Immersive Analytics 2.0: Spatial and Embodied Sensemaking

Barrett Ens
Monash University
Melbourne, VIC, Australia
barrett.ens@monash.edu

Maxime Cordeil
University of Queensland
Brisbane, QLD, Australia
Monash University
Melbourne, VIC, Australia
max.cordeil@monash.edu

Chris North
Virginia Tech
Blacksburg, Virginia, USA
north@vt.edu

Tim Dwyer
Monash University
Melbourne, VIC, Australia
tim.dwyer@monash.edu

Lonni Besançon
Monash University
Melbourne, VIC, Australia
lonni.besancon@monash.edu

Arnaud Prouzeau
Inria & LaBRI (University of Bordeaux, CNRS, Bordeaux-INP)
France
arnaud.prouzeau@inria.fr

Jiazhou Liu
Monash University
Melbourne, VIC, Australia
jiazhou.liu@monash.edu

Andrew Cunningham
University of South Australia
Adelaide, South Australia, Australia
andrew.cunningham@unisa.edu.au

Adam Drogemuller
University of South Australia
Adelaide, South Australia, Australia
adam.drogemuller@mymail.unisa.edu.au

Kadek Ananta Satriadi
University of South Australia
Mawson Lakes, SA, Australia
kadek.satriadi@unisa.edu.au

Bruce H. Thomas
University of South Australia
Mawson Lakes, SA, Australia
bruce.thomas@unisa.edu.au

ABSTRACT

Immersive Analytics is now a fully emerged research topic that spans several research communities, including Human-Computer Interaction, Data Visualisation, Virtual Reality and Augmented Reality. Immersive Analytics research has identified and validated benefits of using embodied, 3D spatial immersive environments for visualisation and have shown benefits in the effective use of space and 3D interaction to explore complex data. As of today, most studies in Immersive Analytics have focused on exploring novel visualisation techniques in 3D embodied immersive environments. Thus far, there is a lack of fundamental study in this field that clearly compares immersive versus non immersive platforms for analytics purposes, and firmly delineates the benefits of immersive environments for analytic tasks. We feel that it is time to establish an agenda to assess the benefits and potential of immersive technologies, spatial interfaces, and embodied interaction to support sensemaking, data understanding, and collaborative analytics. This workshop will aim at putting this agenda together, by gathering international experts from Immersive Analytics and related fields to define which studies need to be conducted to assess the effect of embodied interaction on cognition in data analytics.

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CCS CONCEPTS

• **Human-centered computing** → **Visualization**; **Virtual reality**; **Mixed / augmented reality**.

KEYWORDS

Immersive Analytics, Sensemaking, Spatial User Interfaces, Embodied Interaction

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1 INTRODUCTION

Immersive Analytics has now fully emerged as a research topic in the Visualisation and Human-Computer Interaction research communities – there has been an Immersive Analytics track at the IEEE VIS conference for the past 5 years – and it has been flourishing with applications like abstract, scientific and medical data visualisation. Much of the published research for the past several years in Immersive Analytics has focused on building novel attractive systems, toolkits and techniques, as well as providing initial evidence that Virtual Reality (VR) and Augmented Reality (AR) have benefits for certain types of data exploration.

Prior work in Immersive Analytics has been motivated by assumptions about the benefits of spatial interfaces and embodied interaction, for instance, the use of unlimited space around users [4,

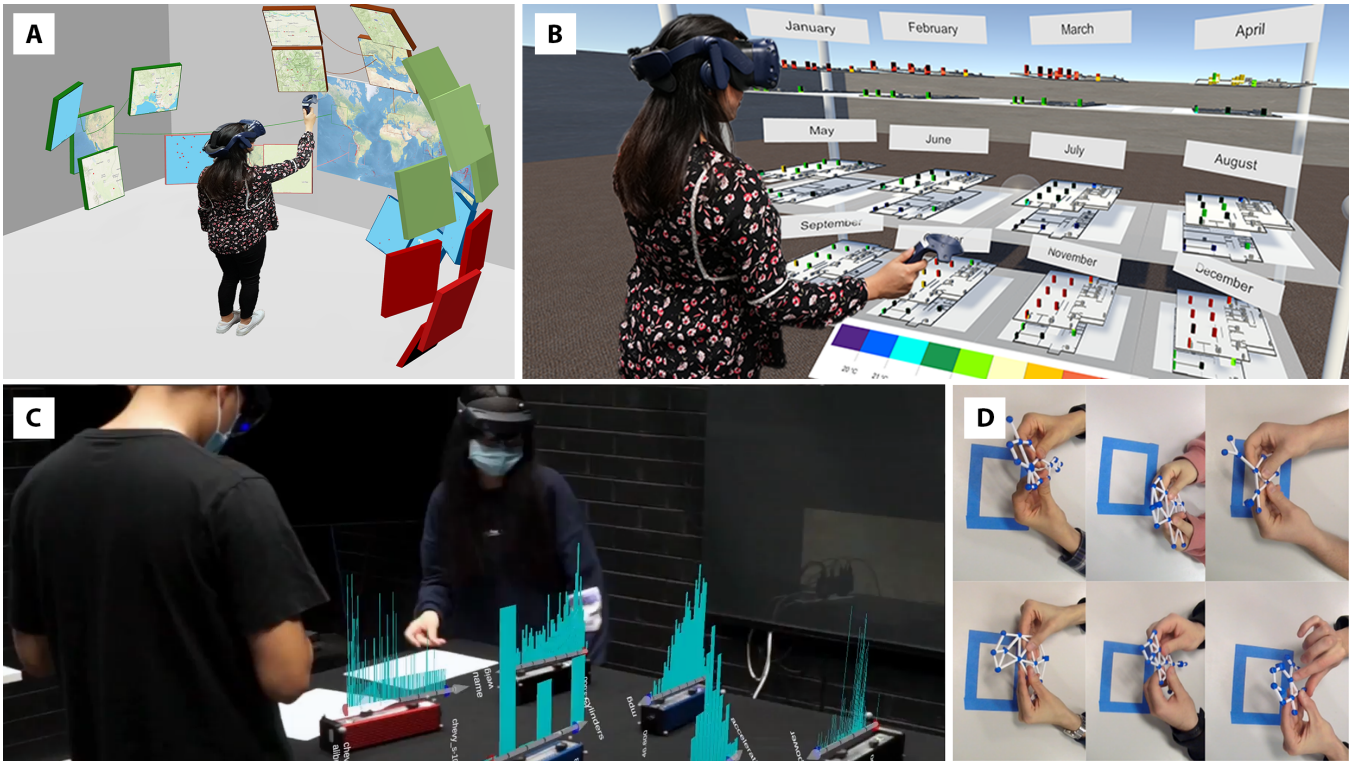

Figure 1: This workshop will focus on the use of immersive technologies to support sensemaking activities. We aim to increase our understanding of the benefits of Immersive Analytics applications, for instance A) using space around the user to support visual analytics; B) spatial layouts of immersive small multiples; C) using tangible interfaces to support collaborative embodied interaction; or D) using hands to enhance comprehension of data physicalisations.

14, 19, 24], spatial memory [23], proprioception, 3D spatial interaction [21, 25], tangible interaction [7, 13, 28, 29], collaboration [18, 26], kinesthesia, engagement [5, 6], etc. While evidence of these benefits has been accumulating even prior to the establishment of Immersive Analytics, we have still attained only a basic understanding of the extent to which they can support human sensemaking, and reliance on such assumptions is prevalent in the exploration of applications.

It is now time to take the next steps to extend both the depth and breadth of Immersive Analytics. This includes diving deeper to answer questions around the underlying motivations about spatial and embodied interaction, as well as broadening the potential of Immersive Analytics towards new research areas and applications. These efforts will also help us clarify where Immersive Analytics stands in Visualisation research and will provide convincing arguments to adopt immersive technologies to tackle complex data analytics scenarios. But first we must more clearly define these areas of expansion to more efficiently direct future efforts.

This workshop aims to define a roadmap for new directions in leveraging the benefits of spatial and embodied interaction to support sensemaking. A mix of synchronous and asynchronous, remote and collocated sessions will bring together researchers with varying backgrounds and experience. Participants will be drawn from Immersive Analytics and related research areas such as interaction design, data visualisation, VR, AR, CSCW, embodied cognition, and other fields to provide a wide range of perspectives.

1.1 Background

This workshop builds on a previous series of workshops in Immersive Analytics beginning with a NII Shonan Seminar (2015), a Dagstuhl seminar (2016), and workshops at ACM ISS 2016 [3] and IEEE VIS 2017 [1], which focused on establishing Immersive Analytics as a new research field and building a research community, which is now thriving. Two more recent workshops at ACM CHI 2019 [2] and ACM CHI 2020 [11] were focused on further engaging members of the CHI research community in this new field, and establishing several Grand Challenges for Immersive Analytics that have emerged after several years of effort [12]. In this workshop we aim to deepen our understanding of the field by establishing key principles as well as asking fundamental research questions.

1.2 Workshop Aims

A main goal of this workshop will be to set an agenda for broadening and deepening the establishments made so far in Immersive Analytics, with a focus on understanding the benefits and applications of spatial interfaces and embodied interaction for enhancing human sensemaking. This agenda will define, for instance, key research questions, new application areas, and novel evaluation

methods. Since we don't expect this agenda to be fully developed within a single workshop, an additional aim will be to create a research community who will collaborate toward this focus in the future. This workshop therefore aims to build momentum towards a sustained effort. One of the key workshop outcomes will be to initiate a proposal for follow-up activities including a Dagstuhl or Shonan workshop to further engage a larger cross section of researchers in a more complete definition.

Additional aims are:

- To identify fundamental questions to support further research in Immersive Analytics.
- To identify research methods and approaches for answering these questions.
- To broaden the fundamental understanding of perceptual and cognitive benefits of Immersive Analytics (as well to better understand its current limitations) to motivate its expansion into further application areas.
- To connect researchers and discuss methods for studies that identify benefits of spatial and embodied interaction for sensemaking.

1.3 Perspectives of Interest

The central component of this workshop will stoke a broad discussion of benefits, opportunities, and applications for spatial and embodied interaction. These discussions will focus on a group of themes defined during asynchronous pre-workshop activities. Discussion themes may include:

Fundamental Research Questions — A wide range of prior work pre-dating and including Immersive Analytics has been based on assumptions about the benefits of spatial and embodied interaction. While this research includes comparisons of technologies with varying immersive capabilities, more work is needed to more clearly link their benefits to knowledge in related areas such as embodied cognition, education and training, or collaboration, and to define key underlying questions for a new research agenda.

New Evaluation Methods — While a substantial amount of evidence has been collected to demonstrate the benefits of spatial interface designs and embodied interaction techniques, this is primarily focused on low-level elements such as target selection, spatial memory, and performance metrics of input and output modalities. Revealing benefits at a higher level of sensemaking activities, such as the collection of data, organisation of artifacts, and communication of insights will require the development of new evaluation methods. For instance this may include objective measures of a user's physical and cognitive state using sEMG, EEG or eye-tracking sensors, as well as quantitative and qualitative methods for measuring impacts on sensemaking steps and workflows.

Human-AI Sensemaking — Beyond interacting directly with data, immersive analytics may offer new opportunities for spatial and embodied interaction with AI and analytical algorithms to support sensemaking [31]. AI-based analytics could benefit from rich immersive interactive input for steering and additional spatial representations for explainability. New research agendas are needed to conduct studies that identify benefits and challenges of immersion for Human-AI interactions.

Accessible Sensemaking — Immersive technologies offer opportunities for non data experts to explore and understand their own data in more intuitive ways [30], e.g. using gestures and tangible interactions. These interaction modalities could also enhance and improve the lives of people with disabilities, for instance using tangible models or spatial audio to support blind and low vision users.

Data Physicalisation — Data physicalisations [10, 16, 17] involve "physical artifacts whose geometry or material properties encode data". Physicalisations allow novices and experts to perceive data through novel channels of information such as texture, weight, and temperature. Physicalisations also encourage embodied sensemaking with information, where comprehension of a dataset is not typically inhibited by electronic peripherals or displays. Research opportunities for physicalisations pertain to investigating methods for fabricating physicalisations as well as the cogntive benefits and behavioural differences to traditional desktop displays.

Situated and Embedded Data Visualisation — Situated and embedded data visualisations are defined by Willett et al. [32] as information encodings placed in the vicinity of a related data referent, or virtually integrated into the physical form of the referent. While much work has been inspired by the potential intuitiveness of such visualisations, important questions remain about the direct benefits of integrating information spatially, effects on the cognitive state of users, and best practices for communicating information in a way that can be effectively interpreted by users in dynamic real-world conditions.

Authoring Immersive Data Visualisations — Toolkits like IATK [8] or DXR [27] can be used to author immersive visualisations. However, supporting the ability to design and create visualisations using immersive technologies is a necessary step to create complete systems. Some works have started to explore this direction, such as ImAxes [9], which focused on the use of embodied interactions to create visualisations, DataHop [15], which explored how to use the space to organise the analyse, and Corsican Twin [22], which used digital twins for authoring situated and embedded visualisations, but a vast space still needs to be explored. Research opportunities in this area are on the authoring of more complex visualisations, the study of the impact of embodied and spatial methods on the creation process and on the authoring of interactive visualisations.

2 ORGANISERS

The workshop organisation team draws from leading expertise the the field of Immersive Analytics, data visualisation, and user interface design and evaluation for VR and AR. These include organisers from previous Immersive Analytics workshops (Ens, Cordeil, Dwyer). Organisers include a mix of senior, mid-career and early-career academics, along with students who have expertise in the areas of spatial user interface design, embodied data visualisation, and support for human-in-the-loop sensemaking. The organisers have substantial experience publishing and reviewing publications in these areas.

Barrett Ens is a Lecturer at Monash University in Melbourne in the Data Visualisaiton and Immersive Analytics research group. Ens led Immersive Analytics workshops at CHI 2019 and CHI 2020

as well as the follow up paper on Grand Challenges in Immersive Analytics [12], presented at CHI 2021. His research overlaps HCI with augmented reality, spatial information layouts, and data visualisation.

Maxime Cordeil is a Lecturer at Monash University in Melbourne working in the Data Visualisation and Immersive Analytics group. Cordeil was a co-organizer of the IEEE VIS 17 Workshop on Immersive Analytics and Immersive Prototyping workshop at CHI 19. His research addresses and explores information visualization and visual analytics in virtual and augmented reality.

Chris North is a Professor of Computer Science and Associate Director of the Sanghani Center for AI and Analytics at Virginia Tech, USA. His research foci are in immersive analytics, human-AI interaction, and sensemaking.

Tim Dwyer is a Professor of Computer Science at Monash University in Melbourne, Australia. He directs the Monash Data Visualisation and Immersive Analytics Lab and was co-editor of the first Immersive Analytics book [20].

Lonni Besançon is a Postdoctoral Fellow at Monash University in Melbourne working in the Data Visualisaiton and Immersive Analytics group. Besançon was a co-organizer of several IEEE workshops (Failfest 2020, alt.VIS 2021) as well as a co-organizer of the first National Junior Faculty conference in Sweden (2020). Part of his work focuses on 3D interaction for visualization tasks.

Arnaud Prouzeau is a Researcher in the French Institute for Research in Digital Science and Technology (Inria) in Bordeaux in the Potioc team which focus on multimodal interaction. Prouzeau was a co-organizer of the Energy Data Visualisation workshop at the E-Energy conference in 2020 and 2021. His research focus on interaction with data visualisation in immersive environments.

Jiazhou Liu is a PhD student at Monash University in Melbourne, Australia. His research focuses on multi-view visualisations in immersive environments, embodied interaction, and spatial skills.

Andrew Cunningham is a Lecturer at the University of South Australia and a researcher at the Australian Research Centre for Interactive and Virtual Environments. Cunningham's research focus is on the application of virtual and augmented reality technologies, immersive analytics, and embodied interactions for understanding data.

Adam Drogemuller is a PhD student at the University of South Australia at the Australia Research Centre for Interactive and Virtual Environments researching data visualisation beyond the desktop and Post-WIMP interfaces.

Kadek Ananta Satriadi is a Research Associate at the Australia Research Centre for Interactive and Virtual Environments, University of South Australia. His work focuses on immersive analytics and geovisualisation. Satriadi is an early-career academic with conference organising experience, including organising CHI Down Under 2020 and OZCHI 2020.

Bruce H Thomas is a Professor and the Director of the Australia Research Centre for Interactive and Virtual Environments at the University of South Australia. His work focuses on immersive analytics, narrative visualisation, and situated analytics.

3 WEBSITE

We will setup a website (https://ia2workshop2022.github.io) to communicate the Call For Participation and general instructions for pre-workshop activities. Workshop submissions (e.g. mini papers or statements of motivation) will also be made publicly available on the workshop's website upon acceptance to the workshop. Finally all relevant information such as sessions date and time, organising committee contact information will be available on the website.

3.1 Participant Recruitment

To recruit participants, we will distribute a call for participation within our networks and across community mailing lists such as CHI Announcements, as well as with attendees or previous workshops. Prospective attendees will be invited to complete a short form including their background, experience, and interests in discussion topics. Participants will be invited through curated selection by the organisers, with a focus on inclusive selection of researchers with a range of backgrounds (industry and academia), career level (including PhD students, early-career, mid-career, and senior), research interests, gender, and world location.

4 WORKSHOP STRUCTURE

The workshop will make use of both asynchronous and synchronous sessions with virtual and in-person sessions to provide a number of opportunities for participants to contribute. The format of this workshop will adapt to an in-person/virtual hybrid or fully virtual style, according to the pandemic situation in 2022.

4.1 Pre-Workshop Activities

Prior to the workshop, participants will be invited to engage in defining the set of themes to be discussed during the workshop. A set of initial themes will be proposed by workshop organisers, however, we will encourage an inclusive discussion with hopes of introducing new and interesting themes. Discussions will begin with a set of brief virtual sessions (with repeat sessions held in different time zones, according to participant locations), in which the organisers will present an overview of the workshop plan and initial topics. This will also provide an opportunity for participants to introduce themselves and engage in ice-breaking activities. The remaining pre-workshop activities will be conducted asynchronously.

Participants will also be asked to prepare 2-3 interesting examples of how spatial or embodied interaction can facilitate human sensemaking tasks to present in the opening session. These may include examples from their own work or other research related to their expertise.

Our workshop website will provide information about the organisers, call for participation, and workshop plans.

4.2 Asynchronous Engagement

Prior to the workshop, in order to elicit the important themes to be discussed in the workshop, we will make use of online collaborative tools such as Miro boards and a Discord server to support. This will allow us to help organise activities, keep a trace of our activities, provide a place to post continuous updates, and start some

community building before the conference workshop. Email communication will be used to update participants with any important information.

4.3 Main Workshop Activities

The main workshop will focus on interleaved *world cafè* sessions and lightning talks, including both in-person and virtual attendees. Remotely located participants will be invited to join in either the morning or afternoon sessions. To limit 'Zoom fatigue' and to accommodate people from different time zones, remote participants will only be required to join one of these two session. Ample breaks will be scheduled between sessions and during long discussion sessions.

Introductions and Overview — In the morning session, organisers will kick off by introducing themselves and the motivation for the workshop. They will provide an overview of the activities, and the plans for managing hybrid participation. In the first set of lightning talks, participants will take turns giving an introduction and brief overview of the 2-3 examples of spatial or embodied interaction that they prepare in advance of the workshop.

Morning Session: Theme Organisation and Discussion – Following the introductions, participants will work *en masse* to categorise the examples given during the workshop. The categories produced will be added to the initial set of themes developed in advance of the workshop. These categories will be grouped into a set of topics to be included in the first round of discussions. These discussions will focus on identifying the key principles, theories, and evidence that support the proposed benefits of spatial and embodied interaction in each case, as well as identify gaps in existing research.

These discussions will follow a *world cafè* format, in which each topic is designated its own 'table' (in-person, online, or hybrid). Every 30 minutes, participants will rotate between different tables to engage in short, focused discussions on topics of their choice. Each table will have a designated host (primarily workshop organisers) who will take notes and guides the discussion flow from one each to the next. The morning session will conclude with a series of lighting presentations by table hosts to summarise each of the discussions.

Networking Lunch – An off-site networking lunch break will provide participants with an opportunity to learn more about one another and engage in focused discussions on topics of interest. Online participants will be invited to an optional, shorter online social discussion during the break.

Afternoon Session: Theme Refinement and Discussion – The second session will mirror the first, accommodating the inclusion of newly-joined remote participants whose time zones are not accommodated the morning session. As in the first round, new participants will give a lightning talk to introduce themselves and present their prepared examples. Following the introductions, a second *en masse* session will revisit the topics from the first session to reorganise these as needed, taking into account results of the first session and any additional themes introduced by new online participants.

A second round of *world cafè* discussions will ensue, however with a new focus on sketching out a research agenda for each topic, including key opportunities, immediate steps, long-term aims, and potential barriers. Discussions will conclude with a final set of lightning presentations, summarising the outcomes.

Closing Session The final workshop session will focus on summarising the workshop events and defining next steps. First, organisers will provide a recap of events, including topic definitions during pre-workshop activities, and a summary of the outcomes of the morning and afternoon sessions. A final group discussion will be held around action items for further developing and implementing the roadmap initiated during the sessions. This discussion will include options for follow up publications, and future workshops or other events to continue building the community, including a draft proposal for a Dagstuhl or Shonan workshop.

5 POST-WORKSHOP PLANS

We aim to document our results and agenda on our website, which will be permanently archived for future collaboration. We also aim to conduct follow-up communications to continue work on the research agenda, which will be disseminated in at least one high-quality research publication, with all workshop participants invited to contribute. We also aim to follow up with further workshops and international grant proposals to further support the growing research community.

6 CALL FOR PARTICIPATION

The workshop on Immersive Analytics 2.0: Spatial and Embodied Sensemaking will take place on (TBD) at CHI 2022. It will focus on the use of immersive technologies, spatial interfaces, and embodied interactions to support (collaborative) sensemaking and data understanding. It will provide a stimulating environment for interactions and discussions with researchers from the field of Immersive Analytics or researchers who want to discover it. Early-career researchers and PhD students are strongly encouraged to participate to broaden their networks and explore new research directions.

Immersive analytics has been a growing field in the last five years, with several workshops organized in various venues (VIS 2018, ISS 2019, CHI 2019, CHI2020). While we understand the potential of the use of immersive technologies for analytics, there are still important research directions to explore in order to understand where Immersive Analytics stands in Visualisation research and to increase its adoption. We believe that directing a concerted focus on the benefits of spatial interfaces and embodied interaction will help us define the new research agenda for this field.

The program will consist of a balanced mix of lightning talks, group discussion and activities around data analytics methods and design considerations regarding the use of immersive technologies. Pre-sessions will be organised remotely to allow participants to join in preparation for the workshop (with repeat sessions to accommodate for time zones) by proposing and defining topics for discussion, which may include:

- Fundamental Research Questions
- New Evaluation Methods
- Human-AI Sensemaking
- Accessible Sensemaking
- Data Physicalisation
- Situated and Embedded Data Visualisation
- Authoring Immersive Data Visualisations

Submissions

To apply to the workshop submit your expression of interest using our online form (available on our website https://ia2workshop2022.github.io) to answer questions about their background, experience, and interests in potential discussion topics. Participants will be carefully selected to reflect a wide range of varying backgrounds, experience, interests, gender, and world locations.

Important Dates

- EOI deadline: February 1, 2022
- Acceptance notification: February 15, 2022
- Virtual kick-off: April 14, 2022
- Workshop at CHI 2022: April 30 or May 1 (TBD), 2022

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