Setting up virtual reality and augmented reality learning environment in Unity

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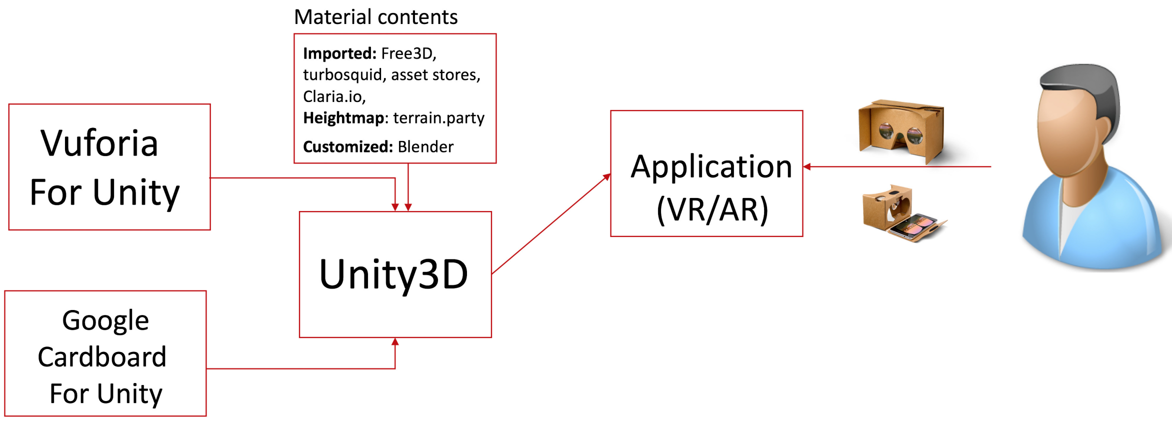

Figure 1: The framework to build the watershed game using augmented reality and virtual reality techniques

Abstract

We propose framework and a setup for presenting complex models for curriculum contents in both augmented reality and virtual reality environment. After constructing a number of three-dimensional models representing real world objects such as trees, stones, rivers, dams, and buildings, our workflow uses the Unity engine in combination with Virtual Reality headset devices to create interactive applications for both Virtual Reality and Augmented Reality environments to support students understanding the curriculum contents through their surrounding. Typical challenges are addressed when creating 3D curriculum contents, integrating these models into Unity and solutions are proposed where possible. The overall structure of the project is described with some functionalities added to Unity for visualisation and interaction with the models.

Keywords: Mixed reality, computational thinking, curriculum contents, Unity engine, watershed.

1 Introduction

It is widely recognized that instilling and inculcating computational thinking skills (CTS) such as problem formulation, effective representation of big data, and identifying, analyzing and implementing possible solutions [22, 25] are essential for student success in STEM disciplines [2, 8], especially for under-represented students to become interested in STEM careers [13]. Evaluation and understanding of highly complex systems with extensive inter-connections and feedbacks has become an integral focus of many STEM fields as the world we live in is increasingly becoming dynamic, self-organizing and continually adaptive [1, 17]. A strong grounding in CTS is a critical requirement to study these complex adaptive systems. There is also growing recognition that technology-human behavior and environmental impacts are tightly inter-related and leveraging computational thinking to understand complex human-environmental interactions is vital to foster systemic sustainable solutions [7].

Watersheds, for example, are landscapes that define the drainage or catchment area for rainfall events and are the most readily accessible complex systems as every student lives in one. Most students pass by many watershed features such as creeks, dams, culverts, detention basins and wetlands without fully grasping how these natural and engineered systems alter water quality and availability within their watershed. The concepts of hydrologic cycle and ecosystem services such as aquatic habitats for recreation and sustenance, cleaning up of pollutants discharged into rivers by cities, industries and agricultural non-point source pollution are often discussed in high-school environmental science curricula. However, these concepts are rarely given a real-world context despite the availability of large living laboratories (aka watersheds) in which we live. More importantly, mathematical skills such as algebra, trigonometry and pre-calculus can be used to develop mathematical models to simulate the flow of water and the fate of pollutants such as biochemical oxygen demand (BOD a surrogate indicator of organic wastes), nutrients (nitrogen, phosphorus) and dissolved oxygen (DO an indicator of aquatic health). The watershed can be envisioned as a readily-accessible, yet complex system to help instill higher level CTS among high school students

Current science standards advocate for K-12 teachers to use disciplinary-specific ideas to explore scientific phenomena and develop problem solving skills [4]. Game-based interventions have been recently lauded as a viable vehicle to not only engage students in STEM content but also develop CTS [3, 9, 19] along with traditional teaching and learning methods. Recently, with the advancement of modern technologies, virtual reality and augmented reality have emerged as a vehicle to help students achieve specific knowledge. While virtual reality creates a programmed environment that simulates reality, augmented reality on the other hand integrates digital information into the real environment in which people are

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living in. Many of the available applications toward virtual reality learning based have centered on the hard sciences such as anatomy, biology, and astronomy [18] with a set of pre-defined objects and programmed processes. Although this approach greatly engages students in understanding the object and its phenomenon, students are mostly limited in the modelled environment without exploring in the real world. Further more, the idea of having students create and design their own experiences is becoming more feasible as new technologies pave the way for virtual reality going its journey into the K-12 education sector.

Therefore, there is a need to develop an educational support system using both virtual reality and augmented reality techniques to 1) Demonstrate how CTS and problem solving skills learned in high school can be used in practical engineering and environmental management applications using a sustainable watershed development game based on the watershed they live in; 2) Help students connect theoretical concepts with real world water systems and related infrastructure within their watershed using augmented reality (AR) techniques to identify and learn how natural systems interact and how engineers use infrastructure to manage flooding and pollution and develop sustainable ecosystems; 3) Explore Moursunds [12] adapted model by taking a real-world large-scale data set like a local watershed (physical capability) in conjunction with an augmented reality application (mental capability) using problem based learning (peer collaboration or group learning), to evaluate CTS growth and understanding of the interdependencies and adaptations of the systems within ones watershed.

In response, this paper aims to take the initial step toward building computational thinking game application for students with the following contributions:

- We propose a practical comprehensive structural framework for building an application using virtual reality and augmented reality techniques;
- We demonstrate how each component of the framework can be integrated together in Unity game engine;
- We address some typical technical challenges when integrating components and provide solutions where possible.

The idea of this game can be divided into categories in the same application: Augmented reality game where students go out in the real environment and use mobile phone camera pointing to a real object (tree, for example). A 3D model of this tree will pop up, students click on this model to add into their inventory. The collected 3D models will later on be used in Virtual Reality application where students are assigned a random land. Students will use collected assets in the inventory to build the city.

The rest of this paper is organized as follows: We first summarize existing techniques on virtual reality and augmented reality in education in Section 2. Section 3 provides an overview of the comprehensive structural framework toward building the application. We evaluate the effectiveness of our application in Section 4. We discuss some of the technical challenges and possible solutions in Section 5 Finally,we conclude our paper with future plans in Section 6.

2 Related work

Serafin *et al.* [20] provide a number of approaches in integrating virtual reality (VR) and augmented reality(AR) in musical education from an academic and a commercial perspective. The study showed that the quality of learning and the retention rate of students in classroom have improved significantly. Several potential applications taking into account of are suggested to help students gain better performance and feel more confident in public spaces. However, this paper only points out some available approaches and promising research directions without any further guiding on how to build a real application.

Miyata *et al.* [11], on the other hand, create an educational learning environment for developing VR applications. Team work and collaboration are emphasized through competition for creating different VR applications. Similar to this approach, Dinis et al. [6], provide a more a practical approach for engaging students in the learning process. During a 6-week introductory class project, first year students of the Master in Civil Engineering will create virtual environments in which the models are created in CAD drawings and imported into Unity3D. The output results then will be viewed in Oculus Rift headset device. Augmented reality is also implemented for mobile device to recognize the image of an object. This is very interesting approach since it helps students engage in the whole process, from creating a model, incorporating the model into Unity3D and exporting results to VR/AR headset devices. However, this useful report does not outline the overall framework of how to build the application from technical perspective. No-Savvy technology readers in the same field find it difficult to reconstruct the learning process.

Chen *et al.* [5] provide an AR-based system to increase the spatial awareness and interest of learning for Engineering Graphics Education. 3D virtual objects are overlaid on 2D drawing to help students quickly access to 3D solid structure and spatial detail information. This application greatly reduces time spent by the instructors and students in the classroom. Messner *et al.* [10] provide an expensive approach by using the CAVE-like projection system for undergraduate Architectural Engineering students to create VR interfaces. The application has a great influence on the student performance since students are able to develop a plan of the construction of a nuclear power plant within a short time (1 hour) with very little experience concerning buildings and infrastructures.

Regarding to the geosciences education, Jiayan Zhao *et al.* [26] create an immerse environment platform for students by using LiDAR (Light Detection And Ranging) technology and images to reconstruct the Iceland's Thrihnukar volcano. Data imported from OpenTopography.org portal then transcribed into Unity3D. The simulation result is rendered and view in HTC Vive headset device. The 3D model of the volcano is created in the Agisoft PhotoScan Pro, a rapid 3D modeling software that intuitively stitches together photos to form 3D geometry. This study described very detailed necessary steps to get data, construct models and put them into virtual reality environment. In addition, this work leverages existing advanced technology to enhance student learning process without going to dangerous places such as inside the active volcano.

A very similar approach to our study is the work proposed by Parmar *et al.* [14]. Based on the similarities of dance with programming, Parmar creates a Virtual Environment Interactions (VEnvI) application that allows students to learn complicated concepts of programming such as sequences, loops, conditionals, variables, functions and even parallelization. The study results showed that students are motivated by learning activities and remembered what they saw in the VR context rather than laboratory based demonstrations.

Obtaining free 3D models and then customize them to use in VR/AR is also investigated by Voinea *et al.* [23]. The aim of this study is to animate the avatar of the musculoskeletal system. 3D model is obtained from medical datasets with the help of the supporting tool (Simpleware Scan IP), then skeletons are added to the model to simulate animation.

There are still more available VR/AR applications in the literature targeting educational purposes; however, most of these approaches focus on programmed scripts or a set of static data. Understanding material contents through real life surrounding environment and playing with contents are the main concerns that should be taking into account. In addition, a comprehensive framework for guiding learners and educators to set up similar environment is highlighted in this paper.

3 Design

In this section, we propose a practical comprehensive structural framework for building an application using virtual reality and augmented reality techniques and describe how each component in the framework is incorporated into Unity3D. As depicted in Fig. 2, our framework includes five main components namely: Material contents, Vuforia package for Unity3D, Google Cardboard package for Unity3D, Unity3D game engine and Application (VR/AR).

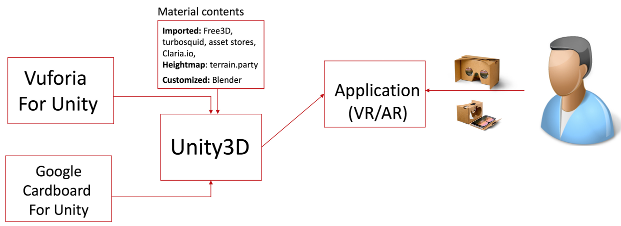


Figure 2: A comprehensive framework to build VR/AR application.

3.1 Material contents

In our application, material contents are the most important factors to engage and motivate students in the learning process. Creating contents for a classroom is very time consuming so we come up with an idea of getting free available contents without the need to reinvent the wheel. For example, rivers, trees, animal are those models we import from the internet. In general, our materials come from two main sources: free 3D models and manually created models. There are plenty of free 3D models available such as free3D.com, tuborsquid.com, clario.io, cgtrader.com, archive3d.net or assets store in Unity. We choose four main sources as indicated in Fig. 2 because they provide most of the assets related to our project. Fig. 3 illustrates some 3D models that we will integrate into our application (trees, house, river, dam, cow)

Figure 3: Example of some free3D models that will be used in the application.

A virtual environment is another important factor needed to take into account. Instead of building the surrounding environment manually, we reconstruct the virtual environment close to where the student lives in by using height map. A heightmap is a raster image used to store values, such as surface elevation data. Black color represents the lowest point and white color represents the highest point. A survey conducted by Smelik [21] showed that heightmap is often used as the basis of a terrain model. Natural, mountainous-like structures are gained by adding and rescaling several levels of Perlin noise [15] to each point in the heightmap. Input data for heightmap is generated from the terrain.party portal website as depicted in Fig. 4. We find this website quite useful because it allows users to generate a heightmap for a given area anywhere in the world. The square box overlaid on top of the screen lets the user select the desired area; this box can be expanded or contracted based on user's preference. The main drawback of this portal is the size of the selection box since it is limited to only 60 km. For our application, the average number of students in the classroom is around 25 students; each student will be assigned a land randomly of 500m. So 60km in our case study is far more enough and reasonable. Note that in every dimension, the size of the heightmaps should be 1 pixel larger than the resolution of the terrain texture, that is the power of two plus one. Because each pixel from the texture must be mapped to a polygon which consists of two triangles, not a pixel, in the terrain mesh.

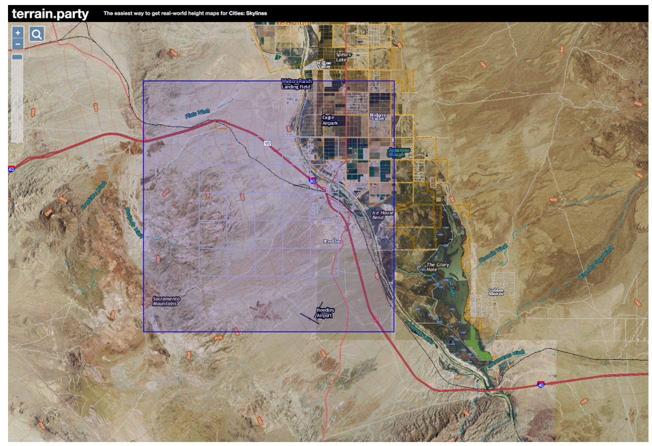
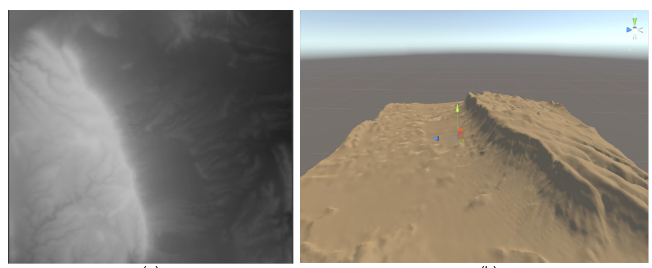


Figure 4: Heightmap generator from terrain.party

Fig. 4 (b) shows the actual terrain generated from heightmap Fig. 4(a).



(a) (b)

Figure 5: Terrain generated from heightmap in Unity

As mentioned earlier, the majority of the assets in our application are imported from the internet. However, some of the assets need more work such as animation, rigging, texture or modification to suite our need. In addition, unavailable models for our application also need to be created such as typical kind of trees or birds. Among much other 3D software, we choose Blender for this purpose because it is free, powerful, rich of community involvement and compatible for many platforms. Cow, for example, is a free static 3D model. We import this model into Blender and add some skeletons for rigging and animation that allows it to move around the certain area.

3.2 Vuforia package for Unity3D

For the creation of Augmented Reality applications in mobile devices, we use Vuforia [24] Software Development Kit package for Unity3D. It is a free development kit and supports multiple platform such as Android, iOS, or Unity. To make it works, users have to register and download licence key from Vuforia website. The process is shown in Fig. 6

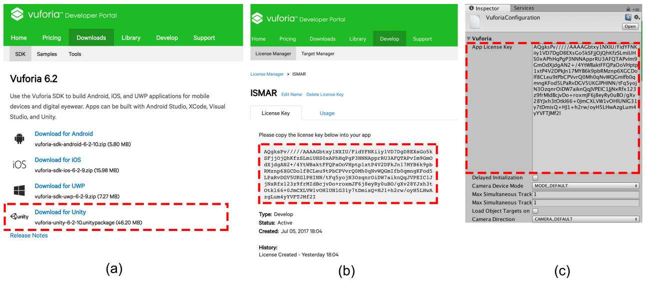


Figure 6: Download Vuforia and get the license key. a) Select package for Unity. b) Get the license key from Vuforia website and c) Apply the license key to Unity

The most used functionality of this package is its ability to recognize and track planar images in real time. Each object in the real world will be labeled with an image, and the application can recognize this image then position the corresponding 3D model about real world object. Fig. 7 illustrates the use of augmented reality to collect real world objects. Students will go outside of their classroom to the watershed and collect the objects they like (trees, dams, rivers...). The collected objects will be put in their inventory in the virtual reality game.

Figure 7: Birch tree 3D model

3.3 Google Cardboard Package

While Vuforia package helps to create Augmented Reality application through using a mobile camera, Google Cardboard package, on the other hand, provides some pre-programmed features such as user head tracking, side-by-side stereo rendering, detecting user interaction with the system which we will use to build our application. Side-by-side stereo rendering splits mobile phone screen into two parts. Users will look into this virtual environment using Google Cardboard.

Downloading and importing Google VR SDK for Unity is straightforward. Users go to the Google Developer page and download the appropriate SDK Kit for their Environment (Android or iOS). After the package is downloaded, users will import into Unity in the Assets folder as shown in Fig. 9. Our application runs on iOS device, so additional software package (XCode) is installed to port the application on iPhone.

Figure 8: Example of using tree in the inventory to plant and build the city

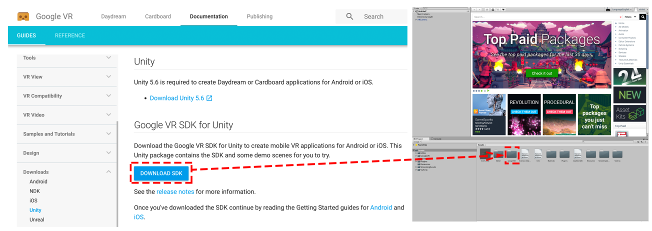


Figure 9: The process of downloading Google VR SDK and importing to Assets in Unity

3.4 Unity3D

Of the many available software for 3D game development, Unity3D is chosen in our project due to its free pricing for development, porting a game to multi-platform, rich of the community, plenty of models and objects in the assets store, supporting two of the most popular programming languages (JavaScript, C#). A study conducted by Peters [16] also shows that Unity 3D is the most cost-effective, flexible and sustainable solution to develop VR/AR application. As depicted in the framework in Fig. 2, Unity3D is the core component to connect all other components and port application for users.

3.5 Application

Unlike other 3D game applications in which users collect objects that are already available in the game. Users are not required to go outside for assets. Our VR/AR game comes up with a new idea by combining both VR and AR techniques. To reconstruct the virtual world, users need some assets. These assets can be bought from other players or can be collected from a real world. Users use a camera on their mobile phone pointing to a real object. A three model corresponding to this object will appear, and then users can get this object and put it into their inventory. When students come back to Virtual Reality game, they can use the assets in their inventory to construct their environment. To switch between VR and AR mode, users rotate their phones to the right to go back to main screen and then select the desired mode. Interactions between users and objects in the game are performed using a gaze system, which includes a small circle (reticle) on the screen moving along with user's head (small white circle in Fig. 10). Movement in the game is performed through a button on the Google cardboard, users point the reticle to the desired location and keep pressing that button. The central idea behind the watershed development game is to introduce the students to systems thinking and help them visualize how human activities and natural events (climate) are intrinsically coupled and how actions of one in the watershed have implications on others downstream

To use our watershed based games, users only need to have a Google cardboard (which only costs a few dollars) and a smartphone with an integrated web browser (no additional software is required). Currently, there are many available VR devices on the market, such as Oculus Rift, Gear VR, HTC Vive, View-Master, Google Cardboard to name a few. Out of these devices, Google Cardboard is chosen due to its low-cost VR headset and simple design, making it feasible to implement in most mainstream U.S. classrooms. Fig. 10 illustrates of main menu in the game, when user taps "Explore world" on the screen, the application will switch to AR mode, where as "Enter your game" will go to VR game.

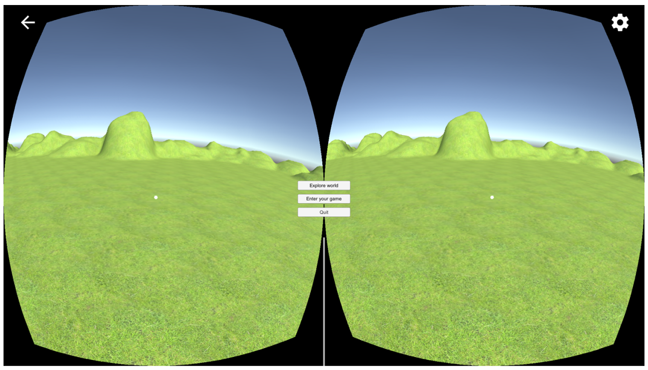


Figure 10: Main menu of the VR/AR game that allows to switch between VR/AR mode

The watershed based games will contain a set of units with tasks which engage students in learning and understanding water features. The immerse and interactive experiences make students feel more attached to the environment as being the center of all consequences of their observations and actions.

4 Evaluation

In order to evaluate the effectiveness of our application, we conduct a use case with two students (one Master student and one PhD student in our lab) who are not involved in any process of the development. The aim of this study is to help students understand their surrounding environment. The experiment is conducted in the campus where there are several kinds of trees, and bushes. The expected outcomes of this study is the ability to find, recognize, name and collect a number of objects in real life.

We setup the environment by labelling some typical trees where they are easily be spotted. Each student will be given an iPhone with installed app and a Google Cardboard headset. Students are required to go around the campus and pick any real life objects they like by using the application in Augmented Reality mode. After collecting their desired assets, they are asked to position these objects in Virtual reality game.

The study shows that the students are highly motivated when using the application because it helps them recognize and naming some kinds of trees that students saw before but do not know trees' names or vice versa. Being immersed in the virtual environment, students find it interesting to build the territory in the way they want.

However, there are some technical problems of the application that need to be improved. First is the ability to recognize the labeled objects. Since our application use printed paper to label objects, students have to go very close to the objects and point mobile phone camera toward the images at certain angle. This problem can be solved by scanning target image as an object for recognition. Although this process is time consuming when designing material contents, we find it feasible and useful for a large class. We argue that, when the size of the game is big, users do not want to spend too much time to grab a single object.

The second problem that students encounter is loading 3D objects in the VR game. When the number of objects increase, the loading process is slow and moving in the scene is lagging. We find that all the objects in our model are rendered upon the application starts, so that is the reason why it is slow. The solution to overcome this problem is to "simplifying" the scene, meaning that the application only renders objects that are close to player or visible to camera. Distant objects will not be rendered.

5 Challenges and Discussion

The first challenge in our project is to incorporate 3D models from different websites into Unity3D. Some of the models are not fully supported by Unity3D, for example the Wavefront format. This 3D model format includes two files with extension: .obj and .mtl where the obj holds information of the object such as the position of each vertex, the UV position, vertex normals, and the faces that make each polygon, and texture vertices. The MTL File Format describes surface shading (material) properties of objects. In other words, it holds texture information of an object. Unfortunately, this extension is outdated and not supported by later technology such as Unity. One possible approach is to use another 3D software that can read these files then exports these files into another format. We use Blender to import these files then export to Unity3D readable format such as .blend or .fbx.

The second challenge is to use mobile phone camera to recognize object in the nature. While Vuforia package allows developers to pre-define Image Targets by scanning the object, it has too many limitations that we cannot use in real situation. First, it requires to print out the Object Scanning target that is a small image. Second, the object being scanned should be aligned with the position of the printed image. This will result in the capability of scanning only small objects. In addition, objects should be scanned under some lighting conditions, so scanning big objects for recognition is not feasible. Our solution to overcome this problem is to label an object with a name tag. Because our focus is going out to collect the object, not the object recognition. We found this solution is utmost simple and easy to deploy.

The third challenge is the VR contents, it is the most time consuming part of the application. The more they look realistic in the environment, the longer it takes to produce them. In order to alleviate this problem, importing available models with texture from the internet is the first solution. The second solution is to get similar poly mesh of the object we want to reconstruct and modify it in 3D software. And the third solution is try to create low poly mesh as much as we can to the acceptable level and use high resolution texture.

6 Conclusion

In this paper, we have presented a comprehensive framework for building an application using virtual reality and augmented reality techniques. How each component of the framework can be integrated together in Unity3D. This framework will work as a guideline to help students and instructors in the other fields to build and construct their own material and application. Several challenges in each step in the work flow is discussed and we suggest some possible solutions. And an environment for the application is setup so that students can first understand their surroundings.

This is the on-going project toward enhancing computational thinking for students. In future work, we will apply mathematical model into the game, for example excessive building many factories can cause pollutants into streams and creeks that will affect other players. A set of compliance points (CP) are set up on the stream segment to monitor water quality in the stream. When critical thresholds are reached at CPs, the player causing the pollution will be asked to pay a penalty. In some instances, several players with land holdings upstream will be asked to pay a penalty directly proportional their pollutant loadings and inversely proportional to the distance from their parcel to the point of concern on the river. These penalties are apportioned among downstream players based on their distance from the polluted point.

Further investigation on the balance between complexity and fidelity of 3D model contents should be carefully considered because complex models can give correct material information. On the other hand, they could overload the application.

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