Serviceable Visualizations

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Abstract— *The term 'Serviceable Visualizations' encompasses the diversified visualization architecture proposed in this paper as an alternative approach to traditional visualization approaches. It is proposed specifically to harness the facilities and capabilities that cloud computing can provide. The architecture is composed of service packaging of visualizations including plug-in architecture and interfaces needed for end-user manipulation, parameterization and linking; a diversity virtual exchange to provide the matching of end-user requests with the visualization services and a lightweight client framework on the end-user local platform for the display of the visualizations. A discussion of grand research challenges and the recent work of the author to address these challenges is also included.*

Keywords: Visualization, Cloud Computing, Visualization Service

1. Introduction

There is a lot of recent interest in cloud computing and the related virtualization of cyber-commodities, the service packaging of the commodities, and the delivery of such to the end user. Literature abounds, from research oriented papers that describe cloud computing (see for example, [1], [2], [3]) to popular World Wide Web based literature (see for example, [4]). Commercialization of this infrastructure is fast developing and many vendors are involved in various aspects related to cloud computing (see [5], [6] for vendor lists). Clearly, cloud computing and related areas have 'caught-on'.

Visualization is a powerful way in which to present information to end-users. It is widely adopted and popular and comes in many forms, from spreadsheet charts to scientific presentations of molecules; and varies in fidelity, graphical user interface (GUI) designs, interactiveness, and in many other ways. Some common aspects that pertain to many modern day visualizations include the manipulation of images: an animation (video) is composed of multiple image frames shown in sequence; scientific visualizations usually provide for user-directed interaction for scaling, panning (scrolling), zooming and/or rotation of images. Such manipulations require computational capability and potentially large data (imagery) capability. Furthermore, user interactive visualizations require a real-time quality of service. These requirements are often exacerbated for high fidelity visualizations. On the one hand, locally generated visualizations on user platforms require computational and data storage support on the user platforms, and on the other hand, remote generated visualizations require such support on the remote platform, and in addition require sufficient communication and local platform quality of service necessary to provide for the real-time requirements. As technology and infrastructure changes, the relative capabilities to support either local or remote visualization also changes.

The focus of this paper is to present a position on local and remote visualizations in the context of the cloud computing infrastructure. The rest of this paper is organized as follows. Visualization as a service is discussed in the next section. Section 3 describes the proposed service infrastructure and Section 4 describes the issues that motivate future work. Conclusions are given in Section 5.

2. Visualization as a Service

The end-user community is diverse in user needs, experiences, knowledge and skills. Broadly, the end-user community includes scientific users, commercial users, decision makers and general users. Typically, the scientific community has specific needs in understanding some model as it relates to a scientific experiment, simulation, process, etc. These visualizations tend to be high fidelity, interactive to allow the user to explore the data and thereby requiring regeneration of possibly many images, perhaps also including animation; moreover, data set sizes may be very large. Commercial users tend to also require high fidelity visualizations so as to produce the 'wow effect'; single images suitable for printed media are common, however, online presentations, for example, flash or video on websites would require multiple images. Decision makers are interested in having as much information and facts, particularly, trend analysis related information, so as to be able to make mission-, life- or cost-critical decisions, or to set policy. Visualizations for this group would range from moderate to high fidelity, for example, cost-critical decision making facilitated by 2D trend graphs could be presented in moderate fidelity visualizations; however, life-critical medical diagnosis needs would be best served by high fidelity visualizations. As well,

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degrees of interactiveness and data set sizes would exist depending on the nature and requirements of the decision making community. General users include the 'home user', the 'school user', etc. and tend towards low-to-moderate fidelity, more moderate data set sizes, less stringent real-time interactive requirements. Even within this breakdown, specific user needs, experiences, knowledge and skills suggest a wide-range of potential visualizations.

The current approaches to visualization 'on the cloud' are mainly monolithic and are extensions of the current day remote visualization approaches providing cloud-enabled remote visualization engines and renderers that send images to the local client machine for user viewing. Examples include the visualization system by NICE [7] and Sun's approach [8]. Such visualizations are particularly aimed at specific end-user communities providing specific sets of capabilities. This approach provides high-end graphics capabilities by centralizing the visualization resources thereby enabling end-user access to such visualizations that may ordinarily not be available locally. However, in the 'bigger picture', the limitations by not designing a diversified architecture lead to multiplicity of visualization-type services, essentially replacing the current on-local-platform models with corresponding services. And, users would still need to identify and learn the appropriate use of the software. Portability may not be ideally provided, and cross end-user community access would also be limited.

A visualization architecture that is parameterizable and service oriented is needed in which to support the grand scope of end-user visualization needs. Such architecture could address many of the issues raised in the previous paragraph, in particular, addressing the wide-range of possible visualizations. However, providing this diversified architecture for visualization is challenging; this motivates this paper and the subsequent discussion. Cloud computing provides both the vision and infrastructure to consider this alternative approach. Figure 1 illustrates the overall visualization community that would be enabled by considering a diversified approach to visualization.

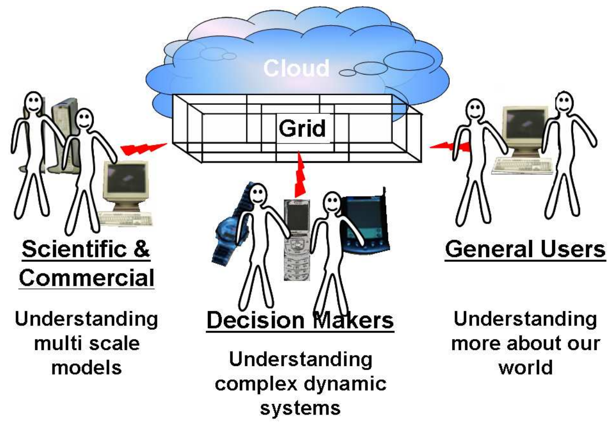

Fig. 1: The visualization community

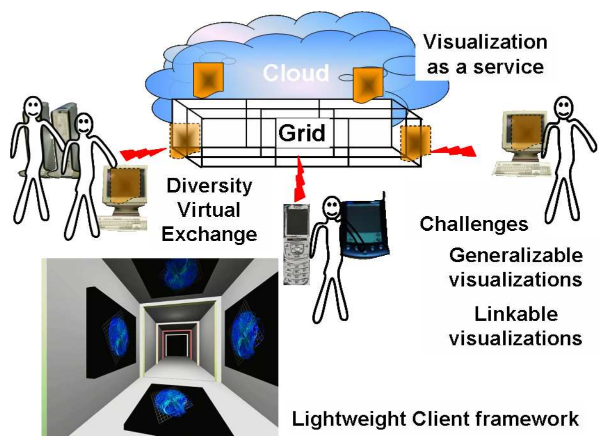

Fig. 2: Components of Serviceable Visualizations: Visualization as a Service (virtualization), Diversity Virtual Exchange, and a lightweight client framework; with grand research challenges.

3. Service Infrastructure

Visualization as a service in a diversified architecture requires several components that include virtualization of visualization and its service packaging so as to accommodate the diversification in the visualization, a diversity virtual exchange so as to accommodate the 'matching' between end-user needs and requirements and the visualization service, and a lightweight client framework so as to provide portability and consistent user experiences across visualizations. Figure 2 illustrates the proposed diversity in visualization architecture approach that is enabled by cloud computing. These are discussed subsequently.

3.1 Virtualization

Visualization itself is 'guided' by a number of models, whether implicit or formally explicitly defined. A presentation model guides the visual display of information (e.g. a 2D graph model consists of two axis and a relationship between the axis associated variables drawn as a bar, line or point). The visualization algorithms are usually defined over an internal model that structures the data. Other models that influence the visualization and its processes may also be defined. Where a visualization is well-defined by models, the models may allow the visualization to be parameterized, thus also providing a semi-automatic way in which to develop the visualization. Charting wizards are a particular example of such successful parameterization of the visualization-related models.

Once a visualization is virtualizable, then it needs to be connectable to the lightweight client framework. A plug-in architecture is common nowadays to accommodate such connections. As an example, many spreadsheet and document preparation software provide charting facilities and the incorporation of the final chart visualizations into the document. The more advanced visualization models presented in [9], [10], although at present are only very roughly plug-in enabled, may be extended and adapted to be more generally plug-in compatible.

3.2 Diversity Virtual Exchange

The end-user community is diverse in user needs, experiences, knowledge and skills. A diversity virtual exchange facility is needed to as to provide a 'matching' of user needs and requirements with visualization services (i.e. so as to be able to select the best visualization plug-in). It is expected that end-user roles would be relatively fixed and vary only slightly from specific application to specific application, for example, a medical user would most usually be interested in the high fidelity imagery for diagnosis. At the same time, there are likely to be many parameters that would be need to be recorded on a permanent basis so that the user would not need to re-specify for each time a visualization is requested.

The technical infrastructure includes both local and remote visualization support. In some situations, the end-user needs may be best served by a combination of local and remote visualizations; given that the service packaging may provide either individually, or both. The diversity virtual exchange also should provide evaluation of such factors as the computational (graphics) capability, data storage and communication bandwidth together with the local or remote nature of the visualization service package so as to provide the best matching of service for the available technical infrastructure as well as the needs of the user.

The implied economics (see next section) suggests a supply-and-demand model for visualization users and visualization plug-in suppliers. A publisher-subscribe (pub-sub) model would be highly suitable to providing both the persistence and economic related aspects needed by the diversity virtual exchange. Such pub-sub models are nowadays common and the implementation of such should be rather straightforward. A web-portal interface is envisioned to provide the user-interface.

3.3 Lightweight Client Framework

A lightweight client framework at the end-user point is needed to accommodate the various kinds of end-user devices. At the higher end, traditional CAD/CAM and visualization workstations as well as modern day desktops and mobile computers (e.g. laptops) commonly have moderate to high end graphics cards, Internet connectivity and multi-core processors that can provide for local manipulation of data and visualization. At the lower end, cell phones, PDAs, etc. have little capability in providing for local computer support of visualizations. Yet, these lower ended devices would typically be more useful in assessing merely the most important and salient aspects of the data; corresponding visualizations would not require computer intensive support. A lightweight client framework providing consistent user experiences which is sufficiently flexible and adaptable to accommodate the presentation of diverse visualizations is needed.

Visualizations within visualizations is a term defined here to refer to the visual semantics of the framework. In order to provide consistency in user experiences across the broad diversity spectrum of the end user communities, the framework should provide a visual context within which the particular visualization service is displayed. For higher end platforms, the framework can make this context explicitly visible whereas for lower end platforms, the context can be implicit. There are likely several visualization presentation models that can be designed to accomplish this. The model presented in [11] could be extended and adapted to provide for this framework: specifically, in this model, a linear corridor metaphor is used with wall, ceiling and floor mounted windows organized into rooms; visualization services could be plugged-in to the windows. An artist's conception that depicts this visualization model is shown in the lower-left of Figure 2.

4. Issues

The proposed diversified architecture, while addressing the needs of the diversified end-user communities, nevertheless poses significant research and development challenges. This section discusses some of the major issues involved.

4.1 Generalizable Visualizations

The plug-in architecture suggested for connectivity of visualizations with the lightweight client framework requires a packaged visualization with a well-defined interface. Although charting is based upon a well-defined explicit model allowing for such packaging, in general, visualizations by its very nature have much less affinity for formal explicit model definitions. This suggests a varying degree scale of formal model basis: at the well-defined degree, specific designed visualization models can be crafted and parameterized leading to packaging with examples of the afore-mentioned charting facilities and specific visualizations aimed at domain restricted applications such as medical imagery; at the moderate-defined degree, classes of visualizations defied by the application of more general techniques such as isosurface- or contour-based data visualizations have semi-to well-defined models that are amendable to parameterization however the holistic modeling and subsequent parameterization may be much more difficult, examples include the associated graphical user interfaces available in AVS/Express (a well-known and high-end visualization tool); at the low-defined degree, packaging of visualizations that consist of crafted scenes is problematic. It would seem that the incorporation of guiding models is needed to satisfy the packaging nature of the proposed diversified visualization architecture. Yet, the attempt to formalize visualizations in the literature has resulted in a plethora of model approaches and models, some of which may be difficult to reconcile. And the attempt to do so may be contra to the notion of visualization as artistic and aesthetic.

The challenge is to adopt a balance between formalism and freely accessible visualizations so that parameterization and packaging is possible: that is, Generalizable Visualizations.

4.2 Linkable Visualizations

Packaged visualizations downloaded as plug-in modules must link-in with the lightweight client framework and must be consistent with other such plug-ins. Whereas the framework is designed for such requirements, packaged visualizations must also be so designed. This imposes additional design requirements on the package which could influence the visualization model itself. Constraints and conditions for intra-plug-in linking need to be added to the visualization packages. For example, glyph-based data visualization (say vector (arrow) glyphs) and isosurface visualizations are consistent over the same data set, but such could be inconsistent with charting or graph-based visualizations (depending on the nature of the data set). Although linking seems simple enough for obvious cases, more thoroughly, many factors are involved; some of which include the nature of the data set and the derived data (e.g. trend analysis), the requirements of the user-communities and what information is wanted to be understood, and the technical details of such implementation. Ideally, a meta-model that provides for composition of packaged visualization modules would address these issues; however, it is problematic that such modeling can be successful in general, especially in light of the comments in the preceding section concerning the nature of visualization modeling.

The challenge is to determine an appropriate meta-model that can capture the essentials necessary to linking plug-in visualization packages but at the same time not placing restrictive upon the visualizations.

4.3 Commodity Economics

It is clear from the direction of cloud computing that the proposed diversified architecture for visualizations would also follow the same direction; specifically, the technical infrastructure providers of package storage and delivery, service providers providing the visualization plug-ins and service enablers providing the 'how to' skills are cost-associated and profit-motivated entities. The nature of visualization is to facilitate end-user understanding of the data and often the end-user has the mind frame of information exploration. At the other extreme, end-users could be interested in generating finalized visual images to be incorporated into their own for-profit endeavors. Moreover, end-user visualizations could be combined with other activities such as news perusing or scientific simulation and modeling, some of which may be also cloud-enabled. Lastly, visualization itself requires compute, data storage and sufficient communication bandwidth. The cost structuring of packaged visualizations is likely not to be a one-size-fits-all solution; therefore, appropriate cost models taking into account these different (and perhaps contradictory factors) needs to be considered. Perhaps the 'best' way is a 'free-service' approach, that is, provide the visualizations as a 'service' to the end-user communities since, in many cases, end-users could understand the implications of the data 'faster' and 'better' and thus utilize other cost-associated services more wisely.

The challenge is to determine an appropriate cost-model that fairly distributes the cost-profit of serviceable visualizations without limiting the potential and use of the visualizations.

5. Conclusion

The term 'Serviceable Visualizations' encompasses the diversified visualization architecture proposed in this paper as an alternative approach to traditional visualization approaches. It is proposed specifically to harness the facilities and capabilities that cloud computing can provide. The architecture is composed of service packaging of visualizations including the plug-in architecture and interfaces needed for end-user manipulation, parameterization and linking; a diversity virtual exchange to provide the matching of end-user requests with the visualization services and a lightweight client framework on the end-user local platform for the display of the visualizations.

Visualizations have unique aspects that pose challenges to the design and implementation of serviceable visualizations: including the computational, data storage and communication bandwidth technical requirements, visualization modeling needed to define and design visualizations as a service, and the cost structuring of ensuring fair but widely available visualizations. Clearly, further research in addressing these issues is much needed.

The author has already begun working on adapting several visualization models and defining new models, techniques and approaches as foundation-building for serviceable visualizations. At present, such endeavors are only in-the-rough. To a large extent, this paper identifies the necessary requirements, issues and implies a future direction of research. Time will tell...

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