An Epidemiological Model By Membrane Systems

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(Davide's master thesis work)

Project Overview and Objectives

Goal:

- Create an epidemiological model based on P Systems starting from previous LOIMOS work [1].

Features:

- Implementing spatiality and behavioral dynamics in an epidemiological model.

[1] Fernando Baquero, Marcelino Campos, Carlos Gil Llorens, and Jos´e M. Sempere. P systems in the time of covid-19. Journal of Membrane Computing, 3:246 – 257, 2021.

New Implementations

Human Movement

- Human mobility to be represented, for esample as a random motion where the displacement of particles is not linear: more ``rapid'' than expected.

Space and Time

- Hourly infections considering the context (space and time).

Population Dynamics

- Population behavior aligns with information spread in model.

Human Movement

Humans are represented as objects with different age ranges.

Their movement is described through rewriting rules.

Their behavior is based on the epidemiological context of the destination.

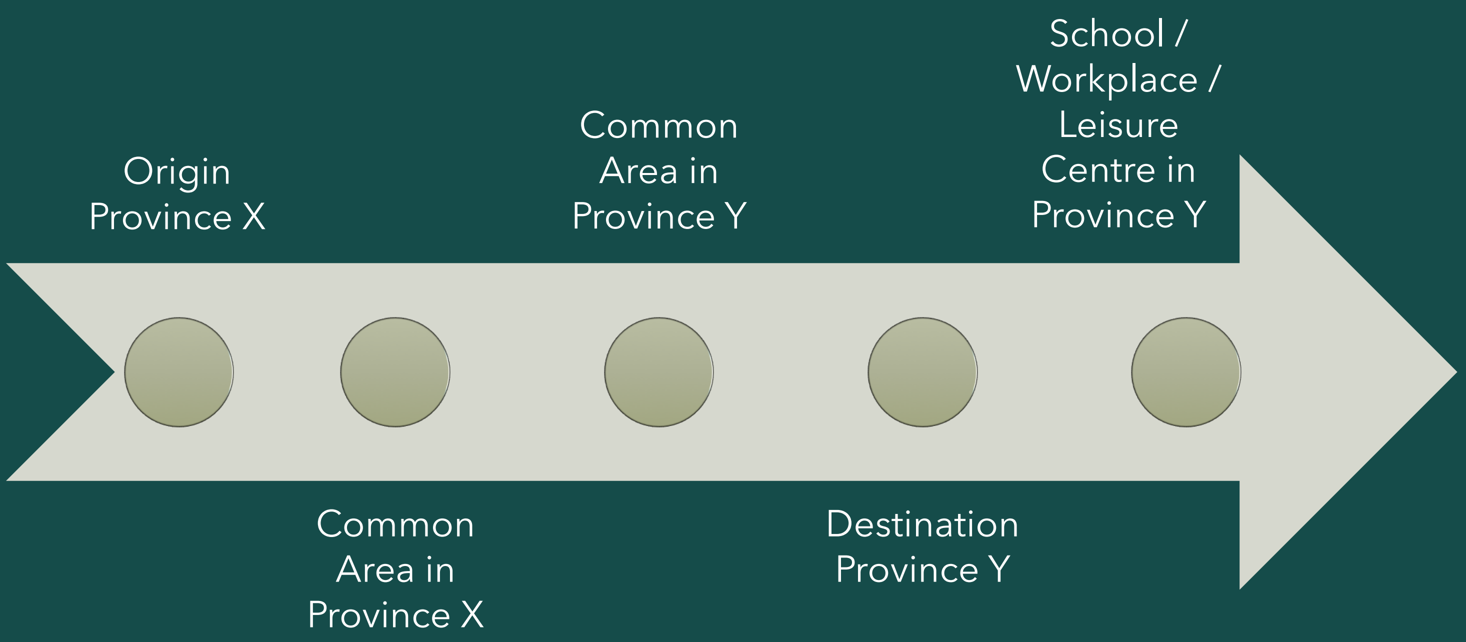
Probabilistic rules, no priority

$$R_X+ = \{R_{X,Y} : g_{X,Y}\ Hour_i\ day_j \xrightarrow{1-(\phi_Y/npopulation_Y)} (g_{X,Y}\ Hour_i\ day_j, in_Y)\} \text{ where } Y \in H_P \backslash \{X\} \text{ and } X \neq Y$$

- R_X set of rules for province X.
- $R_{X,Y}$ movement rule with origin X and destination Y.
- H_P set of all provinces.
- $g_{X,Y}$ young individual (living in province X and travelling to province Y).
- $Hour_i\ d_j$: Time i and day j, with i and j in given ranges.
- Φ_Y total confirmed cases in Y.
- $npopulation_Y$ total population of the Y province.
- $1 - \frac{\Phi_Y}{npopulation_Y}$ is the probability of traveling to the province Y.

Path Towards Destination

- Young individuals move between Provinces X and Y based on destination's epidemiological context.



To move from one province to another one crosses two provinces, two common areas (one for each province, internal to these) and a final Place Membrane. 2 Province Membranes and 3 Place Membranes to reach a location into another province.

Infections Linked to Space and Time

01

Different age groups, different infection probabilities.

02

Rules simulate infection dynamics in places.

03

More contagious people mean more infections.

04

More cases of infection mean more awareness and fewer new infections.

Infection and Evolution of Infection

Healthy

A susceptible individual who can get infected

Incubation

Incubation period for the virus.

Infected

Can transmit the disease.

Recovered

Individual has overcome disease.

$$a_j \; a_kI \; Hour_i \; d_l \; \phi \xrightarrow{0.02\ (\phi/nwork)\ \psi(M)} a_jIinc \; a_kI \; Hour_i \; d_l \; \phi+1$$

- a_j: $j-th$ healthy adult individual.
- a_kI: $k-th$ infected adult individual.
- $Hour_i$: Time I of the day.
- d_l: Day j of the week.
- $0.02\ \left(\frac{\phi}{nwork}\right)\psi(M)$ is the infection probability: product of infectivity rate, infection-to-contagiousness ratio, and information function ψ.
- a_jIinc: Resulting infected adult individual (incubation).
- $\phi+1$: Infections count update.

Population Dynamics and Dynamical Behaviors

Behavior is influenced by model's information spread.

Vaccination crucial for infection reduction; decisions influenced by awareness.

Infection awareness proportional to number of cases.

Young Healthy Individual

Random Probability of getting vaccinated

Funcion f measures the `Willingness to get a vaccine'' Increasing and non-negative. x represents information in the model.

Young Vaccinated Individual

$$g_j \xrightarrow{P(v)\ f(x)} g_j V$$

Conclusion

- **Features of this membrane model**

  - **Integration of behavioral dynamics into an epidemiological framework**, revealing how human behavior shapes the disease spread.

  - **Incorporation of spatial and temporal factors** to offer insights for targeted interventions based on the context.

Open Questions

How the integration of behavioral dynamics can be further refined?

What are the (not implemented) spatial and temporal factors that most influence the scenario? (Such as seasonal changes)

Other aspects to be addressed for greater accuracy in infection awareness?

Finding main limitations of the model and their possible impovements