

Embodied Game Agents in Environmental Design Education

Ahmed Sarhan¹, Peter Rutherford²

^{1,2}School of Built Environment, University of Nottingham, United Kingdom

<http://www.nottingham.ac.uk/sbe>

¹taxas4@nottingham.ac.uk, ²Peter.Rutherford@nottingham.ac.uk

Abstract: *Over time, design instructors have become more encouraged to accommodate the play metaphor in their courses, for its rich technical and psychological assets. While there are issues regarding the interactive narrative structure of the game, embodied Multi-Agent-Systems (MAS) have been introduced to address these issues and handle complicated game objectives. With the ever-growing complexity of design concepts and the mounting demand to design for sustainability, more variables and intricacies are introduced to the design and decision making process. This paper presents a proposed method that utilizes MAS in game engines to resolve the environment design complexity for design students and untrained professionals. This method offers better comprehension of the implication of data generated from building analysis tools, and presents guidelines to develop the proposed design accordingly.*

Keywords: *Game engines; environmental design education; embodied multi-agent system; interactive narrative.*

Introduction

In their aspiration to “Design for Sustainability”, designers presently rely on analyzing environmental data generated from building performance simulation tools like Ecotect (www.ecotect.com). The wealth of data generated is often presented in a rather intricate format, relying significantly on the designer’s expertise to read, analyze, interpret and correlate data sets. This paper presents a method that incorporates embodied Multi-Agent-Systems (MAS) into game engines, in an attempt to facilitate the interpretation of environmental data analysis in an interactive narrative virtual context, and offer designers a more solid comprehension of the building’s potential performance at various design stages. The

game also presents sets of guidelines and strategies that can give the opportunity to iterate design and produce alternatives leading to improved building performance. The proposed method targets mainly students and designers who are not fully equipped to solidly interpret these complex data sets or utilize them in the decision-making process.

Games in design education

Playing games, in recent years, have become a prevailing paradigm and pattern of life for most adolescents. Immersion and engagement in games has become an extension to youngsters’ lives, to the extent that recent studies show that they spend more time playing online or video games than playing outdoors. It has become eminent to incorporate

the “Play” metaphor in other aspects of their lives, particularly education. Bower (1974) argued that protecting the play modalities of thinking that the youngsters developed in their childhood will positively affect their sense of creativity and imagination when they grow up. The game context is generally pervasive in the modern society, where many people are attracted to and familiarized with. In this sense, many design instructors have recently become less reluctant to oversee the negativities of “playing” and accommodate the game metaphor in their courses. They have realized that the traditional methods of design teaching are comparatively restricted, and lack the sense of flexibility and degree of engagement the young generations are accustomed to. They have shown increasing interest in what the effects these games have on players, and how some of the motivating aspects of video games might be harnessed to facilitate the learning process (Dickey, 2005).

Playing a game is in general a goal-oriented process. Games tend to give the players a series of challenges that they should confront and conquer to achieve the overall goal. This notion is in many aspects similar to the design process, which made it quite easy to mould the two and develop the notion of designing while playing. The playful context of the game has a great effect on easing the tension of problem solving. Students in a game context are more self-motivated, entertained, challenged, and engaged with the presented materials, which leads to them tackling the design problem more effectively and willingly, which facilitates the complex cognitive process of design learning. Thus, students are required –in many recent design courses- to import and present their design model within a 3D game engine, to accommodate the play paradigm. This is accomplished through casting the students as active participants rather than passive observers, encouraging them to think about their architecture more as a social and spatial experience than schematic drawings and series of calculations (Woodbury et al, 2001). This was proven quite effective, to the extent

that 3D application toolkits added new features to incorporate a game-like playing context.

Games in education have very rich technical and psychological assets. In technical terms, games are considered more effective, reliable, high-quality, and cheaper (in cost and time) mean of visualization, compared to traditional methods of visualization, virtual reality systems, and even CAD applications. In Psychological terms, the entertaining and engaging nature of the game rose from the “*Interactive Narrative*” techniques that the game follows, allowing improved conception, investigation, analysis, collaboration, and experience sharing within a virtual environment.

Embodied multi-agent-systems

Tallyn (2005) has argued that the interactive narrative temperament of a game’s context still has its problems; in that the author’s management of the narrative techniques is abridged if more and more interactivity is offered to the participants. Several methods and strategies have been implemented to address this problem, like defining a pre-designed storyline which the users have to stick to, or instigating sequential paths determined by specific goals, all having the same start and end-point or the presented storyline (Stappers et al, 2001). These methods have been proven to lack a degree of flexibility, have little consideration to users’ interaction, and negatively affecting the sense of simulation as they have stranded from emulating real-life activities.

Agents’ technology has been recently implemented into game engines in an attempt to resolve the interactive narrative problems and improve the users’ overall virtual experience. The benefits this technology offers are:

- Higher degree of believability, generated from an improved sense of real-life emulation
- Higher degree of interaction offered to the users.
- Higher flexibility in the narrative structure of the game, as the agents reform the storyline according to the users’ inputs and interaction.
- Real-time response to dynamic environments.

Wooldridge (2002) defined the game's multi-agent system as an intelligent entity that is comprised of a set of multiple assorted and diverse agents. These agents are embodied within the game/system, and have the aptitude to interact with each other as well as the system's environment. The benefit of using multiple agents rather than a single omniscient agent is the opportunity to simplify complex game's objectives, and break down tasks that could be rather problematical to smaller supplementary tasks. The broken down sub-tasks are allocated subsequently to multiple autonomous agents, which communicate, negotiate and collaborate with each other in a peer-to-peer fashion to resolve different aspects of the problem and present the solution back to the observer.

The ability of an agent in a MAS to perform its tasks depends on its scope, which could be restricted to knowledge, goals, computing processing resources, and general perspective (Wooldridge, 2002). The prominent independent nature of an agent might be enough to perform the sub-tasks allocated, but agents still have to communicate and interact with each other to attain the overall objective of the game. Agents' interaction can be either cooperative, where agents act as a team to achieve specific goals, or competitive where agents try to exploit their benefits and dominate over other agents (Siebers and Aickelin, 2008). In this format, the embodied agents not only become a complementary part of the system, but also the architect of the users' narrative experience within the game. The storyline of the users' game is no longer sequential or pre-structured; it is dynamically scripted according to the players' actions, decisions, strategies, and preferences. Having a powerful narrator in the game enriches the users' virtual experience and gives them more control with higher degree of interactivity and engagement.

Environmental design

The design and decision making process is facing an ever-growing challenge with the increasing complexity of design concepts, and the mounting

pressure to preserve energy and environmental resources through "designing for sustainability". For a design to be sustainable, it has to address two main objectives for a high performance building; maximizing occupant satisfaction and minimizing the energy requirements throughout the building's life-cycle. Architects and designers have been facing the challenge of achieving the building occupants' satisfaction through creating comfortable conditions in almost any climate. This challenge was addressed -in many cases- with a costly demand of using high grade energy and valuable environmental resources. With the rapid diminishing of environmental and energy resources, it is no longer a challenge for designers but a necessity to adopt a design approach that can eventually help reduce the reliance on precious resources while offering sensible level of occupants' satisfaction.

The increasing demand for green and environmental-friendly designs has evolved the traditional design method from just masses and social spaces, and introduced series of new variables and equations generated from the highly complex social, cultural, technological, and economical issues in Sustainable Design. The proposed design should fulfill and resolve these new variables in order to become acceptable and indeed sustainable. Design students are thus facing bigger challenges to develop their ideas, and there is a big risk of getting more involved into these variables and equations could hinder their creativity and sense of space.

Many building performance simulation packages are widely employed by designers to provide high level of environmental assessment to their proposed designs; these include Ecotect, TAS, IES Virtual Environments. While these packages present data in various formats (tables, graphs, plans, sections and even 3D), they generally rely on specialist knowledge to both frame the question and interpret the resultant output, thus posing numerous challenges especially to design students and untrained professionals who are not fully conversant with interpreting environmental design. The data generated from building

performance assessment is often presented numerically, through complex graphs, tables, and charts, which requires a highly experienced user to read, analyze, correlate, and critique. Inadequate interpretation and lack of understanding of these results and their implications may lead to inaccurate design decisions, bad judgement, and higher risk of errors, leading eventually to unforeseen effects on building performance and waste of valuable resources.

Playing the environmental design game

Prior to developing the proposed method (game), interviews with early design students and design instructors have been conducted. They were asked about their view on two matters; exploiting the proposed design within an interactive narrative virtual context, and the design decisions that have been conducted according to their interpretation of building analysis data. These interviews have concluded that:

- Design students are increasingly encouraged to exploit different aspects of their design within an interactive environment like a game. The highly interrogative context of the game enriches the student's perception of their design, as well as their sense of space and geometric relations. Students in many previous exercises have shown high acceptance to build the proposed design in their own game for its significant entertaining factor.
- Early design student find it quite challenging to generate and analyze data in building performance applications like Ecotect. Instructors noted that in many cases, students make design decisions according to misinterpretation of the generated environmental data, or lack of understanding the reasons and causalities behind any unusual or unexpected figures. They also noted that lack of understanding of their decisions implications could prove to be problematic.

The proposed method is designed to address these issues, attempting to resolve the complexity of

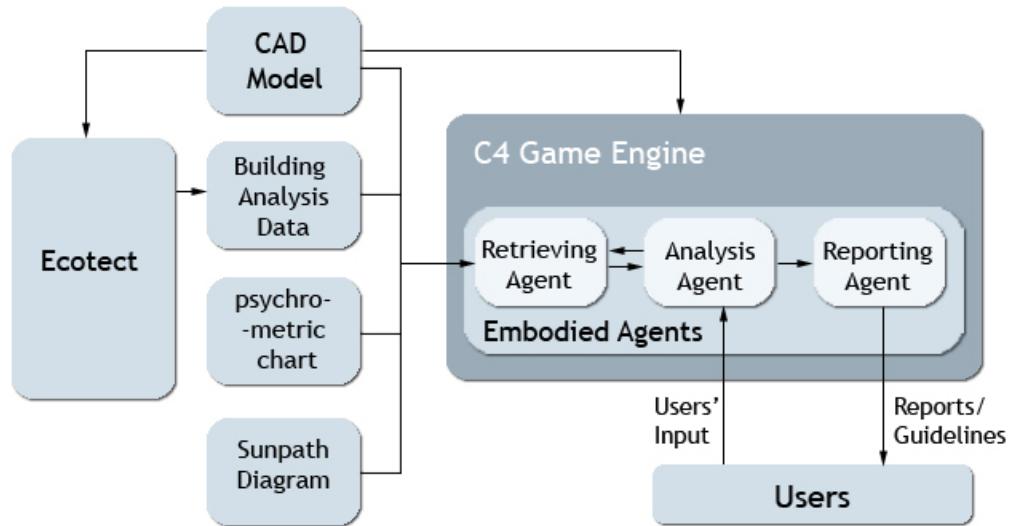
data generated and minimize the risk of misinterpretation. It relies on extracting custom environmental data from an environmental building analysis application (like Ecotect), and representing a report analysis of parts of this data that are relevant to the current users' experience. The generated reports are represented in a simple user-friendly dialogue format within the virtual narrative structure of the game. It relies on embodied agents within the game engine to interrogate various data structures and inputs, trigger events and actions performed by the users, and present relevant data subsequently. This method is envisioned to be of great value within the architectural education context, where data analysis, calculations, interrogation, and negotiation occur, and guidelines and suggestions are presented within an engaging interactive narrative context, which improves students' perception and comprehension of their design decisions and strategies to tackle sustainable design variables.

It is comprehensible that when students and designers (who are not conversant to interpreting and analyzing environmental analysis data) develop a design, the initial outcome will require substantial improvement and iteration, in order to meet acceptable results and achieve the building's comfort targets. There are two ways to move a building's interior into comfort temperatures; the first is to harvest passively (as much as possible) like using/omitting solar gain, implementing different grades of insulation, addressing thermal mass, etc; and the second way is to enforce the interior temperatures actively, through using HVAC system for example. Since the students do not yet possess the required qualities to treat the building passively, the value of the proposed system is not only to analyze data and flag problems, but also to walk users through the process, and present guidelines and possible routes for resolving them.

The game

The first phase in the proposed game is for the agents to gather as much information as possible

Figure 1
Proposed System Architecture



and build a knowledge base about the building. This is achieved through logging data from different initial sources:

- The CAD model: which is imported to the world editor of the game engine (we are using C4 game engine (www.terathon.com/c4engine/index.php) in this project). This is the same model the users initially build and import into Ecotect to run various calculations.
- Ecotect exported building analysis data: The users can use a pre-scripted code in LUA language (the scripting language used by Ecotect) in the script manager tool. This script can be used to automate calculations and export data in the required format to be interpreted by the agents.
- User inputs: A set of information gathered inside the game context and provided by the user before starting the game. This includes information about the building's location, occupants, operating hours, activities, and any information about an HVAC system implemented (Figure 2).

The game engine provides the GUI to the users playing the game, and the world editor for altering their designs. Though the game engine is considered

the shell encompassing the MAS, each of the agents has a separate identity and freedom to roam and communicate, with other agents and external sources, in order to mine all possible information. The embodied agents comprise three different multi-agent structures (Figure 1):

1. *Retrieving agent*, which is responsible for gathering information that is relevant to the game's current state of affairs, and that the other agents can utilize to build a set of problem causalities and decision guidelines. This agent receives a request for information, and then starts interrogating various sources of information, and mine as much related data as possible before passing them to be analyzed.
2. *Analysis agent*, which is considered the most sophisticated agent in the MAS. It receives information from the users in terms of inputs, actions, or decisions. The analysis agent then structures a specific query to be sent to the retrieving agent to gather filtered information. The analysis agent then starts the correlation process, where the data is examined against particular standards and climate equations (Szokolay, 2004), to de-

velop a set of possible reasons that could be the cause of any out of the ordinary outcomes. The assessed data is separated into three categories; problems, causalities and guidelines. These are then passed onto the reporting agent.

3. *Reporting agents*, which is the main communicator and point of contact with the players. It receives filtered information set from the analysis agent, and presents them to the users when required (Figure 2). The reporting agent is considered the narrator of the building story, and the users' companion throughout their journey within the different building zones. The generated reports are presented in a simple and user-friendly manner, to avoid any confusion and uncertainty that could affect any judgment or decisions.

The power of the MAS in a game is its investigative and interrogative routines. These are techniques that the agents use in order to develop themselves and their knowledge and thus mining information at multiple levels. In this sense, this system can move into an exceptionally sophisticated reporting and knowledge-based tool. In their attempt to mine building information, agents tend to interrogate different internal and external resources, including (Figure 1):

- The CAD model: It is important for the agents to gather information about the current zone, as it can be used in analyzing the feasibility of spe-

cific design strategies. For example, it is important to know the room's depth and windows' size to assess against equations for single sided and cross ventilation. Another example is detecting insulation as an interlayer; it could affect the admittance thermal mass strategy. The agents can seek alternative solution if the zone's dimensions fail to satisfy the specified requirements.

- Building analysis data: This is the main source of knowledge and initial set of information to be gathered by the agents. The agents use this information to present the basic reports to the users, including the indoors and outdoors temperature. It also uses this data to seek causalities when a problem is flagged. For example, high temperature in a zone could be caused from inter-zonal gain, or fabric gain.
- Psychrometric / bioclimatic chart: interrogating the psychrometric chart is one of the most important and sophisticated tasks allocated to the agents. They aim to initially calculate the comfort zone, which is one of the main criteria to assess each zone. Agents then interrogate the overlays on the chart that reflect different design strategies (e.g. passive solar, evaporative cooling, etc.) and if this can be implemented as a solution to a current zone problem.
- Sun-Path diagram: a main source of information to query in positioning the sun within the game engine. It is also a source to interrogate by the



Figure 2
First screen: gathering information from users' input. Second screen: Reporting a problem in the current zone and presenting possible causalities

Figure 3
Reporting a problem in a
design decision and providing
guidelines for resolving it



agents in some design strategies. For example, if the users want to drive a mass by solar radiation, sun-path diagram can examine if/how-much sunlight reaches the walls of the zone in question. Another example is being useful in placing sun breakers at specific angle, when solar radiation is not required inside a room.

The agents use the data mine and their gathered knowledge, as well as the calculated outcomes and possible causalities to presents a set of guidelines, suggestions, and design strategies that could be implemented to resolve any highlighted issues (figure 3). The set of guidelines is based on the work of Watson (1983) and Loftness (1970). The agents generate specific criteria (based on the current state of the building, or any attempted design strategies). These criteria constitute queries to the set of stored guidelines that are presented as solutions and/or proposed improvement to the current design.

The system is designed to communicate with the users in a sequential format, asking them a question and based on their answer, presenting the next question (or possible guidelines). This QA manner insures a simple, user-friendly, and engaging narrative structure to the users, as they are not sucked into deeper sub-levels of interrogation. This in general enriches the value of the users' immersive learning experience.

Conclusion

Games have been proven to be a very rich virtual learning context. It provides the students with an engaging, entertaining interactive narrative experience with a "play" metaphor. Embodied agents have been recently implemented into games to take them to a higher edge, offering more flexibility, higher level of interaction, and better emulation of real-life activities, which in turn enhanced the students' overall learning experience. With the increasing demand for preserving environmental resources through "green designs", students are facing bigger challenges with the introduction of more complex variables in the design equation. This paper presented a method that utilizes the benefits of embodied MAS within a game engine, aiming to assist students and untrained professionals in interpreting, analyzing, correlating, and visualizing environmental and building analysis data, thus facilitating the comprehension of implication of their strategies on a building in different design stages.

The embodied MAS has the potential to turn this "game" to a sophisticated teaching and knowledge-based tool. The agents aim to mine relevant information about the proposed building design from several available resources through "interrogation routines". Agents use this data to assess geometric spaces, as well as users' strategies. The wealth of this method lies not only in presenting the problems, but also providing possible causalities and related guidelines for design development.

References

- Bower, E.M.: 1974, Play's the thing, in L.M. Shears and E.M. Bower (eds), Games in Education and Development, Charles C. Thomas, Springfield, IL, pp. 5-11.
- Dickey, M.D.: 2005, Engaging by design: How engagement strategies in popular computer and video games can inform instructional design, Educational Technology Research and Development, 53 (2), pp. 67-83.

- Loftness, V., 1970: Regional Guidelines for Building Passive Energy Conserving Homes, The AIA Research Corporation, for the US Department of Housing and Urban Development in cooperation with the US Department of Energy.
- Petzold, F. and Frohburg, J.: 2006, Not Every new Monday: on using computer-games technology in architectural design education, *Computing in Architecture / Re-Thinking the Discourse: The Second International Conference of the Arab Society for Computer Aided Architectural Design*, UAE.
- Siebers, P.O. and Aickelin, U.: 2008, Introduction to Multi-Agent Simulation, in Adam, F. and Humphreys, P., (eds), *Encyclopedia of Decision Making and Decision Support Technologies*, Idea Group Publishing, Pennsylvania, pp. 554-564.
- Stappers, P.J.; Saakes, D. and Adriaanse, J.: 2001, On the narrative structure of Virtual Reality walkthroughs, An analysis and proposed design, *Proceedings of the Ninth International Conference on Computer Aided Architectural Design Futures*, Eindhoven, pp. 125-138
- Szokolay, S.: 2004, *Introduction to architectural science: the basis of sustainable design*, Elsevier Ltd., London.
- Tallyn, E.; Koleva, B.; Logan, B.; Fielding, D.; Benford, S.; Gelmini, G. and Madden, N.: 2005, Embodied Reporting Agents as an Approach to Creating Narratives from Live Virtual Worlds, *Proceedings of the Third International Conference on Virtual Storytelling (ICVS)*, pp. 179-188.
- Virvou, M.; Katsionis, G., and Manos, K.: 2005, Combining Software Games with Education: Evaluation of its Educational Effectiveness, *Educational Technology & Society*, 8 (2), pp.54-65.
- Watson, D. and Labs, K.: 1983, *Climatic Building Design, Energy Efficient Building Principles and Practice*, McGraw-Hill.
- Woodbury, R.F.; Shannon, S.J. and Radford, A.D.: 2001, Games in Early Design Education, Playing with metaphor, *Proceedings of the Ninth International Conference on Computer Aided Architectural Design Futures Eindhoven*, pp. 201-214.
- Wooldridge, M.: 2002, *An Introduction to MultiAgent Systems*, John Wiley & Sons Ltd.