PROTOTYPING FIRE EVACUATION SERIOUS GAMES USING ARTIFICIAL INTELLIGENCE AS A CODER

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ABSTRACT

Computer simulation of the experience of a stressful situation, such as a fire, is a source of learning and training material used by architects, firefighters and users of various facilities. In addition to the programs themselves, devices such as virtual reality glasses, mobile phones and 5G networks enable a wide variety of examples for the application of modern technologies in solving complex problems that fire poses in various built environments. The latest development of artificial intelligence provides a fast and intuitive way to create online applications and serious video games. This paper demonstrates and explores the possibilities of creating various computer simulations of fires that can be used in architectural education and practice, as well as in other relevant disciplines.

Keywords: architecture, fire, serious games, evacuation, artificial intelligence

INTRODUCTION

Each year, fire incidents in buildings are causing large numbers of casualties globally. [3][4][5][6][7] [22][17][12] With 7348 incidents recorded, the global frequency of disasters has risen by 73% between 2000 and 2019, compared to the 1980–1999 period. [23] Evacuation research publications mostly come from China (37%) and the USA (22%). [9] In the USA, in 2017, 1.319 million fires were reported resulting in 3400 fatalities, 14,670 injuries, and a financial loss of 23 billion US dollars. In China, in 2018, 237,000 fires were reported resulting in 1407 fatalities, 798 injuries, and a loss of 3.67 billion Chinese Yuan. In England, in 2017/18, 167,000 fire-related incidents were recorded, resulting in 334 fatalities and over 3000 injuries. [8] [21]

Serious games

An effective way for safety training is the use of serious games. [1] Serious Games can be classified in five categories: Edutainment, Advergaming, Edumarket Games, Political Games, and Training and Simulation Games. [11] Serious games provide engagement to their players, keeping them concentrated, while also allowing for evaluation of the players' performance. [12] [17] Serious games can used to improve evacuation capacity and investigate evacuation behaviour. [20] Serious games effectively improve knowledge retention and evacuation behaviour. [24] [27] There is also a mention of ERVGs (Educational Virtual Reality Games) defined as combination of technology, pedagogy and gaming and designed for all levels of formal education, from K-12 to tertiary education students, as well as lifelong learners. [26]

Examples of serious games include EVA, which enables the evaluation of the evacuation time in case of fire, the indication of which exit was used by the participants, and the rescue time needed to rescue a given person [17], another fire evacuation training system based on the numerical simulation data of fire and a real-time virtual reality (VR) training system for evacuation based on Kolb's experiential learning theory. [20] Train station fire in a VE was used to analyse the effects of different stress levels (alarm-only or alarm combined with fire) on individuals' evacuation choices or non-immersive VR was used to conduct online surveys regarding the impact of environmental and social factors on evacuation exit choices. [9]

Simulation software

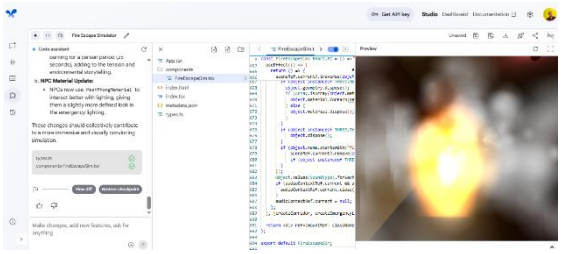
Currently, two types of evacuation simulation software are widely implemented for evacuation simulation and disaster prevention: commercial software (e.g., STEPS [7], Pathfinder [3] [7] [22]) and open-source software (e.g., such as NetLogo, Repast). [4] Building EXODUS and Simplex are also among the mentioned digital tools. [7] Pathfinder is a commercial evacuation simulation software developed by Thunderhead Engineering, and its application lies in comparing different evacuation routes to identify the optimal path during a fire crisis. [3] There are also specific software solutions for crowd dynamics, such as MassMotion (advanced pedestrian simulation software) and Evac (extension of Fire Dynamic Simulator developed by the National Institute of Science and Technology (NIST) and the Technical Research Centre of Finland (VTT)). Results from such simulations are integrated with the Unity3D model. [2] [7]

Game engines provide a rapid way for prototyping 3D virtual fire drill simulators. [11] [12] Unity and Unreal Engine 4 are the most commonly used game engines used to create 3D virtual environments. [4] Unity is also widely used in the field of scientific research. [2] [4] [11] [12] [14] [20] [27] Game engines are used to combine different types of digital mediums (3D models, sounds, 2D graphics, user interface and controls, and other elements) into a single virtual experience. 3D modelling in studies is mostly done in Blender. [11] [27]

Prototyping serious games using AI

The field of Artificial Intelligence (AI) is rapidly developing and evolving along with rising public awareness, acceptance and engagement. [31] [34] ChatGPT, Google Gemini, Anthropic Claude and other Large Language Models (LLMs) are popular tools which revolutionised artificial intelligence, facilitating substantial progress in natural language comprehension, reasoning and text generation. [28] [31]

A prompt is a text containing instructions to customise, refine or enhance the capabilities of GPT model. [29] The performance of LLMs is directly related to how they are prompted (instructed), making prompt engineering a crucial factor in optimising output quality. [32]



Prototyping code for fire and smoke simulation using Artificial Intelligence, credits: Author.

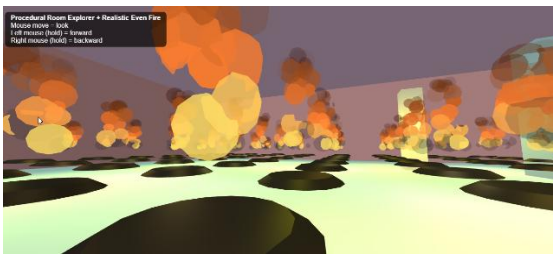
Prompt engineering is recognised as an important skill required for efficient communication with LLMs, and prompts are a form of programming but described through natural language. [33] [29] [28] [32] [31] Some of the examples of prompts include the following textual inputs:

1. Answer factual questions based on provided samples [32]

2. "From now on, I would like you to ask me questions to deploy a Python application to AWS. When you have enough information to deploy the application, create a Python script to automate the deployment." [33]

By designing specific prompts aimed to instruct AI models to generate code that can be run as a HTML application (compatible with web browsers, such as Google Chrome or Firefox Mozilla), it was possible to re-create 2D and 3D computer simulations of pre-evacuation and preparedness, evacuation procedures, crowd dynamics, building layout analysis, and other relevant research topics presented in the study.

For the purpose of experimentation with the capabilities of current AI technology to develop computer simulation of fire evacuation, two case studies were made, the 2D and 3D simulator.



Prototyping code for fire and smoke simulation using Artificial Intelligence, credits: Author.

Case study: Emergency evacuation simulator

3D fire evacuation simulator game starts in a normal casual state in the long hallway with cylinder-shaped agents walking around. The hallway has lights and obstacles in the shape of planters. There are doors on the sides of the hallway to simulate the space of a large office building. Some moments after the game starts, the normal lights turn off, red lights turn on, agents start running towards the exit (on the other side of the hallway) and alarm sound is on. The idea behind this experiment is to address issues such as pre-evacuation and initial response to emergencies, simulate and study stress levels in emergency simulations, explore the effects of given computer graphics and sound on realism and immersion.

The prompt for this case study was carefully designed through numerous trial and error examinations,

which eventually resulted in a prompt that generated working code without errors. The following is an excerpt from the input prompt that generated the whole 3D experience, logic, simulations, crowd agents, and 3D environment:

3D environment for fire evacuation simulation generated by Artificial Intelligence based on the natural language input prompt, credits: Author.

"You are: The most talented three.js creator of 3D games, animations, websites ever, you do everything locally, procedurally, you are the world known expert for parametric geometry design with Grasshopper, you design everything mathematically, combining simple elements into the beautiful complex structure. Less is more.

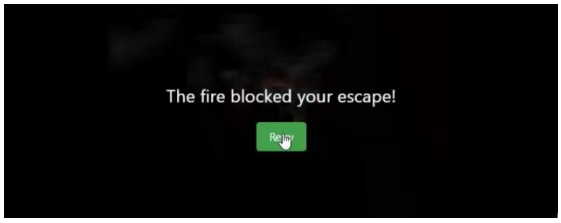
Output: Single file, self-contained HTML of the [Most Realistic Serious Game] using three.js library. Code is beautiful, elegant, smart, creative, highly structured, and interconnected.

[Most Realistic Serious Game]: Most immersive first person fire escape simulator for educational purposes. The idea is that the game is so immersive that the educational effects are maximised. It is both mobile and PC friendly.

[Player/Camera Movement]: Movement only using mouse, left click for forwards right click for backwards, camera look rotation with cursor movement without cursor lock and - always look while moving the mouse. Can rotate up and down and left and right, make sure it can rotate 360 degrees (180 for each side). For the mobile just use the tap and drag to move around."

Simulated emergency fire situation with smoke and fire effects and agents generated by Artificial Intelligence based on the natural language input prompt, credits: Author.

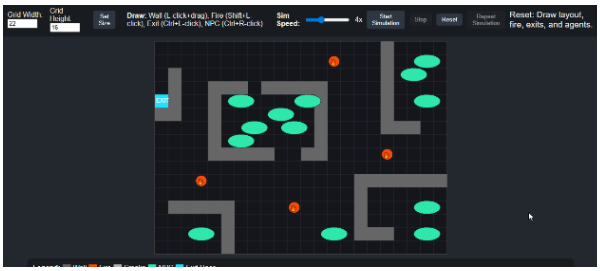
The simulation experience was designed using Google AI Studio with Gemini model. The player has a limited amount of time to realise the emergency situation and to start the evacuation while avoiding other agents who also are heading towards the exit. If the player fails to complete the evacuation in a limited time frame, the screen saying that the fire has blocked the way appears and the player can retry the game.



End screen of the game if the user fails to reach the evacuation door in time, credits: Author.

Ultra scientific 2D fire and smoke simulator

This prototype is available as a HTML code and allows for simple yet effective way to simulate the motion of fire and smoke within a specific building layout. The user can draw the walls, mark exits, spots from fire and smoke will spread out and also add agents who are coded to collide and behave realistically at doors and exits. Players can try different scenarios combining different building layouts with fire and sources and number and distribution of evacuation agents.



User draws the walls and positions exits, starting place of fires and agents, credits: Author.

Through careful input prompt design, AI was prompted to create a 2D fire and smoke building evacuation simulator. The intuitive drawing system was conceptualised to allow for simulation of a variety of possible scenarios. The user can specify the grid dimensions which correlated to the total area, while the single grid cell size is determined to be 30 cm.

User plays the simulation which starts the fire and engages agents into evacuation, credits: Author.

Within the input prompt that was used to generate the 2D simulator, AI was asked to design autonomous intelligence of agents which will be evacuating. For example, AI was instructed to only allow one agent at the time to pass through the opening enabling crowd simulation and more realistic end results.

Simulation ends showing the agents who were not able to complete the evacuation, credits: Author.

Conclusions

Fire simulation is an important tool in fire investigation. [2] The presented study offers a quick insight into the immensely large field of serious games aimed at training and research of fire evacuation in constructed environments. The ability of AI to create usable applications and games is emerging as a powerful tool allowing for new experimentation and research possibilities to researchers.

Design and programming of computer simulations requires significant resources and knowledge base, requires different simulation algorithms and programs as well as experts who are able to compose algorithms as immersive virtual environments. In this context the study was aimed to explore capabilities of AI to write code and to serve as a computer simulation prototyping tool. In several experiments and studies aimed to create fire evacuation simulators using artificial intelligence, the results came out surprisingly good, and the current state of the art indicates that AI will be used much more in the future for similar projects.

Educational institutions should use digital games as a powerful tool to improve students' behaviours and knowledge related to safety culture. [17] In general, research in the field of design of serious games for evacuation education includes a lot of important questions, such as the quality and realism of fire and smoke representation and the consequent immersion and experience, exploration of stress levels induced by experience of stressful simulations, evaluation and examination of laws and standards, experiments with different input devices and screens, and how different combinations of devices affect the overall immersion and experienced reality.

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IZRADA PROTOTIPA OZBILJNIH IGARA ZA EVAKUACIJU U SLUČAJU POŽARA SA UMJETNOM INTELIGENCIJOM KAO PROGRAMEROM

SAŽETAK

Kompjuterska simulacija doživljaja i iskustva stresnih situacija kao što je požar predstavlja izvor učenja i materijala za vježbanje koji koriste arhitekti, vatrogasci i korisnici različitih objekata. Pored samih programa, uređaji poput naočala za virtuelnu stvarnost, mobilni telefoni i 5G mreže omogućuju najrazličitije primjere primjena savremenih tehnologija u rješavanju kompleksnih problema koji požar predstavlja u različitim građenim okruženjima. Najnoviji razvoj umjetne inteligencije omogućava brz i intuitivan način za kreiranje online aplikacija i ozbiljnih video igara. U ovom radu demonstrirane su i istražene mogućnosti kreiranja različitih kompjuterskih simulacija požara koji se mogu koristiti u arhitektonskoj edukaciji i praksi, kao i u drugim relevantnim disciplinama.

Ključne riječi: arhitektura, požar, ozbiljne igre, evakuacija, umjetna inteligencija

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