



# Knowledge and Distributed Artificial Intelligence for Smart and Cyber-physical Systems

Shanghai University - September 25, 2019

Prof.Dr. Stéphane GALLAND



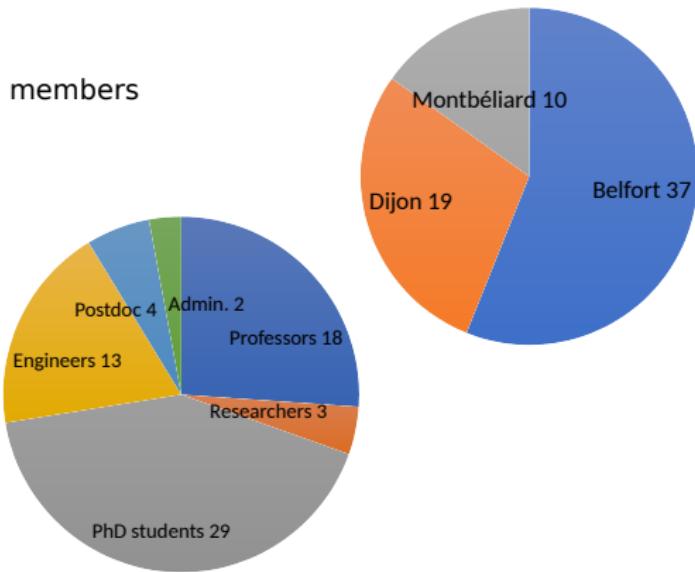
- 1 CIAD Laboratory in Brief**
- 2 Examples of Achievements**
- 3 Focus on the Drone Simulator**

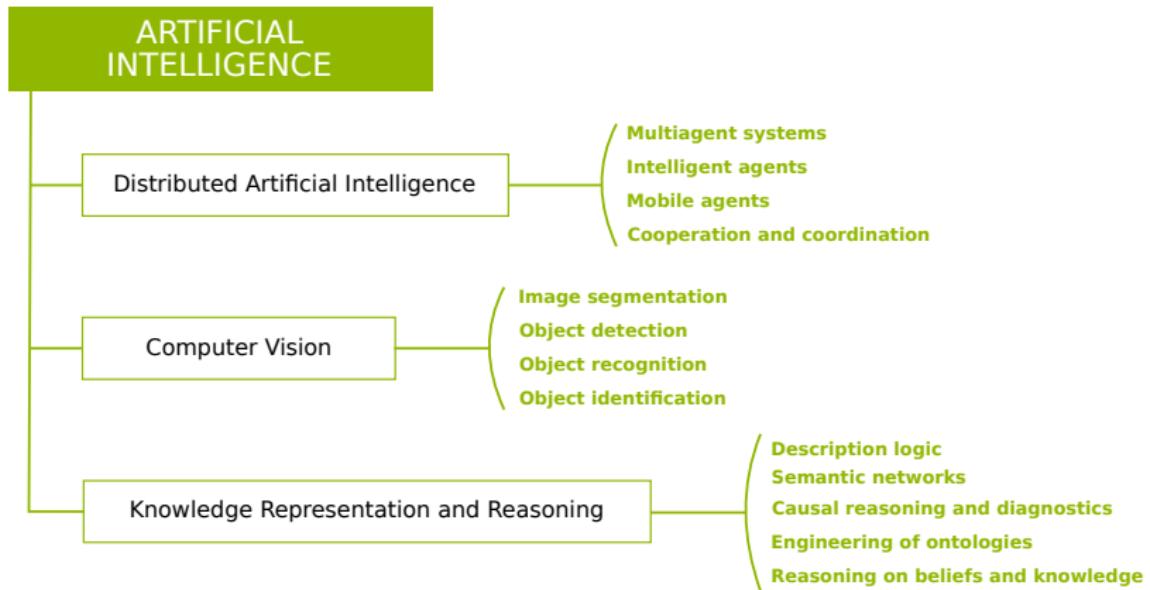


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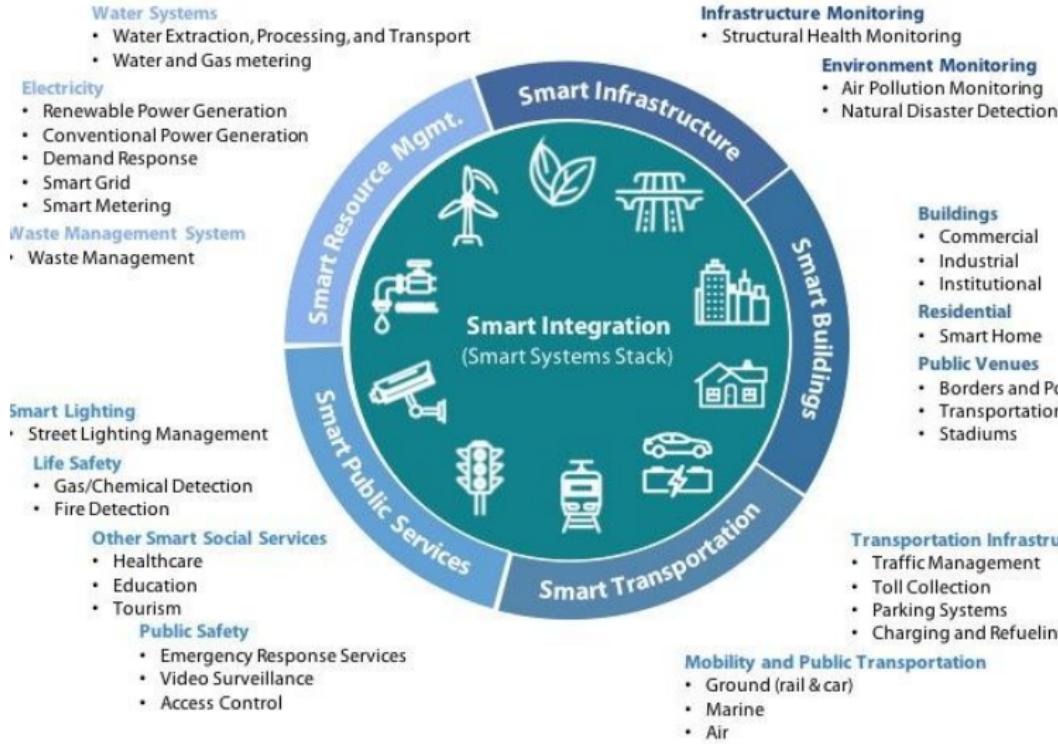
2 Universities, 3 cities, ~65 members







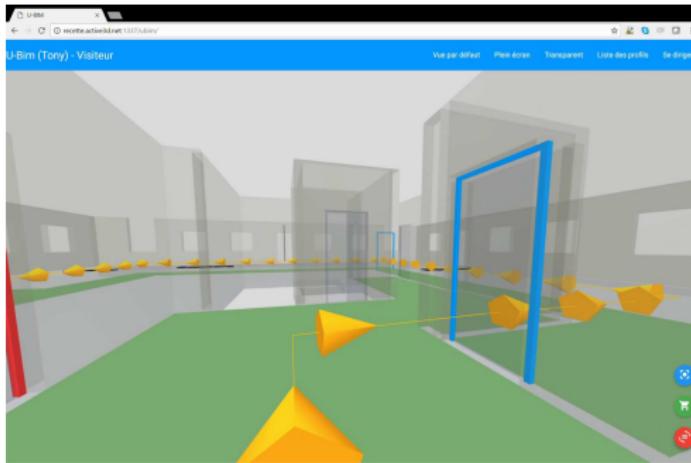
# APPLICATION DOMAINS





## Perception, qualification of knowledge veracity and value in a massive intelligent environment

- Extraction of knowledge from business know-how or multi-sensor/multi-source data
- Data analysis, probabilistic and belief function modeling, with ontological or multi-agent analysis



Video: EIMA tools by CIAD at UBM



## Distributed reasoning on the interoperability of heterogeneous information systems

- Multi-agent systems and reasoning formal systems
- Agent and Organizational software engineering (CRIOS metamodel, ASPECS methodology, SARL language, Janus platform)
- Application to cyber-physic systems



Video: Several projects done at CIAD at UTBM



## Prescriptive recommendation and simulation for complex and distributed systems

- Simulation models, usually multi-agent based simulation
- Modeling and simulation of complex systems:
  - organizational modeling (CRIo, ASPECS)
  - holonic multi-agent systems (SARL, Janus)



Video: Several projects done at CIAD at UTBM



# INDUSTRIAL PARTNERSHIP: A KEY CAPABILITY

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More than 26 projects with industrial partners across France and EU.

≈ 3000k€ (\$3300k) of cumulative budget over 5 years



Logos of the major partners of CIAD



## 1 CIAD Laboratory in Brief

## 2 Examples of Achievements

- Autonomous Car
- Automatic Generation of 3D Environments
- Video Analysis for Decision-Helping Tools
- Intelligent Systems for Activity Planning
- Interactive Systems for Knowledge Management
- Simulated Train
- Smart City Simulation

## 3 Focus on the Drone Simulator



# OUTLINE

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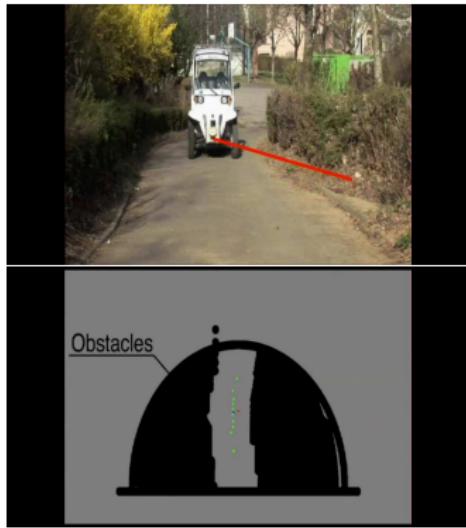
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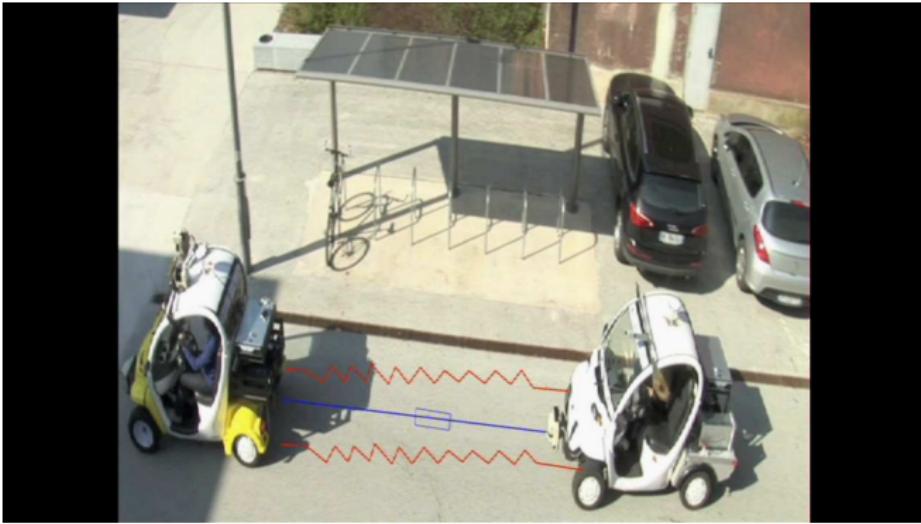
## 3 Focus on the Drone Simulator



- Laser-range sensing to build a map of the environment
- Intelligent agents decide together of the safest direction:
  - Repulsion from obstacles and other agents
  - Attraction by current command's point
- Safest direction = barycenter of the agents



- Follow another car without physical connection
- Physic-inspired model: virtual springs/dampers





- Identification of obstacles from sensing data
- Adaptative speed control
- Follow the trajectory of an target object, or GPS





- Wireless communication between vehicles
- Cooperative intersection management:right of way negotiation
- Proof done with 3 autonomous vehicles at ITSWS 2015





## 1 CIAD Laboratory in Brief

## 2 Examples of Achievements

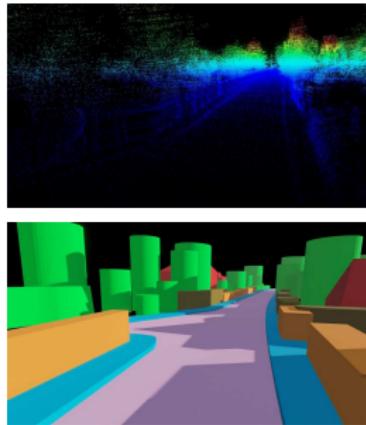
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## 3 Focus on the Drone Simulator



Construction of realistic informed 3D environments for simulation of cyber-physical systems

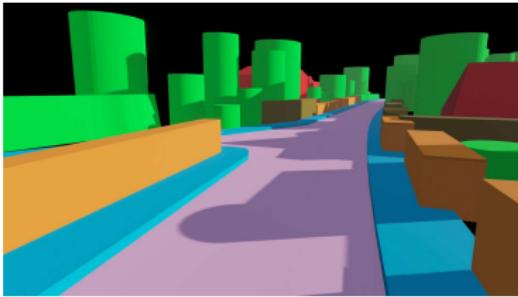
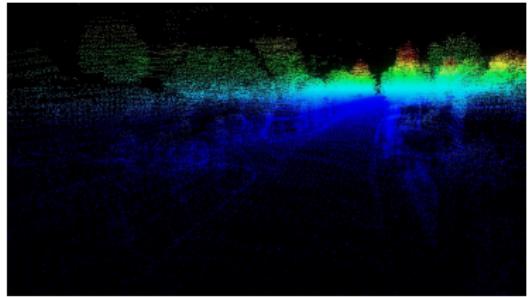
- Data collection from embedded sensors and IoT
- 3D model building from big and semantic data





# AUTOMATIC GENERATION OF URBAN ENVIRONMENT

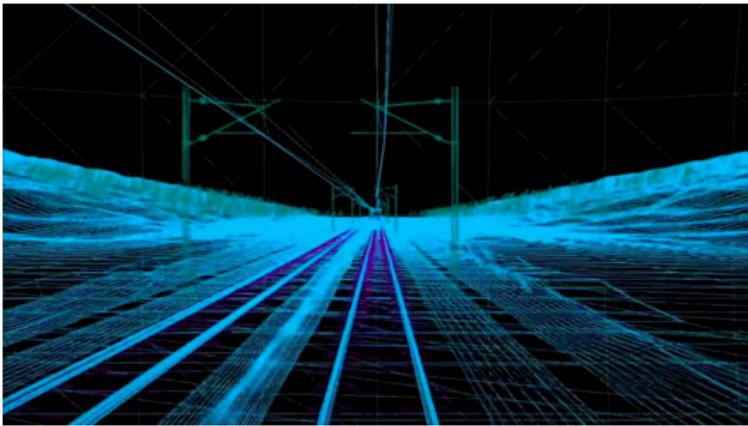
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**ALSTOM**

- Definition of railways in Excel document
- Ground definition in GIS
- Extraction and automatic generation of the 3D model (3D spline definition, railway shape extrusion)
- Optimized for realtime rendering





## 1 CIAD Laboratory in Brief

## 2 Examples of Achievements

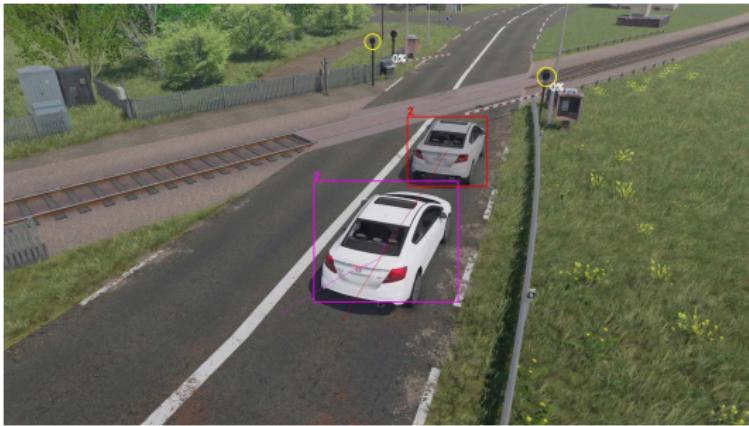
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Tool for monitoring and detecting divergent behaviors

- Video analysis from primitive detection
- Semantic and spatial qualification of the primitives
- Divergent behavior detection with deep learning





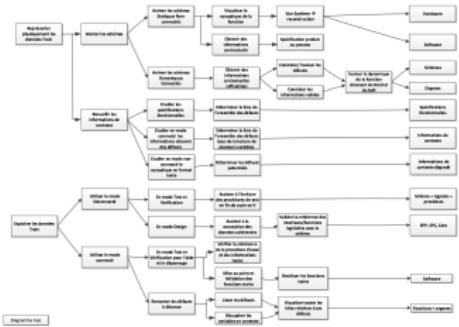
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## 3 Focus on the Drone Simulator

- Semantically enriched environment model
  - Activity planning in agents
  - Dynamic rescheduling based on incoming events
  - Short and long term recommendation by a multi-agent system





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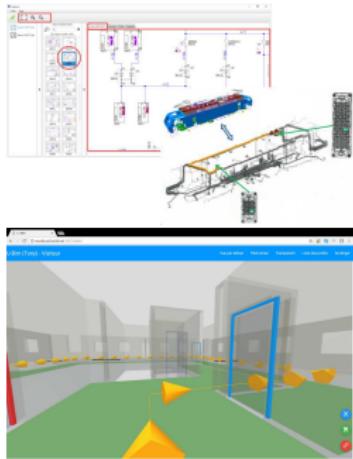


**ALSTOM**

Strasbourg.eu  
eurometropole

WITTYM

- Business know-how Modeling: ontology, knowledge database
- Interactive rendering of knowledge
- Predictive maintenance with intelligent agents



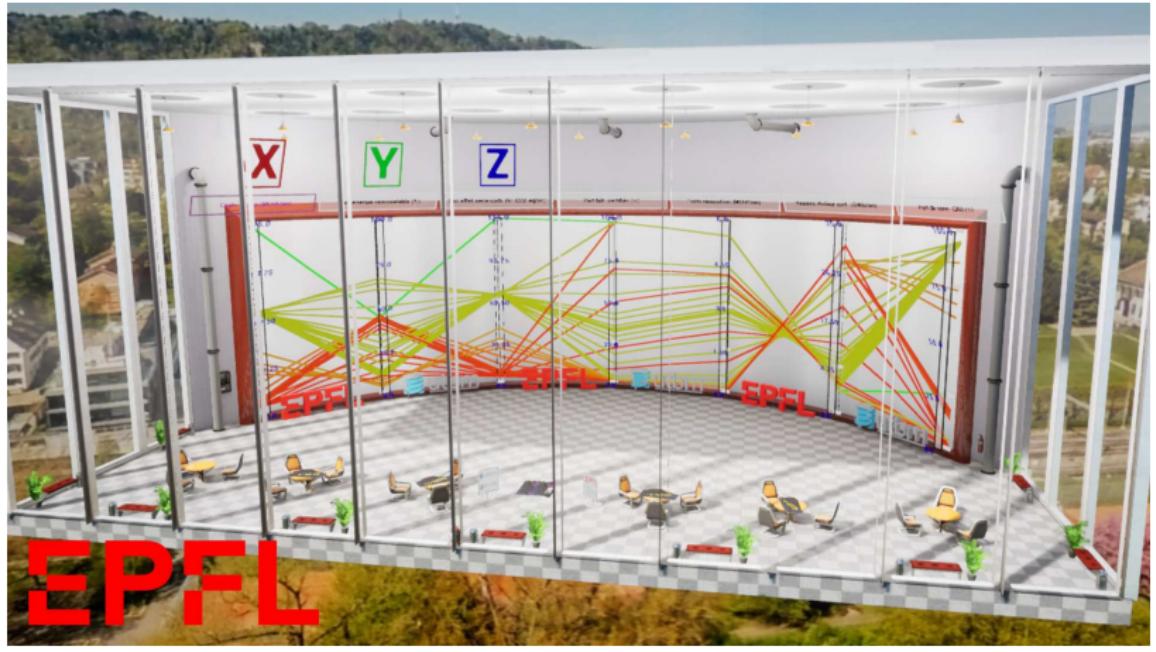
StrasView

Outil de présentation de projets urbains sur tablettes



# VIRTUAL REALITY FOR VIEWING BIG DATA FROM A SMART CITY

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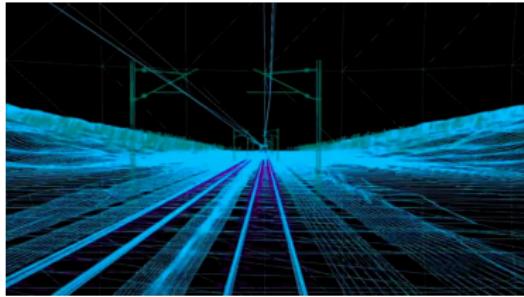
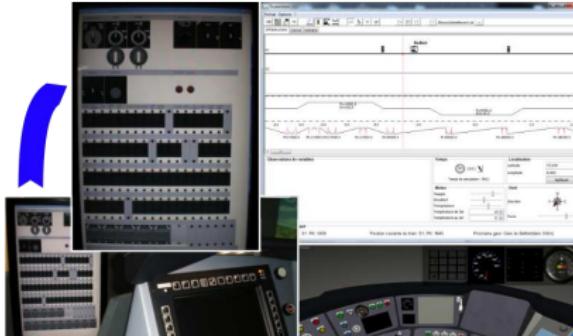
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## 3 Focus on the Drone Simulator



- How to validate the components of a train in different usage scenarios?
- Multiview model: mechanic, electronic, electric components
- Cyber-physical simulation: mixing virtual and real components
- Human in the loop: virtual reality platform, with haptic devices
- Serious game: definition of learning scenarios





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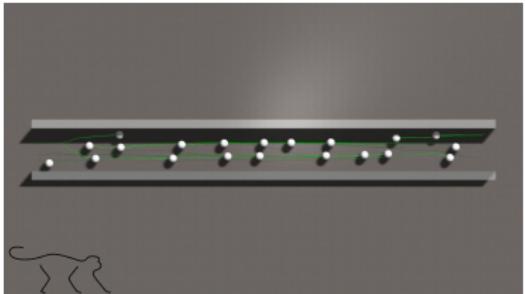
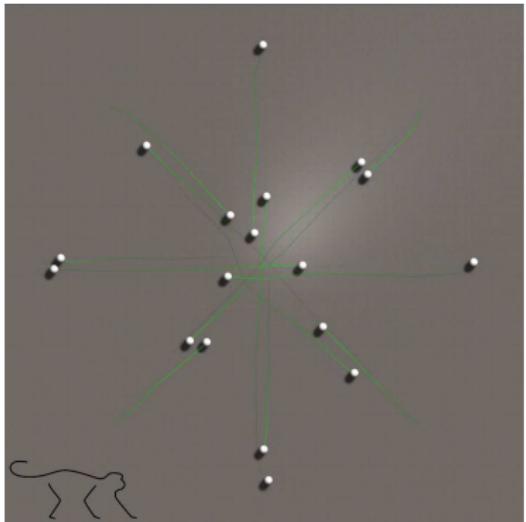
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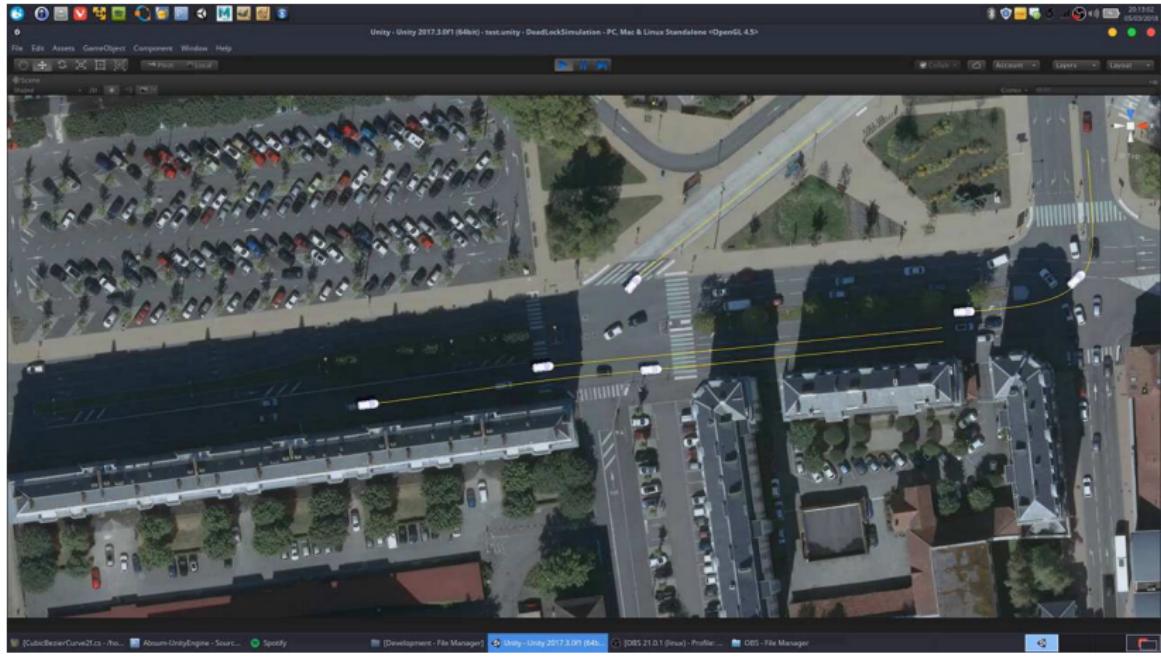
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## 3 Focus on the Drone Simulator



- How to simulation pedestrian motion at individual level?
- Social force model: repulsive and attractive forces
- Physic model of the pedestrian bodies

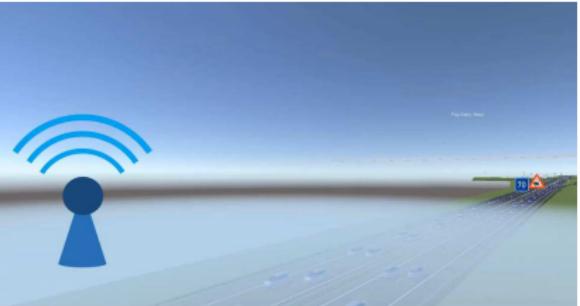
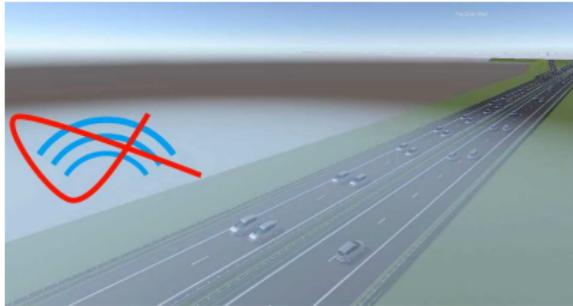




## Simulation of Lane Changing Behavior (Lombard, 2017)



Simulation of emergency situation on a  
french highway (Buisson, 2014)



Traffic and V2X simulation

Comparison between scenarios  
in fog situation

Simulation of fog situation in Qatar (Abbas-Turki, 2017)



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  - SARL and AirSim
  - Introducing a framework for agent-based simulation
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  - Results and Performance Benchmarks
  - Conclusion



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- 1 **Security and Privacy:** How to guarantee the security and confidentiality of information captured by drones?
- 2 **Safety:** How to guarantee the continuous and safe operation of drones?
- 3 **Traffic Regulation:** What are the regulations to implement? At what level (international, EU, national, local)?
- 4 **Traffic Management:** How to control the air traffic and its fluidity?
- 5 **Measuring the impact:** of drone introduction on socio-economic and environmental aspects .



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## Multiagent System in SARL

A collection of agents interacting together in a collection of shared distributed spaces.

### 4 main concepts

- Agent
- Capacity
- Skill
- Space

### 3 main dimensions

- **Individual:** the Agent abstraction (Agent, Capacity, Skill)
- **Collective:** the Interaction abstraction (Space, Event, etc.)
- **Hierarchical:** the Holon abstraction (Context)

**SARL: a general-purpose agent-oriented programming language.** Rodriguez, S., Gaud, N., Galland, S. (2014) Presented at the The 2014 IEEE/WIC/ACM International Conference on Intelligent Agent Technology, IEEE Computer Society Press, Warsaw, Poland. (Rodriguez, 2014)

<http://www.sarl.io>

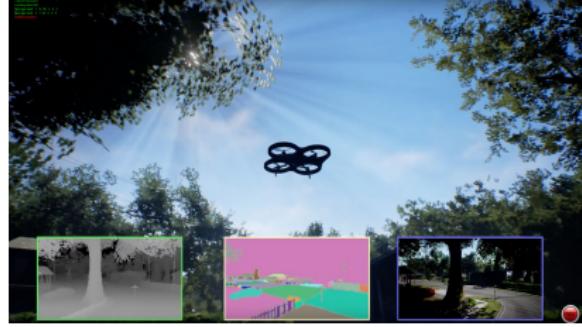


AirSim is:

an open-source simulation platform developed by Microsoft

## Major Characteristics

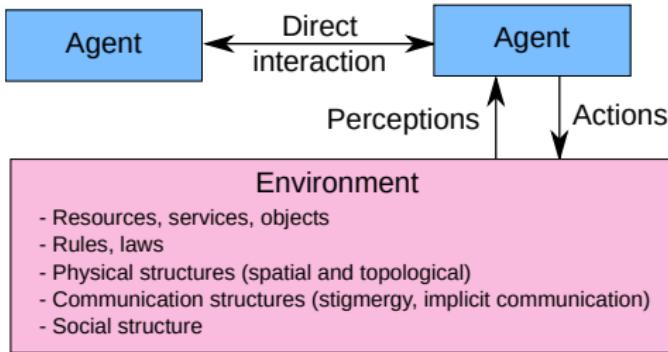
- Focuses on drone and car simulation.
- Manages the physics of the world.
- Simulates sensors, e.g. laser range finder.
- Provides an API to allow sending control commands to the vehicles.

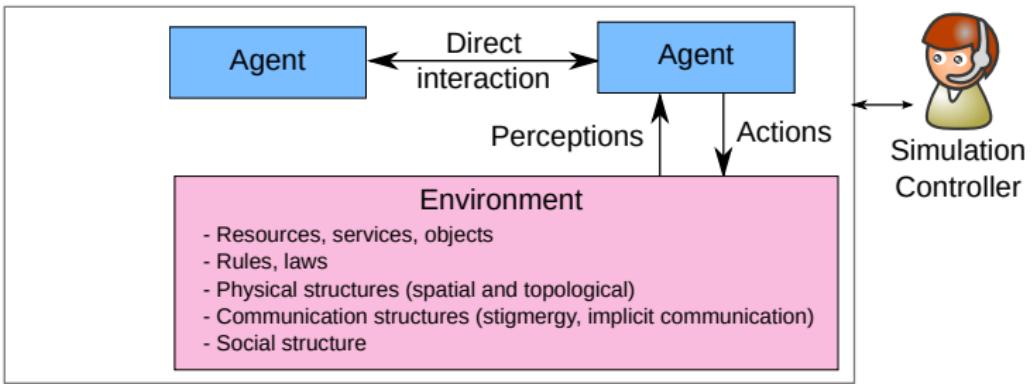




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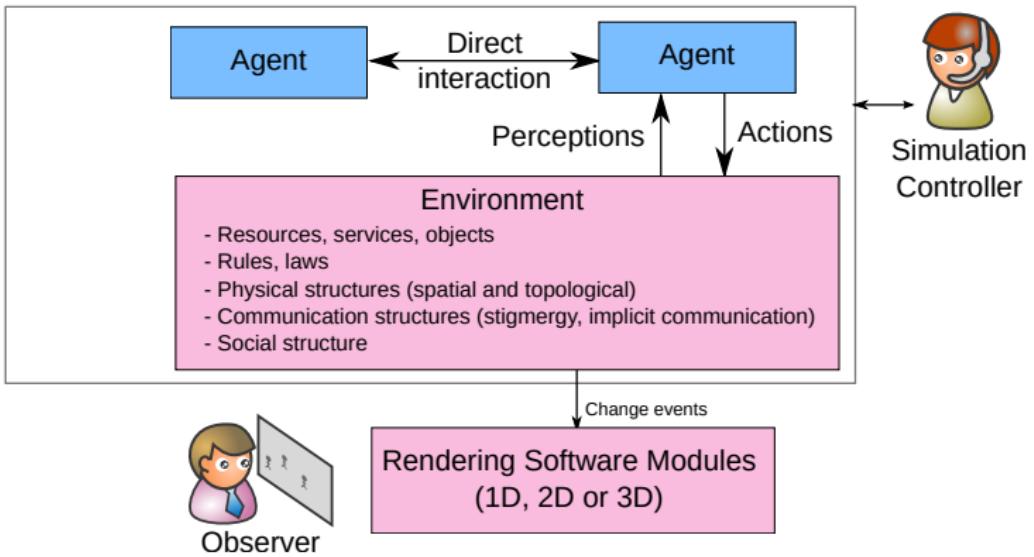
# GENERAL AGENT-BASED SIMULATION ARCHITECTURE





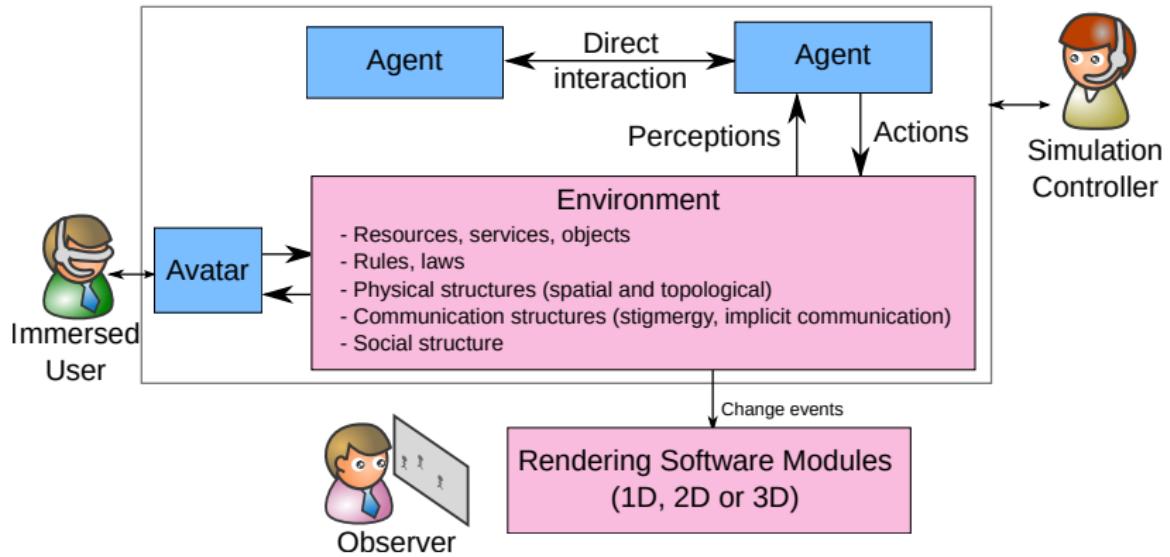
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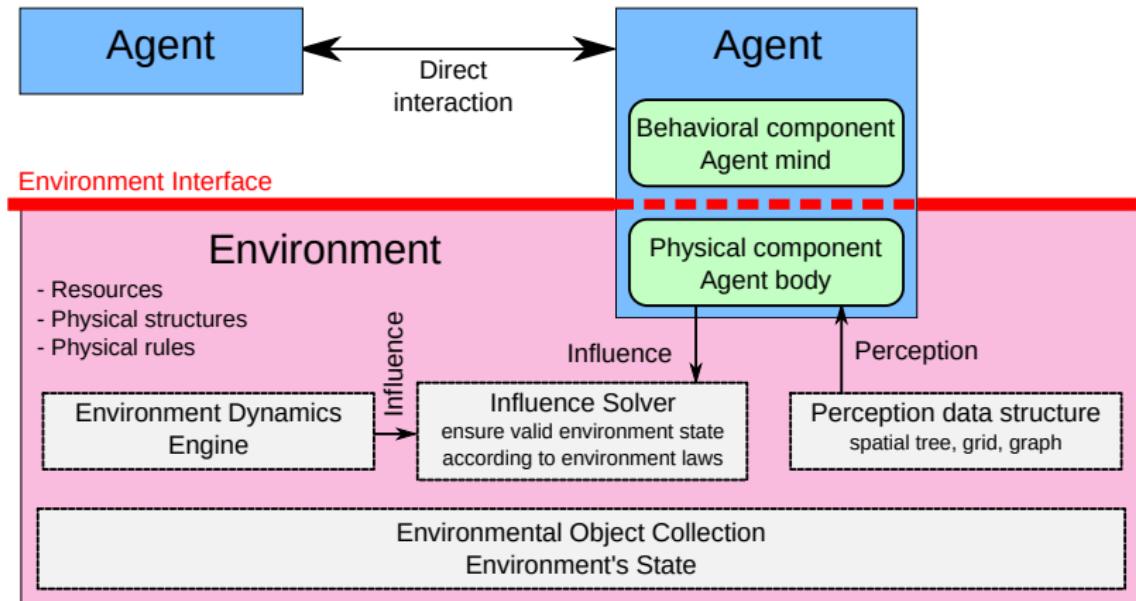
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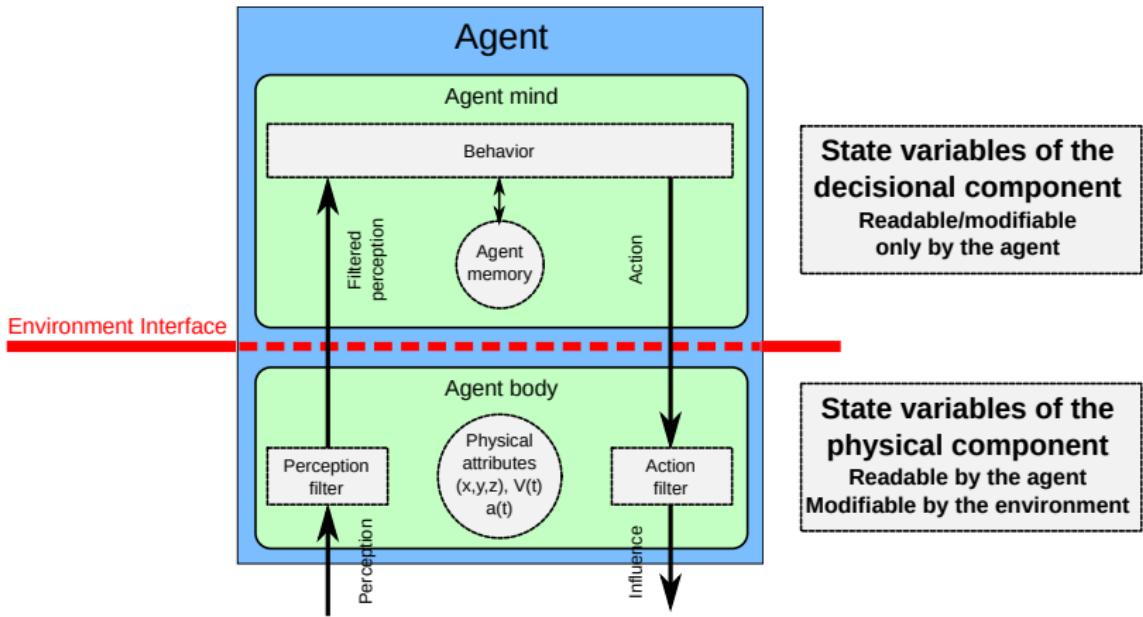




# SITUATED ENVIRONMENT MODEL

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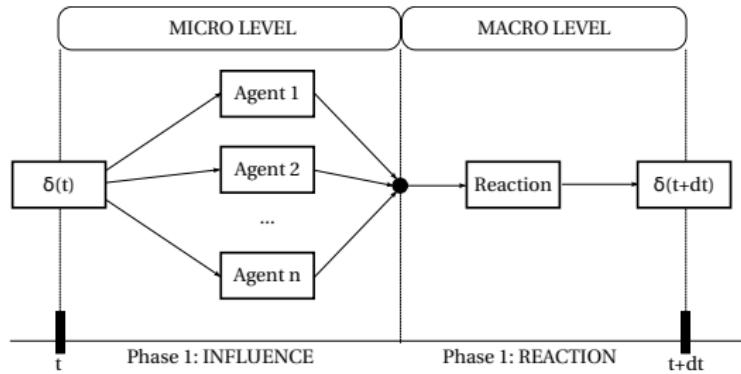


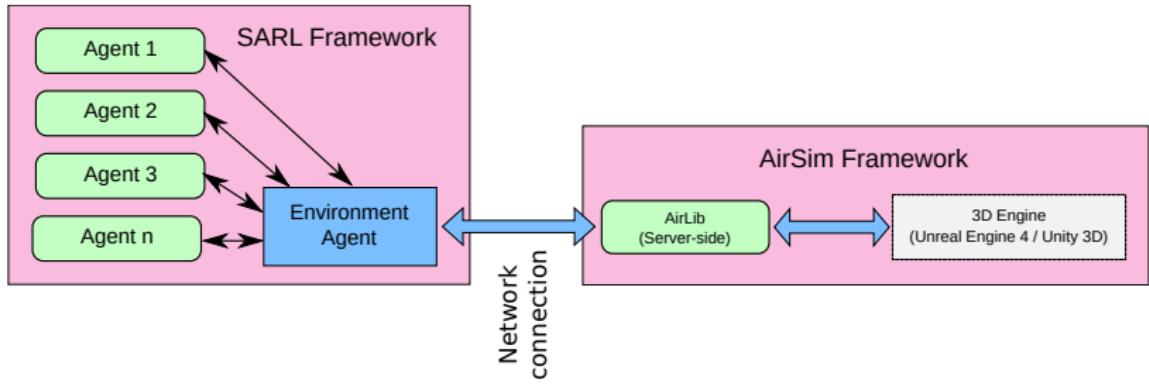




## How to support simultaneous actions from agents?

- 1 An agent does not change the state of the environment directly.
- 2 Agent gives a state-change expectation to the environment: the influence.
- 3 Environment gathers influences, and solves conflicts among them for obtaining its reaction.
- 4 Environment applies reaction for changing its state.







## 1 Link agents to vehicles:

- Receive the perceptions of each vehicle and dispatch them to linked agents
- Collect and transmit the influences from the agents to AirSim

## 2 Manage the simulation schedule



- The agent has the capacity to use its body.
- The body supports the interactions with the environment.

```
event Perception {  
    val object : Object  
    val relativePosition : Vector  
}  
  
capacity EnvironmentInteraction {  
    def moveTheBody(motion : Vector)  
    def move(object : Object,  
             motion : Vector)  
    def executeActionOn(object :  
                        UUID,  
                        actionName :  
                        String,  
                        parameters :  
                        Object*)  
}  
  
skill PhysicBody implements  
    EnvironmentInteraction {  
  
    val env : UUID  
    val body : UUID
```

```
def moveTheBody(motion:Vector) {  
    move(this.body, motion)  
}  
def move(object : UUID,  
         motion : Vector) {  
    emit(new MotionInfluence(  
        object, motion))  
    [UUID == this.env]  
}  
  
def executeActionOn(  
    object : UUID,  
    actionName : String,  
    parameters : Object*) {  
    emit(new ActionInfluence(  
        object, actionName,  
        parameters))  
    [UUID == this.env]  
}
```



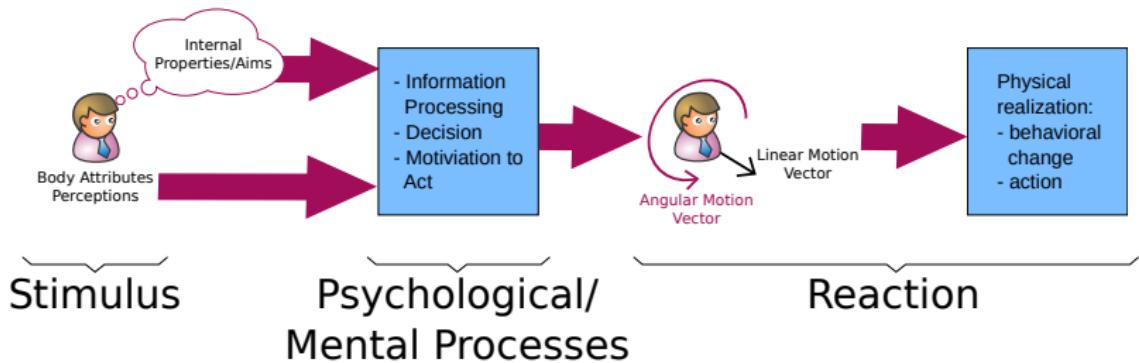
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- K. Lewin. “**Social fields (Social forces).**” Field Theory in Social Science, Harper & Brothers, New York, 1951.
  
- “A sensory **stimulus** causes a behavioral reaction that depends on the personal aims; and
- It is chosen from a set of behavioral alternatives with the objective of utility maximization.”

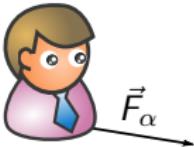


# SCHEMATIC REPRESENTATION





- The systematic temporal changes  $d\vec{w}_\alpha/dt$  of the preferred velocity  $\vec{w}_\alpha(t)$  of a drone  $\alpha$  are described by a vectorial quantity  $\vec{F}_\alpha(t)$ .

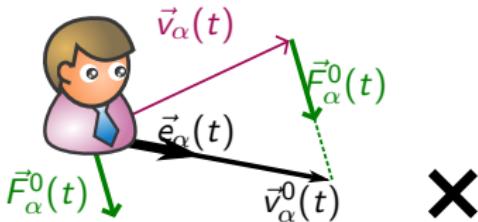


- This force represents the effect of the environment (e.g. other drones or borders) on the behavior of the described drone.
- It is a quantity that describes the concrete motivation to act.
- One can say that a drone acts as if it would be subject to external forces.



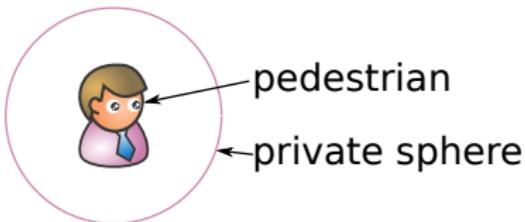
- If a drone's motion is not disturbed, it will walk into the desired direction  $\vec{r}_\alpha(t)$  with a certain desired speed  $v_\alpha^0$ .
- A deviation of the actual velocity  $\vec{v}_\alpha(t)$  to the desired velocity  $\vec{v}_\alpha^0(t) = v_\alpha^0 \vec{e}_\alpha(t)$  due to necessary deceleration processes or avoidance processes leads to a tendency to approach  $\vec{v}_\alpha^0(t)$  again within a certain relaxation time  $\tau_\alpha$ :

$$\vec{F}_\alpha^0(\vec{v}_\alpha, v_\alpha^0 \vec{e}_\alpha) = \frac{1}{\tau_\alpha} (\vec{v}_\alpha^0 \vec{e}_\alpha - \vec{v}_\alpha)$$





- The motion of a drone  $\alpha$  is influenced by other drones.
- It keeps a certain distance from other drones that depends on the drone density and the desired speed  $v_\alpha^0$ .
- The private sphere of each drone, which can be interpreted as territorial effect (Scheflen, 1976), plays an essential role.

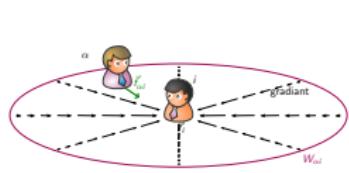
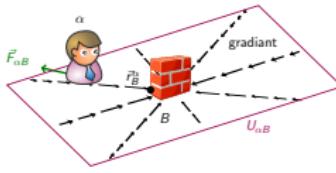
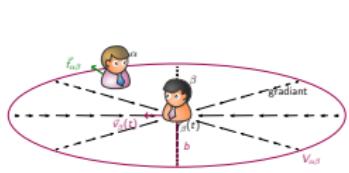


- A drone normally feels increasingly uncomfortable the closer another drone  $\beta$  is inside its private sphere.
- This results in repulsive effects of  $\beta$  that can be represented by vectorial quantities  $\vec{f}_{\alpha\beta}$ .



The total motivation of a drone is affected by

- Its acceleration term  $\vec{F}_\alpha^0(\vec{v}_\alpha, v_\alpha^0 \vec{e}_\alpha)$
- The repulsion from mobile objects
- The repulsion from immobile objects
- The attraction to other objects





- The total motivation for the drone  $\alpha$  is:

$$\vec{F}_\alpha(t) = \begin{aligned} & \vec{F}_\alpha^0(\vec{v}_\alpha, v_\alpha^0 \vec{e}_\alpha) && \text{acceleration term} \\ & + \sum_\beta \vec{F}_{\alpha\beta}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_\beta) && \text{mobile object repulsion term} \\ & + \sum_B \vec{F}_{\alpha B}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_B^\alpha) && \text{immobile object repulsion term} \\ & + \sum_i \vec{F}_{\alpha i}(\vec{e}_\alpha, \vec{r}_\alpha - \vec{r}_i, t) && \text{attraction term} \end{aligned}$$

- The social force model becomes:

$$\frac{d\vec{w}_\alpha}{dt} = \vec{F}_\alpha(t) + \text{fluctuations}$$

- The *fluctuation* term takes into account random variations of the behavior.



## Problems with the Social Force Model

- 1 Difficult to define the attraction term: what is the attraction length, regarding the repulsive terms?
- 2 It may be difficult to reproduce the smooth trajectories that are followed by real Humans.

Introduction of sliding forces that hide the attractive force, and make the trajectory smoother.



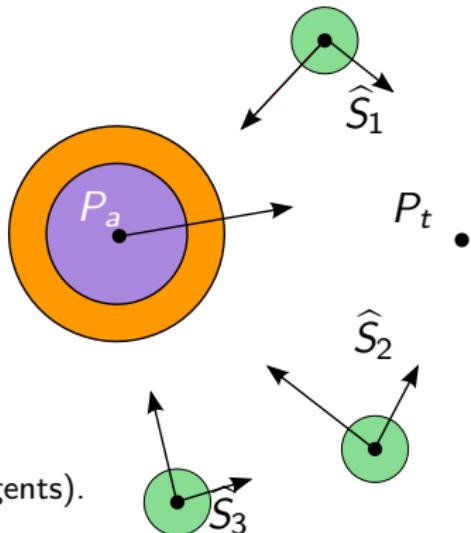
The force to apply to each agent is:

$$\vec{F}_a = \vec{F} + w_a \cdot \delta_{|0\vec{F}|0} \cdot (\widehat{p_t - p_a})$$

$$\vec{F} = \sum_{i \in M} U(t_c^i) \cdot \widehat{S_i}$$

where:

- $\vec{F}$  is the collision-avoidance force.
- $\widehat{S_i}$  is a sliding force.
- $t_c^i$  is the time to collision to object  $i$ .
- $U(t)$  is a scaling function of the time to collision.
- $M$  is the set objects around (including the other agents).
- $w_a$  is the weight of the attractive force.
- $\delta_x g$  is  $g$  if  $x \leq 0$ , 0 otherwise.

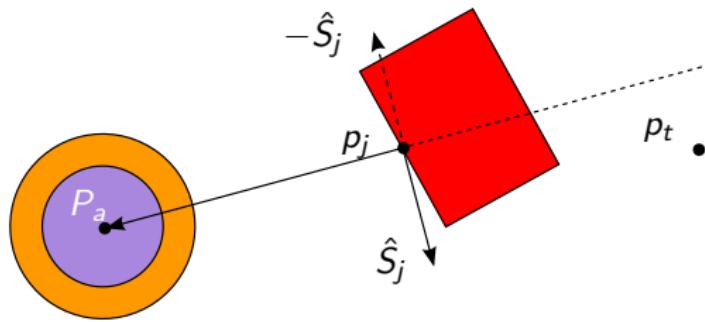




- The sliding force  $\vec{S}_j$  is:

$$\vec{s}_j = (p_j - p_a) \times \hat{y}$$

$$\hat{S}_j = \text{sign}(\vec{s}_j \cdot (\vec{p}_t - p_a)).\hat{s}_j$$



- $\hat{y}$  is the vertical unit vector.



- How to scale  $\hat{S}_j$  to obtain the repulsive force?
- Many force-based models use a monotonic decreasing function of the distance to an obstacle.
- But it does not support the velocity of the agent.
- Solution: Use time-based force scaling function.

$$U(t) = \begin{cases} \frac{\sigma}{t^\phi} - \frac{\sigma}{t_{max}^\phi} & \text{if } 0 \leq t \leq t_{max} \\ 0 & \text{if } t > t_{max} \end{cases}$$

where:

- $t$  is the estimated time to collision.
- $t_{max}$  is the maximum anticipation time.
- $\sigma$  and  $\phi$  are constants, such that  $U(t_{max}) = 0$

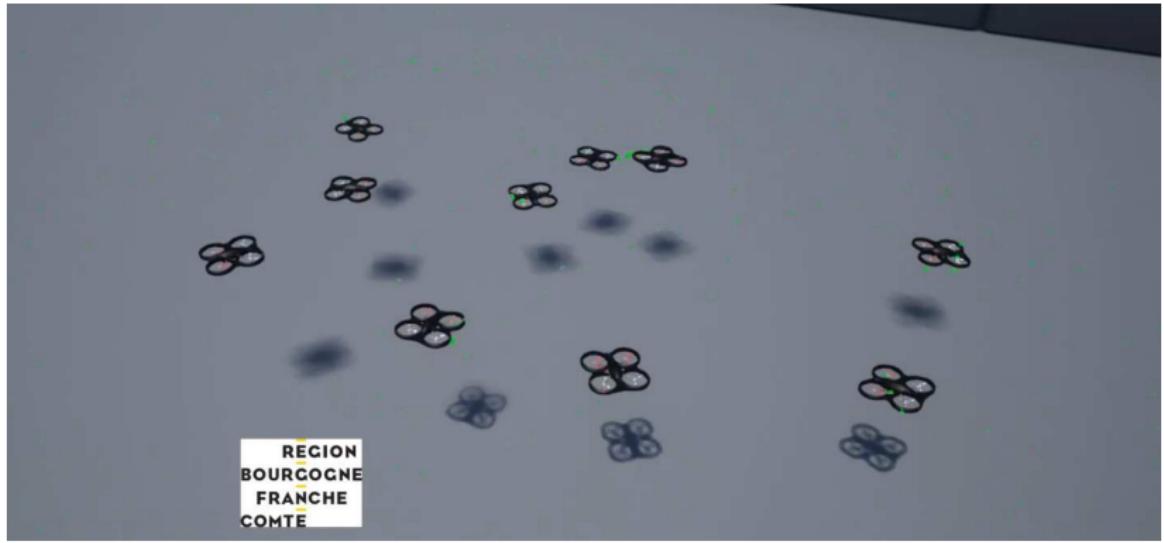


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- Simulations can run in real-time with up to 50 drones (30 FPS on a good PC)
- The current bottleneck is AirSim
- It is still possible to increase the amount of drones (but it will not be in real-time anymore)
- There is on-going work made to improve AirSim efficiency for multi-agents simulations



- 1 CIAD Laboratory in Brief**
- 2 Examples of Achievements**
- 3 Focus on the Drone Simulator**
  - Context
  - SARL and AirSim
  - Introducing a framework for agent-based simulation
  - Defining Collision Avoidance Behavior
  - Results and Performance Benchmarks
  - Conclusion



- 1 Create autonomous drones that will be used by CIAD in EU
- 2 Use the CIAD simulator for validated the drones of SHU. Inputs are:
  - model of the physic behavior of the drone (include the low level control algorithm)
  - model of sensors that are embedded
  - 3D model of the drone
- 3 Create collaborative drones, or swarm of drones:
  - use the agent layer
- 4 Extend the SARN language in order to include embedded system and real-time constraints





# Knowledge and Distributed Artificial Intelligence for Smart and Cyber-physical Systems

Shanghai University - September 25, 2019

Prof.Dr. Stéphane GALLAND



# Appendix



# HOW TO USE THE UAV SIMULATOR?



Installation Process: download and install

- 1 Unity 3D<sup>a</sup> or Unreal Engine<sup>b</sup>
- 2 AirSim<sup>c</sup>
- 3 Java 1.8 Standard Development Kit
- 4 SARL Development Environment<sup>d</sup>
- 5 AirSim-to-Java wrapper<sup>e</sup>
- 6 SARL program<sup>f</sup> with agents linked to AirSim

<sup>a</sup><https://unity.com>

<sup>b</sup><https://www.unrealengine.com>

<sup>c</sup><https://github.com/Microsoft/AirSim>

<sup>d</sup><http://www.sarl.io>

<sup>e</sup><https://github.com/alexandrelombard/airsim-jvm-api>

<sup>f</sup><https://github.com/alexandrelombard/sarl-airsim-interface>

Adapt to your application

Update the code of the later in the SARL environment



*Full Professor*

Co-founder and Deputy Director of the CIAD Laboratory  
Université de Technologie de Belfort-Montbéliard, France



**Topics: Multiagent systems, Agent-based simulation, Agent-oriented software engineering, Mobility and traffic modeling**

Web page: [http://www.multiagent.fr/People:Galland\\_stephane](http://www.multiagent.fr/People:Galland_stephane)  
Email: [stephane.galland@utbm.fr](mailto:stephane.galland@utbm.fr)

Open-source contributions:

- <http://www.sarl.io>
- <http://www.janusproject.io>
- <http://www.aspecs.org>
- <http://www.arakhne.org>
- <https://github.com/gallandarakhneorg/>



# OUTLINE

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