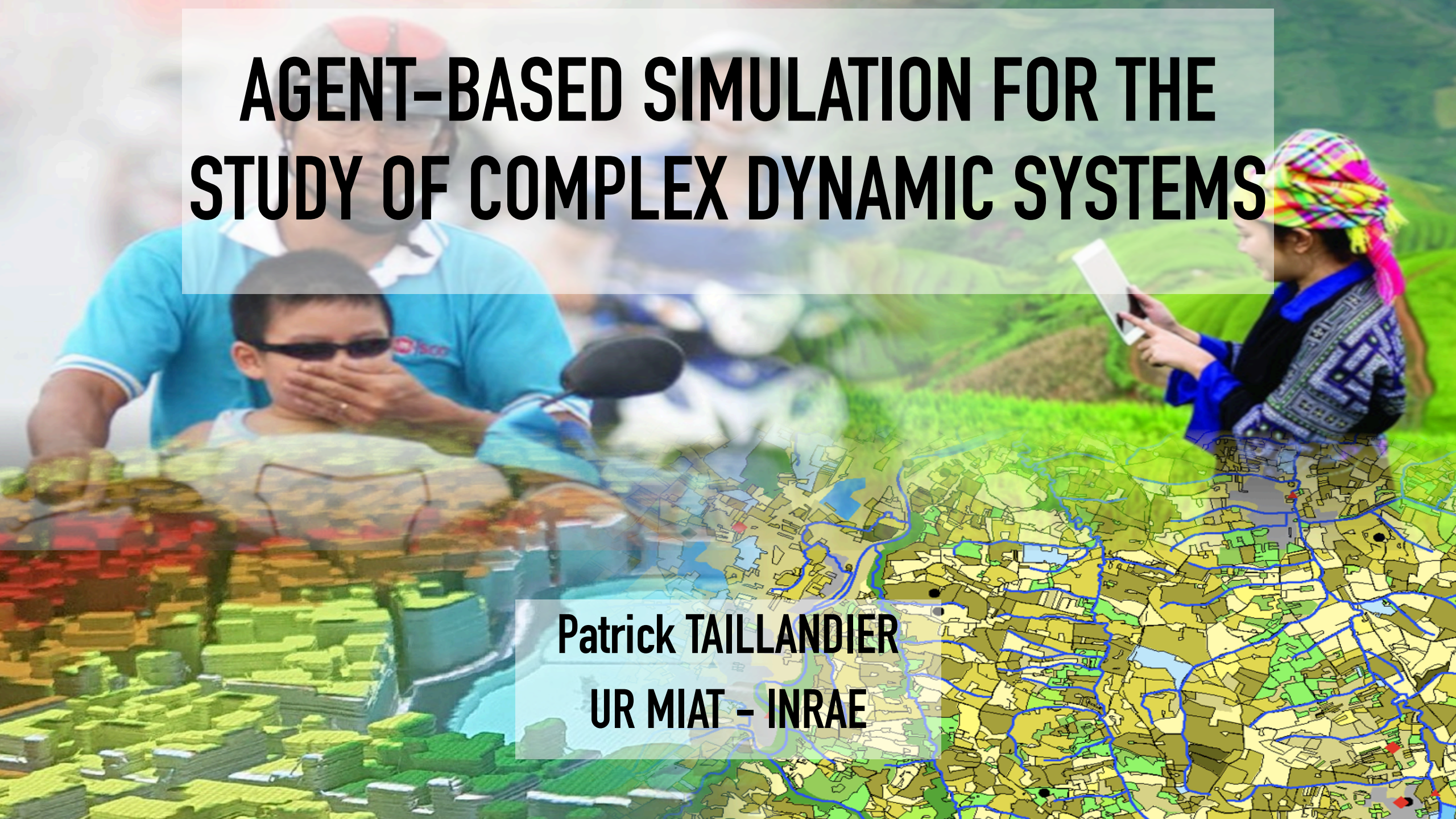
AGENT-BASED SIMULATION FOR THE STUDY OF COMPLEX DYNAMIC SYSTEMS



Patrick TAILLANDIER

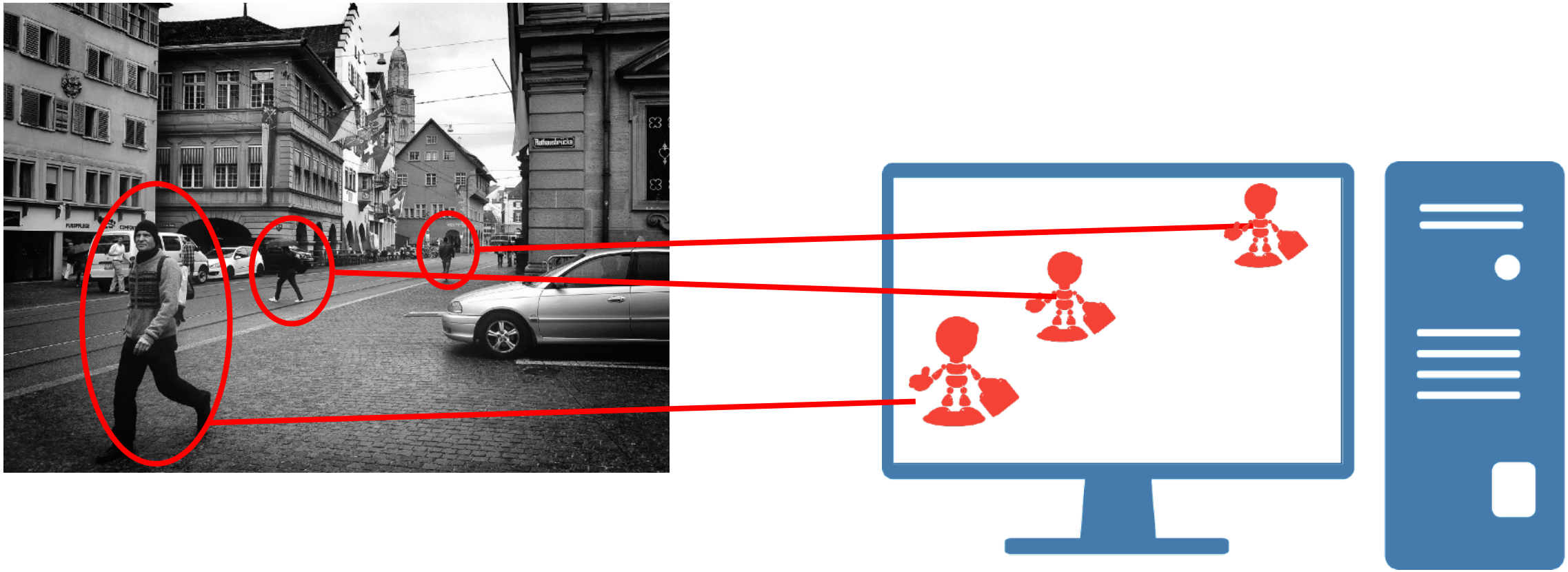
UR MIAT - INRAE

SHORT BIOGRAPHY

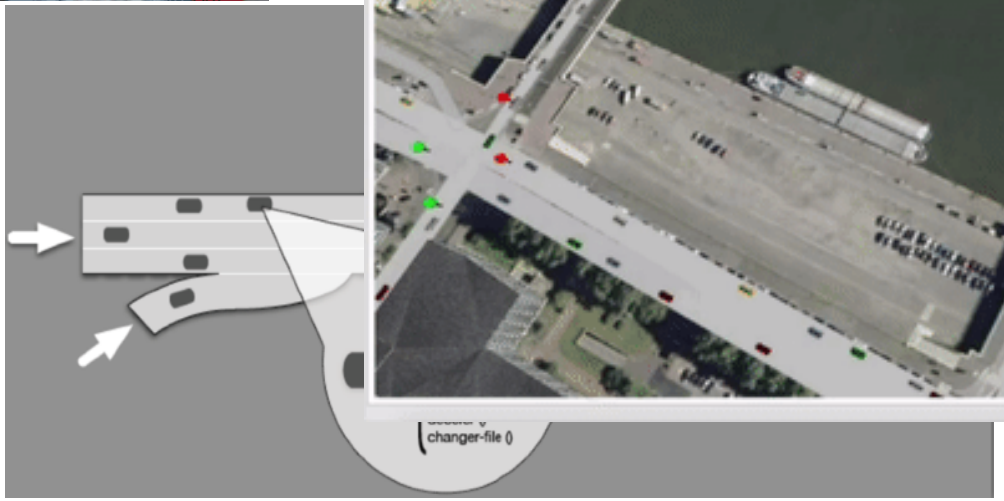
- ✓ Senior researcher in computer science at INRAE (MIAT unit – Toulouse)
- ✓ Between 2011 and 2016: Lecturer in Geography at the University of Rouen (UMR IDEES)
- ✓ Invited researcher at IRD in Vietnam for 4 years (2020–2024)
- ✓ General research topic: computer simulation (agent-based simulation)
- ✓ Fields of application: agriculture, risk management, epidemiology, transportation, environment…

Agent-based simulation

AGENT-BASED SIMULATION



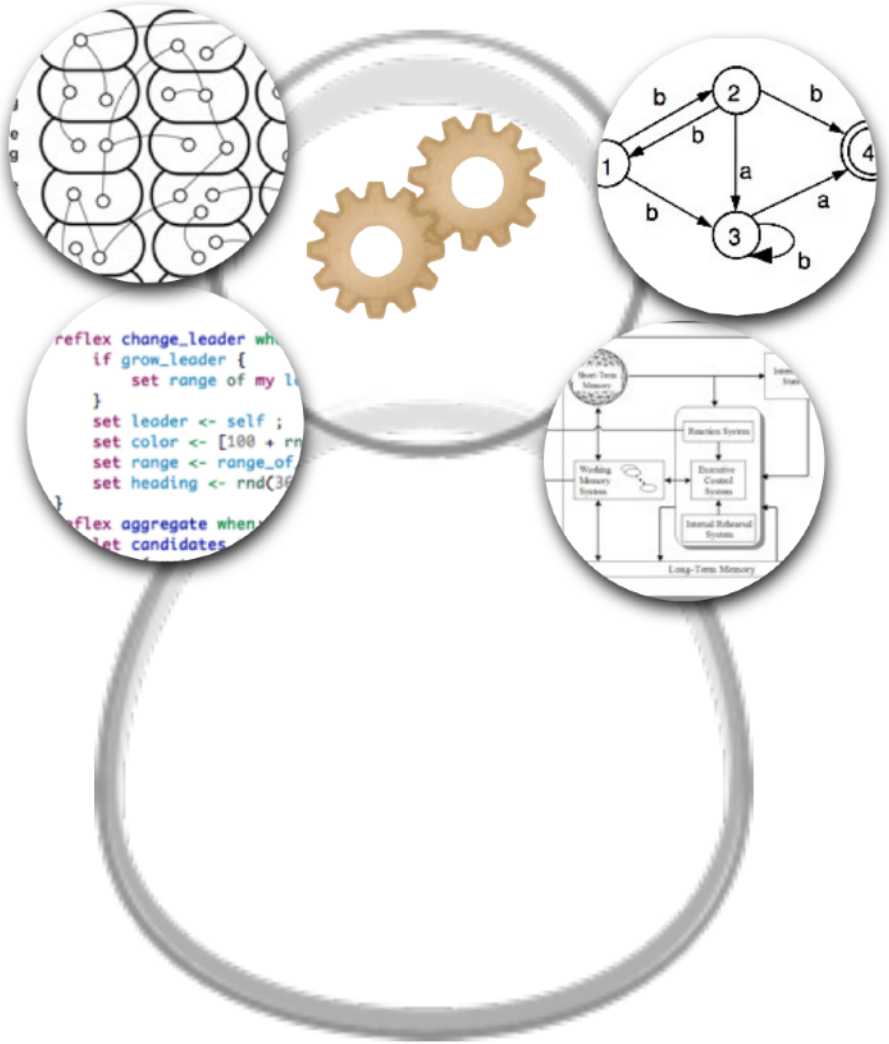
AGENT-BASED SIMULATION



AGENT-BASED SIMULATION: AGENTS

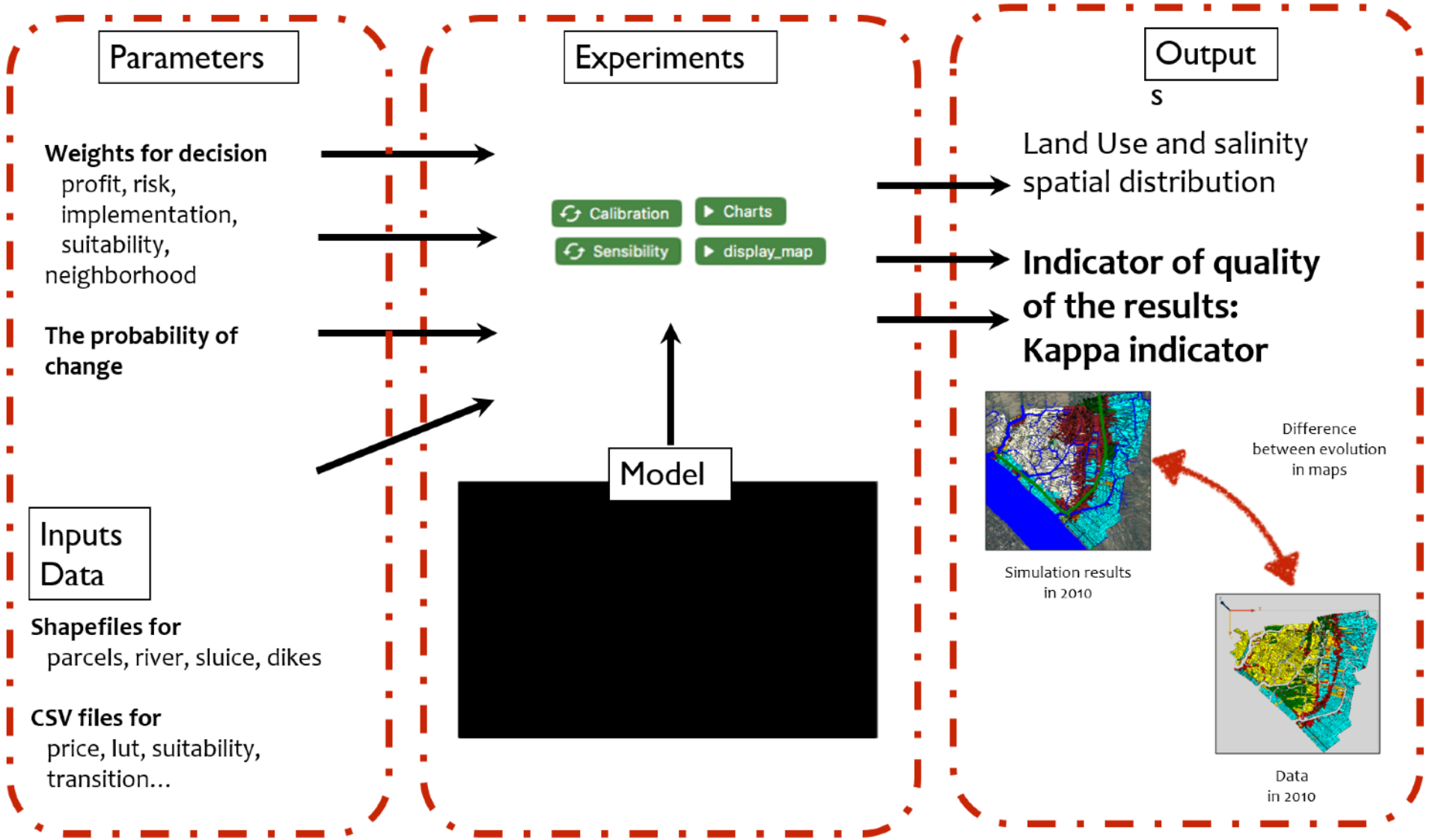
SimPop model
http://www.simpop.parisgeo.cnrs.fr/

AGENT-BASED SIMULATION: AGENTS



- Any programming language
- Expert systems
- Finite state automata
- Task-based architectures
- Perception-decision-action architectures
- Planning architectures
- Neural networks
- Bayesian networks...

CLASSIC USE OF ABM

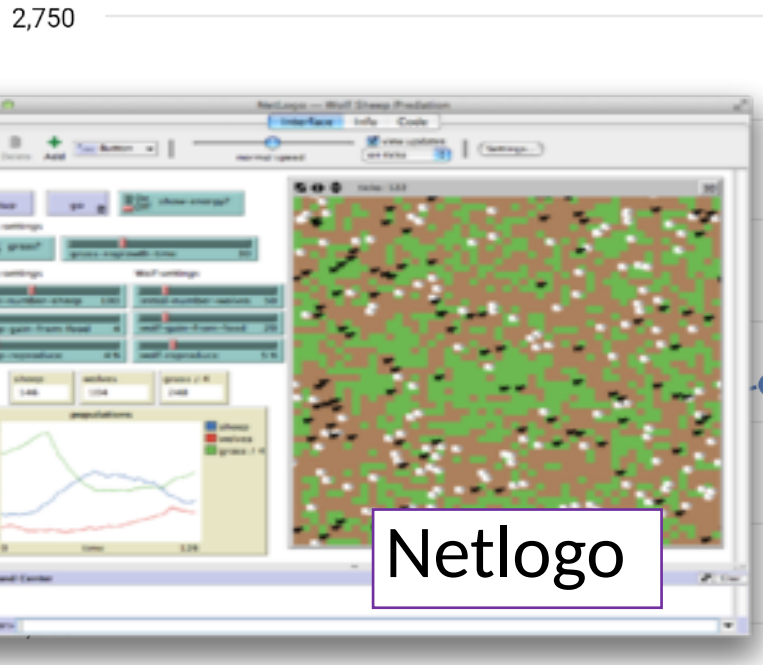


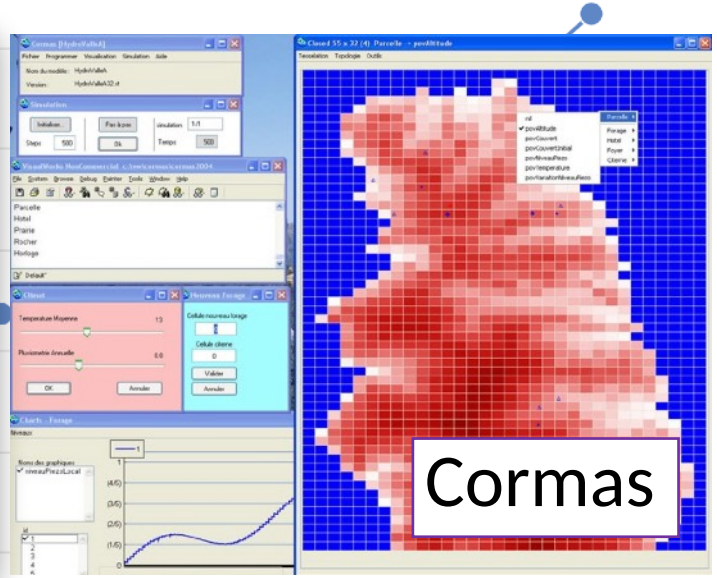
PARTICIPATORY SIMULATION

PARTICIPATORY SIMULATION

AGENT-BASED SIMULATION PLATFORMS

With « Agent-based simulation » in the title





2,750

1,000

2010 2011 2012 2013 2014 2015 2016 2017 2018

Publications (total)

https://app.dimensions.ai/analytics

GAMA WAS CREATED IN 2007 IN VIETNAM, IN A FRANCO-VIETNAMESE TEAM.
IT HAS SINCE BEEN DEVELOPED BY TEN INSTITUTIONS AROUND THE WORLD

France
IRD (PI), CNRS, INRAE, University of Toulouse 1 Capitole, University of Paris Sud, University of Rouen

A. Drogoul, B. Gaudou, P. Taillandier, N. Marilleau, K. Chapuis, P. Caillou, A. Brugière, Nguyen Huu Tri, Y. Sklab, JD Zucker

Netherlands
Delft University of Technology

S. Bhamidipati

USA
MIT Media Lab
Cambridge, MA

A. Grignard

Vietnam
Thuyloi University,
Can Tho University

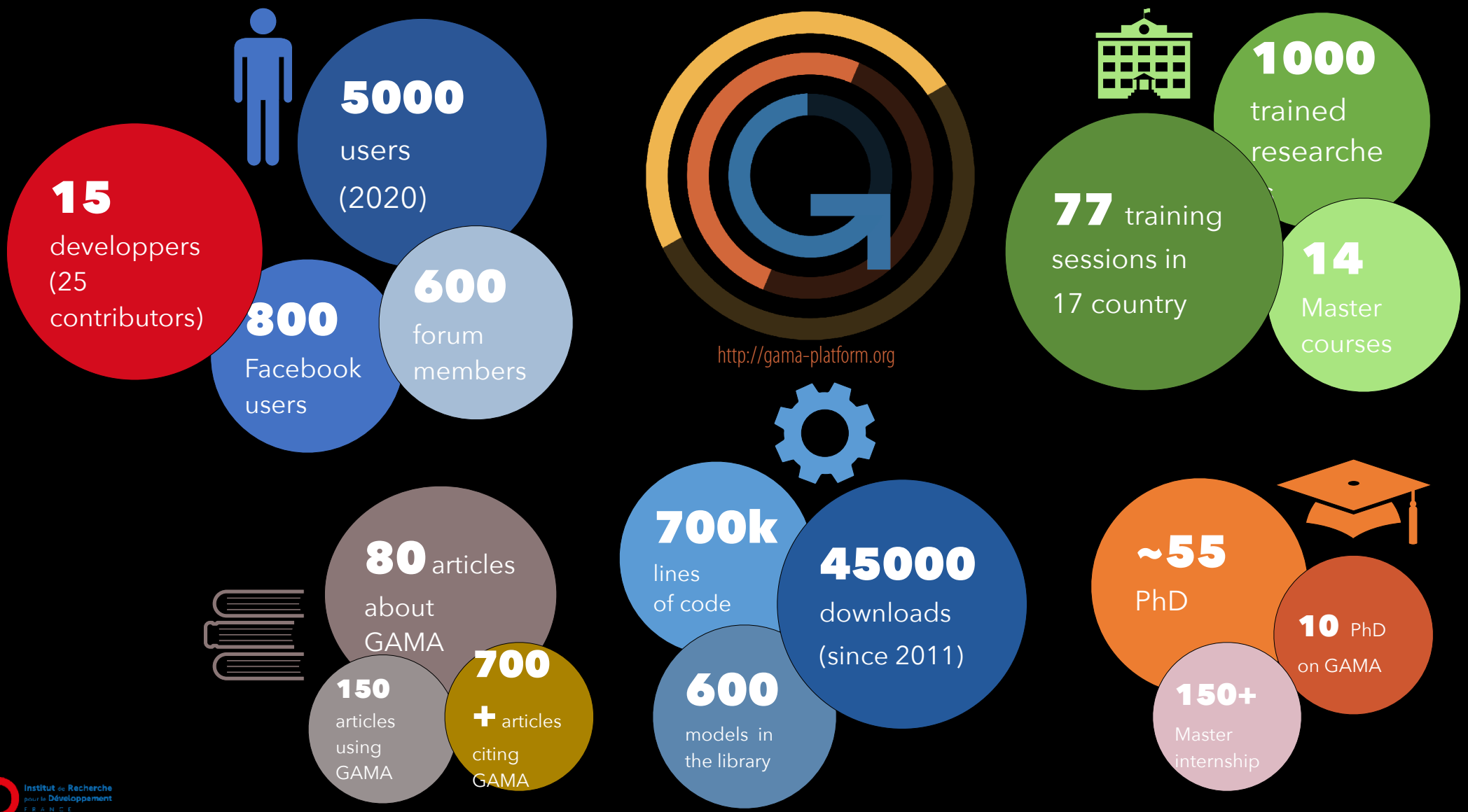
Huynh Quang Nghi,
Nguyen Ngoc Doanh

http://gama-platform.org

Taillandier, P., Gaudou, B., Grignard, A., Huynh, Q. N., Marilleau, N., Caillou, P., ... & Drogoul, A. (2019). Building, composing and experimenting complex spatial models with the GAMA platform. *GeoInformatica*, *23*, 299-322.

GAMA PROVIDES A COMPLETE INTEGRATED DEVELOPMENT ENVIRONMENT (IDE) TO BUILD MODELS

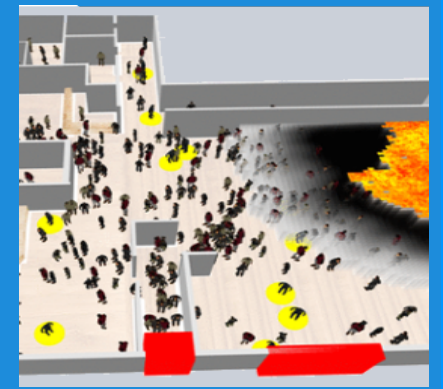
GAMA IN A FEW STATISTICS...



PRESENTATION OF MY WORKS

1. Spatial Dimension

2. Human Behavior Modeling

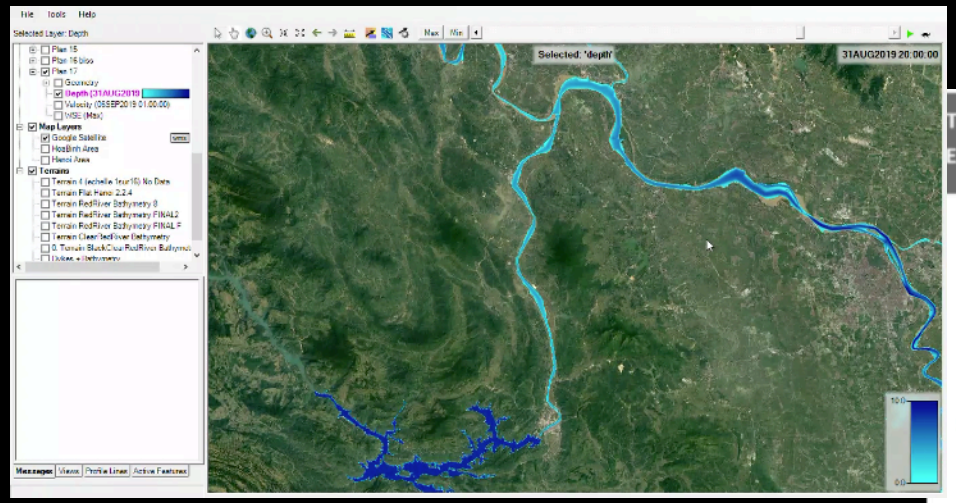


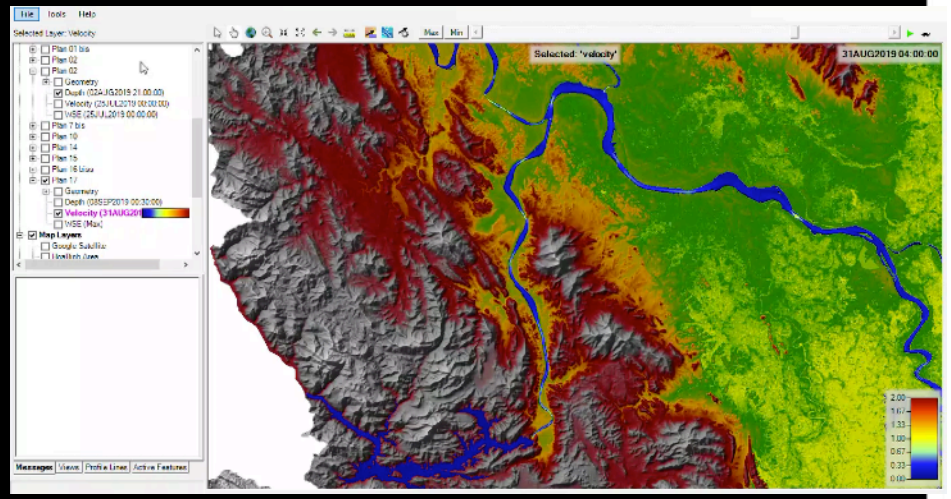
AGENT-BASED SIMULATION

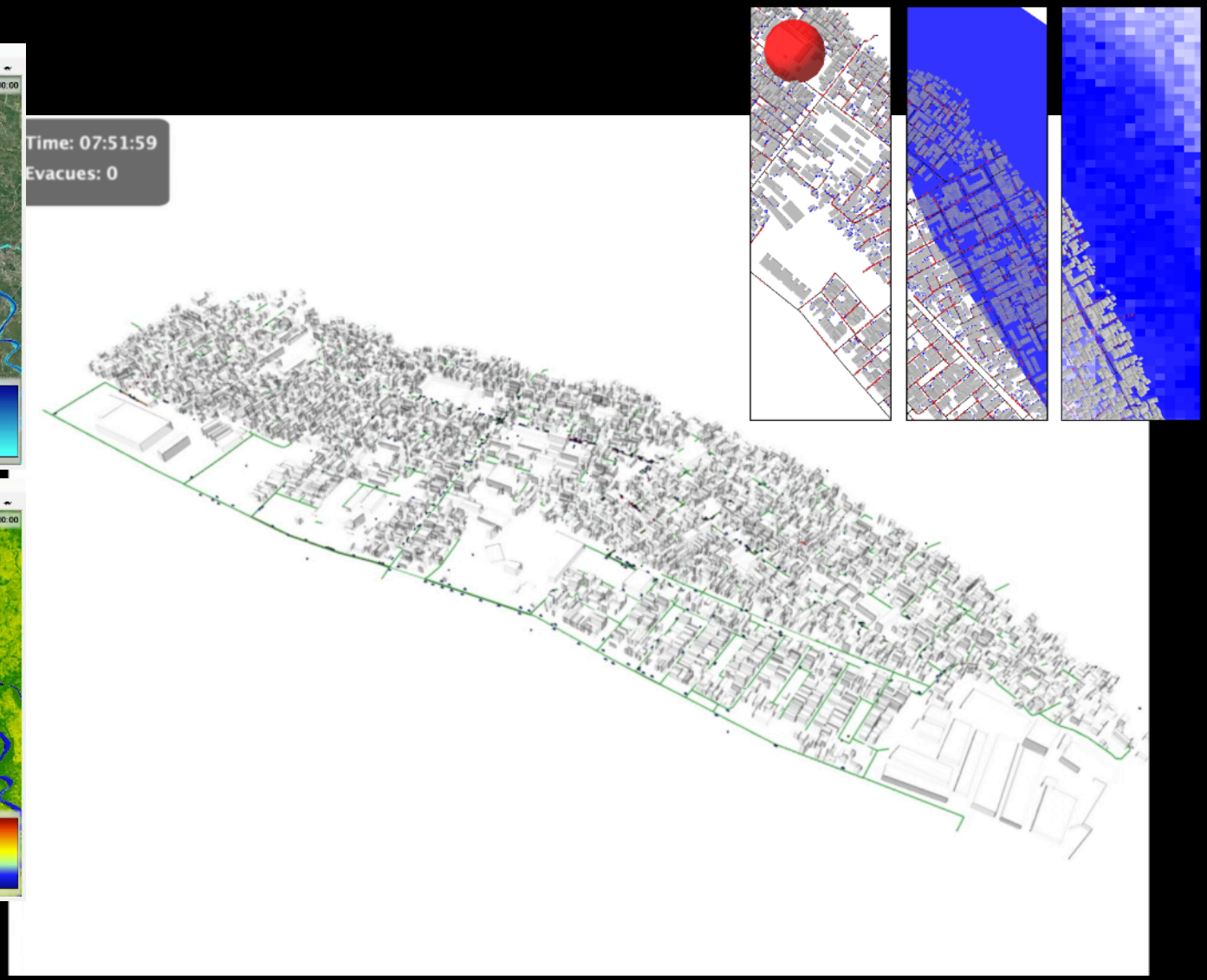
3. Participatory Simulation

Spatial Dimension

ESCAPE, ASSESSING AND COMPARING STRATEGIES OF EVACUATION







Flood caused by dam break on the Red River

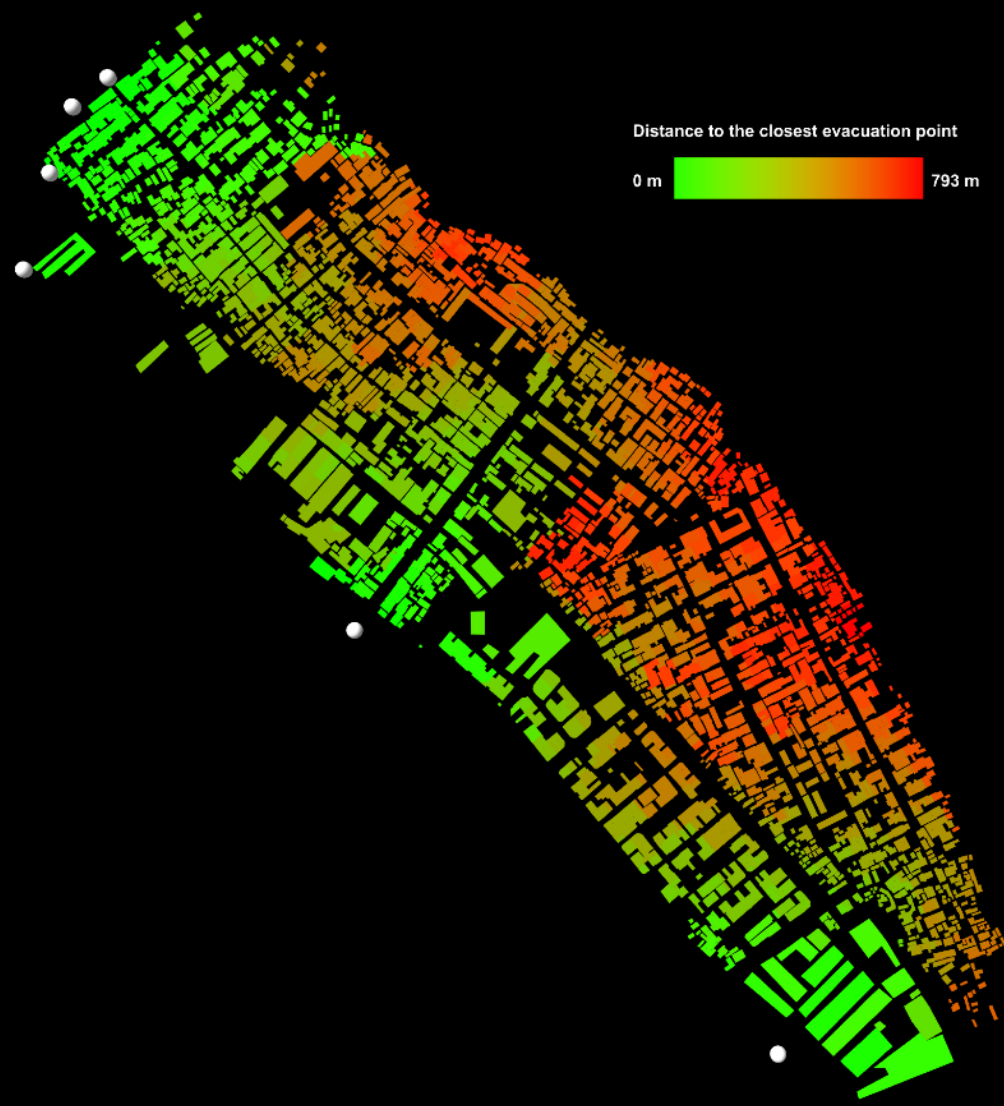
Co-funded by the Erasmus+ Programme of the European Union

Phuc xa, a neighborhood at risk of flooding

- Landlocked Hanoi district of approx. 1 km2 located in the “flood zone”.
- Density of 17,000 inhabitants/km2, one of the highest in the capital - average around 9,300 inhabitants/km2.
- The flow of the Red River is subject to significant seasonal fluctuations, reaching 30,000 m3/s during the monsoon season.
- Since the 1970s, a number of dams have been built in China (Yunnan province) and Vietnam.
- The Hoa Binh and Thac Ba dams pose major risks to Hanoi's riverside neighborhoods, particularly in the event of failure or sudden discharge.

Possible evacuation points

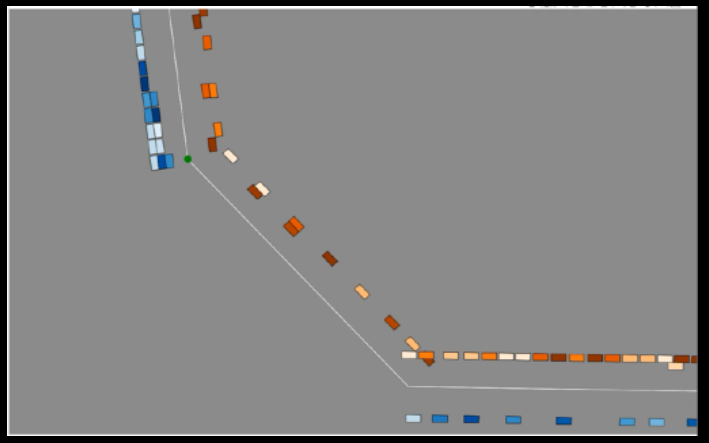
- Evacuation point
- Distance to nearest evacuation point

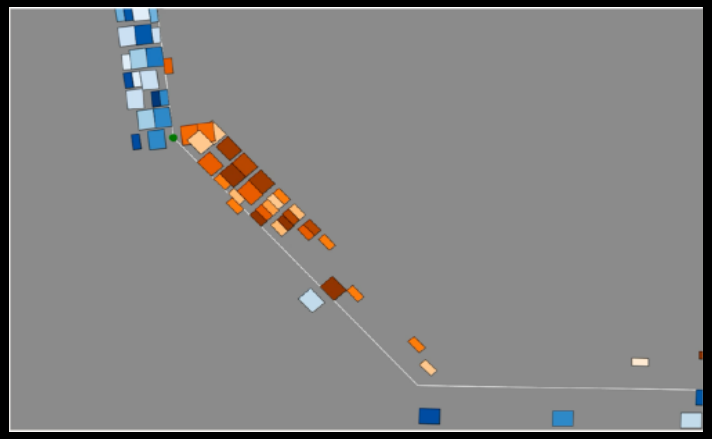


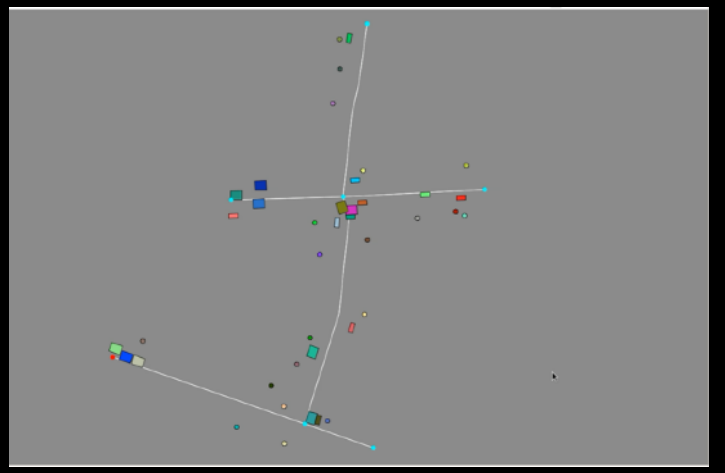
TOWARDS MORE REALISTIC TRAFFIC SIMULATIONS

Traffic in HCM/Hanoi (2017 data):

- 74% motorcycles
- 19% bicycles
- 6% pedestrians
- 1% cars



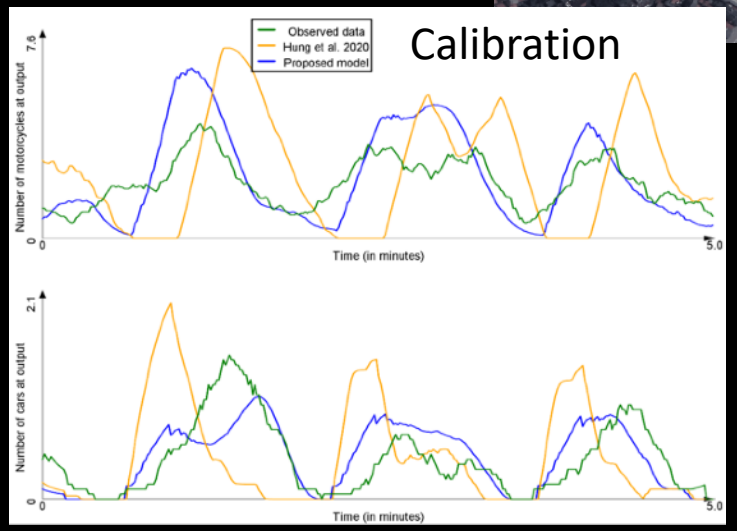




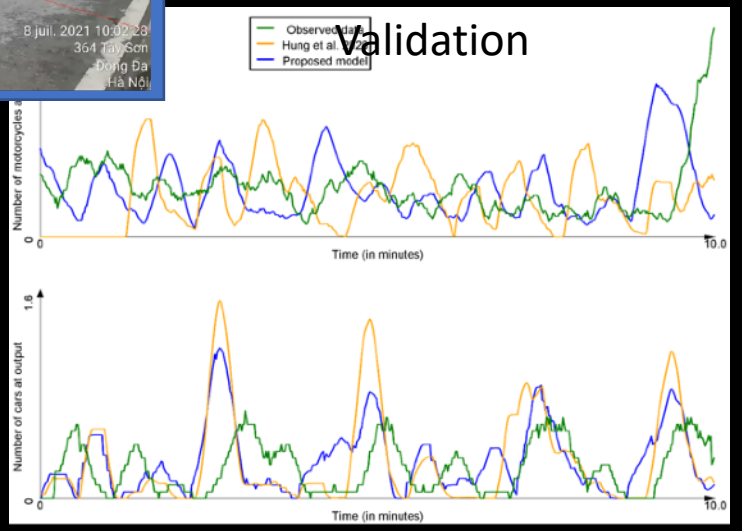
Work on traffic simulation:

- ➡ **Allows you to manage traffic with different types of vehicles (cars, motorcycles, even pedestrians).**
- ➡ **Acceleration model inspired by IDM**
- ➡ **Lane changing using the MOBILE model**
- ➡ **Simulates tens of thousands of agents**

TOWARDS MORE REALISTIC TRAFFIC SIMULATIONS – CALIBRATION/VALIDATION

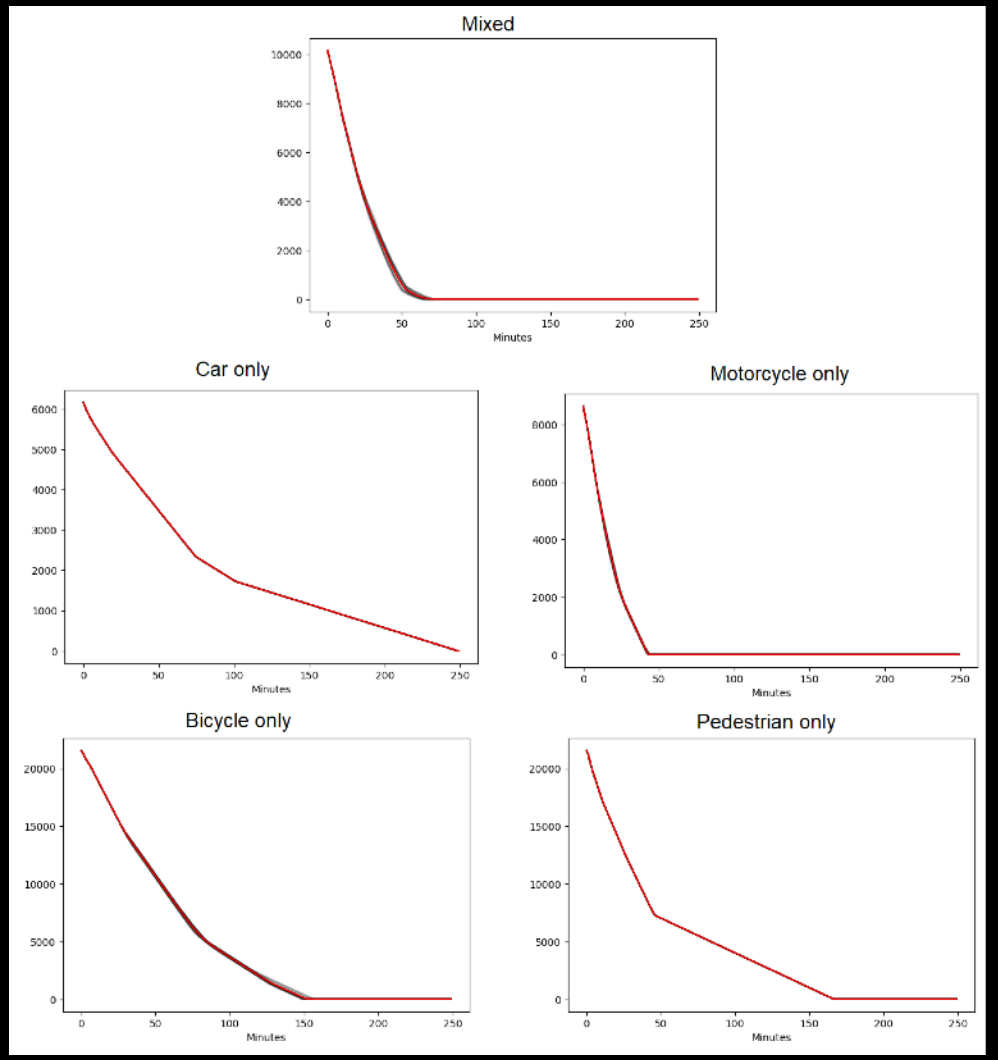


Saval, A., Minh, D. P., Chapuis, K., Tranouez, P., Caron, C., Daudé, É., & Taillandier, P. (2023). Dealing with mixed and non-normative traffic. An agent-based simulation with the GAMA platform. Plos one, 18(3), e0281658.

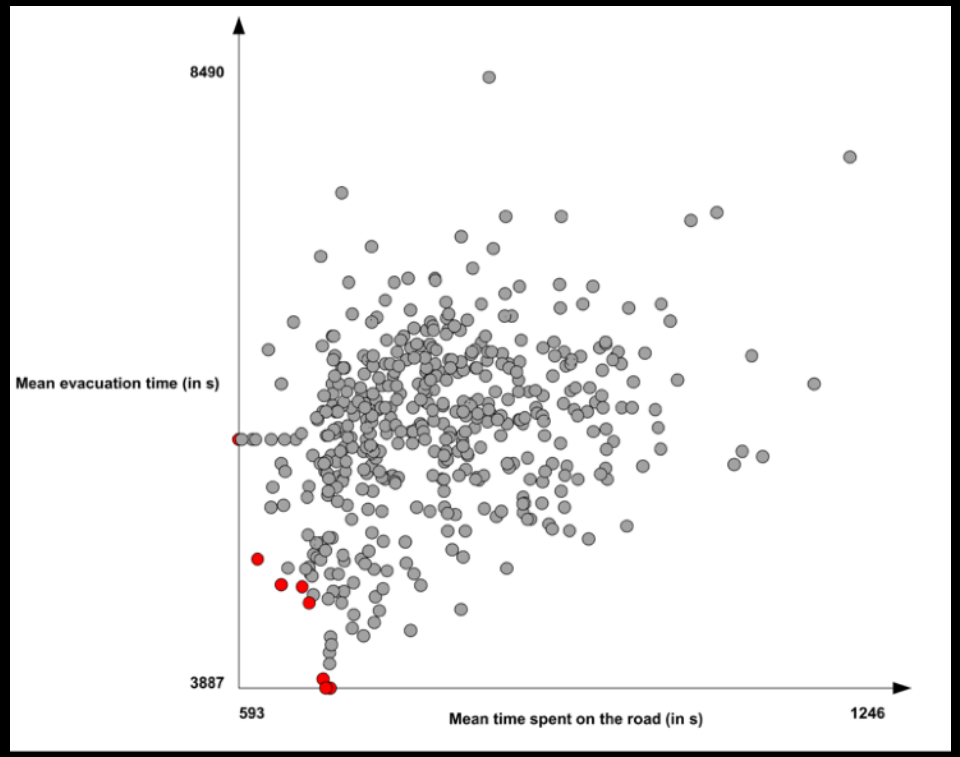


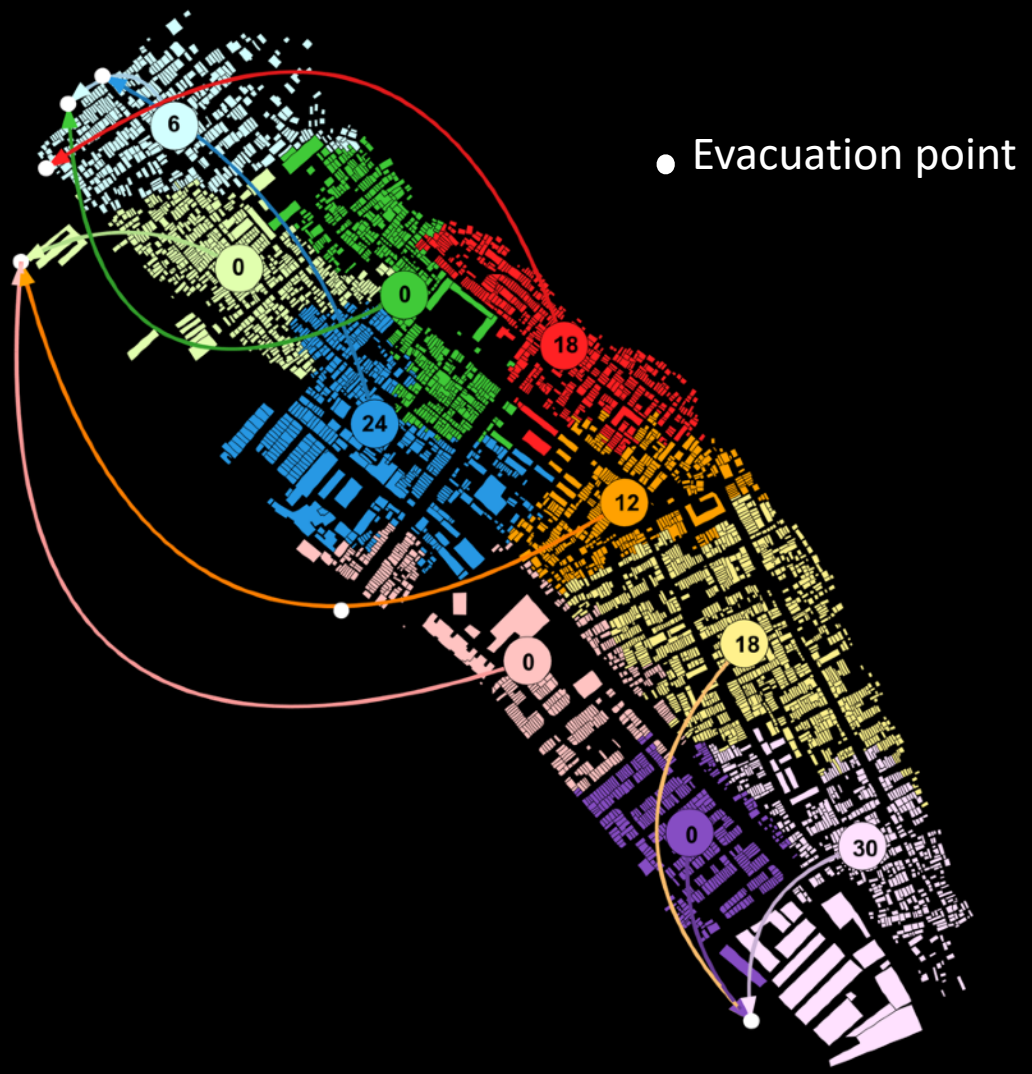
IMPACT OF TYPE OF TRANSPORT

- ➡ Everyone evacuates to the nearest exit
- ➡ Everyone tries to evacuate at the same time
- ➡ 25 repetitions
- ➡ Exits: number of vehicles/people not yet evacuated



EVACUATION OPTIMIZATION

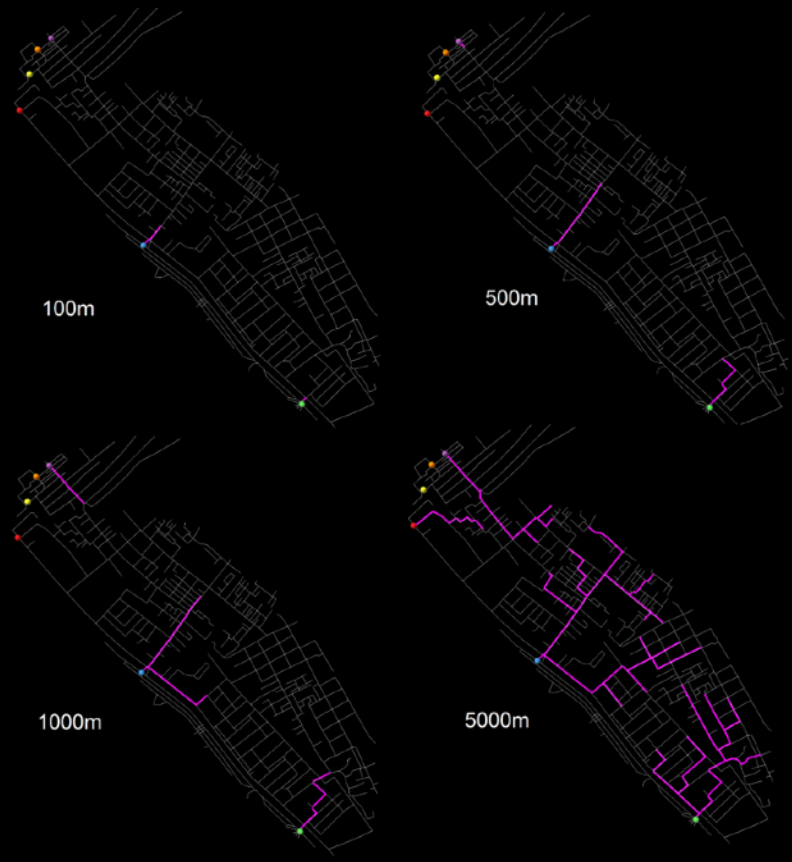




- Evacuation point

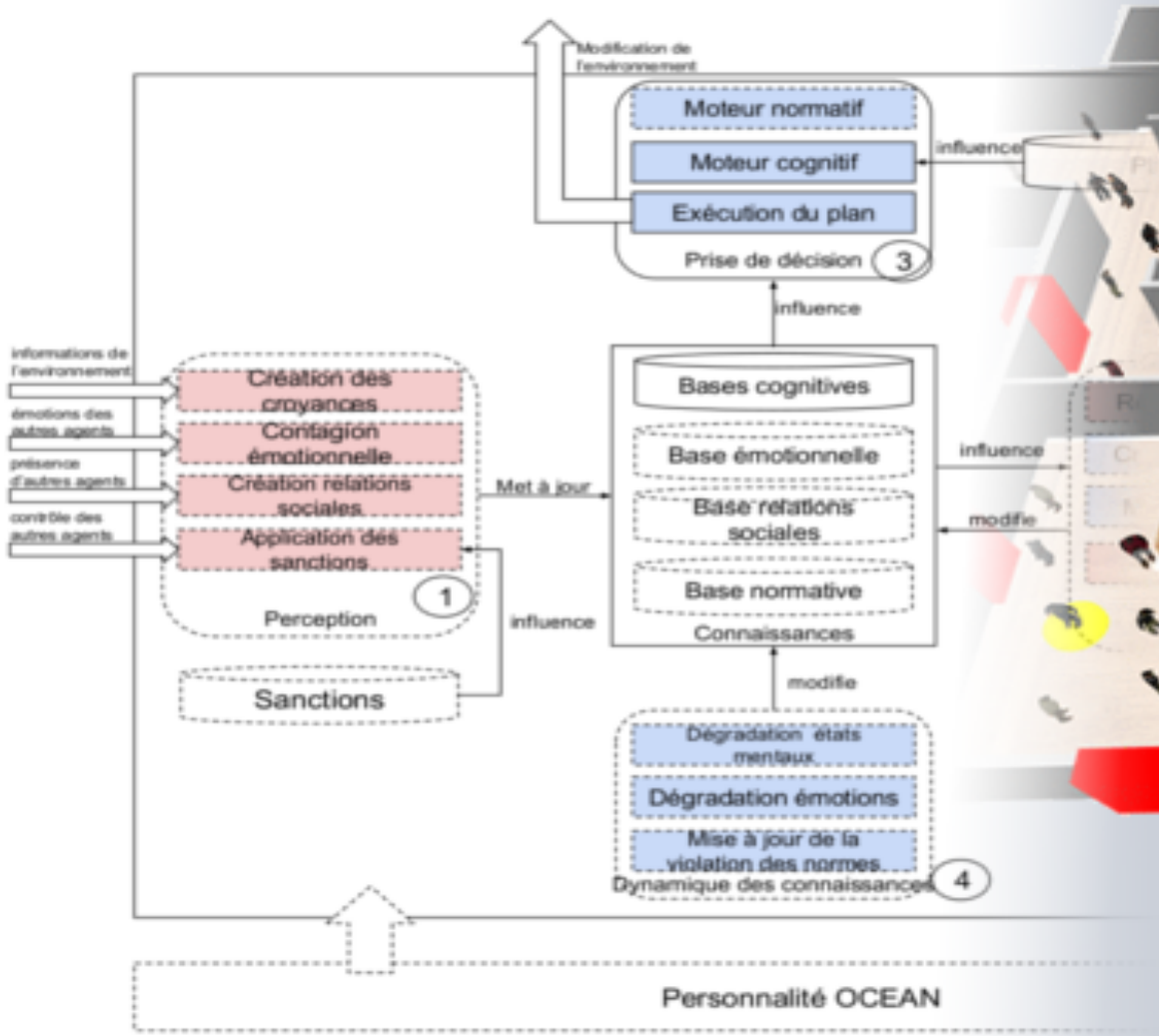
ROAD NETWORK IMPROVEMENT

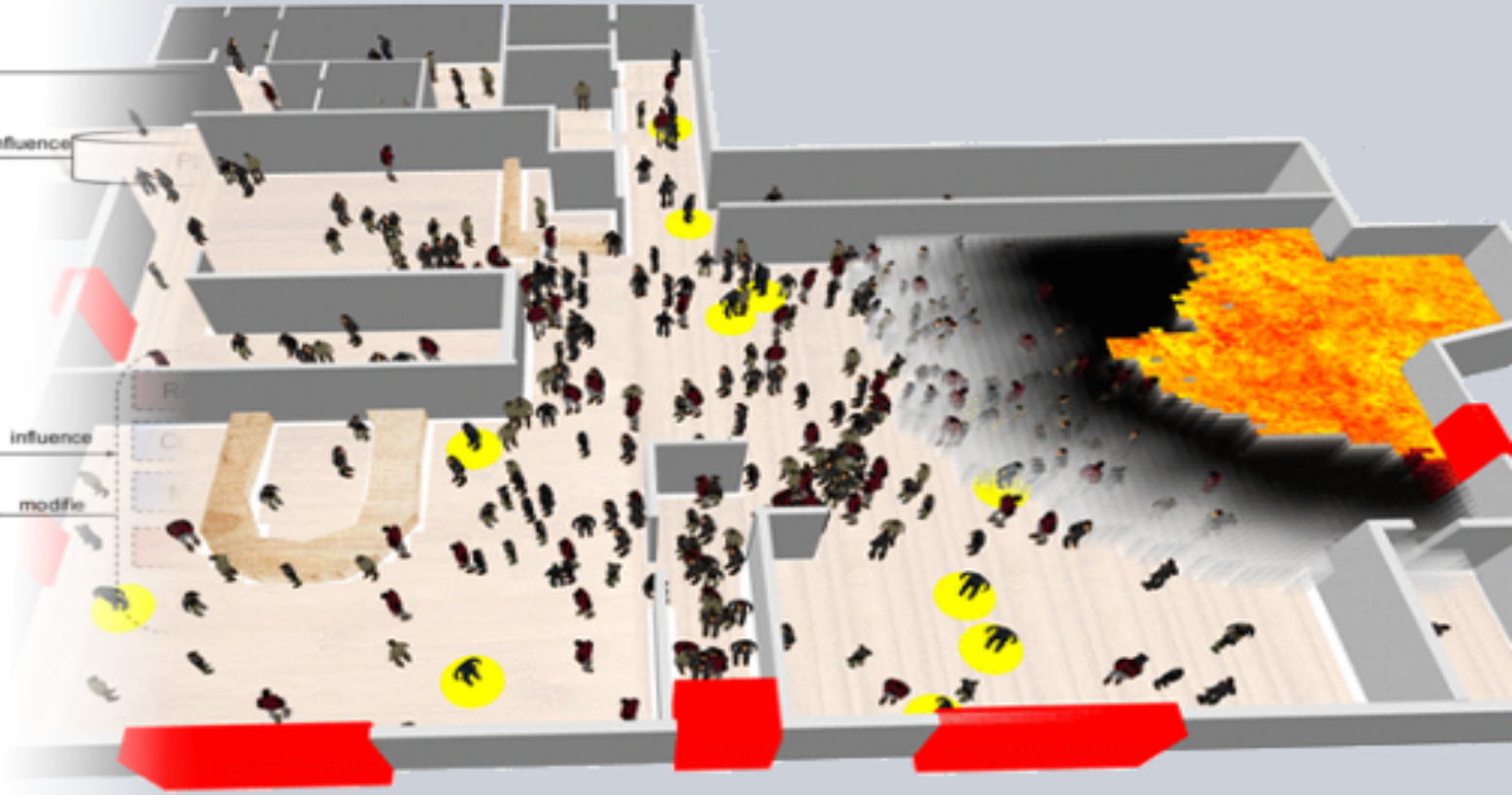
Chapuis, K., Minh-Duc, P., Brugière, A., Zucker, J. D., Drogoul, A., Tranouez, P., ... & Taillandier, P. (2022). Exploring multi-modal evacuation strategies for a landlocked population using large-scale agent-based simulations. International Journal of Geographical Information Science, 36(9), 1741-1783.



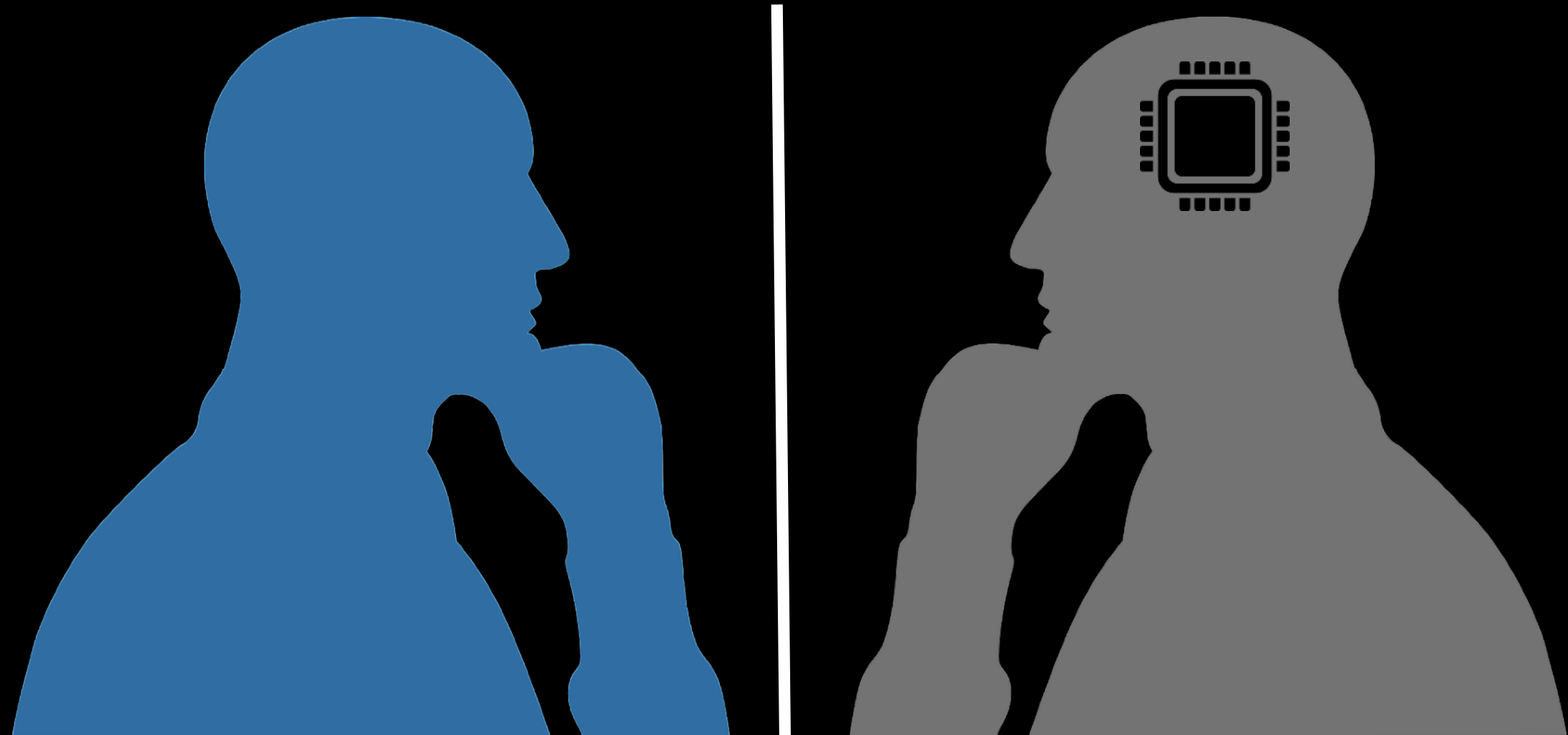
road perimeter threshold (in m)	evacuation time (in s)	Time spent on the roads (in s)
0	4686 (±624)	1372 (±31)
100	3736 (±550)	1196 (±22)
500	3643 (±417)	1178 (±22)
1000	3307 (±292)	1132 (±22)
5000	3383 (±392)	1090 (±14)

Modeling human behavior

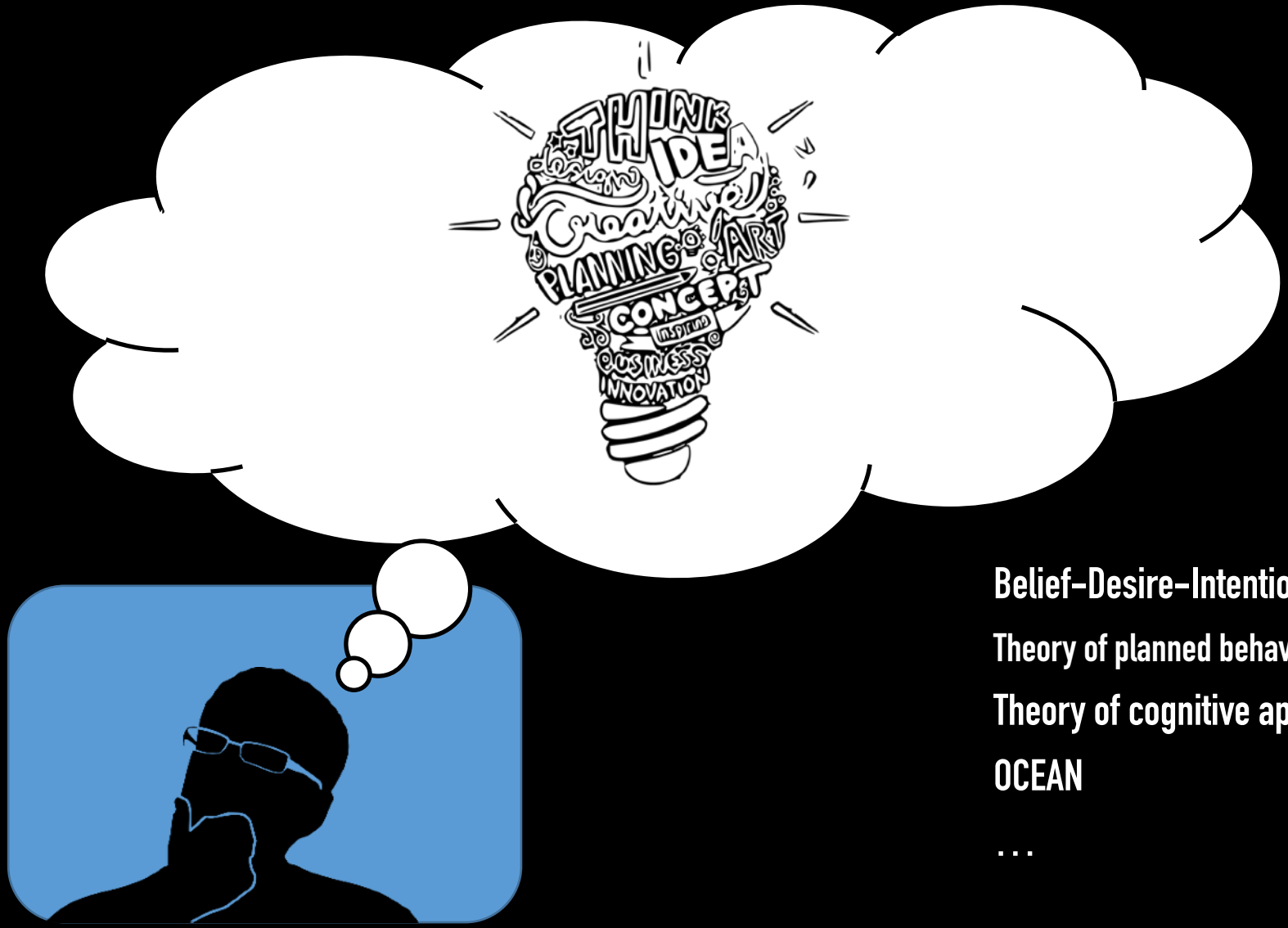




A LOT OF WORK HAS BEEN DONE ON THE MODELING OF HUMAN BEHAVIOR



INSPIRATIONS COMING FROM PSYCHOLOGY, PHILOSOPHY, SOCIOLOGY…. TO FORMALIZE DIFFERENT DIMENSIONS OF THE BEHAVIOR.



Belief-Desire-Intention model

Theory of planned behavior

Theory of cognitive appraisal of emotions

OCEAN

…

EXAMPLE 1: STUDYING THE EVACUATION OF A BUILDING

PhD of **Mathieu Bourgais** - Towards cognitive, affective and social agents in simulation

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR
ANR

CONTEXT

- The Station Night club in the US
- A **fire** occurre
  100 people a
- Safety rules v
  evacuation m

How can we take better account of people's behavior to minimize deaths and injuries?

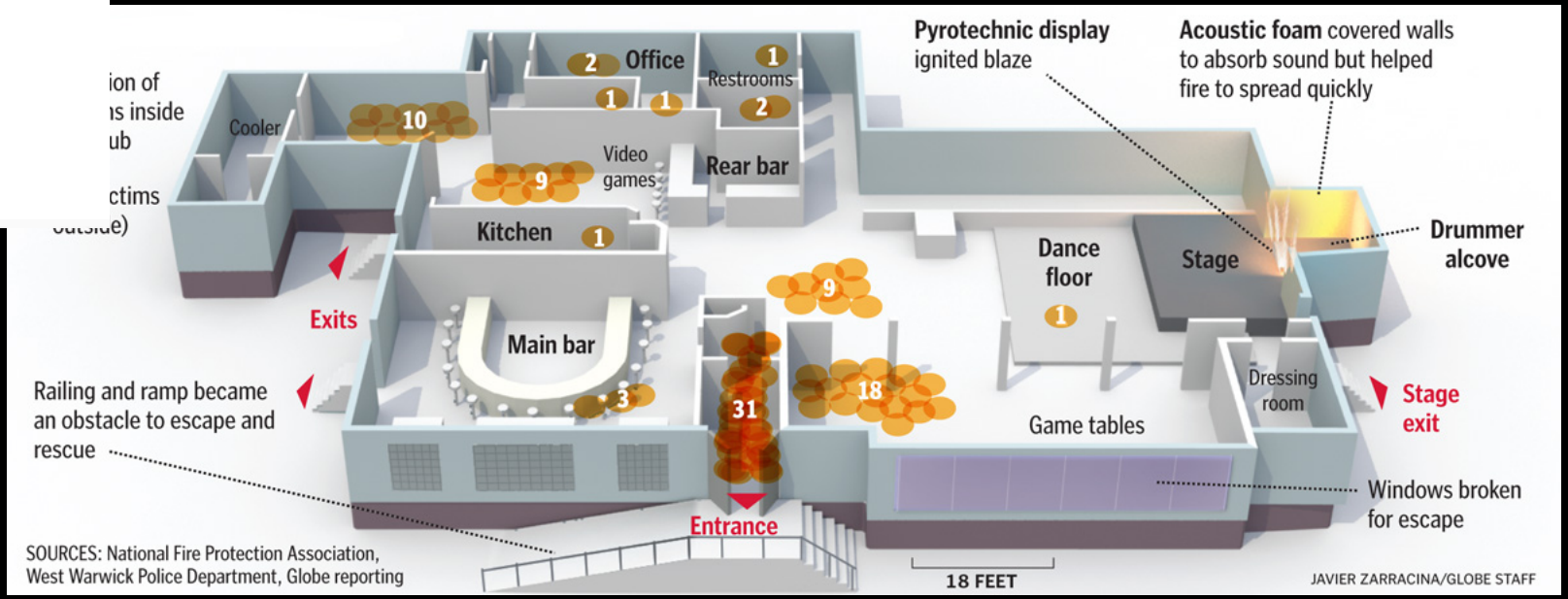
STEP 1. ANALYSIS OF REPORTS

NIST NCSTAR 2: Vol. I

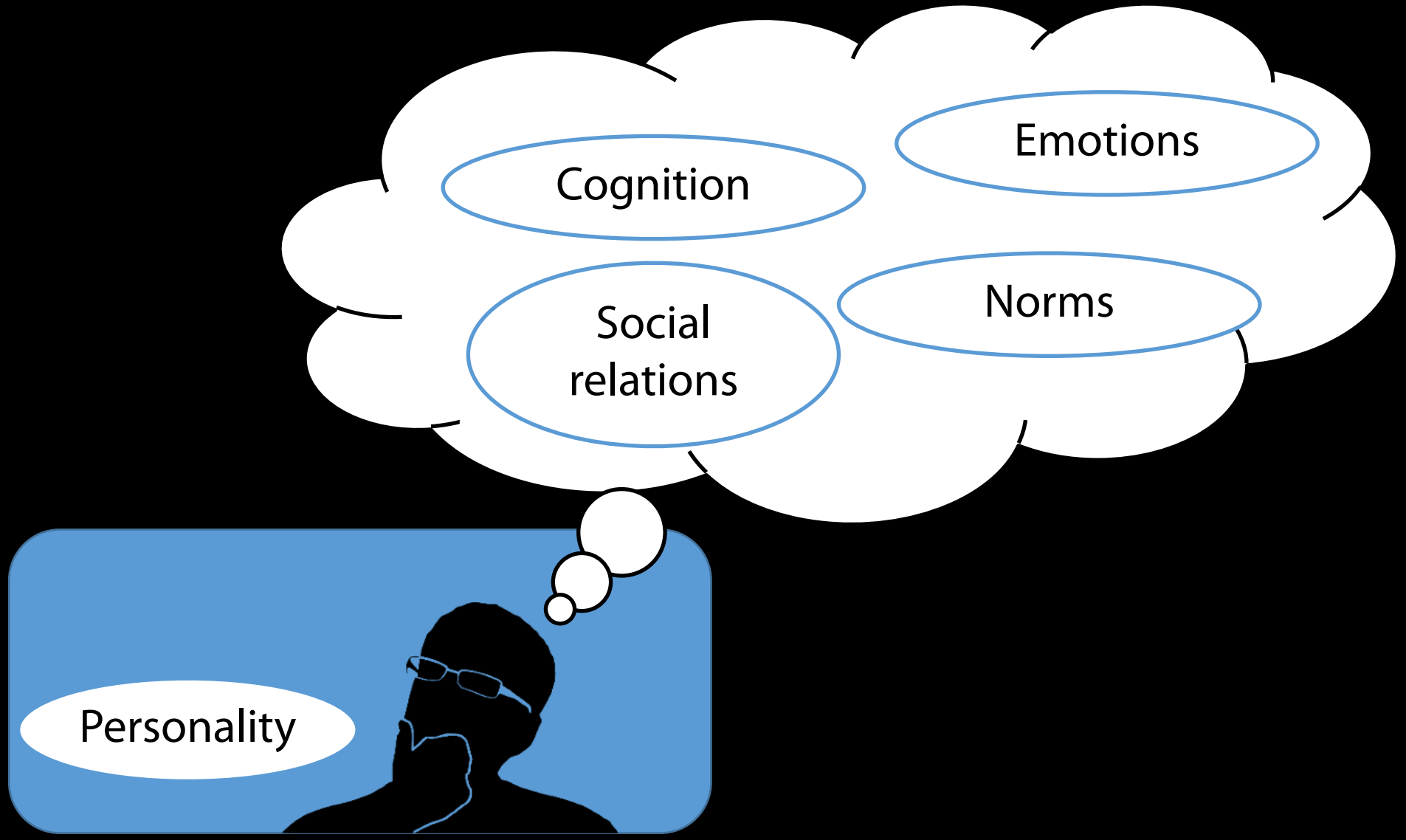
Report of the Technical Investigation of The Station Nightclub Fire

William Grosshandler
Nelson Bryner
Daniel Madrzykowski
Fire Research Division
Building and Fire Research Laboratory
National Institute of Standards and Technology

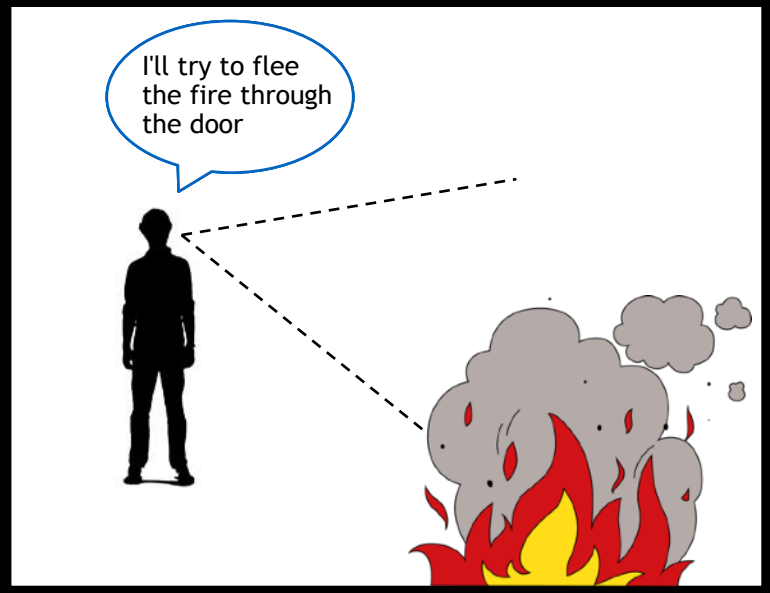
Kenneth Kuntz
Federal Emergency Management Agency
U.S. Department of Homeland Security



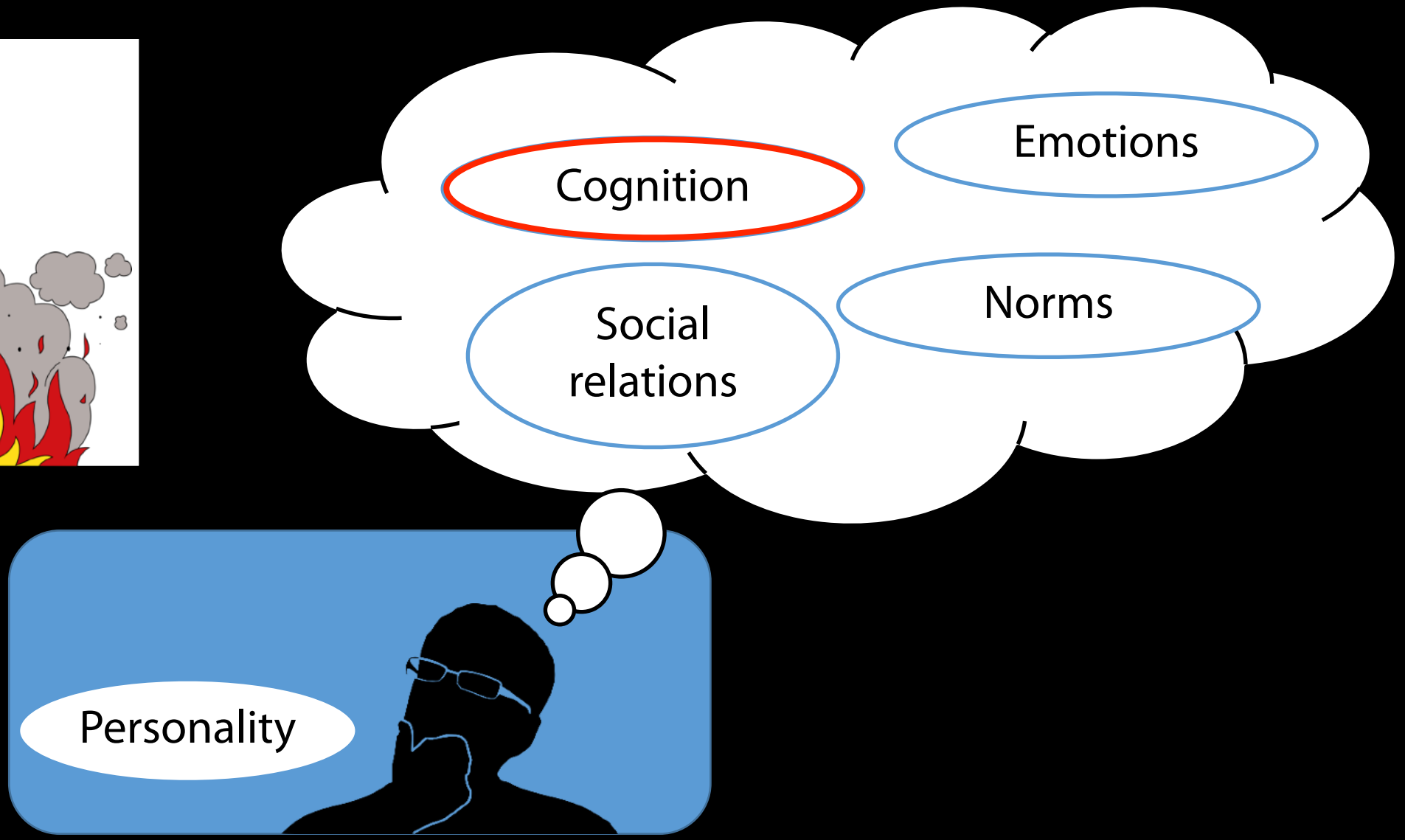
STEP 2. DEVELOPMENT OF THE MODEL



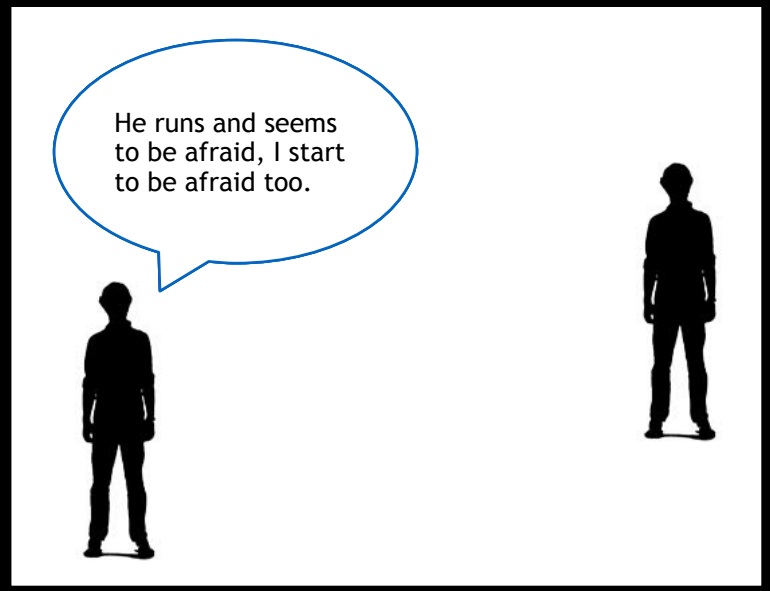
STEP 2. DEVELOPMENT OF THE MODEL



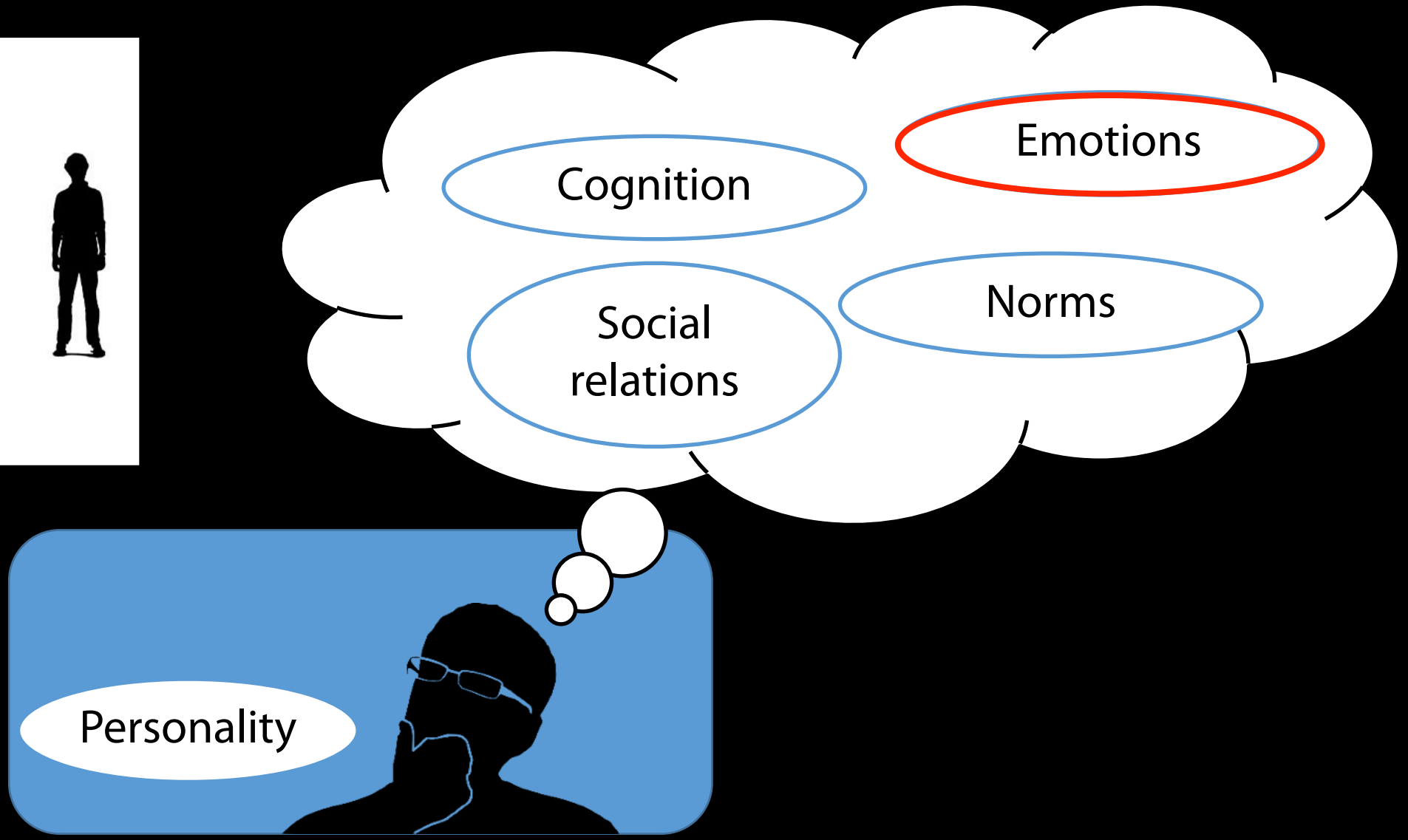
BDI (Belief – Desire – Intention) model of human practical reasoning - Bratman (87)



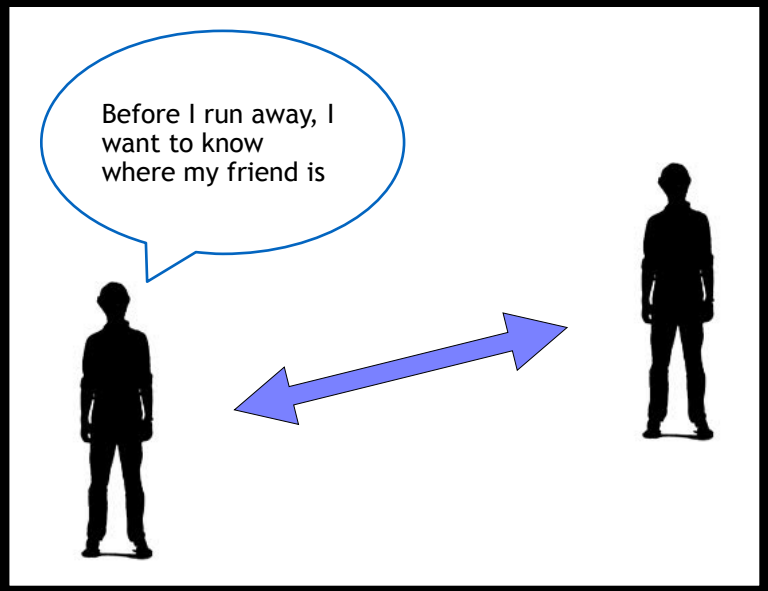
STEP 2. DEVELOPMENT OF THE MODEL



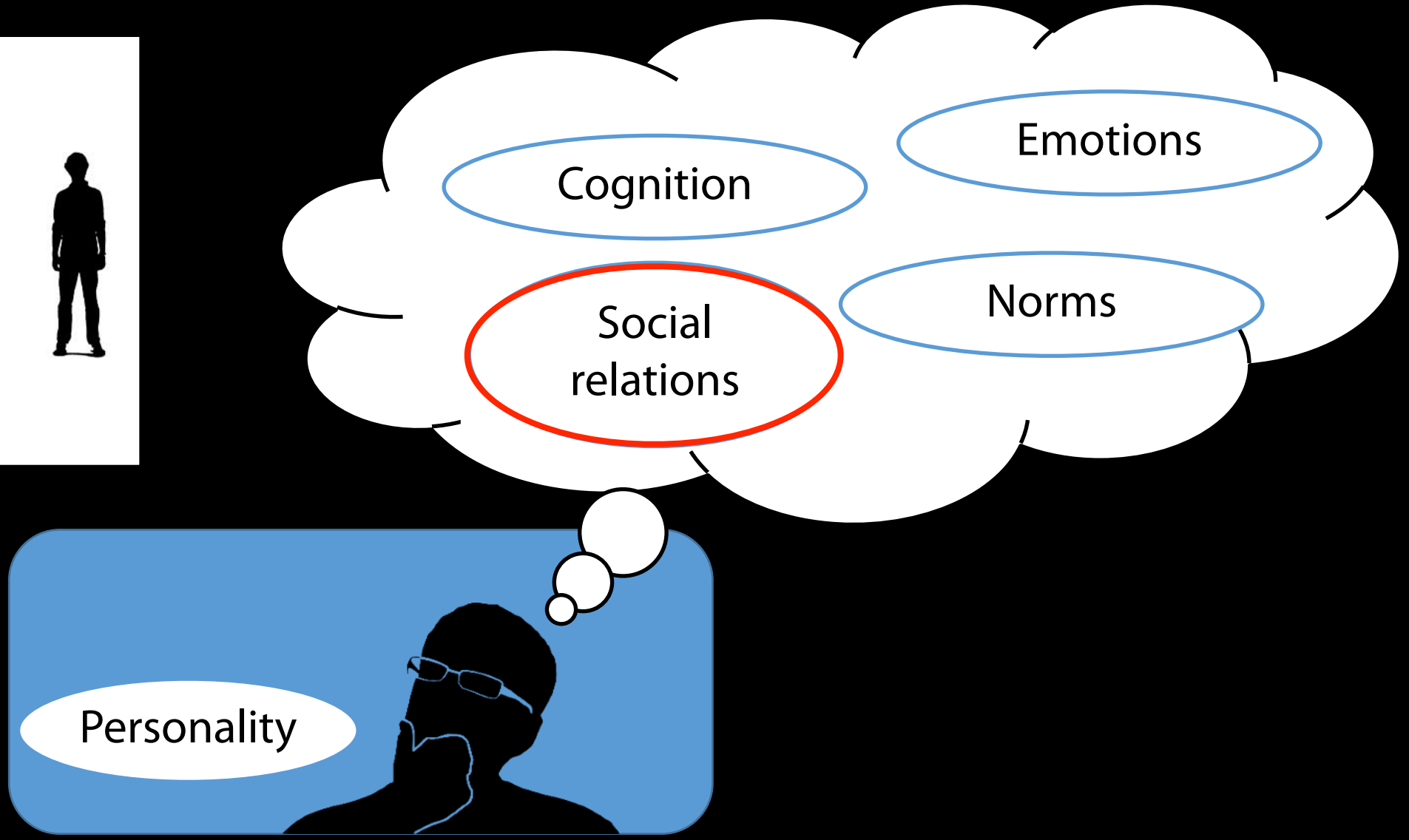
OCC model of Emotions - Ortony, Clore et Collins (90) + Emotional contagion - Bosse (09)



STEP 2. DEVELOPMENT OF THE MODEL

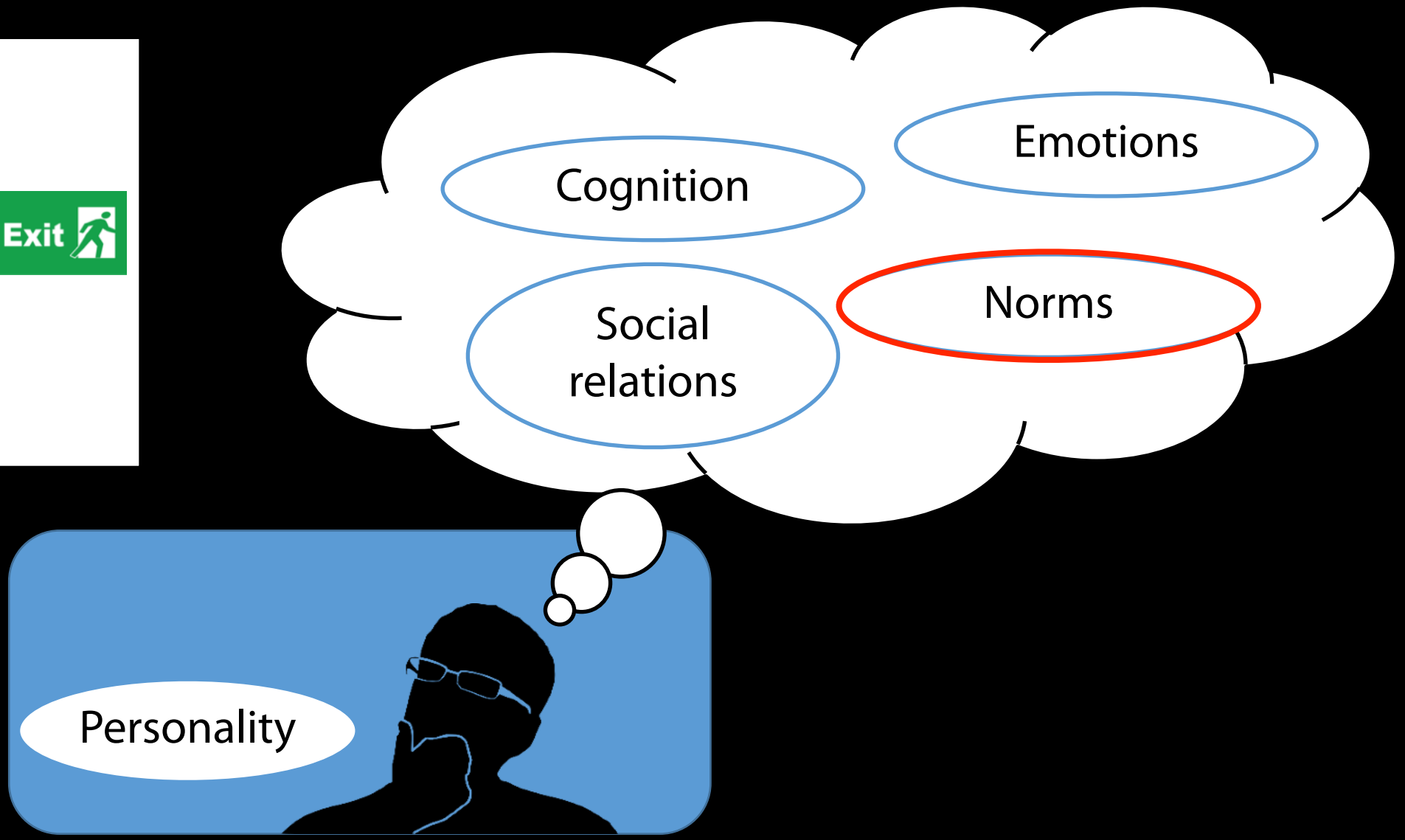


Model of interpersonal relationship with 4 dimensions: appreciation, dominance, solidarity and familiarity - Svennevig (00)

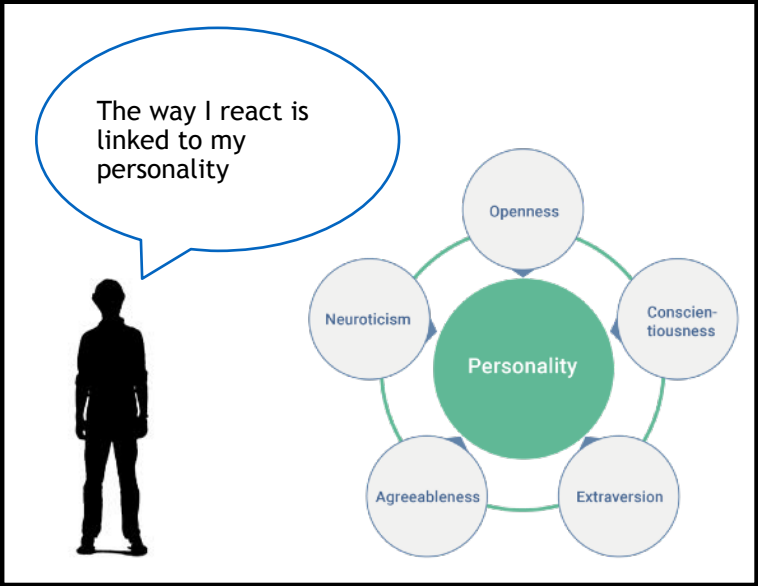


STEP 2. DEVELOPMENT OF THE MODEL

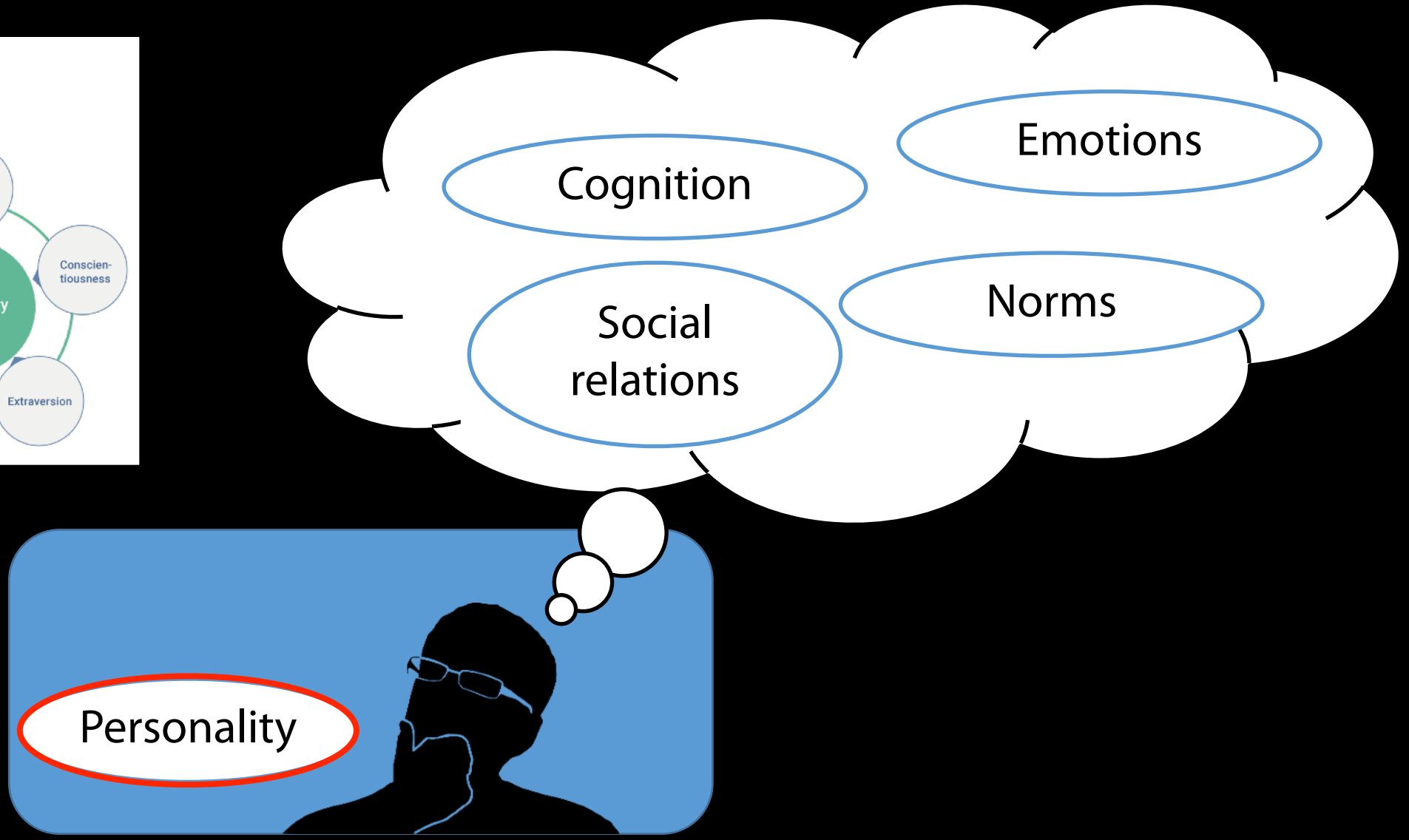
Unified and formal representation of a normative system - Lopez y Lopez (06)



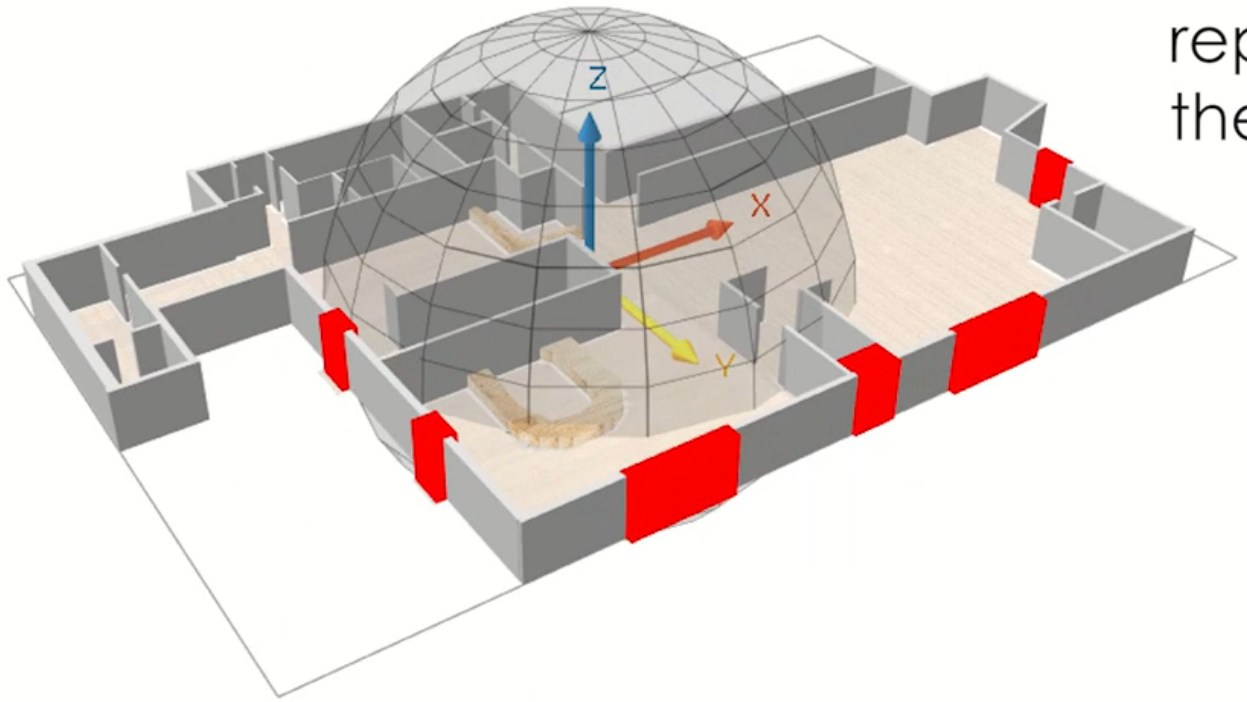
STEP 2. DEVELOPMENT OF THE MODEL



OCEAN model based on 5 numerical factors to categorize someone's personality - McCrae (92)



STEP 3. SIMULATION



Map of the building:
4 exits and 2 windows
represented by
the red rectangles

Bourgais, M., Taillandier, P., & Vercouter, L. (2020). BEN: An architecture for the behavior of social agents. Journal of Artificial Societies and Social Simulation, 23(4).

EXAMPLE 2: STUDYING THE ADOPTION OF NEW TECHNOLOGIES

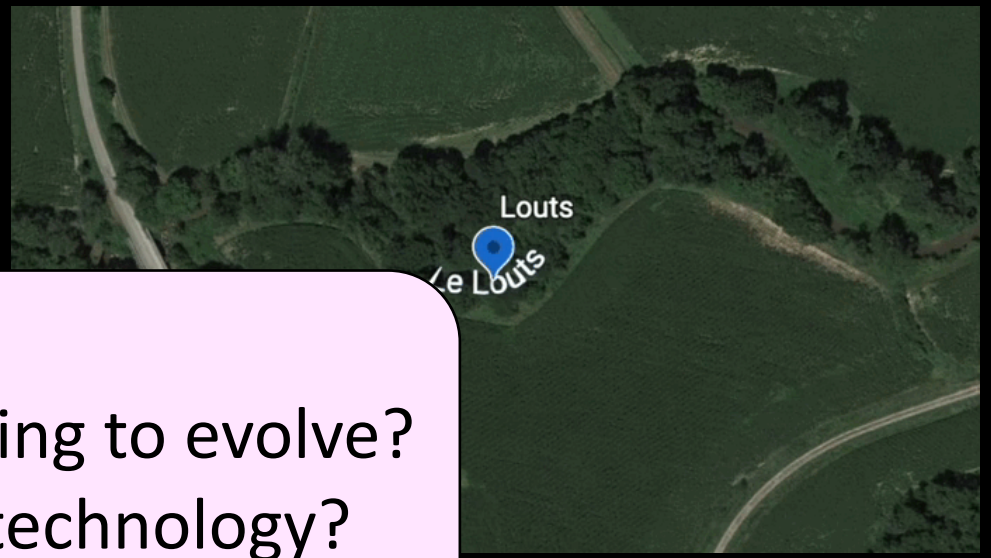
PhD of **Loïc Sadou** - Using agent-based simulation and argumentation theory to better understand the diffusion and appropriation of digital tools in agriculture

#DigitAg

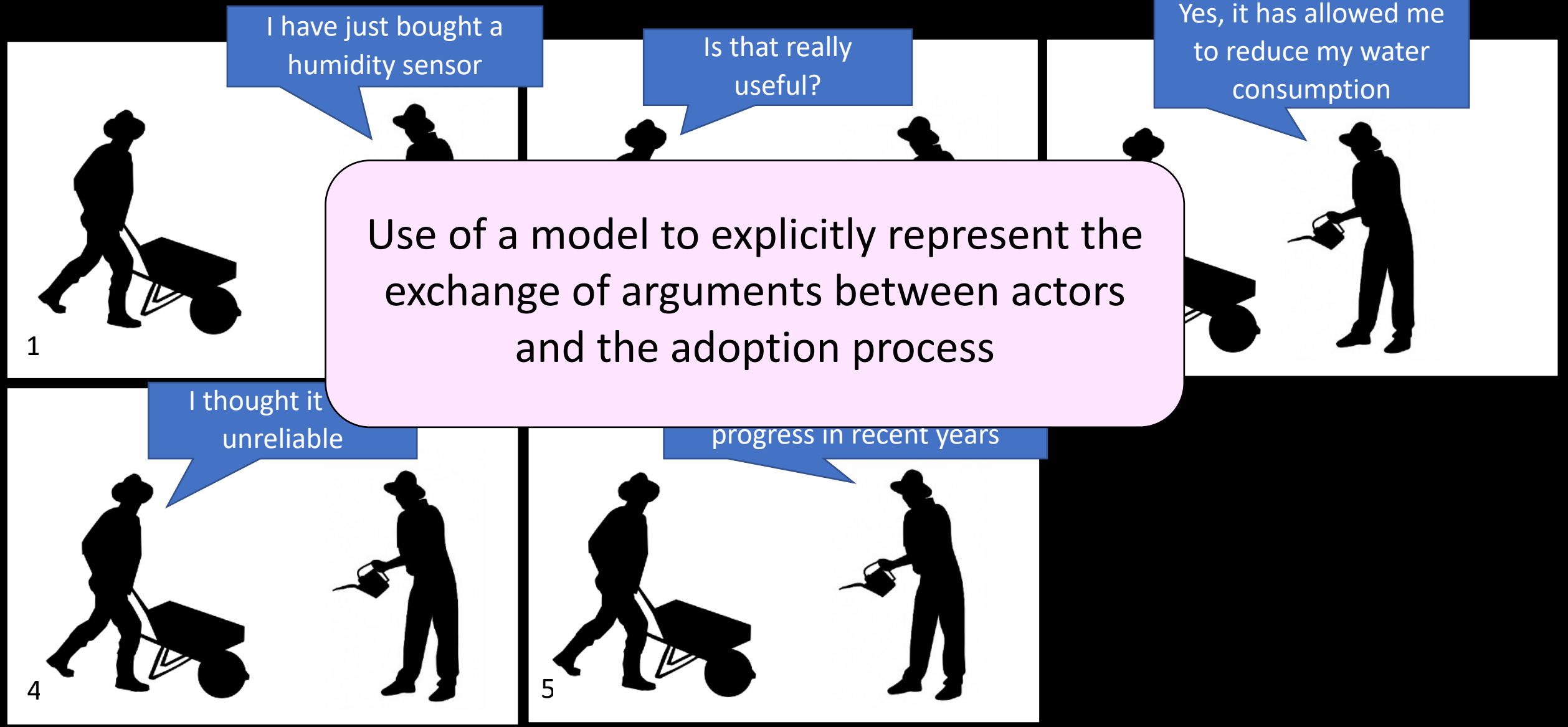
CONTEXT

- Area: the region of Le Louts (south of France)
- Issue related to
- Local water inst
  water meters – a
- Bad global opinion from farmers

How this global opinion is going to evolve?
How to promote this new technology?



CONTEXT: SOCIAL INTERACTIONS

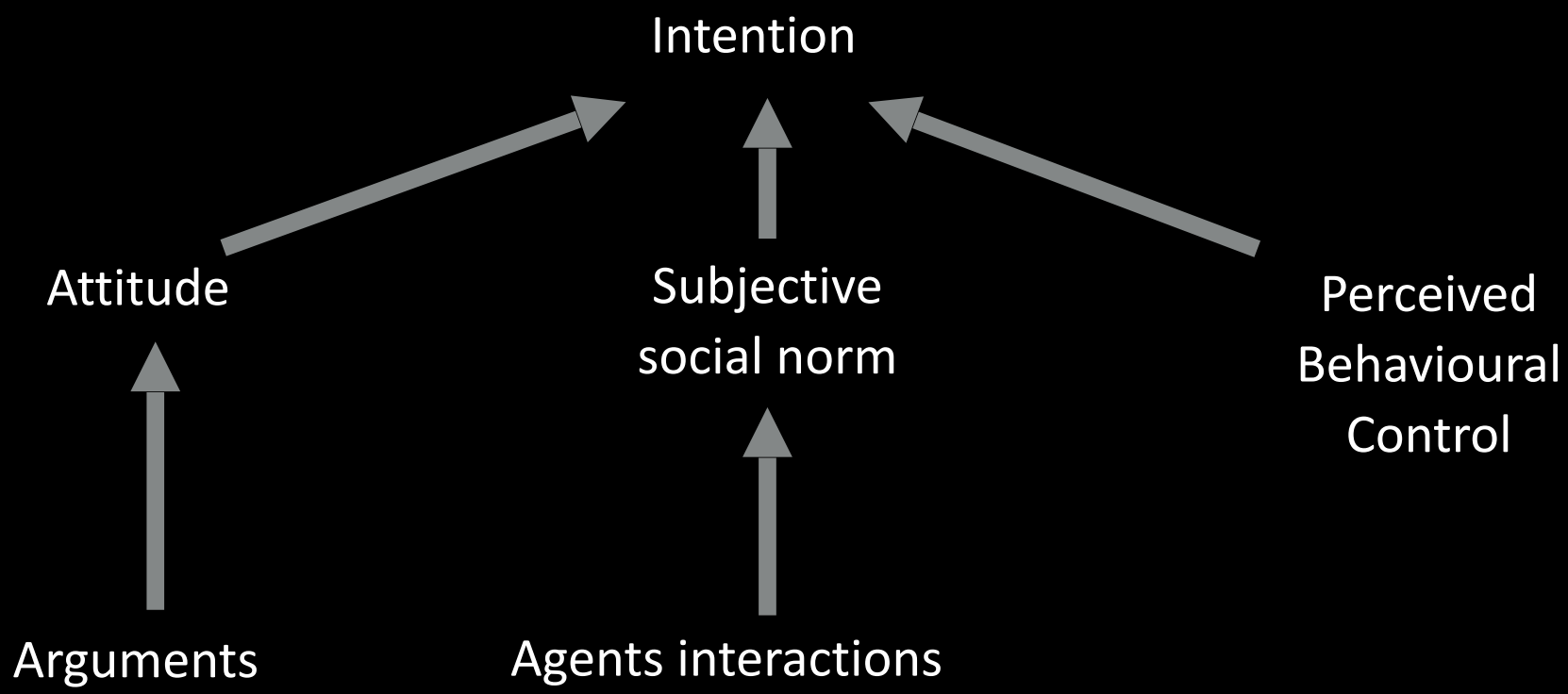


Use of a model to explicitly represent the exchange of arguments between actors and the adoption process

STEP 1 : ANALYSIS OF THE ARGUMENTS USED BY PEOPLE

Id	Type	Statement	Rationale	Criterion	Actor	Source type
1	-	Vegan diet is deficient in B12 vitamin	Vegetal proteins do not contain B12 vitamin	Nutritional	Jounalist	Newspaper
15	-	Plant proteins trigger allergies	Plant-based food are more regularly allergic	Nutritional	Innovation cluster	Powerpoint
23	+	Vegetarian diet is good for health	Diabetes, cancer and coronary risks are reduced	Health	Scientists	Scientific paper
56	+	Stop eating animals does not mean animal extinction	Deforestation for the cultivation of animal feed provokes species extinctions	Environmental	Blogger pro-vegan	Blog post
59	+	Animals suffer when eaten, not plants	A nervous system is needed to suffer, which plants do not have	Ethical	Blogger pro-vegan	Blog post

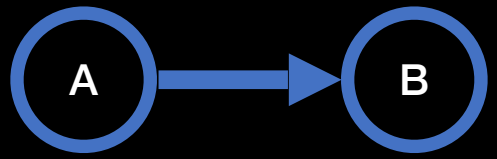
PROPOSED MODEL: THEORY OF PLANNED BEHAVIOR



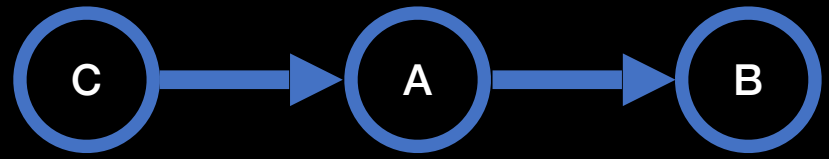
Ajzen (1991) *The Theory of Planned Behavior*

PROPOSED MODEL: DUNG'S ARGUMENTATION FRAMEWORK

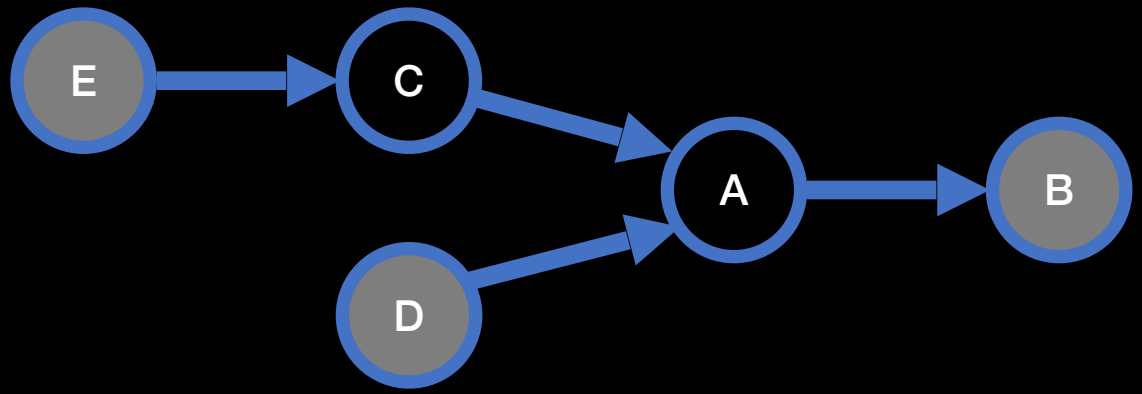
Argument



Attack

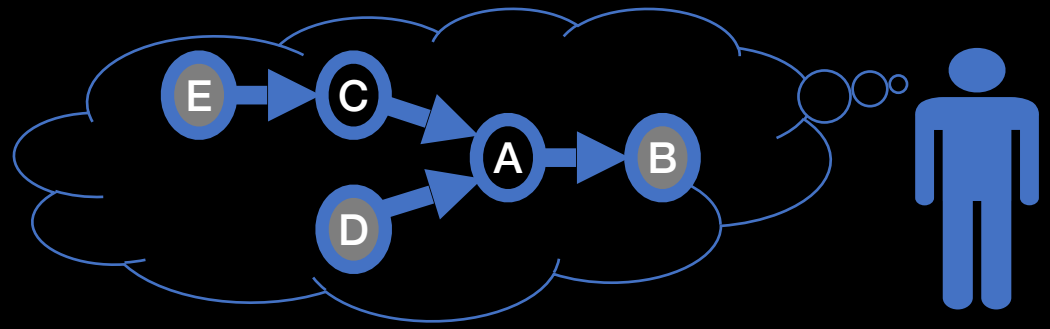


Defense



Prefered Extension

PROPOSED MODEL: ATTITUDE FROM ARGUMENTS



- I : 1
- T : +
- S : New meters are more accurate
- J : The ultrasound technology allows accurate mesures
- C : Performance
- Ts : Seller

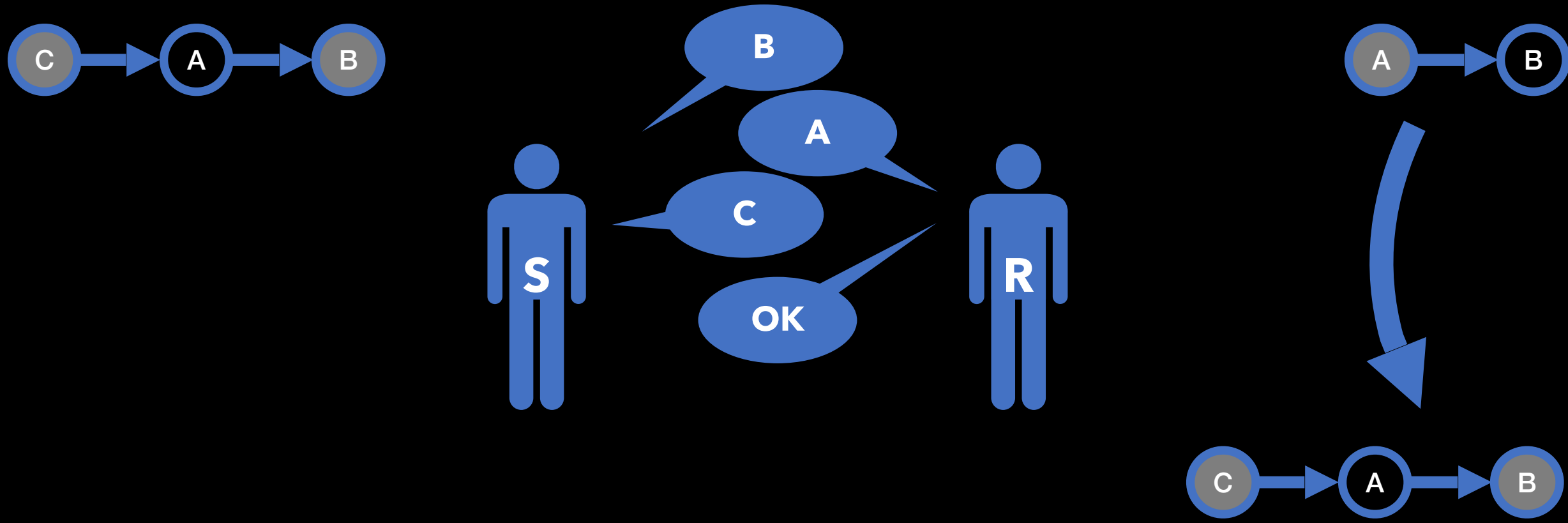
Performance	0.52
Ecology	0.78
Economic	0.82
Social	0.40
Website	0.40
Science paper	0.95
Seller	0.15
Other farmer	0.75

PROPOSED MODEL: DIALOGUE BETWEEN AGENTS

- An agent can communicate with a relative
- Update subjective social norm
- Bilateral trade of arguments

Gabbriellini & Torrini (2013) *MS Dialogues: Persuading and getting persuaded*

PROPOSED MODEL: EXAMPLE OF DIALOGUE

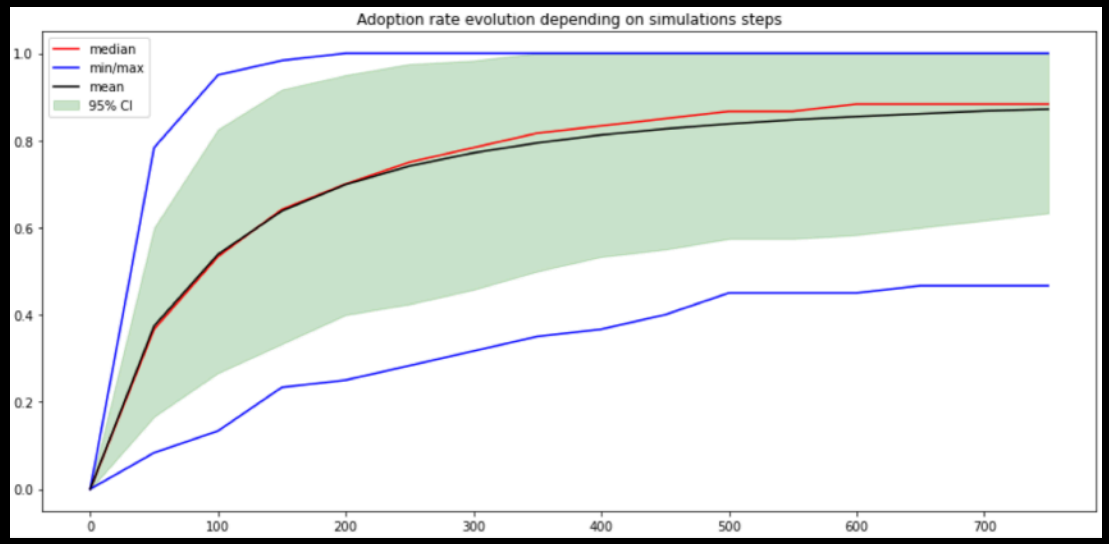


STEP 3. DATA COLLECTION & ARGUMENT LIST CONSOLIDATION

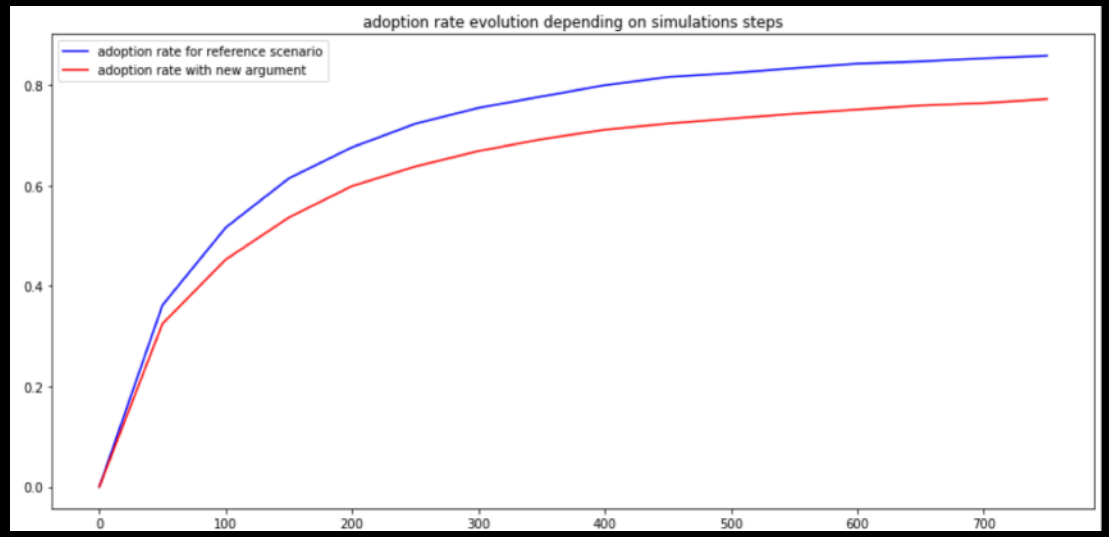
Interview with stakeholders to consolidate the list of arguments and to evaluate the values for their psychological profile (through role-playing game) and preferences

STEP 4. SIMULATION

- Tendency towards a greater acceptance of communicating water meters - similar phenomena were observed when mechanical water meters were introduced.

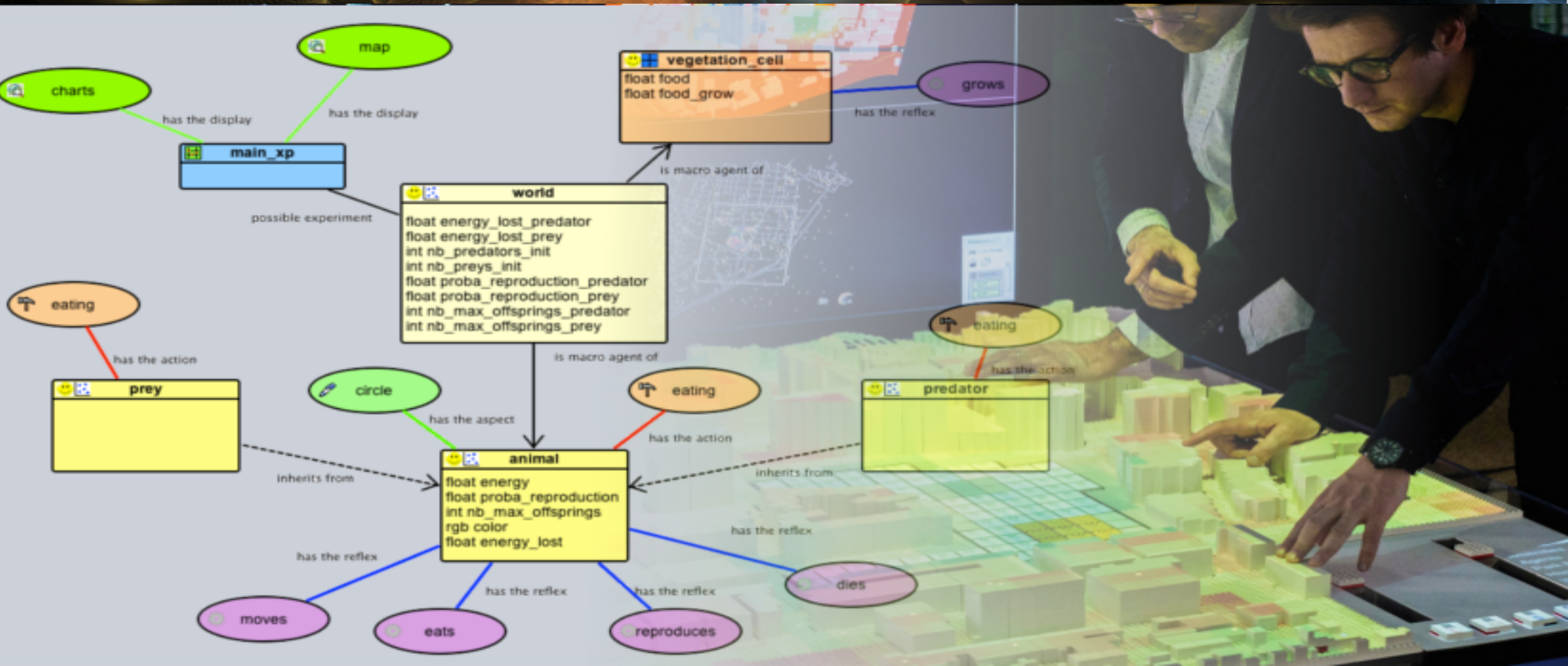


- The introduction of a new argument can have a strong impact on the adoption rate (here an example of a new argument against smart water meters concerning their reliability).



L Sadou, S Couture, R Thomopoulos, P Taillandier. Better representing the diffusion of innovation through the theory of planned behavior and formal argumentation, Social Simulation Conference, 2021.

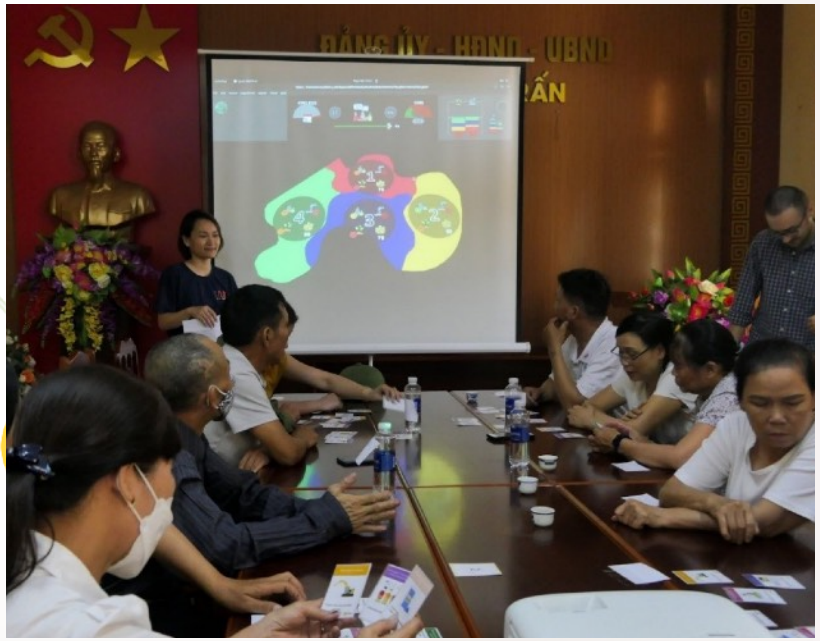
Participative simulation



RAC: A SERIOUS GAME TO PROMOTE COOPERATIVE SOLID WASTE MANAGEMENT

French National Research Institute for Sustainable Development

RAC IS SITUATED IN A FICTIONAL ENVIRONMENT



- 4 villages sharing the same irrigation system: farmers produce rice, inhabitants produce pollution, which is diffused along the canals, collected by the collectors, accumulated in soils…
- Players play the role of managers in each village and are asked to discuss and undertake some action(s) to collectively keep an *EcoLabel*
- They deliver the chosen actions in a virtual environment and observe their results during the next update of the environment.

SIMPLE

Innovating in the education to sustainable development

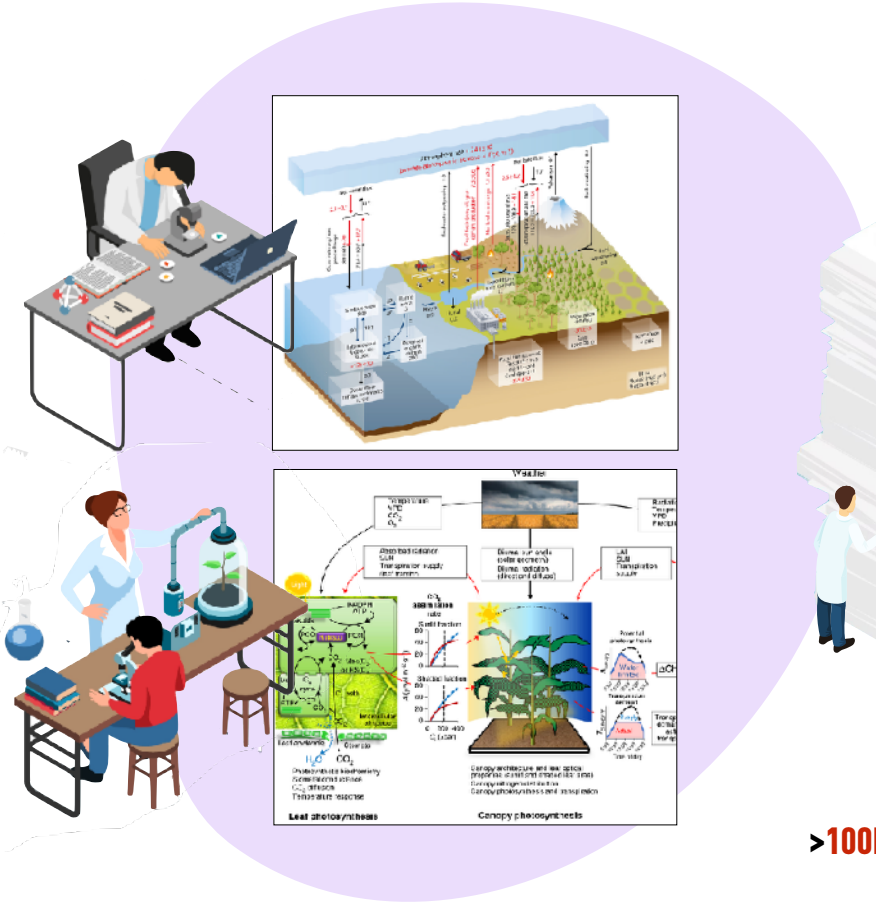
Co-funded by the European Union

Global Gateway

NSTDA

Institut de Recherche pour le Développement FRANCE

WHAT DOES THE KNOWLEDGE ON SUSTAINABLE DEVELOPMENT, MOSTLY DERIVED FROM SCIENTIFIC MODELS, BECOME ? WHO HAS ACCESS TO IT ?



= ?

>100K / YEAR OF ARTICLES PUBLISHED ON THESE SUBJECTS !

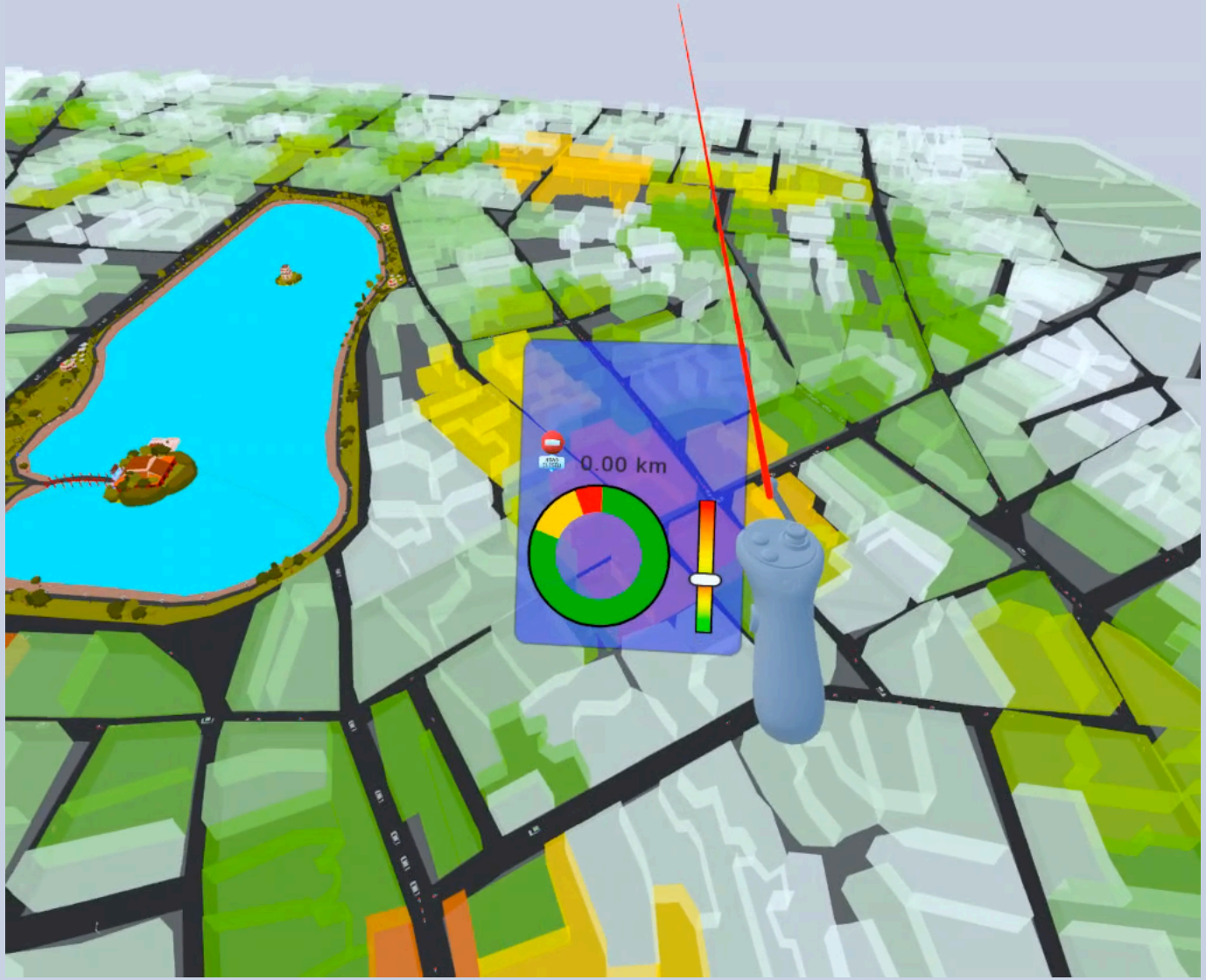
SIMPLE PROPOSES TO DESIGN VIRTUAL REALITY UNIVERSES TO GIVE EVERY CHILD ACCESS TO EVIDENCE-BASED KNOWLEDGE AND EXPERIENTIAL LEARNING ABOUT ENVIRONMENTAL ISSUES IN THE CLASSROOM

PROTOTYPE #1: RÁC VR, A SERIOUS GAME ON WASTE MANAGEMENT

- A fictional environment sporting 4 villages sharing an irrigation system: farmers produce rice, inhabitants produce pollution, diffused along the canals, collected by collectors, accumulated in soils…
- Players play the role of managers, discuss and undertake action(s) to collectively keep an *EcoLabel,* using cards and VR interactions

PROTOTYPE #2: HOAN KIEM AIR, MIXING PHYSICAL AND VIRTUAL INTERACTIONS

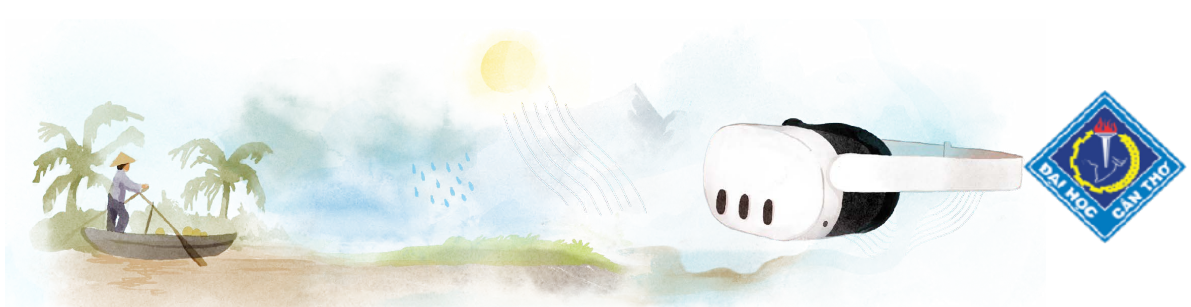
- An integrated model in GAMA and a mediation platform that can be used both to support policymakers' decisions and to raise awareness on the impact of creating pedestrian zones on traffic displacement and air pollution.



THE COUPLED SIMULATIONS AND VR UNIVERSES ARE ALREADY BEING TESTED IN CLASSROOMS IN VIETNAM AND THAILAND

- Robustness of the software framework is crucial for handling the VR universes to professors and making sure students can benefit from them.
- 6 more VR universes will be built using this framework and delivered in the next 3 years in Vietnam, Thailand, Laos and Cambodia

Active development of the two first virtual universes



Virtual activities (e.g. positioning dikes and pumps) to help children understand how to adapt and remediate to subsidence and climate change in the Vietnamese Mekong Delta

Virtual activities (e.g. collecting seeds) to help children understand how to protect and restore biodiversity and the balance of species in forests in Thailand.

Drogoul, A., Taillandier, P., Brugière, A., Martinez, L., Sillano, L., Lesquoy, B., & Nghi, H. Q (2024). Coupling Agent-Based Simulations and VR Universes: the Case of GAMA and Unity.

THANKS FOR YOUR ATTENTION!

Patrick TAILLANDIER

UR MIAT – INRAE