Extending User Coverage on Virtual Campus Using Web3D Technology: A Case Study

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Abstract. Web3D site which uses standard format has begun to elicit difficulties for some users, coupled with browser compatibility that is increasingly narrowing. This also happened on the sites which represented an institution in the form of a virtual college campus. For the campus Web3D to keep providing its services and facilitate access to more prospective users in the future, an update is needed that requires major changes. This can be done by the use of different technology approach which has wider features and possibilities of use. In this research, an experiment was first carried out to see the prospect of using it on the campus Web3D site. Furthermore, the prototype world using newer format was developed and then tested in a variety of browsers that are currently widely used. The resulting world was able to be displayed on more browsers and platforms, and it kept the same complexity which leads to similar appearance and functionality as the previous one. Performance decrease did occur, so further optimization was needed.

1. Introduction

The Web3D site requires a certain format in order to be realized. Generally, a format that is accepted by users on the Internet will always be updated so that it can have better capabilities to become the basis of technology solutions for the needs of its users. Some specific formats even have a derivative format which is then replace the previous one because the features provided by the latter are superset of the format being replaced [1]. This happened to the VRML format [2] which has been succeeded by the X3D format [3]. Both of these formats are official standard formats maintained by the Web3D consortium.

Many Web3D implementations have been made using VRML. One of such implementation is campus Web3D site as in [4], [5], [6], [7], and [8]. Sites like this can be used as an online representation of the real campus from a physical aspect, forming a virtual campus [9]. Without having to visit the actual campus, visitors can get a visual picture of how the campus is, which sometimes can be an added value for the campus for many people. This makes the 3D site have another function as a promotional medium.

For the next implementations, campus Web3D site can also be directed to become an entry gate to virtual 3D classrooms or other scenes that allows interaction between avatars who are representatives of students, lecturers, and other academic staff, for learning or socializing purpose [10]. Classrooms like this may look more attractive than virtual classrooms that use video conferencing, as it will appear to mimic the interaction as in the real world [11]. The campus website will look more attractive because it resembles an online 3D FPS game, such as Counter Strike [12] or many similar games.
VRML has become the choice of many Web3D site developers even today because of some of the conveniences it has, including the support of various popular 3D modeling software [13]. This support allows developers to build complex 3D models in a shorter time [14] compared to building them manually using a text editor. However, not all popular 3D modeling software can export to VRML, and creating complex 3D models is not an easy task [15]. In addition to using 3D modeling software, developers also have alternatives to particular authoring tools for Web3D. Vendors in the Web3D field have provided commercial authoring tools, such as BS Content Studio [16] from BitManagement Software, Cortona3D RapidAuthor [17] from Cortona3D, and AC3D [18] from Inivis, or open source tools [19] from various sources.

The main problem in VRML is the need for specific plugins to be able to display VRML documents in the browser [20]. Plugins are added to the browser, and not all browsers have plugin support. This leads to browser compatibility issues that often lead to unexpected behavior, even though the world on the Web3D site can be displayed properly in other browsers or with certain plugins. Narrowed visitor coverage due to compatibility issues also limits the types of devices and systems that can use plugins in their browsers. Another problem is that plugins for browsers on mobile devices are not widely available, thus further limiting their spread to mobile users [21].

The problems of VRML still arise when using X3D, another standard format from the Web3D Consortium. X3D is basically a 3rd generation VRML [22] so it has many basic properties similar to VRML, including problems that come from plugins [23]. Plugins that are also used by several non-standard formats has caused many problems to visitors as they found incompatibilities to their browsers which led to instability of their system. For campus use, either for promotion, online representation, or a platform to online e-learning, this problem will make it difficult for users to access the Web3D site and ultimately the site will not be visited. Thus the Web3D site cannot be used for its intended purpose due to the absence of visitors. Therefore, there is a need for different technologies in the form of document format that can overcome the problems posed by earlier formats.

2. Related Works

3D worlds in the internet has vast potential to become a medium that can serve advertizers, marketers, and organizations to achieve commercial success. However, some challenges can hamper the effort, including limitations on platform and hardware. In [24], an integrated solution was proposed to be the alternative to overcome the challenges. In another study, users stated that the 3D viewing style allowed them to have a deeper understanding of the product they were studying. Research conducted in [25] shows that most users feel they can better interact with the promoted product and thus have more basis for making judgments.

To publish in 3D, VRML and X3D are the choice of most developer, along with many other format which requires plugins. But for today, the preferred technologies are the ones which work without plugins. In [26], X3DOM was chosen as the choice of implementation since it has wide support in web browsers. Poor compatibility and the need for plugins are disadvantages for Web3D solutions. HTML based solution can become a way to solve these problems [27]. Web3D is basically designed to demonstrate interactivity, accessibility, and compatibility with other web technologies. However, elements built with HTML cannot simply be used to interact in standard Web3D technologies such as X3D. In [28], the consolidation of X3D and HTML for accessing 3D content natively in DOM form eliminates the need to use a Scene Access Interface (SAI) that uses plugins.

Integrated use is also shown in [29] where the X3DOM application makes use of the models built in X3D. Since X3D alone cannot render volumetric datasets interactively, X3DOM together with other technologies are used to form the volume rendering component in [30]. Utilizing newer technology can be done by producing 3D model from scratch or converting from the older version. Conversion does not always produce an identical result to the original version, both in appearance and functionality included in it. In [31], comparison has to be done to determine which tool that can conserve as many features as possible.
3. Methodology
Method used in this research consists of following set of steps: initial, main, and test. In the initial step, careful examination was made to discourse and references regarding the application of potential formats to be used as replacement formats. In addition, observations were also made on various examples of sites and applications that use Web3D technology. An experiment was carried out to obtain information on the practicality and ease of use of the technology. The experiment also looked at the impact of using each candidate technology in preserving the inherent features of the objects used in the original site.

In the main step, once the new format is determined, all resources were collected from the original site. All files, especially the 3D model description document from the last update, were placed on the media used in the world creation process with the new format. All old 3D model description documents cannot be used immediately because they must be decompressed first. Conversion was performed after all object files were decompressed. The conversion results were then displayed in the browser to be compared with the old version of the objects. The individual converted files that have been checked for similarity with the old files were then stored in a specific media location.

The 3D model file in the new format was then opened in a text editor. Adjustments were made to all external references contained in each file. Furthermore, the world configuration was also adjusted so that it can provide performance at least like the old version of the world. After all the modifications and adjustments have been made, the object description files were compressed.

In the test step, what is done was a test on the world as a whole, seen from various aspects when compared to the old version of the world. Begin by comparing the visual aspects of the world when displayed in a dedicated browser for testing. Performance comparisons were also carried out while the world is being displayed, so that the efficiency of the new world can be seen immediately. The final test was carried out in the form of an examination of the level of compatibility with several browsers that are currently widely used. In brief, the overall steps in the methodology is shown in Figure 1.

![Figure 1. Method with the steps carried out in this study.](image-url)
4. Selection of Suitable Format
At first, there were 3 choices of technology implementation initially chosen for the alternate candidates to replace the previous one. The candidates were WebGL [32], XML3D [33], and X3DOM [34]. These technologies were selected mainly because their implementation did not use plugins and they have close connection to HTML. Although X3D is a newer standard than VRML and can be combined with other technologies [35], this format requires a plugin so it cannot be selected as one of the candidates.

The suitable format should be as close as possible to the standard format in use, especially in terms of feature conservation. The format has to be able to minimize the potential loss of display quality when the constituent components were changed into a new format. Based on these considerations, the X3DOM which is based on X3D and HTML DOM became the choice to replace VRML implementation as a world composer format. X3DOM has backward compatibility with X3D [36], and allows the development of Web3D world with a declarative approach in HTML [37].

5. Model Generation
In order to obtain information on the use of X3DOM to replace VRML as the main format of world documents on sites that represent an institution's infrastructure assets, a site with a world that has utilized VRML technology was needed. Furthermore, to prove that the newer format will be able to retain most of the site features, the site should have the majority of its composers are polygons with high detail [38].

The world from the Web3D site of Universitas Ahmad Dahlan 3rd Campus [39] located in Yogyakarta, Indonesia, was selected for this purpose. The site was built using the VRML format, has high detail and complexity with the use of polygons reaching 92% of the total contents, and has a large 3D model size because it is based on a reference to the actual building complex in the real world. Based on statements from visitors, they have had many difficulties in trying to visit this campus world. Most problems were around plugins, browsers, platforms, and other compatibility issues. This was in accordance with the problem to be solved in the study.

Basically, the modular drafting method which uses the division of objects into several major constituents in large sizes has been used on the original 3rd Campus Web3D site. This method poses many problems when it is displayed in a browser. This includes the transfer failure of supporting files, causing a flawed display of the model, or problems because lack of compatibility resulting in inaccurate object placements. To reduce these problems, the object is divided into smaller constituents so that the total number of 3D models is greater. Even though there are more files, the smaller size makes file delivery failures considerably less. Figure 2 shows the world structure which used modular type constructors divided to smaller group of objects.

![Figure 2. World structure in group of objects.](image-url)
5.1. Decompression
The former Web3D site uses compressed version of scene description files so it requires decompression process to all 3D models. To minimize the possibility of errors, decompression process was simplified by creating batch decompression script. The batch consisted of a list of all compressed files and their corresponding decompression attributes.

5.2. Document Conversion
Building a new set of object models with a new format, apart from taking a very long time, can also make the functions embedded in the old objects no longer appear. To shorten the process, the choice of object conversion was taken. To shorten the time of changing each model, automation was carried out using a set of tool, namely the InstantReality Framework.

In order to ease the process of changing the format, all the original world objects were directly used as source files to be converted. However, when using this technique, conversions have to be done one by one to each of 407 individual object files with sizes ranging from 1 KB to 2454 KB. This technique has caused code errors in many individual conversion process for each object compiler file. As in decompression step done earlier, the conversion process has been simplified to reduce the errors by using batch process.

The result of batch conversion was the new folders containing all files that have used the X3D format, except the main file which took the X3DOM format. In general, all components of the old world has been converted properly, but can not be used immediately since all references in the converted documents still lead to external components in the old format.

5.3. External Reference Correction
References in the old file lead to file names followed by the .wrl string with the appropriate path. Each world file can contain many references. An automation mechanism by a custom made program was used to avoid missing any component in each file. However, the checking still has to be done one by one.

5.4. General Changes to Documents
Following is the overall transformation carried out on campus world documents to fit the X3D that would be referenced by the main new world document which uses the X3DOM format:

- Changing the header.
- Changes in the way attributes are written.
- Changes in the way the coordinates are set.
- Changes in the way the position description is written.
- Changes in the way the coordinates index is written.
- Changes in the way the texture coordinate index is written.
- Changes to the way the normal vertex is written.
- Adjustment of reference to new components.

Since it is not possible to refer to HTML documents to form a merged Web3D world, the X3DOM format was only implemented to the primary file, the main world file calls all the files making up the world. All files other than primary file use X3D format. Primary file refers to all other files in the source world. Figure 3 shows the relationship between the files, while the structure of the primary document used for this world is shown in Figure 4.

5.5. Overall Process Result
The first result that can be seen was the changes of overall file size. The conversion did not break down the object components organized in each file or combine the components previously built in separate files. 3D models description of the new format were more efficient than the old format. Table 1 shows information on the original world and after conversion.
The absence of changes in the basic information contained in the converted world reduces the possibility for major changes that might occur after conversion. The converted world also maintained the original directory structure. Since the structure was similar, the documentation that was formed based on the old format can still be used almost without changes.

### Table 1. World information before and after the process

|                        | Original world | New world      |
|------------------------|----------------|----------------|
| File size (uncompressed)| 94,056,015 bytes | 72,535,422 bytes |
| Files and folders       | 488            | 488            |
| 3D files                | 352            | 352            |
| Non-3D files            | 136            | 136            |

### 6. Discussion

#### 6.1. Visual Quality

One of the main things achieved from this research is the maintained world view as in the old format. The use of the new format in this research has not been prepared to provide special additional features unavailable on the old world. Provision of additional features requires the allocation of resources for analysis, design, and re-coding of the existing world documents, and this was not part of what was planned to be applied in this study.

Observation of components using various viewpoints and possible display modes in the world also shown that the individual components of both worlds can be deemed as visually identical. Figure 5 shows the world with both formats. Figure 6 shows the inside of one of the classrooms.

Visually, through static observation and by exploration, no significant differences were found. The two complete worlds can be assumed as identical by 8 users from the institution brought in to check the visuals of both worlds. No visible deformations, texture errors, or other problems in the converted world.

**Figure 3.** Relationships between files in format conversion.  
**Figure 4.** Primary document structure of the campus world.  
**Table 1.** World information before and after the process  
**Figure 5.** World campus in the old format (left) and new (right).
All information about the object to be formed through the appropriate command were maintained wherever possible including predefined values. Also maintained was the use of the digit number after the decimal point in each set of 3D coordinate data or all other units. Segments of all objects were also not changed so that the details of the 3D model polygons were intact. Equal count of component resources has produced similar appearances in the browser.

6.2. Converted World Performance
Performance monitoring was done by comparing the frames per second (fps) and seconds per frame (spf) values of each world. The navigation mode selected was “walk” which is the standard mode for applications that can generally be categorized as virtual tours.

Each final count was the average of the same navigation movements done in 10 times since each repetition of the movement does not always display the exact same number. Each movement was done in 10 seconds, and the numbers read were recorded every 2 seconds. Thus each final count was based on 50 values taken on average. The comparison of fps count results are shown in Figure 7, while the comparison of spf count are shown in Figure 8.

The average decrease of the new world fps value compared to the old world in the same browser was 23.1%. This decrease brought up a resulting visual that seemed no different between both worlds. Even so, slight differences can be seen when the camera moves using the various modes possible in the browser. In terms of average spf result comparison, it shows an average increase of 28.8% which also contributes to the decrease in visual performance.

Unlike VRML which is able to utilize 3D graphics hardware API through plugins, the same number of polygons and complexities of the world in the X3DOM seems to burden the rendering process. Most likely this happened because the exploration of the 3D environment in the new site does not use any 3D acceleration installed on the computer.
6.3. Testing on Various Browsers

Both worlds were not examined online, thus the aspects of connectivity are not included in this research. Comparison carried out in this study requires the old world to be placed on a local web server along with the new world. The test results on various popular browsers are shown in Table 2.

Table 2. Results from various browser test.

| Browser   | World | Browser   | World |
|-----------|-------|-----------|-------|
| Old       | New   | Old       | New   |
| MS IE     | √     | x         |       |
| MS Edge   | x     | √         |       |
| Firefox   | x     | √         |       |
| Chrome    | √     | √         |       |
| BlackHawk | √     | √         |       |
| Cyberfox  | x     | √         |       |
| Opera     | x     | √         |       |
| Torch     | x     | √         |       |
| Vivaldi   | x     | √         |       |
| Epic Privacy | x     | x         |       |
| Yandex    | x     | √         |       |
| Slimjet   | x     | √         |       |
| Puffin Secure | x     | √         |       |
| Tor       | x     | x         |       |
| IceDragon | x     | √         |       |
| Brave     | x     | √         |       |
| Maxthon   | x     | x         |       |

Although testing was limited to only using the PC platform, the possibility of usage on other platforms is high since there is no need for plugins. The main requirement for displaying the new world is HTML5 compatible browsers that can also be found on mobile devices currently widely used.

6.4. Other Observed Aspects

The file size in documents using the new format are slightly smaller than the original. The size reduction ranges from 18% to 31%. It should be pointed out here that the polygon complexity of the old version was not reduced, there is no segment reduction or any modification that can reduce the detail of the original version. Although the header is slightly longer than the original version, the more efficient way of writing the code which based on the X3D reduces the overall size. In general, this suggests prospects for improved performance.

However, unlike VRML and X3D which allow compression on object description documents, the same cannot be done in X3DOM which uses HTML documents. However, since X3DOM can refer to the X3D document as a component used to build the world described in the X3DOM document, compression can be performed on X3D files which provided smaller size than older format. However, the use of binary compression on X3D was avoided because this method turns out to make the X3DOM document unable to recognize its contents.

Slightly visible performance degradation occurred in both compressed and uncompressed component files for the new world. The decrease occurred in almost all browsers as depicted by the number of frames that can be displayed per second. The amount of rendering time per frame also looks higher, as well as slower browser response in redrawing the world when the camera moves in various navigation modes.

7. Conclusion

The new Web3D site in X3DOM format can be used as the next online representation of the 3rd Campus physical appearance. The site has shown more benefits compared to the old version. The user platform is also increasingly diverse and broader since many browsers support the new format as it was designed to work with HTML5. Since there are more browsers that can display the new world, the user coverage of the campus world can be expanded to reach more users in the future. Further optimization still needed to increase the visual performance of the site.

Based from this research, web sites that represent institutions through the use of Web3D may reduce their problems by using the format based on HTML which is a native technology for the web. Common problems in current VRML or X3D applications such as browser incompatibility, difficulty in obtaining plugins, or the difficulty of combining 2D and 3D views is possible to be minimized by
the use of X3DOM. College campus sites which contain complex and large-sized 3D models can take advantage of this, especially sites where the majority of its composers are polygons with high detail such as the one used as the case study in this research.

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