

Nicolas Tixier, Annie Luciani

## **Describing/Modelling the Dynamics of Pedestrian Behaviour**

### **From the Role of Ambiance to a Hypothesis for a Physical Model**

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*"Vivre, c'est passer d'un espace à un autre, en essayant le plus possible de ne pas se cogner"*  
in Perec Georges (1974). *Espèces d'espaces*, Paris : Éd. Galilée, p. 14.

*\*\*To live is to move from one place to another, trying as much as possible not to bump into things"*

#### **1 Introduction**

Let us look a little closely at the movement of people in public space. What do we see if we follow their paths, the relations played out among them, the areas occupied or left empty and, more importantly, the dynamics of these constant variations and adjustments? In designing public space, it is increasingly important to look at potential movement. This is the case whether considering the quality and diversity of itineraries (e.g. through parks, museums, stadiums, squares) or for the ease with which the public can get in to or out of a given place (e.g. shopping centres and railway stations). We must therefore seek to understand both the individual and collective dynamics involved here and bring to bear analysis and design tools that take them into account.

Pedestrian behaviour in public space is a vast subject of research, involving numerous disciplines. This article will address it from the point of view of path making. The approach developed here highlights the role played by architectural and urban surroundings (Jean-François Augoyard 1979) in pedestrian dynamics, as situations of sensory interaction, which we experience according to a network-actor system (Bruno Latour, 2006). The actor may be a physical person, a group of persons, a moveable or fixed built object or semiographic features within the space, sensory elements of the environment such as a particular light, a zone or source of heat or coolness, soothing or stress-inducing sounds, and so on.

We will first present the adaptation of a method of observation in situ (recurrent observation, (Pascal Amphoux, 2001), then describe experiments with a numerical relational model. This is the physical model developed by ACROE, which generates dynamics using the descriptors and operators of Newtonian physics (the force concept and the principle of action-reaction).

The initial subject of study is an element of public architecture that is particularly dynamic, namely the automatic double doors at the entrance to a shopping centre. Since this first study (Tixier, 2000), numerous applications of this model have been developed and have enabled an approach to the whole of urban configurations having to do with public space to take place with a view to analysing existing spaces and investigating spatial design. This is covered in the third section of this article.

## 2. Pedestrian behaviour as an object of study

Our literature search concerning pedestrian behaviour enabled us to lay the foundations for our paradigm. It is summarised here and boiled down to a particularly significant handful of authors:

- There is no single way of making a path through an area. Similarly, there are not ‘good’ and ‘bad’ ways of making paths [cf. Walter Benjamin, Jean-François Augoyard, Jean-Paul Thibaud etc.].
- Types of pedestrian behaviour are forms of expression [cf. Jean-François Augoyard].
- There is a link between path-making attitudes, types of space, and the types of sociability observed [cf. Jean-Paul Thibaud, Rachel Thomas].
- Path making brings out reciprocal interaction and modes of reciprocal attention [cf. Erving Goffman, Louis Quéré, Dietrich Brezger, John R.E. Lee, Rodney Watson, etc.].
- To make a path is to communicate [cf. research carried out at the Palo Alto school].
- Public path making involves collective behaviour because it involves shared, everyday skills [cf. Eric Livingston, Michèle Jolé, etc.]
- This collective behaviour and individual adjustments are usually visually identifiable as significant categories for everyone [cf. Michèle Jolé, Pierre Livet].
- This collective behaviour features organisational characteristics that are noticeable and recurrent [cf. Eric Livingston, Michèle Jolé, etc.]
- Pedestrian behaviour can arise from economising movement and even from the principle of least effort (cf. John R.E. Lee, Rodney Watson).

The majority of the foregoing remarks involve dynamic behaviour or organisations. Thus the question we pose is how exactly can we incorporate these dynamic dimensions into our analysis of pedestrian behaviour as pragmatic rules of thumb and in our understanding of space for practical purposes.

The initial idea was to analyse a small-scale architectural system within which dynamics of various types are taking place over time. These dynamics had to be directly “observable” and had to be sufficiently repetitive and of appropriate frequency. It was desirable for the system to be relatively variable in terms of the atmosphere reigning therein. Furthermore, the system had to feature two types of interaction, namely that occurring between individuals and the spatial system and that occurring amongst the individuals present therein.



Sliding Double-Door System  
Grand' Place Shopping Centre – Grenoble South

The aim was to study behaviour in a built environment and in relationship to it. Consequently, we needed a place featuring movement and action and one wherein these could be observed without too much difficulty. The idea of studying a spatial and technical setup on the scale of the human body ruled out a large-scale urban. We needed a place that was public or semi-public and within which there was enough throughput, this being a sine qua non condition for the examination of pedestrian behaviour. In terms of future modelling a space was required that was not overly complex in spatial terms – one with simple geometry.

The decision to look at the area between automatic double doors in a public place was thus rooted in spatial and time dynamics and the constantly changing interaction that occur within such a system. Here everything is in motion in fact. Thus the main aim of this video observation was to bring out the dynamics occurring using videograms, by describing emergent phenomena and strikingly noticeable interaction.

We proceeded to generate a video data base using a discretely placed camera. This provided us with eight short sequences, showing considerable variation and being representative of what took place. These sequences became the basic data for so-called recurrent observation, the principle of which is to ask specialists from a range of disciplines (in this case an architect, town planners, technicians from the automatic door company, psychologists, and so on) as well as regular users of the system (regular passers by, shop-keepers and so on) to state their interpretations of the data, whilst also getting them to react to the remarks and interpretations of earlier commentators. Following this, we crossed and retabulated commentaries and observation materials with a view to understanding the main emergent phenomena. « In this way, this qualitative approach is intrinsically indirect, interpretative and cumulative » (Amphoux 2001).

Analysing the set of interpretative remarks enabled us to capture or update the principle recurrent phenomena. We then stated these in terms of seven principles and emergent dynamics.

These seven categories are described hereafter in terms of « descriptive levels » and outline a possible modeling approach. Grosso modo we begin with the principles underpinning the phenomena, then what is observed from interaction, followed by individual and observable dynamics. We conclude with heavily narrative-laden observations concerning the scenario as a whole.

### ***Elasticity: an emergent principle***

There is one situation that reoccurs constantly between the double doors. It appears when two people proceed through it in Indian file throughout, or when one yields priority to another or again when mutual positional adjustment takes place. The elasticity concept is probably a basic one for modelling interaction: it is relevant to questions of priority, cooperative processes, the idea of psycho-perceptive volume and no doubt also impressions of flow dynamics with stretching and narrowing effects.

### ***Psychophysical space: an emergent principle***

This principle of psychophysical space (a concept developed by E.T.Hall) depends on an ordinal relationship between distances rather than a ratio scale. The variables involved are, above all, physical ones: a volume, a particular solid shape (it is not really natural to have one's shape modified) and a volume within which gestures take place. This volume may change as a function of the person opposite, by a bodily adjustment: people may put themselves sideways on or make themselves smaller, and so on. These variables are at once physical, psychological and cultural. Their description involves a person, a cross-section, a group and even built objects such as doors. The "volume" depends on the nature of the relationship that one believes that one has with the person opposite (and this works both ways). The "volume" may be boiled down to a flexible, horizontal disk for the purposes of our study of automatic doors, since the interaction that arises from their workings mainly take the form of changes of trajectories or in compression/decompression phenomena.

### ***The dynamics of priorities/the priorities of dynamics***

Many hypotheses can be put forward concerning the concept of priority in the context of recurrent observation sessions. Who has priority when two people cannot get through simultaneously? Under normal circumstances priority conflicts do not arise very often, despite the fact that they are potentially and continuously present at the entrance to and exit from the double-door system. A certain number of priority systems were observed, namely: right vs. left, the person who has penetrated the most deeply into the system, the person who has the largest psycho-physical volume, the one who takes the straightest path in terms of shared trajectories, the one who moves the fastest or who gets to the double doors first, gestures of politeness, and so on and so forth. It would appear that all these rules of priority apply simultaneously. They get updated depending on physical variables such as proximity, volume, speed and direction. And

they may also be updated according to rules of a cultural nature, such as priority being given to the first person into the system, or according to politeness or psychophysical volume. The dynamics of the situation are governed as much by systems of priority as systems of priority are governed by dynamics.

### ***The dynamics of cooperative processes***

Interactions between people of a cooperative nature are observed. We can classify these processes into two sets. One set corresponds to the voluntary involvement of participants manifesting reciprocal attention (deliberately triggering door opening to facilitate the passage of someone else, holding the door open and passing this task on to someone else, bodily and trajectory adjustments); the other set consists of cooperative behaviour that is almost involuntary emanating from at least one of those involved, (positioning oneself in the wake of someone who happens to be going through, to get priority or to find out which way to go, and so on).

The expression “cooperative process” is used here in a generic sense. Phenomena such as taking advantage of someone else going through or even bodily adjustments could be classified more precisely along similar lines to those used by Michel de Certeau and his “*arts de faire*”; he has elaborated the concepts of strategy and tactics in the context of trickery.

### ***Anticipation dynamics***

These concern door opening, people going by one another in opposite directions, and so on. Viewing the film reveals, much more clearly than observation in the field, the contrast between the idea of the collision that is about to occur and the triggering of the opening, which enables this to be avoided and everyone to keep going at the same speed. In terms of bodily and trajectory adjustments, we really see that people believe in the cooperative system, which ensures that people will make adjustments as a function of others and vice versa. And this is a continuous and ongoing process. Anticipation and adjustment dynamics are fairly similar. Anticipation includes the notion of there being a time preceding the event that lasts longer than the adjustment time, which occurs at the last minute. Erving Goffman has put forward a concept on which anticipation can be based, namely scanning, which covers an area that varies constantly as a function of the density of the surrounding traffic.

### ***Adjustment dynamics***

These are the minor bodily and trajectory adjustments observed when people see the doors opening: they may take a step to one side thus slightly increasing their path length to give the doors the time to open without having to reduce one’s walking speed, take a step backwards when they reach the doors so quickly that they have not yet opened, seek out the sensitive detection zone, reduce speed, place oneself in the central axis of the doors so that when they do open one is in the best position to slip through them, halt a gesture in mid-air (this comes out clearly when looking at the videos in slow motion) and initiate a perfunctory gesture that could turn out to be required. For instance, sticking one’s hand out towards the doors when they take a while to open up or putting one’s arms down by one’s side when passing too close to

the open doors. These adjustment dynamics are also observed when two people go by one another on opposite directions or when a single person meets a group going the other way.

### ***Threshold dynamics***

The double door system is in fact a sophisticated threshold, separating the inside from the outside and on it, or rather within it, we find a number of types of behaviour, some of which are throwbacks to the days of the traditional threshold, whereon certain attitudes and traditions manifested themselves, e.g. (French) people exchange kisses on the threshold before parting. We observed five threshold behavioural patterns. First and foremost it constitutes a meeting point where people wait for one another; on the contrary it is also a place where people say goodbye to one another; again it is a gathering place: the threshold is crossed together once grouping has been accomplished, in all cases it is a place where behaviour change: people change their gait, they take off certain garments, they unbutton their jackets, and so on and so forth. This is particularly noticeable in the case of children: they run up to the doors to trigger their automatic opening, they play in the area between them, and so on. Lastly, it constitutes a meeting place, an intersection where it is impossible not to see others.

Our study of this system showed that here we have a double interaction system: on the one hand there is the interaction between passers-by and the door system and, on the other, interaction among the passers-by themselves. One thing emerges particularly clearly and that is that, in general, there is no clear dividing line between causes and their outcomes. Both are constantly updated and take shape in patterns of mobility and sociability. Spatial forms give rise to types of behaviour just as these very types of behaviour configure space in terms of time and significance, and spatial terms too. We do not have a situation with the built system on one side and the public on the other. We also observe a perception-action-representation continuum, clearly brought out by dynamics of adjustment, anticipation and cooperative processes, and indeed the lack of conflict.

Lastly, although this is not covered in detail in this article, we also used the door system to look at the effects *in situ* of inserting a perturbation into the system to see how pedestrian behaviour then changes. Such perturbations help to uncover the rules that regulate certain forms of interaction. Thus we see that walking on the left gives rise to conflicts; halting between the doors perturbs pedestrian flows and changes their fluidity. When the doors are out of order, special behaviour and attitudes towards the doors immediately appear. It is also possible for experimenters to deliberately generate artificial perturbations in the system. It is possible, for example, to prevent the doors from moving, to get someone to stop in the middle of the system, and so on and so forth. In this way, by experimental manipulation, observation and then induction we can lend support to or favour the rejection of hypotheses concerning the nature of relationships such as interaction, cultural behavioural rules, and so on. For example, this sort of experimentation can be carried out for research into priorities, cooperative processes and so on. But it is also possible to set up an experiment protocol pour to see how sensitive elements of the model are

to changes in other constituents. (We shall see that this experimental freedom can be extremely useful and can even prove indispensable for evaluating the settings and the suitability of a model; (we are referring here to the robustness of a model).

To sum up, we may safely say that, thanks to its automatic workings, this type of system provides a situation for research into pedestrian dynamics *in situ* that is at once fairly complex and yet clearly demarcated (with respect to the study of other public spaces such as streets, squares, and so on.) These are two useful features when it comes to modelling.

### 3. The physical model hypothesis

Pedestrian behaviour has led to the development of a great many computer models. These are often collectively referred to as the “crowd model”. Although almost all of them may be classified as multi-agent models, they are based on different working hypotheses, depending on the nature of the model used. Now these differences sometimes mean that they are associated with theoretical hypotheses that are often completely in opposition to one another (behavioural category, perception ecology, cognition, distributed intelligence, and so on.).

In many models there appears at one level or another a “perception - decision - action” loop. This loop does not appear in ACROE’s physical modelling approach. It does not feature a time for perception, a time for the decision phase, and a final time for the action that constitutes the upshot of all this. Since interaction computations are carried out at the link level and not at the particle level (point particles in the physical model), all perception is action and therefore communication. In this system, “elementary” communication is not directed towards the exterior, towards our senses, but rather towards the other participants and the other relationships within the model. It is even possible to be one of these participants, but, in this case, we become part of the network, as another of its elements. The simulated model can be made accessible to our sensory apparatus via a representational step requiring a digital-analogue converter. This would then be a second level of communication.

Moreover, *nor is there a decision phase*. Apart from the opening sensors and the times to closing of the automatic doors the model is governed by no cognitive or logical processing.

ACROE’s physical model is built with operators taken from physics. In so-called classical physics, there are two major theoretical systems, Newtonian physics and Hamiltonian physics, each of which has its own rules and operators. Newtonian principles define algebra of dynamic systems (using the concept of force as an operator and action-reaction as a principle). Hamiltonian principles, on the other hand, define a geometry of dynamic systems (using the concept of action as an operator (energy, momentum, and so on.) and the least action principle. Hamiltonian mechanics, from the outset, requires that we look at a movement globally, as a whole and that we compare it with the infinite number of virtual movements of which it is a privileged member. Newtonian mechanics gives us an algebra of motion; in this it is synthetic, whereas Hamiltonian



mechanics is a geometry of motion and in this it is analytical. Newtonian mechanics enables incremental calculus (involving calculus steps, each of which can depend on the preceding steps), whereas Hamiltonian mechanics does not allow this. Hamiltonian mechanics allows us to consider causes without knowing their effects. The ACROE physical model, Cordis-Anima, is based on the principles of Newtonian mechanics.

It is then the Newtonian formalism that is used here as a language. It is based on the notion of force and on the action-reaction principle, which is itself equivalent to the principle of the superposition of forces. It is on the basis of this formalism, which defines to a certain extent the elements involved and the rules of the game, that the models created simulate dynamics. Within this formalism, a dynamic system is usually described by a set of differential equations. Rooted in the discrete medium of the computer these assume that not only space but also time are discrete variables. This discretisation implies the choice of a sampling frequency that corresponds to the step length used for the iteration. It is because the ACROE physical model principle is based on a calculating system that is intrinsically dynamic and independent of sensorial particularities, that we are hopeful it will prove relevant for modelling complex and multi-sensorial dynamics.

The first property of the Cordis-Anima modules is their ability to communicate and to interact. The basic idea is that of "points of communication". For reason that are too lengthy to detain us here, there are two sorts of points of communication:

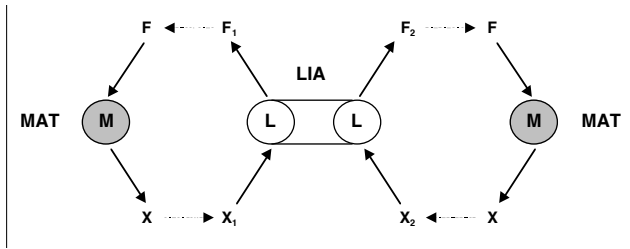
- M points, which receive force data and which send back positional data
- L points, which receive positional data and send back force data.

These two types of points of communication form indissociable pairs. All physical communication between two modules takes place via these points of communication. Only one M point can be connected to an L point and a point can only have one position at a given time. However, on the contrary, several L points can be connected to an M point. The force entering M is then equal to the sum of the forces emanating from the L points.

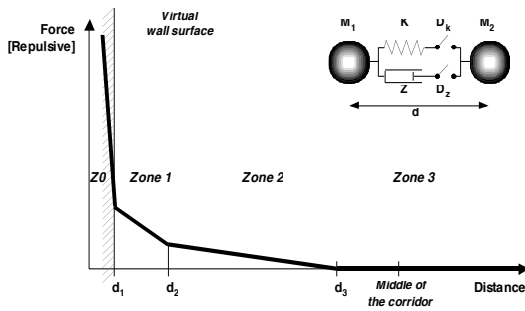
Given the concept of points of communication and their categorisation into two types, Cordis-Anima defines the two types of module that are necessary and sufficient to build any sort of network that satisfies the principle of action-reaction. We have then:

- MAT modules, consisting of a single point of communication M; these receive a force and generate a position
- LIA modules, consisting of two L-type points of communication; these receive two positions and, after comparing them, generate two forces; these forces are always equal and opposite and the principle of action -reaction is always satisfied.

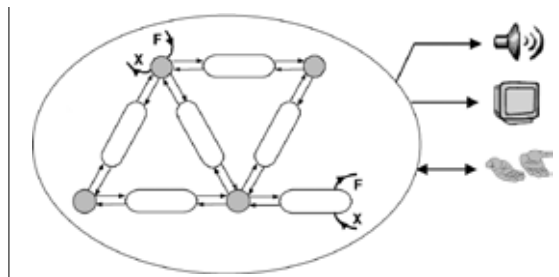
An assembly of MAT and LIA elements defines a Cordis-Anima network. From this we find recursively that the Mat and LIA modules can contain far more than a calculation linked to point



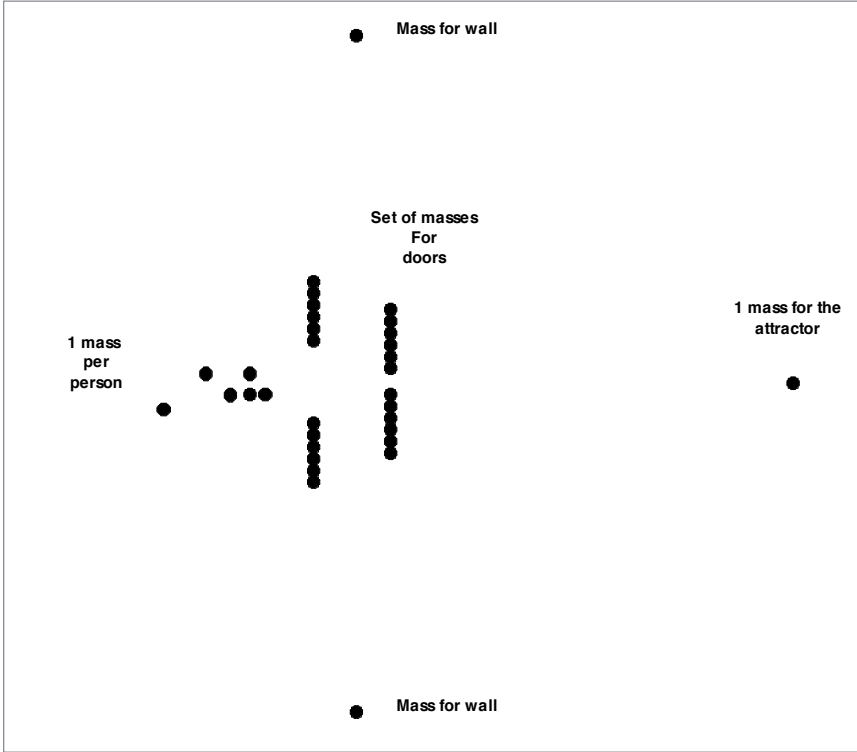
Two MAT modules linked by a LIA module



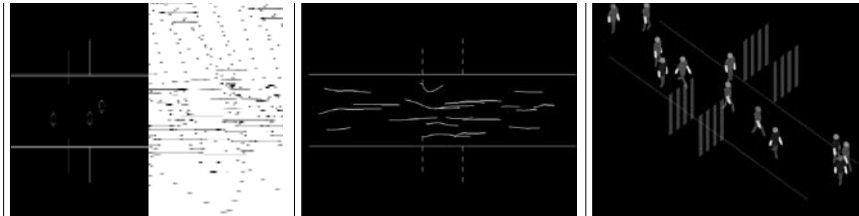
Interaction definitions: example of a link between two elements: viscoelastic-type collision (In this case, a linear piecewise interaction function for individual/wall links)



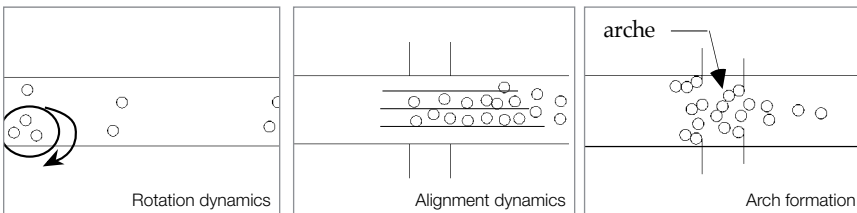
Principle of the ACROE physical model  
Model space/Sensorial updating



Model Space Definition. Hypothesis concerning the minimum elements required for the model



Updating the model, here shown as computer animations. Three examples of visual renderings



Digital observation. Characterisation of dynamic patterns, etc.

mass in the case of the former and element interaction in the case of the latter. They can contain an entire Cordis-Anima network, provided that the nature of inputs and outputs is adhered to. Thus a MAT Complex Module computes the dynamics for any system (set of forces  $\rightarrow$  sets of positions) and an LIA Complex computes the inverse dynamics for any system (set of positions  $\rightarrow$  sets of forces).

Inversely, any object defined by the Cordis-Anima formalism can be written as a carefully selected network of MAT and LIA. To define the model is therefore to write down the Cordis-Anima network that fits it.

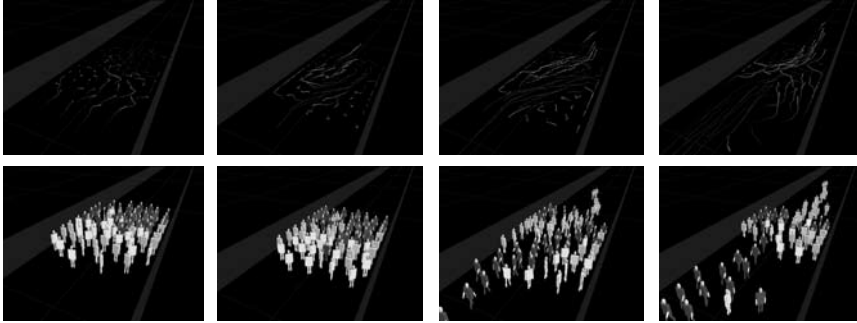
The basic Cordis-Anima link is a spring-friction type link. Its attributes are length  $L$  at rest, a stiffness constant  $K$ , and a viscosity constant  $Z$ . These links are also known as viscoelastic links. They can also be transformed into conditional viscoelastic links and this is necessary for dealing with crowd-type applications.

The ACROE modelling system enables any Cordis-Anima model to update itself in sound, visual or tactile-proprioceptive space. The model simulated can generate dynamics that update themselves in each space individually or in all three simultaneously. It seems reasonable to expect that the correspondence of the three will seem “relevant ” with a “multi-sensorial coherence effect”. This coherence should then stem from the underlying digital model that is common to the senses and the dynamic processes that give rise to them.

Observation work in the field together with digital experiments using the model on the double door system have revealed the following dynamics.

- Anticipation of how to avoid the obstacle by velocity adjustment (detours, slowing down and speeding up, and accelerations) over average and long distances
- Traffic jams with the formation of cohesive sub-groups and evacuation by avalanches to the sides of the jam
- Flow penetration, mixing and changing of possible objectives
- Turbulent flow with the formation of vortices, allowing flows to find an automatic solution to blockages.

Much research has been carried out at the ACROE since the early work (in particular by François Thil and Annie Luciani). Some examples of this are given below showing spaces of different types and especially the varied modes of visualisation. Each representative method has its strong points. Some enable us to see collective dynamics clearly. Others help us perceive individual variations. For example, the technique of filaments (people represented by points, but featuring an afterglow of a few tenths of a second, enables us to see their velocity and their trajectory, highlights halts, velocities, the slightest changes in direction, criss-crossing paths, minor reversals, and alignments. Inversely, this does not describe the rotations of individuals. Group overview becomes very arduous, but it does bring out all the individual dynamics, no matter how small they may be.



Simulations of two dense flows meeting in a narrow street: trajectory visualisation and humanoid visualisation



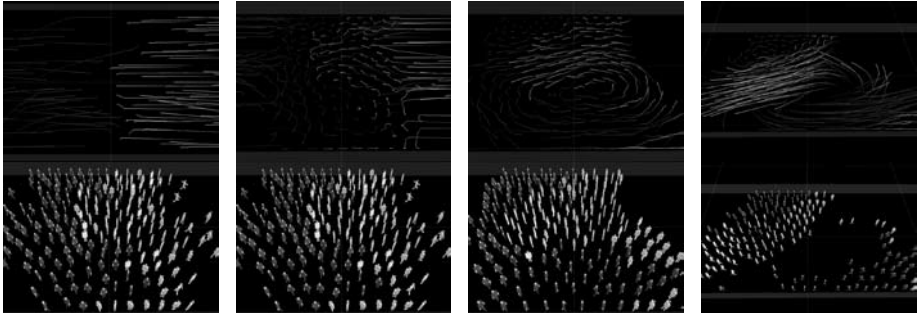
Simulations of the meeting of two very dense flows: trajectories and humanoids

#### 4. A system of relational intentions

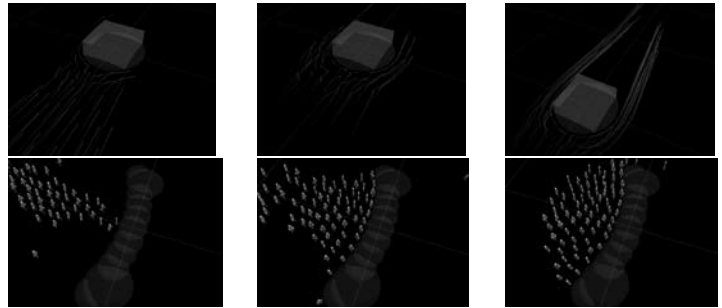
The model features multiple virtual situations that are easily updated in sensorial dynamics. In addition to being a helpful tool for understanding phenomena and a predictive tool for dynamics it brings us a radically new way of thinking about space.

- Any physical model can be conceived independently of the senses via which it will be updated. The same model will generate sound, visual animations or a driving force
- Any physical model is intrinsically dynamic. When it is not dynamic we say that the system is at rest, awaiting fresh spontaneous or experiment-induced activity
- Any physical model is intrinsically relational. When we define modules we define both the elements and the relationships between those elements. It is these relationships that are the main vectors for content.
- Any physical model can be interactive via reactive mechanisms that enable an external element – either human or machine – to become, in a way, an element of the model.

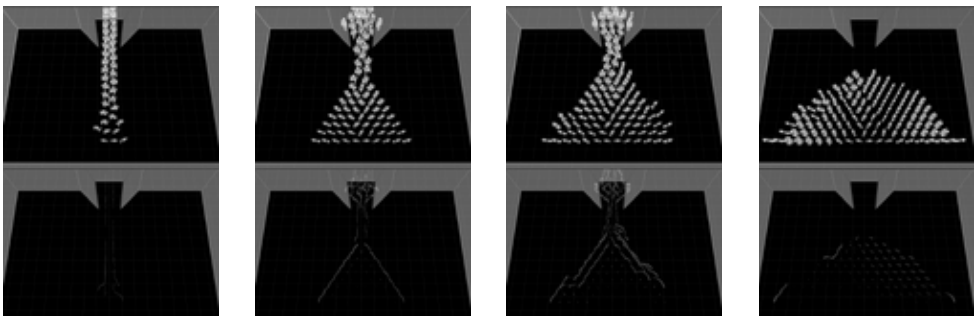
It is the application of the foregoing principles to the design of sensorial, built and active space that enables us to understand the reversal that this logic implies. Let us take a simple situation. For example, when modelling corridors or the space between double doors, we had to define walls. To define a wall, we can imagine not merely a description (such as where it is, whether it's made out of concrete, how high it is, and so on), but relational properties, which would tell us



Simulation of a flow coming up against a large fixed obstacle



Simulation of a flow meeting a large fixed obstacle with piling up, surface avalanches and internal collapses



Simulation of the meeting of three flows in a public space.  
Representation of the trajectories with regard to the velocity of the persons.

for instance that it is impossible to go through it, that we can lean on it to take a rest, that it can be used as a guide for paths, and so on. In an observational-type description, the wall is not defined just as a separate entity, but as a set of relational situations involving one element that we call “wall”, another that we call “person” and a link that defines possible and impossible actions. These elements are defined from the outset as a function of their links with others. The links are dynamic and non-sensory. In the example of the wall we can easily imagine that its role as a guide for path-making is not concretised by vertical material system, but why not by a sound system or a simple variation in the ground or perhaps a light signal. The non-penetrability function can be satisfied by a semiographic element showing that it is forbidden to enter, and so on. Writing down the link never predetermines the material nature of the elements of the built environment; it merely enables us to interrogate them in terms of the relationships that they are to have or not to have with other elements, including users. Architectural objects are thus defined upstream of their material nature in a network featuring relationships evolving according to an actor-network system (cf. Bruno Latour). Later, they are updated in the course of the simulation using the model.

The very nature of the model makes it capable of representing multiple virtual realities that merely need to be updated in sensory dynamics. These in turn can be observed and will have their tale to tell. It should not be thought that the generator aspect of the model means that we have no control over what is produced, but it would also be wrong to think that, on the contrary, one benefits from total mastery at all times. Everything depends on the model, its construction, the complexity of its elements and the quality of the experiments, which build up data enabling the model's parameters to be fine-tuned. When the model is applied to space, it would be a mistake to adopt either of these attitudes. The first would be to use a computer model purely in order to take advantage of its generating capacity. We could run it until the outcomes were satisfactory without seeking any control over the elements of the model and real-world phenomena. The other attitude would be to use the model as a tool that we would refine more and more until we reached a single target dynamic. There has to be a happy medium. Let us consider the field of public space. Usually this is not in state of totally unforeseeable chaos and nor is it perfectly organised under constant and complete control. It often falls between these two extremes. The case of path dynamics reveals this. There is no question of defining a space within which everyone has to walk in the same way and in the same place, but nor is it a question of defining a space with no notion of correct use and potential appropriation. Pascal Amphoux uses the terms *ménager* and *manager* for this. Designers must at once manage space and come to terms with it. The same applies to a model: it is reasonable to want to control to some extent the simulated dynamics whilst at the same time allowing them to be multiple, varied and sometimes surprising.

Both in terms of the *in situ* observations and the computerised simulations, design would no longer involve reference images but rather relational intentions (cf. Nicolas Bourriaud). These call into question the simulated data as much as the social and sensorial data. Better still, they can be cross-referenced with data and linked to it. Description enables us to define, the model enables us to organise space. In fact, they are structural intentions that one can define at the begin-

ning of an architectural or town-planning project, which can therefore form its foundation, and from which they can find support and develop the project in a coherent dynamic movement. For example, we can ask what relationships should be defined between one space and another in terms of sound, visual or temperature levels or in terms of motor vehicle accessibility or, above all, the expected social interaction from the project, and so on. Moreover, relational intentions can give rise to a debate among designers, clients and users.

By linking together description and the model in this way project management is no longer bound to a linear time frame, one that assumes that design is a phase that must inevitably take place following a phase of analysis. We find ourselves in a process that is defined as recursive over time, which seeks to formalise an intention by constant cross-fertilisation between the activities of analysis and design, to such an extent that they can no longer be differentiated according to these terms. This methodological process must enable us not to oppose things that are generally separated. On the contrary, it must enable cross-fertilisation to take place: cross-fertilisation of analysis and design, of reality and virtuality, between description and model, between observation and experiment, and between objects and relationships.

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### Notes

The Cresson laboratory's research focuses on the perceptible environment, and architectural and urban atmospheres, advocating a qualitative approach that may influence design strategies and processes. After concentrating initially on the soundscape, the laboratory extended its scope in the 1990s to include the many dimensions of in situ sensory perception (light, heat, smell, touch and bodily movement) with original pluridisciplinary methods at the meeting point between human and social science, architecture and engineering.

The ACROE has produced a method of image and audio creation known as Physically-based Model Synthesis. It has also pioneered in modular multisensory synthesis and force feedback gestural control. Its research in Virtual Reality has applications in Computer Technology and Artistic Creation, particularly Music & Animation, as well as in robotics, telecommunications, education and industry.