

Stereoscopic 3D Web: From Idea to Implementation

Wenmin Wang, Shengfu Dong, Ronggang Wang, Qinshui Cheng, Jianlong Zhang, Zhongxin Liu
School of Electronic and Computer Engineering, Shenzhen Graduate School, Peking University
Lishui Road 2199, Nanshan District, Shenzhen, China 518055
wangwm@ece.pku.edu.cn

Abstract—In recent years so called 3D web has emerged that gives people to view 3D web contents in a standard web browser, and the representative technologies are Web3D, WebGL and O3D. But since the standard web browser has only a single view in which the 3D contents are shown on a 2D display device, therefore the 3D web is essentially a kind of monoscopic 3D. Nowadays with the rapid development of stereoscopic 3D display device, especially glasses-free auto-stereoscopic 3D display device, we think stereoscopic 3D web will become a hot research field, as that can be used to stereoscopic 3DTV GUI, stereoscopic 3D games, stereoscopic 3D photo gallery, stereoscopic 3D virtual reality, and so forth. In this paper we propose our idea and its implementation for stereoscopic 3D web, and give an example that has been used as a stereoscopic 3DTV GUI.

Keywords— stereoscopic 3D; stereoscopic computer graphics; stereoscopic 3D web; Webkit

I. INTRODUCTION

Traditionally the term 3D refers to a geometric 3-parameters model of the physical universe without considering time, in the late 1890s 3D movie has been invented, and at present the 3D movie becomes very popular, however the 3D movie is different from the traditional 3D. In this section we firstly distinguish them with the terms “monoscopic 3D” and “stereoscopic 3D”, then summarize monoscopic 3D web, finally provide our idea and its implementation for stereoscopic 3D web.

A. Monoscopic 3D and Stereoscopic 3D

Definition 1: It is called monoscopic 3D, if it is viewed using only one eye at a time, or has been obtained by imaging from a single viewpoint.

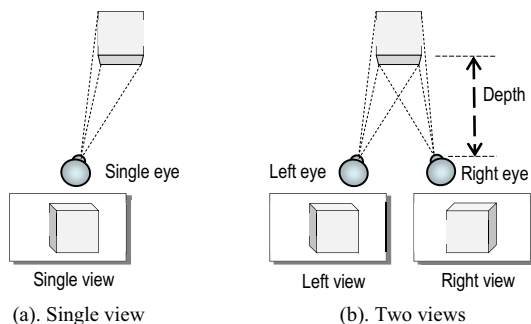


Fig. 1. Monoscopic 3D and stereoscopic 3D

As shown in Fig. 1(a), the monoscopic 3D has two characteristics: 1) there is a single view or image from only one viewpoint; 2) it is displayed on a 2D display device. According

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to Definition 1, 3D graphics is a type of monoscopic 3D, and 3D web based on 3D graphics is also a type of monoscopic 3D web.

Definition 2: It is called stereoscopic 3D, if it is viewed using both eyes or has been obtained by imaging from two viewpoints simultaneously based on binocular parallax theory [1].

The stereoscopic 3D, as shown in Fig. 1(b), has also two characteristics: 1) there are two offset views or images separately to the left and right eye of the viewer; 2) it is displayed on a stereoscopic 3D display device. According to Definition 2, the 3D movie including 3D video is a kind of stereoscopic 3D.

B. Monoscopic 3D Web

Monoscopic 3D web has become a better way to advance web technologies and meet the needs of businesses and individuals for 3D.

As early as 2006 Leavitt Neal overviewed on 3D web and potential obstacles [2]. In 2010 Ortiz Sixto thought 3D content still is not widely found on the web, even though several new technologies may widen 3D's presence on the web [3]. Up to now 3D web has been developed rapidly, the representative technologies are Web3D [4], WebGL [5] and O3D [6] that have been used to create 3D web contents such as 3D cultural content [7], 3D GIS [8], virtual reality [9] and so forth.

Initially Web3D was the idea to fully display and navigate web sites using 3D, its beginnings was named as Virtual Reality Modeling Language (VRML) that is extended from XML. In 1997, as the successor of VRML, Web3D Consortium [4] released Extensible 3D (X3D) that is an XML-based file format for representing 3D graphics. Now the term Web3D refers to all interactive 3D contents which are embedded into web pages, and that can be seen through a web browser. Usually Web3D technologies require to install a web 3D viewer, formed as a plugin for web browser, to show their contents. Since both of VRML and X3D is based on 3D graphics essentially, Web3D is a kind of monoscopic 3D web.

WebGL designed and maintained by Khronos Group [5] is a JavaScript API based on OpenGL for rendering interactive 3D graphics and 2D graphics within any compatible web browser without the use of plugins. It is integrated completely into all the standard web browser allowing GPU accelerated usage of physics and image processing and effects as part of the web page canvas. As a piece of JavaScript source code, WebGL elements can be mixed with other HTML elements and composited with other parts of the page or page background. WebGL programs consist of control code written in JavaScript and shader code that is executed on a computer's GPU. Moreover, O3D is created by Google which is a JavaScript API for creating interactive 3D graphics applications running in a web browser window [6].

Currently O3D is as open source in Google's incubation lab, the new implementation of O3D is a JavaScript library implemented on the top of WebGL.

It should be noted that existing standard web page languages such as markup language HTML and style language CSS have no the way to represent stereoscopic 3D contents, existing browser architecture does not support two frame buffers for two view stereoscopy, the web content rendered by existing web browser is shown on a 2D display device, and Web3D is based on existing standard web browser without changing its basic architecture, therefore Web3D is still monoscopic 3D.

JavaScript, as a part of web page languages, is a kind of script language to interact with user, but not to construct a web page layout like HTML and CSS. Although some contents created by the JavaScript API provided by WebGL or O3D look like stereoscopy, but both of WebGL and O3D is still monoscopic 3D web in principle.

C. Stereoscopic 3D Web

It is known that a stereoscopic 3D video is a sequence of stereoscopic video pairs, in which each pair consists of two offset (left and right) video frames. Similarly, if we are able to represent the two offset web page frames and to render them by a web browser, then we will achieve the stereoscopic 3D web, which is just what of our innovation.

Nowadays many kinds of stereoscopic 3D, especially glasses-free auto-stereoscopic 3D display devices have been created, for example 3DTV, 3D notebook, 3D tablet, and 3D smart phone, therefore we believe stereoscopic 3D web on the 3D display device will become a hot research field, due to stereoscopic 3D web will make user experiences better than monoscopic 3D web, just like stereoscopic 3D video on stereoscopic 3D display device.

Had a lot of experiments, we submitted a patent in May 2011 about an implementation method of stereoscopic 3D web browser based on binocular parallax theory [10], and we have been granted the patent in April 2013.

In December 2012, we found World Wide Web Consortium (W3C) published a draft "Extensions for stereoscopic 3D support" in November 2012 on their website [11]. The draft was published by Stereoscopic 3D Web Task Force (TF) that is a subset of Web and TV Interest Group (IG) in W3C, the TF's goal is to investigate the impact of 3D videos and graphics on HTML and other web standards, and to discuss the use cases and requirements of stereoscopic 3D rendering on the web. In the draft it described the extensions for CSS 3D Transforms to provide stereoscopic 3D, a web browser to enable the feature should be able to render stereo views of 3D objects. Here it is worth to point that the draft publishing date is 18 months later than our patent submitting date.

This paper aims at expatiating on our idea, methods and implementation for stereoscopic 3D web, Section 2 will gave an outline of 3D video formats, Section 3 describes the calculation method of stereoscopic pair, Section 4 discusses the calculation of stereoscopic 3D image pair, Section 5 will be the details of stereoscopic 3D web page and stereoscopic 3D web browser

respectively, and Section 6 gives an example that has been used as a stereoscopic 3DTV GUI.

II. 3D VIDEO FORMATS

Like stereoscopic 3D video on 3D display device, stereoscopic 3D web content will be shown on same 3D display device, so that we should study stereoscopic 3D video formats to make stereoscopic 3D web content with same formats.

There are two types of stereoscopic 3D video formats, one is frame sequential 3D and the other is frame compatible 3D. The frame sequential 3D format, as the name implies, consists of a sequence of alternating video frames, wherein each successive frame carries the video frame meant for one eye or the other eye, which is also called full-resolution 3D format. The frame compatible 3D format, combines left and right video frames into one frame with same resolution as normal individual high definition (HD) frame, i.e. any one of left or right video frame has only a half HD resolution. The benefit of the frame compatible format is to allow handling 3D video as normal HD video using existing TV channels. There are five ways for frame compatible format: side-by-side, top-and-bottom, row interleaved, column interleaved and checkerboard [12]. The frame compatible 3D is also called half-resolution format. In side-by-side 3D, the horizontal resolution of a HD video frame is reduced by half, in order to store the left and right eye video on a single frame, this means that the two sub-frames are stacked side by side, as implied by this format name itself. In other hand, top-and-bottom 3D, the vertical resolution is reduced by half as the video sub-frames for the left and right eye are stored on top and bottom within a single frame, like this format name. The formats of side-by-side and top-and-bottom are used to 3DTV.

III. CALCULATION OF STEREOSCOPIC PAIR

There are some methods to calculate stereoscopic pair for left and right view [13]. Hodges described two ways in his 1992 paper of which are off-axis and on-axis projection, although mathematically identical, the two ways produce slightly different images, and he discussed that on-axis projection has one significant advantage [1].

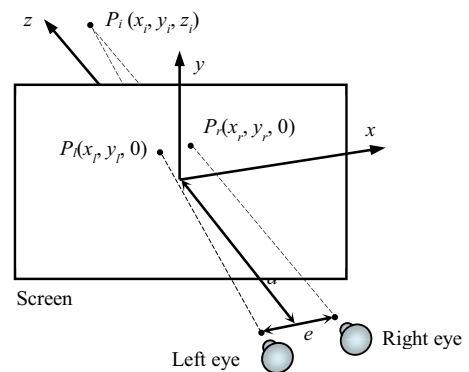


Fig. 2. Stereo pair calculation

As illustrated in Fig. 2, assume there is a screen in which its center point coordinate is $P(0, 0, 0)$, with two different, horizontally aligned centers of projection. The right view is produced by projection to a right center of projection, and the

left view is produced by projection to a left center of projection. The left center of projection is at $(-e/2, 0, -d)$ and the right center of projection is at $(e/2, 0, -d)$, in which e represents the total horizontal separation between the centers of projection, and d is the distance from screen to projection. For a point $P_i(x_i, y_i, z_i)$, it projected two points: P_l in left view and P_r in right view on the screen. It can calculate the projected points P_l and P_r by:

$$x_l = \frac{d(x_i + \frac{e}{2})}{d + z_i} - \frac{e}{2} \quad y_l = \frac{y_i d}{d + z_i} \quad (1)$$

$$x_r = \frac{d(x_i - \frac{e}{2})}{d + z_i} + \frac{e}{2} \quad y_r = \frac{y_i d}{d + z_i} \quad (2)$$

Where the equation y_l is same as y_r .

For Equation 1 and 2, assume

$$x'_l = \frac{d(x_i + \frac{e}{2})}{d + z_i} \quad x'_r = \frac{d(x_i - \frac{e}{2})}{d + z_i} \quad (3)$$

Then

$$x_l = x'_l - \frac{e}{2} \quad x_r = x'_r + \frac{e}{2} \quad (4)$$

Based on above equations, the algorithm to calculate left view frame can be designed as shown in Algorithm 1. Similarly, the algorithm to calculate right view frame can also be elicited.

Using those algorithms, complete left and right view frame for a stereoscopic 3D web page can be calculated.

Algorithm 1. Calculation of left view frame

```

input:  $d, e$ 
output: left view frame
begin
  for each  $P_i(x_i, y_i, z_i)$  do
     $x'_l \leftarrow d(x_i + e/2) / (d + z_i)$ 
     $y_l \leftarrow y_i d / (d + z_i)$ 
  end
  moving entire left view frame to  $(-e/2, 0, 0)$ 
end

```

IV. WEB PAGES FOR STEREOSCOPIC 3D WEB

A traditional web page is coded by the web page languages, i.e. markup language HTML, style language CSS and scripting language JavaScript that are standardized by W3C and ECMA, but it is unable to represent stereoscopic 3D. Our approach is to make all the web page languages to support stereoscopic 3D.

A. HTML for Stereoscopic 3D Web

The way for HTML to represent stereoscopic 3D is adding a tag `<view>` in HTML, we name it HTML-S3D.

1) *Definition and Usage:* The tag `<view>` is used to represent stereoscopic 3D by marking left or right view of stereoscopic pair. It is a sub-root element next to HTML root element `<html>`.

2) *Attribute and Values:* The attribute of the tage `<view>` is 'frame', the values are 'left', 'right' and 'both'. As shown in Table 1, the tag, its attribute and values are used to inform web browser which one of left or right view will be rendered.

TABLE I. ATTRIBUTE AND VALUE OF THE `<VIEW>` TAG

Attribute	Value	Description
frame	left	left view of stereo pair
	right	right view of stereo pair
	both	both view of stereo pair

3) *Use Case:* A HTML-S3D document for left view of stereoscopic 3D is shown in Fig. 3.

```

<!DOCTYPE HTML>
<html>
<view frame="left">
  <head>
    <title> Title of the document </title>
  </head>
  <body>
    Content of the document
  </body>
</view>
</html>

```

Fig. 3. A HTML-S3D document with a `<view>` tag

B. CSS for Stereoscopic 3D Web

The way for CSS to represent stereoscopic 3D is adding a 'parallax' group, we name it CSS-3D.

1) *Definition and Usage:* The 'parallax' group is used to indicate binocular parallax.

2) *Parallax Properties:* The 'parallax' group is consisting of 'eye-distance', 'depth' and 'view-frame', used to specify eye distance, depth and view-frame for an element in CSS document, as shown in Table 2.

TABLE II. PROPERTY AND VALUE OF THE PARALLAX GROUP

Property	Value	Description
eye-distance	<i>length</i>	The distance between left and right eye in cm.
	default	Default value is 6.5cm.
	inherit	The value is inherited form parent element.
depth	<i>length</i>	depth between element and display in cm.
	inherit	The value is inherited form parent element.
view-frame	left	The element is in left view frame.
	right	The element is in right view frame.
	both	The element is in both of view frames.
	inherit	The value is inherited form parent element.

3) *Use Case:* For instance, there is an icon in left view frame, with default eye distance and 100cm depth, so that the CSS-S3D document is shown in Fig. 4.

```

<div class = "leftIconClass">
<img src = "view/leftIcon.png" />
</div>
.leftIconClass {
    eye-distance: default;
    depth: 100cm;
    view-frame: left;
}

```

Fig. 4. A CSS-S3D document with a parallax group

C. JavaScript for Stereoscopic 3D Web

The ‘format’ object is added into JavaScript, we name it JavaScript-S3D.

TABLE III. THE PROPERTY OF THE ‘FORMAT’ OBJECT

Property	Value	Description
format	“FS”	frame sequential
	“FC-Sbs”	frame compatible ‘side by side’
	“FC-TaB”	frame compatible ‘top and bottom’
	“Mono”	monoscopic

1) *Definition and Usage*: The ‘format’ object is used to get the format from current 3D display device, or to set the format to stereoscopic 3D browser.

2) *Property and Method*: The property and the method of the ‘format’ object are shown in Table 3 and Table 4, corresponding to frame compatible 3D formats. The two JavaScript methods are designed to get current format of the 3D display device, or to inform browser to render stereoscopic 3D web page with the given format. Their parameters are ‘side-by-side’, ‘top-and-bottom’, and etc.

TABLE IV. THE METHOD OF THE ‘FORMAT’ OBJECT

Method	Description
get()	get the format of current 3D display device
set()	set the format to stereoscopic 3D browser

D. Images for Stereoscopic 3D Web

The image coding formats supported by current web standard are JPEG, GIF, PNG and SVG, divided to the two types: the format for raster image and the format for vector image, in which JPEG, GIF and PNG support raster image, and SVG supports both of raster and vector image.

1) *Raster Images for Stereoscopic 3D Web*: There are two ways to create stereoscopic pair for raster image: one is using 3D computer graphics software; the other is creating the algorithm of 2D-to-3D image conversion.

2) *Vector Images for Stereoscopic 3D Web*: For a vector image with SVG format, we proposed an approach named as SVG-S3D to create stereoscopic 3D vector image [14]. Since a 2D SVG image and its behavior are defined in a XML text file, SVG-S3D is based on existing 2D SVG format for the shapes

in the image, and adding some attributes for the shapes to describe their thickness and depth. In other word, our approach is 2D-plus-thickness-and-depth to form the stereoscopic 3D SVG images.

V. WEB BROWSER FOR STEREOSCOPIC 3D WEB

To render the stereoscopic 3D web pages, we should implement a stereoscopic 3D web browser to support HTML-S3D, CSS-S3D, JavaScript-S3D and SVG-S3D. Webkit, the open source supporting HTML5, CSS3 and SVG, is chosen as our base layout engine, and what we did is focusing on the implementation to support stereoscopic 3D.

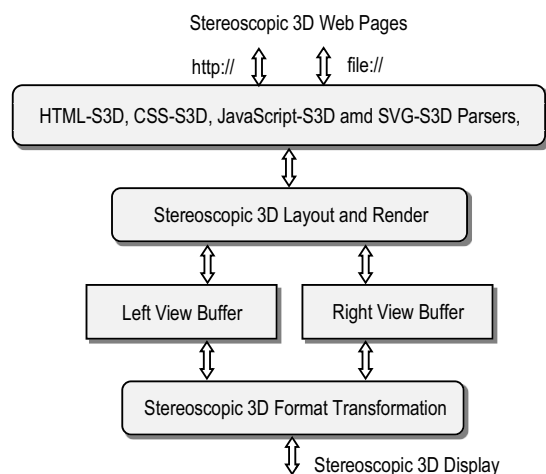


Fig. 5. Architecture of Stereoscopic 3D Web Browser

The architecture of our stereoscopic 3D web browser is illustrated in Fig. 5, the changes in Webkit are as below:

1) *Rewritten Modules*: The modules including web page document parser, DOM tree constructor, rendering tree constructor, layout and paint engine are modified to support HTML-S3D, CSS-S3D, JavaScript-S3D and SVG-S3D;

2) *Changed Frame Buffer*: The frame buffer is changed to two ones for left and right view frame respectively;

3) *Added Module*: A module for stereoscopic 3D format transformation is added and used to transform the full-resolution left and right view into the frame compatible 3D format.

VI. APPLICATION OF STEREOSCOPIC 3D WEB

Web-based software platform for DTV have been a hot topic for decades [15], so we chose web-based stereoscopic 3DTV GUI as one of stereoscopic 3D web applications. The steps to design and implement the stereoscopic 3DTV GUI are as below.

1) *Designing web page layout for stereoscopic 3DTV GUI*: Like a traditional web page, it designs the layout for stereoscopic 3DTV GUI, and extractes the coordinate for each element; unlike a tradition one, it should assign the depth value for each element.

2) *Creating 3D image element for stereoscopic 3DTV GUI:* For a raster image element, it creates each stereoscopic 3D image element for left and right view respectively, but for a vector image element, it uses SVG-S3D.

3) *Writing the web page for stereoscopic 3DTV GUI:* Like a traditional web page, it uses HTML-S3D, CSS-S3D and JavaScript-S3D to create the web pages for the stereoscopic 3DTV GUI.

In the stereoscopic 3D web browser, the web page for stereoscopic 3DTV GUI is processed as following: firstly it is parsed by inside parsers for HTML-S3D, CSS-S3D and JavaScript-S3D; secondly it is constructed into a DOM tree and a render tree; third its layout is done by paint engine; and finally the frames of left and right view will be rendered respectively. According to the format of 3D display device, the left and right view will be transformed into one frame such as side-by-side, top-and-bottom. Fig. 6 is the effect picture of a stereoscopic 3DTV GUI on 3DTV.



Fig. 6. The effect show of the stereoscopic 3D web GUI.

VII. CONCLUSIONS

Stereoscopic 3D web is different from existing monoscopic 3D web such as Web3D, WebGL and O3D, in addition the stereoscopic 3D web proposed by us is different from the draft proposed by W3C [11], the differences will be stated as below.

A. Differences between Stereoscopic 3D Web and Monoscopic 3D Web

1) *Different Viewpoint:* The stereoscopic 3D web is obtained by web page from two viewpoints simultaneously based on binocular parallax theory; but the monoscopic 3D web is obtained by web page from a single viewpoint only.

2) *Different Display Device:* A stereoscopic 3D web page is shown on a 3D display device; but a monoscopic 3D web page is shown on a 2D display device.

B. Differences between Our Approach and W3C Draft

1) *Different Extending:* The stereoscopic 3D web proposed by us is extending all of web page languages that are HTML, CSS and JavaScript; but the draft proposed by W3C is extending CSS only.

2) *Different Proposing Time:* The time we submitted the patent of stereoscopic 3D web is in May 2011; but the time W3C proposed the draft is in December 2012.

Our experimental results including stereoscopic 3DTV GUI indicate that stereoscopic 3D web will be a new approach for stereoscopic 3D, and this approach is easy to be extended to support multiview 3D display devices [16].

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