

Case study: an epidemiological model

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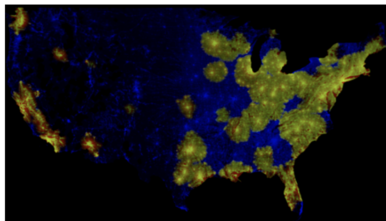
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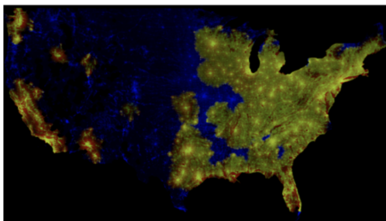
June 24, 2019



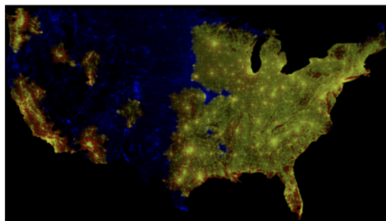
(c) 1 Week



(d) 2 Weeks



(e) 3 Weeks

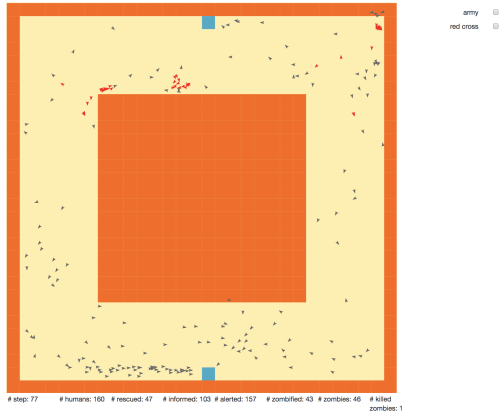
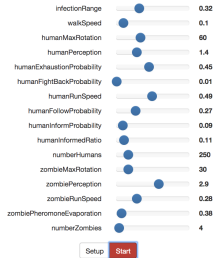


(f) 4 Weeks

Simulation of the 2010 Zombie outbreak in the US [Alemi et al., 2015]

- ▶ 2007: first outbreak in Iceland, relatively contained through ad-hoc measures
- ▶ 2010: it becomes pandemic
- ▶ 2010-2015: no clear records of events
- ▶ 2015-2018: reorganization of institutions, the MOLE (Medical Overview of Ludicrous Experiments) center in Chongqing gathers observational data from many local invasions across the world
- ▶ 2019: they released the first version of the model ZOMBIE (Zone of Optimal Management for Bacillus Infecting Everyone) and successfully applied

An operational model for local Zombie invasion



Local scale agent-based model

- ▶ A submodel is available at <https://om.exmodelo.org/coop>.
Try the GUI and changing parameters
- ▶ Most of next courses will be based on that model (additional processes will be detailed when needed)

- ▶ Simulate agent-level collective movements at the scale of a district
- ▶ Include behavioral processes for human (panic, search for rescues, ...) and zombies (self-organization, spontaneous attacks, ...), which can be adapted to local settings
- ▶ Include realistic pedestrian dynamics and realistic spatial configuration, which can be applied to local configuration

Objective of the model: better understand the Zombie invasion process; possible applications to optimal policies and behavioral prevention to minimize the impact of recurring invasions

Issue with model application: model has many parameters and processes, model behavior is unknown, application may be strongly case-dependent

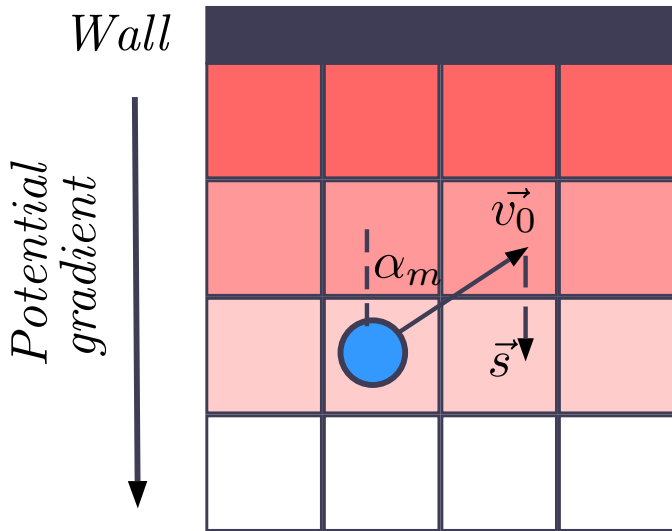
→ we need **YOU** to understand this model to save the world

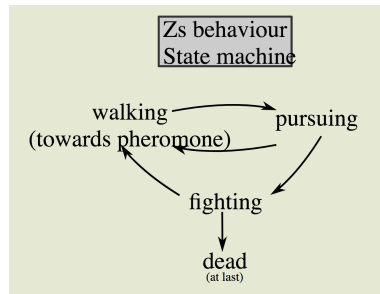
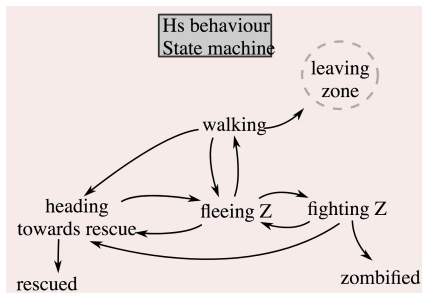
- ▶ Humans and Zombies walk/run randomly (smoothed random walk) in an open urban space (movement parameters: rotation angle, walk and run speed)
- ▶ Interactions: human flee from zombie, zombies run for food, fight when encounter
- ▶ Humans can be rescued and information on the existence of rescues propagates between humans
- ▶ Additional processes in a multi-modeling approach (army, vaccination, ...)

Multiple approaches to pedestrian simulations:

- ▶ Social force models [Helbing and Molnar, 1995]
- ▶ Granular flows [Cristiani et al., 2011]
- ▶ Behavioral models [Antonini et al., 2006]
- ▶ Cellular automata [Burstedde et al., 2001]
- ▶ Potential field [Jian et al., 2014]

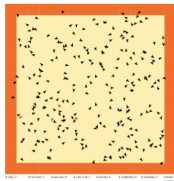
The ZOMBIE model takes the last approach, relatively realistic in a panic setting



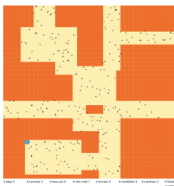


- ▶ Some spots allows informed humans to be rescued and get out of the world
- ▶ An initial ratio of humans `humanInformRatio` is informed of the existence of rescues
- ▶ Informed humans which are not in a panicking state follow a specific potential field leading to rescues
- ▶ A human can inform an other one at the same location with a probability `humanInformProbability`

With the additional parameter `humanFollowProbability` (probability for a human to begin running and follow when they encounter an other running human), the submodel with three parameters is aimed at studying cooperation between humans.



quarantine:
no rescue zones.
You'd better run.



jaude:
one rescue zone
of width 1

*Alternative worlds ... and many more automatically generated
(spatial sensitivity module on Wednesday)*

- ▶ The general model, of which the three-parameter model is a particular case has more processes (deactivated or fixed)
- ▶ No need to know them for now, with the aim to understand the submodel on which we have the less knowledge
- ▶ Multi-modeling and model embedding (model as black box)

- ▶ Model implemented in scala (highly performant language mixing the best from functional programming and object programming)
- ▶ Simple GUI for interactive exploration
- ▶ Integrated into OpenMOLE as a jar plugin in the GUI

Scala syntax to run an execution of the model

```
import zombies._

val rng = new scala.util.Random(replication)

val result = zombieInvasion(
  humanFollowProbability = humanFollowProbability,
  humanInformedRatio = humanInformedRatio,
  humanInformProbability = humanInformProbability,
  zombies = 4,
  humans = 250,
  steps = 500,
  random = rng
)

val humansDynamic = result.humansDynamic(20)
val zombiesDynamic = result.zombiesDynamic(20)
```



Alemi, A. A., Bierbaum, M., Myers, C. R., and Sethna, J. P. (2015).

You can run, you can hide: The epidemiology and statistical mechanics of zombies.

Physical Review E, 92(5):052801.



Antonini, G., Bierlaire, M., and Weber, M. (2006).

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Burstedde, C., Klauck, K., Schadschneider, A., and Zittartz, J. (2001).

Simulation of pedestrian dynamics using a two-dimensional cellular automaton.

Physica A: Statistical Mechanics and its Applications, 295(3-4):507–525.

-  Cristiani, E., Piccoli, B., and Tosin, A. (2011).
Multiscale modeling of granular flows with application to crowd dynamics.
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-  Helbing, D. and Molnar, P. (1995).
Social force model for pedestrian dynamics.
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-  Jian, X.-X., Wong, S., Zhang, P., Choi, K., Li, H., and Zhang, X. (2014).
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