Ecovr: Visualizing Real Ecosystems And Big Data In Virtual Reality

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ABSTRACT

Enter a virtual recreation of a real research forest where each tree can tell the story of its growth. EcoVR allows visitors to walk in a living forest in VR and see, on the landscape, the once invisible forces that shape how forests grow. Standing in the forest, users can look at a tree and see its height; they can turn on data layers to see temperature flow through the air; zoom out in time to see a season pass in a minute or zoom in to a day and watch humidity change after a rain. EcoVR uses the power of VR to merge the feeling of being in a real place with 3D data to create a new experience in data visualization, science and education.

1. Introduction

Forests were once measured as a single data point but now we can track every leaf in 2,000 bands of color, in 3D, through time. These types of measurements are crucially important for ecology and conservation, but our ability to collect data has rapidly overtaken our ability to analyze and visualize these data in meaningful ways. The human brain is excellent at finding patterns in complex information, but only if they are presented in a format that we can make sense of. Modern data sets have become so advanced that researchers lack the tools to make full use of them. Visualizing complex ecological data is a design problem, requiring new tools for visual storytelling and interactivity that have not yet been invented.

Virtual and Augmented reality provide new ways of understanding and seeing science, but the language of these tools has not yet been created and their future is wide open. Hollywood and the gaming industry have created powerful tools for building imaginary worlds. We can use these tools to model the real world in ultra-rich detail, enabling a new type of experience, combining visual storytelling with scientific inquiry.

Scientists go into the field to make observations and develop an intuitive understanding of the landscape. In the lab, computers and software provide tools for visualizing and making sense of complex data. VR and modern game engines give us the means to merge these two methods of understanding through an interactive recreation of any research site. Complex sensor data can be mapped in 3D onto the digital landscape and viewed through time, unveiling previously invisible patterns.

EcoVR is a proof-of-concept project that explores using virtual reality for re-creating ecosystems and visualizing high-resolution time-lapse sensor data, on the landscape. EcoVR is a spatially accurate recreation of a research forest at the National Arboretum in Canberra, Australia built in Unreal using data from repeat drone flights, laser scanners (LiDAR), and satellites. Data from a 20-node mesh sensor network measuring air and soil temperature, humidity, soil moisture and tree growth at 10 minute intervals is mapped onto the landscape.

Movie final text

Virtual and Augmented reality provide new ways of understanding and seeing science, We can use these tools to model the real world in ultra-rich detail, enabling a new type of experience, combining visual storytelling with scientific inquiry. We have currently modeled the National Arboretum as a proof-of-concept, but EcoVR can be extended to work with any spatially referenced time-series data, from agricultural fields to greenhouses.

New technology has provided ecology with a wealth of new data sources at spatial and temporal resolutions that were previously unmanageable.

While ecology has struggled to keep up with technological change, the entertainment industry (computer gaming, high-budget film studios, etc.) have spent billions of dollars developing tools for rendering the world in very high resolution. The gaming industry in particular has been developing relatively easy to use tools for creating interactive 3-dimensional models of the world. Additionally, since 2012, virtual reality (VR) and augmented reality (AR) headsets have gone from non-existent to reasonably affordable consumer devices. In the same time frame, off-the-shelf UAV or "drone" technology and robust 3D reconstruction software has become widely available, allowing rapid imaging of outdoor environments that can be easily converted into a 3D model of the area surveyed.

The National Arboretum Virtual Reality Project is a proof of concept project to explore new methods of visualizing complex time-series environmental data, on the landscape, using the Unreal gaming engine and the Oculus Rift VR headset. Working with a group of students from the ANU Computer Science Department TechLauncher project, we have developed a 3D interactive model of the National Arboretum in Canberra, Australia where time-series environmental data is overlaid on a spatially accurate 3D model of the ANU research forest.

With drones,

EcoVR is layers like 3D GIS with timelapse - EcoVR allows scientist to interact with complex datasets in an intuitive way to see how cold air flowing down a hill changes how trees grow.

Keywords

Concepts

The human brain is designed to recognize patterns, but only if they are presented in a format that it can make sense of. Research data has become so complex, scientists often struggle to visualize their data, let alone analyze it. Visualizing complex data is a design problem, requiring tools for visual storytelling and interactivity that have not yet been invented. EcoVR is a new interface for science and education where the ecosystem being studied is recreated in virtual reality with the data overlayed onto the trees and landscape letting giving the user the advantage of directly seeing their data layered onto the landscape. Combining data from satellites, drones, weather sensor networks, multispectral and gigapixel resolution cameras, EcoVR paints complex time-lapse data onto the landscape allowing the user to walk inside a real forest with so the user can see the temperature change while the trees grow Time lapse controls let

the user watch a year go while the trees grow, or zoom into a day and watch the temperature changes as the sun rises.

Overview

Our tools for monitoring the environment have become too complex for us to visualize their outputs with existing tools. Visualizing such complex time-series ecological data is a design problem, requiring tools for visual storytelling and interactivity that have not yet been invented. EcoVR is the a Virtual Reality software package for re-creating ecological landscapes and visualizing high-resolution sensor data, on the landscape visuliazing time-klapse sensor data visualizing

; see soil moisture in the ground, watch temperature flow through air.

Our tools for monitoring the environment have become too complex for us to visualize their outputs with existing tools. Where we once measured at the scale of data points per forest, we can now measure the behaviour of every leaf in every tree in 2,000 bands of color and 3 dimensions at centimeter resolution, through time.

Until recently, ecological research was data limited - an entire forest reduced to a few data points. Now, we can track every leaf in 2,000 colors, in 3D, time lapse but we lack the tools to effectively visualize such data. Eco

New technology is letting us capture a forest growing at leaf-level resolution with thousands of data layers. But science lacks the tools needed make full use of such data; often the tools for even visualizing such ultra-high resolution data don’t even exist. Virtual and Augmented reality offer a new tool with which we can create

With drones, mesh sensor networks, hyperspectral cameras and other new technologies we can now measure the behaviour of every leaf in every tree in 2,000 bands of color and 3 dimensions at centimeter resolution, through time. Now, our tools for monitoring the environment have become too complex for us to visualize their outputs with existing tools. Visualizing such complex time-series ecological data is a design problem, requiring tools for visual storytelling and interactivity that have not yet been invented. EcoVR is the a Virtual Reality software package for re-creating ecological landscapes and visualizing high-resolution sensor data, on the landscape visualizing time-lapse sensor data visualization

Technological innovation has provided the biological sciences with novel tools for collecting ultra-high resolution datasets. These spatially and temporally dense data are crucially important for environmental

monitoring, @as as climate modeling and informing conservation decisions but limited tools exist for analyzing and visualizing such data.

The gaming industry has developed advanced tools for rendering the world in very high resolution. Virtual reality (VR) and augmented reality (AR) hardware are rapidly becoming affordable consumer technologies. UAV/drone technologies and robust 3D reconstruction software have become widely available, allowing rapid imaging and 3D modeling of outdoor environments.

EcoVR is a proof of concept project demonstrating novel methods of visualizing complex time-series environmental data, on the landscape, using the Unreal gaming engine and the Oculus Rift headset. We have developed a 3D interactive model of the National Arboretum in Canberra, Australia where time-series environmental data is overlaid on a spatially accurate 3D model of the ANU research forest.

1 Overview

In 2014 we instrumented a research forest at the National Arboretum in Canberra, ACT with a 20-node mesh sensor network to monitor above and below ground temperature and moisture and micrometer resolution tree growth (the "Phenomic Environmental Sensing Array" [PESA]). While traditional environmental monitoring may measure some of these data at one location in a forest, such "next-gen" mesh sensor systems allow us to measure microclimate variation at the tree-level. Traditionally, a single weather station would provide weather data and research outputs were at the tree stand level rather than per individual tree. Coupled with time-series 3D size, height and colour information derived from UAV overflights, these types of dense datasets create the potential to monitor tree-resolution environmental variation and to tie these measurements with low-cost full genome sequencing to identify genetic traits of interest in individual trees. However, in practice, even viewing the data, let alone organizing it into a usable format and analysing it are a significant and unsolved challenge. This type of challenge is becoming increasingly an issue for research biologists. Our ability to collect novel data of high complexity has vastly outstripped our ability to analyze it. What is needed are new tools that enable researchers to rapidly organize and visualize complex, multi-layer time-series data.

The National Arboretum is a unique 250-hectare site featuring more than 4,000 trees growing in 94 forests, most of them in single-species stands. Most forests are less than 5 years old, providing the opportunity to monitor and document tree growth from "birth" through maturity over the coming decades. While such novel

2 Related Work

There has been much work on visualizing biological systems for research purposes. Such efforts typically focus in either modelling a particular biological process (eg, dictyostekiun, ants, etc) or organelle (cells, photosynthesis) for research or educational purposes. Some work has been done to

model such systems in 3 dimensions, either for scientific visualization, artistic, or explicitly for virtual reality applications. More recently, with the recent emergence of virtual reality as an available consumer product at relatively low cost, additional projects have been undertaken to model wild places for educational and experiential purposes, gaming or education. GIS systems provide tools for visualizing static or time-series Geospatial data on map layers while products such as Google Earth provide interactive map layers within a Geospatial accurate model of the earth.

However, to our knowledge no previous efforts have attempted to visualize time series data layers over spatially accurate 3D models of forests or other wild areas. This model has 3 unique innovations that differentiate it from existing software approaches.

(1) 3 dimensional vegetation with time series growth
    (a) Google Earth currently has low resolution visualization of some vegetation feature but the data is patchy and does not change over time
(2) Interactive Time-series data. Google Earth and gis can show animations but they lack dimensionality and spatial context. The ecovr software is built around a time slider system that lets users quickly zoom in and out of time periods of interest. This enables the user to zoom from viewing years if data to a particular day or hour to quickly zoom into a time period or event if interest
(3) Injection of Web data natively into the model. The ecovr viewer is integrated with a traditional Web site for visualizing time series data in graphical format. Because all online and model data are built from the same data standards, users within the software can pull up a virtual data "tablet" to Viera graphs of the data for individual or groups of trees. Within the model, the user can put up traditional line graphs next to the tree, because the trees in the model represent real trees in the world and data for the model and website at the same data, the model can detect which virtual tree or group of trees a user is viewing and query the website for related dats to visualize in graphical format. This interface merges the utility of Geospatial visualization which let's the user see spatially how data may vary on the landscape with the strengths of conventional graphing. (Fig)

Usage for other datasets

The importance of continetnak scale monitoring networks has been increasingly recognized and has resulted in the emergence of nation wide networks of field sites that feature high density monitoring and instrumentation. Such sites are ideal because the all capture the same data using well defined data standards tied to high time and spatial resolution data.

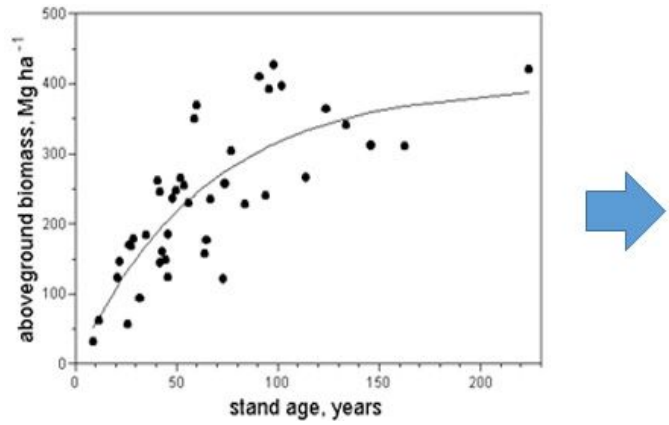
Although the ecovr code was developed to visualize data for a particular place, it had been built as a standalone software package such that any other location with the required assets, DEM, tree or plant location and model, and Geospatial time series data, can also be visualized. Thus data from sites such as Tern and NEON can be loaded into the model as a general model for viewing data from any site.

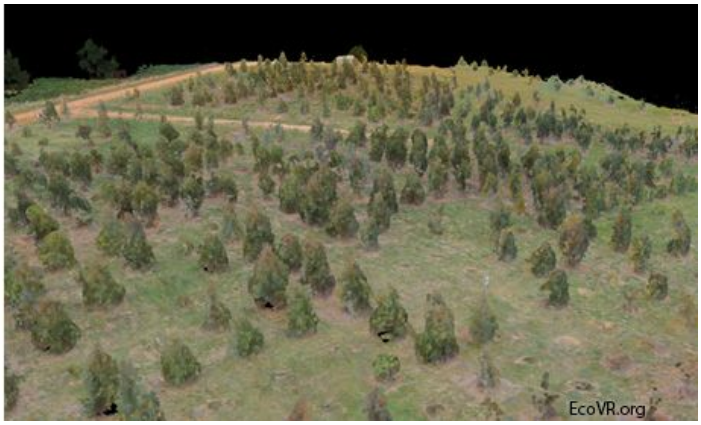
3 Implementation

References

Visualizing and analyzing complex data

Traditionally, data has been visualized and shared through graphs and figures. To the trained eye, these tools organize data in ways that (sometimes) helps trained scientists make sense of complex data streams. While these tools are well understood and useful, their shortcomings rapidly become obvious when trying to visualized spatially varied and high temporal resolution data. Historically, a data set describing a forest might have included a few tree height and growth measurements taken at bi-yearly intervals and a weather station near the site. In contrast, at the PESA site, we currently measure, sub-millimeter tree growth, temperature, humidity, sunlight, below ground soil moisture and temperature, for twenty trees at 10-minute intervals. The site will be flown monthly with a UAV providing a [3D model of the entire site] with tree height, leaf density and leaf color. As full genome sequencing costs come down, we will be sequencing every tree in the forest enabling us to couple precision environmental measurements with genomics data to look for any genetic variation that contributes to tree growth differences as the trees interact with the environment.





From forest to leaf. Traditional forestry methods often collect data at the “stand” or forest level (left image). New sampling technologies are enabling us to model whole forests in 3D using UAVs and other tools.
Likewise, it is very difficult to co-visualize huge, varied data types using conventional graphs, particularly if spatial and temporal variation between sensors plays a biologically important role in the data. Thus the challenge is to develop new ways to organize and visualize these new and exponentially more complex data types in ways that facilitate the human native brain’s ability find patterns.

Merging the old and new: Natural History meets virtual reality

Data such as tree height and area appears when users look at any tree in the site
The human brain is highly tuned to notice patterns and to organize and synthesize highly complex visual data. In previous centuries, the majority of ecological research was observational. Ecologists spent time on the land, watching and taking notes. Modern ecology added the scientific method, coupled with quantitative analysis, to augment our intuition and provide statistically rigorous tools for quantifying and verifying our intuition. New technology from microclimate mesh sensor networks to drones to NextGen LiDAR and gigapixel imaging give us tools to monitor the earth with unprecedented complexity. Virtual and Augmented Reality gives us the ability to merge these two approaches directly, building immersive replicas of ecosystems where the physical objects in the landscape carry their own datastreams that researchers can access on demand.

REFERNCES

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