3D and the Web
The last twenty years and the future

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Abstract
A critical view on two decades of 3D graphics "standards" for the Web. Starting with the first W3C standard (VRML) and its evolution (X3D), the reasons for decay and why according to several evidences WebGL, by the Khronos group, seems to be the unavoidable road ahead. Among them, a new phase of "WebGL era" is coming, with full grown 3D applications being WebGL ready.

Keywords
Web3D, Virtual Reality, Virtual Worlds, VRML, X3D, WebGL.

1. INTRODUCTION

In October 2014, HTML's 5.0 final version arrived. It includes in the norm significant definitions for several media (audio, video, 2D graphics) but, against what was expected by some developers. 3D is absent. At least apparently because, on one hand, VRML/X3D[1] - the "official" norm - was not yet revoked although never widely adopted and still relaying on third party plugins. A X3D Working Group inside W3C and the Web3D consortium have been working for years with "the purpose of fully integrating X3D with HTML" (Web3D Consortium, 2011) but had no success; on the other hand another Web Graphics norm, WebGL, proposed by the Khronos group (well known by its open standard OpenGL) is strongly emerging and already runs plugin less over the major web browsers.

Summarizing, this article addresses the following points:

- VRML/X3D: the first 3D graphics standard for the Web
- VRML/X3D technology: what went wrong?
- WebGL, the road ahead for 3D on the Web?
- Tools for designers with some programming skills
- 3D Graphical editors and Web deployers

2. VRML/X3D: THE FIRST 3D GRAPHICS STANDARD FOR THE WEB

Before any attempt to foresee the future of Web 3D graphics one needs to briefly rationalize and review what has been learned from the history of 3D graphics standards on the Web.

In the first years of the Web era (started in 1991) and the excitement over a multimedia global experience, 3D come naturally as the next level. Proposed in 1994 (Pesce, Kennard, & Parisi, 1994) and endorsed shortly after (Bell, Parisi, & Pesce, 1994) by vrml.org (now web3d.org), an organism under w3c consortium, VRML/X3D technology has been around for two decades as "the" intended 3D graphics standard for the Web. Yet, despite this "official" status, it was never implemented natively on any major web browser. Until today, users must consider installing a plugin in order to run VRML/X3D content inside a browser.

2.1 Enthusiasm in the 1990s

VRML looked, back then, cool and unique for the Web. It supported 3D geometry, animation, and scripting (Web3D Consortium, 2015). From the beginning and especially on the second half of the nineties VRML/X3D gathered considerable attention and enthusiasm among artists, engineers and educators. Since it was doing well and achieving an interesting (moderate) widespread use over the Web, the enthusiasm spread, engaging some reference public and private organizations, from NASA to SUN Corporation. Even today search engines still show a significant evidence of the quantity and quality of VRML work done back then. Beside its own potential and "official" status as a web technology, some key important factors have contributed in our view to this early enthusiasm and use of VRML:

- **General Interest/curiosity for 3D**

In the nineties the curiosity and general interest about 3D

[1] We will use the term VRML/X3D to refer the continuity of this technology with two norm versions that coexist, even today.

was growing and the possibility of associating it to the, also new, Web was appealing.

- **Browser Wars and VRML endorsement**

During the first "browser war" days, in mid-nineties, Netscape and Microsoft had their focus on every relevant novelty to promote their browser and, in no time, Netscape Navigator and Internet explorer had, each one, their free VRML plugin to offer. This was in the public eyes an obvious technology endorsement and clear incentive for users and content developers to install VRML capability on their browsers and use/create 3D for the Web.

- **Multiuser worlds, avatars & 3D Communities**

The third key element was surely the quite immediate availability of 3D multiuser solutions. Innovative 3D multiuser (VRML) worlds with avatars, most using technology from "Black Sun" (latter reborn as Blaxxun), formed at Sun Technologies (Dammer, 1997). Black Sun's worlds open in 1997, Cybertown in 1997 (Poster, 2014) and "Le Deuxième Monde" from 1998 are among the most significant and iconic early projects done in VRML. They gathered on the nineties a significant amount of world users around this technology.

It's important to highlight that in addition to 3D graphics, provided by VRML, Blaxxun and others, brought 3D multiuser technology that constituted a solid base for virtual communities on the Web (Blaxxun Interactive, 1998). The solution was quite *easy* to implement, working nicely and well integrated in the Web ecosystem. This looked back then incredibly innovative and appealing, gathering an enthusiastic community which remained the hallmark of VRML and X3D evolution throughout many development cycles (Butzman & Daly, 2007)

3. VRML/X3D: WHAT WENT WRONG?

In this point we rationalize about how VRML/X3D technology changed from a phase of initial enthusiasm to the present low pace.

In 2001 Web3D.org proposed X3D, a new 3D web graphics norm, meant to solidify the VRML path and ideally be included in Web browsers core, avoiding plugin need, but this never happened. Unfortunately in the early 2000s Netscape had already lost the browsers war and the winner, Microsoft, backed the posture of browser innovation, dropped the support for his own VRML plugin and removed it from their site! Moreover, including VRML in Internet Explorer core was also out of the question.

From then on, there were no more "official" VRML/X3D plugins for specific browsers and users had to take the risk of installing a third party plugin. The opportunity was lost and, despite being an official "3D standard for the Web", since then the interest for VRML/X3D technology dropped significantly.

Cybertown, a vibrant and innovative free community until 2001 was sold to IVN in 2002 and started to charge users a fee for membership. That led to a massive abandon. At first users and creators looked for other free VRML/Blaxxun related communities and multiuser servers (even Blaxxun had its own free server). ABNet/Babel X3D[2] was one of them.

In early 2002, Blaxxun went out of business and the support for its free VRML/X3D plugin (Blaxxun contact) was at risk. Bitmanagement took the plugin development, renamed it as bs contact on a new version and ... started to charge for it! The users of their "unrestricted" demo had to cope with an annoying floating logo over the 3D scenes and worlds. Bitmanagement did a fine technical work evolving bs contact to the most recent 3D graphics norms and enhancements, but that ugly logo was probably the last drop that disgusted users and creators.

Many moved away from VRML/X3D to other emergent technology communities, including Second Life[3] that was opening its doors in 2002.

From 2002 on, 3D over the web took a low pace but did not die. The "need" was there but now, instead of one, several 3D technologies along with VRML/X3D concurred to fulfill the demand. Among them Unity3D, with its 3D Web plugin and especially Flash.

> "2001 saw Adobe's notable rise to web 3D power with version 8.5 of their Director software. Featuring Shockwave 3D technology, Adobe Director allowed creatives to produce hardware-accelerated 3D graphics with scripted interaction using the Lingo language. Full 3D browser based games could be created, such as Xform Games' GoKartGo!Turbo!" (Helix Design Studio, 2013)

For the past decade Flash has been regarded as the de facto standard for deploying rich graphics (including 3D) and multimedia on the web. Unfortunately Adobe professional tools remained out of reach from common 3D non-profit or educational creators since they are expensive and the company never had a policy of free tools (as others like Autodesk do, for example).

3.1 The swan song of VRML/X3D

From the VRML/X3D side, among other interesting projects. Vivaty, a 3D virtual worlds community, deserves special mention. One of the VRML founders, Tony Parisi, took the lead of a brilliant team, including Keith Victor (creator of VRML/X3D editors, Spazz3D/VizX3D/Vivaty Editor) and Rick Kimball (creator of ABNet multiuser server) and founded Vivaty in 2007 (Parisi, 2010). In there we could see a new level of professional quality graphics and innovative social interaction rarely seen before in VRML/X3D. It showed how VRML/X3D was a fantastic Web 3D technology up level with others much more recent. Vivaty closed in 2010 and was, in several ways, the VRML/X3D well deserved swan song.

[2] http://www.odisseia.univ-ab.pt/abnet2

[3] Second Life, a non-web 3D technology, uses a specific client program as is out of scope in this paper.

4. WEBGL, THE ROAD AHEAD FOR 3D ON THE WEB?

Now we rationalize about WebGL and the available evidence pointing it as the road ahead.

4.1 What is WebGL?

In mid 2000s the non-profit Khronos group deploys OpenGL ES, a 3D rendering API for mobile and "embedded systems" (ES), based on the desktop long-established 3D rendering standard OpenGL but optimized for mobile/handheld devices. As an industry standard and royalty free, OpenGL ES became universally adopted on small computing devices, most notably phones and tablets to deliver a hardware-accelerated 3D experience.

In early 2009, the non-profit technology consortium Khronos Group started the WebGL Working Group. WebGL is a Web version of OpenGL ES 2.0. The designers felt that, by basing the API on OpenGL ES's small footprint, it would be more achievable to deliver a consistent, cross-platform, cross-browser 3D API for the web (Parisi, 2014).

WebGL is implemented as low-level API JavaScript. It uses the HTML5 canvas element and is accessed using DOM (Document Object Model) interfaces. Automatic memory management is provided as part of the JavaScript language. As such, WebGL runs directly in browsers (desktops or mobiles) without the need for a specific plugin to harness the full power of the computer's 3D rendering hardware. It is today supported by all the major browsers (IE, Firefox, Chrome and Safari) on desktops and mobile platforms..

4.2 Why WebGL? Some relevant aspects

- Technically sound and proved standard. WebGL is based on long experienced, widely adopted, open and free standards and is already supported by all major browsers (IE, Firefox, Chrome and Safari) on desktops and mobile platforms. It is the long waited 3D on the web without plugins!
- It's light and fast. Based on standards with a small footprint, it is more capable to deliver a consistent, cross-platform, cross-browser 3D API for the web and capable to deliver a hardware-accelerated 3D experience using the device GPU directly. We should say here that we were amazed by the incredible speed a demo scene ran on a three year old galaxy note II mobile phone.
- Perfectly integrated in HTML 5 canvas. WebGL wires the GPU to the browser with a JavaScript-based OpenGL ES API, thanks to the HTML5 canvas tag. This means WebGL content is a DOM element (this was never true with VRML, because it operated as a plug-in) and can be manipulated with the same procedural or formatting techniques as any other element. It's finally at reach a seamless 2D/3D web content integration.

4.3 WebGL risks, performance and compatibility

Comparing to VRML/X3D, WebGL as a lower level language is much harder to cope with and direct content creation is for serious 3D graphics programmers.

"WebGL is simply a programming API for JavaScript built on top of OpenGL which is a graphics abstraction layer. Since WebGL makes direct JavaScript calls to OpenGL, content creation is for serious 3D graphics programmers who know how to deal with a 4×4 transformation matrix and who can speak the GLSL shader language fluently. Exposing OpenGL as JavaScript is nice, but we do not expect web-page authors to become graphics programmers …

X3D describes scene graphs and 3D content declaratively. This means that authors define what geometry and interaction belongs in a model, rather than programming the low-level details for how polygons get built and drawn. Authors can write XML descriptions for their content in a manner similar to (X)HTML.

Therefore X3D authoring is much more like Web development. Content creators can also easily export VRML or X3D models from their favorite authoring tool, from whatever format, and publish them using the Web." (Anita Havele, 2012)

There are some concerns with WebGL security risks coming with direct access to the GPU. Due to these risks, initially Microsoft and Apple refused to support WebGL but that changed in time partially because the browsers war is back again and no one wants to be left behind and also because the upcoming WebGL versions addressed the security concerns. According to WebGL Security white paper, by the Khronos Group, WebGL conforms to all the security principles of the web platform and was designed with security in mind from day one.

WebGL performance is in general not as good as native execution - it is limited by the dynamic nature of JavaScript. Even so, performance has increased over time and the current browser implementations do a great job of optimizing it. In situations mostly GPU-bound, we can now expect WebGL to perform very similar to native code.

Universal WebGL availability and compatibility is growing but, in the meantime, here and there problems may occur. We have experienced problems with Android running in virtual machines, which was to be expected, but problems may also occur, as we also have experienced, on systems with older graphics cards (GPU) and/or outdated drivers. In some cases certain features or all of WebGL isn't available. The Khronos WebGL wiki has a list of supported configurations.

4.4 How are the alternatives to WebGL going?

Comparing to VRML/X3D, WebGL advanced clearly in browser support and it's popular "plugin less 3D graphics" feature is highly appealing. Google Trends shows clearly that in search statistics WebGL term has become much more popular than VRML and X3D immediately after version 1.0 launch in 2011 (Figure 1).

On the other side comparing to Flash it did not. Flash has been an incredible platform, done a lot for the web as an interactivity and entertainment platform. The reasons to change from Flash to WebGL in the foreseen future are more "political" than technical.

The exact timing is not entirely known right now but there

is a declared intention (started by Apple in 2010) to end, sooner or later, the support for plugins in major browsers, especially plugins that run proprietary compiled code. It affects Java, Silverlight, *bs contact* (VRML/X3D), Unity 3D Web plugin, Flash and many others. This is one of the reasons why Unity dropped flash to switch all development efforts in the creation of a WebGL deployer.

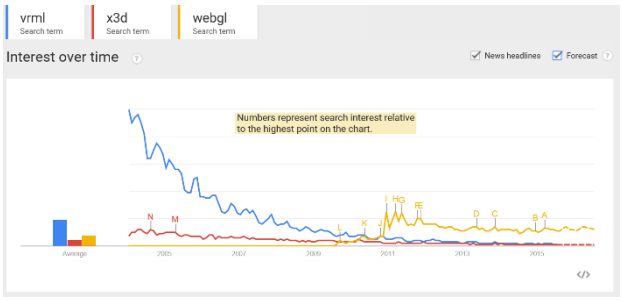

Figure 1 - Comparing VRML, X3D and WebGL Search terms. Source: Google Trends, 2005-2015

Facing an uncertain future, Flash's popularity has been falling in search term statistics (Figure 2).

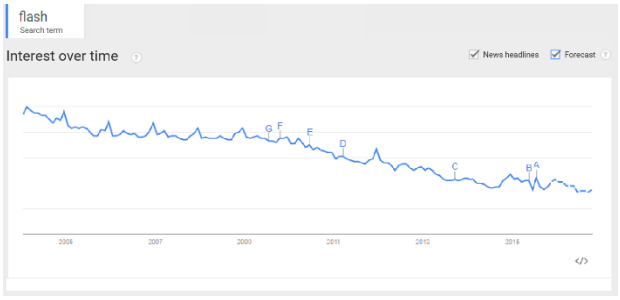

Figure 2 - Flash in Search terms. Source: Google Trends, 2005-2015

4.5 WebGL is already supported on more devices than Flash

"The times they are a-changin'". The declared intentions to end the support for third party plugins in major browsers and the mobile market growth are changing the landscape dramatically and Flash is no longer the largest platform on the planet for interactive browser graphics. Flash is not supported on mobile browsers out of the box; it primarily reaches Mac and PC desktop browsers. On the contrary, WebGL reaches all platforms, desktop and mobile, via the browsers but can also be packaged into native apps and run independent of a browser on both desktop and mobile. It is now supported on more devices than Flash (Krüger, 2014).

With such a wide support for WebGL, the demand for content is growing rapidly and the software industry is already committing. Tool producers are working on WebGL exporters or already have the solutions to offer. Unity 3D stopped Flash export development (the feature was removed in recent versions) and is now committed to WebGL. The recent version 5 outdoes the former Web plugin by a WebGL export format. Even Adobe itself has adapted its professional tools to produce content in HTML5 and WebGL alongside with Flash. Adobes position is incredibly pragmatic and, obviously, endorses WebGL as the road ahead for 3D graphics on the Web.

In the remaining parts of the article we comment about some fundamental tools for programmers and designers to create WebGL content for the ongoing virtual Web.

5. TOOLS FOR DESIGNERS WITH SOME PROGRAMMING SKILLS

Firstly we comment on tools intended for programmers and designers with some programming skills: the JavaScript middleware libraries for WebGL. Intended for creators with programming skills, they are fundamental to convert and create WebGL content.

WebGL is a low level programming language; this means its code appears very technical and, without a layer of helpful abstraction to assist in reading and learning the syntax, it may frustrate designers with low programming skills who want to produce creative, 3D interactive scenes for webpages. Thankfully a good number of developers have already produced tools and JavaScript libraries to help increase the accessibility of WebGL (a popular one is Three.js). These JavaScript "wrappers" provide an alternative set of commands for creating objects in 3D space. For creators with low programming skills, but that don't fear coding, these libraries simplify the development of WebGL applications and the conversion from other 3D formats to WebGL.

5.1 X3DOM

Web3D Consortium's member, Fraunhofer, using WebGL has developed a JavaScript based interface for X3D intended as a useful framework for WebGL development and transition from X3D. It runs in any HTML 5 browser and supports native X3D within an HTML page. Former VRML/X3D creators will find X3DOM interesting since it converts VRML/X3D objects and scenes to WebGL using a X3D interpreter written in JavaScript. It works well for static scenes and simple animations but, to our knowledge, does not implement the full X3D spec; that would be a major undertaking.

This has been a fine development as the projects available in the site (x3dom.org) demonstrate. Although not exclusively X3DOM is of particular interest to VRML/X3D developers.

5.2 Other JavaScript middleware libraries for WebGL

- Three.js (http://threejs.org), is the most popular and has become a reference platform for WebGL development.
  A quick browse of the demos page (http://threejs.org/examples) shows how powerful and practical this library is. Three.js can convert to WebGL from many popular formats including VRML.
- A list of other JavaScript libraries for WebGL is available at: http://www.webgl-game-engines.com/

6. 3D GRAPHICAL EDITORS AND WEB DEPLOYERS

Finally we comment about useful 3D graphical editors to convert and create WebGL content.

6.1 3D editors and WebGL converters

Although JavaScript middleware libraries may be fundamental at some point in the building process, common graphic creators might have a hard time dealing with them. Nothing like using a good graphical 3D editor, indeed. Fortunately a significant number of new editors, tools and plugins (for mainstream 3D editors) appear daily. Look for news and info about them in places such as http://learningwebgl.com/blog/.

One of the most interesting new editors is *Coppercube* (http://www.ambiera.com/coppercube/), a commercial product. It appeared a couple of years ago and was the first WebGL ready 3D editor. It uses CopperLicht, an open source WebGL library developed by the same owner. Coppercube is not (yet) as full featured as mainstream 3D editors like Blender, but is clean, easy to use and has been until now one of the few tools around that made WebGL content development easy, practical and exciting, as its demos and user forums show.

Unfortunately, the absence of a free editor version for nonprofit users and education somehow restrained a potentially larger dissemination that this fine product has merited. Now that the big named editors are committing to be WebGL ready, Coppercube faces a harder fight.

Bitmanagement´s BS Content Studio, a commercial product, is another interesting authoring tool that, in the steps of the company's long experience on VRML/X3D, now also exports to WebGL among other format platforms. Unfortunately, also here, the absence of free versions for nonprofit users and education has restrained Bitmanagement fine products from a potentially larger dissemination.

6.2 Free mainstream 3D editors to deploy WebGL

As we see it today, by the products already in place, the ones coming soon and the intentions declared, Unity 3D seems to be best positioned to build and deploy high quality dynamic Web 3D content, whether it's games or interactive virtual scenes and environments, for multiple purposes. Since Unity is not a 3D modeler, designers will need to choose a modeler. Blender and Sketchup are two among several possible options.

6.2.1 3D modellers

Blender is free and one of the best tools for 3D. Does not have (yet) its own native WebGL exporter, out of the box, but we can install the excellent Blend4Web exporter plugin and enjoy its promising WebGL conversions.

Blender is a complete tool and can also create games (includes its own game engine) and interactive virtual scenes. With Blend4Web plugin scenes with limited interactivity can be deployed to the web but not yet games (not yet at least) nor highly interactive virtual scenes. In a WebGL scenario Blender is much more interesting when used with Unity 3D. In this *duo virtuoso* Blender is the modeler for objects and scenes that Unity (which reads blender files directly) uses as assets to create the action of the game/virtual environment and deploy to end user platforms. Unity manual (Unity Technologies, 2015) has useful info on how to integrate both seamlessly.

One should have in mind that Blender is a serious choice, surely a good one in the long run, but is not necessarily the easiest choice for beginners.

Sketchup instead is a powerful 3D editor, highly intuitive and, from our experience, beginners find it much easier to work with than Blender. Sketchup free version is still a great 3D creation tool and exports to *collada* (.dae), a universal format that Unity3D can import quite well. It has good documentation, instructional videos, a huge collection of free 3D objects and plugins. Adding to this, Sketchup has a legion of followers and tons of free tutorials and resources on the Web.
There are several ways/services to display a Sketchup model in WebGL; the easiest is to upload the model to 3D Warehouse (https://3dwarehouse.sketchup.com) which will render exactly this kind of stream automatically and without cost. Once the model has been processed, can be embedded in any web page.

6.2.2 Scene assembler and deployer

The best placed for the moment is probably Unity3D. The reasons why in our vision is a fundamental tool to build and deploy Web 3D content are:

- It is one of the best tools available to deploy games and dynamic virtual environments on several platforms: desktop, mobile and Web. Unity has committed itself to WebGL, starting on version 5 released in early March 2015. Apart from that it deploys content to more than 20 platforms including the former Unity Web plugin, now overtaken by WebGL.
- Until 2014, Unity 3D had a hardly interesting free version since it did not include some essential features of 3D (like dynamic shadows and advanced water, among others) and that disappointed users. That has changed completely and now Unity3D Editor has the same features on free and paid versions. Only some very "high" advanced features, related to special services and game optimization, more directed to professional developers, are reserved for paying customers. In our view, the free version is totally adequate for non-profit users and education.
- In addition, Unity renewed the interface editor (GUI) starting from version 4.6. The 3D editor is now more intuitive and easier to learn.
- Multiuser worlds have for long been created with Unity using its network capabilities, but it was not an easy task so Unity team has committed itself (in the official blog) to deploy with Unity 5.1, recently released, tools and features that simplify the creation of multiuser 3D environments and games, an area much appreciated by former VRML/X3D creators and from other 3D communities.

6.3 A new phase of WebGL era with full grown 3D applications being WebGL ready

We do not want to promote a specific product, but would not be fair to omit that Unity's commitment to WebGL is

not to be seen as one more in a long list. Unity 3D is the first "big named" 3D/game editor to have a full WebGL deployer (not a limited exporter for simple stuff). As a reference tool for games and interactive virtual scenes/worlds creation with almost everything we need, including avatars, special effects, and so on, Unity's WebGL deployer has to be incredibly advanced, a first of a kind, in order to generate correctly all the interaction and special effects demanded by commercial games.

This defines a new era for WebGL where we change from experiments with limited tools (even Coppercube is an ongoing experiment, some relevant features are not entirely implemented or still in development), limited exporters and "specific" tools to full grown 3D applications that offer in WebGL all we had before for other technologies/3D formats. An article about the first commercially available Unity WebGL game (Schwartz & Nyman, 2014) has important information and is a vivid confirmation of what we said about Unity´s WebGL deployer relevance.

We have commented here on a selection of tools, most free, to deploy 3D on the Web via WebGL. There are, of course, other alternatives and choices, free or paid, to deploy WebGL content.

7. CONCLUSIONS

VRML appeared in the mid-nineties and was rapidly endorsed by main browser producers through their “official” free plugins. This, joined to a relatively accessible language syntax and the novelty effect of a cool and unique 3D standard for the Web, led to a considerable early enthusiasm that has grown rapidly into powerful multiuser technology developments and the appearance of multiuser worlds and communities of considerable dynamism and influence in the nineties.

The 2000s did not bring the expected boom. Despite the norm upgrade to X3D in 2001, VRML/X3D was never included in major bowsers native code. On the contrary, the major browser producer Microsoft, that had recently gained the browser war with Internet Explorer, ended its endorsed free VRML plugin and thus removed millions of users from this 3D technology confining it to a very small market niche. Shortly after, major players like Blaxxun and Cybertown went out of business. Some of their heirs, like Bitmanagement, kept evolving the technology and tried to survive the difficult years but some disregard for nonprofit users, marketing policy and prices, kept moving common users and creators away to other web 3D technologies (among them Flash and Unity3D) and to non-Web as well (like Second Life and Open Sim).

In early 2009, Khronos consortium started the WebGL Working Group and Version 1.0 of WebGL specification was released in March 2011. Developed upon OpenGL ES 2.0 free standard WebGL benefitted immediately from a wide acceptance since it was supported natively by major browsers such as Firefox and Chrome on desktop platforms. The successive announcements of Flash’s inglorious deprecation in major platforms also helped WebGL that widespread rapidly to all major browsers and platforms. The initial lack of good content creating tools for non-programmers has changed over time and now major 3D content creators, like Unity3D, are WebGL ready or aiming to.

Today everything apparently points to WebGL as the major 3D graphics technology running on Web browsers from now on. However, WebGL itself is not a language created for Web designers and direct content creation with the language is reserved for advanced 3D graphics programmers. Middleware JavaScript libraries and mainstream 3D graphical editors reduce this problem significantly but do not eliminate it. At some point, in an exploding 3D on the Web scenario, a Web designer may need to tweak the code directly but WebGL was not designed with that user in mind as VRML/X3D was. Some progress in this regard would be highly welcome

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