TIME AND SPACE MANAGEMENT IN CROWD SIMULATIONS

Benoit Lacroix
Philippe Mathieu
Sébastien Picault

LIFL CNRS UMR 8022
Université des Sciences et Technologies de Lille
Cité Scientifique bat. M3
F-59655 Villeneuve d'Ascq Cedex
E-mail: {lacroixb,mathieu,picault}@lifl.fr

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ABSTRACT

In this paper, we present a contribution to time and space management in reactive simulations, especially for crowd simulation in an urban or closed environment. We are not interested in mere individual scheduling, but rather in the link between global rythm issues and individual behavior. Our aim is to simulate real moving behaviours in constrained environments, taking into account the link between the macroscopic predictions of the simulation and experimental data. The simulation must deal with collision problems, rythms variations or multiple moving models. We argue here that a synthesis between temporal and spatial features is needed. This work relies upon our MISC model which allows to simulate 2D-moves with different rythms according to population classes, and gives a statistical control on the life cycle of the individuals.

INTRODUCTION

Our objective is to simulate pedestrians motion through complex environments. Space is to be considered on the level of modelisation of pedestrians and their environment, like with that of the motion models used. A temporal dimension has to be added: the simulation must proceed in a "simulated" time. We have to make sure that a transformation exists which makes it possible to convert this "simulated" time to an "exact" one for which simulation is constantly in phase with the real situation. Finally the validation of the simulation is also one of the most important concerns. It imposes on the time problematics, and implies the require to be able to confront the obtained data with reality, and to reproduce real behaviors (fig. 1).

Only the issue of exact simulations, where it is necessary to be able to validate the results by an adequate step rather than providing a mere realistic appearance, is considered here. Two forms of prediction can then be considered: at the macroscopic level first, with flows at entrances or exits and distributions in space and time; and second at the microscopic level, by analyzing individual behaviors and comparing them with data available from psychology and sociology.

This work led to the development of the MISC platform (for "Modeling of Individuals in Spatialy Constrained environment"), which allows the simulation of reactive entities. (This work is supported by the French CPER TAC of Region Nord-Pas-de-Calais and by European Funds from FEDER.) The agents which simulate moving persons employ algorithms of collisions and adjust their movements in an autonomous way according to their particular characteristics and their limited perceptions. The model used is based on the concepts of blurred path following and sources of agents, those being able to be parameterized to generate agents of a given family at specified intervals. Being able to take into account all the possible situation, from point-to-point displacement to queuing at a ticket distributor, is also a problem which has been studied, through the use of multiple models of placement/displacement. Global measurements of spatial and temporal aspects of the simulation are provided, in order to compare the predictions of the simulator with the real data.

We will first present the state of the art in the field of pedestrian studies and simulations of displacement, and then describe the main difficulties involved: it is mainly about how to take time and space into account, and to be able to validate the results of simulations. We also present the tool which results from the integration of this temporal model to models of realistic displacements in this context. Finally our proposals for the resolution of these problems are presented, before indicating the prospects for our work.

RELATED WORK

The modeling of the displacement of human individuals is an active subject of research which was approached along various models, roughly divided into three categories. The first one compares the individuals to particles to carry out analogies with fluid or gas dynamics. However these models, by

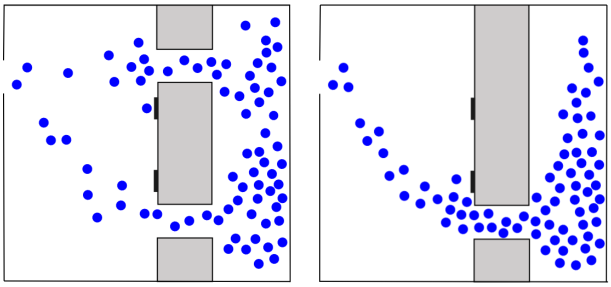

Figure 1: An example of the kind of problems we aim at resolve : is the organization of this train station more efficient with one or two exits, and what is the influence of the placement of the exit(s) ?

treating individuals in a uniform way, lead sometimes to predictions which do not correspond to reality (Kerridge et al. 2001). The second approach consists in discretizing space in cells, for example by representing the agents and their environment by a cellular automata. The displacement of the individuals and the physical occupation of space are then determined by the rules of the automat. This approach presents however two main difficulties (Still 2000), such as a limitation of the capacity of space description, and difficulties in implementation and interpretation of results. Finally the last category gathers the models based on a continuous environment and privileging the emergence of behaviors from individual rules, like the Magnetic Force Model (Okazaki 1979) or the Social Force Model (Helbing and Molnar 1995), based on three forces (the motivation of achieving goals, interactions with other individuals and environment, and attractive effects of the environment). Nevertheless, the fact that the model is not based on real data makes it difficult to parameterize and validate.

Many platforms apply these models. We will describe here three ones more in detail, in order to have an outline of their possibilities. First, K. Teknomo tries to model the behavior of pedestrians in an as exact as possible way, while being particularly interested in the possibilities of validation (Teknomo 2002). The model used is based on the Social Force Model. Each pedestrian is subjected to three forces: one of attraction (making the agents advance towards their destination), and two of repulsion (for target anticipation and collision avoidance). This approach has the advantage of being based on measurable physical data, by construction of the used forces. However this model does not incorporate in its current version the management of other obstacles than the agents themselves, and the interactions with the environment are then limited.

G. Keith Still, in its study of crowd dynamics, has for objective to obtain an emergent simulation from the simplest possible rules (Still 2000). The system is based on four behavioral rules, and one displacement rule. Each agent must try to reach its objective (fixed, or imposed by a given situation), while trying to get to its maximum speed. It must also maintain a minimal distance with the other objects of its environment, while having a certain reaction time to the external events. The rule of displacement is based on the principle of the least effort, making it possible for the agent to choose the shortest way in term of displacement time. This model makes it possible to reproduce certain charasteristical behaviors of the pedestrians, like their capacity to use short cuts, or the formation of lines in bidirectional flows. It remains however difficult to gauge compared to the real data.

C. Reynolds uses a different point of view: he does not care about obtaining exact results, but desires a probable and effective simulation (Reynolds 1999). His work, inspired by robotics, intends rather for the design of games or animations, but is nevertheless interesting, since it aims at reproducing realistic behaviors. Each agent uses elementary behaviors, exploited according to the circumstances, such as the *arrival* (consisting in slowing down near the objective), the *obstacle avoidance* (adjustment of the vision distance according to the speed so as to anticipate the skirting of the obstacles), or the *path following* (the agent follows a preset way made of broken line, adapting his speed in order not to move too far away from it). The association of these various elementary behaviors makes it possible to obtain complex and realistic simulations.

TIME AND SPACE IN AGENTS SIMULATIONS

Pedestrian studies involves complex phenomena, and the emergence of realistic behaviors like the possibilities of validation are related to the resolution of fundamental questions, which have to be answered during the conception. We will first consider the individual characteristics which seem essential to us.

Taking individual features into account

A first parameter is the space occupied by a person. It expresses its morphological characteristics, and can depend on various parameters An other important factor likely to influence the behavior of the individuals is the concept of personal space. Each person defines around itself a private zone, which it tries to preserve of the influence of the others (Sommer 1969) or to regain if it is reduced. People also have an individual velocity, regarded as a preferred speed. This speed will also be function of various factors.

As for personal space, the characteristics of the person are important, but also depend on external parameters. Last, a person perceives its environment. These perceptions will determine the possibility to anticipate and to react to the interactions with other agents and obstacles. The visual field for example has interesting characteristics, which can be taken into account. The manner and the capacity to perceive the environment also depend on factors like size or density: small or tall people, dense or sparser crowd will be as many elements which will influence perceptions.

Types of displacements

As we have seen, various models of displacements were developed. However their characteristics are not perfectly appropriate for all situations, and it is difficult to conceive a model which would take all of them into account. For example, to take a train an agent must first go to the train, then wait on the platform, next go up on board and finally find a place. During the phases of displacement a traditional model as those described above could be appropriate to go to a precise place under the constraints of the environment. But during the waiting phase, rather than staying at a precise point the agent is likely to hover around in a small zone while respecting constraints such as the density of the crowd. It can thus be more accurate to change behavior, and thus of type of displacement during the time, rather than to seek to design a global and consequently complex model, to bring an adequate solution to all possible situations.

Complex behaviors to reproduce

In the reality individuals often adopt complex, adaptive behaviors. While moving, an agent sometimes has to move backward to leave the way to another one. When advancing towards a precise goal, such a behavior is a difficult problem, even in the case of co-operative robots where the space of evolution is bigger (Lucidarme et al. 2002). It is the same for behaviors in waiting queues or areas. Moreover those behaviors depend on the culture or the social standards.

In addition some emergent phenomena can be observed, such as the formation of lines in multidirectional pedestrians flows or flocking/herding effects caused by the sociability of individuals. It is also important to offer to the agents the capacity to anticipate their actions, in order to observe natural behaviors.

Various manners to take time into account

Time can be taken into account through various manners, according to the required objective. In the first approach, i.e. real time simulation, the outputs of the simulation correspond at any time at the precise current state of simulation. In a second approach where time could be qualified as an "exact" one, the objective is to obtain an output which is constantly in phase with what would occur in the real world. The observation of reality and that of simulation must then have an exact correspondence during the time. Finally a last approach is the "simulated" time, where a mathematical transformation to convert simulated time to exact time has to exist.

This last approach makes it possible to accelerate or slow down simulations, the maximum speed corresponding to the speed limit of calculation of the platform used. Each step of time does not have the obligation to use a constant computing time, as long as the correspondence with the "exact" time is maintained.

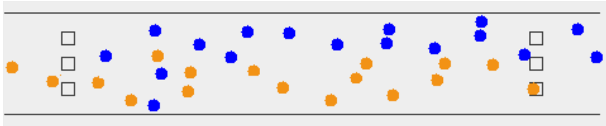

Figure 2: The MISC platform running a simulation of bidirectionnal flows in a corridor. We can observe the formation of lines and that fast people pass the others.

The issue of the validation

One of the most important problem in this type of simulation is the issue of the validation. Validation can be obtained at two different levels: macroscopic (input/output flows) and microscopic (analyze of the individual behaviors). To be able to extract these two kinds of data during the course of the simulation is then very important, in order to be able to check their exactitude.

A crowd can be characterized by various parameters: average distributions, values, flows, densities. These macroscopic characteristics are very often the only ones which can allow a validation from real data, being the only available ones. The concept of level of service (Fruin 1971) raises on the establishment of relations between flow, velocity and density. To reproduce these relations ensure a certain validity of the results of simulation. However, as Keith Still underlines it (Still 2000), the sociological studies on this subject generally correspond to a particular context. The confrontation of their results with those of simulations is then particularly difficult, because of the complexity of transposing the context.

The validation from a microscopic point of view is less clearly defined. A regularly proposed aspect relates to the capacity of the model to reproduce auto-organization phenomena observed in reality, as those mentioned above (fig. 2). The interest of a model of displacement based on real and measurable physical data is also here clearly visible. In addition to allowing easier calibration, the input parameters can be directly fixed by observations in the real world.

OUR PROPOSAL: THE MISC PLATFORM

Each one of the existing platforms make it possible to answer some of the problematics raised above, but none is today able to solve the totality of them. The approach we implemented with the development of the MISC platform aims to bring a solution to these various problems. We will see now an outline of the answers we gave them.

The agents and their environment

First of all can the pedestrians have various profiles. These profiles determine their physical characteristics (size, preferred velocity…) and their perception capacities. These various elements can be allotted grouped or individually managed in order to allow a great flexibility in simulations.

Their behavior, within the determination of the objectives that they will be seen assigned, will be discussed further below.

The generation and the disappearance of the agents are managed by elements called sources and wells. Sources generate the agents using temporal criteria, in order to integrate flow data. The wells constitute the final goals of the agents, and remove them from the simulation.

Environment, in addition to the static elements constituting the architecture of the places (entries and exits, fixed obstacles...), can include elements likely to interact directly with the agents. The first type of elements gathers those able to divert or capture the attention of the agents. They can lead them to introduce additional intermediate goals into their objectives (stands, shops...), or to allow the realization of goals initially present (ATM, vending machines...). The activity near these elements is modified and thus has an incidence on flows and the spatial distribution of the agents.

Another type corresponds to purely informative elements, which modify the knowledge of the agents and influence their behavior, such as traffic signs. Some agents, though they are nonfamiliar with the environment, can use these informations to achieve their goals. On the contrary an agent knowing the environment will not take them into account.

The behavior

The behavior of the agents uses a three-level logic: a strategic level, a tactical level and a level of local resolution.

The strategic level corresponds to the determination of the various goals the agent will have to reach during its life cycle. For example an agent using the subway can thus have to reach the objectives “to take the subway”, “to stay in the subway during three stations” and then “to go out and to leave the arrival station”.

The tactical level determines the local objectives that the agents have to achieve to reach their strategic objectives, while taking into account their individual characteristics. A strategic objective “to take the subway” can thus be split in various manners. A tourist, nonfamiliar with the environment, must determine his access path to the platform before being able to go there, or at least while going there. On the contrary a person knowing the station can immediately determine its way, because of its familiarity with the organization of the station. Another example is the roundabout, where all the agents have to adopt the same direction of circulation (fig. 3). The simple calculation of the shortest way does not make it possible to respect the circulation rules.

Finally the last level corresponds to the choice of local resolution. It can for example be the calculation of the next point where the agent will be, by applying the method of displacement determined at the tactical level, or the wait for an additional step of time if the agent is in a queue.

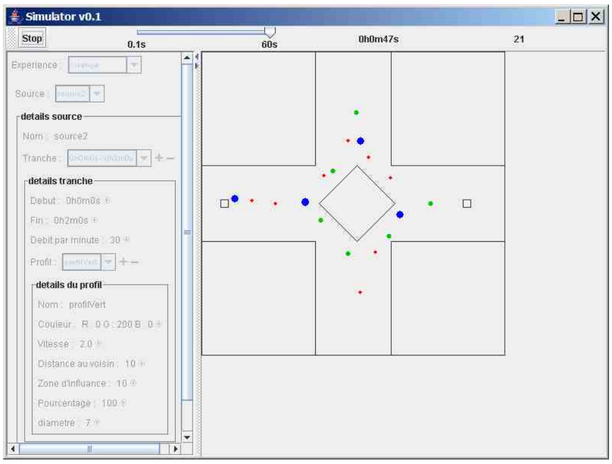

Figure 3: The simulator with various types of agent, having varied characteristics (size, speed...), which moves around a central rhombus representing a roundabout. It is not possible to circumvent this kind of obstacle and respect the circulation rules only by using flocking or shorter way.

This decomposition includes feedback and backtrack mechanisms to take into account local constraints when achieving higher goals.

Displacement

As for the models of displacement to be used, two particularly interesting approaches can be combined: the blurred path following, and a variant of the Social Force Model. The blurred path following takes as a starting point the method implemented by Craig Reynolds for path following. After having determined its next point of destination, the agent tries to join up with it while following a straight line, and respecting various constraints. It must locally solve the collisions constraints with the other agents and the static elements of the environment, and remain as close as possible to the direct trajectory. One of the main advantages of Social Force Model is the capacity of anticipation it offers to the agents. The use of forces inspired by it for the resolution of the local constraints would then make it possible to integrate it into our model.

Simulated time

The chosen approach for the management of time is the simulated time. Our agents do not necessarily have to be conscious of time, as long as they can be precisely managed by the simulation. However this flexibility is obtained only by taking care of various points.

First of all it is essential to be able to preserve a total control of the scheduling of the various tasks. An intuitive approach which would be to try an implementation in traditional multitask would likely lead to failure. A specific scheduler must be set up.

In addition to the rhythm given to the agents, the temporal concept is integrated in the notion of source. Sources are the entities that govern the creation of the agents, according to various parameters. The objective is to offer an operation by temporal phase. This way macroscopic data like input flows can be integrated and translated at the macroscopic level by the corresponding agents.

A big difficulty encountered in this type of simulation is the management of the waiting points, like lineups or waiting zones. Without an adequate model, instabilities or blockings can occur in special points of activities. A switch between different modes which modifies the behavioral rules between the phases of waiting and activity is then necessary. In order to be able to validate in experiments the effects of these activities, it is necessary to attempt to reproduce their rhythmic characteristics (flows of entries, flows of exits, etc), rather than the detail of the individual behaviors that are not relevant for the rest of the environment in the level of local resolution of displacements. From this point of view they will have space and behavioral characteristics which will evolve according to the number and the type of agents on standby.

The validation of the results

In terms of validation, we will first carry out a macroscopic validation using flows in clearly identified points of passage, spatial distributions of the agents, densities, etc. The real data are acquired by counting (for flows) or by video (for the distributions) and are confronted with the results of simulation. Those can in this case be calculated offline (without visualization of the individual behaviors). In addition, we can also carry out a microscopic validation of the behavior of the individuals. For example, the detail of the displacement of the agents can be observed and then compared with the data of the literature; it is also possible to study the “emergent” group behaviors such as circulation in file or congestion.

The problem of the scheduling of the tasks has also to be considered, in order to determine a policy of activation of the agents within the simulations. Indeed the choice of this policy is not neutral for the obtained results: an inequity in the treatment of the agents could significantly influence them. A satisfactory solution is to carry out a random draw between the agents at each step of time in order to determine scheduling, a solution which can still be improved by entangling the various behaviors. This last solution implies however that we have to set up a complex scheduler, after having carried out a classification making it possible to preserve the integrity of the simulation.

CONCLUSION AND FUTURE WORK

In this paper we proposed an approach mixing the problematics of displacement with a proposal for the taking into account of time in agents centered simulations. The objective here is to offer a model and tools adapted to crowd simulations with temporal constraints. In addition to the problems of collisions, considerably discussed in the literature, one of the difficult problems is to make it possible for the agents to change their system of displacement during their move towards the objective, and to have a global and effective system of management of the temporal constraints. The approach presented here and implemented in the MISC platform is based on the concept of sources of agents giving rythm to their life cycle from temporal constraints. These sources assign objectives to the agents, objectives that will be solved by their behavioral logic. Their displacements follow blurred paths, which are marked with stop points in queues. An agent is thus able to make half of his way, to wait a few minutes and then to start again to carry on its way. We use a method for the validation of simulation with measurement of flows of exit of the agents. The MISC platform, already operational, enables us to carry out experiments on varied levels and to advance towards our next stage: validation based on real data.

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