Resynthesizing Reality

Driving Vivid Virtual Environments from Sensor Networks

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Figure 1: The virtual world of Doppelmarsh mirrors the physical world of Tidmarsh.

ABSTRACT

The rise of ubiquitous sensing enables the harvesting of massive amounts of data from the physical world. This data is often used to drive the behavior of devices, and when presented to users, it is most commonly visualized quantitatively, as graphs and charts. Another approach for the representation of sensor network data presents the data within a rich, virtual environment. These scenes can be generated based on the physical environment, and their appearance can change based on the state of sensor nodes. By freely exploring these environments, users gain a vivid, multi-modal, and experiential perspective into large, multi-dimensional datasets. This paper presents the concept of "Resynthesizing Reality" through a case study we have created based on a network of environmental sensors deployed at a large-scale wetland restoration site. We describe the technical implementation of our system, present techniques to visualize sensor data within the virtual environment, and discuss potential applications for such Resynthesized Realities.

CCS CONCEPTS

•**Human-centered computing** → **Virtual reality; Information visualization;** •**Computing methodologies** → *Interactive simulation;* •**Hardware** → Sensor applications and deployments;

KEYWORDS

Virtual Environments, Ubiquitous Sensing

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1 OVERVIEW

As microelectronics, sensors, and wireless technologies advance and become lower cost, we are now able to gather massive amounts of environmental data about the physical world. Ongoing work at the Responsive Environments group at the MIT Media Lab researches how sensor networks can extend and mediate human perception. One approach, termed "cross reality" has explored the link between the physical and the virtual, where sensor networks can "tunnel" dense real-world information into virtual worlds, and interactions in the virtual world can incarnate back into the physical world through displays and actuators [Lifton et al. 2009]. Our work on "resynthesized realities" extends the concept of cross reality. It examines how exploration within rich virtual environments can give users a qualitative "sense" for complex streams of live and cached sensor data by taking advantage of humans' innate abilities to interpret sensorial cues in the physical world. Our sandbox for resynthesized reality is Doppelmarsh, a virtual replica of an ongoing large-scale wetland restoration site in Plymouth, Massachusetts called Tidmarsh. Environmental changes at Tidmarsh are tracked over time by dozens of sensor nodes deployed across its landscape [Mayton et al. 2017]. Data from these sensors are then used to modulate the appearance of the virtual environment.

2 RELATED WORK

Doppelmarsh inherits from two prior projects from the Responsive Environments Group, ShadowLab and DoppelLab. Both feature virtual environments generated from sensors deployed within the physical building of the MIT Media Lab.

ShadowLab [Lifton et al. 2007] employed temperature and infrared motion sensors embedded in physical devices called "data ponds" situated in thirty locations around the building. A virtual version of each data pond can be found in a stylized depiction of the Media Lab within the shared virtual environment Second Life. The appearance of each virtual data pond changes based on the state of its physical counterpart.

Inspired by ShadowLab, DoppelLab also tracked many parameters like temperature, humidity, motion and audio across the building, and used RFID readers to sense the presence of people with tags [Dublon et al. 2011]. A virtual version of the lab was built in Unity, where colored spheres and flames represented the state of environmental sensors, and boxes texture-mapped with photos represented people.

Doppelmarsh extends its predecessors in the quantity and types of sensors as well as in the setting. Its approximately 150 nodes are scattered across the landscape and include not only measurements of temperature and humidity but also pressure, wind, precipitation, and ambient light, as well as cameras, microphones, and hydrophones (tidmarsh.media.mit.edu). Moreover, these sensors are deployed outdoors in nature rather than inside a building, resulting in more variability and unpredictability in the data.

3 IMPLEMENTATION

Doppelmarsh is built with the Unity3D game engine. Its terrain is rendered by LIDAR measurements collected by the United States Geological Survey (USGS). High-resolution photographs of the soil are used to paint the different textures of the virtual terrain, and the vegetation is selected from models of trees and herbs that resemble those at the actual site. The geo-tagged sensor nodes are also represented in the virtual environment at their designated locations, where an animation triggers each time a node trasmits an update. The audio, captured from microphones and hydrophones deployed on-site, is streamed into the game engine and mixed with an ongoing generative musical system fed by the sensor data in real-time [Lynch and Paradiso 2016]. Other basic components like the sky box, the player and its motion, as well as the water rely on standard assets assembled in the Unity3D editor. To enhance this telepresence experience, we parse multiple streams of data incoming from environmental sensors via ChainAPI [Russell and Paradiso 2014], cameras deployed on site via WebSocket, and historical weather forecast via the Wunderground API. These three data streams allow us to deduce and store the state of the environment at any given time since 2014, when the network first came online. These frames of reality are used to simulate physical processes on the virtual terrain, such as wind, seasonal changes, and others. Table 1 indicates the various sensors used and how they affect the virtual environment. We are also exploring other more complex sensor mapping strategies, featuring the representation of longer-term sensor data. One such strategy embodies long-term sensor data in the behavior and morphology of virtual creatures.

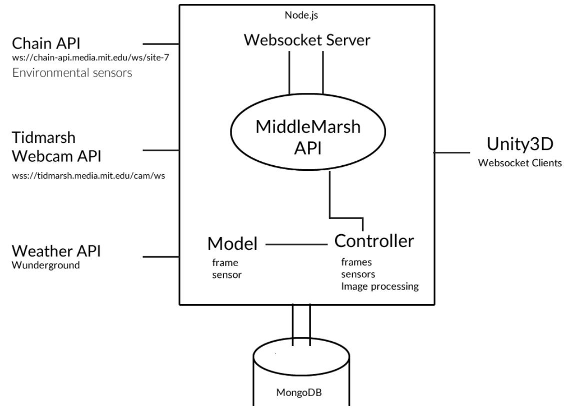

Figure 2: High level system diagram.

Table 1: Sensor-data mapping

Element	Sensor	Animation
Wind direction	Wind sensor	Trees direction
Temperature	Temperature Sensor	Red/Blue filters
Rain	Precipitation Sensor	Rain intensity
Snow	Cameras	Snow height
Fog	Cameras	Fog intensity
Seasonal changes	Cameras	Grass/Trees colors

3.1 System Architecture

The MiddleMarsh server, build with Node.js (v.7.5.0), connects to the scene in Unity via Websockets, where a script parses String messages into JSON from the server when requested by the client. Once parsed, these objects are used to trigger the appropriate behavior in the environment. Wind, temperature and precipitation data are pulled from ChainAPI, images captured by fixed on-site cameras are analyzed with the Google Vision API to detect snow and generate color palettes of the grass, and missing frames are filled with basic data fetched from the weather API. All is then stored in different MongoDB (3.4.2) collections.

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