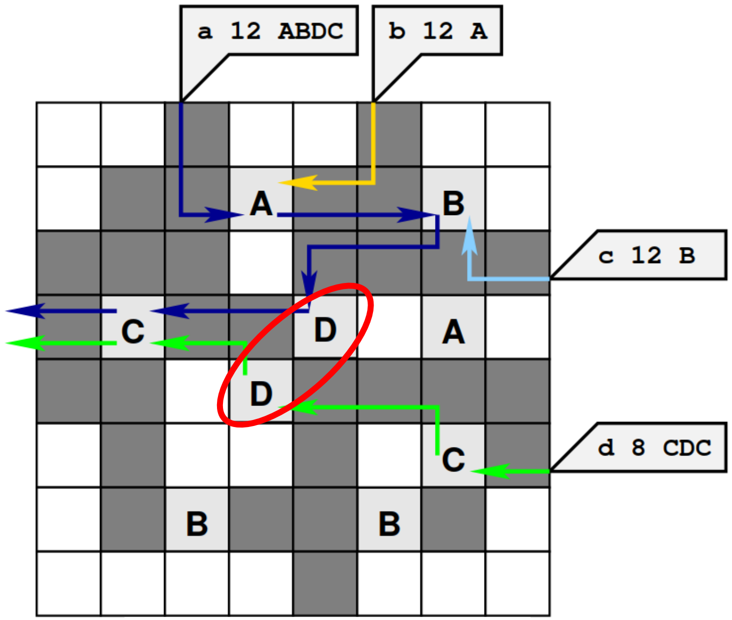
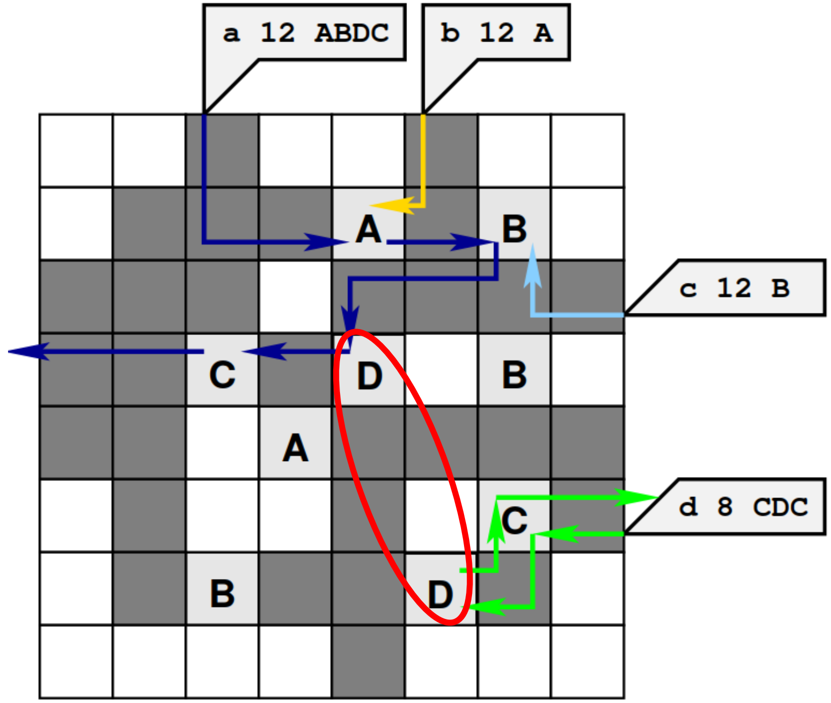
4. Case Study – *Biological Cell*

initial grid



Number of Steps: 88

optimised grid



Number of Steps: 60

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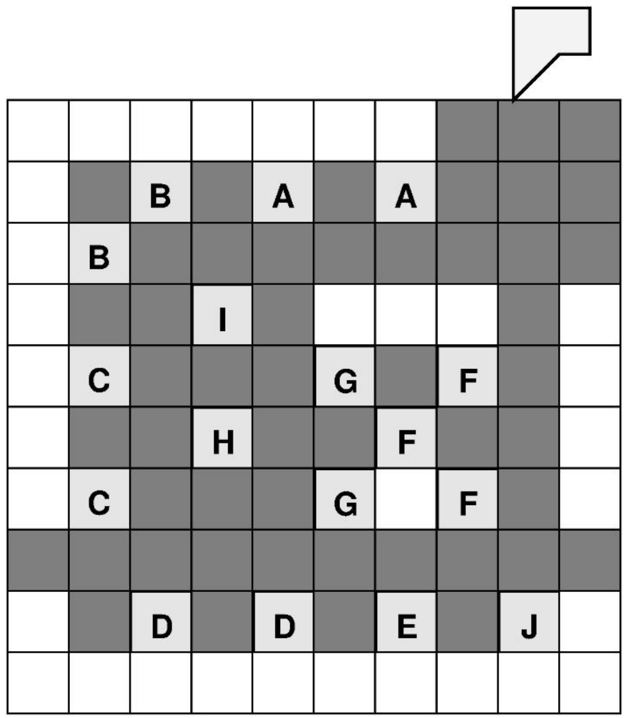
4. Case Study – *Supermarket 2.0*



No. Steps: 135

processing units (shelves)

A: fruit, vegetables
B: bread, bakery products
C: dairy products
D: meat, sausages
E: newspapers, magazines
F: beverages
G: confectionery
H: frozen foods
I: ingredients, tins
J: non-food bargains

(for all:
* → *
proc. duration: 1)

particles (customers)

a	23	C
b	18	F
c	17	A
d	13	ACF
e	12	B
f	10	ABG
g	8	ABCF
h	8	BG
i	7	EF
j	6	ABCDEFGHIJ
k	5	GHIJ
l	3	DIF
m	1	EJFG

paved area:
duration of passage: 1, capacity: 150

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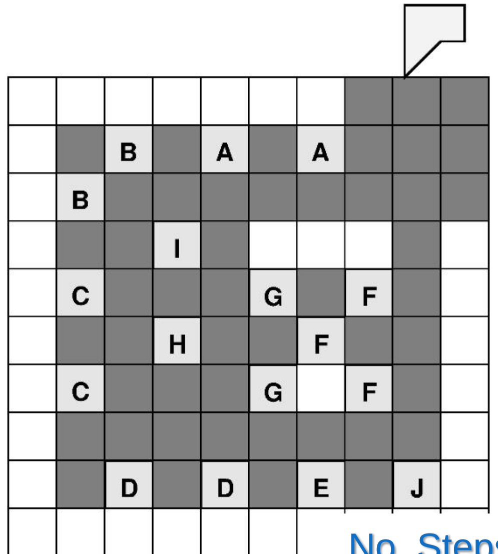
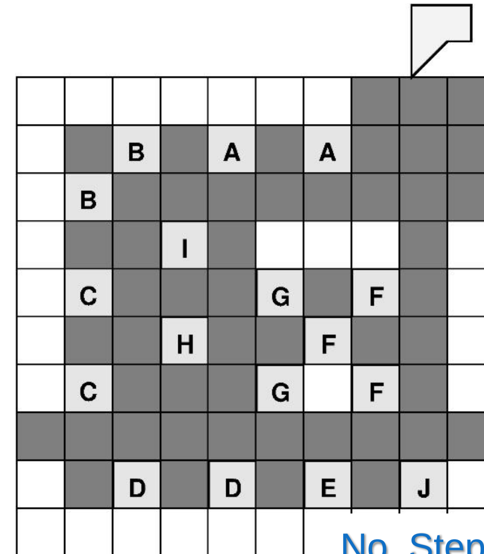
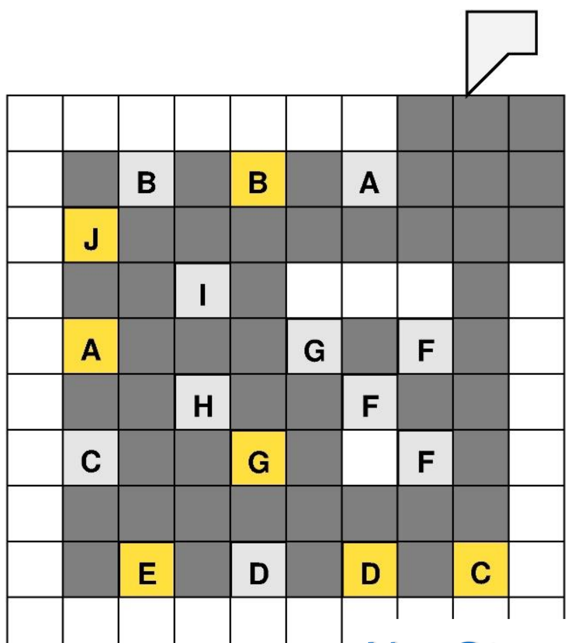
4. Case Study – *Supermarket 2.0*



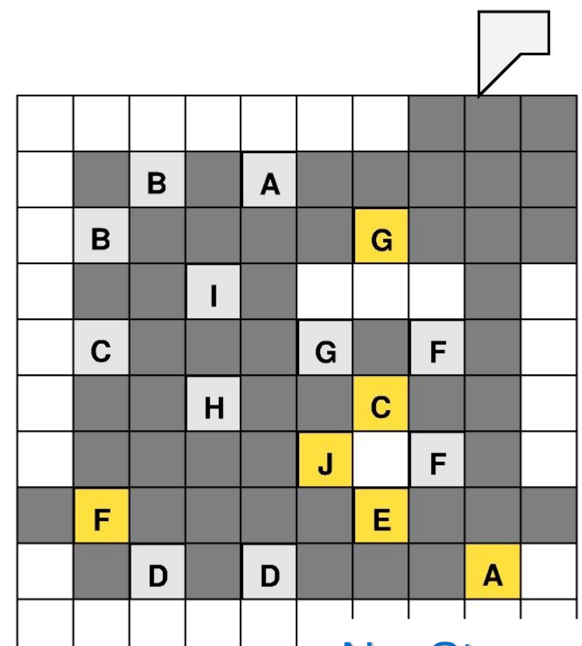
No. Steps: 146



No. Steps: 135



No. Steps: 120



No. Steps: 116

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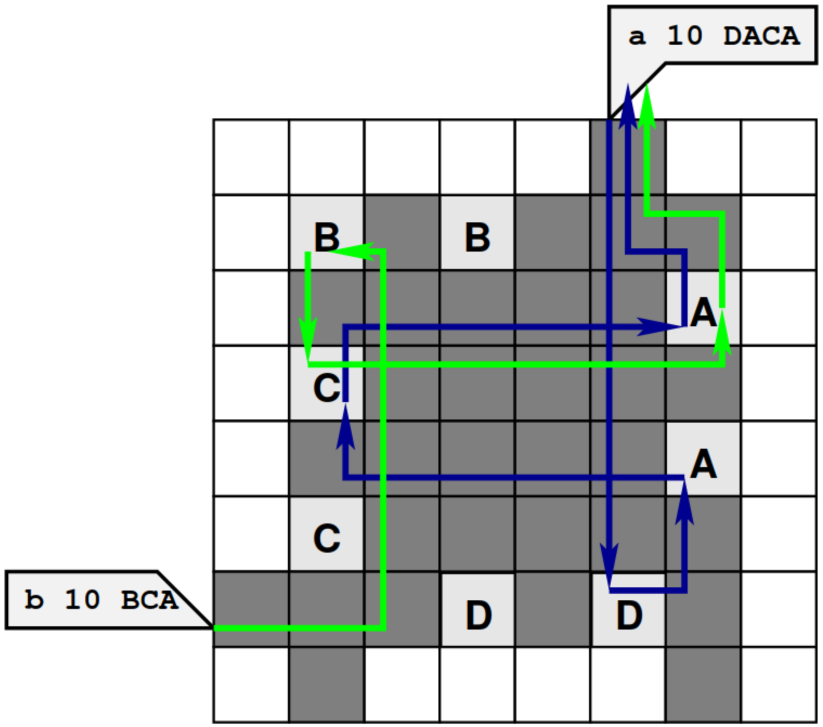
4. Case Study – *Cabinet Makers*



Number of Steps: 61

A drilling, screwing
* → *
processing duration: 1

B cutting, planing, grinding
* → *
processing duration: 3

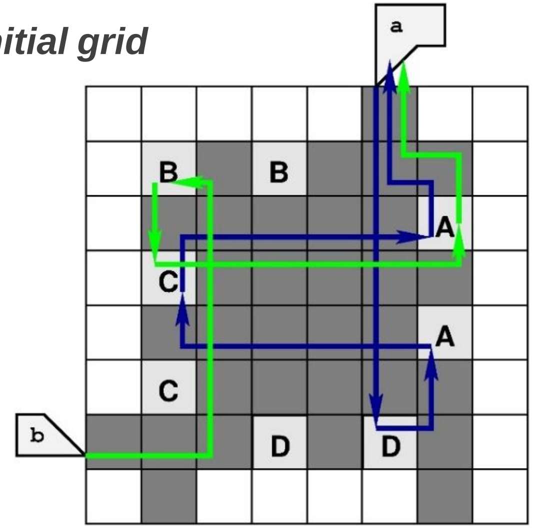
C machine-based veneering
* → *
processing duration: 1

D chipped wood compression and press sizing
* → *
processing duration: 1

particle capacity: 40
duration of passage: 1

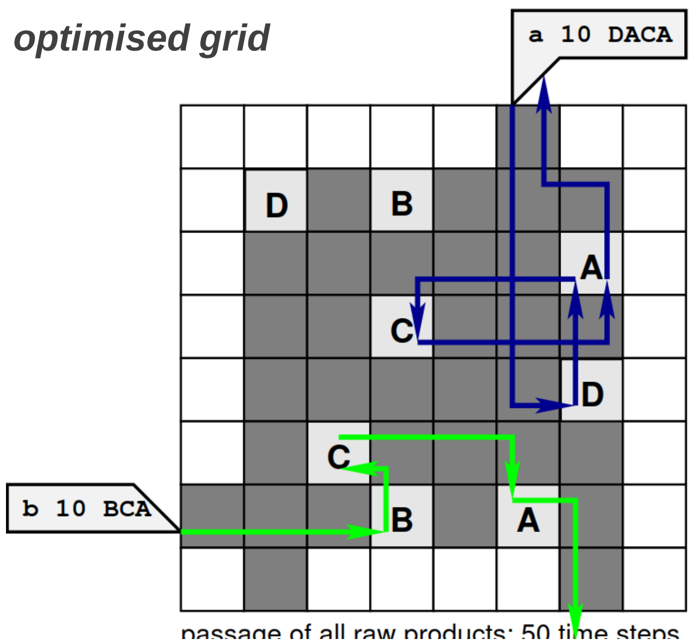
4. Case Study – *Cabinet Makers*

initial grid



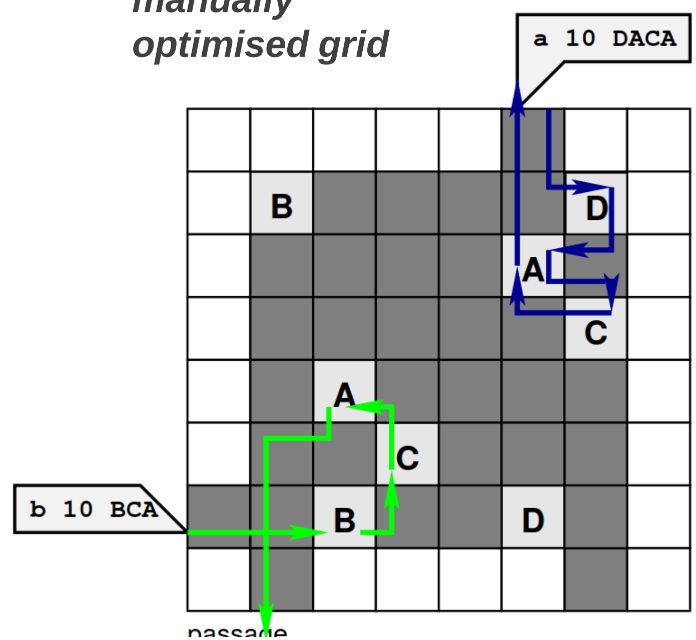
No. Steps: 61

optimised grid



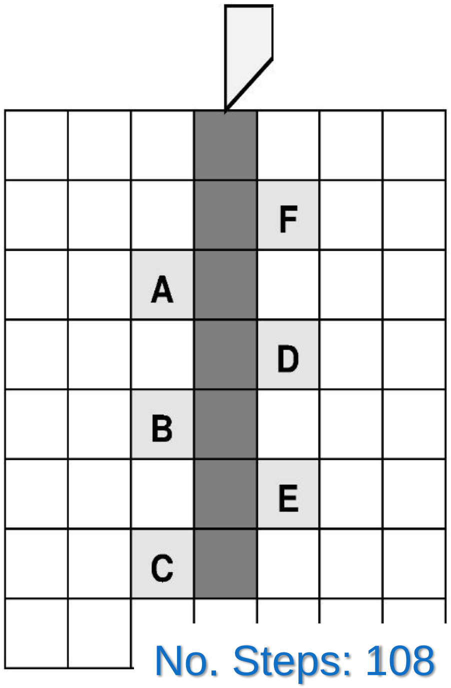
No. Steps: 50

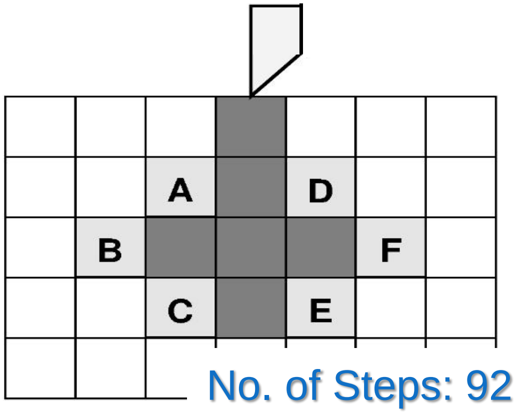
manually optimised grid



No. Steps: 48

4. Case Study – *Processor Architecture*





processing units (components)

A: register A/accumulator
B: register B
C: counter
D: decoder
E: ALU
F: memory/flash

(for all:
* → *
processing duration: 1)


duration of passage: 1, capacity: 90

particles (machine code):

a: 2, instructions: DEC
b: 5, instructions: DFAFEC
c: 4, instructions: DFBFEC
d: 3, instructions: DAC
e: 6, instructions: DC

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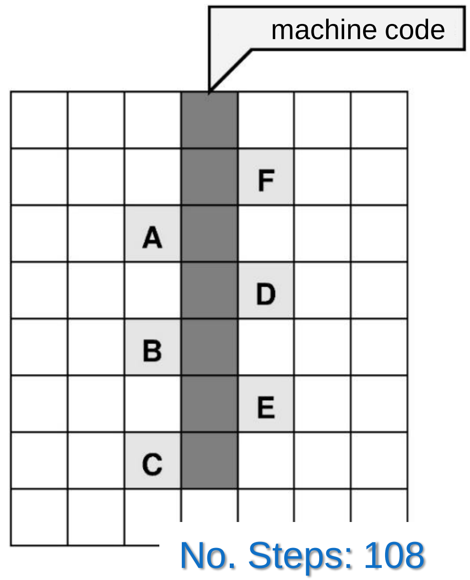
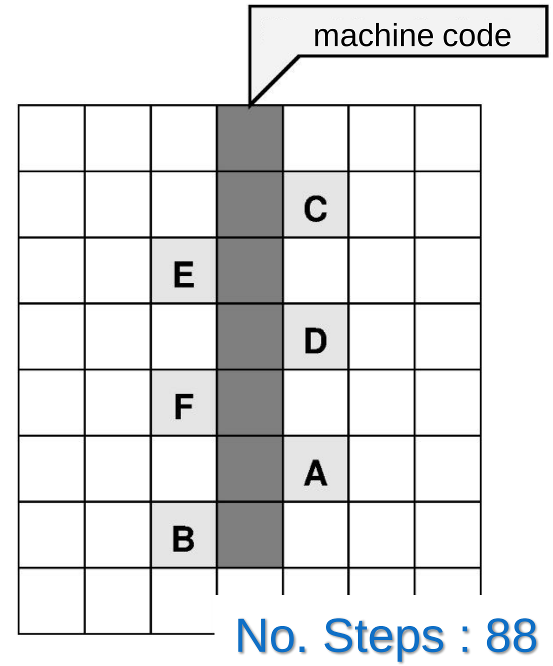
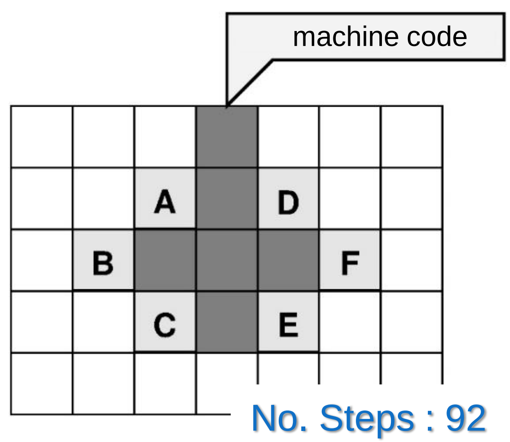
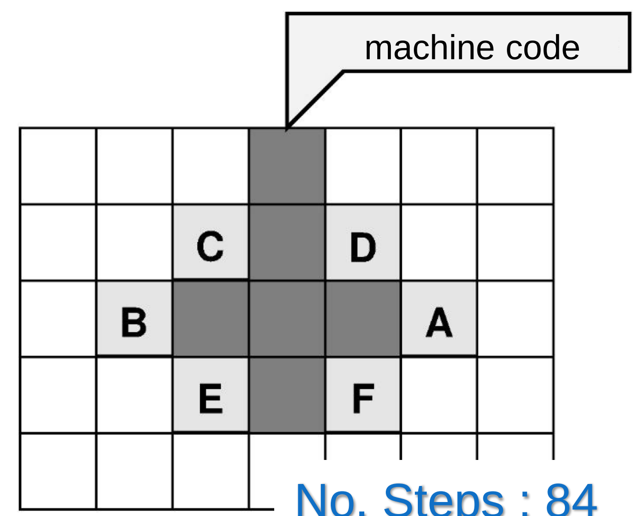
4. Case Study – *Processor Architecture*









5. Summary & Conclusion

- model inspired by nature‘s ability for self-organisation
- specifications build on similarities of real life examples
- successfully applied to case studies

Outlook

- new types of processing
- stationary processing units
- more dynamic software (eg. handling queues)

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