United Nations World Geospatial Information Congress
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VR Based Experiments on Crowd Evacuation

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① Three phases of VR/AR development, VGE , VGExperience

② Modeling and VR simulation of Crowd Evacuation

③ Concluding Remarks (VR for GISci and Society)

1.1 Three Phases of the VR development

Head-Mounted Immersive VR techiniques for the public open a new VR era and a new virtual world.

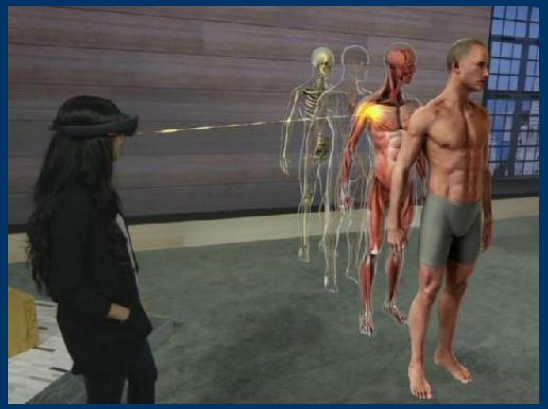
2016 is the first year of VR/AR.

Oculus Rift VR

HTC Vive VR

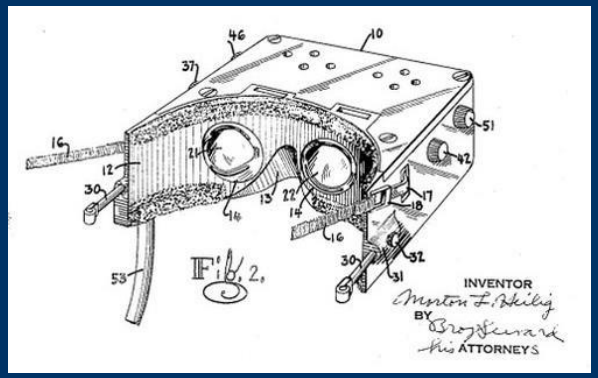
Gear VR based on Mobile

Da-peng all-in-one VR



HoloLens MR

- VR 1.0： Since 1950s； In 1956， Morton Heilig invented Sensorama (3D interactive devises)； in 1965， Sutherland Published an article on “Ultimate Display”；
- VR 2.0： Since **1990s**； ***in 1989，Jaron Lanier in VPL Research Company， coined the term “Virtual Realty”；***
- VR 3.0： Since **2014?** ***in 2014, Facebook acquired the Oculus company；***



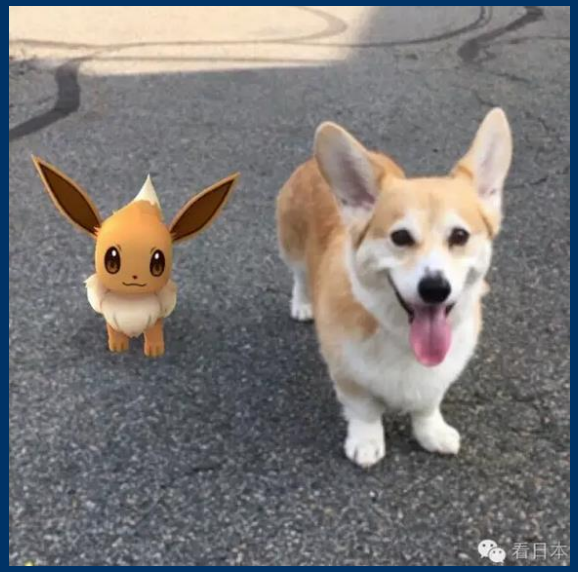
Sensorama , 1956

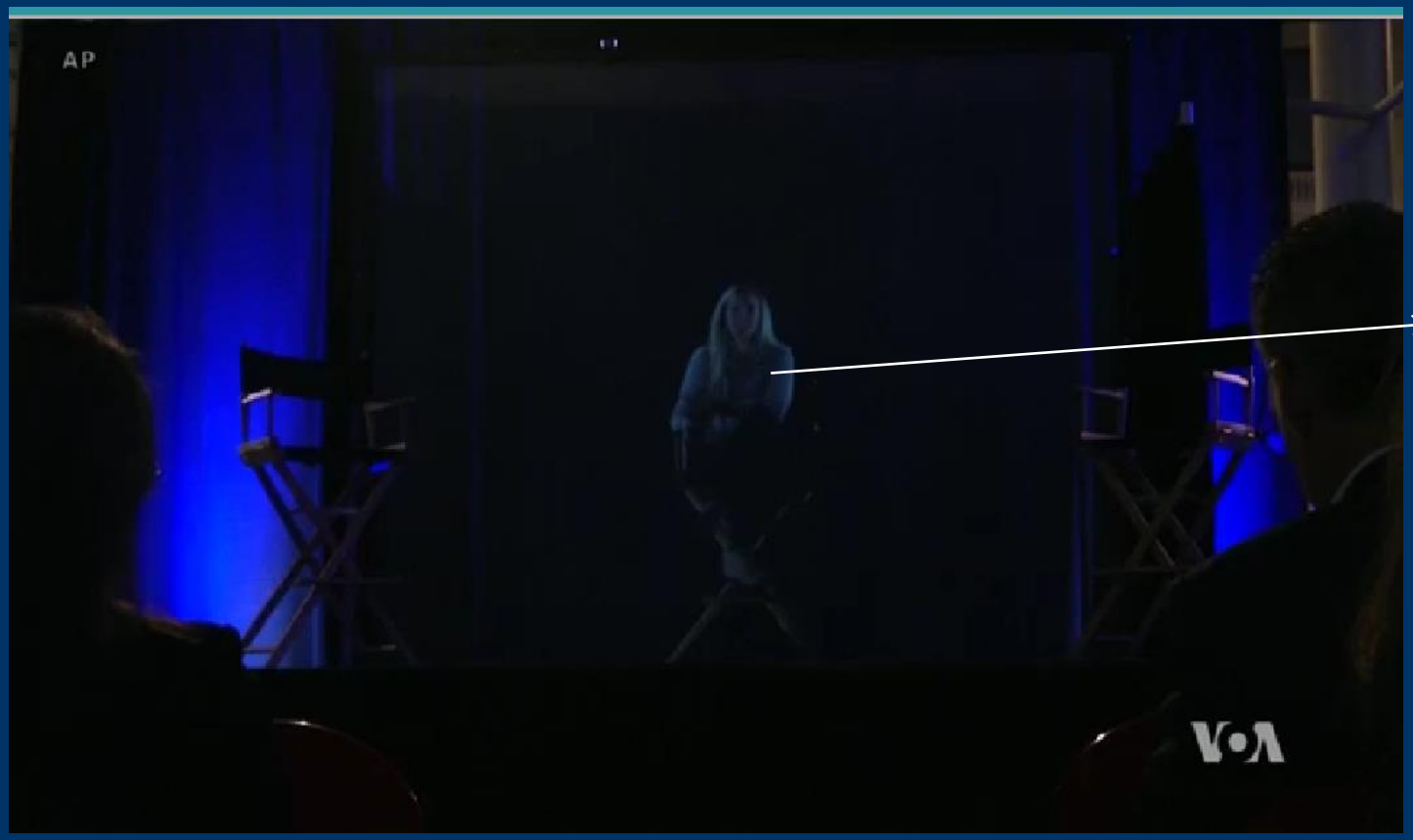
in 2014, Facebook acquired the Oculus company

Pokemon GO,a AR based game developed by Nitendo and Niantics

The market value of the Nitendo company is less than 20billion US $，and increased by 80% after a week of the game online, and in July 19,2016, it estimated as **39** billion US $ 。

According to Survey Monkey，the number of active game players per day arrived at **21 millions US $.**



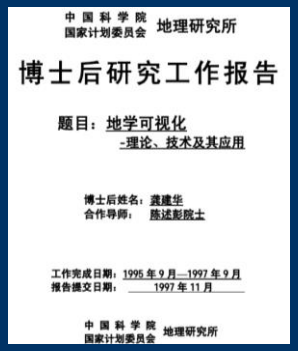


The teacher in 3D Holographic figure

According to VOA News on Nov.12,2018, the London's Imperial College Business School is using Holographic Technology to present lectures to Students.

1.2 Development of Virtual Geographic Environments

In 1997-1998， We (with Prof. Hui Lin) developed the concept of virtual geographic environmens regarding the VR's impact on GIS and geography.


中国科学院 地理研究所
国家计划委员会

博士后研究工作报告

题目：地学可视化
-理论、技术及其应用

博士后姓名：龚建华
合作导师： 陈述彭院士

工作完成日期：1995 年 9 月—1997 年 9 月
报告提交日期： 1997 年 11 月

中国科学院 地理研究所
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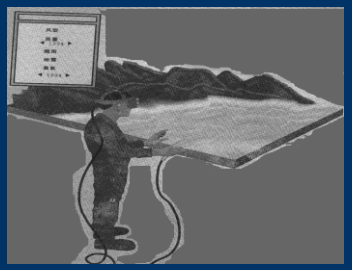
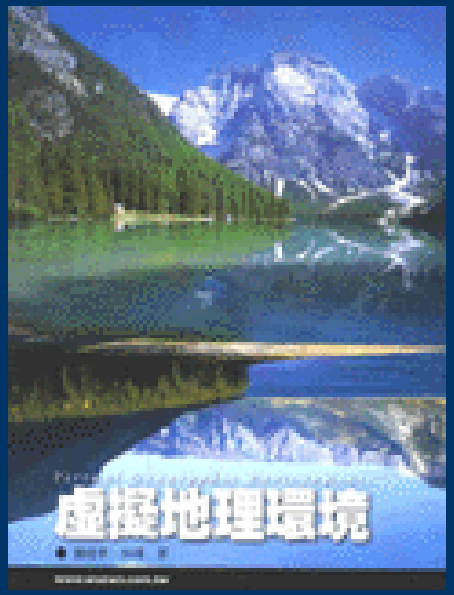
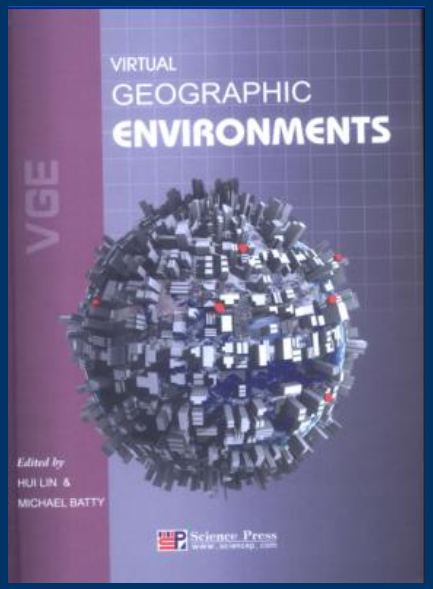


1997





1999 2001 2002 2009

Virtual geographic environmens refer to environments concerning the post-humans and 3-D virtual worlds, which can represent and simulate the geographic environments.

Since 1997-1998，A group of GIS scientists in China are persisting to the study on exploring VGE for about 20 years.

2002 VGE conference, Beijing, China

In October 14, 2017, a special committee of VGE in the Internatonal Society of digital earth was founded

2017 VGE conference, Chengdu, China

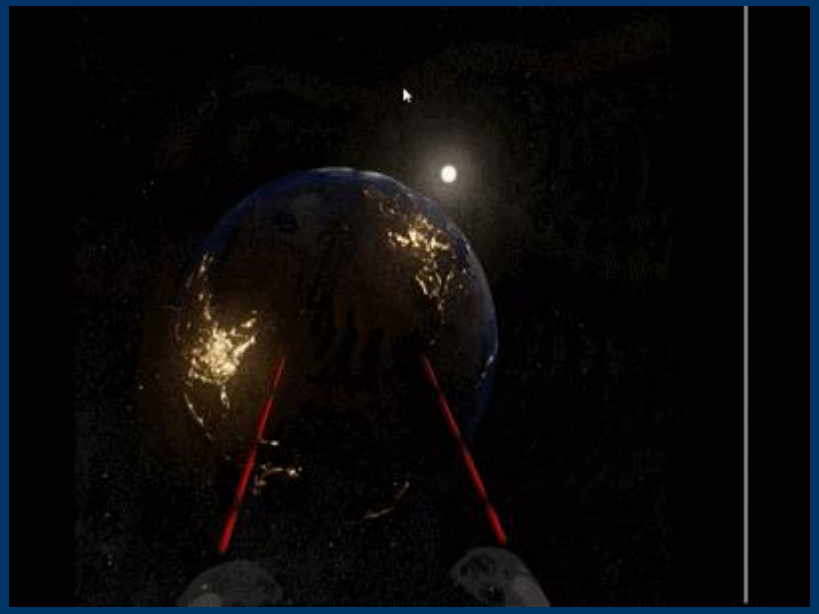
National VGE Conference every 2 years in China

1.3 Virtual Geographic Experiences

VGExperience 1： immersive

Interaction with a beautiful global earth

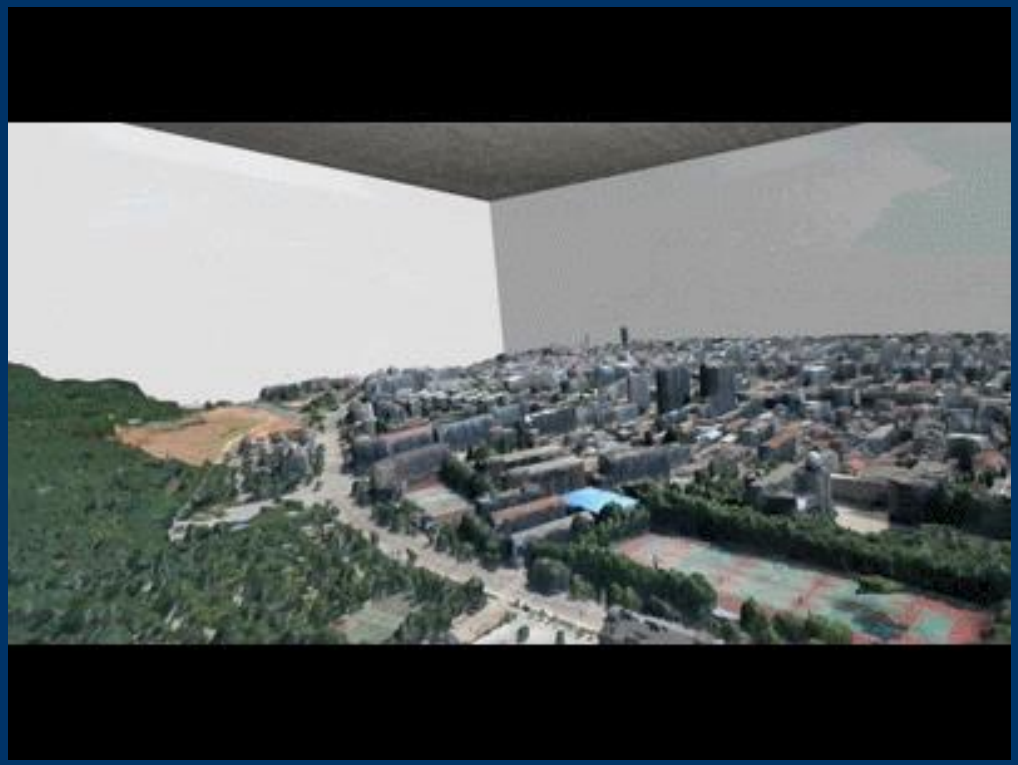
(HTC Vive VR Head-mounted display)



VGExperience 2： immersive

Interaction with a regional city

(UAV based modeling, HTC Vive VR device)

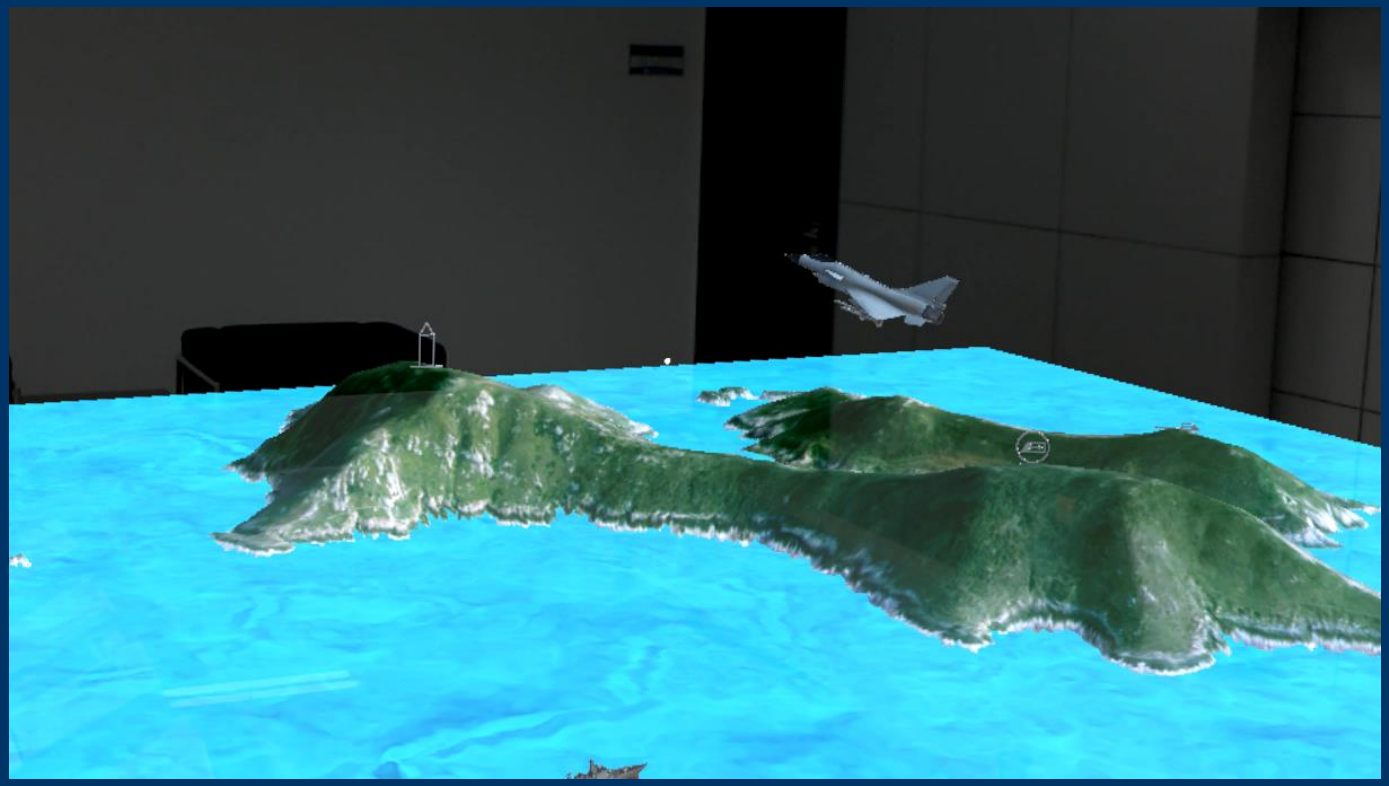


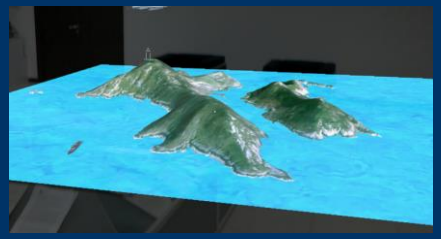
VGExperience 3： immersive

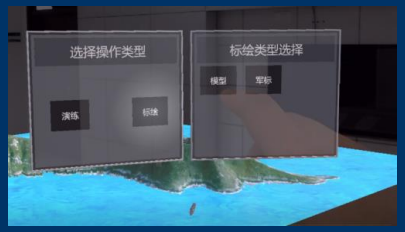
Interaction in a school and classroom

(Oculus cv 1/ Gear VR)

AR-based VGExperience 4：Augmented Reality (Hololens MR)

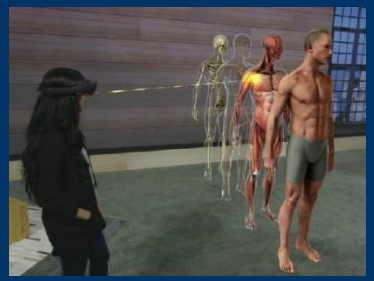






Chances and challenges of VR GIS

VGE = VR+GIS



① Sensing and cognition of a new space
② Interaction（Body based , Motion Capture)；
③ Mobile AR interaction and cognition

VR cognition

① Content Production (3D data , Data Processing for VR, VR Video modeling)；
② 3-D data model and organization；
③ VR realtime rendering（90 fps）；
④ 3D Mapping 0f vectors in VR/AR;
⑤ Big data processing and analytics ；

Representation and Analysis

① Geo-collaboation；
② Crowd computing and simulation；
③ Public participating VR；

The Pubic

① Three phases of VR/AR development, VGE , VGExperience

② Modeling and VR simulation of Crowd Evacuation

③ Concluding Remarks (VR for GISci and Society)

Based virtual geographic environments, we can conduct computing and virtual geographic experiments to explore geographic processes such crowd evacuation in case of fires in inside buildings

2015,
Nanchong School

2017, HK subway station

Fire Disaster

Fire Drills

① **Social force based modeling and simulation**

② **Deep learning based modeling and simulation**

③ **VR experiments based on social forces**

④ **VR based collaborative crowd evacuation for distributed multi-users**

⑤ **AR based visualization of crowd evacuation**

2.1 Social forces based modeling and simulation

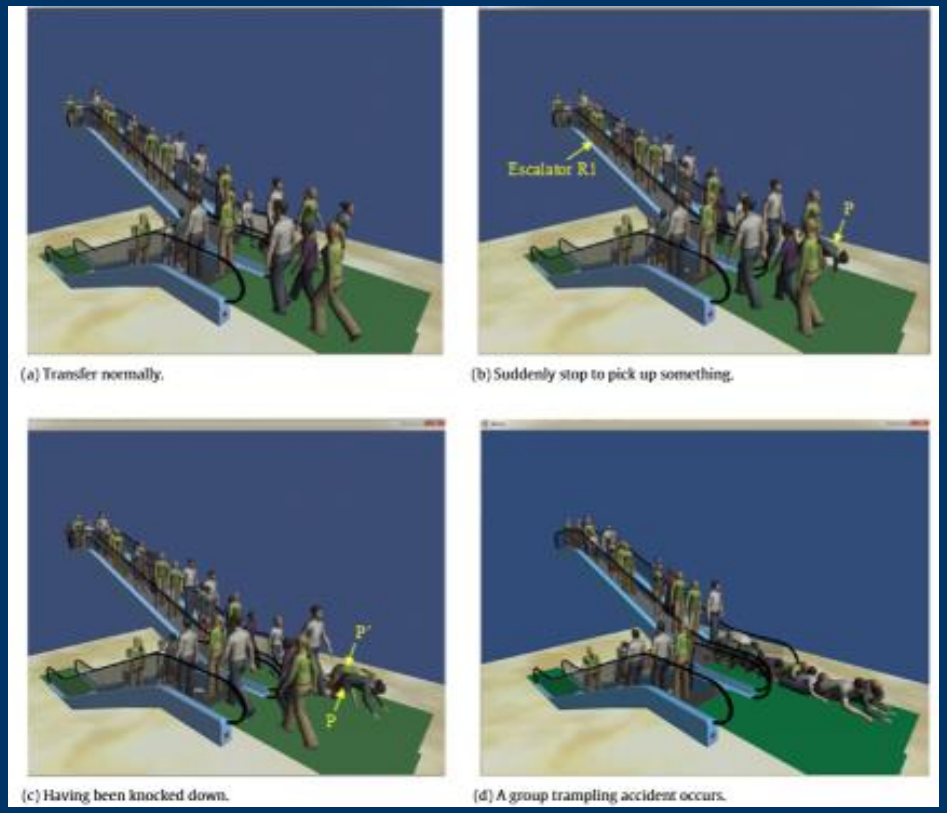
$$m_i \frac{\mathrm{d}\boldsymbol{v}_i}{\mathrm{d}t} = m_i \frac{v_i^0(t)\,\boldsymbol{e}_i^0(t) - \boldsymbol{v}_i(t)}{\tau_i} + \sum_{j(\neq i)} \boldsymbol{f}_{ij} + \sum_{w} \boldsymbol{f}_{iw}$$

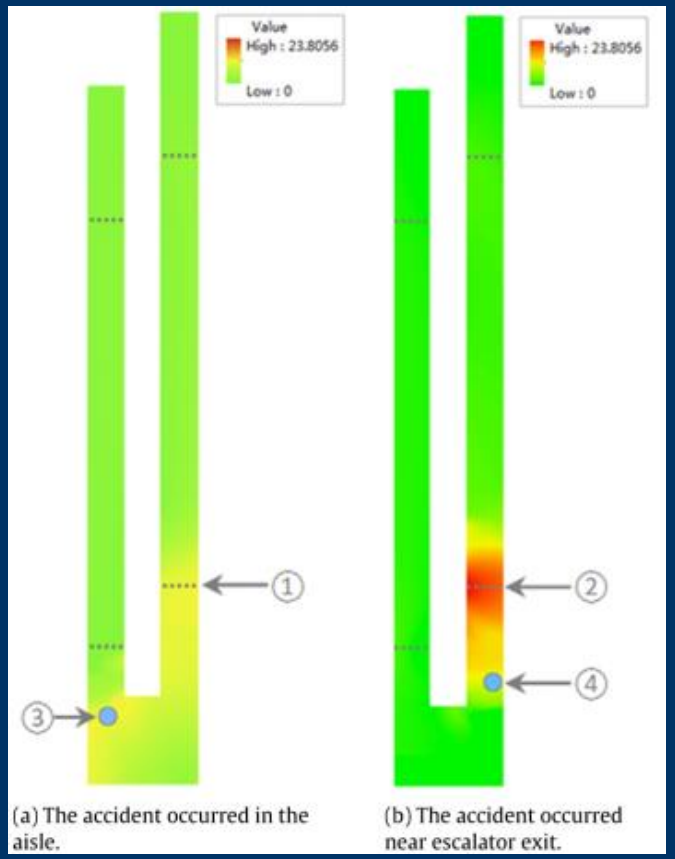
Self-Propelling Force

Force among Individuals

Forces between Individuals and environment(walls)

The SFM consists of three components: : a self-propelling force and two repulsion forces with other pedestrians and walls, respectively





Modeling, simulation and analysis of group trampling risks during escalator transfers using social force model

spatial distribution of pedestrian forces

Findings: The result also shows that the impact of the accident was more serious when it occurred near the escalator exit than in the aisle.

Modeling, simulation and analysis of the evacuation process on stairs in a multi-floor classroom building of a primary school

(a) Congestion in the real drill. (b) Congestion in the simulated process.

Fig. 10. Contrast of the congestion in both processes.

(a) Lane phenomenon in the real drill. (b) Lane phenomenon in the simulation.

Findings: A preferred layout is one where a building has classrooms with the same grade, so that blocking on the stairways is minimized, thus stabilizing the evacuation process.

Group behavior based social force model

Social Force Model-Based Group Behavior Simulation in Virtual Geographic Environments

Lin Huang [1,2], Jianhua Gong [1,3,*], Wenhang Li [1], Tao Xu [4], Shen Shen [1,2], Jianming Liang [5], Quanlong Feng [6], Dong Zhang [1,7] and Jun Sun [1,3]

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Abstract: Virtual geographic environments (VGEs) are extensively used to explore the relationship between humans and environments. Crowd simulation provides a method for VGEs to represent crowd behaviors that are observed in the real world. The social force model (SFM) can simulate interactions among individuals, but it has not sufficiently accounted for inter-group and intra-group behaviors which are important components of crowd dynamics. We present the social group force model (SGFM), based on an extended SFM, to simulate group behaviors in VGEs with focuses on the avoiding behaviors among different social groups and the coordinate behaviors among subgroups that belong to one social group. In our model, psychological repulsions between social groups make them avoid with the whole group and group members can stick together as much as possible; while social groups are separated into several subgroups, the rear subgroups try to catch up and keep the whole group cohesive. We compare the simulation results of the SGFM with the extended SFM and the phenomena in videos. Then we discuss the function of Virtual Reality (VR) in crowd simulation visualization. The results indicate that the SGFM can enhance social group behaviors in crowd dynamics.

Keywords: virtual geographic environments; social force model; avoiding behaviors; coordinate behaviors; crowd dynamics

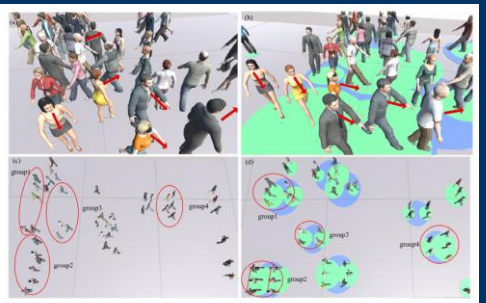
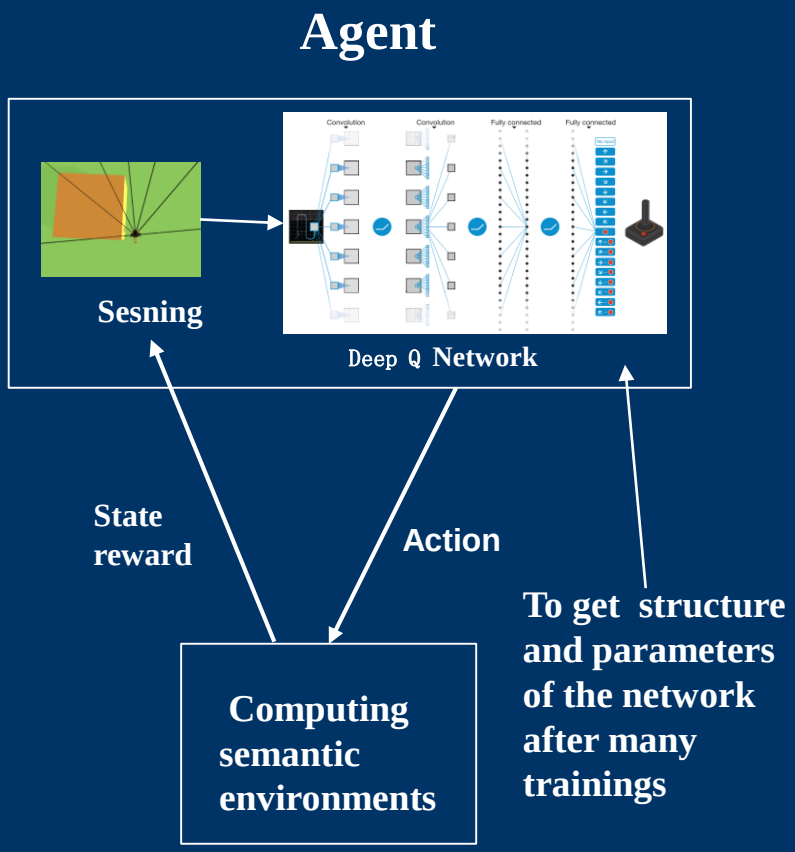
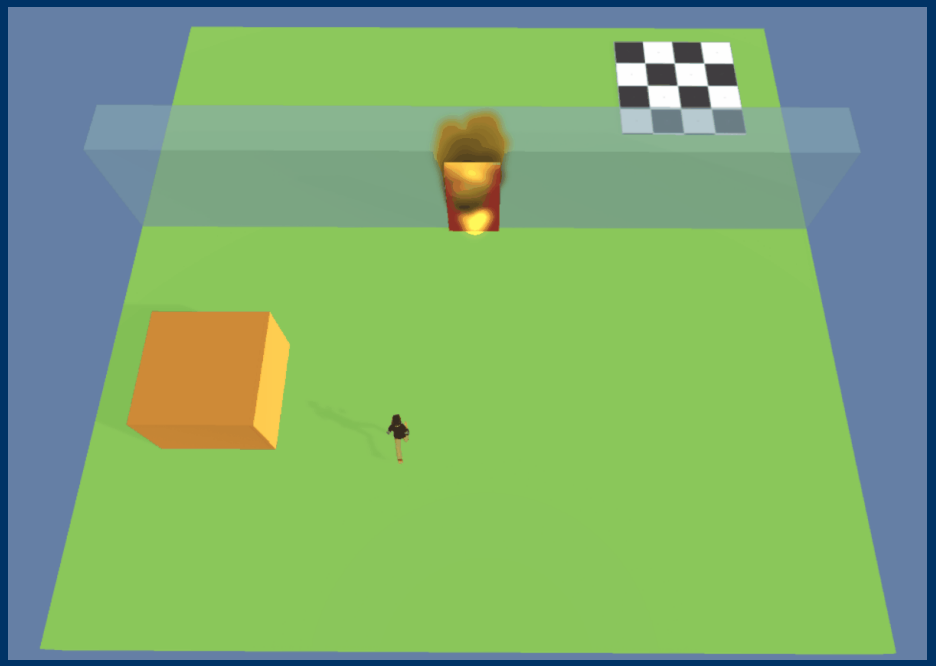


Figure 11. Qualitative comparisons between the extended social force model (**a**,**c**) and the SGFM (**b**,**d**). (**a**,**b**) Pedestrians' directions of the same social group. (**c**,**d**) Structures of groups after avoiding.

Considering the **avoiding behaviors** among different social groups and **the coordinate behaviors** among subgroups that belong to one social group

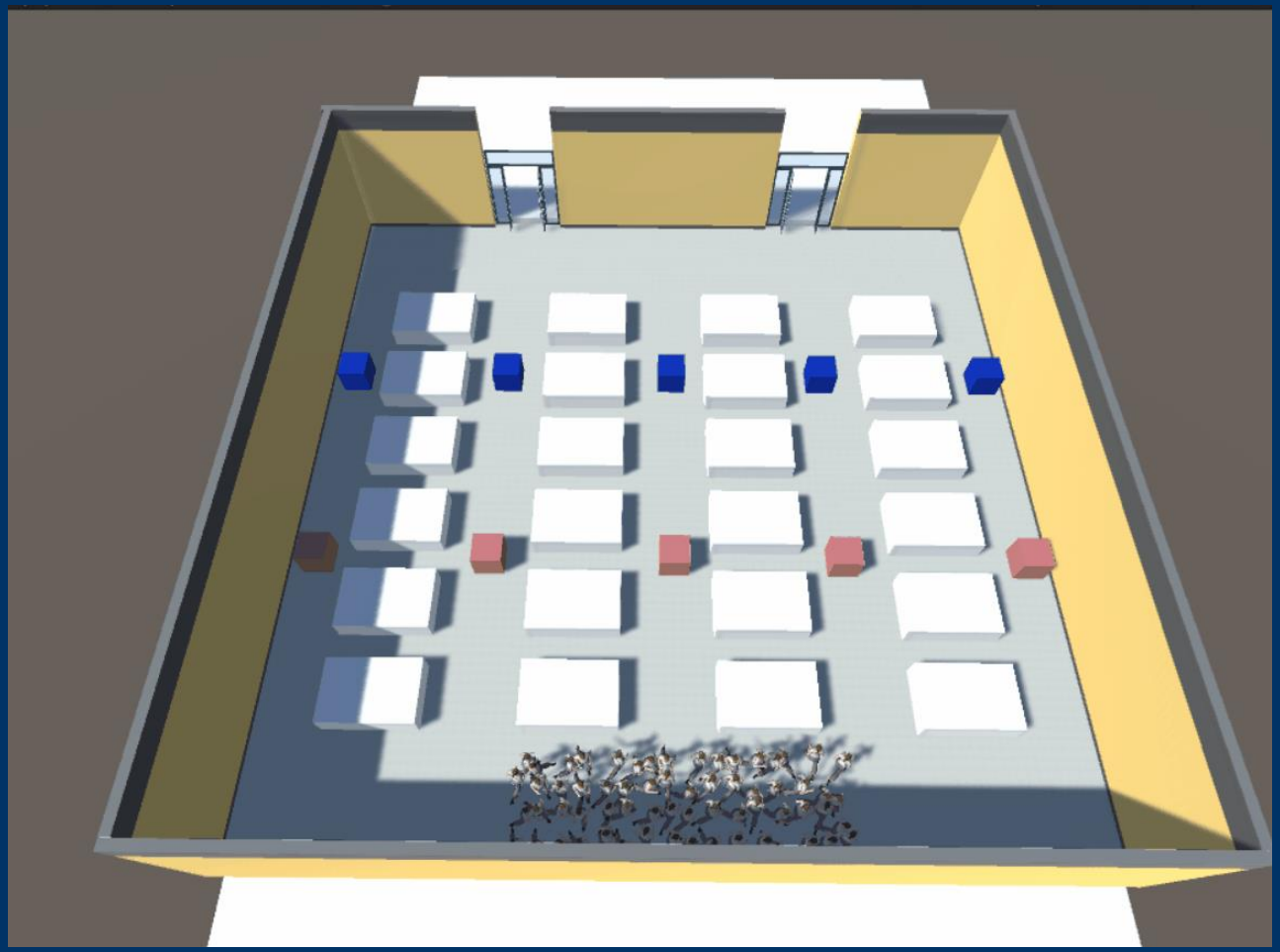
2.2 Deep learning based crowd evacuation



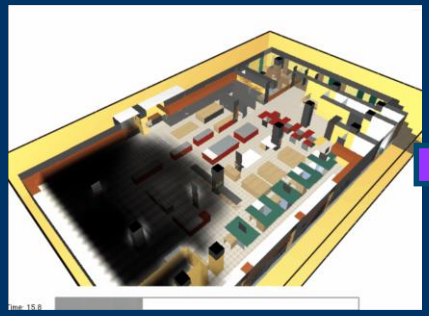


The theory is build an agent who has sensing ability and computation brain, the brain is a deep Q network. After the training of the Q network, the agent will get a reward when move a step. If the step is in right direction for evacuation,then the reward is higher. Using this method to implement the evacuation process.

Deep Reinforement learning based evacuation simulation within a changeable and dynamic supermarket



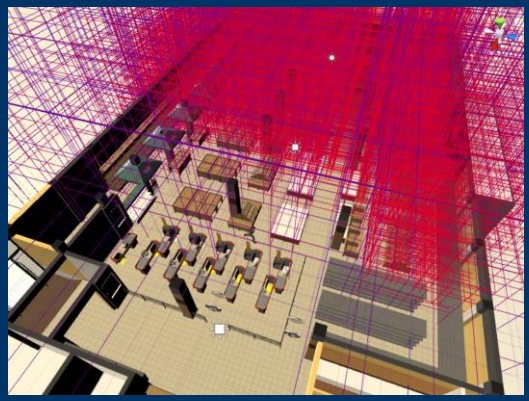
Data organization and rendering of real-time smoke , and exposure evaluation of agents within smoke for modeling and simulation in a supermarket



FDS Based simulation of smoke

X	Y	Z					
m	m	m		kg/m3	kg/kg	kW/m3	C
0.00E+00	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
1.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
2.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
3.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
4.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
5.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
6.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
7.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
8.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
9.00E-01	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
1.00E+00	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
1.10E+00	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01
1.20E+00	-8.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E+01

Voxel based attributes

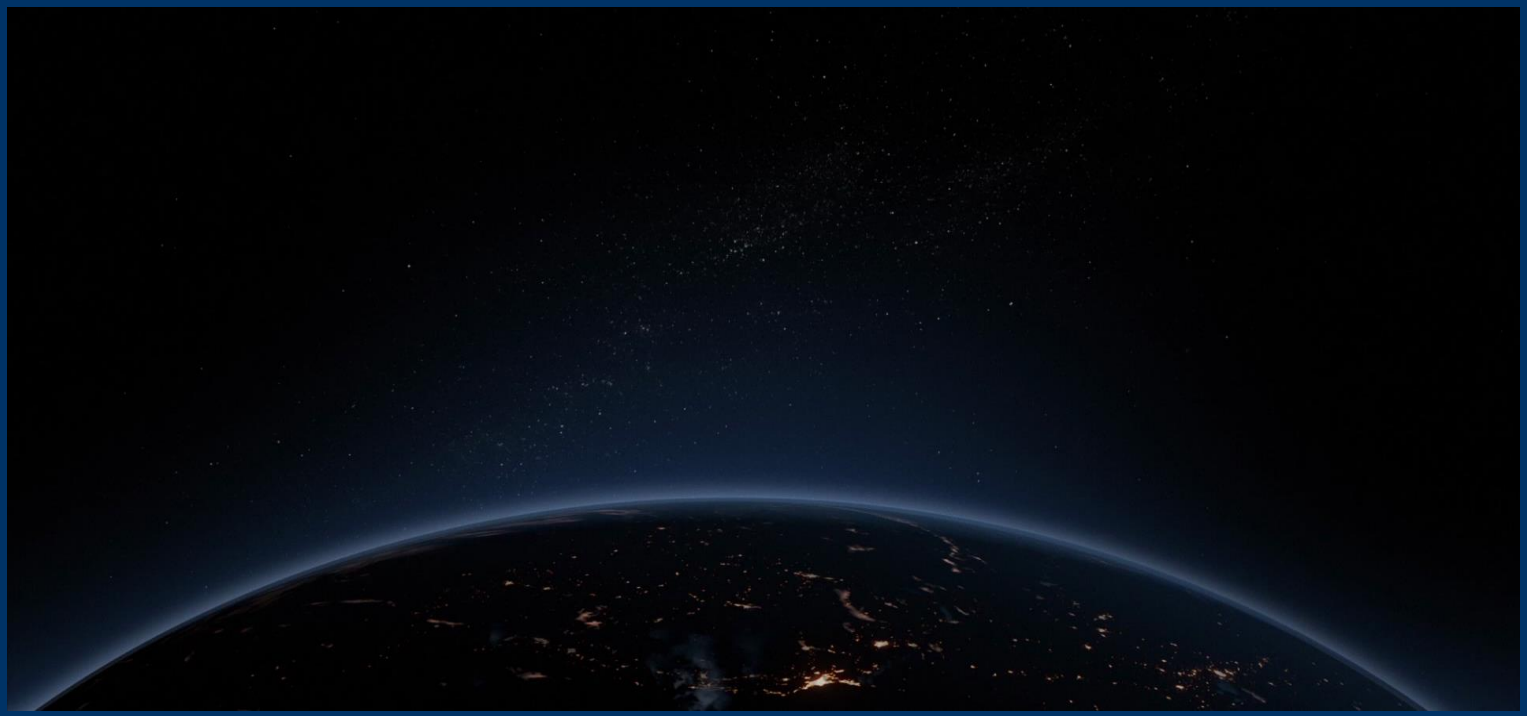


Octree data structure

Voxel rendering in real-time

Exposure evaluation of agent’s head

2.3 VR experiment based on computing data by social force model (just for a single user)



A VR user can follow virtual agents to observe the evacuation process

2.4 VR based collaborative crowd evacuation for distributed multi-users)

A Heterogeneous Distributed Virtual Geographic Environment—Potential Application in Spatiotemporal Behavior Experiments

Shen Shen [1,2], Jianhua Gong [1,2,3,*], Jianming Liang [4,*], Wenhang Li [1], Dong Zhang [1,5], Lin Huang [1,2] and Guoyong Zhang [1,2]

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Abstract: Due to their strong immersion and real-time interactivity, helmet-mounted virtual reality (VR) devices are becoming increasingly popular. Based on these devices, an immersive virtual geographic environment (VGE) provides a promising method for research into crowd behavior in an emergency. However, the current cheaper helmet-mounted VR devices are not popular enough, and will continue to coexist with personal computer (PC)-based systems for a long time. Therefore, a heterogeneous distributed virtual geographic environment (HDVGE) could be a feasible solution to the heterogeneous problems caused by various types of clients, and support the implementation of spatiotemporal crowd behavior experiments with large numbers of concurrent participants. In this study, we developed an HDVGE framework, and put forward a set of design principles to define the similarities between the real world and the VGE. We discussed the HDVGE architecture, and proposed an abstract interaction layer, a protocol-based interaction algorithm, and an adjusted dead reckoning algorithm to solve the heterogeneous distributed problems. We then implemented an HDVGE prototype system focusing on subway fire evacuation experiments. Two types of clients are considered in the system: PC, and all-in-one VR. Finally, we evaluated the performances of the prototype system and the key algorithms. The results showed that in a low-latency local area network (LAN) environment, the prototype system can smoothly support 90 concurrent users consisting of PC and all-in-one VR clients. HDVGE provides a feasible solution for studying not only spatiotemporal crowd behaviors in normal conditions, but also evacuation behaviors in emergency conditions such as fires and earthquakes. HDVGE could also serve as a new means of obtaining observational data about individual and group behavior in support of human geography research.

Keywords: virtual geographic environment; virtual geographic experiment; virtual reality; VRGIS; heterogeneous distributed clients

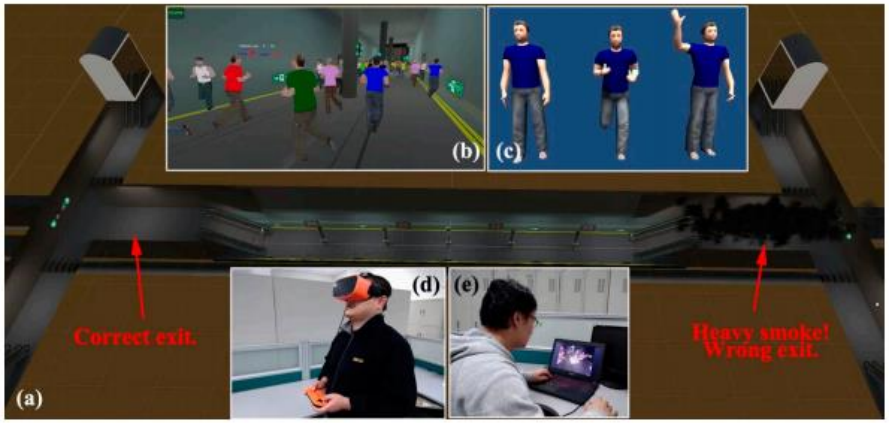
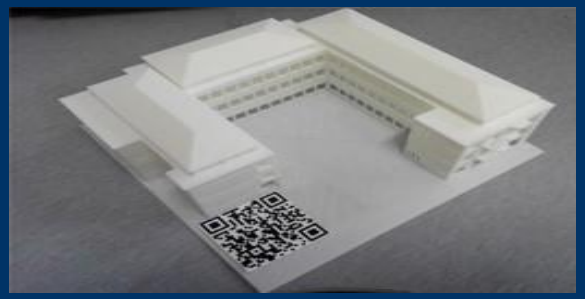
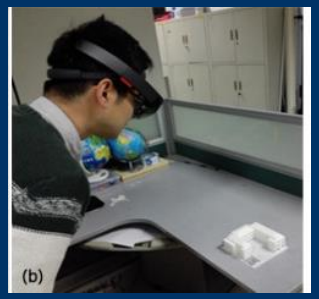


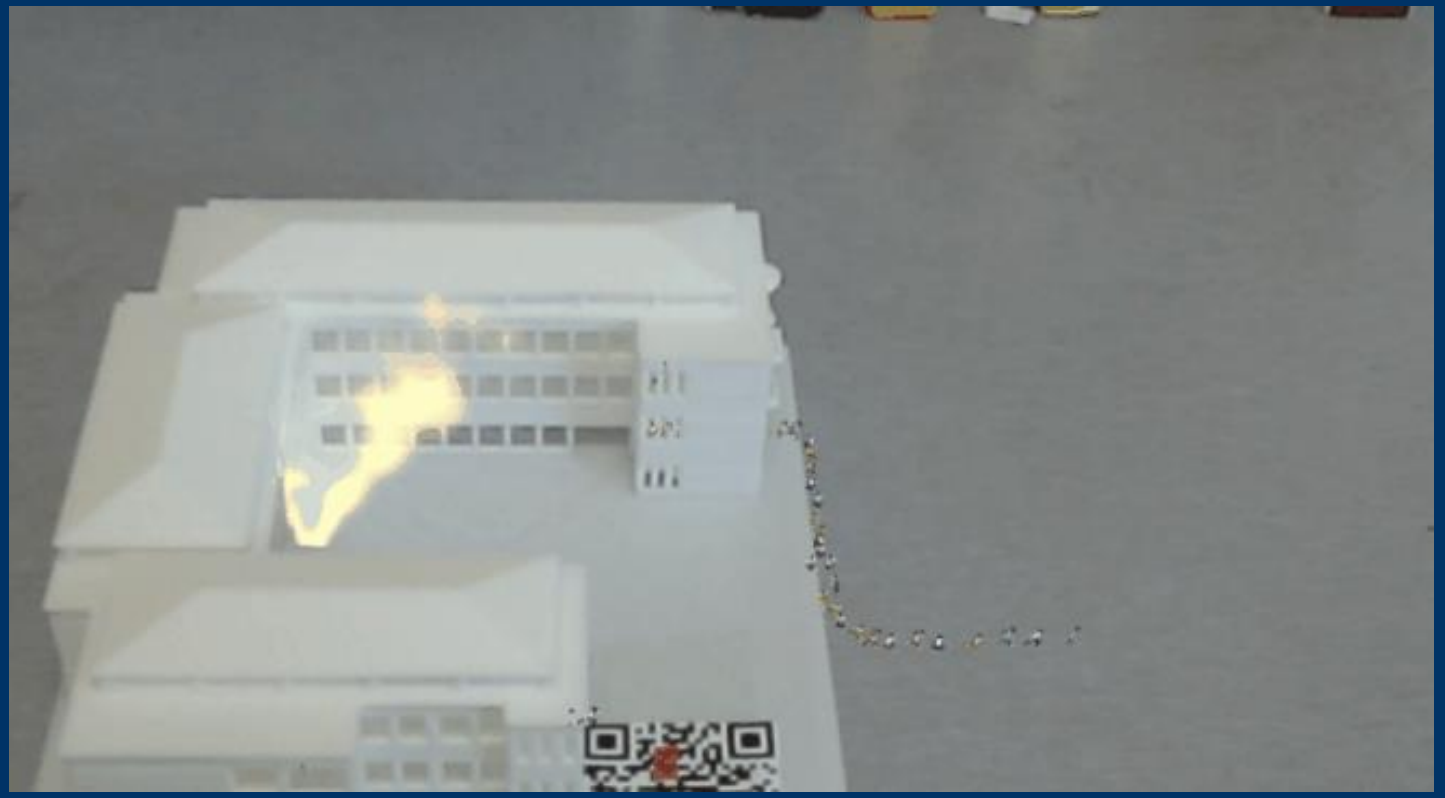
Figure 6. Prototype system overview: (**a**) subway scene with heavy smoke and dim lighting; (**b**) first person view with GUI; (**c**) three skeletal animations of an avatar; (**d**) all-in-one virtual reality (VR) client; (**e**) personal computer (PC) client.

We design and devolop a heterogeneous distributed virtual geogrphic environmnet for geocollaboration. Two types of distributed clients based on PC and all-in-one VR conduct the experiments of a fire evacuation drill in a subway.

2.5 AR based visualization of crowd evacuation based on 3-d printing school building







The future interesting and difficult research work in virtual experiments include:

① **The relationships between social force model and deep learning model for crowd evacuation;**

② **The integration of the mathematical model based agents and the VR driving agents.**

① Three phases of VR/AR development, VGE , VGExperience

② Modeling and VR simulation of Crowd Evacuation

③ Concluding Remarks (VR for GISci and Society)

Summary:

- ✓ Three phases of VR/AR development, VGE concept, examples of VGExperiences

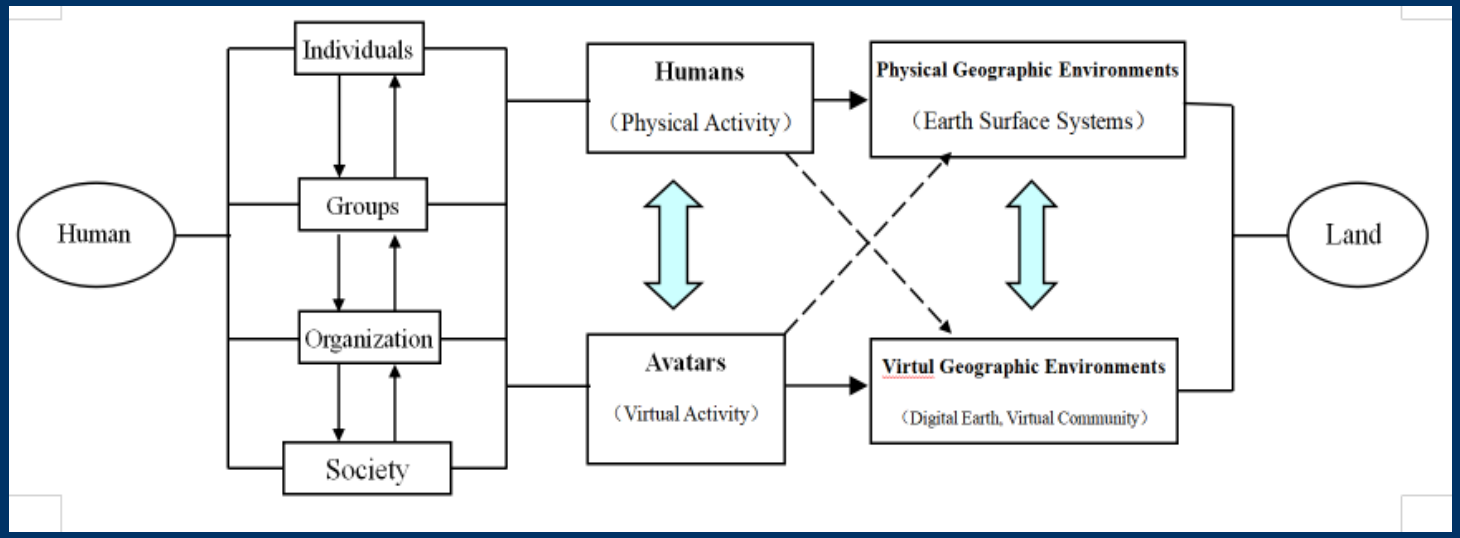
- ✓ Two approaches of modeling (social force and deep learning) and VR/AR based simulation of Crowd Evacuation

With regards to the new information technology of VR/AR, big data , and artificial intelligence, some reflections about the future GIS,geography, and society.

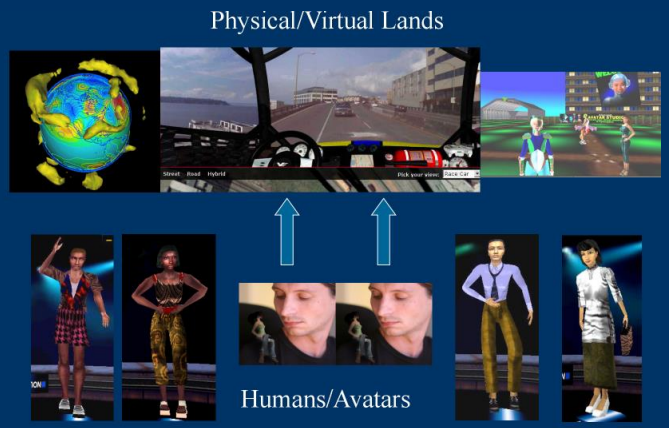
In view of GIS, Develoment from Land Based to Human Centered GISci

GISci is involving in body-based sensing and interaction, virtual interaction and communication among people, as well as virtual social worlds.

In view of geography, comptuing land-human relationships need highlighted.



- **Physical and digital Humans**
- **Physical and digital environments**



In view of the future of society:

Virtual social geographic environments, virtual and real integration spaces and society, post-humans, and virtual civiliation are in incubation and evolving ?

VR/AR based worlds will become important parts of sustainable society.

A famous science fiction novel: «The Three-Body Problem » ,by **Chinese author Liu Cixin, winner of the 2015 Hugo Award for Best Novel.**

Liu Cixin: "I think VR will cause a revolution of human living state, it will lead to a second migration from the physical reality to future imaginary worlds."

Thank You!

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