Extensible Experiences: Fusality for Stream and Field

Nicholas F. Polys * Peter Sforza W. Cully Hession John Munsell
Virginia Tech

Figure 1: *Fusality X3D data mashups in the VT Hypercube (26,214,400 stereo pixels with head tracking) and WebVR (right)*

Abstract
This paper describes our initial methods and results for the collection, fusion, and delivery of geo-referenced data to Web3D clients. We are working to publish environmental monitoring data and citizen sensors to create compelling and scientific experiences of local places. We describe our collection and fusion of 3D point clouds and photospheres and describe the challenges and approaches to data registration. We demonstrate how these interactive online experiences can be delivered to different immersive platforms from handhelds to HMDs to high-resolution immersive environments and illustrate our methods with data from our water monitoring lab and our environmental research stations.

Keywords: 3D Scanning, site capture, immersive geo-visualization, citizen science

Concepts: • **Human-Centered computing ~ Visualization application domains;** *Geographic visualization;*

1 Introduction
Food, Energy, and Water continue to be major challenges for humanity's survival. Toward this end, we are developing a Spatial Data Infrastructure (SDI) and Web visualization platforms that enable the fusion and analysis of varied sensor and simulation data across the network. We target the integration of diverse georeferenced data from across the ecosystem, including sensor nets and mobile students and citizens. When interactive 3D graphics of real locations are updated with events from the physical world, we call them Mirror Worlds [Tilden et al, 2011]. Mirror Worlds present great opportunities for the wide delivery of telepresence applications for monitoring, research, and education.

Fusality is our next-generation open Web3D platform that enables multidisciplinary scientists and citizens to access sensor-driven information, GeoDesign inputs, and crowd-sourced content [Polys et al., 2015] . The extensible experiences we are building can help local stakeholders and property managers obtain a more integrated, comprehensive view of their landscape and its connectivity.

We are piloting our SDI system with data from either side of a unique triple divide found here in Blacksburg, VA. This point is the source of the New River (Mississippi River - Gulf of Mexico), the Roanoke River (Albemarle Sound - Atlantic Ocean), and the James River (Chesapeake Bay - Atlantic Ocean) watersheds.

The Virginia Tech Stream Research, Education, And Management (StREAM) Lab is a full-scale, outdoor laboratory along a natural stream with high-resolution monitoring capabilities that provide a unique opportunity to concurrently conduct research, education, and outreach activities [e.g. Jones et al., 2015]. The StREAM Lab has sampling bridges with continuous water-quality sensors (oxygen, temperature, turbidity, conductivity), a groundwater well array, stage transducers, a full weather station, two water-proof digital cameras that take images hourly of the stream and floodplain, and a wireless system for routing all sensor data to a server that provides live updates via the Web. The lab is currently used for more than 16 courses across five colleges at Virginia Tech.

Another location is the Catawba Sustainability Center (CSC), which is a research and education center for sustainability that works to advance environmental stewardship, community engagement, economic growth, and innovative solutions to sustainability challenges. We also maintain a live gauge link there to stage and water quality data through the Stream Lab. Thus, the CSC offers hands-on learning opportunities for faculty and students and serves as an outdoor classroom for field trips, graduate and undergraduate research and environmental conservation programs. Along with our scans and photos, we are using GIS layers and Web3DS to deliver different applications for the property.

Our stakeholders are seeking a Web3D platform for planning, establishing, and maintaining productive multifunctional agroforestry riparian buffers and silvopasture systems. Silvopasture is an upland pasture agroforestry practice where livestock, forage, and tree crop components are intensively managed together on the same piece of land. Optimizing component performance of both systems in a GeoDesign planning and management environment will refine production and conservation outputs derived from these complex polyculture systems [e.g. Trozzo et al 2014]. We integrated our localized LiDAR and GIS layers as 3D GIS context for our property planners. Viewing these locations and planting scenarios in virtual reality can provide unique experiences and insights.

*e-mail:npolys@vt.edu.

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2 System Architecture

2.1 Capture

We worked with several sensors to populate our extensible experiences. We used two different sensors to capture 360 degree photos from optical cameras. These generate spherical images, 'photospheres', which can be geolocated in the Fusality system. The first capture method used Google's Streetview app on an Android mobile phone. Although the app provides feedback to guide the user to each shot, it still requires some practice and patience to compose a full photosphere of 6144 x 3072 pixels. The second method we piloted with a Ricoh theta camera, which is tri-pod mounted and captures the sphere in one shot.

Laser scans were collected from two different sources: the Structure.io sensor for detailed 3D models of smaller forest plants and the Velodyne Scanner for streambank foliage morphology. Both data sets were converted to X3D and X3DOM and embedded in the photosphere of that location. There are still real challenges with this method: the scanner range is limited for outdoor applications, the accuracy of the structure sensor and reconstruction algorithm (geometry and appearance) is not perfect, and the varied performance in different environmental conditions, including windy days where the leaves are moving over the time of a scan.

Velodyne scanners are typically used in autonomous vehicle applications. The point cloud data incudes some attributes including return intensity and azimuth. Scan frames are saved as separate binary files averaging 10,000 return points per frame. The data was processed through the open source Paraview toolkit.

2.2 Processing and Registration

We collected several local, regional, and national GIS data layers to provide the geospatial context for our collected sensor data. Because GPS locations are inexact, our demonstrations still rely on some expert curation to align features between different captures and perspectives. We can report that in the face of no automated methods, the visual alignment process was faster and more acute when the task was performed on immersive (head tracked, stereo) platforms. Figure 2 show the result of a Fusality mashup.

Figure 2: *StREAM Lab photospheres with scanner data in X3D*

2.3 Web3D Service Delivery

We have previously published on our data and service Web3D portrayal system for 3D geospatial data [Kim et al 2015]. We continue to develop and apply our open stack Web3D Geoserver implementation. In our architecture, declarative assets such as pre-computed terrain tile Levels-Of-Detail (LODs), 3D building LOD models, layers, photospheres, and laser scans all exist on a web file system and are indexed for spatial queries in a PostGIS relational database. Using the platform-independent open standard of X3D for Web3D portrayal services, we can deliver our extensible experiences to Head Mounted Displays (HMDs) and Immersive CAVEs (such as our HyperCube, Figure 1). We used X3D to compose the captured models and publish them online as X3DOM.

For an immersive web experience, we used WebVR to connect head tracker data to a side-by-side stereo view (e.g. Oculus, Cardboard). For navigation of the scene, we used a hand-tilting gesture from the Leap Motion data to drive positional steering along the direction of gaze. In our HyperCube deployment, the X3D models were rendered with active stereo and head tracking for position and orientation; a tracked wand was used for navigation.

3 Conclusions and Future Work

Based on our experience and applications, we believe that the X3D representations for PointSet Appearances should improved; for example, the ability to specify point size and other PointProperties would enable the dynamic visual weighting of points for example. Alternatively, a splat or sprite solution such as a ParticleSet could provide even more visual flexibility.

Photospheres can provide a high-resolution capture result and may be used for site assessment by experts or learners. Aspects such as site crowding, canopy closure, and even soil types can be apparent when such 2D images are projected into 3D. With our framework, the next step is to extend the experience of a place by adding audio clips of soundscape captures. In addition, we will connect this X3D content with our multi-user mirror world server and enable the real time sharing of experiences. We believe methods and frameworks like ours will enable citizens to become both producers and consumers and to deliver compelling virtual fields trips.

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