ABSTRACT
In this paper, we describe the evolution of web-based applications in the context of data visualization, with respect to the capabilities of modern day browsers in terms of performance and graphical complexity.

CCS Concepts
• Human-centred computing ➔ Visualization ➔ Visualization application domains ➔ Information visualization.

Keywords
Data visualization; information visualization; web applications; three-dimensional graphics.

1. INTRODUCTION
People have been generating and subsequently visualising data over a long period of time. Indeed there is reference to the English mathematician William Playfair[1] using bar and line charts as far back as the 18th century.

Modern society generates vast quantities of data; “big data” appears to be ubiquitous in present day terminology. The sources of this data are many and varied; financial, scientific, healthcare, economic, political, sports, architectural, social media; the list is seemingly endless. With all this data comes the need to visualise, interrogate and interpret all the information to extract some form of pattern or meaning.

How, then, do we deal with the large quantities of data, both in terms of access and distribution and what tools are available to allow us to gain a better understanding of the underlying patterns or areas of interest?

2. VISUALISING DATA
A few decades ago the process of obtaining and then visualising such information would typically consist of loading information into a spreadsheet application (or similar) and generating common visual representations such as graphs, bar charts or pie charts for example. Although such visualisations are still in regular use, data is now more plentiful and complex, often containing multiple dimensions and therefore requires the relevant interaction metaphors to identify and interrogate the information accordingly. Figure 1 shows a comparison of typical visual elements with a common bar chart on the left compared to an interactive three-dimensional visualization on the right.

Figure 1 – Visual Elements
There are numerous desktop visualisation tools available such as Excel [2], Tableau [3] and Matlab [4] to name but a few, as well as a programming languages and tools such as R [5] or Processing [6].

A common workflow for this type of application typically consists of: installation; data acquisition; visualisation and interrogation; results. Although there is nothing inherently wrong in this method, does a web-based approach offer any advantages or improvements?

3. WEB VISUALISATIONS
Web applications offer a different workflow to that outlined above. They differ in terms of installation, distribution and accessibility. We will explore these options below.

3.1 Data Distribution
With web applications there is no concept of having to install anything; no plugins or additional components. Traversing to the required url usually instigates the process. Any associated data may typically reside on the same server as well (or via some form of cloud-based architecture) so the data acquisition phase may be inherent in executing the application. This efficiency is further amplified by the ease of access. The visualisations and the distribution mechanism is available to everyone who has access to the internet. Therefore the target audience/customer base is vast. But perhaps one of the most appealing aspects is that not only is the distribution of the data very effectively managed but so is the interpretation of this data. You are typically met with a ready-made visualisation; there is no requirement to point the application at some dataset, unless you specifically wanted to (and you would hope that well-designed application would allow for a high degree of customisation anyway).

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3.2 Accessibility
When the above facets are also coupled with the accessibility of such applications then their potential becomes even greater. As the visualisation is running inside a web browser then, in theory, they can be executed on any web-enabled device. This means that they may be viewed on a whole range of devices in a whole range of differing scenarios; from desktops to tablets to mobile devices and all irrespective of the host operating system. This also makes development a lot more straightforward as only one application needs to be developed which can then run on multiple devices (obviously there are irregularities between differing browsers and devices but these are being minimised all the time with the uptake of browser standards and the associated software libraries continually catering for the discrepancies).

3.3 Performance
Another important aspect is that of performance. Do web applications offer the same interaction experience as their desktop counterparts in terms of richness of interaction and speed of execution? In short the answer is yes. There are now numerous web-based visualisation tools that offer capabilities that compare very favorably with native applications such as D3.js [7], Google charts [8] or timeline.js [9]. Indeed there are numerous resources available to end users and developers alike to enable all manner of visualisations to be implemented and/or created [10].

3.4 Graphical Complexity
One of the main contributory factors in the evolution of web-based applications is the advancement of graphical capabilities within web browsers. The modern web browser can not only display detailed two-dimensional graphics typically associated with visualising information; graphs, bar charts, scatter plots for example, but now complex three-dimensional graphics are commonplace [11]. Figure 2 shows a three-dimensional interactive modelling tool, complete with an extensive user interface to afford all the necessary interactions, executing from within a web browser.

Figure 2 – Modelling Tool
This functionality allows for much more complex multidimensional data to be explored, offering such capabilities as watching time-varying data evolve, animation, simulation, investigating subsets of the data, etc.

New application areas in the data visualisation sector are also starting to emerge. Information can be accessed on mobile devices in remote locations; presentations may be web-enabled offering interactive demonstrations targeted at specific audiences and the real-time nature of the internet means that data may be delivered at the instance that it is generated and consumed by eager audiences.

4. REFERENCES