Case study: an epidemiological model

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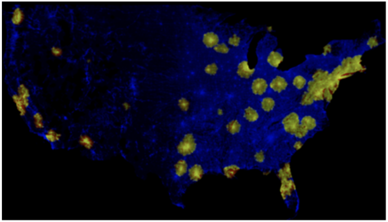
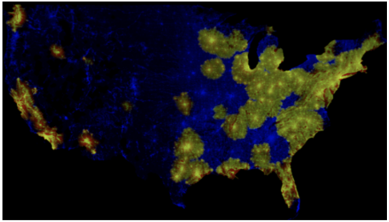
June 24, 2019

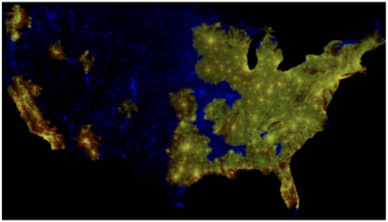
Decision making in a chaotic world



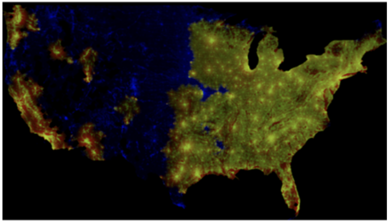
(c) 1 Week



(d) 2 Weeks



(e) 3 Weeks



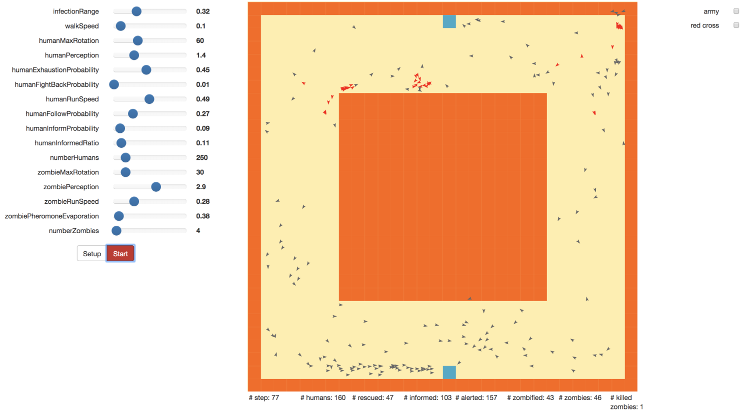
(f) 4 Weeks

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

History of Zombie epidemiology

- 2007: first outbreak in Island, 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 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

Let's get your hands on it

OpenMOLE

- 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)

Overview of the model

OpenMOLE

- 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: 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

$\rightarrow$ *we need YOU to understand this model to save the world*

Basic processes and parameters

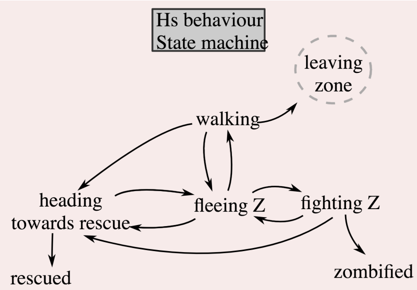
- Humans and Zombies walk/run randomly (smoothed random walk) in an open urban space (movement parameters: rotation angle, walk and run speed)
- Interactions: human flee from zombie, zombies run for food, fight when encounter
- Humans can be rescued and information on the existence of rescues propagates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

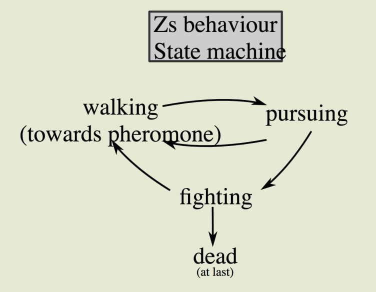
Multiple approaches to pedestrian simulations:

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

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

Agents state machines





Information and rescues

- 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.

A flexible and more general model

The model in practice

The scala model

OpenMOLE

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)

```
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)
```

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