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# Immersive Analytics: A new multidisciplinary initiative to explore future interaction technologies for data analytics

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# Immersive Analytics: A new multidisciplinary initiative to explore future interaction technologies for data analytics

#### Organizers:

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#### 1 Introduction

There is a tidal wave of big and complex data across many domains. Several research directions are concerned with the development of methods to support the analysis of such data, including machine learning, information and data visualisation, data analytics and human computer interaction. However, there is still a major gap to fill: how can we immerse analysts in the data in order to provide more natural ways for data exploration, data analysis and collaboration?

In recent years we have seen significant advances in the development of new technologies for human-computer interfaces. Immersive environments like a CAVE make use of ultra-high resolution technology, and combine 2D and 3D visualisations to allow users to immerse themselves into computer generated scenes, e.g., in the virtual reality created in a flight simulator. Driven by the entertainment industry, tools and methods like voice- and gesture-based control as well as 3D VR and AR visualisation are becoming more and more part of everyday life. This has meant that technologies for natural user interfaces, virtual and augmented reality devices have progressed very quickly to provide very engaging and immersive experiences, and they are rapidly becoming available and affordable for small businesses and the general public.

In response to these new technologies, we propose a new facet of data analytics research that we call Immersive Analytics. This new research direction explores how these new display and interaction technologies can be used to create more engaging experiences and seamless work-flows for data analysis applications. The environments we envision that will be developed by immersive analytics researchers should be usable by experts and analysts to help in the detailed analysis of complex data sets, but will also be accessible to decision makers, that is, the managers who spend more time working face-to-face than in front of a desktop computer, and to the everyday public to help them in tasks like balancing nutrition, social and ethical concerns and price when buying groceries.

The ability to move inside the data with new display devices, to interact with the data representation in various direct and embodied ways allows the user to create a richer experience that may lead to better understanding and finally deeper insight. For that to happen, the visualisation and interaction concepts need to allow a faithful representation of the data and provide intuitive and efficient orientation and navigation in the data space. We expect that to create productive tools many gaps will need to be filled

Immersive analytics is inherently multi-disciplinary and involves researchers from human computer interaction, data sciences, visual analytics, augmented reality, data and information visualisation, as well as experts from application areas.

The aim of the seminar is to bring together experts in these fields to

- define a new research field, 'Immersive Analytics',
- · create a community of researchers into immersive analytics,
- take the first steps in the creation of a research manifesto for the new field.

#### 2 Program and Schedule

The seminar's schedule reflected that the main goals of the meeting were different from usual meeting goals.

Experts from quite diverse fields did participate and thus we needed introductory talks to give an overview on the research fields and application areas.

- Wolfgang Stuerzlinger gave an overview talk on a VR perspective for Visual Analytics,
- Christopher Collins gave an overview talk on an Information Visualisation perspective for Visual Analytics.

Tim Dwyer, Bruce H. Thomas, Yang Cheng, Lingling Shen, Oliver Kohlbacher and Tom Chandler gave examples from application areas.

However, most time was devoted to discussions in small groups focusing to investigate the research questions, potential, and challenges of immersive analytics, and to prepare the research manifesto. The participants agreed on the idea to prepare a book publication for the manifesto.

Initially, groups were formed to propose a definition for immersive analytics. First discussions were inconclusive, but by the end of the meeting the participants agreed on the following working definition of immersive analytics.

Immersive Analytics studies how to engage people with data and with each other in data analysis and decision making with the aim of improving the outcomes. Engagement may be through the use of immersive virtual environment technologies or responsive interactive analytics but is not limited to these technologies.

After the introductory and talks sessions on the first morning, a general discussion lead to the formulation of challenges and research questions for working groups. The rest of the seminar was spent in working groups, except for a few feedback and reporting sessions. The meeting's schedule is given in Table 1.

Sunday:	Welcome Banquet
<b>Day 1:</b>	Seminar start, welcome, introductory presentations, and working
09:00:	groups Opening and individual introductions
10:00:	Introduction to Immersive Analytics and goals of the meeting
10.00.	(Kim Marriott)
10:30:	Break
11:00:	Invited Talks session (Wolfgang Stuerzlinger and Chris Collins)
12:00:	Lunch
13:30:	Group discussions
14:00:	Working group discussions – IA research agenda
15:00:	Group reports
15:30:	Break
16:00:	Book discussion: Definition of book chapters and general book struc-
	ture
17:00:	Definition of working groups according to book chapters
18:00	Dinner
Day2:	Working groups, discussions, presentations
09:00:	Recap from Monday
09:15:	Applications presentations
10:00:	Group discussion: How does IA map onto those areas?
10:30:	Coffee break
11:00:	Working groups
11:30:	Progress reports
12:00:	Group photo
12:15:	Lunch
13:30:	Working groups
15:30:	Break
16:00:	Working groups
17:00:	Progress reports
18:00	Dinner
Day3:	Working groups and excursion
09:00:	Recap from Tuesday
09:15:	Working groups
10:30:	Break
11:00:	Working groups
11:30:	Progress reports
12:00:	Lunch
13:30:	Excursion
19:00:	Banquet
<b>Day4:</b>	Working groups, discussions, planning beyond the seminar
09:00:	Recap from Wednesday
09:15:	Working groups
10:30:	Break Working groups
11:00:	Working groups Progress reports and wrap up
11:30:	Lunch – end of the seminar
12:00:	Lunch – end of the seminar

Table 1: The meeting schedule

#### **3 Working Group Reports**

#### 3.1 Applications in Life & Health Sciences

**Participants:** Yang Cheng, Tobias Czauderna, Oliver Kohlbacher, Karsten Klein, Falk Schreiber, Lingling Shen

**Summary:** The group "Applications in Life & Health Sciences" was responsible to outline the chapter about Immersive Analytics applications in the life and health sciences domain. It started off their discussions together with the group "Exploring Immersive Analytics For Built Environments" about a general outline of chapters discussing applications in Immersive Analytics. Eventually the two groups decided to break down the application chapters into the four sub-chapters "Introduction", "Overview Application Examples", "Application Examples in Detail", and "Challenges and Outlook". The ongoing discussions took place in the individual group with a particular focus on the life and health sciences domain and the goal to outline the subchapters in more detail.

The sub-chapter "Introduction" will illustrate which part of the application area is covered, will review state-of-the-art Visual Analytics and Immersive Analytics in the life and health sciences domain, and will introduce data types as well as discuss the complexity of biomedical data. Sub-chapter "Overview Application Examples" will briefly showcase application examples covering the different omics technologies as well as application examples from healthcare and medicine to provide the reader with a broader overview of possible applications. In "Application Examples in Detail" a number of applications will be presented in more detail.

During the discussion the group came up with a common structure for the examples being presented. For each example different questions should be addressed, e.g., a) What is the problem to be solved?, b) Which approaches/methods have been used to address this problem?, c) What worked and what didnt work?, and d) How can or did methods from Immersive Analytics help to solve the problem?

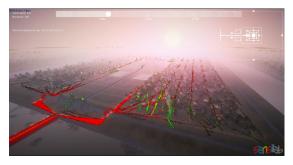
Currently, the list of detailed examples includes four examples covering quite diverse topics: one example exploring an omics (genomics) data dataset, one example from structural biology, one example discussing an image analysis related problem, and one example detailing a healthcare/medical application in particular electronic health records.

Finally, the sub-chapter "Challenges and Outlook" will discuss challenges such as the amount of data, the integration of data, and problems with existing approaches. Furthermore an outlook to further developments of applications in Immersive Analytics will be given.

#### 3.2 Exploring Immersive Analytics For Built Environments

Participants: Tom Chandler, Uwe Wössner, Torsten Kuhlen

**Summary:** In simulations of the built environment, 3D is much more than a graphic gimmick; it is crucial to discern essential information such as line of sight issues, material flows and intersections of objects, all which are best remedied by a full 3D, dynamic reconstruction. The utility of 3D models has been known to architects, engineers and urban planners for some time, but new Immersive Analytic interfaces, augmentations



(a) Crowd simulation for archeological sites





(b) Architectural design

(c) Factory planning

Figure 1: Built environments

and overlays promise to significantly extend the interpretation and exploration of these virtual environments.

In this chapter we will overview ongoing research into three prototypical built environments ranging from production planning, architectural design to the reconstruction of heritage listed landscapes and archaeological sites, see Figure 1.

**Outlook and Challenges** All of the applications we have discussed above have the potential to be deployed as Augmented Reality applications in the field.

Annotation and Provenance tracking these immersive 3D environments are visually and spatially rich, and they also include a wide range of text overlays, - a general problem is that we are mostly navigating within the immersive environment and the challenge is to embed documentation that can be viewed consistently within the environment without loosing immersion, occlusion issues, and unnecessarily complicating user experience

A minor point - in our field, aspects like motion sickness and latency are more critical than compared to, for example, medical visualisations and neuroscience where the graphics are more centred and not presented as scale models of real spaces careful design of the interfaces is important in dealing with challenges like hiding latency.

#### 3.3 Immersive Analytics: Human in the Loop

**Participants:** Jian Chen, Christopher Collins, Tim Dwyer, Andreas Kerren, Gerik Scheuermann, Wolfgang Stuerzlinger

**Summary:** We consider the space of human engagement with data analysis tools. Machine learning techniques are rapidly growing in power in their ability to find pat-

terns in data, yet they remain dumb in the sense that a human is still required to interpret the implications of these patterns. To make tools that support people in this collaboration with machines we need to first understand how people form insights about data and the limits of their cognition and memory. Then, we need to consider the technical issue of how automatic algorithms used in data analysis must be instrumented to support close supervision and control by humans. Further, we consider interfaces that can support such interaction with these analytics engines providing, for example, controlling a number of simultaneous analysis, differential views, and so on. Finally, we consider future directions using advanced human physiological input and biofeedback to create enhanced adaptive and seamless integration of human supervision with machine analytics.

#### 3.4 Immersive Interactive Storytelling

Participants: Masahiko Inami, Harald Reiterer, Bruce Thomas, Chris Weaver

**Summary:** Immersive environments hold great potential for interactive wandering, investigation, interpretation, and narrative. We investigated how people inhabit virtual data spaces to create, examine, explore, interpret, explain, and share information and knowledge. Immersion offers a richly structured design space to target different degrees of immersion, dimensions of data, forms of immersion, modes of transition and navigation, scopes of audience and user roles, and kinds of narrative. We used sidebar stories from our own experiences to share several current examples and discuss the immersive interactive storytelling needs of domain experts.

Motivated by these stories, we laid out a framework for defining how immersive spaces enable location-oriented, scale-oriented, path-oriented, and rate-oriented modes of entry, movement, and exit through visualized data. We focused on how the wide variety of navigation, selection, annotation, and composition interactions of existing virtual environments and visualization tools (and well-known taxonomies of these) carry over into interaction in immersive spaces. We also examined the effects on immersion of coordinated and collaborative styles of interaction that engage multiple visual perspectives simultaneously.

The framework aims to support a wide variety of narrative styles ranging from explanatory (highly constrained by a designer) to exploratory (moderately constrained by a designer for a wandering user) to situational (lightly constrained by a user on-the-fly within a shaped world) to ambient (minimally constrained through pursuit of affective directions). Based on this framework, we sketched out design guidelines and recommended best practices for integrating visual interactions with path, pace, and perspective into tools that support genuinely immersive storytelling.

#### 3.5 Reconsidering the use of 3D for abstract data visualisation

Participants: Marcel Hlawatsch, Takayuki Itoh, Kim Marriott, Miguel Nacenta, Guido Reina

**Summary:** During the last decade information visualisation researchers have have been very cautious about the use of immersive VR and AR for abstract data representation. This conservatism is quite deliberate. In a recent popular text on data visualization, Munzner [1] cautions against use of 3D for representation of abstract data. The

critique is posed as a reaction to "unbridled enthusiasm" for 3D in the 90's and cites several studies that did not find any benefit to particular 3D mappings for abstract data.

In this chapter we review the evidence for and against the use of 3D for abstract data visualisation and suggest that the answer is not clear cut and that in some situations and tasks it may be preferable to 2D. The chapter is organised as follows

- · Perception of 3D
- Limitations of 3D for abstract data representation
- Potential of 3D for abstract data representation: examples and studies
- A novel design space framework for abstract data visualisation that maps onto different medium (paper, standard display, VR, AR, physical model)
- Using the framework
- · Research questions

#### References

[1] Tamara Munzner. Visualization Analysis and Design. CRC Press, 2014.

#### 4 Participants

- · Takayuki Itoh, Ochanomizu University
- Kim Marriott, Monash University
- Falk Schreiber, Monash University
- Uwe Wössner, University of Stuttgart
- Tom Chandler, Monash University
- · Jian Chen, University of Maryland
- · Yang Cheng, China Novartis Biomedical Research Institute
- Christopher Collins, University of Ontario
- · Tobias Czauderna, Monash University
- Tim Dwyer, Monash University
- Marcel Hlawatsch, University of Stuttgart
- Jason Hideyo Haga, AIST
- · Masahiko Inami, Keio University
- · Andreas Kerren, Linnaeus University
- · Karsten Klein, Monash University
- Oliver Kohlbacher, University of Tuebingen

- Torsten Kuhlen, RWTH Aachen
- Shen Lingling, China Novartis Biomedical Research Institute
- Miguel Nacenta, University of St Andrews
- Guido Reina, Stuttgart University
- Harald Reiterer, Konstanz University
- Gerik Scheuermann, Leipzig University
- Wolfgang Stuerzlinger, Simon Fraser University
- Bruce Thomas, University of South Australia
- Chris Weaver, The University of Oklahoma

#### **Overview of Talks**

There were seven invited talks, two overview talks and five talks on applications.

## **Information Visualization Overview and the State of 3D Visualization**

Christopher Collins, CSIRO & University of Ontario Institute of Technology

This talk reviewed the basics of information visualization theory and practice, including how to construct visualizations and evaluate their effectiveness, following a number of theoretical framings of visualization, including the nested model of Tamara Munzner and the visual variables model of Jacques Bertin. This was intended to help participants who are in other fields such as virtual reality learn a bit about the visualization side of immersive analytics. The talk also reviewed the systemic resistance to using 3D rendering in information visualization, and exposed the criticisms of 3D which are prevalent in the research community. I discussed the potential of virtual reality to improve visualization research and why some of these arguments against 3D and VR may no longer be valid as new interaction devices and display technologies are becoming more readily available.

#### **Virtual Reality + Visual Analytics**

Wolfgang Stuerzlinger, Simon Fraser University

My presentation initially reviews fundamental properties of 3D graphics, stereo display systems, as well as the spatial and interaction abilities of humans. Based on this, I discuss various ways in which visual analytics systems can support immersion as well increase engagement of the user with the content. Finally, I briefly introduce the V4-Space system, which uses eight very large touch-sensitive high-resolution displays in portrait mode to support seamless interaction with big data.

#### **Software Engineering**

Tim Dwyer, Monash University

In software engineering visual analytics can help with both high-level understanding of connectivity between major components and also low-level dependencies involved in particular aspects of functionality or bugs. In this talk we discuss some practical commercial tools that have been successfully deployed to support this kind of visual analysis but also consider what an immersive future may hold for software engineers.

#### **Situated Analytics**

Bruce H. Thomas, University of South Australia

In this presentation explored the research question of how to support visual analytics reasoning by embedding the visual representations and interaction of the resulting data in the physical environment using augmented reality. Situated analytics is this new research area at the intersection of visual analytics and augmented reality.

#### **Multi-dimensional Informatics Platform for Genomic Research**

Yang Cheng and Lingling Shen, NIBR Informatics, Novartis

Next-generation Sequencing (NGS) platforms play a prominent role in biological research. Large amounts of sequencing data generated from extensive R&D initiatives and the demand for storage and analysis are expected to grow dramatically. However, turning this data in biological relevant and actionable results has not been as easy yet. To use NGS at maximum compatibility, we must address IT tools of data management, storage, and analysis. We have implemented several web-based applications from different angels to help researchers to track real-time business workflow and manage the lifecycle of a sequencing service request, easily conduct precise quality check on sequencing data and integrate heterogeneous data from different sequencing technologies, as well as facilitate their data mining effort to provide interactive visualizations.

#### Visual Analytics for (Bio)Medical Data

Oliver Kohlbacher, Universität Tübingen

Biomedical data has changed drastically in recent years. With the availability of high-throughput image and molecular data (genomics, transcriptomics, proteomics, etc.), data analysis has become an indispensible component in biomedical research. In some cases, visual analytics can support the data exploration process, however, care needs to be taken how to employ these techniques to make optimal use of human cognitive capabilities.

#### Simulating a day in the medieval life of Angkor Wat

Tom Chandler, Monash University

Constructed in the 12th century, the world famous heritage site Angkor Wat is the largest religious monument on earth. Recent archaeological estimates suggest that nine centuries ago, the temple was supported by a population of up to 125,000 people, and staffed by a regular workforce of 25,000. Using an extensive library of evidence based 3D models and immersive analytic overlays, this simulation explores how the complex might have operated over a 24 hour cycle; a day in the life of medieval Angkor.

**Acknowledgments** The organizers would like to thank all participants, NII, and the Shonan staff for all their contributions. We hope that the research during the seminar, as well as the exchange between the participants, will lead to new successful collaborations and research findings in the future.