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

Shanghai University - September 25, 2019

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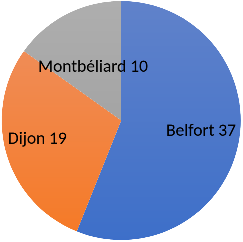
OUTLINE

OUTLINE

Connaissance et Intelligence Artificielle Distribuées

2 Universities, 3 cities, ~65 members



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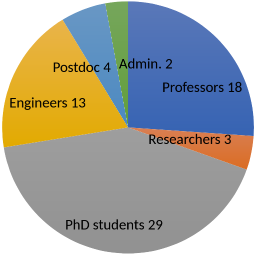


SCIENTIFIC FIELDS

ARTIFICIAL INTELLIGENCE

- **Distributed Artificial Intelligence**
  - Multiagent systems
  - Intelligent agents
  - Mobile agents
  - Cooperation and coordination
- **Computer Vision**
  - Image segmentation
  - Object detection
  - Object recognition
  - Object identification
- **Knowledge Representation and Reasoning**
  - Description logic
  - Semantic networks
  - Causal reasoning and diagnostics
  - Engineering of ontologies
  - Reasoning on beliefs and knowledge

APPLICATION DOMAINS

Water Systems
- Water Extraction, Processing, and Transport
- Water and Gas metering

Electricity
- Renewable Power Generation
- Conventional Power Generation
- Demand Response
- Smart Grid
- Smart Metering

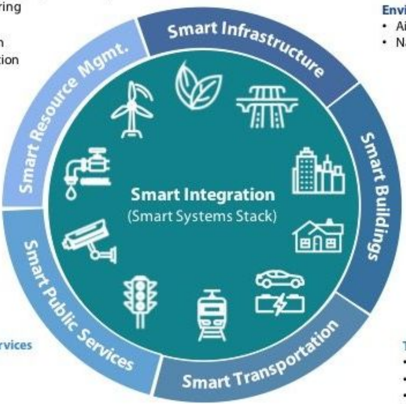
Waste Management System
- Waste Management

Smart Lighting
- Street Lighting Management

Life Safety
- Gas/Chemical Detection
- Fire Detection

Other Smart Social Services
- Healthcare
- Education
- Tourism

Public Safety
- Emergency Response Services
- Video Surveillance
- Access Control



Infrastructure Monitoring
- Structural Health Monitoring

Environment Monitoring
- Air Pollution Monitoring
- Natural Disaster Detection

Buildings
- Commercial
- Industrial
- Institutional

Residential
- Smart Home

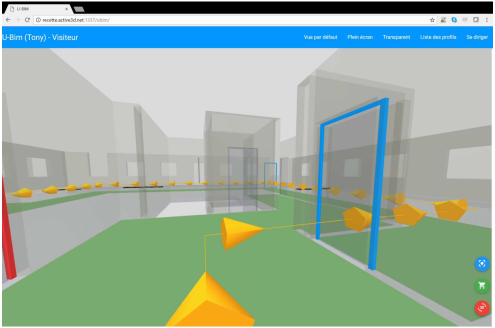
Public Venues
- Borders and Ports of Entry
- Transportation Venues
- Stadiums

Transportation Infrastructure
- Traffic Management
- Toll Collection
- Parking Systems
- Charging and Refueling

Mobility and Public Transportation
- Ground (rail & car)
- Marine
- Air

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



Distributed reasoning on the interoperability of heterogeneous information systems

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

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)

INDUSTRIAL PARTNERSHIP: A KEY CAPABILITY

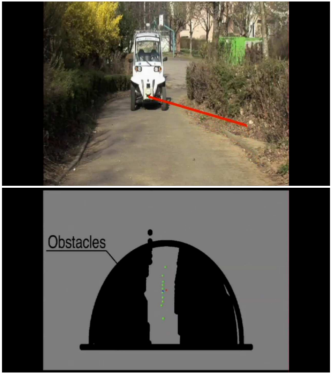
More than 26 projects with industrial partners across France and EU.

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

OUTLINE

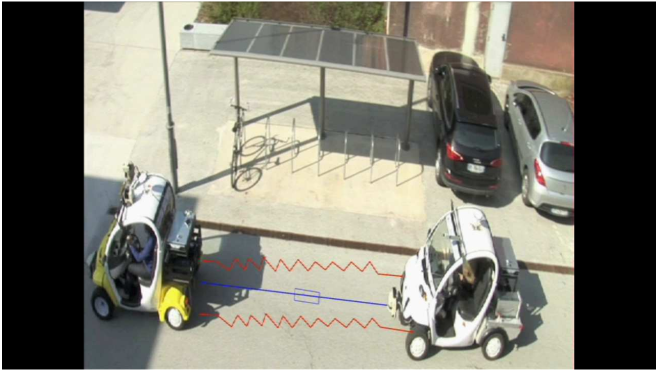
AUTONOMOUS CAR: AGENT-ORIENTED CONTROL

- 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



AUTONOMOUS CAR: PHYSIC-INSPIRED PLATOONING

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



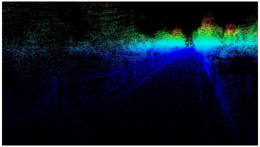
- Identification of obstacles from sensing data
- Adaptative speed control
- Follow the trajectory of an target object, or GPS

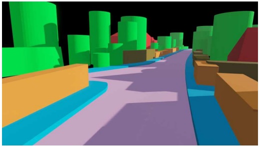
- Wireless communication between vehicles
- Cooperative intersection management:right of way negotiation
- Proof done with 3 autonomous vehicles at ITSWS 2015

AUTOMATIC GENERATION OF 3D MODELS

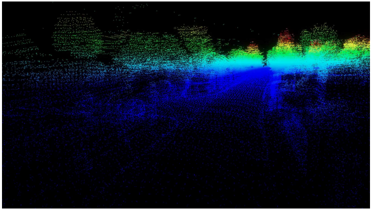
Construction of realistic informed 3D environments for simulation of cyber-physical systems

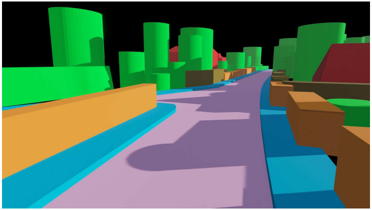
- Data collection from embedded sensors and IoT
- 3D model building from big and semantic data





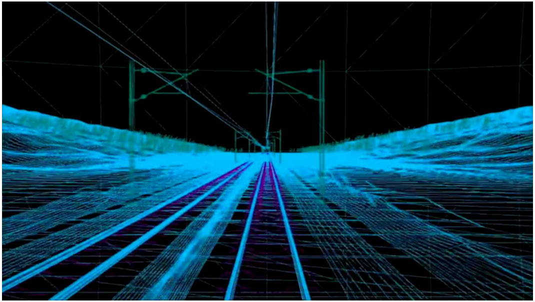
AUTOMATIC GENERATION OF URBAN ENVIRONMENT





ALSTOM

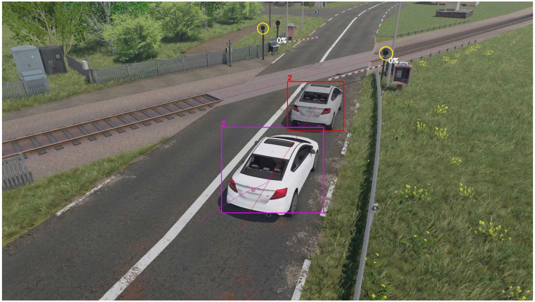
- Definition of railways in Excel document
- Ground definition in GIS
- Extraction and automatic generation of the 3D model (3D spline definition, railway shape extrusion)
- Optimized for realtime rendering



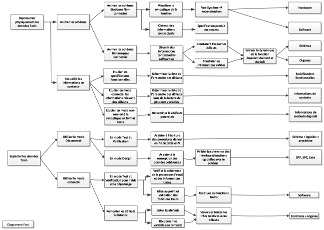
OUTLINE

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

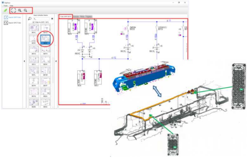


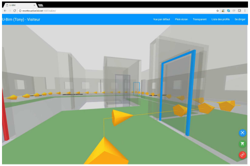
- Semantically enriched environment model
- Activity planning in agents
- Dynamic rescheduling based on incoming events
- Short and long term recommendation by a multi-agent system



OUTLINE

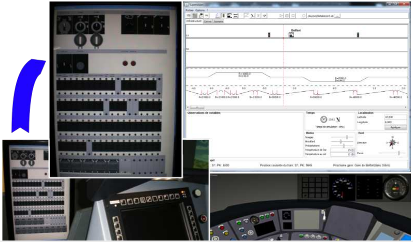
- Business know-how Modeling: ontology, knowledge database
- Interactive rendering of knowledge
- Predictive maintenance with intelligent agents

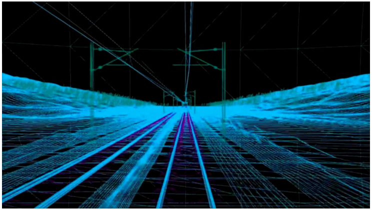




OUTLINE

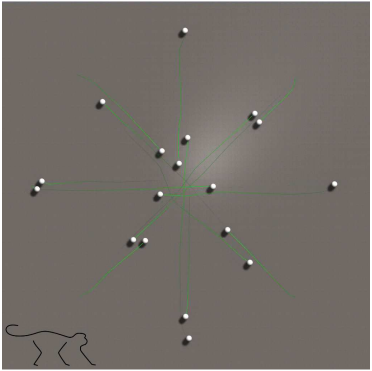
- How to validate the components of a train in different usage scenarios?
- Multiview model: mechanic, electronic, electric components
- Cyber-physical simulation: mixing virtual and real components
- Human in the loop: virtual reality platform, with haptic devices
- Serious game: definition of learning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

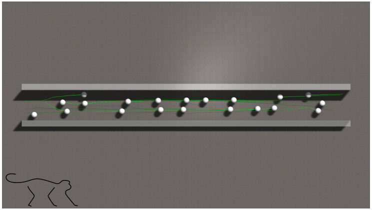




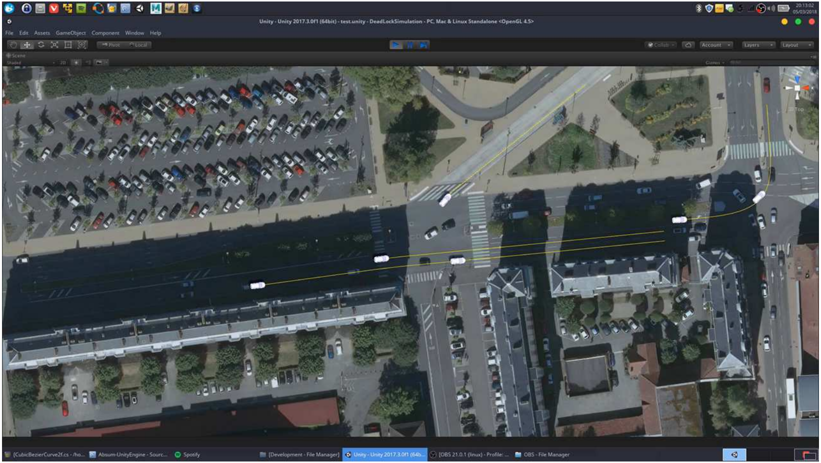
OUTLINE

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



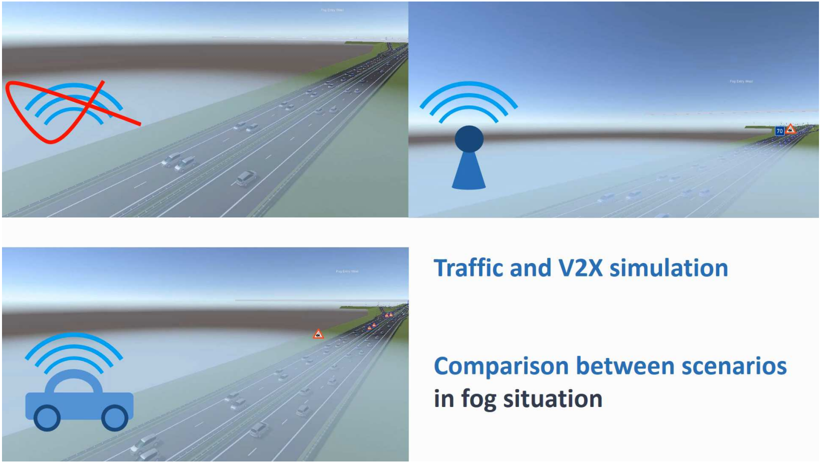


CHANGE LANE SIMULATION



Simulation of Lane Changing Behavior (Lombard, 2017)

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



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

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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)

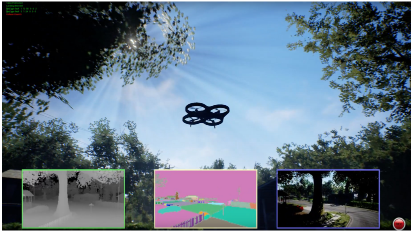
`http://www.sarl.io`

AirSim is:

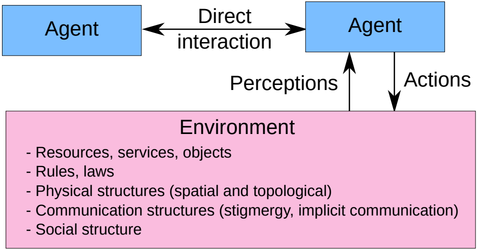
an open-source simulation platform developed by Microsoft

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.

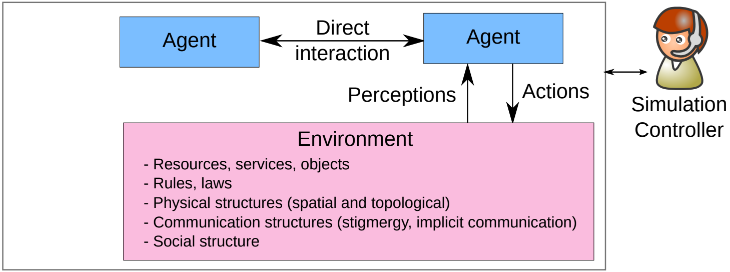


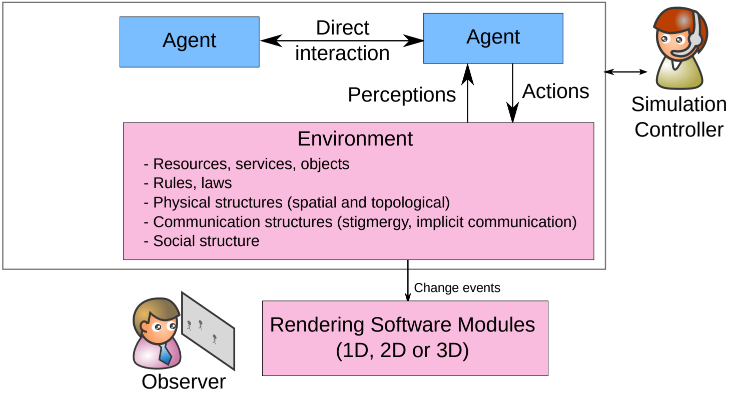
https://github.com/Microsoft/AirSim



Agent
Direct
interaction
Agent
Perceptions
Actions
Environment
- Resources, services, objects
- Rules, laws
- Physical structures (spatial and topological)
- Communication structures (stigmergy, implicit communication)
- Social structure

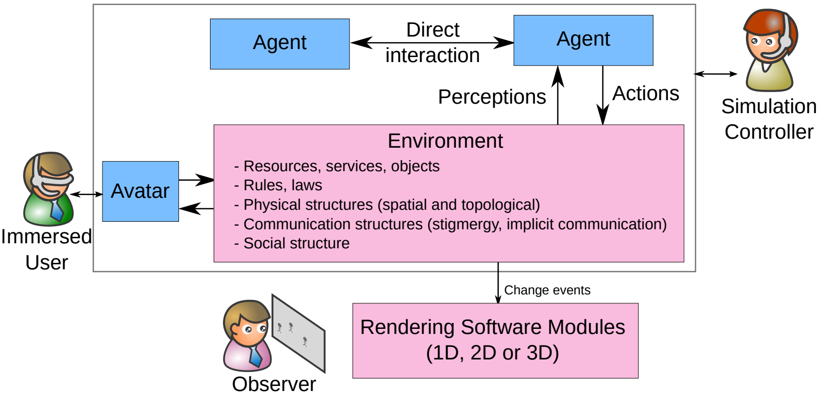
GENERAL AGENT-BASED SIMULATION ARCHITECTURE

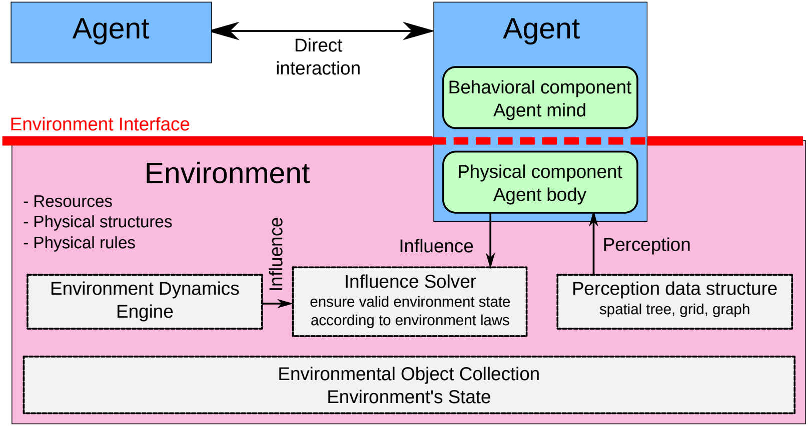




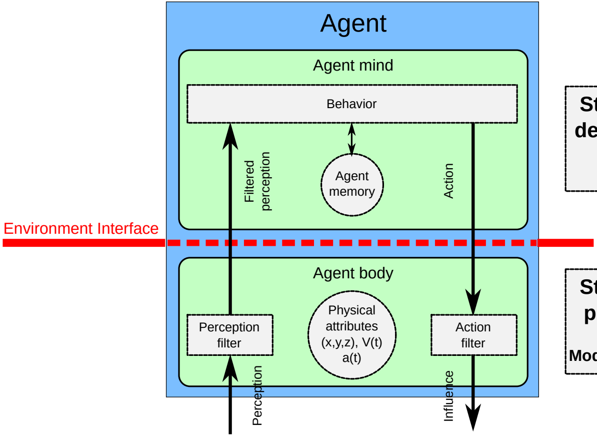
Agent
Direct interaction
Agent
Perceptions
Actions
Environment
- Resources, services, objects
- Rules, laws
- Physical structures (spatial and topological)
- Communication structures (stigmergy, implicit communication)
- Social structure
Simulation Controller
Change events
Rendering Software Modules (1D, 2D or 3D)
Observer

GENERAL AGENT-BASED SIMULATION ARCHITECTURE





Galland (2009)



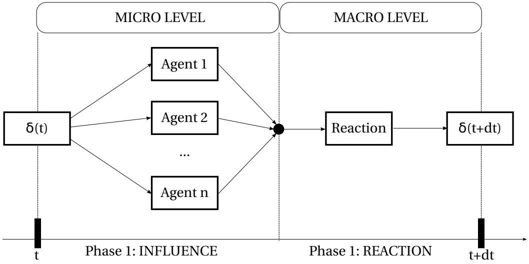
State variables of the decisional component
Readable/modifiable only by the agent

State variables of the physical component
Readable by the agent
Modifiable by the environment

Galland (2009)

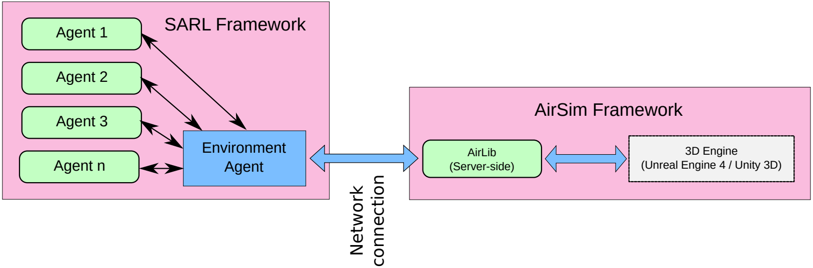
How to support simultaneous actions from agents?

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.



Michel (2007)

SARL-AIRSIM ARCHITECTURE



ROLE OF THE ENVIRONMENT AGENT

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

BODY MANAGEMENT CAPACITY

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

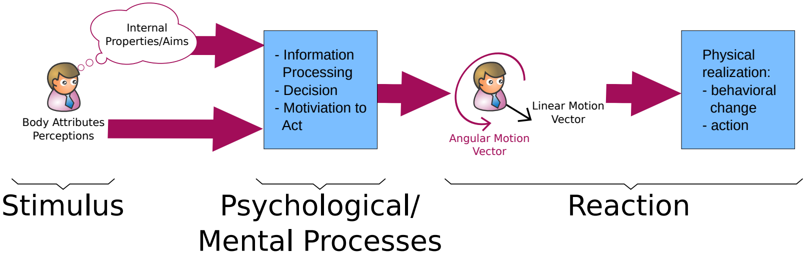
```
event Perception {
  val object : Object
  val relativePosition : Vector
}

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]
  }
}
```

Galland (2015)

OUTLINE

- K. Lewin. "Social fields (Social forces)." Field Theory in Social Science, Harper & Brothers, New York, 1951.

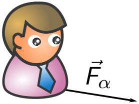
- "A sensory stimulus causes a behavioral reaction that depends on the personal aims; and
- It is chosen from a set of behavioral alternatives with the objective of utility maximization."



Internal Properties/Aims
Body Attributes Perceptions
- Information Processing
- Decision
- Motiviation to Act
Angular Motion Vector
Linear Motion Vector
Physical realization:
- behavioral change
- action
Stimulus
Psychological/ Mental Processes
Reaction

Lewin (1951)

- The systematic temporal changes $d\vec{w}_\alpha/dt$ of the preferred velocity $\vec{w}_\alpha(t)$ of a drone α 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.

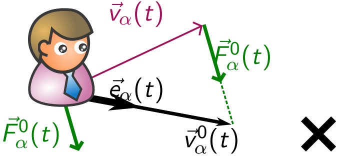
- One can say that a drone acts as if it would be subject to external forces.

Helbing (1997)

- 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_α^0.

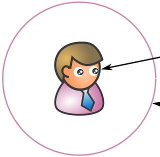
- A deviation of the actual velocity $\vec{v}_\alpha(t)$ to the desired velocity $\vec{v}_\alpha^0(t) = v_\alpha^0 \vec{e}_\alpha(t)$ due to necessary deceleration processes or avoidance processes leads to a tendency to approach $\vec{v}_\alpha^0(t)$ again within a certain relaxation time τ_α:

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



Helbing (1997)

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

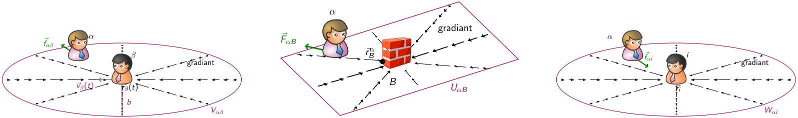


- A drone normally feels increasingly incomfortable the closer another drone β is inside its private sphere.
- This results in repulsive effects of β that can be represented by vectorial quantities $\vec{f}_{\alpha\beta}$.

Helbing (1997)

The total motivation of a drone is affected by

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



Helbing (1997)

- The total motivation for the drone α is:

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

- The social force model becomes:

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

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

Helbing (1997)

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.

Buisson (2013)

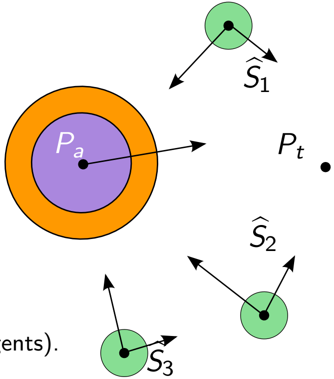
The force to apply to each agent is:

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

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

where:

- $\vec{F}$ is the collision-avoidance force.
- $\hat{S}_i$ 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.



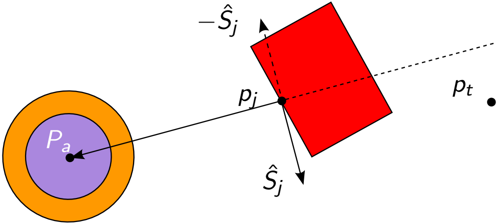
Buisson (2013)

SLIDING FORCE

- The sliding force $\vec{S_i}$ is:

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

$$\hat{S}_j = \text{sign}(\vec{s_j} \cdot (\vec{p_t} - p_a)).\widehat{s_j}$$



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

Buisson (2013)

SCALING THE SLIDING FORCE

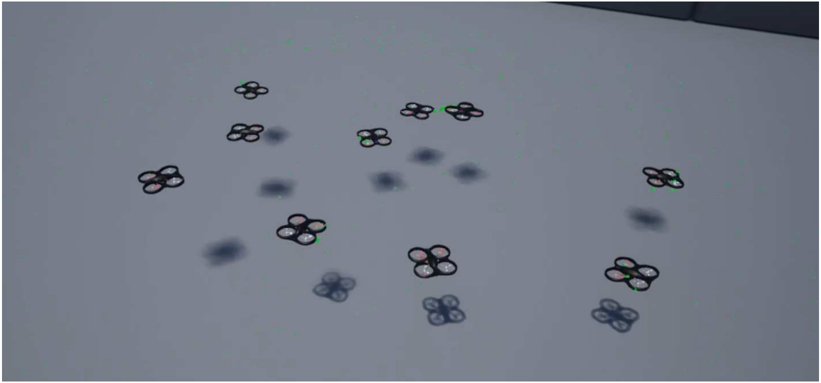
- How to scale $\hat{S}_j$ to obtain the repulsive force?
- Many force-based models use a monotonic decreasing function of the distance to an obstacle.
- But it does not support the velocity of the agent.
- Solution: Use time-based force scaling function.

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

where:
- t is the estimated time to collision.
- t_{max} is the the maximum anticipation time.
- σ and ϕ are constants, such that $U(t_{max}) = 0$

Buisson (2013)

OUTLINE



PERFORMANCE BENCHMARKS

- 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

OUTLINE

HOW TO USE THIS SIMULATOR?

Installation Process: download and install

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

[a] https://unity.com
[b] https://www.unrealengine.com
[c] https://github.com/Microsoft/AirSim
[d] http://www.sarl.io
[e] https://github.com/alexandrelombard/airsim-jvm-api
[f] https://github.com/alexandrelombard/sarl-airsim-interface

Adapt to your application

Update the code of the later in the SARL environment

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Appendix

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

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Open-source contributions:

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

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