Report from Dagstuhl Seminar 16231

# Immersive Analytics

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**Abstract**

This report documents the program and the outcomes of Dagstuhl Seminar 16231 "Immersive Analytics". Close to 40 researchers and practitioners participated in this seminar to discuss and define the field of Immersive Analytics, to create a community around it, and to identify its research challenges. As the participants had a diverse background in a variety of disciplines, including Human-Computer-Interaction, Augmented and Virtual Reality, Information Visualization, and Visual Analytics, the seminar featured a couple of survey talks on the first days, followed by plenary and working group discussions that were meant to shape the field of Immersive Analytics. As an outcome, a book publication is planned with book chapters provided by the participants.

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## 1 Executive Summary

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Immersive Analytics is an emerging new field that studies technologies facilitating a deep cognitive, perceptual and/or emotional involvement of humans when understanding and reasoning with data.

Immersive technologies are commonly defined as technologies aiming at blurring the line between physical and virtual worlds, by employing multimodal input and multi-sensory output to create a state of immersion, i.e. a deep mental involvement of a person into an


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activity and/or an intense concentration or complete absorption into the activity that one does.

The term Immersive Analytics was coined a few years ago, but there is no precise definition of the concept so far, and the corresponding research is scattered across several fields and communities. Hence our goal for this seminar was to discuss and define the field of Immersive Analytics, and to create a community around it. In addition, we planned to develop an outline for a book on the topic.

During the working group and discussion sessions, the participants investigated the potential and the challenges of immersive analytics for research and commercial applications, as well as a variety of aspects like multi-sensory data representation, immersive human-centered data analysis, interaction for immersive analysis, immersion for data-driven narratives, and the use of immersive analytics concepts in application areas like the life sciences and air traffic control.

During the first plenary sessions, major topics for discussion were defined and clustered into working groups, and the participants then joined the proposed working groups based on common interest. Later, the participants could switch between the groups. Each of the working groups was meant to outline a chapter of the book publication. For some of the topics, discussions continued in the evening hours, which were also used to experience new technologies like the Microsoft HoloLens.

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# 3 Overview of Talks

The seminar featured two types of talks – invited talks of half an hour that provided a general overview and an introduction into a field for participants from other fields, and lightning talks of five minutes each for short presentations of current work or open perspectives.

## Invited Talks

There were four invited talks meant to introduce the state of the art in broad topics related to Immersive Analytics.

## 3.1 Augmented Reality

*Dieter Schmalstieg (TU Graz, AT)*



Augmented Reality is an emerging new medium, with the potential of becoming very important for mobile computer use. However, creating Augmented Reality applications that go beyond proof of concept is very challenging, as it requires the successful combination of many non-trivial elements: The technology must be real-time, human-in-the-loop, accurate and precise, context-aware, and work outdoors, operated by potentially naive users. The talk will draw examples from 20 years of experience in Augmented Reality research to highlight trends and directions for future real-world systems.

## 3.2 The Role of Space in Immersive Analytics

*Chris North (Virginia Polytechnic Institute – Blacksburg, US)*



In this talk, we examine the importance of space, large spaces in particular, in immersive analytics. Big display spaces play four fundamental roles in immersive analytics of big data: (1) Space for big visualization enables multi-scale insight and efficient physical navigation with natural visual aggregation in the presence of big data. (2) Space for big interaction enables users to interact at multiple levels of scale, with multiple data objects, through multiple devices. (3) Space for big cognition enables users to efficiently externalize their cognitive and analytical processes. (4) Space for big algorithms enables users and machine learning algorithms to collaborate through a spatial common ground. Continuing research into these four roles of space will enable researchers to push forward in the immersive analytics agenda.

## 3.3 Data Physicalization

*Yvonne Jansen (University of Copenhagen, DK)*



Data physicalizations are data-driven physical artifacts which may involve the use of computers, either to fabricate them or to actuate them. As physical artifacts they allow people to immerse themselves in data representations without the need to leave the physical reality. In this talk, I illustrate different use cases for data physicalizations in data communication, art, and research, and I give an overview of recent empirical work investigating how people engage with data in physical form.

## 3.4 Virtual Reality Overview: Virtual Reality, Augmented Reality, Physical-Virtual Reality

*Gregory F. Welch (University of Central Florida – Orlando, US)*



This talk presents a high-level overview of Virtual Reality, including the related areas of Augmented Reality and Physical-Virtual Reality. The talk includes some historical perspectives on the technologies and example use cases, and examples of modern systems for visual simulation, locomotion, and interaction. Visual simulation examples include head-worn displays, fixed displays, and full-surround visualization systems.

# 4 Lightning Talks

The following lightning talks were presented during the seminar, in the order given:

- *Todd Margolis* – Immersive Analytics for Business Intelligence
- *Steffen Oeltze-Jafra* – Potential Application of Immersive Analytics: Multidisciplinary Clinical Decision Making in Tumor Boards
- *Jon McCormack* – Immersive Technologies for Education, Research and Data Analytics at Monash SensiLab
- *Christophe Hurter* – Augmented Tower of Air Traffic Controllers
- *Raimund Dachselt* – Spatially-aware Magic Lenses and Body-centered Data Interaction
- *Barrett Ens* – Spatial Analytic Interfaces
- *Kim Marriott* – Data Visualisation without Vision: Accessible Graphics
- *Benjamin Bach* – Interactive Exploration of Space-time Cubes (work in progress)
- *Frank van Ham* – Technology means versus user goals
- *Dieter Schmalstieg* – Collaborative Seamless Display
- *Carla Freitas* – Research on Interaction Techniques, Information Visualization and Virtual Reality at UFRGS
- *Mark Hancock* – Game and Interaction Science: Using Principles from Games to Design Novel Interfaces that Compel and Motivate
- *Jonathan Roberts* – Multi-sensory visualization including haptification (moving visualization beyond WIMP)

- *Maxime Cordeil* – Collaborative visualisation + tangible interactions in Virtual Reality
- *Chris North* – Be the Data: Embodiment for Analytics Education
- *Bruce Thomas* – Situated Analytics
- *Pourang Irani* – Ubiquitous Analytics

# 5 Working groups

## 5.1 Immersive Analytics: What, Why, When, How, ...

*Pourang P. Irani, Frank van Ham, Nathalie Henry, Roland Fernandez, Aaron Quigley, Karsten Klein, Falk Schreiber, Hans-Christian Hege, and Tobias Isenberg*



This grouped discussed the definition and scope of Immersive Analytics. The primary question considered is: "What is Immersive Analytics?", but for that matter "what is immersion?" and for that matter "what is analytics?". We consider the different types of immersion possible, not just immersive VR/AR but also narrative immersion and so on. We consider several different visions for people immersed in their data analysis tasks: today, five years from now, 20 years from now, 50 years from now and 500 years from now. We consider a number of different scenarios for immersive analytics and how we can advance the state of the art.

## 5.2 Interaction for Immersive Analytics

*Raimund Dachselt, Steven Drucker, Tim Dwyer, Carsten Goerg, Todd Margolis, Chris North, Uwe Woessner, and Wolfgang Stuerzlinger*



We discuss the central role of interaction in immersive analytics. Particularly, we focus on the fundamental interaction and analysis tasks that enable effective visual analytics. We revisit task taxonomies from previous work in visual analytics. We then consider input modalities and techniques in natural user interfaces and immersive environments. On the basis of this analysis we identify appropriate mappings from interaction techniques to tasks. We divide these mappings into three categories: (1) direct adaptation of existing immersive interaction techniques to basic visual analytics operations; (2) identification of missing mappings; (3) the potential for new immersive environments to enable new modalities. Finally, this leads to a discussion of the opportunities, limitations and resulting research challenges.

## 5.3 Immersive Human-Centered Computational Analytics

*Wolfgang Stuerzlinger, Tim Dwyer, Raimund Dachselt, Steven Drucker, Carsten Goerg, Todd Margolis, Chris North, and Uwe Woessner*



In this chapter we seek to elevate the role of the human in human-machine cooperative analysis through a careful consideration of immersive design principles. We consider both strategic immersion through more accessible systems as well as enhanced understanding and control through fluid immersive interfaces. We extend the classic sense-making loop from visual analytics to incorporate multiple views, scenarios, people, and computational agents. We consider both sides of the machine / human collaboration: allowing the human to more fluidly control the machine process; and also allowing the human to understand the results, derive insights and continue the analytic cycle. We also consider system and algorithmic implications to enable real-time control and feedback in immersive human-centered computational analytics.

## 5.4 Design Considerations for Immersive Data-Driven Narratives

*Maxime Cordeil, Mark Hancock, Petra Isenberg, Bongshin Lee, Todd Margolis, Steffen Oeltze-Jafra, Huamin Qu, and Chris Weaver*



We discuss design considerations for experiencing immersion when interacting with data-driven narratives. By immersion we refer to moments during a data analysis where participants feel a deep cognitive, perceptual and/or emotional involvement with data. Immersion in related media such as books, films and music has been studied extensively in social sciences and psychology. Our design considerations for immersive data-driven narratives build on these studies. We elaborate on the potential of immersive data-driven narratives by analyzing multiple case studies according to our considerations.

## 5.5 Situated Analytics

*Pierre Dragicevic, Barrett Ens, Niklas Elmqvist, Pourang Irani, Yvonne Jansen, Dieter Schmalstieg, Aurelien Tabard, Bruce H. Thomas, and Gregory F. Welch*



People are increasingly becoming interested in understanding data associated with objects, locations, or persons in their everyday life. For example, imagine hunting for a house by walking through the neighborhood in which you want to live and basing your choice on social media posts in the area, census data, and traffic data over time, or imagine collaboratively reorganizing a factory floor for different machines and stations with a team of different experts

by optimizing space, safety, and economical constraints based on past manufacturing data, power and ventilation requirements, worker preferences, past accidents, and legal concerns. For the first time both the technology – such as sensors, wearable displays, natural user interfaces, and augmented reality devices – as well as the data sources – such as dynamically updating social media, ubiquitous sensor information, and large-scale movement data – exist to make this vision a reality. In this chapter, we introduce the concept of situated analytics as the use of data representations organized in relation to relevant objects, places, and persons for the purpose of understanding, sensemaking, and decision-making. After defining this new concept, we characterize its components in greater detail, including the users, tasks, data, representations, interactions, and analytical processes involved in situated analytics. We then examine case studies of projects and products that exemplify situated analytics in action. Based on these case studies, we derive a set of design guidelines for building situated analytics applications, and finally outline a research agenda of challenges and research questions to explore in the future.

## 5.6 Multisensorial Representation and Interaction with Data

*Jon McCormack, Benjamin Bach, Christophe Hurter, Kim Marriott, Takayuki Itoh, Carla das Sossas Freitas, and Jonathan Roberts*



This chapter explores opportunities and challenges for developers and users to utilize and represent data through many sensory channels for the purpose of understanding and interacting with data. While visual cues are traditionally used for visual analytics, immersive multimodal analytics offers many opportunities. Users are able to view the data in new ways, variables from complex datasets can be represented through different senses, presentations are more accessible and can be personalized to specific user needs, interactions can involve many senses to provide natural and transparent methods, all these techniques enable users to obtain a better understanding of the underlying information. While the emphasis of this chapter is towards non-visual immersive analytics, we do discuss how visual presentations are integrated with different modalities, and the opportunities of mixing several sensory signals, especially including the visual domain.

## 5.7 Challenges in Evaluating Immersive Analytics

*Petra Isenberg, Mark Hancock, Bongshin Lee, Roland Fernandez, Carla Freitas, and Tobias Isenberg*



We consider questions surrounding how we can advance the science of Immersive Analytics through rigorous hypothesis testing and the challenges for doing so. For example: *Immersion as a phenomenon we can assess through measurement? Use a grounded theory approach to understanding it? If we want to measure immersion – what are the metrics?*

In the end it was decided that this should not be a separate chapter but that the ideas and considerations should be rolled-in to other chapters throughout the book.

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