Web-based Immersive Analytics in Handheld Augmented Reality

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ABSTRACT

The recent popularity of virtual reality (VR), and the emergence of a number of affordable VR interfaces, have prompted researchers and developers to explore new, immersive ways to visualize data. This has resulted in a new research thrust, known as Immersive Analytics (IA). However, in IA little attention has been given to the paradigms of augmented/mixed reality (AR/MR), where computer-generated and physical objects co-exist. In this work, we explore the use of contemporary web-based technologies for the creation of immersive visualizations for handheld AR, combining D3.js with the open standards-based Argon AR framework and A-frame/WebVR. We argue in favor of using emerging standards-based web technologies as they work well with contemporary visualization tools, that are purposefully built for data binding and manipulation.

Keywords: Immersive Analytics, Augmented Reality, Web standards

Index Terms: H.5.2 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities.

1 Introduction and Background

The emerging domain of Immersive Analytics (IA) has been attracting attention, as researchers explore new, engaging and immersive ways to display data, and collaboratively interact with it [1]. As the way we interact with computers evolves, whether we use mobile devices, head-mounted displays, or gestures etc., we are taking steps away from our desktops, and walk into a mixed reality world of ubiquitous and progressively data-driven information [2]. The ultimate version of this mixed reality is a world akin to the one described by Vernor Vinge's novel, *Rainbows End* [3], where our physical environment is enhanced by ubiquitous, networked digital artifacts. In this world humans wear context-aware smart-clothing and mediated-reality technology is everywhere. Although this vision currently belongs in the realm of science fiction, we have already started exploring how it can be realized. Yet, what we have only recently began to explore is how we can depict data-driven interactive visualizations, in MR.

MR, inclusive of the paradigms of AR and Augmented Virtuality (AV) [2], has been attracting significant interest in this decade, aided by the rapid evolution of 'smart' handheld devices. The recent introduction of interfaces such as the Microsoft Hololens, or frameworks like Google Tango has increased the 'hype' around MR technology and its potential applications. Moreover, MR has always been influenced by advances in the neighboring field of VR, mainly due to the graphics-centric nature of both paradigms. Nowadays, a developer can use the same game-engine ecosystems to create content, both for VR and MR.

However, there have been significant efforts to explore content creation for VR/MR in a Web context. These are driven mainly from efforts to investigate the prospect of standardization and interoperability in AR/MR [4]. Standards like WebGL, ARML, X3DOM and the more recent WebVR form a mosaic of tools that developers can use to create graphical content, suitable for VR and MR on the Web.

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In addition, a number of JavaScript libraries and toolkits provide support for creating MR content on the Web, and recently the mobile Web. Such is the Argon [5] framework, used in this work. The Argon system (browser and JavaScript library) is inspired and motivated by the aforementioned standardization efforts in Web-based AR/MR.

This is where opportunity lies, for Data Visualization. As a large number of contemporary tools for visualization are based on Web technologies, there is scope in exploring the synergy between these tools and the emerging Web-based ecosystem for MR. In this work we investigate this synergy, between the versatile visualization library D3.js [6] and the Argon framework, towards creating basic handheld AR data visualizations. We explore the compatibility of the frameworks and provide a basic demonstration of alternative 3D visualizations.

2 Related Work

The emerging research thrust of IA [1] builds upon the recent advances in graphics and interface technologies, which appear to have reinvigorated the fields of VR and MR. IA is the latest incarnation of a long-standing effort of visualization researchers and developers to explore visual data exploration and analysis away from desktop computers and Window-Icon-Mouse-Pointer (WIMP) interfaces [2]. Yet, although a number of researchers have started exploring the application of different flavors of VR in analytical reasoning [1], very little exploration has taken place using AR/MR. The reason behind this is in our opinion twofold. Firstly, the inherit challenges of MR, i.e., registration and *in situ* interaction are ever present, and cumulative to challenges related to data visualization and analysis. Secondly, the tools for creating MR content have been mainly side-products of those used in VR, and therefore more targeted in replicating physical objects using computer graphics. Thus, they lack mature mechanisms for displaying abstract data-driven information, data loading, data binding and related manipulations.

Nonetheless, some investigation has focused on MR-based data visualization. For instance, the work by ElSayed et al. [7] investigates how AR can be used to link visual information and objects in physical space. They propose an adaptation of the Visual Information-Seeking Mantra, as *"details first, analysis, then context-on-demand"*. Lu et al. [8] review the current state of mobile immersive VR/MR, in relevance to the fields of big data and data visualization. Likewise, Sadana et al. [9] discuss lessons learnt from designing multi-touch interfaces, extrapolating them to VR and AR. Luboschik et al. [10] investigate the effect of spatial cues in data visualization, advocating the need for adaptation of existing non-data related VR and AR approaches.

3 Our prototype

Our prototype is using a combination of emerging, open standards-based web technologies for the creation of 3D graphics on the web, and the established data-visualization library D3.js. At the core of our prototype, we use the Argon4 Augmented Reality browser [5], from Georgia Tech. Argon4 is an open-standards browser that works on iOS and Android, and is especially suited to display AR content created with Argon.js. The latter is a framework, originally built for the Argon browser, but now supporting other WebRTC compliant browsers (albeit not fully, as features in these browsers are being introduced gradually).

The latest version of Argon.js includes AR-specific extensions of A-Frame/WebVR (https://aframe.io/), which is an entity component system (ECS) for the 3D JavaScript library Three.js. Specifically, AR-Frame allows the inclusion of AR content in a Web page, using essentially the same mechanisms of A-Frame for primitives, entities, transformations, attributes etc. AR-Frame registration mechanisms can be (geo)location-based, or marker-based and provided via the Vuforia AR platform (https://www.vuforia.com/). Argon4 also allows the view to be split, for stereo viewing, through a Cardboard HMD, or similar.

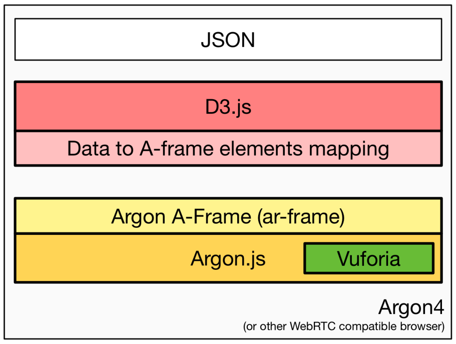
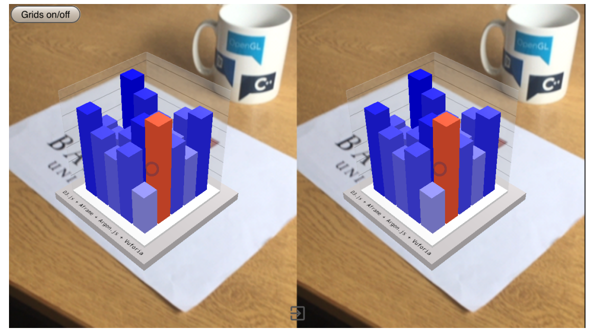
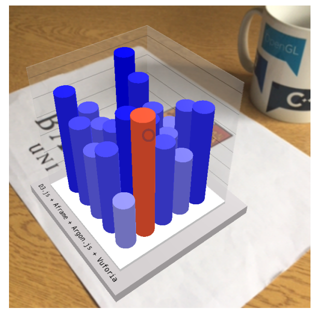


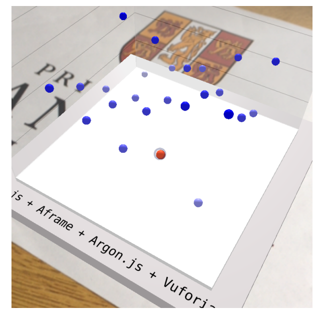
Figure 1: The stack of our prototype application comprises of D3.js for data binding, Argon.js and the Vuforia tracking, all displayed within the Argon4 browser.



(a)



(b)



(c)

Figure 2: Different depictions of the same data set. Top image (a) shows a split screen view of our application, for use with HMD viewers. Marker registration is handled by the Argon framework and Vuforia. The on-screen cursor is used to highlight different bars. The 3D visualization can be rendered with cylinders, using `<a-cylinder>` (b), or as a scatter plot with spheres, using `<a-sphere>` (c). Bar, cylinder and sphere color is dependent on the data value.

In our prototype (see Fig.1), data binding and manipulation is handled by D3.js. The data is read from a JSON file and mapped into a 3D bar-chart using A-Frame's `<a-box>` for each bar. The mapping of the data to 3D objects, and their properties, is an important component of such AR data visualizations, in addition to combining the aforementioned JavaScript frameworks together. Although we use a bespoke mapping, we can envisage a series of generalized mechanisms that could be used to prototype different 3D depictions, and accommodate different data-sets. Such mechanisms are currently our work-in-progress.

Aside from handing the actual data values and mapping them to 3D bars, D3.js provides color information for each bar, based on the data value, using a standard linear color scale (see Fig.2a and Fig.2b). As A-Frame (and Argon's AR-Frame) are using the DOM, integration with D3.js is simple, seamless and powerful. In terms of interaction, we have currently enabled data highlighting using an on-screen cursor. Obviously, moving and rotating the physical marker (or the handheld device) changes our viewpoint, of the 3D depiction. As an additional exploration component, we have added a semi-transparent grid at two sides of the 3D graph, which can be toggled off to avoid occlusion problems.

4 Conclusion and Future Work

Our prototype application combines the versatility of D3.js, in terms of handling data, with the capabilities of the Argon framework, for doing handheld AR/MR. To our knowledge, this is the first demonstration of this combination, and albeit simple, it demonstrates the strength of the synergy, between these frameworks.

Beyond a proof-of-concept, our prototype allowed us to perform a preliminary user-experience investigation. The users were very positive, mentioning that the registration was robust, and rendering fast and smoothly on an iPhone 6s. However, users also stressed that some form of bar annotation was needed, and that more complete highlighting and selection strategies would be useful. We plan to investigate further these suggestions, in parallel to our exploration of the synergy between data visualization libraries and open standards-based Web technologies, towards building more examples of immersive analytics in MR.

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