Abstract. This paper presents a semi-automatic visualization method for the evaluation of urban environments that is based on artificial intelligence. It proposes the use of agent-based crowd simulation software on a mid-scale urban planning level for design evaluation. The information on agents’ movements is noted in standard raster images. The results are maps that are easy to understand. These maps show movement paths of the agents and density and give further conclusion on bottlenecks in planning contexts. Key measures, like the occupant movement in a given district, until now relied greatly on empirical knowledge or data that could be only gathered after an urban design had become built reality. Our method focuses on the adaptation of common software technology that is originally situated in film and TV productions. A practical workflow shows how our method can be easily integrated in daily design tasks.

Keywords: Artificial intelligence; agent-based; crowd simulation; urban planning; design evaluation; occupant movement.

Introduction

Motion planning and path finding has been studied extensively in game development, film and broadcast production, and has a strong background in robotic research and research areas covering knowledge mining and artificial intelligence. In this paper, we restrict ourselves to motion planning approaches to predict simultaneous occupant movement, motion and interaction of multiple agents in urban environments. This paper brings practical insights on how to apply crowd animation on planning issues. Further we span the work done in the areas of artificial intelligence, computer animation, and pedestrian movement as well as traffic flow simulation to architecture.

Our method aims to analyze synthetic architectural mid-scale urban models and inherent spatial configurations in a virtual environment with agents that represent typical occupants of the considered area. Important goals are a) to evaluate the functionality of local networks that can later on be used as representations of modeled urban objects. These objects can be used as landmarks such as train stations, pedestrian crossing, corner shops, office buildings, and courtyards with private zones) and b) the
corresponding load that a covered area will probably achieve. Standard 3D geometry serves as a design input that will be evaluated with adapted agents for urban simulation. The outcomes are a) specific visualization maps showing the movement, residence time, and the density of crowds in a certain area over time, b) 3d animations, which can be easily explored in real-time, and c) animated footages for each agent and, or agent groups.

Related Work
In the following we give a short outline of selected works related to the simulations of groups and crowds. For a more comprehensive description we refer the reader to (Magnenat-Thalmann et al., 2004). Models for group behavior had been an active research field since the late 19th century, for example LeBon (1895). Today’s computer simulation models have a relatively young history. Most relevant approaches have been realized within the last 20 years and are mostly specialized as specific solution for different fields. In architecture Penn and Turner (2001) describe an approach to model urban agents for the use within their space syntax system. Another example is represented with Tecchia and Chrysanthou (2000), who describes a method for populating urban environments in real-time rendering but have a stronger connection to computer graphics like Bouvier and Guilloteau (1996). The authors describe the use of crowd simulation within immersive environments.

More specifically is Reynold's (1987) flocking method is more specific, as it uses particle systems and represents one of the most common approaches for simulating group movement within the entertainment industries. Brooks (1991) provides a comprehensive foundation on which many of the recent agent models and theories are based. He describes many failing artificial intelligence approaches to set-up intelligent agents. Musse and Thalmann (2001) introduced a more flexible model with hierarchical behavior. Physics and body effects had been described by Helbing et al. (2000) to simulate escape panics effectively. In other fields like robotics (Molnar and Starke 2001), safety science (Still 2000) and sociology (Jager et al. 2001) similar simulations involving groups of individual intelligent units have been created.

Overview
This paper is organized as follows: Section 2 starts with an overview of available techniques for evaluating occupant movement within the design process and gives an introduction into the theoretical background agent-based crowd simulation. Afterwards our novel extensions needed for an occupant movement evaluation are stated. Section 3 deals with the description of the main components of our framework and their implementation within our working pipeline. In section 4, we describe examples where we applied our framework. The first example features a simple environment consisting of simple cubic volumes and interacting agents as shorthand example for pre-visualization needs. The second example poses a mid-level urban environment and characterizes an office building block in Split, Croatia. Section 5 outlines our conclusion and Section 6 comprises future work.

Agent-based simulation for urban design

Urban design aims to establish the perfect relationship between streets, buildings and occupants. Many cities prior to the industrial era were largely determined by the social interactions based on walking (see Karunakaran, 2005). Although there had been a lot of development in explaining occupant behavior in urban models, only a few take full benefits from computed simulation. Spatial qualities in architectural design cannot be fully evaluated only by observing geometrical constructs without reference to inhabitants placed inside (see Narahara, 2007). Therefore we propose a computational simulation for visualizing animated human reactions to physical conditions that are expressed with a synthetic architectural model. For the implementation of our
method we use the latest version of Massive Prime an industry standard application for the simulation of crowds and social dynamics. The software itself relies mainly on the fuzzy logic model for artificial intelligence, which had been introduced by Zadeh (1965).

**Current urban design methods**
The current design evaluation process in today’s urban planning mainly relies on models (figure 1), maps, and abstract visualization sketches. The expected quality concerning occupant movement is often estimated by empirical judgment. Different points are elaborated in discussions with other enlisted planners. We can claim that the planners’ intentions can fail in reality from the pedestrian’s point of view.

**Base crowd Animation framework**
Most common crowd simulation approaches are very specific to the application and concentrate on different aspects of the collective behavior, which is also modeled differently. Used techniques include for example those that cannot distinguish individuals and are often used for evacuation simulation models where a flow-rate and a network graph are still sufficient. We can differ between two broader areas of crowd simulations. The first one is favoring realism of behavioral aspects with mainly 2D point visualizations like evacuation simulators. Behavior is in that field extremely simplified and can range from very narrow, controlled scopes (e.g. evacuation scenario) up to real world observations of certain situations.

Another approach in crowd simulation is to achieve high quality visualizations, which can be applied in e.g. movie production or computer games. For this field a broad range of crowd simulation applications exists. Recent applications also include very advanced behavioral models. Massive Prime seems to be one of the most advanced applications in that field. It offers an artificial intelligence engine that is easily accessible for users due to its user interface. It had been used with great success in recent film productions such as Weta’s ‘Lord of the rings’ and ‘King Kong’. The application features several pre-configured agents with certain abilities such as ‘cheering for a team’, ‘run away’ or simply ‘walk’. By adjusting the agent, it can be used for several scales of design and up to very large crowds consisting of of thousands of agents. The main advantage of Massive for the use within urban planning is that it can be used (a) for quantitative visualization and (b) for visualizing high-quality crowd simulation. Massive uses a so-called brain model as a simplification of the underlying artificial intelligence rule-sets. The brain model can be edited and controlled by the user by connecting logical items in a visual language. Due to their limited abilities, agents have to be ‘trained’ for every action. This means the user has to edit specific rule-sets in order to achieve a well-defined

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*Figure 1*
A typical 3d representation of an urban design.
behaviour of an agent in a specific situation. Actions and functionalities can be placed on a drawing desk and connected to each other with a simple input-output layout. Perception inputs for the brain can for example consist of channels, which scan the environment. An input leads always to a (re-)action such as ‘changing direction’, ‘paint the ground’, ‘stop’. The brain model computes these reactions based on a fuzzy logic. A fuzzy logic classifies input values into so-called fuzzy sets, which are voting with different weights for a rather true or a rather false evaluation of a given input. With fuzzy sets continuous values can be reasoned that cannot be expressed with Boolean logic.

**Evaluation System for urban design**

Our evaluation system comprises of an urban agent model that can represent both a resident or a commuter. The agent’s behavior has variance attributes that result in a varied crowd in every simulation cycle. As spatial urban information points we developed special entities like emitters (public transport), attractors (work) and repelling points that can mimic real world likeness. These entities had been carefully adjusted to simulate typical urban coherences over time. Agents can follow these goals sequentially, which leads to a behavior chain and a motion tree.

To run a simulation a three-dimensional geometry model has to be loaded into our evaluation environment. After a simulation has been started each agent draws its movement onto a large bitmap image. The drawing contains information on speed, residence time and density. In that way places with undesirable measures can be easily identified. Since the evaluation pipeline also features the 3D environment the user can easily rerun the simulation, choose an agent and see the urban scenario through the agents walking perspective. After adjustments to the urban design had been applied and the user is finally content with the result a high-resolution urban crowd simulation can be generated. This can be used for example to communicate the quality of the urban scenario to others. As outputs the system offers animation data that can be interpreted within common 3D packages like Autodesk Maya. For offline rendering the system has a connection to nVidia’s Mentalray or Pixar’s RenderMan.

![Figure 2](image.png)

*Figure 2*

Flow fields can be used for vectored movements like the flow of automotive vehicles.
System components

In the following we like to illustrate the components of our method more extensively. The main components comprise of (1) geometry models for agents and urban environments, (2) control parameter that guide the agents, (3) the perceptive system of the agents, and (4) the agent’s brain.

Geometry

There are two classes of geometry representation within the given framework. The body geometry represents a humanoid geometry system consisting of a simple skeleton with specific kinetic features and geometric detail. This model is extended with the artificial intelligence logic that is called the brain within this simulation method. The second class represents the environment consisting of building masses and terrain that should be recognized by the agent.

Control parameters

How agents interact with each other and the urban environment can be determined via control parameters. They are needed to control social dynamics - for example at which speed an agent is allowed to overtake other agents or when agents have to stop and to allow other agents passing by. Other measures like personal space can be defined to setup thresholds for pedestrian stress simulation caused by high density of people movement. In such situations agents can express their ‘emotional’ state by their color. Special control parameters are the flow fields (figure 2), which forces agents due to its strong weight to follow an area with aligned vectors. This control parameter is useful to define car flows, which stay in their lane and only make decisions at junctions and crossings.

Most of the occupant movements like commuters follow goals. Therefore so-called sound beacons can be used, which can be attractive or repulsive to an agent depending on its configuration. Sound beacons are by default global goals to any agent, but they can be weighed and diverted to fulfill functions of minor goals such as kiosks and shops.

Vision and recognition

An agent can be equipped with visual reception (figure 3). This can be used for vision based collision avoidance of other agents and obstacles. The vision is enriched with rating information that is necessary to apply fuzzy rules e.g. for changing directions.

Urban agent

The urban agent is literally represented by its brain - the core of artificial intelligence in our system. It is especially trained and configured for synthetic urban environments. Through several configured behaviors in reaction to spatial entities, agents can move inside the model follow goals, interact with others and place markers.
Examples

Simple environment
The first example (figure 6) features a simple environment consisting of simple building blocks and interacting agents. The agents’ movement started at the sources represented by red dots and headed to a global goal situated at the bottom of the picture. Agents had to sidestep the simple building blocks. An extreme pedestrian stress situation occurs between the right sources.

Split, Croatia
The second example poses a mid-level urban environment: It characterizes an office building block in Split, Croatia (figure 8). Sub-areas serve as membranes and depending from the example’s variation and, or as a set of agent goals. This example simulates the occupation movement in this city block by commuters, which populate this from a train station and a nearby industrial area vice versa. Figure 7 shows how accessible private courtyards will be rather filled by others than by its intended residents. We introduced a major attractor for agents and a source of agents at the train station. The beacon is also configured as a sink for agents who already reached their goal. The train station as a source of agents has to meet the requirements of a real train station source, such as arrivals, which leads to a sudden rise in density of agents. The idea behind the intended architectural design was a pattern of aligned public and private courtyards. The commuters should move through the public courtyards without strict guidance like
fences around the private ones. We simulated local attractors like kiosks. Therefore, we convinced the agents and reduced the flow of people through the private area to a minimum.

Invasion, ETH Hoenggerberg

In this example students of the elective course ‘Information Architecture’ elaborated, which psychological effects a certain occupancy movement can have on a spectator (figure 9) and to examine the production quality possible with our used system (figure 10).

Conclusion

This evaluation environment for occupancy movement and urban environment brings an interesting contribution to the field of urban simulation and city modeling. The presented work offers a practical solution for evaluating urban designs and can be easily embedded into planning projects. The artificial intelligence of this system permits simple and complex evaluation examples independently from the considered urban scale. It is applicable to small as well as large scales.

Future work

Further research covers the resulting deviation between an observed real world situation and a synthetic simulation. Other research areas try to answer the automatic setup and placement of human agents and transportation agents for urban simulation as well as a further simplification of our model.

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References:


