Master of Disaster

Virtual-Reality Response Training in Disaster Management

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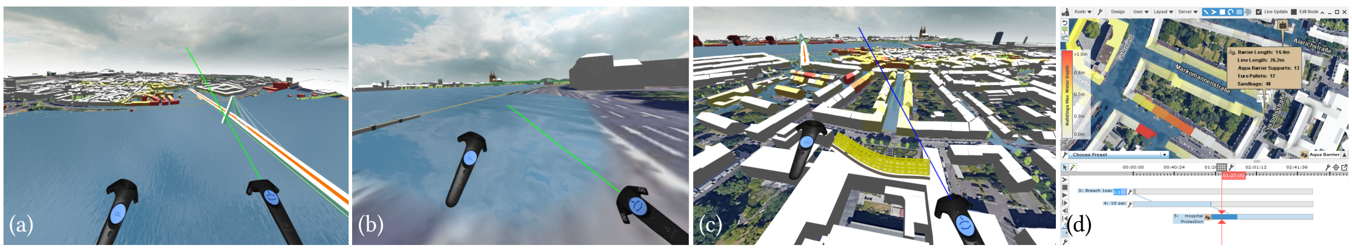

Figure 1: VR client, steering an interactive flood simulation. (a) Navigation through 3D GIS data in VR. (b) Observing a flood wall breach. (c) Trainee placing flood barriers. (d) Operator supervising the trainee's actions on a linked desktop client.

ABSTRACT

To be prepared for flooding events, disaster response personnel has to be trained to execute developed action plans. We present a collaborative operator-trainee setup for a flood response training system, by connecting an interactive flood simulation with a VR client, that allows to steer the remote simulation from within the virtual environment, deploy protection measures, and evaluate results of different simulation runs. An operator supervises and assists the trainee from a linked desktop application.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Computing methodologies** → **Interactive simulation**.

KEYWORDS

virtual reality, flood simulation, disaster training

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1 INTRODUCTION

Flood simulations allow flood managers to predict possible flooding events, which are the basis for the development of response plans to mitigate flood risks. Field personnel has to be trained to execute these response plans during emergency situations. Virtual reality (VR) offers a safe and inexpensive way to create training environments for different scenarios as an alternative to costly or unfeasible physical training environments. Currently available VR training applications [Environmental Tectonics Corporation 2019; Sermet and Demir 2018; Virtual Reality Society 2017] use predefined scenarios, with limited scene sizes and no option to navigate through time or change the flooding scenario.

We demonstrate a **collaborative operator-trainee** system for flood response training **based on a validated real-world flood simulation** [Buttinger-Kreuzhuber et al. 2019]. Our client-server architecture executes a remote flood simulation on the fly and uses a client to render the simulation data in VR, allowing for **fast data updates** and a **smooth flood animation** for **large scenes**. Through the VR client, a trainee can **manipulate the boundary conditions of the simulation** by placing flood barriers to test protection measures. The results of these actions can be investigated by **time navigation** within a flooding scenario and by **scenario navigation** between multiple simulation runs with different barriers. An operator supervises the trainee's actions with a linked desktop client of the decision support system *Visdom* [Waser et al. 2018] to guide and assist in complex tasks. Beyond training applications, our system can also be used in public communication to demonstrate the work of flood managers to non-experts and vividly illustrate the severity of possible flood hazards. This can help to convey the seriousness of a flooding event and the necessity of protection or evacuation measures, which is a crucial task [Kapucu 2008].

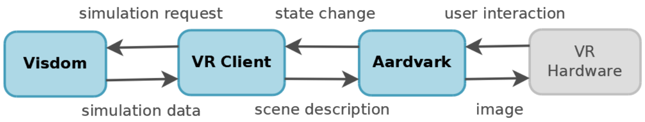

Figure 2: Components and data flow of our System.

2 FLOOD SIMULATION SYSTEM

Our system represents a **VR training module for the flood simulation system Visdom** [Waser et al. 2018]. Visdom is used in flood management to create action plans for flooding situations and is evaluated on real-world data. Its validated, robust simulation [Buttinger-Kreuzhuber et al. 2019] solves the shallow-water equations using the finite-element method and takes buildings, barriers (structure, length), terrain and water levels into account. This allows the system to calculate and display physically correct flooding levels over very large areas and expected damage to infrastructure. This is also true for our presented VR client.

To interactively run a reliable flood simulation and an immersive VR simulation at the same time, we built our system as client-server architecture, where the flood simulation is provided by the server and the rendering is done on the client. It consists of three components (see Figure 2): (1) *Visdom* is a decision support system with integrated flood simulation. It runs on the server, simulates the water propagation and sends the simulation data to the client. (2) The *VR client* connects Visdom and the rendering engine. It processes the simulation data received from Visdom and creates a scene description, which is then sent to the rendering engine. (3) *Aardvark* [VRVis 2019] is a high performance rendering engine that visualizes the scene description data as images on the VR display and receives user input from the motion controllers. User interactions cause a state change, which Aardvark propagates to the VR client. Depending on the state, the client then sends a simulation request to Visdom.

3 VR INTERACTIONS

Our application can handle large virtual environments (VE). For this prototype we implemented *pointing-directed steering* and *teleportation* as locomotion techniques, because they give the user the freedom to navigate freely and quickly through the whole VE to get to regions of interest. Adding natural walking techniques to allow for a more immersive exploration of the VE is part of our future work. To protect important infrastructure from flooding, the user can select a barrier type from a hand-fixed menu (see Figure 3) as well as a placement method (setting control points, free-hand drawing, or 3D placement) and place a barrier in the VE. To investigate the impact of placed barriers on a flooding scenario, the user can play back or pause the flood simulation in VR. The user is also able to step forward or backward in time, using the Vive controller, and switch between different scenarios to compare the impact of flood protection measures.

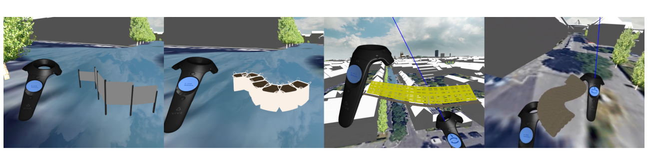

Figure 3: Examples of barriers that can be placed by the user.

Table 1: Data of different test scenarios.

Scenario	S1	S2	S3	S4
Terrain	6.99 km^2	51.15 km^2	34.07 km^2	38.69 km^2
Cell Size	5 m	10 m	10 m	10 m
#Buildings	5 696	55 487	37 889	5 038
#Trees	6 008	38 607	30 795	81 693
Frame Times	~11,17 ms	~14,73 ms	~11,56 ms	~11,17 ms

4 PRELIMINARY RESULTS

In order to prevent motion sickness in VR, our simulation has to achieve a render time of 11 milliseconds or less per frame, to accommodate the 90 Hz refresh rate of the HTC Vive. We evaluated the performance of our system, using four different city models with different terrain size, cell size, and number of rendered objects like buildings or trees (see Table 1). To update a scene efficiently, our implementation leverages OpenGL's *multi-draw indirect* extension together with Aardvark's specific *VRMeshType* (consisting of a single scene object or an object group), which allows rendering multiple scene objects with a single draw call. Hence, we are able to quickly update necessary data in the scene graph and achieve high frame rates in most of our test cases (see Table 1). Our results suggest that frame times are influenced by the size of the city model as well as the number of objects in it. In future work we plan to perform an in-depth analysis of these performance-influencing factors. We collected feedback from users during several test sessions of our VR client, and identified possibilities for improvement of our interaction interface. We are working on methods to improve the user experience by, for example, introducing a non-expert mode with a smaller set of available options.

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REFERENCES

A. Buttinger-Kreuzhuber, Z. Horváth, S. Noelle, G. Blöschl, and J. Waser. 2019. A fast second-order shallow water scheme on two-dimensional structured grids over abrupt topography. *Advances in water resources* 127 (2019), 89–108.

Environmental Tectonics Corporation. 2019. Advanced Disaster Management Simulator. http://trainingfordisastermanagement.com, (Accessed: 2019-08-03).

N. Kapucu. 2008. Collaborative emergency management: better community organising, better public preparedness and response. *Disasters* 32, 2 (2008), 239–262.

Y. Sermet and I. Demir. 2018. Flood Action VR: A Virtual Reality Framework for Disaster Awareness and Emergency Response Training. In *Proceedings of the International Conference on Modeling, Simulation and Visualization Methods.* CSREA Press, 65–68.

Virtual Reality Society. 2017. Applications of Virtual Reality. https://www.vrs.org.uk/virtual-reality-applications, (Accessed: 2019-08-03).

VRVis. 2019. An Advanced Rapid Development Visualization And Rendering Kernel. https://vrvis.at/research/projects/aardvark, (Accessed: 2019-08-03).

J. Waser, A. Konev, and D. Cornel. 2018. On-the-fly Decision Support in Flood Management. *GIM International* issue November/December (2018), 22–25.