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Augmented and Virtual Reality Utilization to Support Geospatial Learning: Making Connections using LandXML

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Abstract

Geospatial programs face a number of difficulties in educational instruction. These include: equipment costs; distance education; accreditation compliance; faculty limitations; and visualization of equipment and concepts.

This particular set of problems can be addressed using a range of technologies that can be grouped as augmented reality and virtual reality tools (AR/VR). While these tools will not provide complete solutions, they will allow programs to get closer to workable solutions than we have now. They can support more immersive and engaged learning in distance mode, as well as provide an improved learning experience in more face-to-face settings.

Augmented reality is starting to appear in some geospatial applications (e.g., Burczyk, 2018) and IDC expect significant growth in AR/VR in many regions of the world, especially in China (IDC, 2018).

The technology can help instructors by providing other paths for instruction using different learning modalities. If an approach to learning involves 'Doing, Talking, Reading, Writing and Visualizing,' then AR/VR provides a significant capability in the Visualizing part of the approach. The visualization can be done by the instructor or the student, as well as being part of the student expressing what they have learned.

In this paper we will outline our progress in this endeavor, as well as providing some guidance for others to undertake similar work.

Special Note

After the abstract for this paper was submitted and accepted, it was found that there were three other very similar papers on the conference agenda. To avoid repetition, we have shifted the focus of the paper to concentrate on using LandXML files as a means of providing land, property and survey data to an Augmented Reality system.

Introduction

In recent years, technology to allow Augment Reality (AR, but also known by various related names) and Virtual Reality (VR) to be implemented using smartphones and other low-cost options has become widely available. While virtual reality systems were available in the 1980s, especially at NASA research centers, they were tied to high-performance computing systems and were very expensive. Movement, orientation and location sensors for the human body were available, together with stereoscopic, wide-angle headsets. More widespread development occurred in the 1990s and early commercial systems started to appear in the 1990s and 2000s.

Virtual Reality effectively closes the user off from the real world, and allows them to interact with virtual objects in a virtual world that they experience through what they see through a stereo headset, and possible also through haptic feedback to other parts of the body, e.g., resistance to movement of the arms, legs or hands. As Fisher and Unwin (2002, p. 1) put it, "Virtual reality is the ability of the user of a constructed view of a limited digitally-encoded information domain to change their view in three dimensions causing update of the view presented to any viewer, especially the viewer." Virtual reality involves the creation of a new world with which the user interacts, and so is best suited to applications where the user doesn't need to be connected to reality, other than through how the world works. For educational applications, it could be deployed for training on a new instrument or exploring a 'world' created through GIS analysis.

Augmented Reality superimposes additional information on top of the real world. This requires the user to interact with the real world, but with additional information apparently injected into what is experienced by the user. As a consequence, the user needs to connect with the real world, and the additional information is commonly superimposed on the user's view of the real world. If the user wears a headset, then there is commonly a camera that provides a view of the real world, but a more common approach is to provide a means of superimposing information in a view of the world, such as Google Glass, heads-up displays in a range of vehicles, and superimposition of information on images seen through a smartphone's camera.

On a reality-virtuality continuum, Augmented Reality is at the 'reality' end of the mixed reality spectrum, as shown in Figure 1. van Krevelen and Poelman (2010, p. 1) stated that an Augmented Reality:

- Combines real and virtual objects in a real environment;
- Registers (aligns) real and virtual objects with each other; and
- Runs interactively, in three dimensions, and in real time.

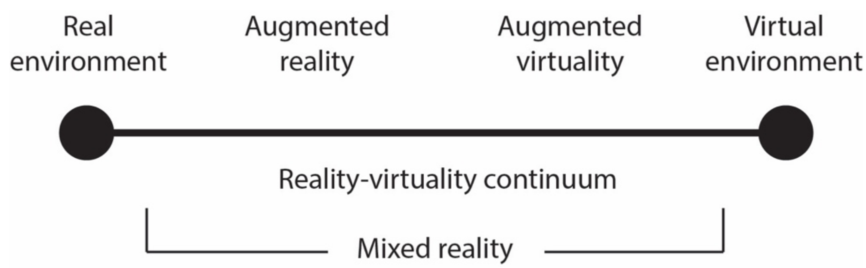

Figure 1 Reality-virtuality continuum (Milgram and Kishino, 1994).

In this paper, the focus is on Augmented Reality (AR) and how this can be connected to practical applications for geospatial professionals, using LandXML as a means of transferring spatial information. In particular, means of incorporating this type of AR system into the curriculum of a surveying/geomatics education program is considered.

About LandXML

LandXML (LandXML, 2019) is a specific application of XML (eXtensible Mark-up Language, W3C (2019)) that permits the communication of land and surveying information in a text-based format. A series of tags have been developed that permit the attachment of attribute information that is directly relevant for land-oriented applications.

As much of the location information used for land-oriented applications is 2-D and 3-D co-ordinates, strings of these can be gathered between tags that describe what type of object is being represented. This allows the key information from a plan or survey to be communicated in a way that allows its use in other applications. For example, some jurisdictions require that the descriptions of property data include the boundary of the property in LandXML. This is a very simple representation, but it allows the data to be read by many different software applications, rather than requiring something that may have to change over time, such as requiring the data to be in a format that ArcGIS can read, but isn't able to be read by other applications.

Unlike a CAD format, where different types of data are commonly separated on different levels, LandXML does not use levels. Different objects are tagged with different attributes, allowing an application to be highly selective about what is visible. Further, the attributes can be linked to different types of display in the attribute, allowing different line styles, symbols, fonts and colors to be used to a very fine level of differentiation.

LandXML has been developed by a consortium of spatial data application organizations, and is in discussions about version 2.0 of the standard (see LandXML 2.0 (2019) for a draft of the schema). The draft LandXML 2.0 schema includes over 400 specific tags, each of which has multiple attribute types. For example, an AddressPoint is a tag that identifies a point that allows a street address to be assigned to a location. AddressPoint allows 20 different attributes to associated with the location, in addition to the location's co-ordinates.

Special readers that can parse and display LandXML are required, but several common surveying software packages can handle LandXML import and export, including AutoCAD, Carlson Software and MicroStation. A free viewer allows LandXML data to be overlaid on pointcloud and other data.

As LandXML provides a rich and extensible method for collecting a large amount of attribute data, it offers the possibility of replacing feature codes, especially as data collectors move to tablet devices with the ability to input text quickly and easily. Voice recognition capabilities will help drive this trend. The ability to use LandXML as a means of mediating the movement of spatial information from data collection to final presentation and transfer suggests that it will become a useful tool in coming years.

Integrating Augmented Reality

While VR allows a user to move into a completely isolated world, AR necessarily connects the user to the real world, but in far more complex way than our regular sensory experience of the world around us. One of the organizations moving forward with AR integration is Adobe. Adobe is paying progressively greater attention to the user interface design and its integration with user experience. In the interests of providing a suite of tools for the purpose, Adobe recently (2018) started marketing a software suite called the Adobe Experience Cloud, which is touted as 'one integrated approach for customer experience management (CXM).' This integrates software tools for analytics, audience profiles, content management, campaign execution, advertising, personalization, commerce and customer engagement, and is for building complex tools to support a business' connection with clients and other businesses (Adobe, 2019).

This has come a long way from early efforts in user interface design. Using a range of studies on human interactions with machines, the earliest implementation of a computer designed with a graphical user interface from its inception was the Xerox Alto, which was introduced in March, 1973 (Xerox, 1975). The Alto was superseded by approaches like the Xerox 'Star' user interface (Smith *et al*., 1982), Apple's Lisa and Macintosh interfaces, and almost everyone's after that.

The resulting desktop metaphor laid out the objects within the computer with which the user could interact. This was a spatial metaphor, and the user could interact with this space using a suitable pointing device, commonly a mouse. As spatial information systems were developed that allowed the user to interact with the spatial information using a graphical interface, it was necessary to move beyond the desktop metaphor. Early GIS interfaces sometimes left much to be desired: Duane Marble once described the early ARC/INFO graphical user interface as 'user surly.' However, as Medyckyj-Scott and Blades (1992) pointed out, user interfaces that fail to account for a user's understanding of space fail to allow users to gain full access to important parts of spatial information systems. Consequently, user interfaces that increase a user's understanding of space and the real world will enhances the user's ability to work with spatial information systems.

More recent GIS interfaces do not use a desktop metaphor *per se*, but tend to work more with a series of maps that can be overlaid for various operations. However, the user still interacts with a map, which is itself an abstraction of the real world. If our representations of the real world for the purposes of analysis and modeling have moved well beyond the paper map, it is time for our interactions with spatial information to follow suit, and move beyond the static, 2-D map. We currently interact with spatial information in a GIS using vision, limited kinesthetics (through a mouse, which provides no feedback), and very limited audio (see Maddulapalli (2003) for discussion of some efforts to extend the audio aspects into digital mapping and GIS). This is not a sensory-rich connection. Recognizing that a human can only gain experience of and information about the world around them through their senses, the user's understanding of space must itself be understood through their sensory interactions with space.

As we are in the early stages of people learning how to interact with space through the sensory medium of AR, as compared to people interacting with space through the sensory medium of a paper map, it is important to aim for a consistent user experience. This has been important in the development of maps and their acceptance as a communications medium over the millennia. To support their efforts in user interfaces and integrating AR into these interfaces, Adobe has developed five sensory design principles to assist creation of engaging and understandable spatial computer-driven experiences. These are:

- Intuitive experiences are multisensory;
- 3D will be normal and core technology;
- Designs become physical by nature;
- Design for the uncontrollable; and
- Unlock the power of spatial collaboration (Miesnieks, 2019).

How can we move the GIS user interface beyond the 2-D paper map, occasionally augmented with a 2-D image of a 3-D model? AR provides the opportunity to interact with the real world directly, at a 1:1 scale, without forgoing the additional information that a GIS carries. Of course, to interact with the real world on a wide range of scales, a VR solution is the better option, but humans tend to interact with the world a great deal at a 1:1 scale, i.e., a human scale, and they tend to interact with the world in a full sensory fashion.

The next question is: How do we move useful GIS information into devices that can be taken into the field and allow the user to interact with the real world? We can implement ArcGIS, for example, on smartphones and tablets, but this is just a fancy version of a paper map that we can carry around. Being able to superimpose GIS information on our view of the real world, in some fashion, is the goal here.

Why LandXML?

When we store data in a CAD package, we have a division between the graphical component and the attribute component, rather like in a vector-based GIS. In addition, the graphical component also carries information, embedded in line styles, weights and colors, symbols attached to points, and the layer on which the graphical element is placed. The attribute component may be carried in an internal data storage system (such as a bill of materials) or in an external file or database.

How do we transfer this information, which may be in a software or user specific format, into a more generic format to pass to an AR package in a mobile device? We could pass it into a format that the AR package requires, which varies with different packages and platforms, or we could use an intermediate format that allowed greater flexibility within the AR package. Using a suitable intermediate format would also allow multiple inputs to an AR package. Finally, a suitable intermediate format would allow the incoming information to be manipulated by the AR package, in particular searched and sorted by attribute. This necessitates a format that can include attributes. A simpler format is, of course, better.

LandXML can meet these requirements. In addition, it is text (ASCII) based and an extension of XML, so it is human-readable and therefore human-editable. But the biggest advantage of LandXML is that it is a single file with the attribute information embedded within it, directly attached to the specific spatial object of interest. This provides two major advantages over many other possible data models. First, a single file is all that is needed. There is no need to deal with several files holding line work, attributes, links and the like. Everything is in one place and LandXML is designed for being easy to display. Second, because of the depth of attributes that can be attached to any particular spatial object, the format allows searching, fine-tuning of selections, and the ability to switch on and off spatial objects with fine-grained precision within the AR package. This sets LandXML apart as an Open Standard format and a format that is highly flexible.

Users can extend LandXML for their own needs, provided that the software for reading the LandXML file can parse the objects and attributes. But AR software can also be configured to be extensible.

There has been some early work using KML (Keyhole Mark-up Language) files, which are used for spatial passing information to applications like Google Earth. KML has aspects of XML, but it is not a superset of XML and lacks built-in attributes pertinent to land-oriented information (Google Developers, 2019). Shojaei *et al*., (2012) used a conversion system to take 3-D LandXML files and convert them to KML files for display in Google Earth. This was a testing process, rather than a production system. More recently, survey-oriented systems have grown to allow inclusion of far more attribute information, and users expect far greater flexibility. KML allows user-created extensions to carry user-defined data, but this works against collaboration and cross-platform compatibility. At this time, LandXML has far greater development potential than KML, which is far more oriented towards graphical display, rather than for carrying attribute information to processing, analysis and display, especially in AR applications.

Applications

Cole (2015) reported on work undertaken at NASA to develop an AR interface for supporting maintenance, training and operations of high value critical equipment, in this case a compressor station, where each compressor contains up to 10,000 individual parts. AR was designed to streamline how operators managed compressor operations, in particular dealing with needing to undertake over 2,000 readings on multiple flows within each compressor set during an 8-hour shift, coupled with transient changes in the readings over short time periods. This approach to supporting operators in a range of situations was also discussed by Schall (2011) and van Krevelen and Poelman (2010).

Augmented Reality can be used for artistic expression, enterprise training (including soft skills training), enhancement of the sports fan experience, and a range of other interesting possibilities (Pangilinan *et al*., 2019). AR can be used as a navigation aid, both through a heads-up display in a vehicle, and by superimposing information on an image on a tablet or smartphone being used in real time by a pedestrian user. Pokemon Go was one example of AR in the latter situation. Google Translate can now operate in an

AR mode, reading a language through the phone's camera and swapping out the original text for the translated text on the phone's image of the sign.

Augmented Reality can allow particular attributes of a situation to be viewed on top of the real world. Abbott (2013) examined a temporal cartography of travel, while Cartwright (2013) considered visualization of historical artefacts and information on the current representation of historical sites. Nowostawski and Münster (2013) examined the ability to leave AR virtual sticky notes. Aurambout et al., (2013) examined the use of various forms of data visualization to support communication about climate change at local and regional scales.

From the geospatial viewpoint, one of the most interesting applications is being able to project a range of cadastrally-oriented information onto images of the real world, in the field in real time. Whether this is boundary information, information pertaining to easements and other rights over land, stratum title locations in 3D, or a range of other information presented spatially in AR, there has been significant work in this area. Shojaei (2014) focused in understanding user requirements for 3D cadastral visualization in his doctoral thesis, while van Oosterom (2018) examined best practices for 3D cadastres. This latter document, a report from a FIG Commissions 3 and 7 joint working group, spent a significant amount of time on legal considerations, registration of 3-D parcel, 3-D parcel modeling information and suitable databases, but devoted an entire chapter to cadastral visualization and new opportunities.

Cadastral applications of AR have particular interest for field surveyors, and by extension students learning about cadastral surveying. Because a large amount of varied spatial information can be carried within a LandXML file, there is no need to restrict the content to the boundaries of the parcel of interest. Everything that was recorded in the field notes of previous surveyors can be included, as it can be properly tagged in the LandXML file, and selected for display or not in the AR application. Suppose a set of field notes was converted to LandXML, along with the final plat of the survey. The location of survey marks that are not part of the boundary itself can be shown or hidden, fencing can be shown, together with its description, and a range of witness objects can be shown. As a critical part of AR is getting the AR data connected to corresponding objects in the real world, the more survey data that can be included in the visualization, and so used to shift the AR data into better alignment with reality, the better for the entire visualization. This would allow a high-quality GNSS location, e.g., using a centimeter-level receiver linked to the data collection and AR tablet, such as the Eos Arrow 200 RTK GNSS receiver (Eos, 2016). Such a system would allow rapid location of cadastral monumentation, while supporting the use of significant historical information about monuments, occupation lines, witness marks and prior surveys. Adjoiner information could be provided, allowing a more comprehensive cadastral survey in the field, together with a more rapid process of determination of adopted boundaries.

To this end, Harding and Foreman (2017) looked at converting 3D stratum information into LandXML, while Shojaei *et al.*, (2012) examined the development of a national 3-D ePlan/LandXML visualization system in Australia. There is clearly movement in this direction internationally, and it seems sensible to adapt existing methodologies and technologies to specific local needs.

Educational Aspects

A key aspect of the research the authors are undertaking in this field is how it ties in to geospatial teaching and learning at the university level. While AR can assist with the application of geospatial information to a wide range of real-world problems and work, how can we utilize it to assist with teaching and learning?

Teaching students quantities of facts and theory is of little use if they cannot connect that information to actually doing things in the real world. Without that connection, students will not have any understanding of the subject matter, even if they have memorized quantities of disparate facts and theory, and so they don't really know anything about the subject (e.g., Feynman, 1985, pp. 202-219).

Augmented Reality offers the opportunity to build that connection in new ways. A critical part of learning is being able to visualize what is read and discussed. Spatial reasoning concerns how we bring our reasoning faculties to bear on spatial problems, and it is a critical component of what geospatial professionals need to master in order to succeed in their profession (Hazelton and Wu, 2019b). AR allows course material to be presented in a manner that combines visual and intellectual components in ways that can have a multiplier effect on understanding. Further, suitable AR systems allow students to produce their own visualizations that can be carried into the real world, allowing a closer connection between classroom and practical work.

As we consider courses for moving on-line, we need to consider the different parts of each course and how knowledge is transmitted, generated and learned through the course. We can break a course down into multiple components and consider the role of AR in supporting student activities and learning in each component. One approach to analysis of courses is presented in Hazelton and Wu (2019a), and this allows a more structured approach to integrating AR into a range of courses.

There have been a range of tools developed that support students in working with spatial information in a way that includes AR or similar technologies. For example, O'Brien and Field (2013) examined a geo-collaborative web map that could support student fieldwork in geography in general. We have a range of collaborative tools of varying degrees of utility and effectiveness in supporting student collaboration in on-line courses, but apart from CAD and GIS software, it was difficult to find effective tools that support visualization in way that strongly support learning. Augmented Reality has a great deal of promise in this direction. The fifth sensory principle listed above—unlock the power of spatial collaboration—is critical to support learning in environments that include more on-line activity.

There are many games with AR that have foundational software for collaborative gaming, and it is a short step to collaborative learning and collaborative problem solving. So a significant amount of the basic work has already been done (Pangilinan *et al.*, 2019).

Within the domain of educating future licensed surveyors, an understanding of the utility of LandXML, as well as the underlying XML, will be an important skill in the near future. Building opportunities to work with LandXML, understanding its capabilities and limitations, and being able to use it as a medium for land information interchange will be an important component of this domain.

Discussion

Using LandXML as a means of passing spatial information to AR systems has considerable promise, as well as a significant amount of support from other researchers in this field. LandXML has far more flexibility for transmitting specific spatial data and information than many GIS and other mixed graphics/attribute systems. It is also a far more flexible and extensible format than KML.

While LandXML files can grow very large, it is important to note that AR applications need a limited spatial extent of data. If you are using a phone, for example, you are limited to the range of the camera, where there is sufficient resolution to make AR a sensible option. AR tends to be limited to shorter ranges, with concentrated information within that limited spatial extent. While LandXML files do not currently support tiling, the repositories of geospatial information that will be used to pass spatial information to AR application often do support tiling. It is reasonable to assume that a large proportion of AR-based tasks will involve limited areas, and that if spatial information is being passed to the mobile device by wireless connection, the data can be tiled for greater efficiency of storage and operation.

XML files were originally developed to allow meaning and other contextual data to be included with more general information. Because XML was extended to support the meaning and intelligence associated with surveying data, and geospatial data more generally, in addition to supporting more regular attribute information, LandXML-based data can be searched and queried on the basis of any type of information within the LandXML file. This provides significant flexibility with field operations, as the field operator is not dependent on a purely graphical set of data. This has the potential to allow far more information to be surveying information to be taken into the field in a searchable electronic format. For example, it is fairly straightforward in many jurisdictions to download electronic records of property boundary information, but survey information, such as abstracts of field notes, tend to remain in purely graphical form, and are often not available electronically. By providing a rationale for having abstracts of field notes in the LandXML format, there is a better chance that this approach will be used to allow submission of electronic abstracts of field notes.

Significant amounts of field surveying are now falling into two distinct camps, in terms of the way that data is collected, and subsequently processed. One camp is taking advantage of the massive productivity improvements of the last couple of decades and generating very large quantities of 3-D points (pointclouds) very efficiently, using terrestrial laser scanners (LiDAR), airborne LiDAR, imagery and photogrammetric solution. The other camp is focusing on the collection of 3-D points with meaning and intelligence directly connected to the points. This usually necessitates visiting each point, in effect undertaking 1:1 digitizing on the surface of the Earth. By bringing as much known data to bear at each point while it is in the process of measurements, there is the potential for significant efficiencies, together with the potential to collect far more meaningful information as part of the data collection process.

Conclusions

Augmented Reality presents many opportunities to enhance student learning in geospatial education programs. This is not only through the dissemination of support information, but by providing visualization of information and processes in the real world. Further, students have the ability to generate their own AR worlds as part of developing and demonstrating their understanding of principles and ideas.

Augmented Reality has the potential to bring significant amounts of cadastral information into the field in ways that allow the information to be quickly and easily connected to objects that are found there. If LandXML is used as the transmission file type for the information used by the AR processor, there is the potential to transmit large quantities of attribute data that can make the AR experience far richer and more flexible. With quantities of attribute information in the field, it is possible to undertake more complex analysis of the information, especially if it is combined with data collected in the field. That ability to make cadastral re-establishment much easier in the field can change significant aspects of how we undertake boundary surveys.

We are at the early stages of AR technology, which promises changes in how we think about and work with geospatial information. This is especially the case in surveys where we visit every point and collect more complex attribute data, along with meaning and intelligence for each point. AR will give the potential for a far more reasoned and structured approach to field data collection, which will tie in with the desire for more comprehensive geospatial databases.

Another Special Note

Ms. Yitong Wu, the lead author of this paper, was awarded a Troy University Chancellor's Fellowship in April, 2019, to undertake research in AR and VR to support geospatial learning. This paper is an early report on some of this research.

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