Course: Modeling Individualities in Groups and Crowds

Author(s) name(s): Stéphane Donikian (IRISA-INRIA), Nadia Magnenat-Thalmann (University of Geneva), Julien Pettré (IRISA-INRIA), Daniel Thalmann (EPFL)

Contact: Daniel Thalmann (EPFL)

Coordinates: EPFL VRlab

Address: EPFL-VRlab, Station 14, CH 1015 Lausanne

e-mail: Daniel.Thalmann@epfl.ch

Phone: +41-21-693-5214

Fax: +41-21-693-5328

URL: http://vrlab.epfl.ch

Title of Tutorial: Modeling Individualities in Groups and Crowds

Half or full day tutorial: Full day

Keywords: population, individualities, crowd simulation, path planning, accessories

Necessary background and potential target audience for the tutorial: experience with computer animation is recommended but not mandatory. The course is intended for animators, designers, and students in computer science.

Detailed outline of the tutorial

Crowds are part of our everyday life experience and essential when working with realistic interactive environments. Domains of application for such simulations range from populating artificial cities to entertainment, and virtual reality exposure therapy for crowd phobia. We mainly focus on real-time applications where the visual uniqueness of the characters composing a crowd is paramount. On the one hand, it is required to display several thousands of virtual humans at high frame rates. On the other hand, each character has to be different from all others, and its visual quality highly detailed.

Variety in rendering is defined as having different forms or types and is necessary to create believable and reliable crowds in opposition to uniform crowds. For a human crowd, variation can come from the following aspects: gender, age, morphology, head, kind of clothes, color of clothes and behaviors.

Creation of individualized population

Simulating virtual environments populated with virtual but realistic crowds requires dozens of different face and body geometries. In this part of tutorial, we will present methods that allow automatic generation of desired population models. A virtual human body simulation environment generally consists of a few template human body models with different material properties applied to simulate the variance. To obtain a better simulation, different size body models (Figure 1) are used to represent the geometric variance. Usually two main criteria are considered while modeling those virtual characters. The first one is the realism and the second one is the efficiency. It is obvious that depending on the application area, one of these criteria must be sacrificed for modeling a virtual character. Using either physical or geometrical methods, it is possible to adjust the optimal load balance between realism and efficiency. Physically realistic body modeling techniques are generally required in case of medical and textile applications while the geometric modeling techniques are preferred in crowd simulation, animation and game programming. While physically realistic modeling techniques deal with underlying layers like fat tissues, muscles and the skeleton, to improve the realism of the existing models during motion, the geometrical modeling techniques just deforms the surface mesh. The efficiency of those methods for virtual body simulation and animation is still one of the most important criteria in computer graphics.
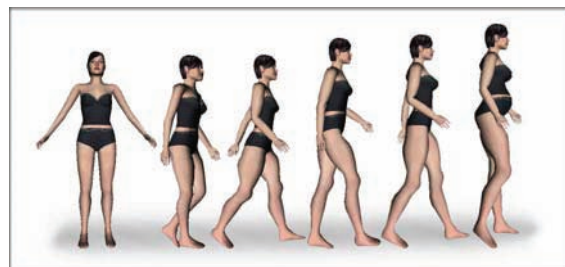

Figure 1 – Different size bodies

Human body deformation methodologies can be classified into creative, reconstructive, and example based approaches. Computationally the fastest technique, the creative approach, is the most preferable one in real-time applications because it doesn't require post processing, initial model database, and supplementary data. As an example, using the anatomic or anthropometric approach it is possible to parametrically generate new size models from an existing template one. These approaches are important especially for crowd simulation because of their efficiency. To generate anthropometry data as parameters for different size body models, anthropometric surveys are conducted by 3D human body scanners. On the other hand, as an example based approach, virtual body models that are generated by 3D scanners are used. According to a user specified anthropometry parameters, scanned body model database is

searched to find the similar size mesh. Most appropriate search result is also deformed to provide exact match between the specified parameters and the existing one.

Individualized versus collective behaviours

The management of big public equipments, such as a railway station, an airport, or a stadium, requires a dedicated expertise in crowd phenomenon, due to the possible high density of population in a short period of time. To be able to study such crowd phenomenon, and the reciprocal relations between individual and collective behaviours, it is necessary to study real situations and propose representative models. Macroscopic simulation has been historically the first approach to be studied to simulate the pedestrian displacement, due to its low calculation cost. In this approach the pedestrian is not treated on its own but as a component of a more macroscopic element. In the case of a low density, a gaseous model can be used. In such a model the displacement of pedestrians is assimilated to those of molecules inside a gas. Other macroscopic models have been proposed such as the hydraulic one for crowd simulation when the density is very high, by assimilating the motion of a crowd to the motion of a liquid inside a tubular structure. More recently those physical equations have been used in the field of computer graphics to animate crowds. Based on huge number of observations, statistical models have also been proposed to put in equation the evacuation delay of a building.

In the contrary of the preceding approach, microscopic models consider persons as the elementary units of the model, and manage their interaction inside the environment. Particle system assimilates the displacement of an entity to the motion of a particle inside a restricted area. This model, the main approach in microscopic simulation, is based on physical laws that allow describing attractive and repulsive forces that can be associated to obstacles and moving entities. Particle based models allow to generate a macroscopically plausible behavior in case of a high density, but in contrary they do not take into account perception or social rules. Several evolutions of the original model have been proposed in the last years to expand its usage domain. Other microscopic approaches have been developed such as cellular automata, predictive geometric models, steering methods, and agent based approaches. More recently, a video based approach has been developed to create a navigation model by examples. However all those approaches are limited to the navigation behavior without the management of individual human goals.

The multi-layered approach tends to model the behavior of crowd participants not only for its reactive navigation inside the environment, but by integrating also its ability to plan a path (cf next part of the course) due itself to a decision about its individual activity based on task planning. Different combinations of model have been proposed in the literature for the different layers. Each layer may have its own frequency and should exchange specific information with the directly upper layer to inform it of some imposed constraints, and also with the directly lower layer to control it. In some models, a rational layer may be in charge of the logical decisions of the agent based on its own objectives and its spatial cognitive map. Coupled with a generic management of functional objects and cognitive tasks, this creates a connection between the abstract decision of the agent and its embodied abilities: perception, path planning, and navigation.

In panic situations, pedestrians wish to move more quickly than usual and, forgetting all social rules, accept to be in a physical contact with their neighbors. Due to this physical interaction situation, they are developing a mimetic behavior consisting in reproducing the behavior of preceding characters in the flow. The homogeneity is developed inside the crowd not because of a spatially coherent organization of the population but because of the tendency of crowd members to respect a predominant emerging norm. This is obligatory followed by the notion of regulation, learned as a normative element by people living together inside the same macrostructure or institution. However, some small groups can be the motor and modify the behavior of biggest units such as a crowd, playing the role of the core group. For example, a band structure inside a crowd of pedestrians moving on a sidewalk could be explained by its optimal configuration to regulate opposite flows. One of the most crucial problems to be solved to generate plausible crowds concerns the relation between microscopic and macroscopic structures and behaviors inside the crowd. The goal is to explain how an individual entity is constrained by the institution and, in contrary, how the community impacts on the individual behavior along time.

In this part of the proposed tutorial, we will review the different nature of microscopic and macroscopic models for crowd simulation, and then the multilayered models. We will then see how individuals which are part of a microscopic model can be parameterized by using macroscopic data, collected in the real case study or resulting from statistical analysis (see Figure 2).

Figure 2 – data collection for small crowds navigation
among obstacles using motion capture

Individualized Path Planning and Navigation

Navigation is probably the most studied behavior in the field of crowd simulation. Models for crowd navigation may be macroscopic – they consider crowds as a whole with no care for individuality – or microscopic – the crowd motion results from a sum of individual trajectories and interactions. In the latter type of models, individual is explicitly represented as a particle or an agent, depending on models. Then, individuality of motion results from the path planning stage providing paths to follow, and the steering method used for path following while avoiding others. Path to follow depends on the goal destination, steering is parameterized with individual parameters such as physical, social or psychological ones.

When several individuals have common destinations from same locations, the path planning stage normally results in identical paths. Then, the differences in their trajectories then only depend on interactions occurring along their way. Yet, in the real world, pedestrians have a large variety in navigation trajectories. As a result, the path planning technique used to compute individual path has a great influence on the believability of resulting motions. Particularly, it should be able to generate a variety of paths from similar queries.

Also, in the case of interactive crowds, simulation and rendering tasks are executed on-line and in real-time: a very low computation time is then available for steering. To address this problem, hybrid techniques combine microscopic and macroscopic models with levels-of-details strategy in order to make still possible the handling of large crowds. The user point-of-view is considered in order to distribute the available computations resources: individual high-quality steering is used for pedestrians at the forefront, and is progressively simplified towards background and invisible areas. How to preserve individuality and natural looking motions, at low computational costs, when lowering steering quality down?
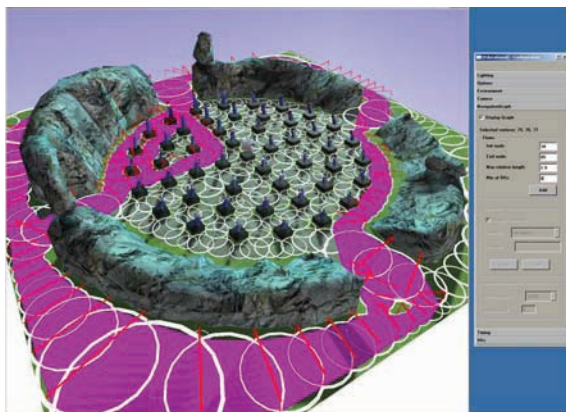

Figure 3 – path planning with variety in a complex environment.

In this part of the proposed tutorial, we will first give the audience an overview of general path planning techniques. We will then present how these techniques are scaled to fit the case of large Interactive Crowds, and how they are

combined with crowd simulations techniques. We will emphasize the need for variety at path planning stage and give key-ideas through a pedagogic description of different existing solutions (see Figure 3).

The impact of individualized crowds on rendering

To simulate large crowds at high frame rates, it is necessary to use several levels of detail (LOD). Characters close to the camera are accurately rendered and animated with costly methods, while those farther away are represented with less detailed, faster representations. The common process is to use many instances of a small set of human templates, i.e., virtual human types identified by their mesh, skeleton, textures and LOD. There are mainly three LOD used in crowd applications: classical deformable meshes, enveloping a skeleton and skinned to perform skeletal animations, rigid meshes, which are precomputed geometric postures of a deformable mesh, and impostors, representing a character with only two textured triangles forming a quad. Deformable meshes are altered by the online computation of their skeleton movements. Although this method is more expensive than using rigid meshes1, it allows to perform special animations chosen or produced at runtime, like looking at the camera, or mimicking facial expressions. Yet, impostors are naturally the most exploited LOD in the domain of crowds. Their main advantage is their rendering efficiency, since only two triangles per character are displayed.

Instantiating many characters from a limited set of human templates leads to the presence of multiple similar characters everywhere in the scene. However, the creation of an individual mesh for each character is not feasible, for it would have too high requirements in terms of design and memory. Thus, methods have to be introduced to modify each instance, so that it is visually different from all the others. Such methods also need to be scalable for all LOD used in crowd simulations to avoid inconsistencies in the individual appearances. We will explain a fast and scalable technique to obtain unique characters from a small set of basic human templates. Firstly, to vary the shape and appearance of a character, we introduce accessories, simple meshes attached to the individuals in order to make them unique, e.g., hats, glasses, or jewelry. Secondly, we present a novel technique to identify body parts with dedicated textures, called segmentation maps. This approach allows to have smooth transitions between body parts and to enhance character and accessory visual appearance with distinctive details, such as make-up, or fabric patterns. Both methods are scalable, so that all characters can be displayed consistently with any LOD used in crowd simulations. Specifically in the case of impostors, we will explain a method to correctly place accessories, and solve occlusion issues with a new algorithm. By combining accessories and segmentation maps, instances of a same human mesh are transformed into unique individuals. The cost of rendering crowds certainly increases with the number of polygons to display. Thus, when real-time performance is required, it is necessary to balance the number of worn accessories with the number of characters composing the crowd. Even so,

this approach can fully simulate thousands of accessorized characters at high frame rates.

Concerning the animation, generating different locomotion cycles online for each individual is unfortunately too expensive. Moreover, depending on the rendering levels of detail, e.g., billboards or rigid meshes, it is impossible to create an animation clip online. One solution is the use of an animation database. At the beginning of a simulation, a virtual human walks at a certain speed. To find the corresponding animation sequence, the framework formulates a request to the database. The database returns an animation clip at the closest speed. To create this database, we generate offline many different locomotion cycles, with varying parameters. A few representative locomotion cycles are selected to create the corresponding rigid mesh animation sequences. An even smaller number of cycles are also selected to create billboard animation clips.

Figure 4 – Appearance individuality in large crowds

Syllabus

Introduction (Daniel Thalmann, 10 minutes)

- Objectives

- State-of-the-Art and Related Work

Real-Time Individualized Virtual Humans (Nadia Magnenat-Thalmann, 90 minutes)

- Automatic construction of unlimited number of population models

- Creation of individualized Virtual Humans

- Automatic construction of unlimited number of population models

- Motion retargeting and Virtual Try-On

- Modeling and Animating Faces

- Defining personaliy and autonomy

Individualized versus collective behaviors (Stephane Donikian, 90 minutes)

- Introduction to experimental studies made about collective behaviours

- Presentation of the different models (macroscopic, microscopic and multi-layered).

- Discussion about the respective advantages and drawbacks of the preceding models

Individualized Path Planning and Navigation (Julien Pettré, 90 minutes)

- Introduction to Navigation Planning and Control: path planning, steering methods, handling crowds.

- Exploring limits, from passive to interactive crowds: sources of complexity, bottlenecks, need for variety.

- In Practice: dedicated path planners and simulators, hybrid approaches, levels-of-detail.

The impact of individualized crowds on rendering (Daniel Thalmann, 70 minutes)

- Fidelities: dynamic meshes, static meshes, impostors

- Colors and textures

- Animation models for each fidelity: walking,

- Accessories handling

- Patches

Conclusions and Further Discussion (all speakers, 10 minutes)

Resume of the presenters

Daniel Thalmann is Professor and Director of The Virtual Reality Lab (VRlab) at EPFL, Switzerland. He is a pioneer in research on Virtual Humans. His current research interests include Real-time Virtual Humans in Virtual Reality, Networked Virtual Environments, Artificial Life, and Multimedia. Daniel Thalmann has been Professor at The University of Montreal. He is coeditor-in-chief of the Journal of Visualization and Computer Animation, and member of the editorial board of the Visual Computer and 3 other journals. Daniel Thalmann was Program Chair of several conferences including IEEE VR 2000. He has also organized 4 courses at SIGGRAPH on human animation. Daniel Thalmann was the initiator of the Eurographics working group on Animation and Simulation which he cochaired during more than 10 years. Daniel Thalmann has published more than 350 papers in Graphics, Animation, and Virtual Reality. He is coeditor of 30 books, and coauthor of several books including the recent books on "Crowd Simulation" and Stepping into Virtual Reality", published by Springer. He received his PhD in Computer Science in 1977 from the University of Geneva and an Honorary Doctorate (Honoris Causa) from University Paul-Sabatier in Toulouse, France, in 2003.

Prof. Nadia Magnenat-Thalmann has pioneered research into Virtual Humans over the last 25 years. She obtained several Bachelor's and Master's degrees in various disciplines (Psychology, Biology and Chemistry) and a PhD in Quantum Physics from the University of Geneva. From 1977 to 1989, she was a Professor at the University of Montreal where she founded the research lab MIRALab. She moved to the University of Geneva in 1989, where she recreated the Swiss MIRALab, an internationally interdisciplinary lab composed of about 25 researchers. She is presently taking part in more than a dozen of European and National Swiss research projects. She has a long experience on simulating humans as she has worked on the early EU project Humanoid in 1993. Actually, she is working in the EU project Leapfrog where everyone can be modelled and animated using a set of individual dimensions. She is the coordinator of the European Research training network Marie Curie "3D ANATOMICAL HUMANS" which goal is to provide anatomy-specific bodies. With her students, she has published more than 400 papers mostly on virtual humans (body, hair, clothes and on VR and AR as recreating life in Pompeii or touching textile for the project Haptex. She is editor-in-chief of the Visual Computer Journal published by Springer Verlag and co-editor-in-chief of the journal Computer Animation and Virtual Worlds published by Wiley. More can be seen at www.miralab.unige.ch

Stéphane Donikian obtained a Master's Degree in 1989, a PhD in 1992 and an Habilitation to direct research in 2004, from the Computer Science Department of the University of Rennes 1. From 1994 to 2007, he has been Research Scientist for CNRS and is now in detachment at INRIA. In 2006 he became the leader of a new team entitled Bunraku, whose objective is to develop cross fertilization of researches in the fields of virtual reality and virtual human. The common challenge of the team members is to allow real and virtual humans to naturally interact in a shared virtual environment. His research interests include Virtual Humans, Individual and Collective Human Behaviors, Informed Virtual Environments, Scenario Authoring Tools for VR applications, Interactive Storytelling. He is author of more than 70 scientific international publications; moreover, he has also served in the scientific committees of several international conferences and serves as referee for many international conferences and journals in the field of computer graphics. He performs technical expertise for national and European agencies on academic and industrial innovative projects in the fields of virtual reality, computer graphics and video game. He has conducted or participated to several national and european research projects.

Julien Pettré is Chargé de Recherche at INRIA-IRISA since 2006. He received B.S., M.S. and Ph.D. degrees in Mechanical Engineering and Computer Science respectively in 1998, 2000 and 2003. Prior to joining the Bunraku team at IRISA, he was postdoctoral fellow at the EPFL-VRlab of Pr. D. Thalmann. His research interests include robotics and computer graphics. His works focused on motion planning for virtual humans: locomotion, manipulation and crowd navigation planning. He organized siggraph class on motion autonomy for virtual humans in 2008.

Selected Publications

Di Giacomo T, Moccozet L, Kim H, Magnenat-Thalmann N. State-of-the-Art on Level-Of-Detail for Virtual Human Animation and Representation. in Shape Analysis and Structuring, Springer, Leila de Floriani, Michela Spagnuolo (eds.), September 2007.

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Magnenat-Thalmann N, Seo H, Cordier F. Automatic Modeling of Virtual Humans and Body Clothing. Journal of

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Paris S, Lefebvre D, Donikian S. SIMULEM : Introducing Goal Oriented Behaviours in Crowd Simulation. PED2008, 4th International Conference on Pedestrian and Evacuation Dynamics. Wuppertal, Germany, 27th – 29th February 2008.

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Pettré, J.; Grillon, H. & Thalmann, D. Crowds of Moving Objects: Navigation Planning and Simulation Robotics and Automation, 2007 IEEE International Conference on, 2007, 3062-3067

Thalmann D, Musse SR, Crowd Simulation, Springer, 2007 Thomas R, Donikian S. A spatial cognitive map and a human-like memory model dedicated to pedestrian navigation in virtual urban environments, in: Spatial Cognition 2006, T. Barkowsky, C. Freksa, M. Knauff, B. Krieg-Brückner, B. Nebel (editors), Lecture Notes in Artificial Intelligence, Springer Verlag, 2006.

van den Berg, J.; Patil, S.; Sewall, J.; Manocha, D. & Lin, M. Interactive Navigation of Individual Agents in Crowded Environments. Symposium on Interactive 3D Graphics and Games (I3D), 2008

Yersin B, Maïm J, Thalmann D, Unique Instances for Crowds, IEEE Computer Graphics and Applications, 2008 (to appear)

A tutorial on "Populating Virtual Environments with Crowds" has been given in Eurographics 2007, but only Daniel Thalmann was presenter and the contents was very different. It was not dedicated to individualities.