Towards a Design Space Characterizing Workflows That Take Advantage of Immersive Visualization

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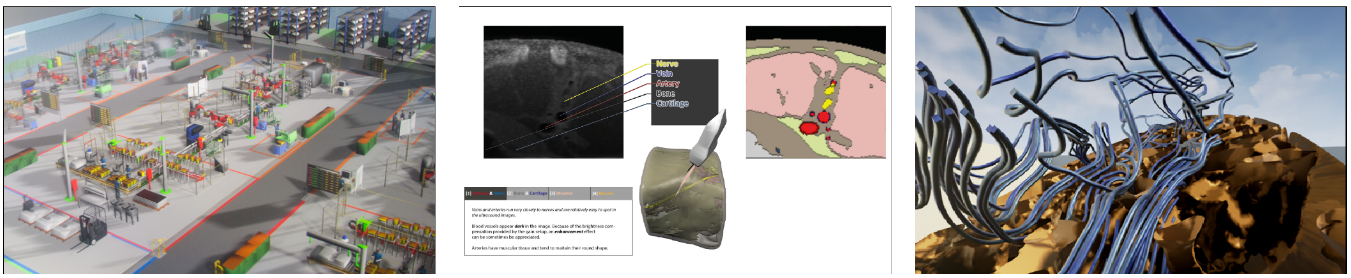

Figure 1: Representative workflows: factory planning (left), medical training (middle), scientific data analysis (right, model geometry by TACC/FIU).

Abstract

Immersive visualization (IV) fosters the creation of mental images of a data set, a scene, a procedure, etc. We devise an initial version of a design space for categorizing workflows that take advantage of IV. From this categorization, specific requirements for an actual, seamless IV-integration can be derived. We validate the design space with three workflows investigated in our research projects.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality

1 Introduction

Immersive Visualization (IV) has the potential to support workflows like virtual factory planning, medical training, or scientific data analysis. Setting up such workflows does not only include the combination of tools but raises additional requirements. For instance, the data to be visualized needs to be transferred and transformed to and from the IV system (i.e., data integration); the system has to be documented well to facilitate its use in the workflow's tool set implementing it (i.e., software integration); and finally, the required virtual reality (VR) hardware and interaction methods have to be properly integrated to enable seamless transitions between those steps in the workflow that use VR and those that do not [4].

A seamless experience is achieved when the user can switch to and from IV with as few manual steps as possible. For instance, the user may create a visualization of a scientific data set outside a VR environment for later exploration using IV. Due to proper integration, data is then automatically transferred into the IV system.

We propose an initial version of a design space for characterizing workflows that take advantage of IV. The design space shall support system designers in selecting strategies for integrating VR technology into such workflows in order to facilitate seamless IV.

However, this work is only the first step starting a discussion on actual, seamless integrations of IV into the workflow. For this purpose, we devise the design space (Sec. 2) and validate it by three representative workflows from our projects (Sec. 3). Furthermore, we outline missing work and possible research directions (Sec. 4).

2 Design Space for Seamless IV

Using IV on the one hand is governed by the same tight constraints as the VR system that is used to facilitate IV: it requires a stereoscopic display, high frame rates, and low latency in order to immerse a user. On the other hand, the workflows pose requirements that can be characterized with respect to six dimensions. These span our initial design space for the seamless integration of IV:

Frequency specifies how often a user switches between IV and non-IV parts of the workflow. The more often they switch the less cumbersome ought to be the transition.

 # users approximates the intended number of persons simultaneously using the system in a single, shared, or collaborative fashion.

Interactivity characterizes the number, the variety, and the complexity of interactions with the IV.

Hardware categorizes the hardware spectrum ranging from a head-mounted display (HMD) to a CAVE in order to use the IV.

Availability characterizes how easy the IV system can be obtained, built, operated, reached, etc.

Costs estimates the required resources, e.g., the financial budget or the time needed to switch contexts (VR, non-VR).

Note that some dimensions are not independent of each other. For instance, using a CAVE requires a significantly larger budget and has lower availability than using a consumer HMD.

3 Representative Workflows

This section validates the initial design space by characterizing a set of representative workflows investigated in our research projects.

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Table 1: Initial dimensions of a workflow characterization.

Dimension	Fact.Plan.	Med.Train.	SciVis
Frequency	very low	low	high
# Users	multi	single	single
Interactivity	medium	high	medium to high
Hardware	CAVE	wide range	HMD + controllers
Availability	low	high	low, eventually high
Costs	high	low to high	low

All of them benefit from IV. Nevertheless, each has distinct characteristics. The initial design space and how the following, exemplary workflows integrate into it are presented in Tab. 1 and Fig. 2.

3.1 Factory Planning

Factory planning includes designing the layout of a factory considering the underlying production process, the physical dimensions of the used machines, work benches, etc., the storage of resources as well as meta information on resource flows, time and complexity of individual production steps. Furthermore, it considers legal rules, e.g., defined in industrial and employment law. The original workflow includes software tools which enable the designer to arrange the various involved machines and working sites as well as tools to analyse the resulting design, e.g., focusing on resource flows. However, in the original workflow the tools do not enable the designer to gain a spatial understanding of the designed site.

IV can help gain the needed spatial understanding. An example for such tools is flapAssist [1] (Fig. 1, left). This tool provides the planned factory including models of machines, work benches, etc., in an immersive virtual environment. Furthermore, additional abstract representations for resource flows are included, as well as interaction concepts for adding annotations to the 3D model during visual inspection [3]. Using IV for this workflow in a CAVE enables collaborative work: several persons can simultaneously inspect the design and discuss possible drawbacks or extensions. By means of an additional device such as a tablet, changes can be directly applied to the design and simultaneously be visualized in the CAVE.

3.2 Medical Training

Medical training is necessary to enable students to execute specific treatment procedures without negatively affecting a patient's health. One specific example is training to interpret ultrasound images [2]. A basic procedure uses static images and videos explaining how to identify anatomical structures in ultrasound images. Aditionally, training with real ultrasound machines is conducted. However, the limited availability of these machines leads to a gap in training.

Using an immersive ultrasound training simulator will likely fill this gap: students explore a simulated tissue model of the human body by using a virtual probe that is coupled to a haptic feedback device. The probe's position, the explored body part, and the simulated ultrasound image are experienced in an immerse virtual environment (Fig. 1, middle). Through continuous exploration, the student learns how to recognize specific structures and tissue types.

Extending the classic workflow by a simulation enables students to train even at home since haptic feedback devices are affordable nowadays (e.g., Novint Falcon[1]: approx. 250 US$). User studies have shown that this type of training simulators supports the understanding and learning of the ultrasound imaging procedure.

3.3 Scientific Visualization at the Workplace

The amount of data generated by numerical simulations or collected by sensors is growing in size and in complexity. Consequently, sophisticated visualization tools like ParaView[2] or VisIt[3] are required to interactively explore the data. However, the topology of the data is often highly complex. Thus, working on a 2D screen and navigating with mouse and keyboard hinders intuitive understanding.

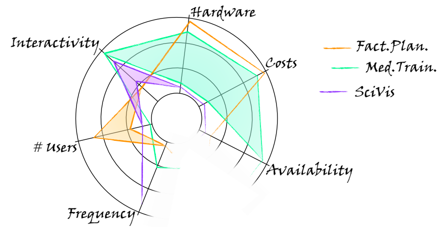

Figure 2: The workflow characterization depicted as radar plot.

IV has a long tradition in scientific visualization (SciVis) using, e.g., CAVEs. However, these are very expensive and require the scientist to change location to experience the data in IV. Recently, the advent of inexpensive HMDs and required hardware can bring a very similar experience directly to the workplace of every scientist.

Even though SciVis tools often provide pre-packed rendering engines for stereoscopic displays, their architecture is often not geared towards the requirements of today's HMDs. Consequently, separate tools are used to provide IV: sophisticated game engines like Epic's Unreal[4] offer a wealth of rendering and interaction capabilities, support all modern HMDs, and support a broad range of data.

Currently, the data transfer between the SciVis tool and the game engine requires many manual steps like geometry pre-processing, defining collision and interaction proxies, or defining the navigable space. Thus, there is no seamless transition to and from IV, yet. Furthermore, these manual steps require supervision by a computer-graphics expert. Nevertheless, we plan to automate the whole process based on requirements devised by surveying end-users.

4 Discussion

We have presented an initial version of a design space for IV workflows. We have validated it by means of three representative workflows, covering it almost entirely. However, we still consider the design space incomplete: more dimensions are likely to be added when considering more workflows. The same will apply, if we also take IV system implementations into account.

Completing the design space will ultimately lead to guidelines on designing productive workflows that enable a user to switch seamlessly between IV and non-IV parts. We are confident that having IV directly at hand will, in the end, reduce the time-to-insight.

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