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Simulating Populations in Massive Urban Environments

O. Balet[1], *J. Duysens[1], J. Comptdaer[2], Gobbetti E.[3], Scopigno R.[4]

[1] CS
Rue Brindejonc des Moulinais
F31506 Toulouse
olivier.balet@c-s.fr
http://www.c-s.fr

[2] MASA
Rue de la Michodière, 8
F75002 Paris
jerome.comptdaer@masagroup.net
http://www.masa-sci.com/

[3] CRS4
POLARIS,
I09010 Pula
enrico.gobbetti@crs4.it
http://www.crs4.it

[4] CNR
Via G. Moruzzi, 1
I56124 Pisa
roberto.scopigno@isti.cnr.it
http://www.cnr.it

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ABSTRACT

The United Nations recently reported [1] that the global proportion of urban population reached 49% in 2005 and that 60% of the global population is expected to live in cities by 2030. Urbanised areas are extremely vulnerable to all sorts of threats. Indeed, the combination of heavy population concentrations, critical infrastructures and built environments make it possible for environmental, industrial or man-made incidents to rapidly escalate into major disorders. Recent events have forcefully demonstrated that authorities at all levels of government turn out to be inadequately prepared for the intricacies and dilemmas of disasters in large urban environments. Therefore, innovative tools are needed to assist them in the studies, planning and inter-organizational preparation efforts, enabling to understand vulnerabilities and security issues, define and assess crisis management procedures, and train personnel. The CRIMSON research project [2] has been funded by the European Commission in the field of Security Research to address this challenging need by researching, implementing and validating an innovative framework combining the latest virtual reality and simulation technologies. For that purpose, several technological challenges have been tackled by an international team of researchers, industrials and users, and important advances have been made in the following fields.

Massive urban environments visualisation

The first technological challenge has been addressed by extending the VirtualGeo [3] system in order to support the 3D interactive and seamless visualisation of massive geographic environments [4][5] including non-Euclidian heterogeneous data (e.g. simulation results, weather forecasts …). Then, a GPU-friendly technique [6] has been introduced to efficiently exploit the highly structured nature of urban environments to ensure rendering quality and interactive performance. Central to our approach is a novel discrete representation, called BlockMap, that compactly represents a set of textured vertical prisms with a bounded on-screen footprint used to encode and render a small set of textured buildings far from the viewer. BlockMaps are stored into small fixed size texture chunks and efficiently rendered through GPU raycasting. We implemented an effective output-sensitive framework in which a visibility-aware traversal of the hierarchy renders components close to the viewer with textured polygons and employs BlockMaps for far away geometry. Our approach provides a bounded size far distance representation of cities, naturally scales with the improving shader technology, and outperforms current state of the art approaches.

Population and traffic simulation

The accurate modelling of the population behaviour is a critical parameter of any crisis simulation in urban environment. In our case, the problem is made even more complex by the size of the population to consider, its geographical concentration, as well as the interactive aspect of the system that needs to feed visual results back to the user at interactive rate (>15Hz). In addition, the simulation must support the global dynamic characteristics of large human groups while simultaneously accounting for fine-grained individuals. We pushed the state-of-the-art in this field by adopting a hybrid approach [7], initially explored in [8][9], using a macroscopic model to simulate global flows and apply a microscopic model on critical areas or individuals. The urban environment is tagged with metadata defining the points of interest and infrastructures (position, capacity, opening hours…) that attract populations. Similarly, incidents and adverse events can have repulsing capabilities. The urban environment is split in categorized zones (residential, offices…). All these metadata are used by the system to initialise the simulation, define potential fields, and generate population flows according to the unfolding scenario. Then, the environment behaves as a set of potential fields, influencing individuals already “polarized” by their current activity. Population is split in groups sharing the same profile (i.e. class), which defines socio-cultural characteristics and activities. The profile implements a DirectIA behavioural model [10] which enables an intuitive behavioural modelling based on environmental stimuli, concurrent motivations, triggered behaviours, and actions. The DirectIA behavioural system is then used to process the behavioural simulation.

Conclusion

The CRIMSON framework offers an effective and generic platform for both the 3D visualisation and behavioural simulation of populations evolving in massive urban environments in response to simulated events. CRIMSON enables both the analysis and the evaluation of complex environmental, industrial or man-made events, their impact on the population and the contingency scenarios that would be difficult to unfold and validate in real conditions. In addition, the 3D visual capability of the system offers a unique mean for creating, communicating and sharing complex knowledge across organizational boundaries. Thanks to its scalable architecture, it is now open to further research on the numerical modelling and simulation of complex events that will be used to stimulate the CRIMSON scenarios. Our system has been successfully validated with real scale scenarios; as an example we were able to interactively and credibly simulate and visualise the complete population of Paris evolving in a massive textured model of the city, on a commodity graphics platform.

There is however still a lot to do to enhance the system. Interactively simulating and visualizing populations evolving in complex environments, with a sufficient level of realism, will probably take decades. In particular, physical simulation of events has not been addressed by the project and important efforts of the research community should be spent on the convergence and integration of numerical simulations and interactive simulations. In the field of massive urban modelling and visualisation, new research fields are now open in order to support indoor environments that represent new challenges in terms of volumes of data to handle, and optimization and rendering techniques. In addition, there is currently no acknowledged metrics to assess the level of realism, or credibility, of the simulated population. This represents a serious roadblock for the adoption of behavioural simulations in the frame of environmental studies and operational preparedness.

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