Data capture and 3D Visualisation

The 5th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST (2004) *Short Presentations*
K. Cain,Y. Chrysanthou, F. Niccolucci, N. Silberman (Editors)

Visualizing Design and Spatial Structure of Ancient Architecture Using Blueprint Rendering

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Abstract

We present the blueprint rendering technique as an effective tool for interactively visualizing, exploring, and communicating the design and spatial structure of ancient architecture by outlining and enhancing their visible and occluded features. The term blueprint in its original meaning denotes "a photographic print in white on a bright blue ground or blue on a white ground used especially for copying maps, mechanical drawings, and architects' plans" (Merriam Webster). Blueprints consist of transparently rendered features, represented by their outlines. This way, blueprints allow for realizing complex, hierarchical object assemblies such as architectural drafts. Our technique renders 3D models of architecture to automatically generate blueprints that provide spatial insights, and generates plan views that provide a systematic overview, and enhances these drafts using glyphs. Additionally, blueprint rendering can highlight features of particular importance and their relation to the entire structure, and can reduce visual complexity if the structural complexity of the 3D model is excessive.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Applications

1. Introduction

This paper describes the novel and innovative blueprint rendering technique applied to architecture of cultural heritage to effectively visualize and communicate their design and spatial structure. It represents a real-time non-photorealistic rendering technique that enhances visually important edges of visible and occluded features of 3D models, e.g., architecture models. In contrast to a wire-frame depiction, which complicates the visual perception of complex object assemblies because it does not differentiate between triangulation edges and actual outlines (e.g., silhouettes), and transparency renderings, whose outlines are hardly noticeable, in particular in regions of high depth complexity, the blueprint rendering technique generates vivid and expressive depictions that facilitate visual perception (Fig. 1). Furthermore, its resulting depictions can be combined with further 3D scene contents. In this way, blueprint rendering becomes an effective visualization tool in applications, e.g., CAD systems, for interactively communicating structure and relationships of ancient architecture.

2. Blueprint rendering

Blueprint rendering [ND04] extracts visible and non-visible edges of 3D models and then composes them in image-space. Thereby, visible edges are edges directly seen by the virtual camera and non-visible edges are edges that are occluded by faces of the 3D model, i.e., they are not directly seen. Technically, blueprint rendering combines depth peeling [Eve01] and an image-space edge enhancement algorithm [ND03] and can be implemented using hardware-acceleration [Kil04].

Layers of unique depth complexity

Depth peeling decomposes arbitrary 3D models into disjunctive 2D layers of depth-sorted order, that we call *depth layers*. Generally speaking, depth peeling successively "peels away" layers of unique depth complexity.

Commonly used real-time rendering generates the first depth layer. That is, the frame-buffer content contains pixels having a minimal z-value if an ordinary depth test has been performed. But, in this way, we cannot determine depth layers that come second (or third, etc.). Hence, depth peeling as a multipass rendering technique performs an additional depth test to extract those layers with respect to depth complexity. Based on depth peeling, we step deeply into a 3D model subject to the number of rendering passes while capturing the contents of each layer. Thus, we can extract the first *n* layers by *n* rendering passes (Fig. 2).

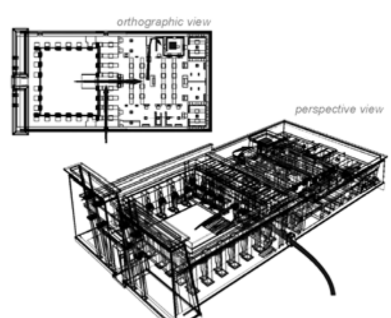

Figure 1: Blueprints of perspective and orthographic views of the Temple of Ramses II in Abydos enhanced with glyphs for guidance.

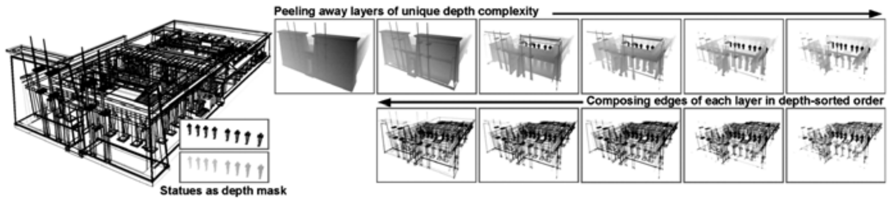

Figure 2: Reducing the structural complexity in blueprints by considering a minimal number of depth layers with respect to a depth mask.

Performing two depth tests

In the first rendering pass we perform an ordinary depth test resulting in the first depth layer and then capture the z-buffer and color buffer for further use. In consecutive rendering passes we perform two depth tests. For it, we reuse the z-buffer of the previous rendering pass. We first test if a fragment is greater than the z-value of the targeted pixel location of the previous depth layer. If so, we, secondly, perform the ordinary depth test again. Otherwise, we reject that fragment prior. Finally, the frame-buffer content forms the next depth layer.

Extracting visible and non-visible edges

The edge enhancement algorithm extracts discontinuities in the normal buffer[1] and z-buffer as intensity values that constitute visible edges of 3D models. The algorithm preserves these edges as *edge map* for further use.

Combining both, depth peeling and edge enhancement allows us to extract edges for each depth layer. For it, we render encoded normal values instead of color values into the color buffer for a depth layer and, thus, can extract visible edges in each rendering pass because the z-buffer is already available. Furthermore, non-visible edges become visible when depth layers are peeled away successively. So, as a result, we can preserve visible and non-visible edges of 3D models.

Composing blueprints

Finally, we compose blueprints using visible and non-visible edges stored in edge maps in depth-sorted order. We render each edge map as depth sprites into the frame-buffer. (A normal buffer contains geometrical normals of a 3D model encoded as color values.) Thereby, we use color blending using edge intensities as blending factors and, e.g., a bluish, mixing color for providing depth complexity cues while keeping edges enhanced (Fig. 3).

3. Highlighting hidden components in blueprints

We introduce depth masking to peel away a minimal number of depth layers until a specified fraction of occluded components of the 3D model become visible. For it, we construct a depth texture as *depth mask* of these components and render it as depth sprite in each rendering pass. In this way, we peel away depth layers until a specified fraction of these components become visible. Finally, we integrate and highlight these components when composing blueprints. In general, depth masking dynamically adapts the number of rendering passes and reduces the visual complexity of blueprints if the structural complexity of 3D models is excessive (Fig. 2).

4. Plan views for architectural drafts

Blueprints generate pl an views automatically to outline architecture comprehensible. Composing plan views using an orthographic camera for rendering is a straightforward task. Edges and depth complexity cueing are suitable to differentiate single components in an overall composition. In the plan views of the temple (Fig. 3), we can identify chambers, pillars, and statues systematically. Thus, blueprints increase visual perception in these drafts.

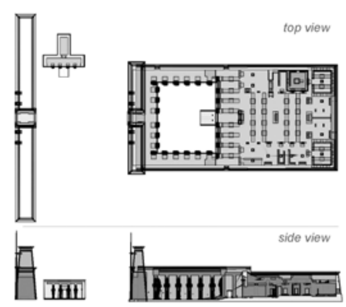

Figure 3: Top and side views illustrate the layout of the temple.

5. Relations and locations in architectural depictions

We enhance blueprints of architecture with glyphs to communicate hidden details, locations, and relations. That is, we include general 3D geometry in blueprints to provide additional knowledge in our depictions of architecture. The illustrations in Fig. 1 mark a hidden chamber (red box) in the rear part of the temple and the pathways to it (red arrows).

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The Application of Colour Reproduction within a Museum Display

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Abstract

Colour is taken to be an important visual cue within a virtual reconstruction because of the implications it has upon our understanding of the cultural and spatial context of the designated subject. The creation of a virtual model detailing the Tudor Merchant's Hall for display in the Museum of Archaeology, Southampton, examines the issues surrounding the accurate representation of colour within a display environment, as well as addressing the matter of data misrepresentation, by stipulating the inferences made during the construction of the model.

Categories and Subject Descriptors (according to ACM CCS): J.5 [Arts and Humanities]: Architecture

1. Introduction

The Tudor Merchant's Hall currently resides in the Old Town of Southampton, and is managed by the Southampton City Museum service, which markets the building as a venue for meetings, conferences, recitals and receptions. It is a well known landmark that has an ambiguous history, beginning in approximately 1400 when it was used as a fish market and cloth hall during its original residence in St Michael's Square. In 1635, the building was moved to its current situation, during which it was repaired, with the once open ground floor heavily modified by the addition of a rubble wall. These extensive alterations make the Tudor Merchant's Hall an ideal candidate for recreation using computer modelling techniques.

The benefits that a computer model would provide for the museum service are threefold. A digital reconstruction, provided as a high quality print and/ or VDU display would educate visitors by allowing them to visualise the original structure of the building in its original position, examine the interior features and contents, as well as learn about its initial function and form. Secondly, the model would be a suitable research tool, providing archaeologists with the opportunity to understand the structural composition of the timber frame, and to explore the sequences and techniques used in its construction. As a medieval environment, it could be used to present information about contemporaneous finds in an authentic atmosphere. Finally, the model could be optimised for use on the museum website to inform people about the history and form of the building, as well as a marketing strategy for its use as a venue.

2. Data manipulation

The creation of the model from REDM survey data introduced a certain level of accuracy by presenting the final 3-dimensional model of the timber frame structure based upon geometric measurements of the timbers themselves, as shown in Figure 1. Additional measurements were taken manually and incorporated into the model. The materials added to the timbers were colour corrected using RGB values taken from digital photographs of the timbers themselves, which included the Gretag MacBeth ColorChecker Chart as a reference for the colour correction procedure, as shown in Figure 2. The digital images were produced using the Adobe RGB colour space and were colour corrected to provide a set of rectified RGB values to define the timber material colour. These results were based upon an averaged set of values measured from images of the chart that were photographed by a high-end digital camera. These calibrated colour values, designated for use on the material components of the model, and lit using authentic values for appropriate luminaires, were used to create an authentic colour rendered model.

Figure 1: Timber structure of the Tudor Merchant's Hall looking North.

The context in which the final representation will be presented within the museum will be assessed prior to completion of the project, such that the colour specifics of the monitors and any printed media used may be accounted for, in addition to the likely viewing orientation. Similarly, it is hoped that an assessment of the efficacy of the colour reproduction procedures included in the project may develop from the display itself. The museum visitors will provide a test audience for the different modelling, lighting and colour correction approaches and as a locus for discussion of the realities of CGI archaeological work in a representational context.

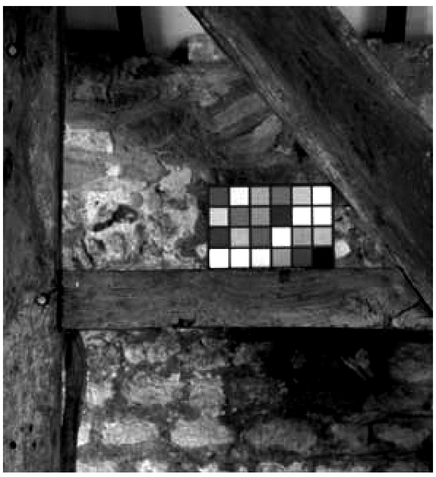

Figure 2: Colour reference image.

3. Application of colour reproduction

The aim of virtual reconstructions is often to provide an environment that is perceptually comparable to a 'realworld' scenario [Bar00][Dev02]. Colour is just one of the many factors that will enhance this experience, since it is used by the human visual system to understand the spatial positioning of objects within a scene, as well as define objects in a cultural context [Rei92]. Hence the more physically accurate the colour reproduction, the closer the colour information approximates the stimuli associated with the real-world experience. The presentation of such a project to a varied audience, within the context of a museum display, will incorporate a discussion and demonstration of this issue, in addition to the wider parameters defining the building thus represented. It is an approach advocated by many archaeologists who wish to avoid the misrepresentation of data defined through the full diversity of archaeological discourse, particularly when the research is presented in a broad and largely undirected educational context. It is unethical to present information as truthful when in fact the end product is based upon circumstantial evidence, although the definition of certainty within archaeological discourse is itself complex [Gill00][Kat00]. This is an area that has much to gain from a simple, efficient multimedia product and interface.

4. Conclusion

The aims of the museum service are fulfilled by this project as it allows for the continuing research into the collections and premises within Southampton, enabling the subsequent results to become publicly disseminated. This encourages people to learn from the museum experience, as well as utilising new media in pursuit of these objectives. By presenting a computer model in such a fashion, the market profile of the collections and premises managed by the museum services is improved.

To date we have only limited information pertaining to the interpretative value to be gained from authentic illumination and colour calibration in a museum context, although the research was initially founded on the premise that fidelity is beneficial. Studies such as this will provide assessments of the outcomes of the use of more accurate colour reproduction. By presenting alternative renders, couched in engaging narratives concerning the building and its use, we shall be able to consider whether attention to detail in colour is a significant step or merely an additional, in a sense spurious, element to claims for reconstruction 'accuracy'. Do archaeological graphics need accurate colour, or can we express our knowledge and understanding of the past using less apparently 'rigorous' techniques ? Only continued engagements with the technology, archaeological and museological theory, and those consuming our graphical work, can begin to provide us with answers.

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From 3D Model to Stereoscopic Video: A Case Study Based on an Ancient Theatre

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1. Introduction

An important factor for the interpretation and the analysis of an archaeological site is its topography. Maps often use dense contours and the information provided is neither always adequate, nor easy to be decoded by non-specialists. The creation of a 3D model, which includes the landscape and the under study monuments is not only a valuable tool but also an interesting final product for the non specialist. Unfortunately, the projection of such product into 2D screens (like monitors or projection screens) wastes the third dimension and leaves it on the – what is called- "2.5D projection". On the other hand, the creation of a 3D product, like a stereoscopic video and its projection, using stereoscopic techniques, is a unique tool for the understanding, perception and promotion of the site. The disadvantage of such products is that they need specialized hardware in order to project correctly the content of the product. Fortunately, nowadays the cost of these systems is affordable not only by organizations, but also by individuals. Even better, some stereoscopic products need only simple "red-blue" glasses in order to be viewed correctly. In this paper, a stereoscopic video of the ancient theatre of Philippi, (Web 1) in N. Greece and its wider area has been created. For the creation of the stereoscopic video, a 3D model of the theatre, a DTM and an orthophotomap of the wider area were used. In order to combine all the data for the creation of the final product, AutoCAD and own home made software (Openview project) have been used. An overview of the successive stages, from theater's 3D scene creation up to stereoscopic video production and some directions for further research based on the conducted work are presented and discussed.

2. The virtual reconstruction of the theatre

In order to meet the accuracy standards for the virtual reconstruction of the theatre, the method of photogrammetry has been used. As first step, the initial topographic network of the whole site had to be defined. For this reason, twenty-nine (29) points inside the theatre and the major area of the archaeological site have been measured by GPS. At next step, eight (8) close-range stereo pairs have been captured in order to cover the whole seating area of the ancient theatre, using a metric Wild P-32 camera. Additionally, control points where measured. The photogrammetric processing of the stereopairs has been realised with the aid of an analytical stereoplotter. AutoCAD software has been used for the creation of the model. Solid modeling has been mainly used in order to create the virtual reconstruction of the theatre, because the use of texture would provide a '*heavy'* model difficult to be managed (Web 2, 3).

3. The creation of the 3D scene of the archaeological site and its wider area

The model of the surrounding area has been considered as important, because the ancient Greeks chose the place of their theatres and furthermore, it can provide a realistic synthetic environment. The DTM has been produced from the photogrammetric processing of eleven (11) overlapping B/W aerial photographs taken back in 1994 and having a scale of 1:15000. The photos were scanned at 1200 dpi (36cm spatial resolution). Sixteen (16) points of the initial topographic network were identified and used as control points. The DTM creation was achieved in a Digital Photogrammetric Workstation (Georgoula et al, 2003). In order to have a color image of the surrounding area, a fused Quick Bird (Q.B.) satellite image (spatial resolution of 0.7m and spectral resolution of four bands) was used as well. The processing of the Q. B images was realised with ERDAS Imagine 8.6 (Georgoula et al, 2004). The fused image of the area overlapped the DTM it produced a realistic 3D scene of the region.

4. From 3D model to 3D video

4.1 Stereoscopic systems

It is common knowledge that, in order for a viewer to have stereoscopic vision of a model, his left and right eyes must see it from different view angles at the same time. In order to obtain this, several "stereoscopic formats" have been used. The next three are the most usual:

- **Anaglyph**. It needs *only* a pair of color-filtering glasses (e.g. blue-red / red-green glasses). Image can be projected by any mean or can be printed.
- **Interlaced**. It needs a pair of shutter glasses. For the moment, projection is made only in CRT monitors who support 80+ Hz refresh frequencies. Specialized graphics card (hardware) must be used.
- **Polarized**. It needs a pair of polarized glasses. Projection can be made using polarized projectors in a silver-dyed panel or in any monitor using specialized filter in front of the screen. In the second case, specialized graphics card must be also used.

The goal of this paper is not to compare these systems. Our conclusion is that the Anaglyph and Polarized formats are the best for presentations because they can support an unlimited number of viewers with very low cost.

4.2 Video path

The most important factors for the video creation are the camera's path and the target definition. For 2D videos, this task has been simplified and can be done by using specialized software such as 3D Studio Max, Lightwave, Maya or CAD software, like AutoCAD and Microstation. But when it comes to create 3D videos, things are getting complicated. In this case, two paths are needed - one for the left and one for the right eye. The problem is that these paths must meet two restrictions in order to have correct stereoscopic view: a) keep the distance between them constant and b) keep the distance between every camera and the model (target) constant for every single frame of the video. Unfortunately, this problem cannot be solved by creating one path for one eye and then just move the path at a constant distance in order to create the second path.

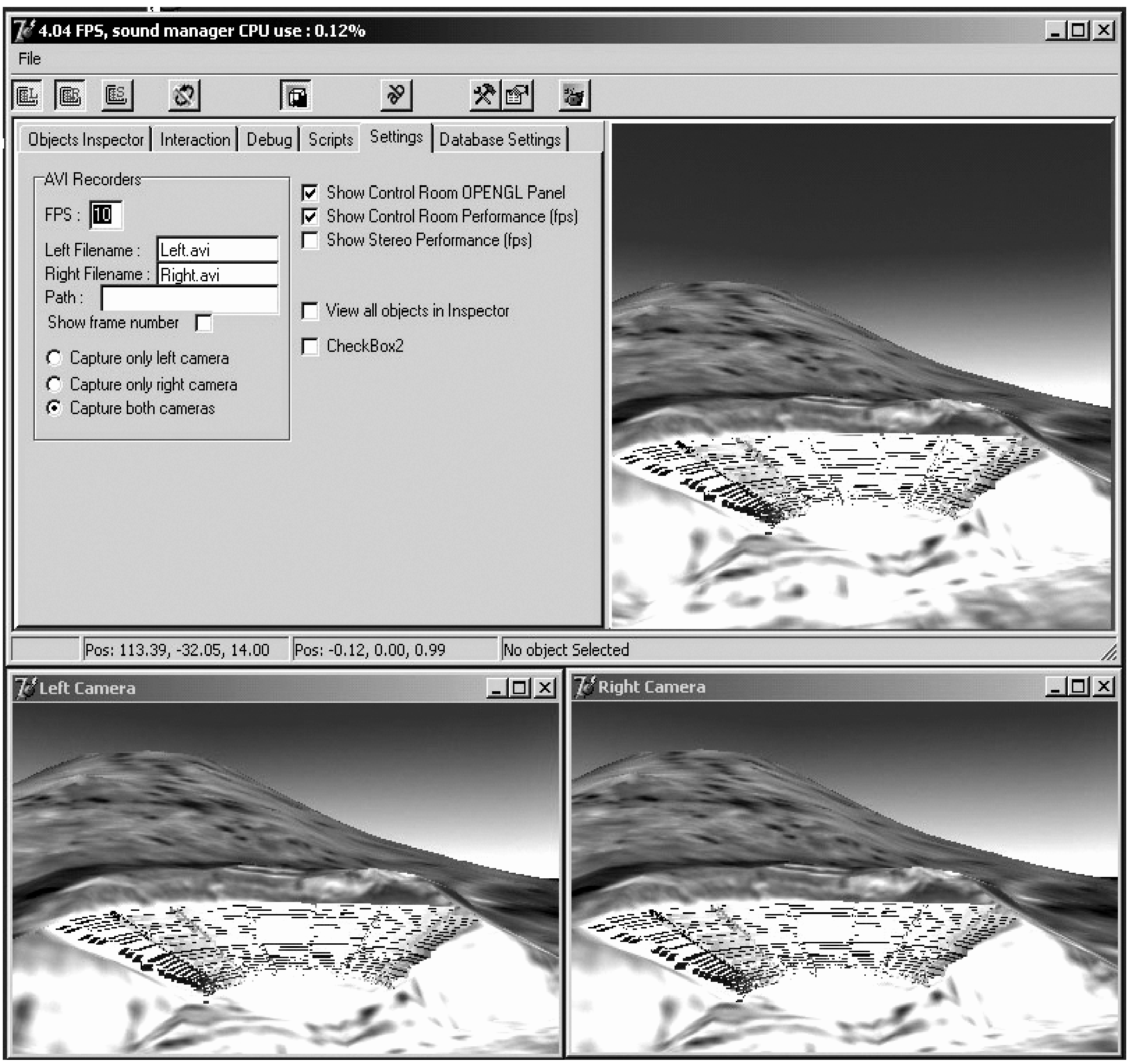

Figure 1: Openview in action. Observer (viewer) moves around theater at real time while both left and right virtual cameras save rendered images in separated videos.

4.3 3D Video creation

Even though very few commercial software gives the ability to create correct 3D videos by defining just a single path (e.g. Microstation), the output video is usually only in *anaglyph* format. Additionally, the path must be very simple; in fact, motions like head rotation or changes in the target while moving are not allowed. In order to solve these restrictions, we have created specialized software, called OpenView. OpenView is a free of cost stereoscopic presentation software (Sechidis et al., 2004). Its main goal is to present, in *real time*, any kind of 3D data, from simple points and lines to huge VR scenes with thousands triangles and textures, by using three virtual cameras at the same time. Additionally, all these cameras can save, on demand, single images or avi files of the rendered scene. Using this ability, the creation of 3D videos becomes an easy task: While the observer (viewer) moves in real time inside the scene, the cameras produce left and right images of the scene and save them as separate images or video files (Fig. 1). Then, an external application (3D Video Creator) imports them and produces the video in any of the above three stereoscopic formats. Additionally, the position and the rotation of every camera, in all frames, can be saved into a file and then stored as metadata to the video stream, in order to create geo-referenced 3d videos (Sechidis et al., 2001).

5. Conclusions and future work

The first results of our ongoing research are the stereoscopic presentation of a virtual walk-through inside the ancient theatre of Philippi and its surrounding area. This can be either predefined (with the help of 3D video) or in real-time, with the direct usage of the OpenView. Additionally, the purpose of the reconstruction is to provide to researchers and the wide public the opportunity to expand their knowledge and to explore the ancient *theatron*, as well as to contribute to the presentation and the documentation of the site. The project can also be used as a tool for further scientific analysis. The first implementation of the new technology seems to be well promising and very useful. There is an ongoing research for the theatre of Philippi. In a second stage, the current model will be improved and further details, like the bas-reliefs of the pillars, will be added. Furthermore, new models of the various phases of the theatre will be created and documents with information about the ancient theatre will be connected via OpenView.

The results of the project ERATO (*Identification Evaluation and Revival of the Acoustical Heritage of Ancient Theatres and Odea*) part of the European Commission Fifth Framework INCO-MED Programme that has started at the beginning of February 2003 will be taken into account.

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