

from particle to people

exploring complex and sustainable systems with agent-based modeling

Sparisoma Viridi

20250620_v2 | <https://osf.io/ahkv9/>

Outline

- intro 3
- physical systems 8
- biological systems 12
- human dynamics 22
- other 34
- closing 37



intro

Agent-based modeling

- Agent-based models (ABMs) are computational models that simulate behavior of individual agents in order to study **emergent phenomena** at the level of the community.
- Depending on the application, agents may represent humans, institutions, microorganisms, and so forth.
- The agents' actions are based on autonomous decision-making and other behavioral traits, implemented through formal rules.

D. Šešelja, "Agent-Based Modeling in the Philosophy of Science", Stanford Encyclopedia of Philosophy, 7 Sep 2023, url <https://plato.Stanford.edu/entries/agent-modeling-philsience/> [20250620].

System dynamics

- System dynamics examines the world through the lens of causal feedback loops.
- The characteristics are
 1. Models are based on causal feedback structure.
 2. Accumulations and delays are foundational.
 3. Models are equation-based.
 4. Concept of time is continuous.
 5. Analysis focuses on feedback dynamics

Asmeret Naugle, Saeed Langarudi, Timothy Clancy, "What is (quantitative) system dynamics modeling? Defining characteristics and the opportunities they create", System Dynamics Review, vol 40, no 2, p e1762, Apr-Jun 2024, url <https://doi.org/10.1002/sdr.1762>.

Boids

- Boids are birdlike objects that were developed in the 1980s to model flocking behavior.
- The aggregate motion of a flock of birds, a herd of land animals, or a school of fish is a beautiful and familiar part of the natural world.

Mark Jacobson, "Boids are birdlike objects - Flocking behavior for birds - Schools of Fish", Computer Science, University of Northern Iowa, url <https://www.cs.uni.edu/~jacobson/025/boids/birds.html> [20250620].

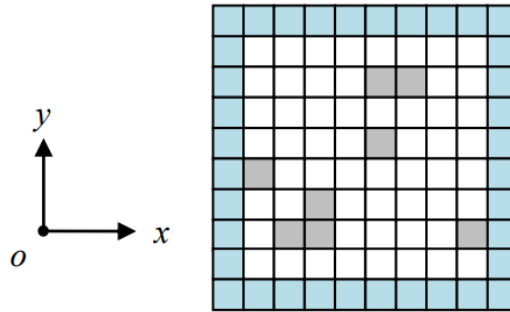
Boids and ABM

- A popular and early example of ABM is the model of coordinated animal movement posited by Craig Reynolds (1987).
- This model, called Boids

Elizabeth M. Gallagher, Joanna J. Bryson , "Agent-Based Modelling", SpringerLink, 17 Nov 2017, url https://link.springer.com/rwe/10.1007/978-3-319-47829-6_224-1 [20250620].

physical systems

ABM for phases of matter



$$P_{\text{Sol}} = [0.000 \quad 0.000 \quad 0.000 \quad 0.000 \quad 1.000 \quad 0.000 \quad 0.000 \quad 0.000],$$







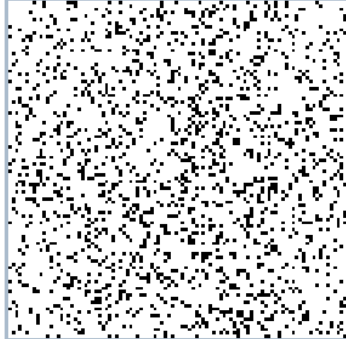

$$P_{\text{Liq}} = [0.060 \quad 0.110 \quad 0.110 \quad 0.125 \quad 0.250 \quad 0.125 \quad 0.110 \quad 0.110]$$

$$P_{\text{Gas}} = [0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125 \quad 0.125]$$

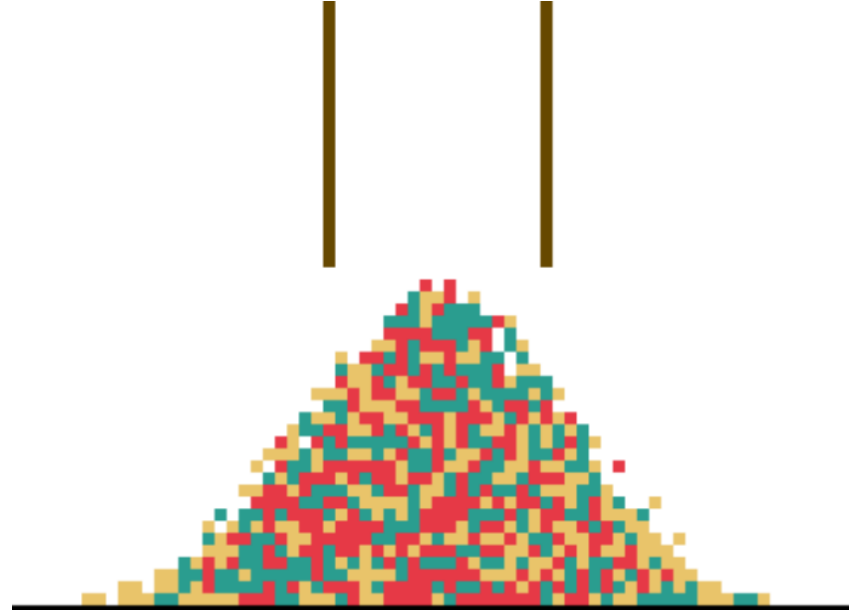
$$P_{\text{Gra}} = [0.000 \quad 0.000 \quad 0.000 \quad 0.250 \quad 0.500 \quad 0.250 \quad 0.000 \quad 0.000]$$

Direction	Abbreviation
↑	NO (north)
↗	NE (northeast)
→	EA (east)
↘	SE (southeast)
↓	SO (south)
↙	SW (southwest)
←	WE (west)
↖	NW (northwest)

Sparisoma Viridi, Freddy Haryanto, "Agent-based model and its potential in simulating some physical systems", IOP Conference Series: Materials Science and Engineering, vol 599, no 1, p 012008, url <https://doi.org/10.1088/1757-899X/599/1/012008>.

(after) initial				
final				
	(a)	(b)	(c)	(d)

Granular materials AOR with ABM



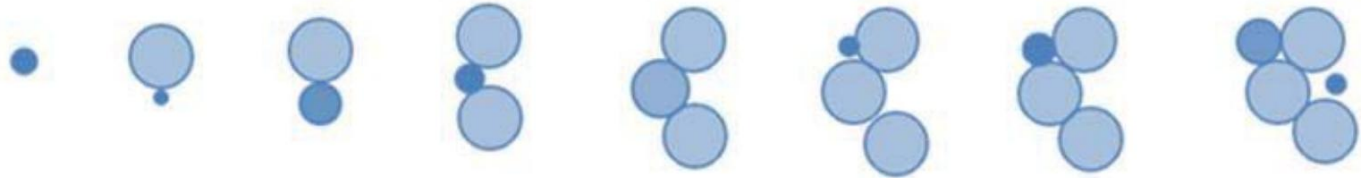
Muhammad Farhan Shadiq, Aurellyallodia Faiza Kusuma, Fifi Fitriyah Masduki, Sevi Nurafni, Putri Mustika Widartiningsih, Sparisoma Viridi, "Modeling Granular Mixtures with Simple Rules: A Student Project in Agent-Based Simulation", The 14th International Physics Seminar 2025 (IPS 2025), 21 June 2025, ABS-148, url <https://interconf.org/2025/ips/kfz/abstract/Ge7LCuvk3> [20250620].

2025-06-20

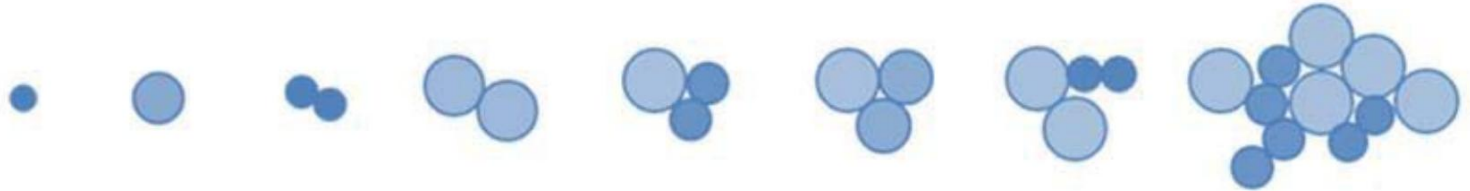
biological systems

Cell budding vs binary fission

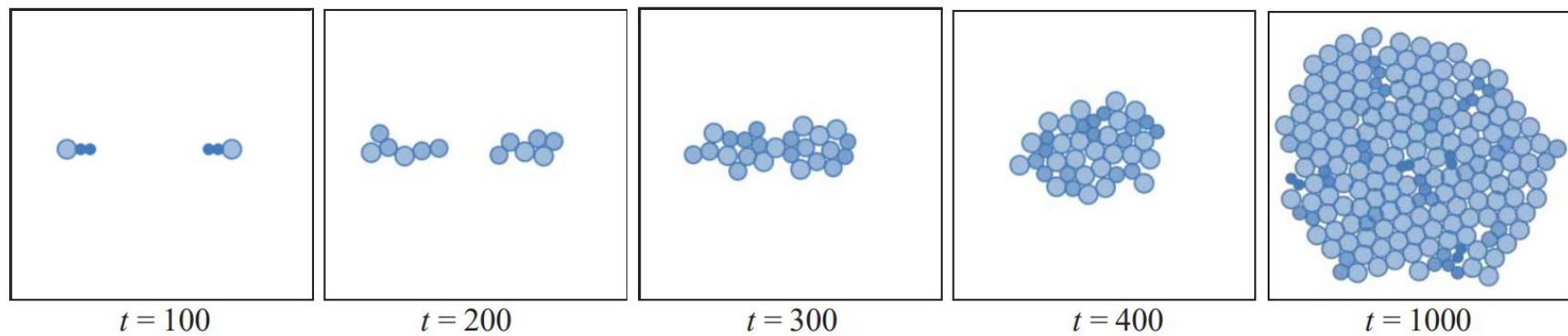
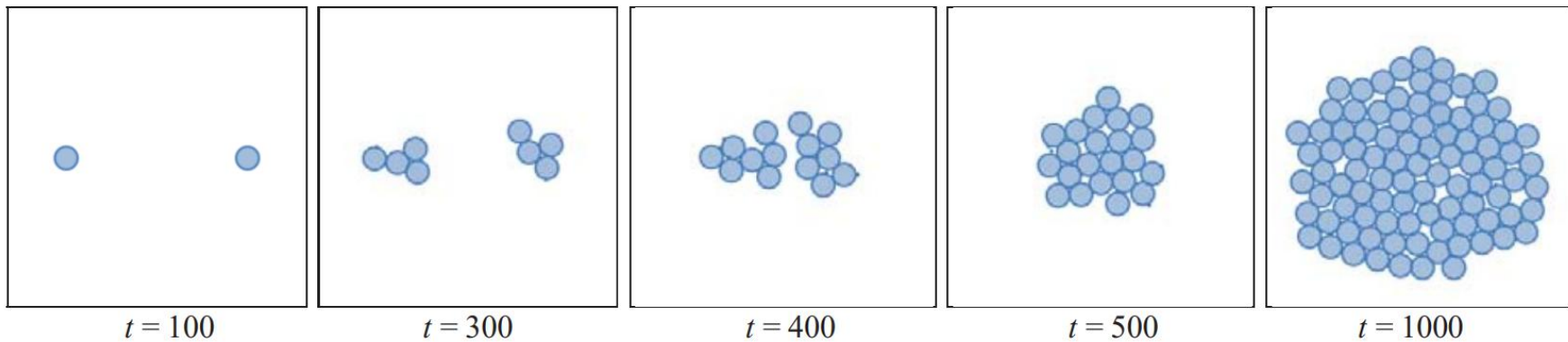
Budding

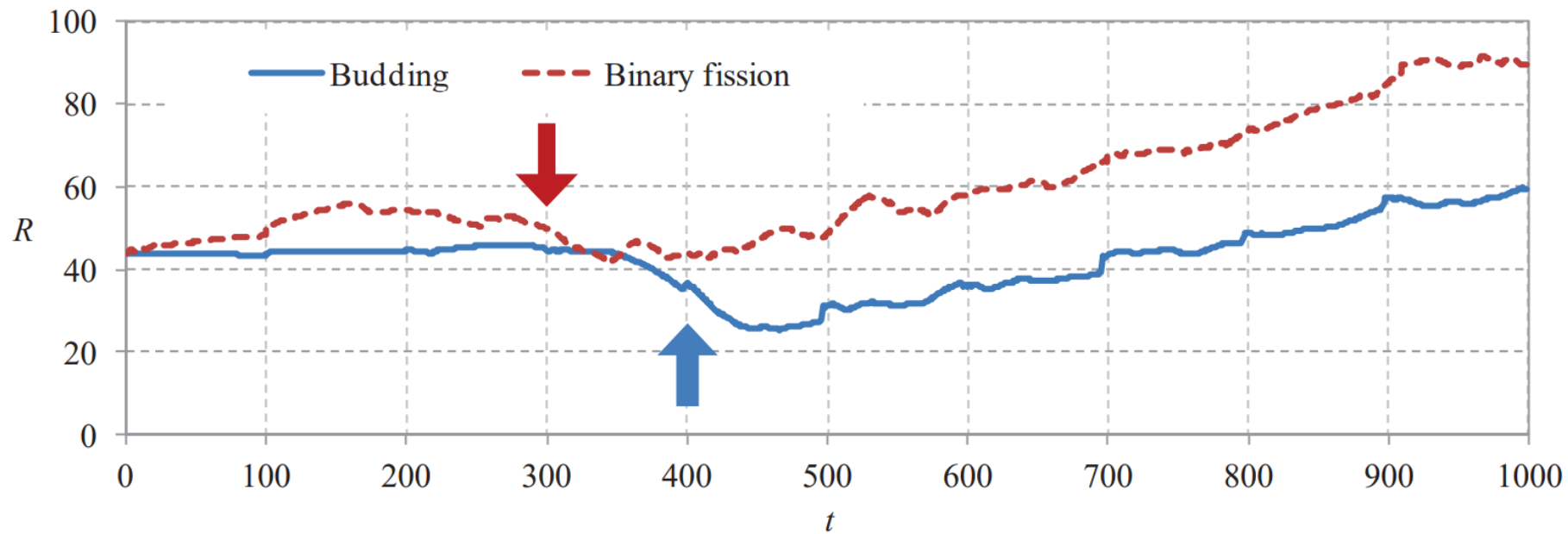


Binary
fission



S. Viridi, A. D. Mauluda, S. H. Pratama, Suprijadi, "Simulation of cell budding and binary fission: A preliminary study using molecular dynamics and agent-based model", AIP Conference Proceedings, vol 2346, no 1, p 020010, 2021, url <https://doi.org/10.1063/5.0048209>.





Boid simulation for fish group motion

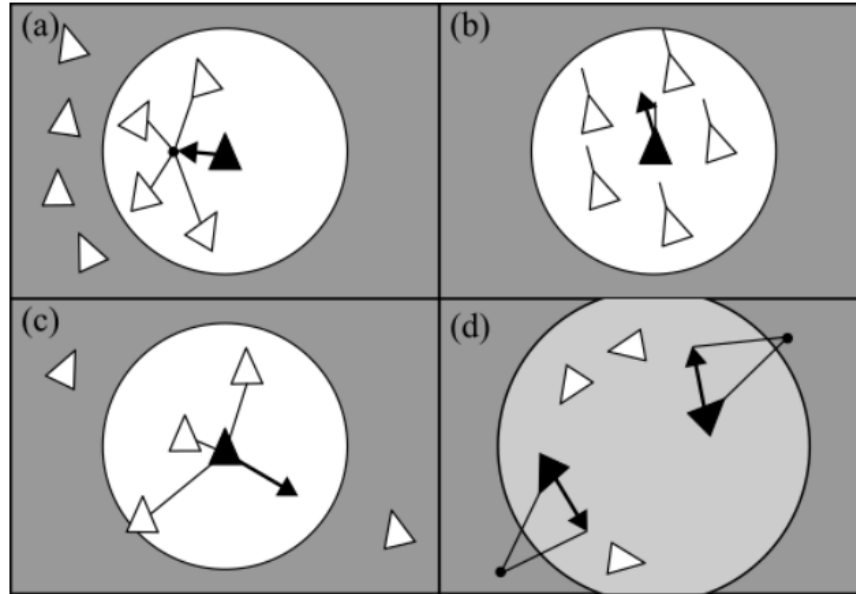
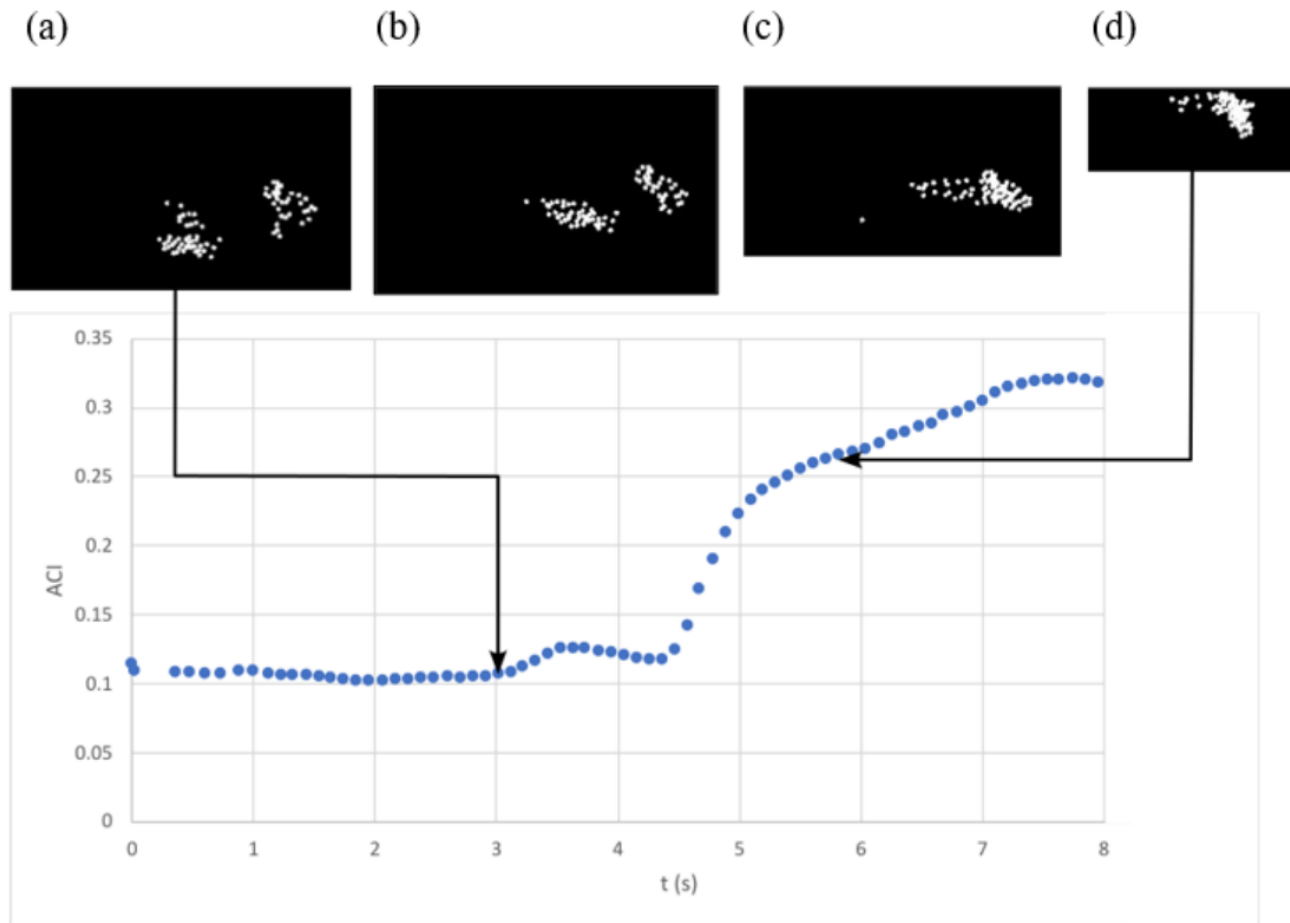


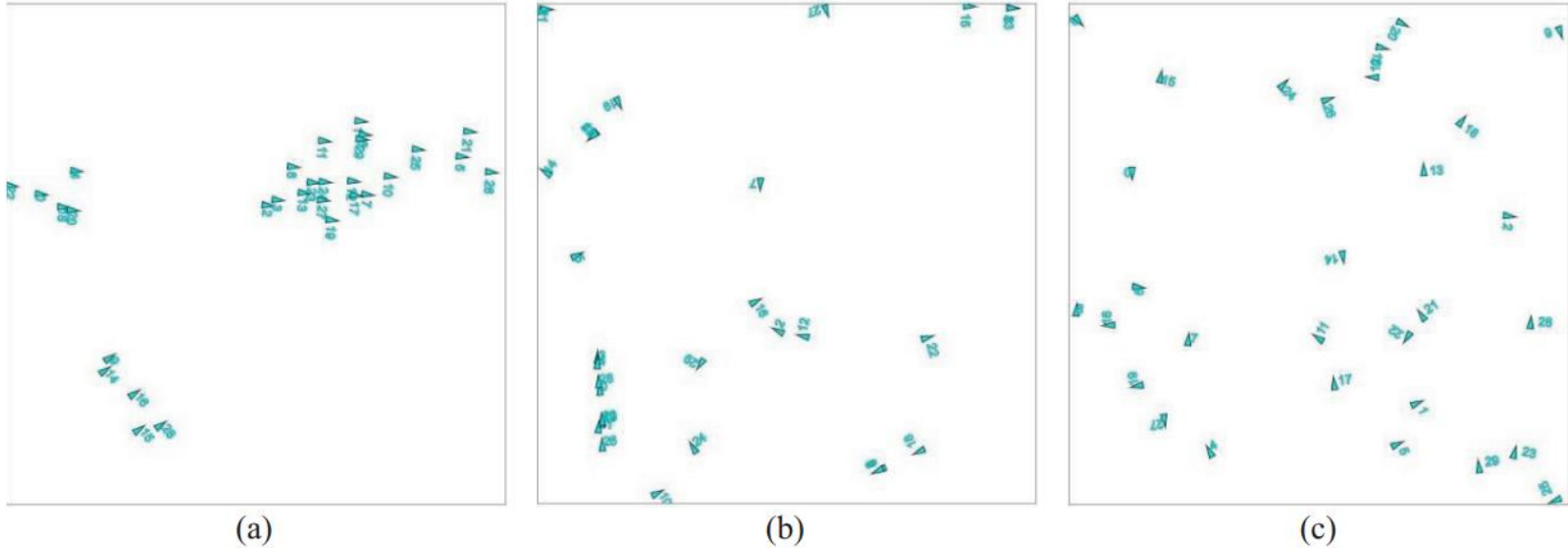
Illustration of each rule (a) cohesion, (b) alignment, (c) separation, and (d) containment.

Faiz Aulia Rahman, Utriweni Mukhaiyar, Sparisoma Viridi, "Analysis of Boid Algorithm Weights using Alignment Clustering Index", BIO Web of Conferences, vol 92, no 1, p 01016, 2024, url <https://doi.org/10.1051/bioconf/20249201016>.

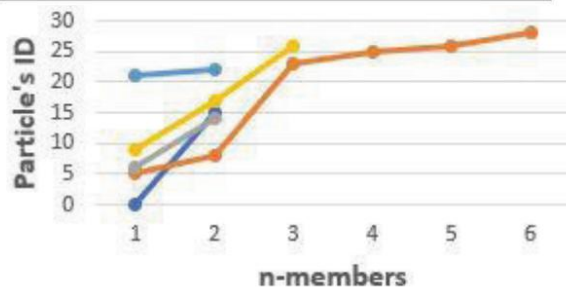
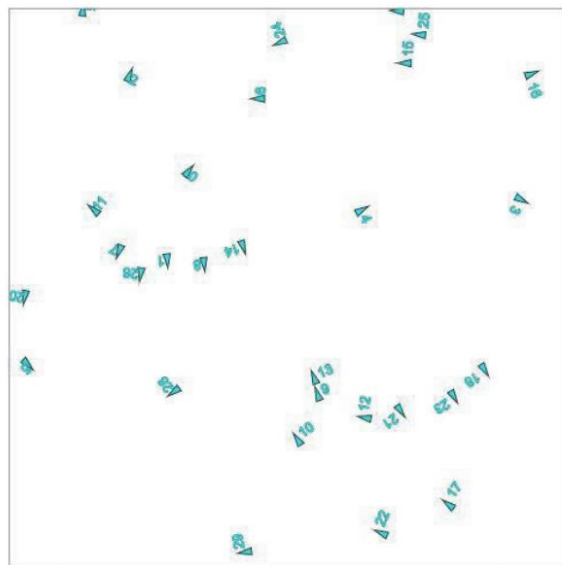
Alignment Clustering Index



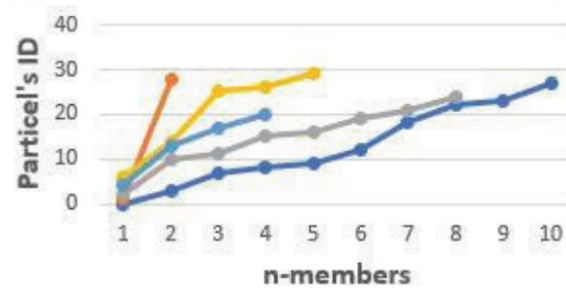
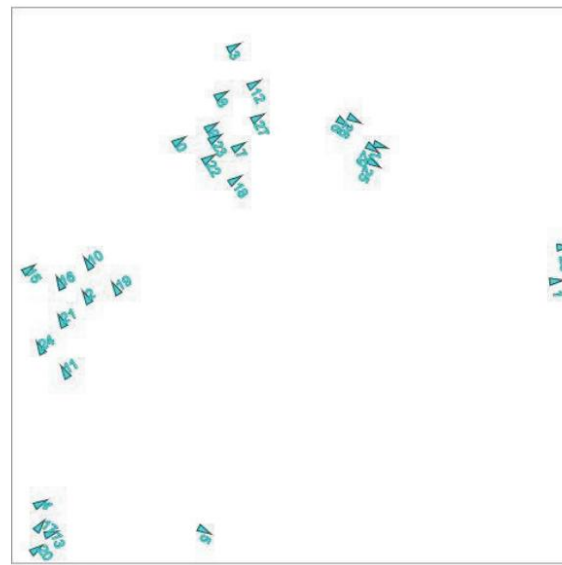
Flocking (birds): A newtonian approach



Ariq Dhia Irfanudin, Dinda Ravi Algifari, Sparisoma Viridi, Yudha Satya Perkasa, "Static and dynamic neighbor interaction of flocking model in Newtonian approach", AIP Conference Proceedings, vol 2169, no 4, p 040001, 2019, url <https://doi.org/10.1063/1.5132664>.

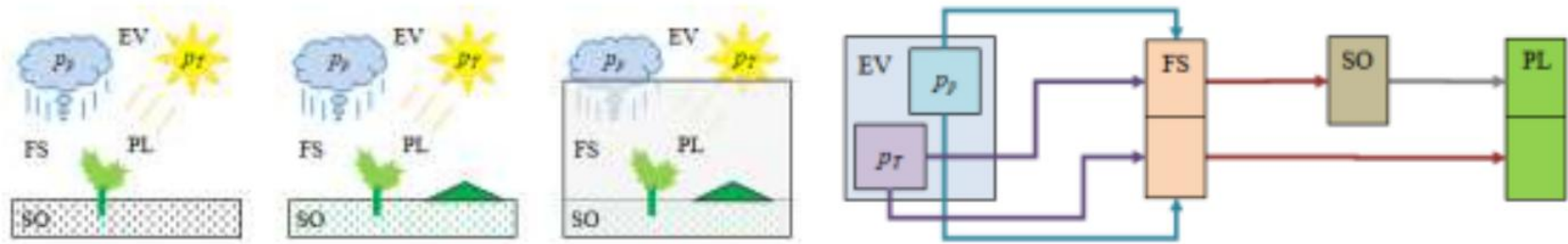


● K1
 ● K2
 ● K3
 ● K4
 ● K5



● K1
 ● K2
 ● K3
 ● K4
 ● K5

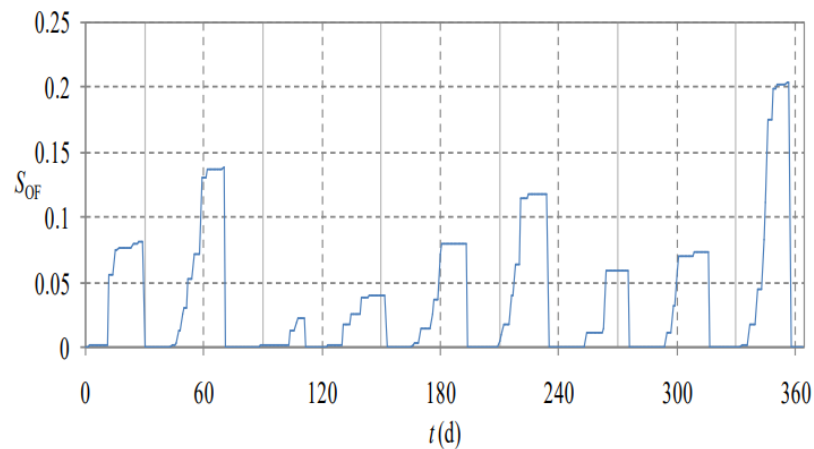
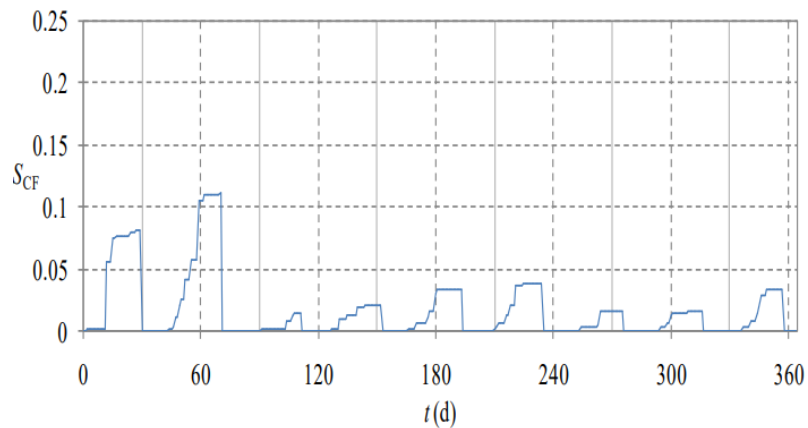
ABM: Conventional, green, smart farming



Farming type	Continue planting time	Control of weather
CF	no	no
OR	yes	no
SF	yes	yes

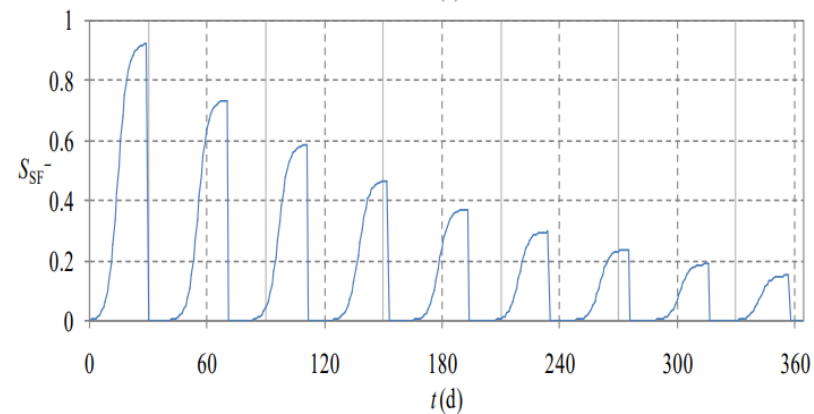
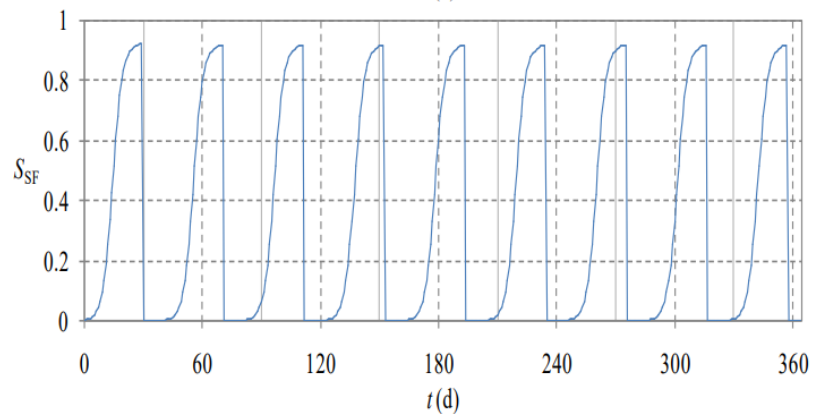
S. Viridi, P. Premadi, P. Aditiawati, E. S. Maqdir, T. Suheri, J. Halid, K. N. Sari, U. S. Pasaribu, N. M. Sudaryani, N. Latifah, S. Rahimah, "Simulation of bioeconomy system using agent-based model in the case of smart, green, and conventional farming", IOP Conference Series: Earth and Environmental Science, vol 230, no 1, p 012118, url <https://doi.org/10.1088/1755-1315/230/1/012118>.

CF



GF

SF



SF

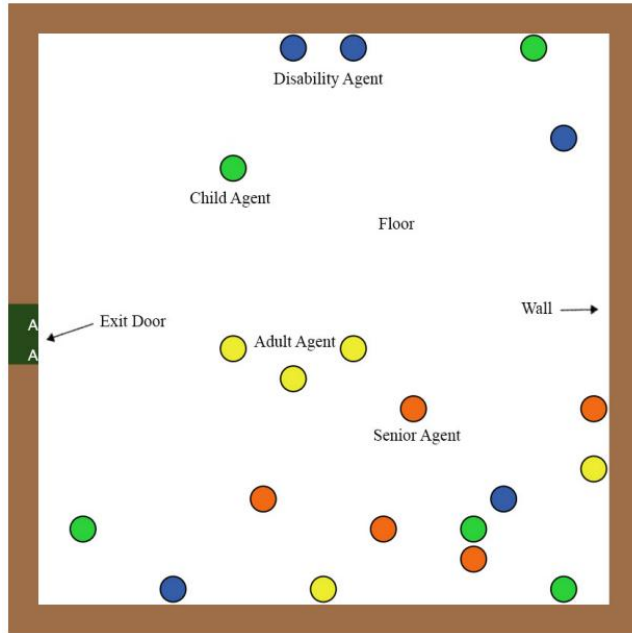
-NB

S: Average size of plant

NB: nutrient balance condition

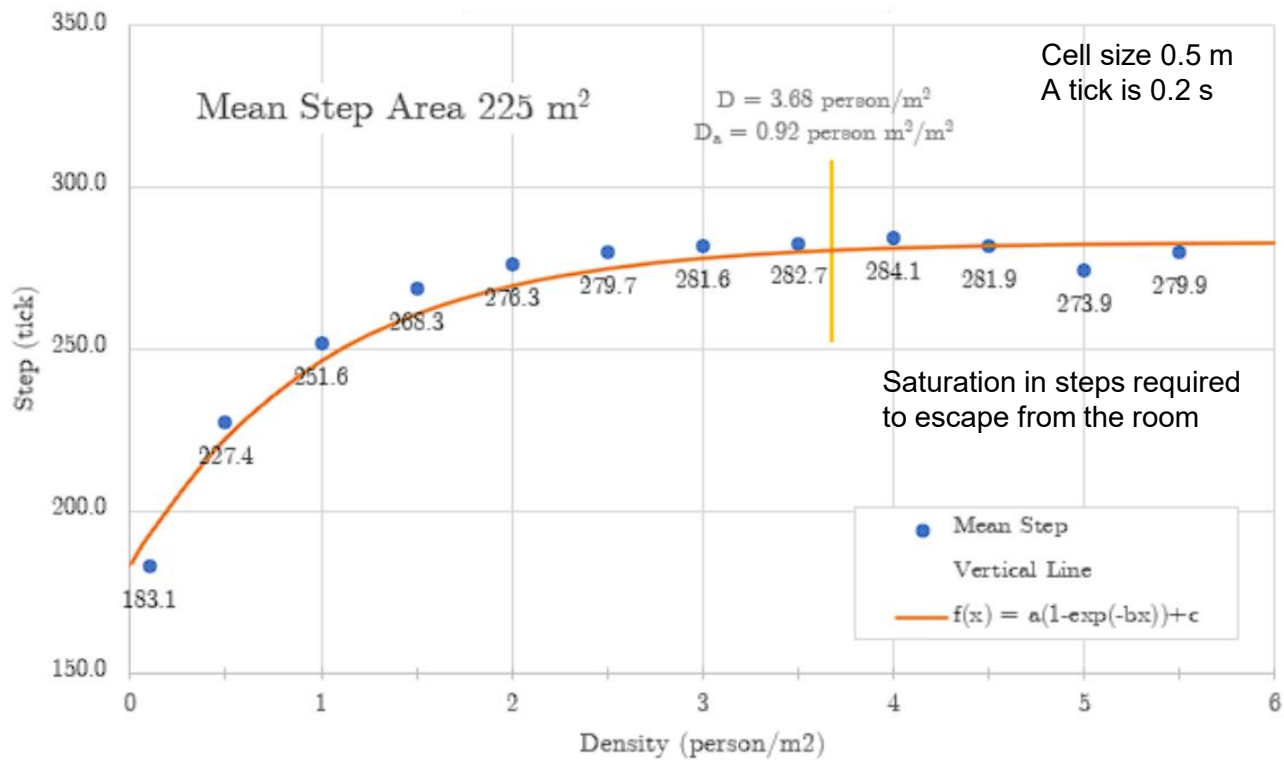
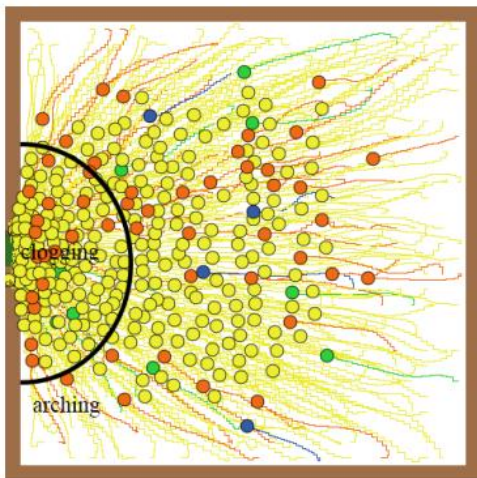
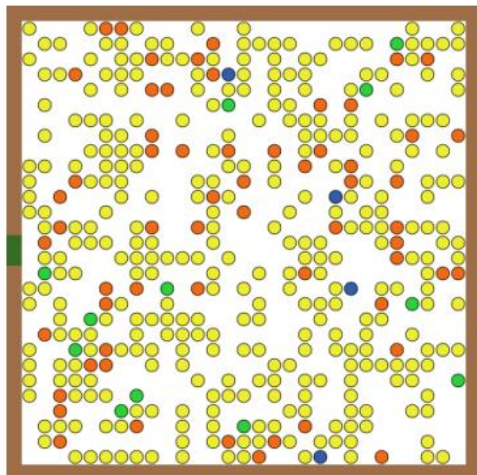
human dynamics

Pedestrian evacuation model

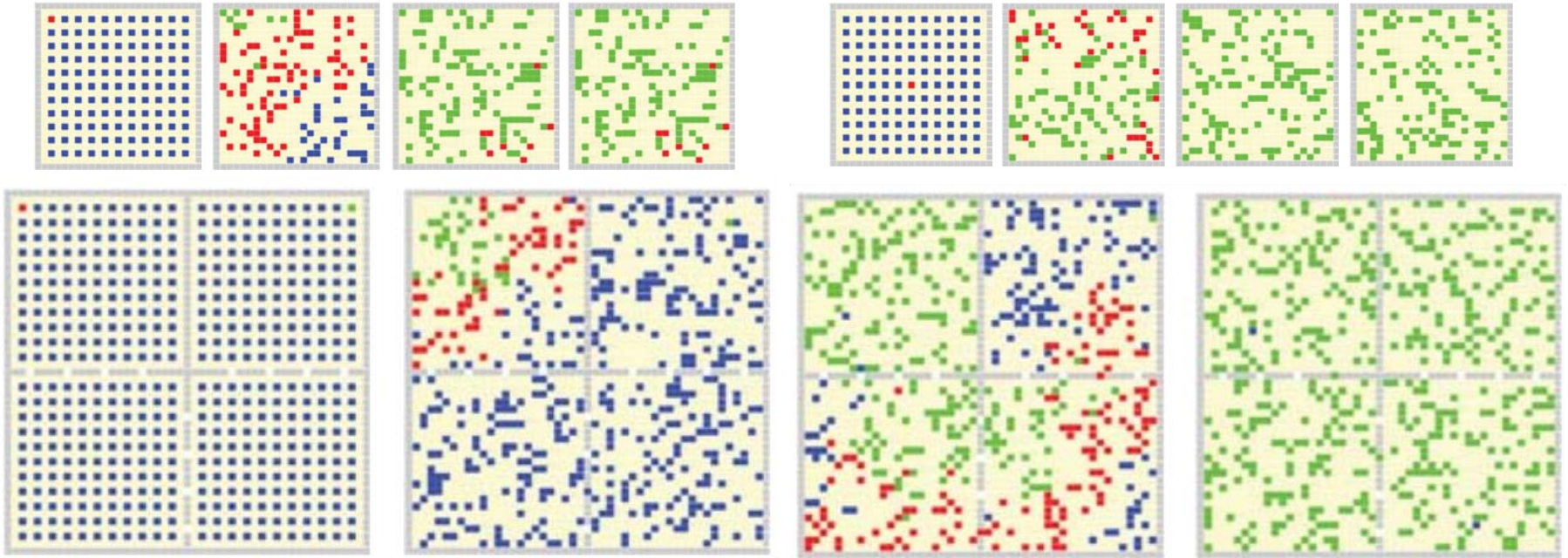


Category	Walking Speed
Child	0.90 ± 0.30
Adult	1.25 ± 0.30
Older Adult	0.8 ± 0.30
People with disabilities	0.79 ± 0.32

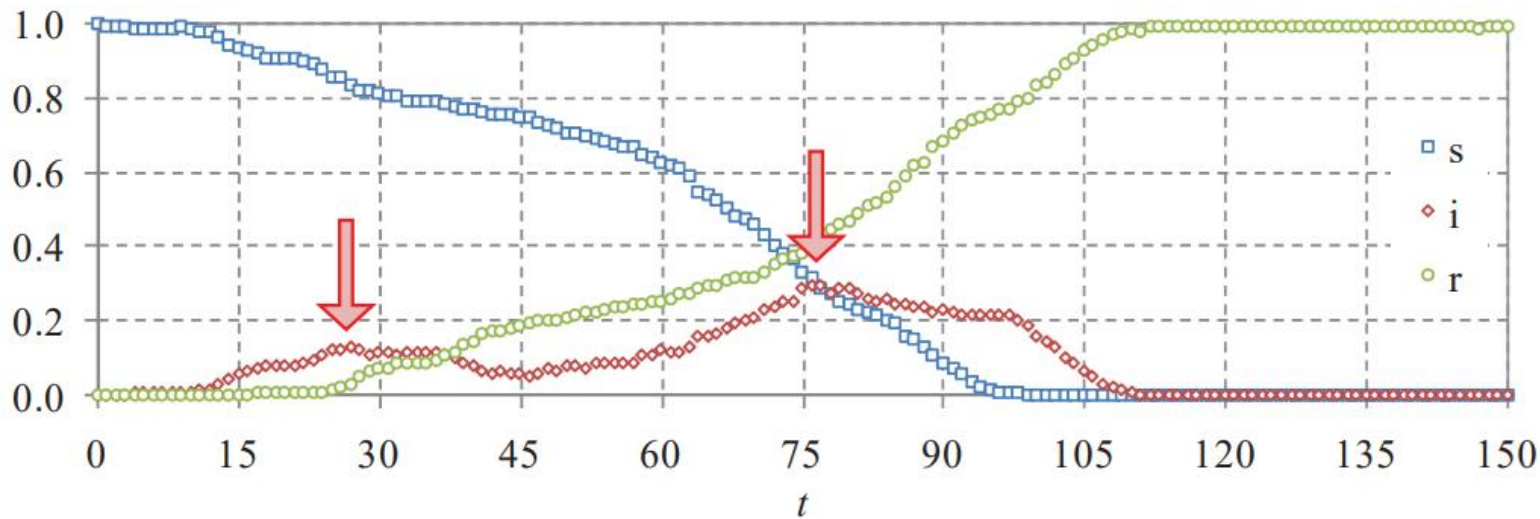
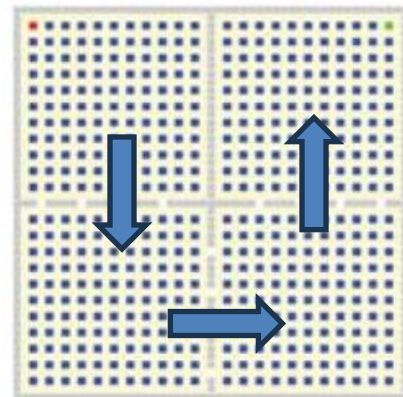
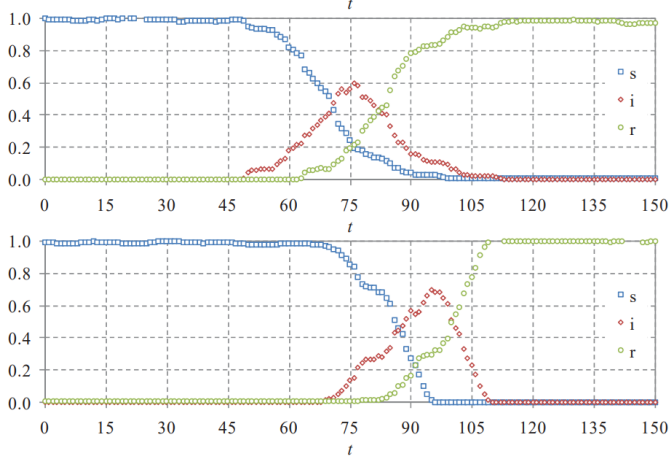
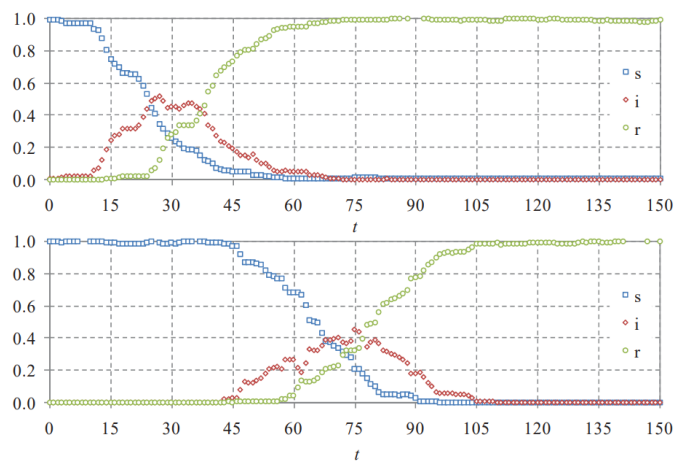
Alya Mutiara Firdausyi, Septian Ulan Dini, Sevi Nurafni, Sparisoma Viridi, "Pedestrian Evacuation Modeling Using Agent-Based Model and Social-Force Model", Journal of Physics: Conference Series, vol 2734, no 1, p 012032, 2024, url <https://doi.org/10.1088/1742-6596/2734/1/012032>.



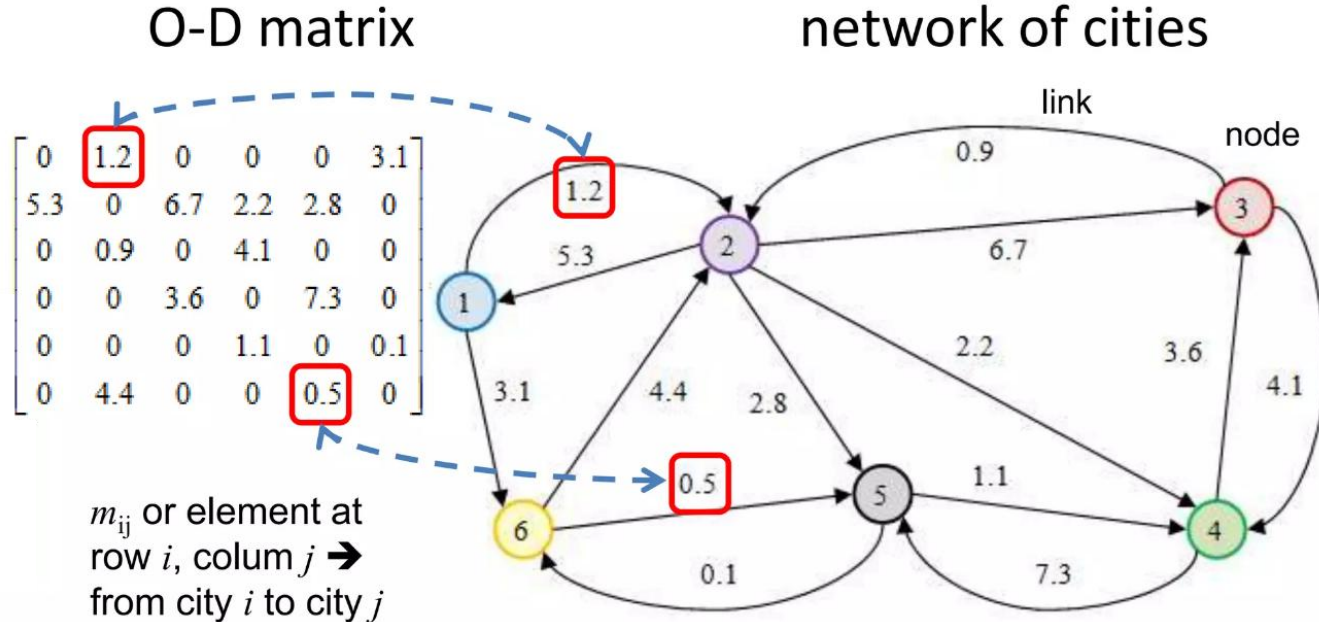
ABM for SIR model



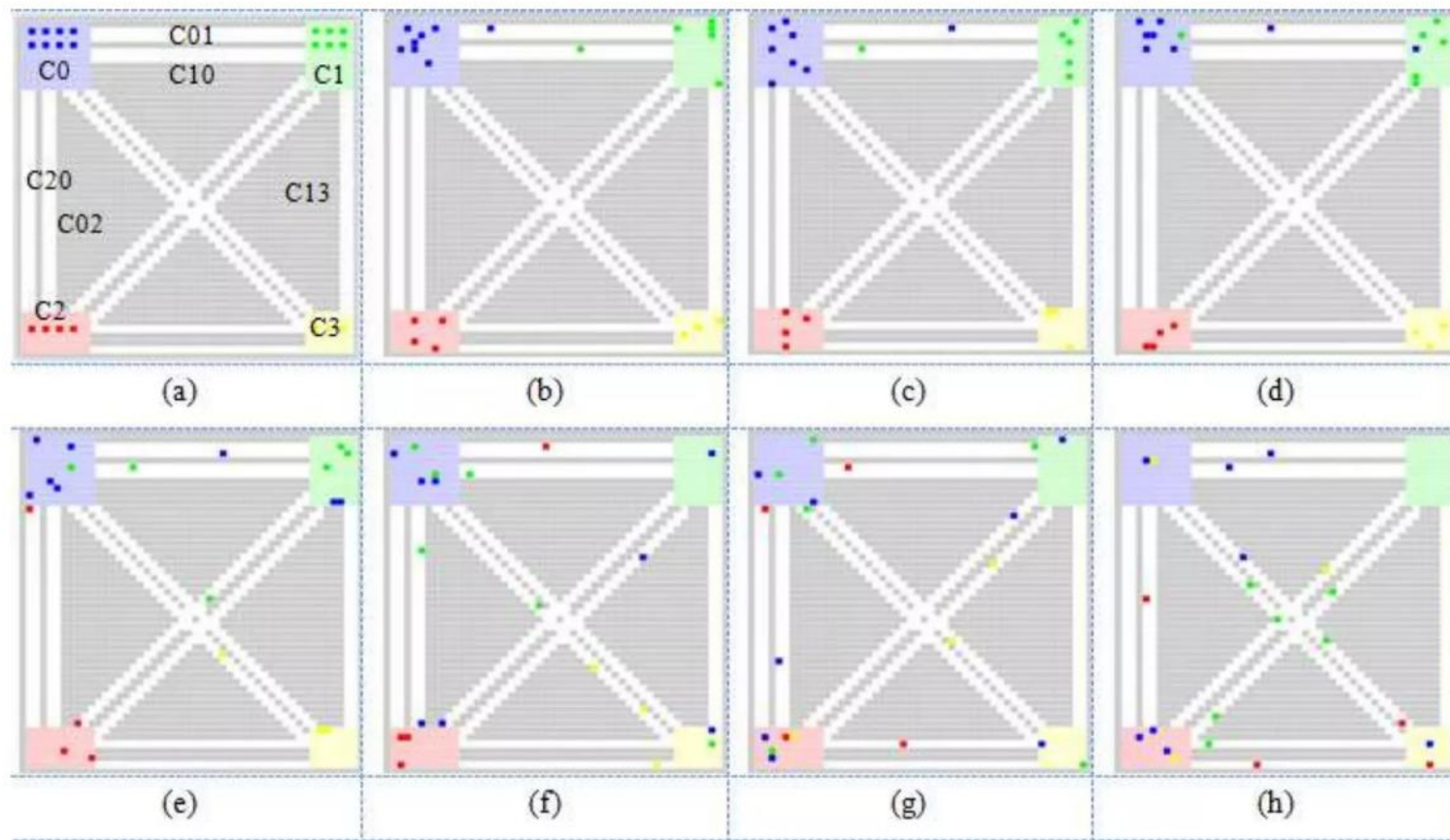
Armi Susandi, Intan Taufik, Pingkan Aditiawati, Sparisoma Viridi, "The relation between agent-based model and susceptible-infected-recovered model for spread of disease", AIP Conference Proceedings, vol 2320, no 1, p 05032, 2021, url <https://doi.org/10.1063/5.0038221>.



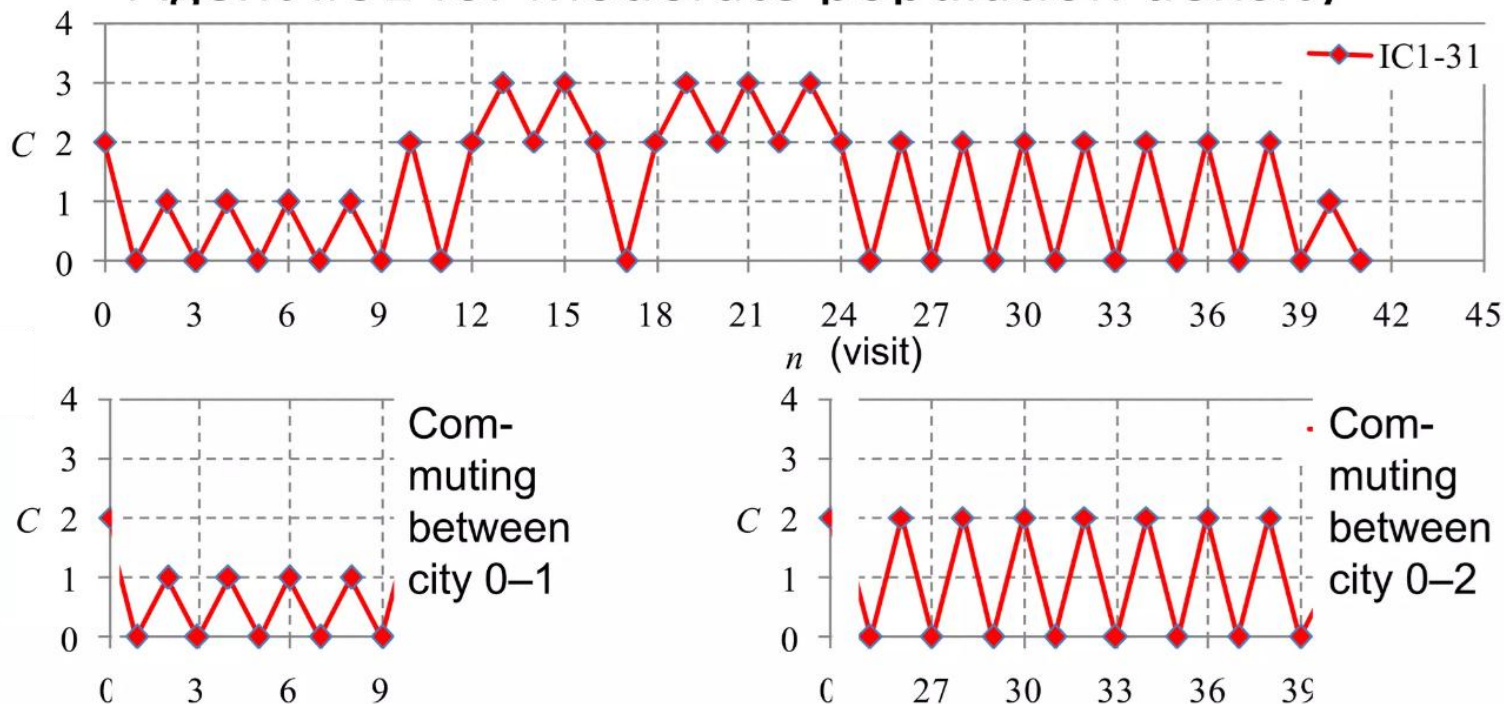
Constructing ODM using ABM



Tatang Suheri, Sparisoma Viridi, "Constructing origin-destination matrix (ODM) using agent-based model (AMB) in multiple points commuting system", AIP Conference Proceedings, vol 050033, no 1, 2021, url <https://doi.org/10.1063/5.0038214>.

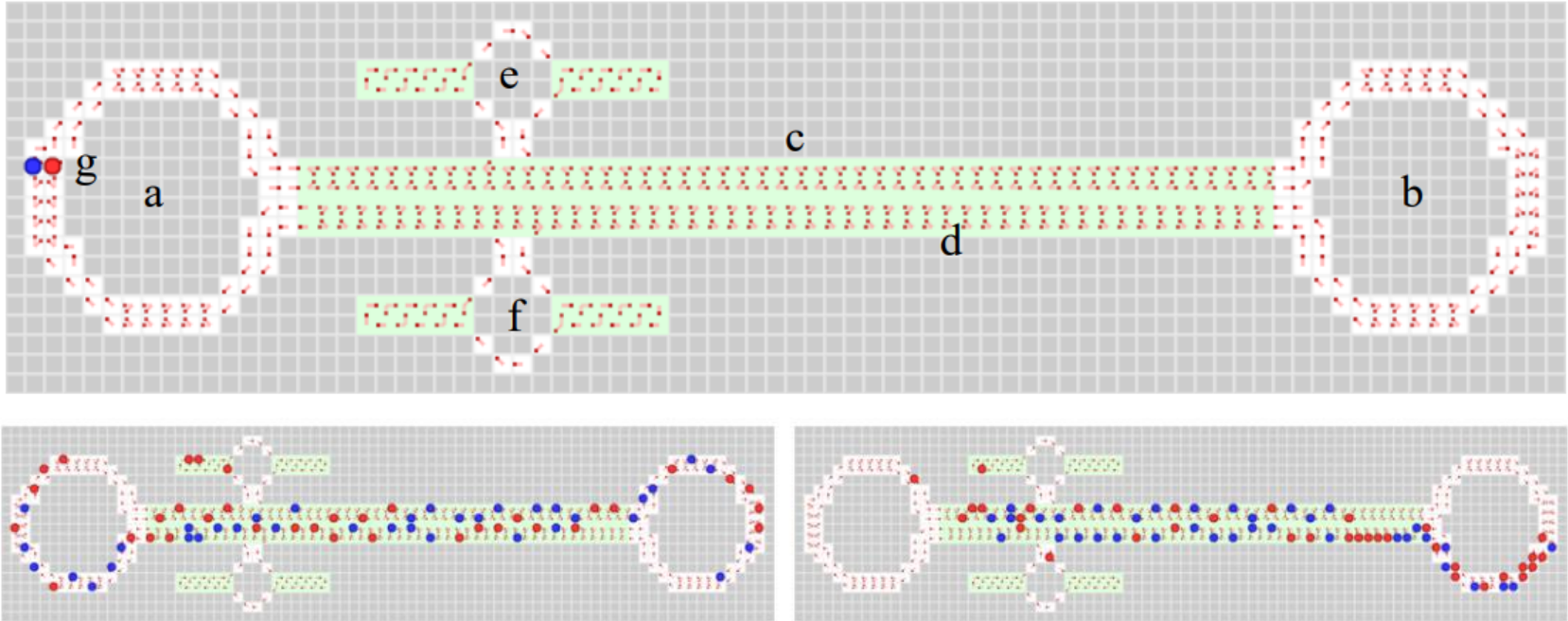


- Agent #31 for moderate population density

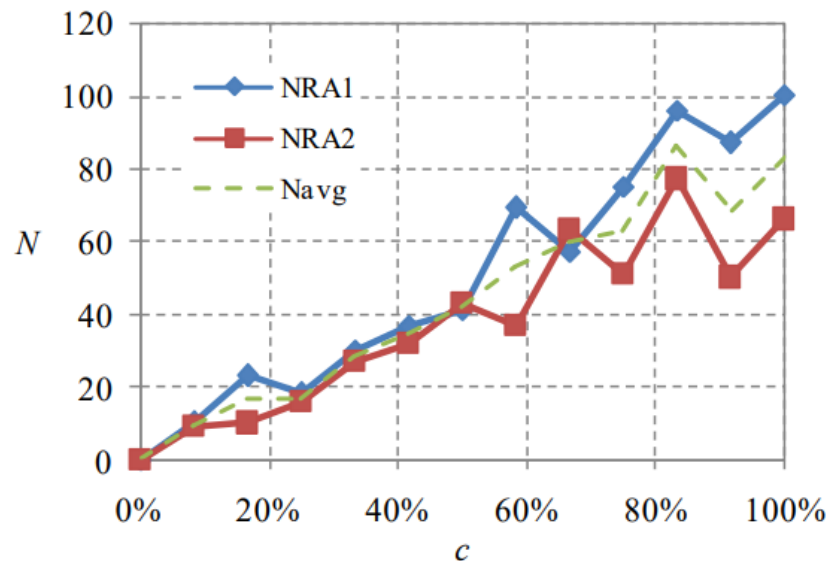
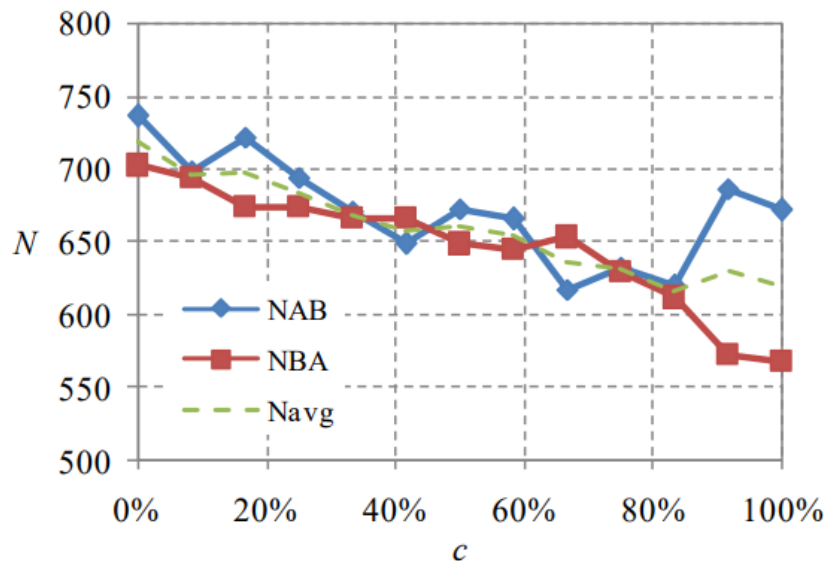


An emergent behavior, which is no programmed

Gravity-driven ABM for economic growth



T. Suheri, S. Viridi, "Gravity-Driven Agent-Based Model for Simulation of Economic Growth a Point Along a Highway", IOP Conference Series: Materials Science and Engineering, vol 662, no 6, 2019, url <https://doi.org/10.1088/1757-899X/662/6/062015>.



Direct from A to B and
from B to A

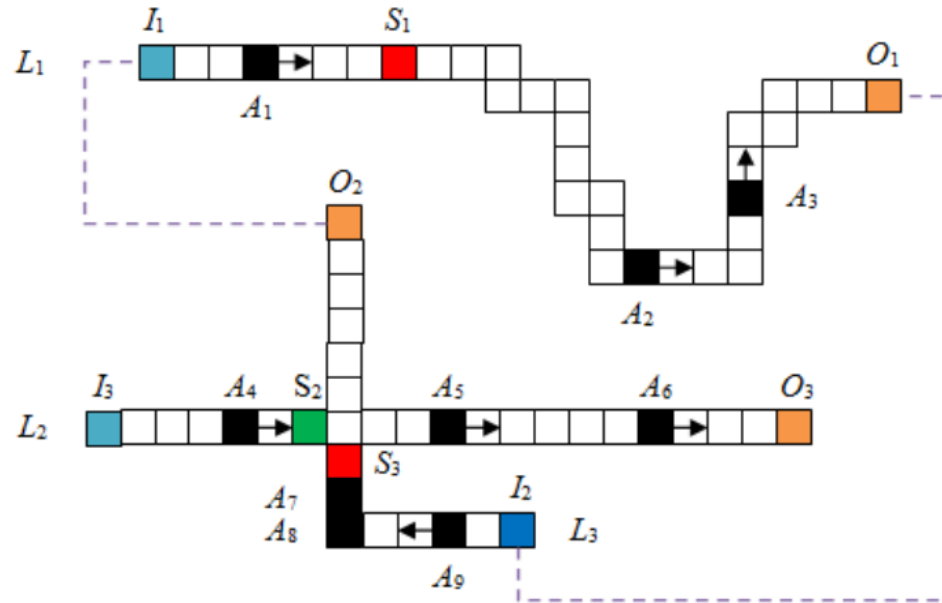
$$c = \frac{N_{\text{red}}}{N_{\text{red}} + N_{\text{blue}}}$$

Red agents need to visit the rest area

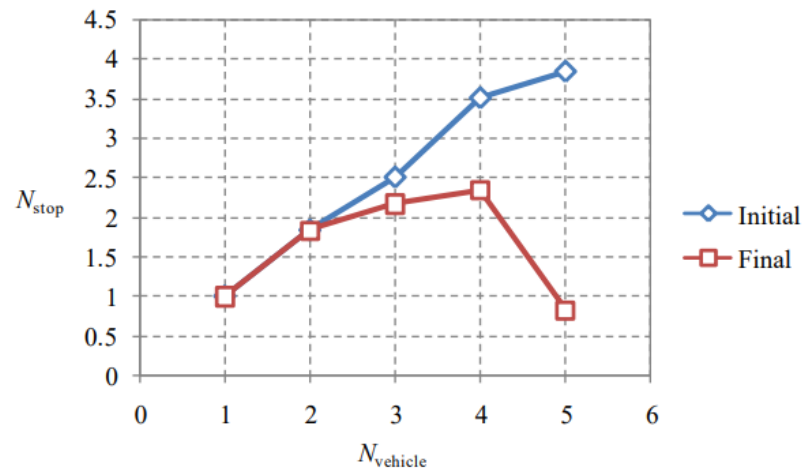
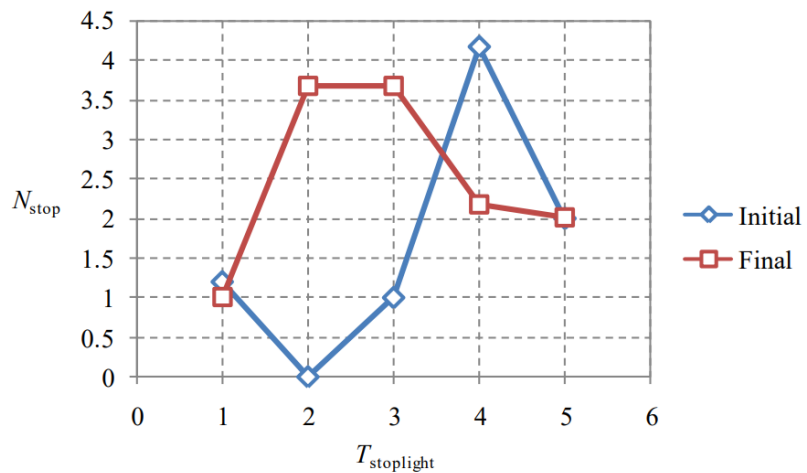
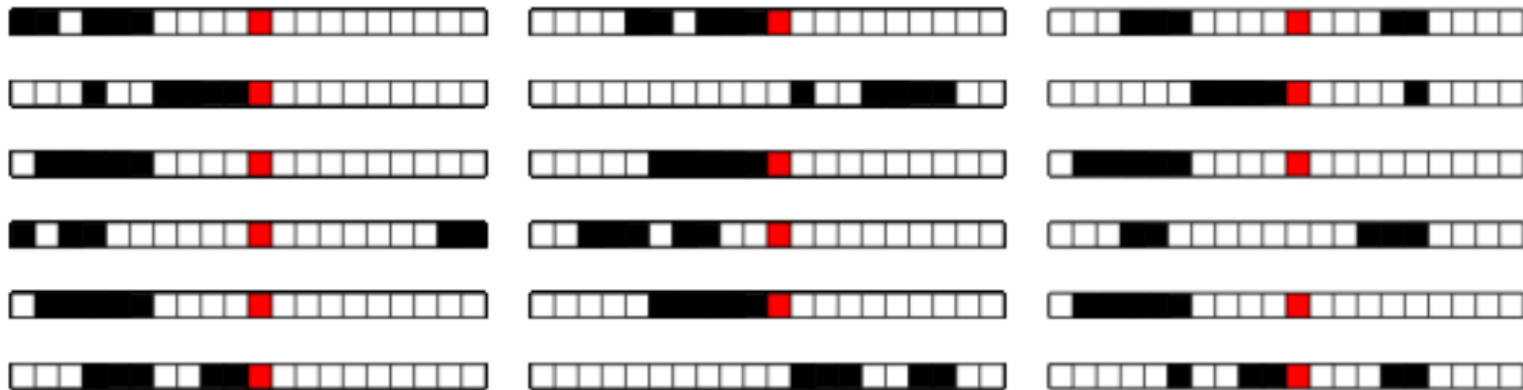
Who visiting the rest area
1 (A to B) and 2 (B to A)

1 nearest > 2 farthest

Traffic flow simulation: Single lane



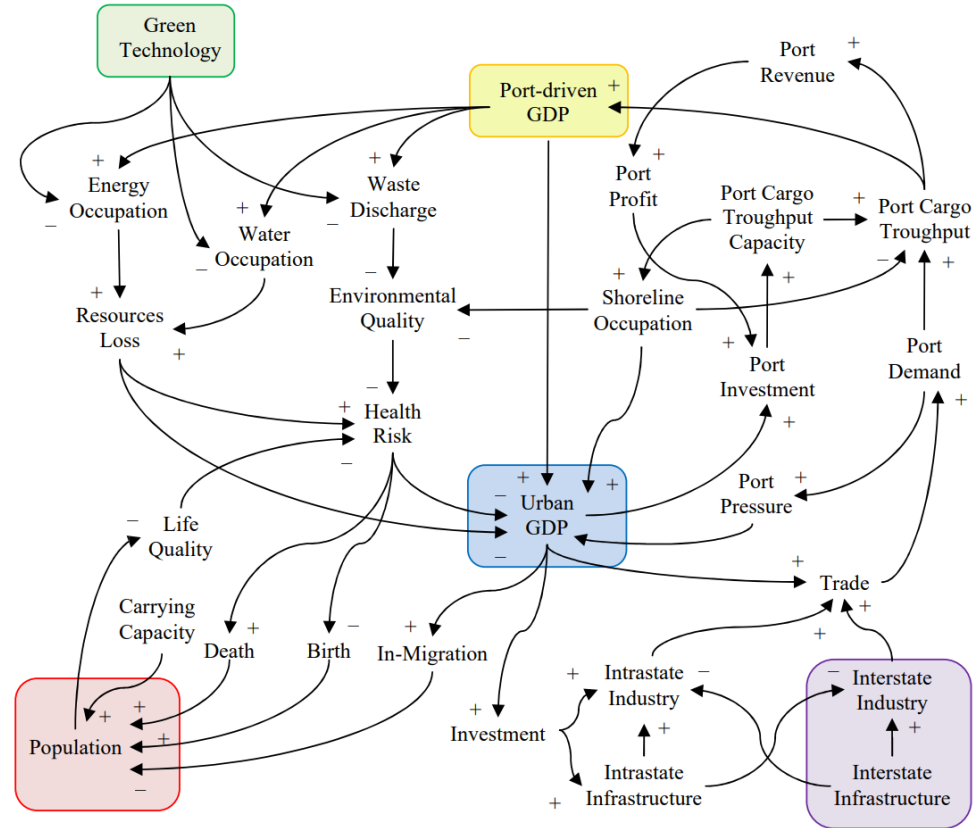
S. Viridi, M. Dwitasari, M. Takaendengan, K. N. Sari, U. S. Pasaribu, "Traffic flow simulation using agent-based model: A case of single lane with multiple traffic lights and input-output node", Journal of Physics: Conference Series, vol 1245, no 1, p 012011, url <https://doi.org/10.1088/1742-6596/1245/1/012011>.





other

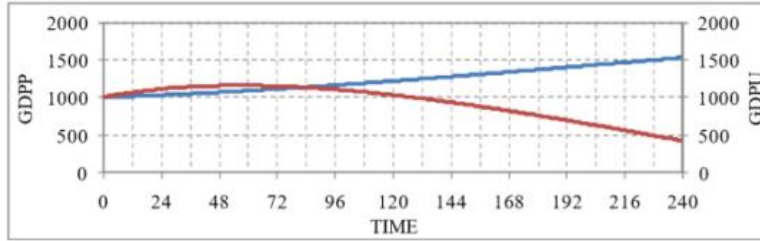
1000 JOURNAL OF CLIMATE



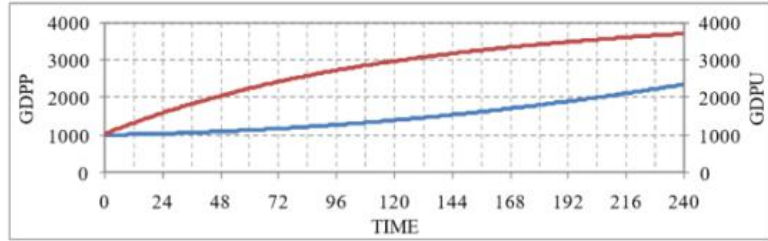
Tatang Suheri, Mohammad Benny Alexandri, Sam'un Jaja Raharja, Margo Purnomo, Sparisoma Viridi, "Interaction between Marine Sectors using System Dynamics for Patimban Deep Sea Port as a Green Port: A Proposed Model", IOP Conference Series: Earth and Environmental Science, vol 799, no 1, p 012021, url <https://doi.org/10.1088/1755-1315/799/1/012021>.

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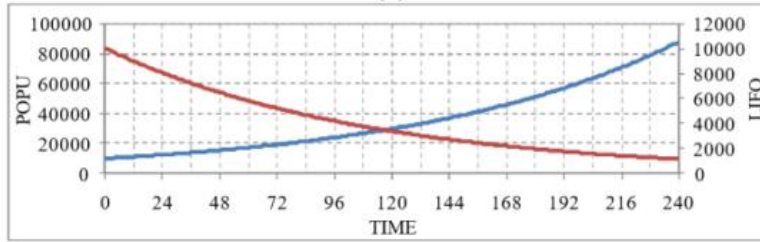
No green vs green



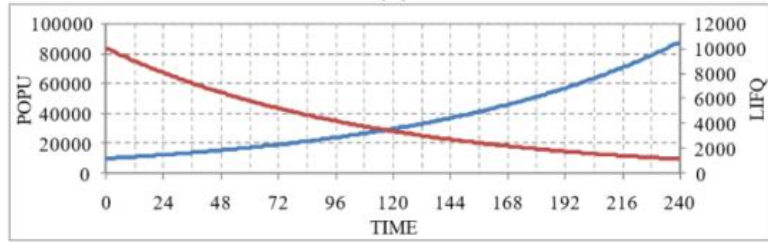
(a)



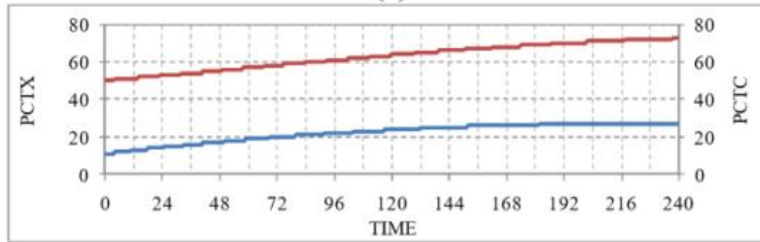
(b)



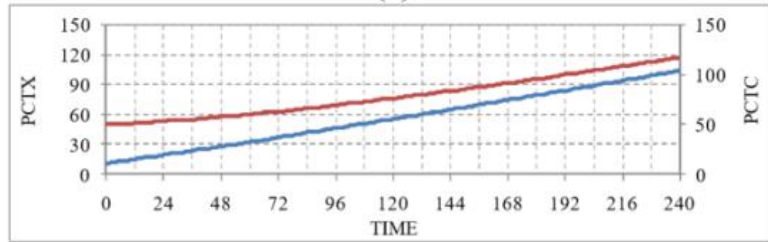
(c)



(d)



(e)



(f)

GDPP for Port-driven GDP, GDPU for Urban GDP
 POPU for Urban Population, LIFQ for Life Quality
 PCTX for Port Cargo Throughput, PCTC for Port Cargo Throughput Capacity

2025-06-20

closing

Summaries

- Previous works related to agent-based model (ABM), system dynamics (SD), and boids have been presented.
- They can be used to simulate various systems, from physical, biological to social system and measuring policy.

Sustainable development goals (SDG)

- These diverse studies illustrate ABM's role in modelling interactions across scales—from microscopic to societal.
- They also align with key Sustainable Development Goals (SDGs): SDG 2 (sustainable agriculture), SDG 3 (health), SDG 4 (education), SDG 9 (infrastructure), SDG 11 (sustainable cities), and SDG 14 (life below water).
- The integration of ABM with SD supports a multi-method understanding of sustainability challenges.

Discussion

- Any comments?
- Suggestions?
- Ideas for collaboration?



Thank you