# 1. Research activity

In this section I will detail my activity research which has started at the Gipsa-laboratory, in France. I will begin by presenting my research contribution during my Internship for the master validation, followed by the main research activities I have done during my PhD thesis. The last part will be dedicated to the recent research activity in transportation Systems as an Assistant Professor at the ERPI laboratory from Nancy, France

## 1.1. Research Internship for Master Validation ( March – June 2009) at the Gipsa-lab, Grenoble, France

**Title :** ***Home support for seniors: statistical inference of sensor data for monitoring activity"***
**Advisors** : Stéphane MOCANU and Alexia GOUIN.

During my research Internship which I have done at the Gipsa-lab, Grenoble, from March to June 2009, I have worked on the home support for elder people living alone in their apartments.

### *Description of the problem*

In the city of Grenoble from Rhône-Alpes, France, the TIMC-IMAG laboratory, in collaboration with the Hospital Charles Foix d'Ivry-sur-Seine and the main hospital from Toulouse, has developed an intelligent housing project, called AILISA [Giard et Tinel, 2004] [1]. The project has installed in 2004, in two apartments from the Notre Dame Residence in Grenoble, a special platform used for the medical evaluation of elder persons living alone in their apartment. The platform contained passive infrared sensors which have been placed in specific areas corresponding to the main activities of the inhabitant.

The main objective of the project was to study and develop new technologies for helping the elders in their every-day life, without disturbing their intimacy and private life. Each room of the apartment contained passive sensors which would detect the person's movements; the structure of the apartment and the position of the sensors can be observed in the following picture.

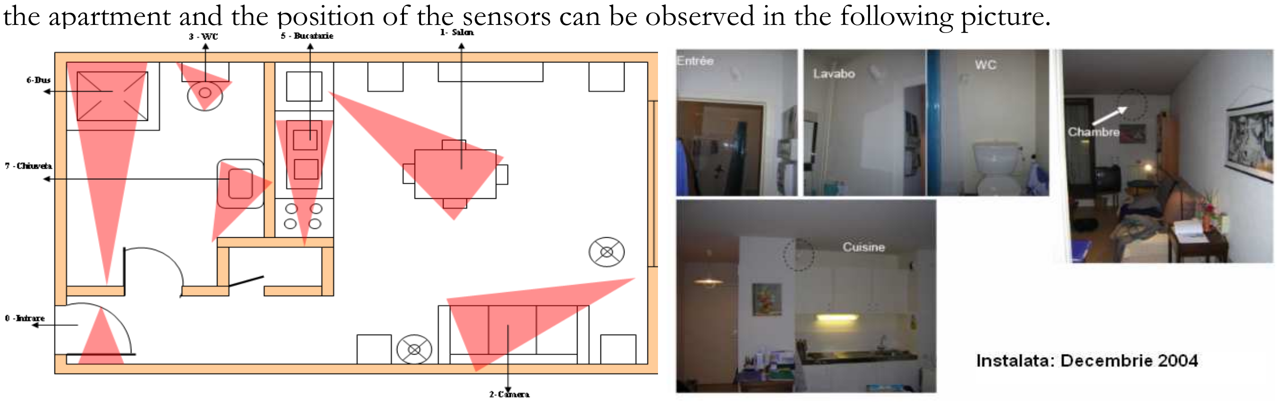


*Figure 1. Placement of the infrared sensors inside an AILISA appartment*

[1] J. Giard, A. Tinel, « L'innovation technologique au service du maintien à domicile des personnes âgées », *Rapport de la Mission Personnesâgées Commandité par le Conseil Général de l'Isère et la Ville de Grenoble,* 2004.

### *Statistical data treatment and applied methods:*

The steps which I have implemented for this project :

- A first part of the work was the data treatment which we have received from the TIMC laboratory, and which contained registered activation times of the infrared sensors. The data processing has been done using the Oracle Data Base, which allowed me to apply different methods for sorting, computing the mean activation times, as well as building the confidence intervals on the main results. When analyzing the data on one day, we have noticed various short activations of the sensors, which would indicate short passage time between different rooms of the apartment. By eliminating these short activities during one day, we have obtained concluding results matching the dairy of the inhabitant during that specific day.
- Extending this method to all the data collected during one month, offered us the possibility to compute realistic mean times of the main activities inside the apartment: sleeping, eating, showering, cooking, relaxing.
- The Continuous Markov chains have been used for modeling the activities of the inhabitant, and the random transition from one activity to another. The Markov Chain properties have also helped us to establish a dual modeling of a general behavior, and represent it using probabilistic finite state automatons.
- The results have been analyzed from a statistical point of view (confidence interval analysis), which allowed us to estimate the duration of determining the parameters of the stochastic model. We have been able to build a reference behavioral model which needs to be periodically reconstructed for each inhabitant. We have noticed that the behavior of one person can be different during each season of the year. The reference model would then be compared each time to the new behavioral models in order to analyze the variations and detect possible long term problems and modifications.

This research project has represented for me the depart of my research career which I am following in the present. It's an interesting domain which I love and which

## 1.2. PhD Thesis at Gipsa-lab, Automatic Control Department (2009 - 2012

**Title :** ***« Probabilistic approach for the event-based control of stochastic switching systems"***
**Advisors :** Hassane ALLA et Stéphane MOCANU.

My research activities during the PhD thesis have been done at the Gipsa-laboratory, France, as a member of the SysCo team, and concern a special class of stochastic hybrid systems, for which we have proposed an event-based simulation method, as well as a probabilistic approach for computing the energy consumed when the control is applied over the system.

During the last decades, the stochastic switching systems, have been used as a special method for modeling dynamical systems, due to their dual behavior characterized by the interaction of discrete and continuous system evolution.

Stochastic modeling has been successfully applied in various domains where the systems operate with discontinuities caused by random event. The system presenting a permanent interaction between continuous and discrete behavior are defined as "hybrid systems" and are largely used in networking, manufacturing, robotics, etc.

### 1.2.1. Stochastic Switching Systems (SSS)

We begin by concentrating our attention on a particular type of hybrid systems, which presents random changes between different states of functioning, caused by extern events. We will denote this system a ***multi-state stochastic switching integrator***, which we will briefly describe in the following.

Let $s \in S$ (a countable set) denote the discrete state, and $x \in X \subseteq \Re^n$ denote the continuous state, or more explicitly, the state variable. A sample path of such a system would consist of a sequence of intervals of continuous evolution, followed by discrete transitions. The system remains in a discrete state s until a random switch will occur. We can therefore state that the system satisfies the following equation:

$$\begin{cases} \dot{x}(t) = r_{Z(t)} + u_{Z(t)}(x(t)) \\ x(0) = x_0 \end{cases} \tag{1}$$

where $\dot{x}(t)$ is the state variable, $x_0 \in \Re$ the initial state of the system, $Z(t)$ the Markov chain defined on the finite state space S = {1, 2, ..,N}, and $r_{Z(t)}$ non-zero switching values of different signs.

If we consider that the future random events depend only on the actual state of the system, we can enhance a modeling of the switching behavior using Continuous-time Markov Chains, which will allow us to characterize and determine the mean passing times in each state, as well as the transition rates between the states.

Let's consider the case of a controlled two-state stochastic switching integrator which is represented in Figure 2, with the following associated transition rates: $r_1 = 2 > 0$, and $\{\sigma_1, \sigma_2\}$ the *transition events* from state 1 to state 2, respectively from state 2 to state 1. The state space now becomes: S = {1NC, 2NC, 1HC, 2HC, 1LC, 2LC}, where {1NC, 2NC} are the system states without control, {1HC, 2HC} are the states with high control, while {1LC, 2LC}are the states with low control. For example the {1NC} state indicates that the Markov chain is in state 1 without control $\{\dot{x}(t) = r_1\}$, unlike the {1HC} state which indicates that the high control is applied in state 1, therefore $\{\dot{x}(t) = r_1 - QH_1\}$.

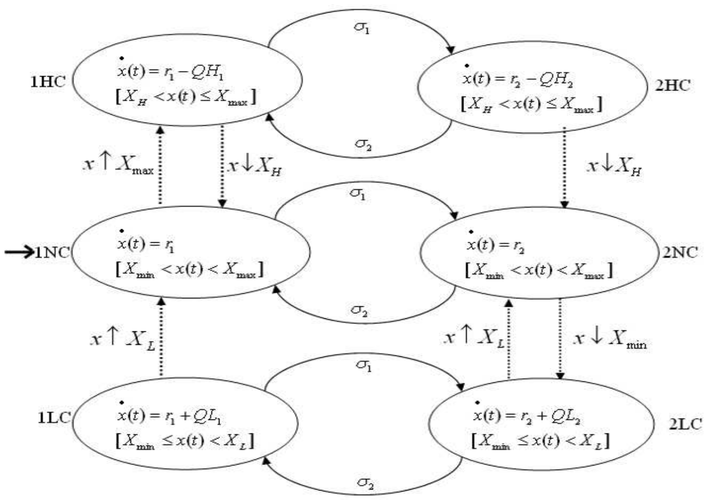


*Figure2. Hybrid Stochastic Automaton for a two-state switching integrator*

### 1.2.2. Event-driven Control (EDC)

Despite a big flexibility of modeling, analytical solutions are very hard to obtain for the stochastic switching systems, and few simulation methods exists for this type of systems. Analyzing these systems having a hybrid and stochastic behavior becomes a hard task, especially when random events occurs. Applying control over such systems with random breaks can be a difficult task even for simple systems. Classical approach of the hybrid stochastic systems is based on a continuous and deterministic control command (a robust controller which will correct random effects) or on a probabilistic and discrete approach (based on the state of the system and the cost to be minimized).

Our approach consists in using an ***event-driven approach***, which allows us to apply the control command only when is necessary, for example after reaching a certain level, until certain functioning conditions are met. So far, this type of control has known great success in industrial systems, networking, biological systems, etc. In Figure 3 I have represented the system evolution when we apply the EDC once the control limits have been reached.

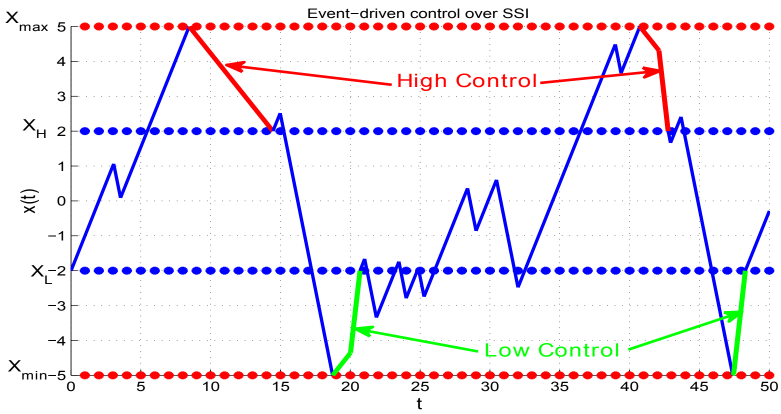


*Figure 3. EDC applied of a stochastic switchign Integrator.*

The above representation and analysis gave us the possibility to build analytical methods which can be used to determine the main parameters of the system, when applying EDC, such as : performability moments of first and second degree of the state variable, exit probabilities from the control zone, mean exit times from the control zone, mean control periods for applying EDC.

We have also implemented a simulation method which is adapted to stochastic switching systems, and which helped us to better understand and apply the EDC. The simulation has also given us the possibility of applying a direct optimization of the control command.

This work has opened new perspectives in the optimal event-driven control command of stochastic switching systems, and can be extended through approximation methods and generalization formalisms.

The work has been publicly defended on the **18th of September 2012** at the Gipsa-lab from Grenoble France, and gave me the title of **Doctor of the University of Grenoble** (Diploma on demand)

The results have been published in two international conferences : IFAC WC 2011 and CIFA 2012, and a journal article in the JESA journal. See the publication list and download page on my website: [http://www.simonamihaita.com/publications.html](http://www.simonamihaita.com/publications.html)

## 1.3. Research at the ERPI laboratory, Nancy France (2012-2013)

Immediately after the PhD defense, I have started to work as an Assistant Professor and Researcher at the ERPI laboratory from Nancy France. Apart from my teaching activity, which is done in the ENSGSI University, I am also involved in research projects which I will describe in this section.

### 1.3.1. Transportation System using FlexSim

**Context:**

The research on transportation systems has begun in 2013, with the modeling and the 3D simulation project of a central intersection from downtown Nancy, France. The intersection C129 represents a high interest in the reconfiguration plans of the city of Nancy, as the urban community of Nancy (CUGN) is modifying the current central neighborhood: Nancy Grand Coeur, in order to respect the ecological norms of living and transportation. The neighborhood has received the EcoQuartier label in 2009 with respect to the efforts of reinventing the mobility in a sustainable city.

Dealing with traffic management for complex crossroads is a challenging problem for traffic control planners. As a contribution to solve this problem, we develop a mesoscopic simulation model for detecting the most suited fire plan for a complex road intersection, using a discrete event simulation tool and an evolutionary algorithm optimization.

**Objective:**

The modeling goal is to eliminate congestion by choosing an appropriate fire plan which will be adapted to the actual configuration of the intersection, as well as to a future reconfiguration meant to accept a higher inflow of vehicles. Four different configurations of the input data flow were studied under the proposed simulation-optimization approach, and an optimal fire plan is proposed.

**Work:**

As a tutor of a five student team, from ENSGSI Nancy France, we have started the work on the modeling and simulation of the C129. The simulation has been done in FlexSim, a 3 dimensional software which offers the possibility of modeling the real-life system according to the real data we have received from the Great Urban Community of Nancy (CUGN) [2] (see Figure 3), during rush hours (7:00-09:00, 17:00-19:00).

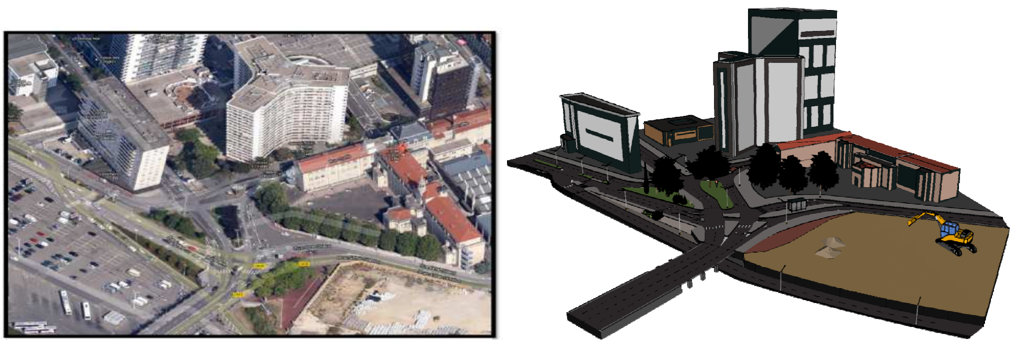

*Figure 3. a) Aerial view over the C129 Intersection b) Modeling the C129 crossroads using FlexSim.*

[2] Communauté urbaine du Grand *Nancy* http://www.grand-nancy.org/

The data we have received from CUGN was a part of the urban project **Big Data of Grand Nancy**, which is meant to bring publicly to the residents of Nancy the data which is collected from their every-day life: transportation, bus-stops, public bicycles services, sharing public cars, etc. We took part into the process of data treatment and analysis concerning the crossroad C129. The data has been used for the model construction and implementation in FlexSim, allowing us to compute mean transportation times as well as mean number of cars inside the intersection at rush hours.

Using FlexSim gives us the possibility to :

- vary the entry data in the system (rush hours, morning and afternoon);
- test several scenarios corresponding to the existing fire plans: 55, 70; 90 seconds.
- vary in a random manner the speed inside the intersection (inside [0,50] km/hm)
- insert pedestrians having a random movement inside the model.

I am currently working as well on an optimization method applied over the simulation results, in order to choose the best adapted fire plan for the intersection. The optimization method shows that some fire plans are well adapted for certain streets, but not suited at all for some others. Figure 4.1 shows that the Plan of 90 seconds is well adapted for the Pont de Fussillés Street, but would give terrible results on the Joffre Boulevard. In Figure 4.2 we represent different test scenarios by varying the real data from CUGN. We notice that the Abbe Didelot street is well adapted for a higher number of input vehicles, while the average Staytime in the whole C129 intersection will considerably increase with the number of cars.

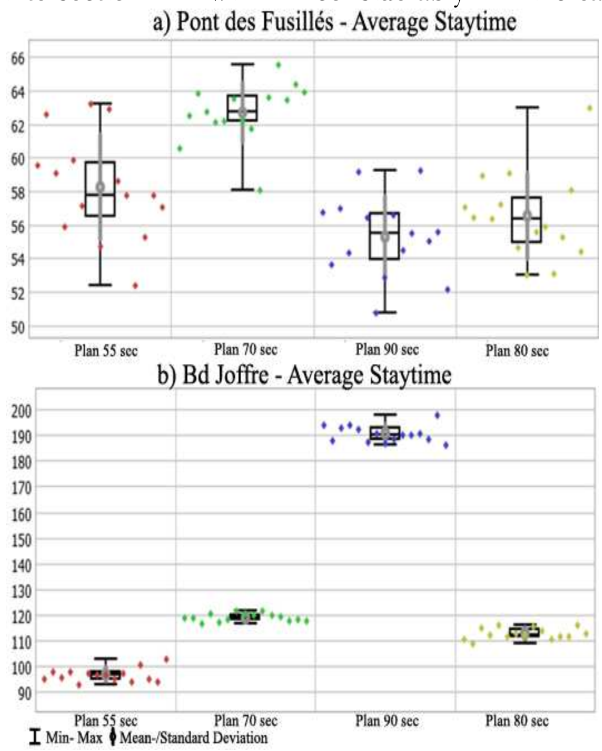


*Figure 4.1 Average Staytime versus Mean number of cars on a) Pont des Fusillés, b) Boulevard Joffre.*

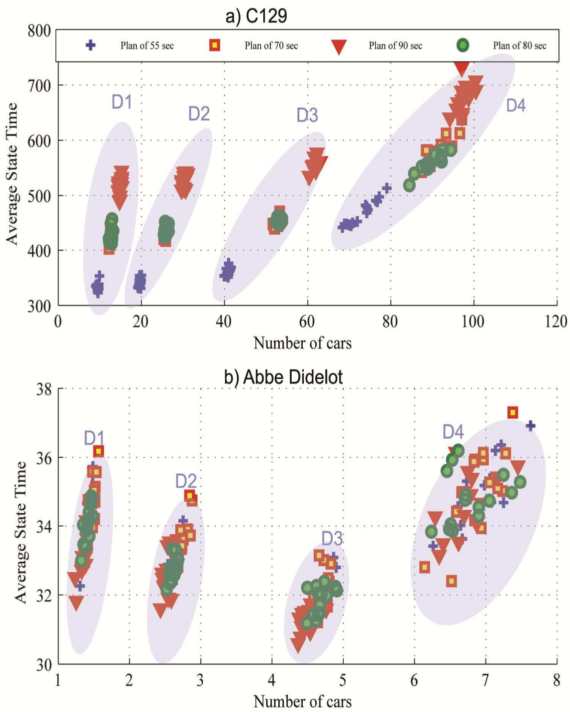


*Figure 4.2 Variations of the real data set on the a) whole C129 b) Abbe Didelot Street.*

***Results:***

- In June 2013, our 3D traffic simulation project, has won the **First prize** at the International Competition organized by **FlexSim** with the help of **SimConseils**.7
- Our current results have been recently accepted for presentation at the **IFAC World Congress 2014 from South Africa.**

***Perspectives:*** This work opens various perspectives on the long term, especially on projects related to the mobility problem in smart cities, by giving a new perspective through a discrete event simulation of a real life system. We are currently interested in extending the actual simulation model of the intersection C129 to the whole EcoQuartier Grand Nancy (curenlty under projection), and analyze the impact of the urban modifications on the traffic flow inside the city centre. We search to determine the parameters which influence the development of an urban systems, and test various transportation scenarios.

### 1.3.2. Multi-Agent Systems (MAS)

During my research activity at the ERPI I am also involved in different research activities concerning multi-agent systems which we apply for different projects which I will detail in this section.

#### 1.3.2.1. MAS for idea generation

During working and collaborative sessions which have the objective to conceive innovative products or novel working methods, the participants and the animators work together to apply different creativity methods in order to explore the best ideas concerning the debated subject. They will therefore apply a creativity method which contains several steps:

1. discover the subject which is in the center of the study
2. apply standard creativity methods such as : brainstorming, purge, mind-mapping, etc.
3. generate new ideas and formalize these ideas
4. share and evaluate the ideas in order to chose the best ones.

So far the creativity seminar have applied standard methods using: paperboards, post-its, crayons and paper to write down the ideas. Our work is focusing into creating a numerical application and collaborative environment using a multi-agent architecture (CIMAS - Creativity Ideas Managed by Agent Systems), which will help the participant generate, collect and select their best ideas.

This is concretized in two articles presented at the : ICFCC 2013 and ICAIA2014 (See publication list).

#### 1.3.2.2. MAS for Knowledge Management

Engineering projects are organizations where several actors with different professional fields and know-how work together to carry out the same aim: to develop a new product. Inside these organizations, heterogeneous and distributed information has to be managed in order to create project memories that will be useful in future projects.

In this work we develop a Multi-Agent System (MAS), which is based on the social and cooperative approach to support the knowledge management process all along mechanical design projects. Indeed, this Multi-Agent System, called KATRAS, aims to capitalize and reuse knowledge according to the roles involved in the design projects. We work in this moment with how the agents capitalize six different types of knowledge (professional vocabulary, process, expertise, project evolution, and return of experience) and how they help the professional actors to reuse knowledge

This work has been accepted for publication in the Knowledge based Journal in January 2014.