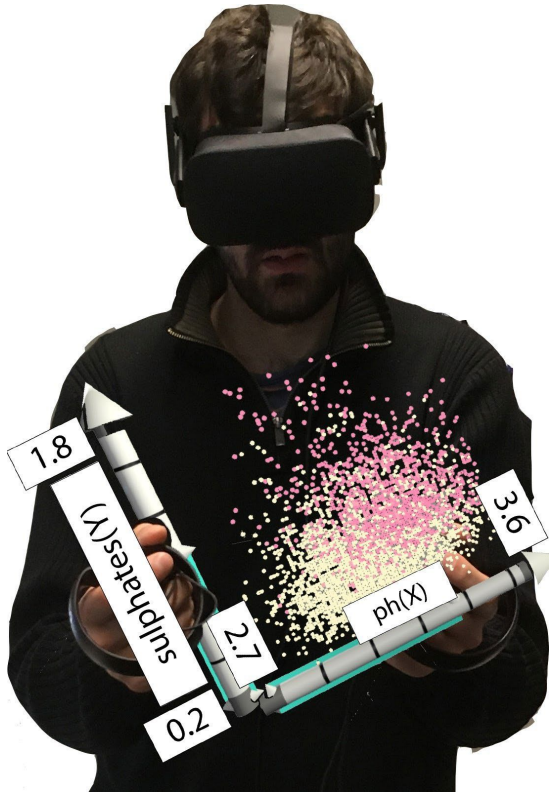
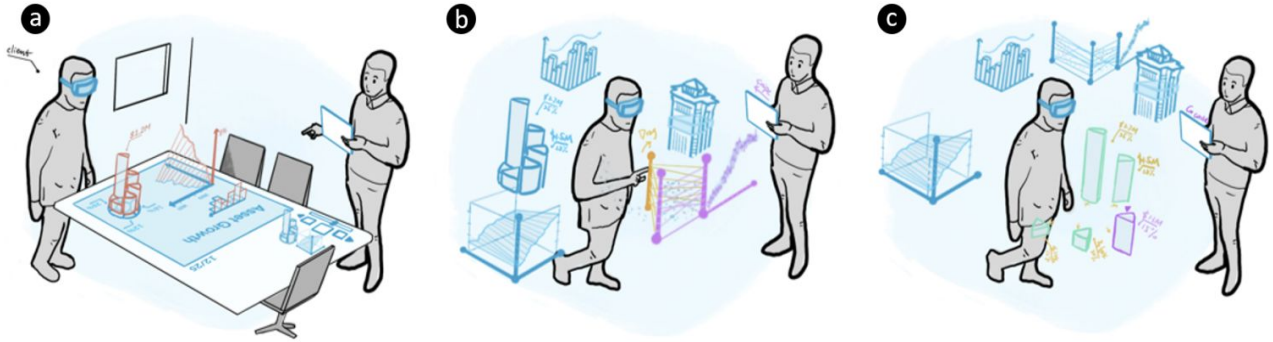
Immersive Analytics: Data Visualization and Exploration using Immersive Technologies





Dr. Benjamin Lee & Dr. David Saffo

JPMorganChase Global Technology Applied Research

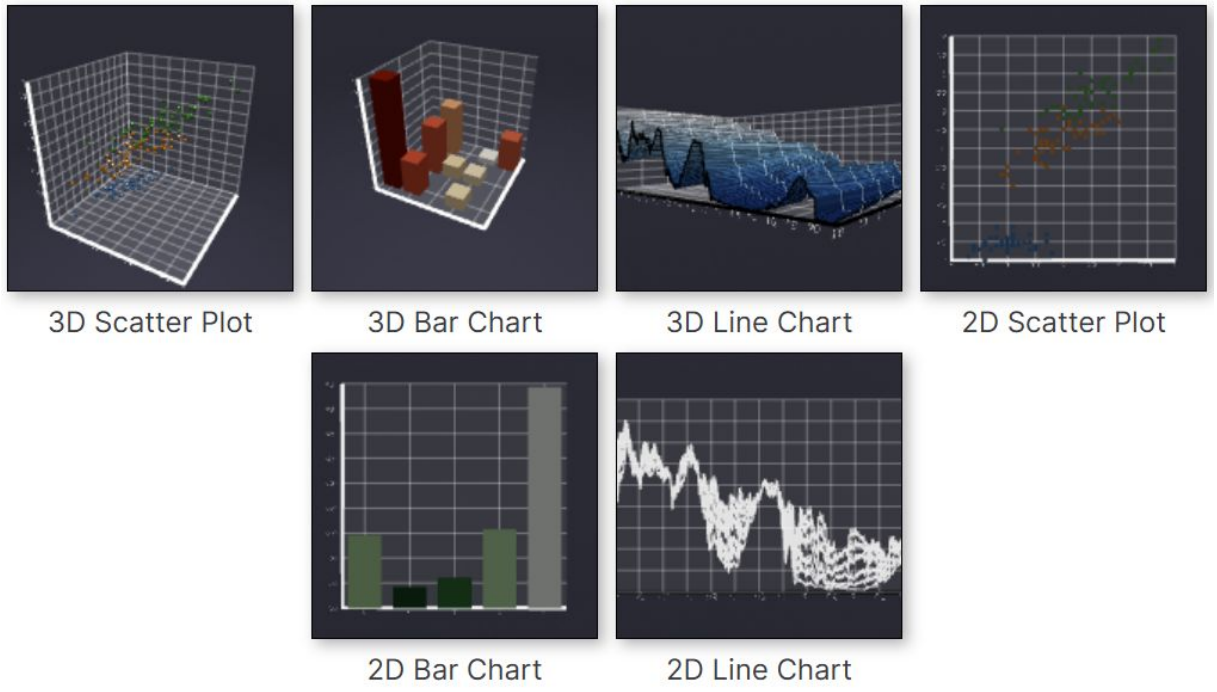
12/05/2024

Agenda

1. What is Immersive Analytics and what is it good for? (45 mins)

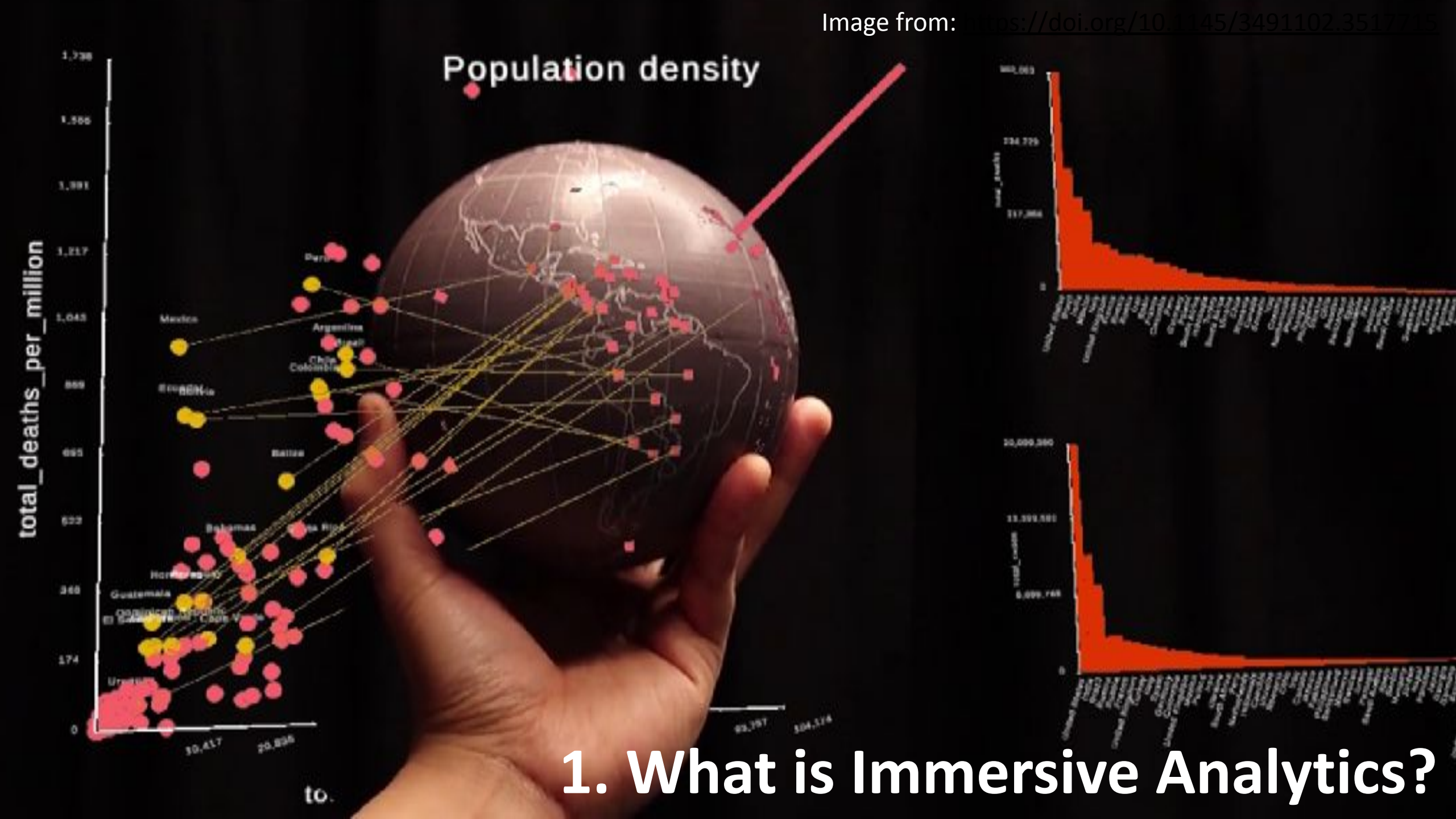
2. Developing immersive data visualizations with Anu.js (45 mins)

3. Build your own immersive visualization on your web browser (45 mins)



"Immersive Analytics", Marriott et al.

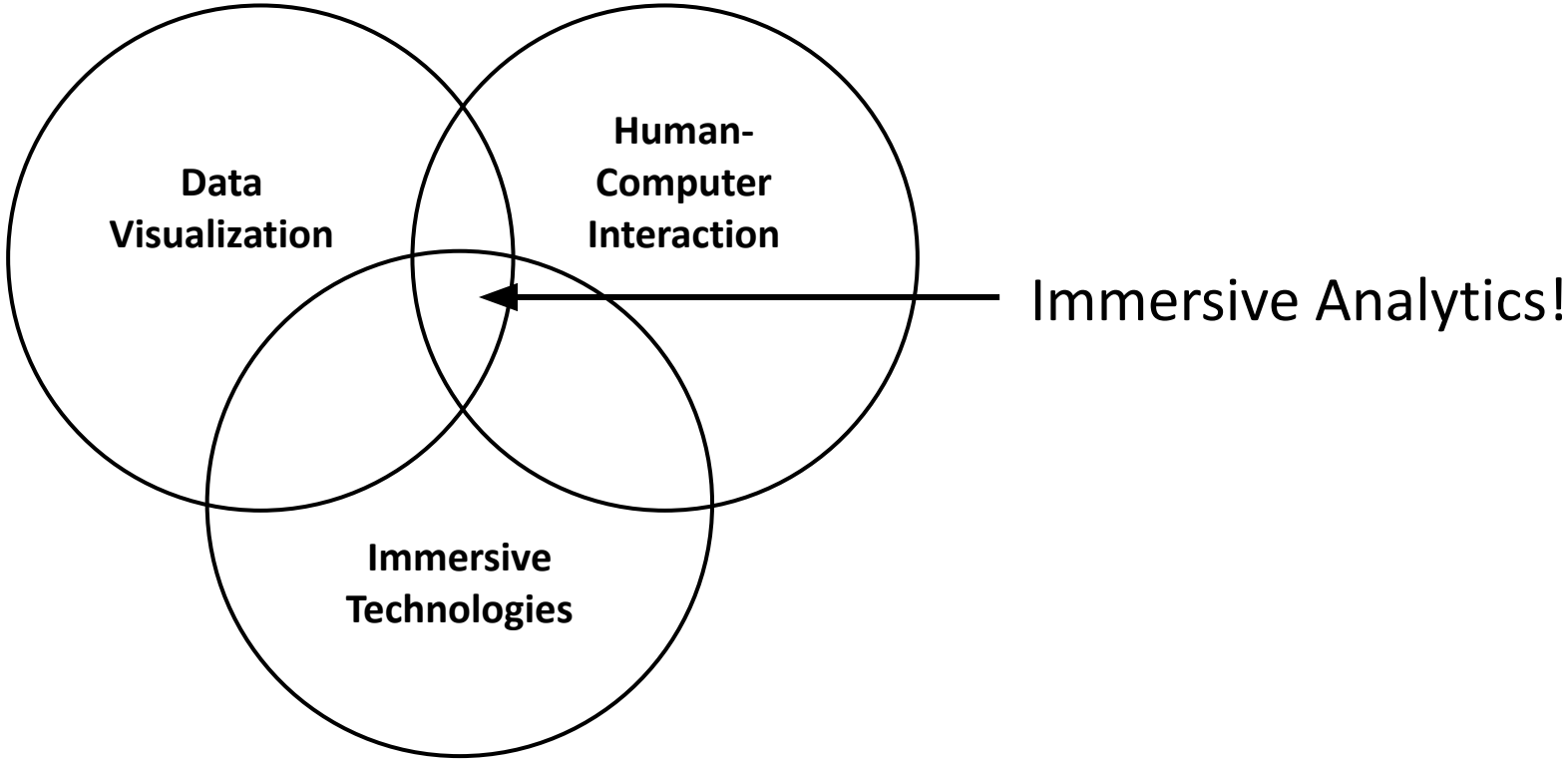
Image from: https://doi.org/10.1145/3491102.3517715



1. What is Immersive Analytics?

What is Immersive Analytics?

- At its simplest, Immersive Analytics lies at the intersection of three areas of study:
  - **Data Visualization:** The graphical representation of data and information
  - **Human-Computer Interaction:** How people interact with technology
  - **Immersive Technologies:** Input and output devices that facilitate multi-sensory experiences that are highly *immersive*, *engaging*, and *embodied*



Examples of immersive technologies (1)

- **Large wall sized displays** envelop user(s) in a high pixel density environment
- Encompass a large region of the users' field of view

- **Projectors** overlay digital content above physical objects, environments, or people

Examples of immersive technologies (2)

- **Virtual Reality** (VR) and **Augmented Reality** (AR) are now the de-facto form of immersive technology for the masses
  - **Virtual Reality:** See the virtual world, not the real world
  - **Augmented Reality:** See both the virtual and the real world together
- **Mobile phones** are a (relatively) inexpensive and massively widespread means of delivering VR/AR experiences

Examples of immersive technologies (3)

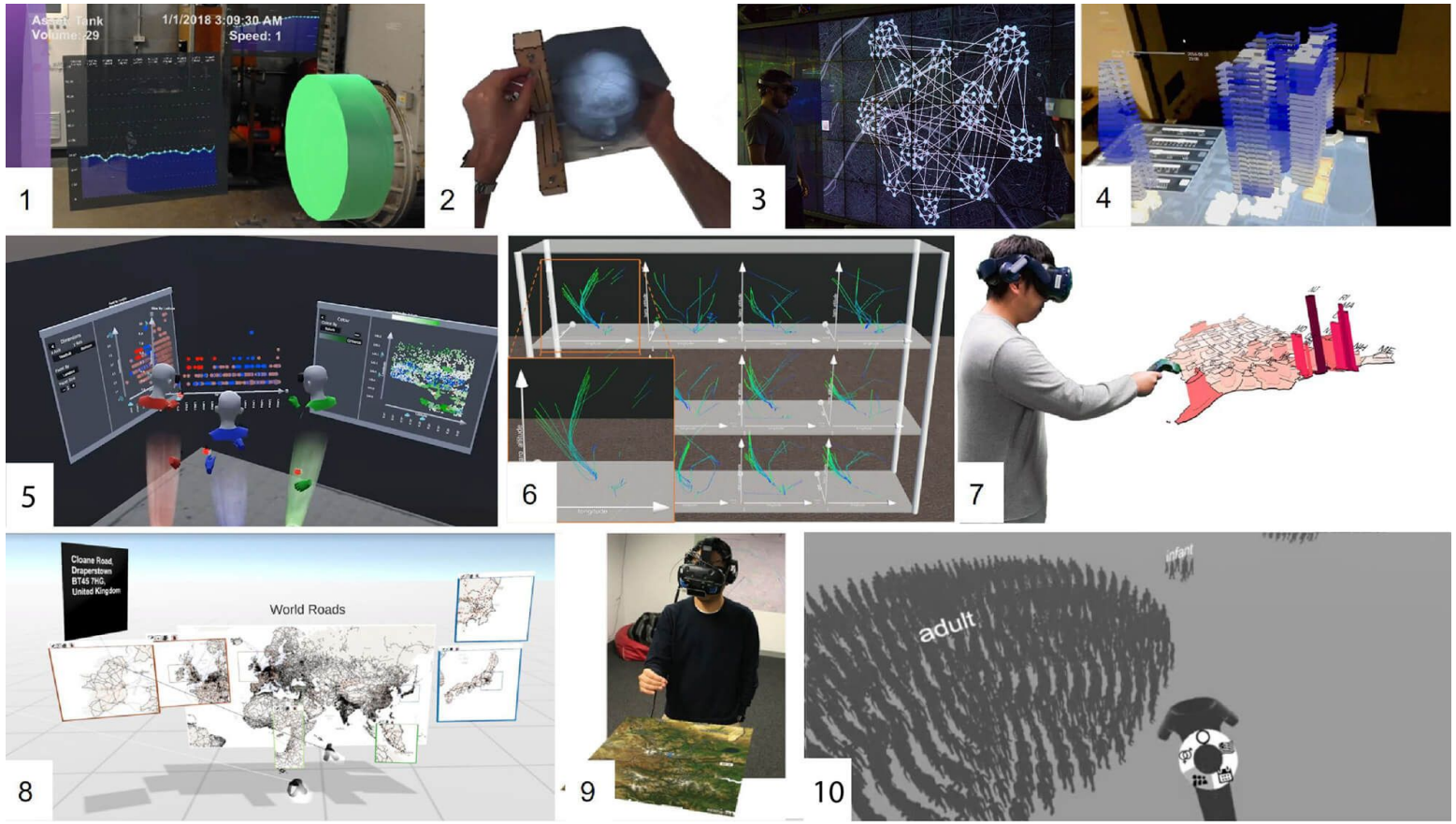
- **Head-mounted displays (HMDs)** are now the standard form factor for delivering truly immersive and powerful experiences
- Price is now actually affordable (~US$300 for a Meta Quest 3S)
- Actively used in many industries:
  - Automobile design and planning
  - Rehabilitation and therapy
  - Simulation and training (e.g., for heavy machinery)

Key concepts of VR and AR

- **Immersion:** The degree in which a system is capable of projecting (multi-)sensorial stimuli onto the user
- **Presence:** The sense of “being there” inside of a space even when physically in a different location
  - *Spatial presence*: The sense that you are in another location
  - *Social presence*: The sense that others are truly there with you
  - *Self presence*: The sense that a virtual self is your actual self
- This distinction is mostly academic, as colloquially, “immersive” is used to an experience which achieves a high degree of presence
- AR naturally takes on a subset of these concepts due to the innate ability to see the real world - more difficult to “transport” the user to a completely different location

What is Immersive Analytics? (again)

- **Immersive Analytics** is a growing area of study which has been defined by Marriott et al. in 2018 as “[...] the use of engaging, embodied analysis tools to support data understanding and decision making"



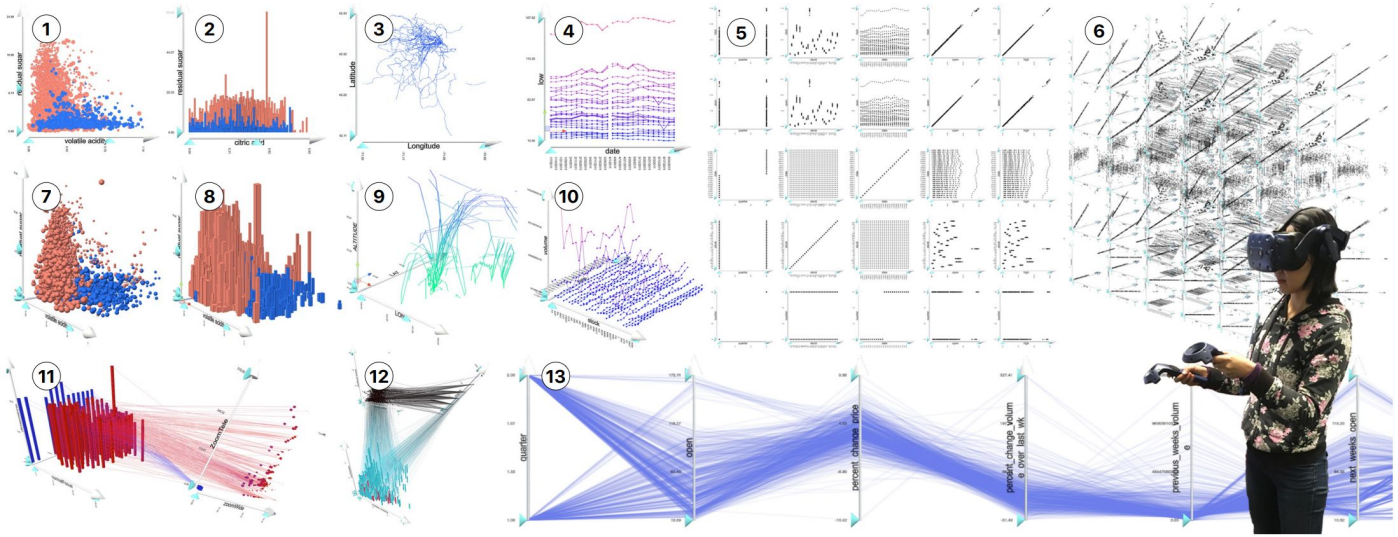
2. What is Immersive Analytics good for?

Why should we bother with Immersive Analytics?

- There are numerous reasons why visualization with immersive technologies (namely VR and AR) might be beneficial over that of traditional computing devices
  - Additional spatial encoding and depth cues
  - Spatial workspaces
  - Embodied & multimodal interaction
  - Immersion, presence, and engagement
  - Collaborative immersive visualization
  - In-situ visualization and analytics

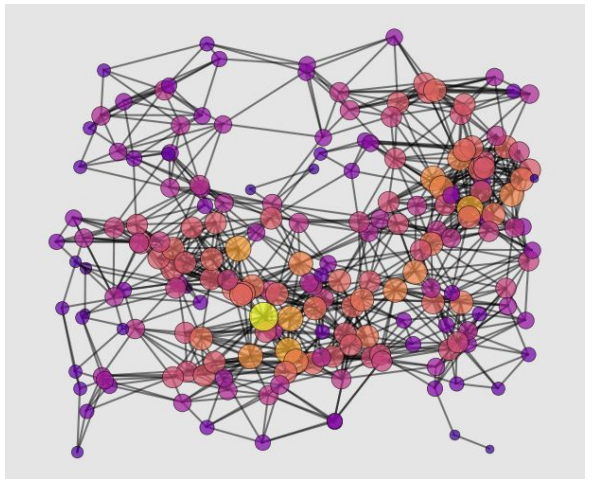
Additional spatial encoding and depth cues (1)

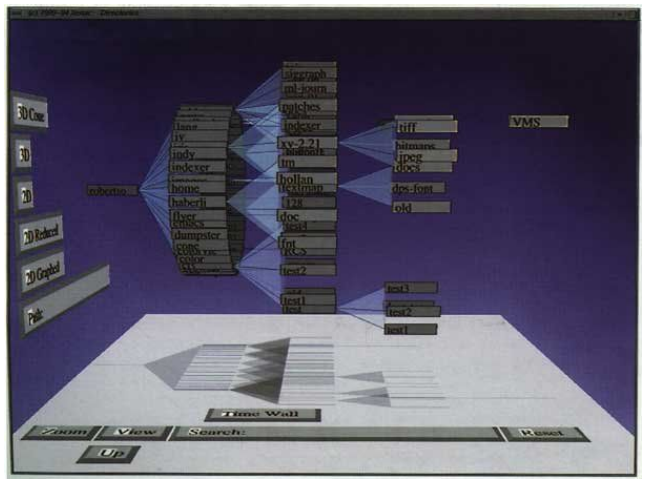
- **Stereoscopic displays** make it possible to view virtual objects (and visualizations) in the same manner as we perceive the real world: in three dimensions
- Perception of 3D mainly relies on depth cues as our visual system is, in practice, only 2.5D (or as Colin Ware argues, 2.05D). Common examples of depth cues are:
  - **Occlusion**: Objects closer in space visually block those behind it
  - **Motion parallax:** When moving, objects that are closer appear to move faster than those that are farther



Additional spatial encoding and depth cues (2)

- Information visualization researchers have been very **cautious about the use of 3D representations for abstract data** and have therefore seen little benefit in the use of spatially immersive technologies
- User studies around the 80s and 90s failed to find any benefits for these 3D representations over the traditional 2D representations in abstract data visualization, due to challenges relating to depth perception and visual clutter
- Does this mean we should never use 3D visualizations?

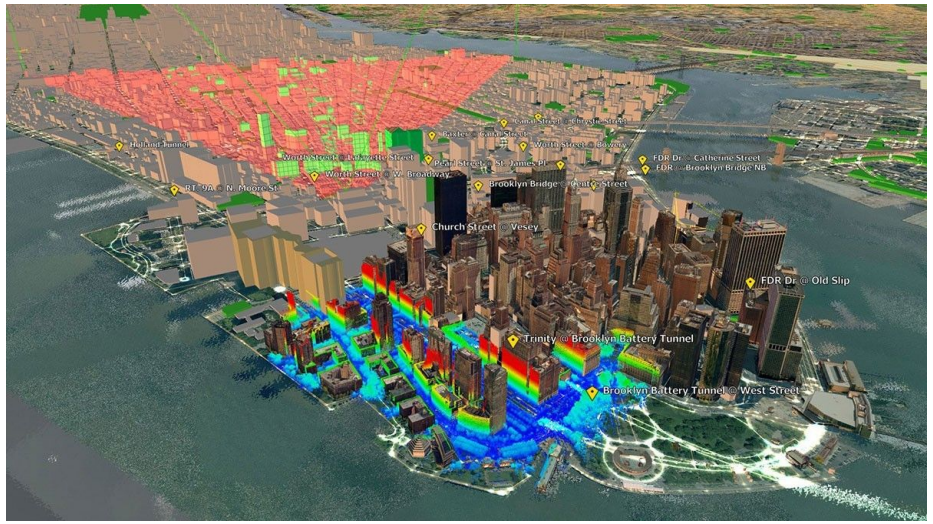


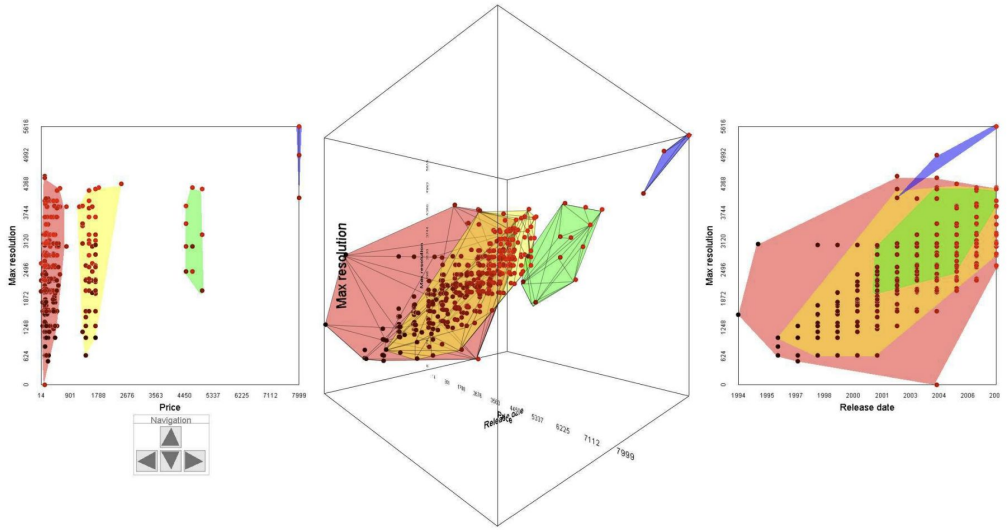


"Immersive Analytics", Marriott et al.

Additional spatial encoding and depth cues (3)

- Certain data types are still well suited for visualization in 3D due to their innate structure, such as **geospatial data** and **spatial data** (e.g., point clouds, 3D imaging)
- **3D can also be used sparingly** to support specific tasks, such as when navigating between scatterplots of a scatterplot matrix
- The free head and body movements afforded by VR/AR HMDs also allow for **depth cues to be better utilized** to understand 3D visualizations and their structures
  - Imagine moving your head around a 3D visualization just like you would a sculpture at a museum





Spatial workspaces (1)

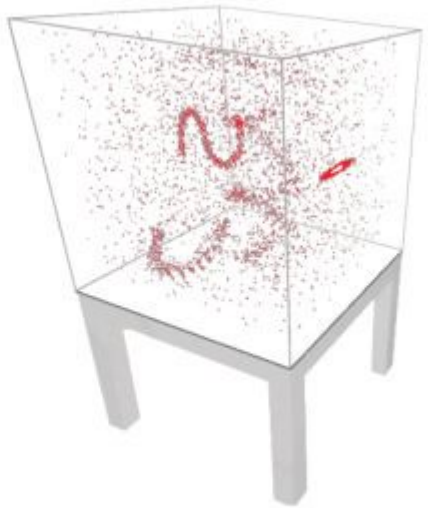
- The spatial nature of VR/AR allows for data to be positioned anywhere in the space around the user, enabling a **spatial workspace** where visualizations can be arranged in any configuration the user sees fit
- **Spatial memory** can be leveraged to recall and access visualizations positioned in space at later points in time, thus aiding task performance and provenance

Spatial workspaces (2)

- This space also enables data to be **visualized at any size and scale**, thus providing a more **space to think** that is no longer confined to the bounds of a physical display
- A common use is to vary the **viewing perspective** of the data
  - **Exocentric perspective**: The viewer looks at the visualization from the “outside”, looking at the visualization in its entirety
  - **Egocentric perspective**: The viewer looks at the visualization from the “inside”, and can only observe parts of the visualization at any time

(b) Flat map

(c) Egocentric globe

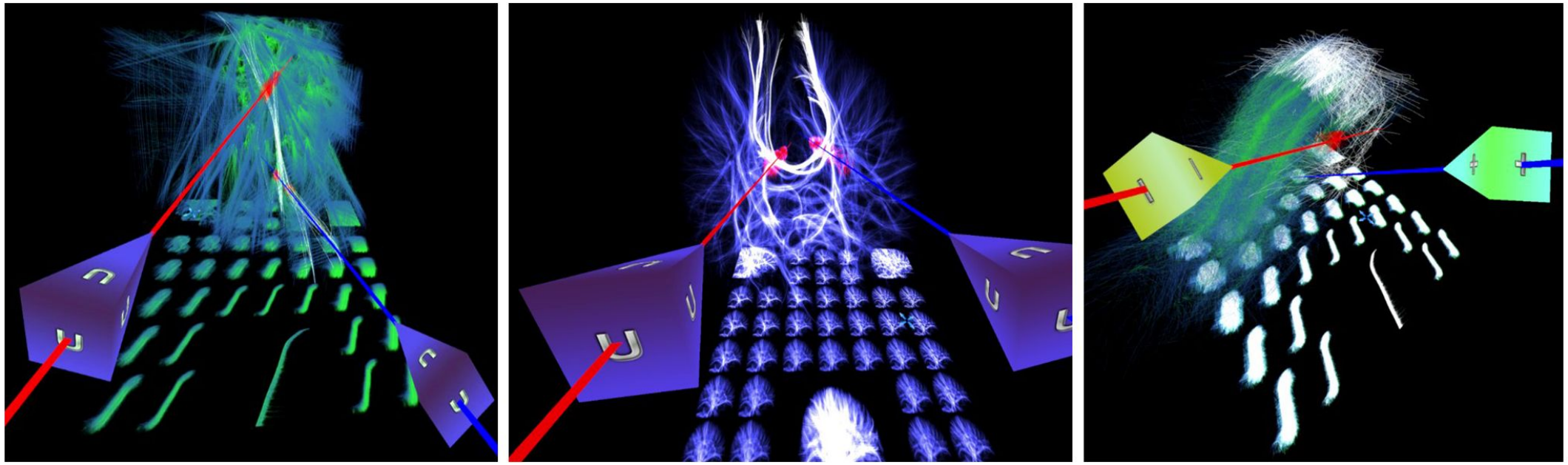


c) VR Table

d) VR Room

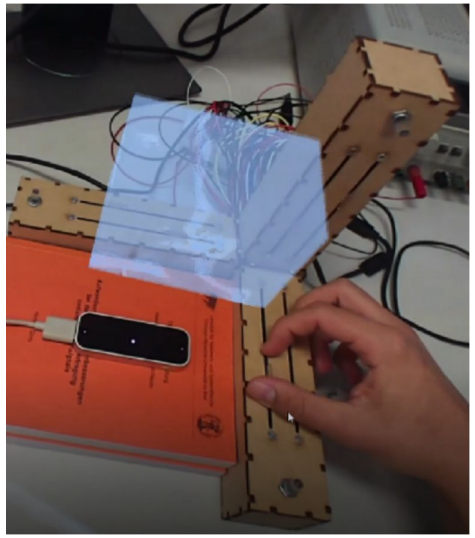
Embodied & multimodal interaction (1)

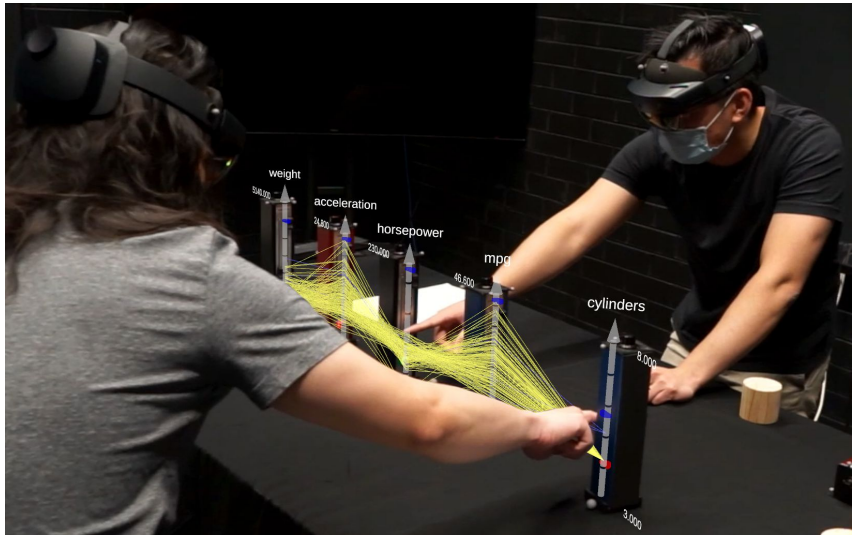
- Recent HMDs support hand-tracking and controllers with 6 degrees-of-freedom (position and rotation), allowing us to go **beyond the desktop**
- We can leverage these to facilitate **interaction and manipulation with data as though they were real objects**
- Mid-air input is oftentimes imprecise however, and are **prone to fatigue** and the "gorilla-arm effect"



Embodied & multimodal interaction (2)

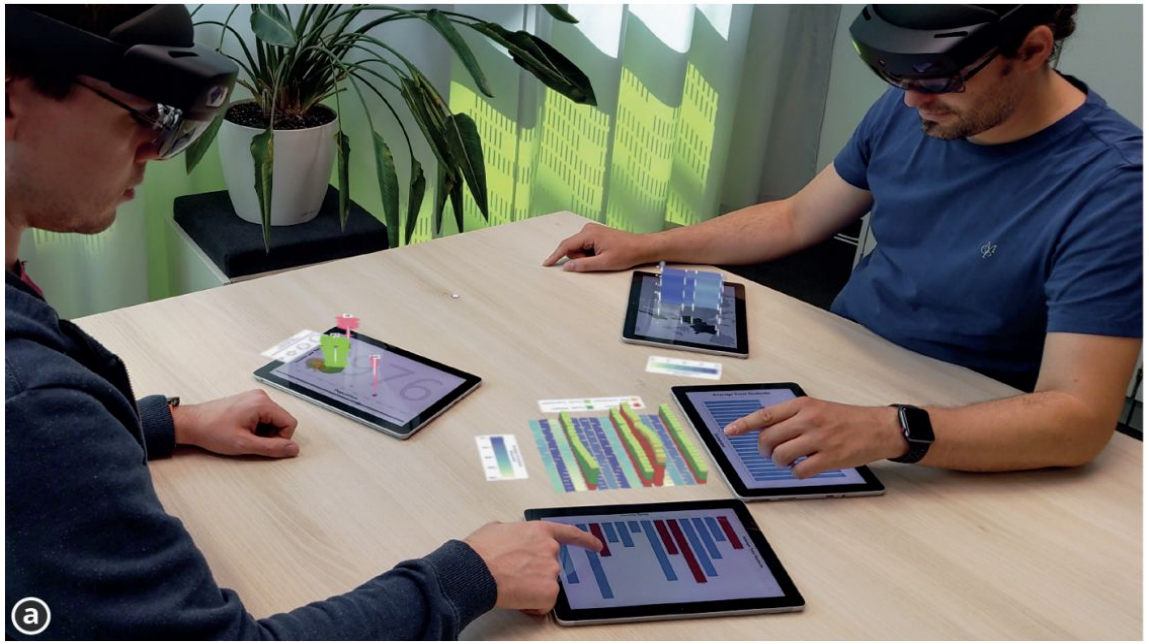
- **Tangible user interfaces** can be used to interact with and manipulate data in a manner that is more precise and comfortable
  - Compare changing your car's A/C with a dial versus a touchscreen!
- Physical input devices can be mapped to different data interactions to support a wide range of tasks, e.g.:
  - Map a slider to a range filter of a data axes
  - Use a rotary dial to cycle between data dimensions to encode
- These devices often require manual fabrication and are not a "one-size-fits-all" (yet)





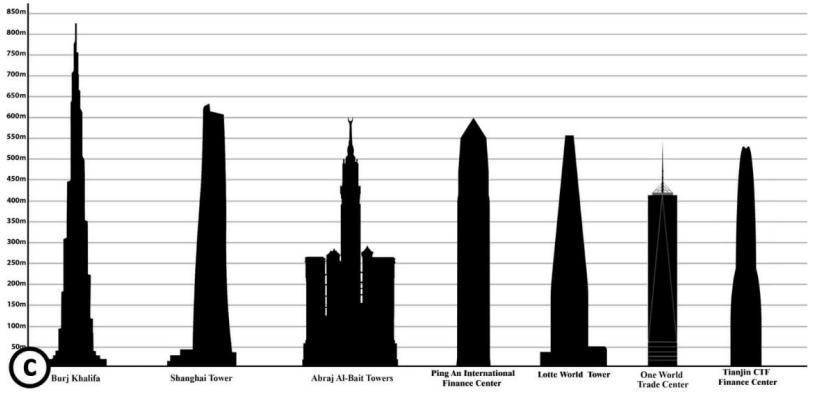
Embodied & multimodal interaction (3)

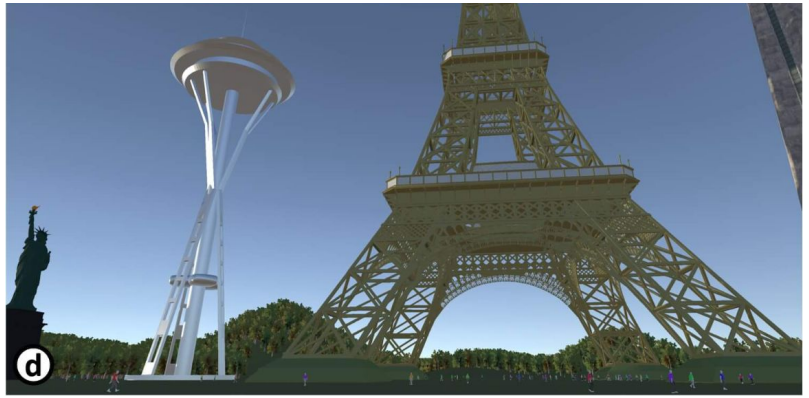
- A practical option is to simply **leverage the existing input devices** we already have around us, including mice, keyboards, and touchscreens
- This forms a **hybrid user interface** wherein traditional computing devices are used in conjunction with immersive displays, particularly AR HMDs, to achieve a “best of both worlds” between the two
  - Consider typing in mid-air versus typing on a keyboard

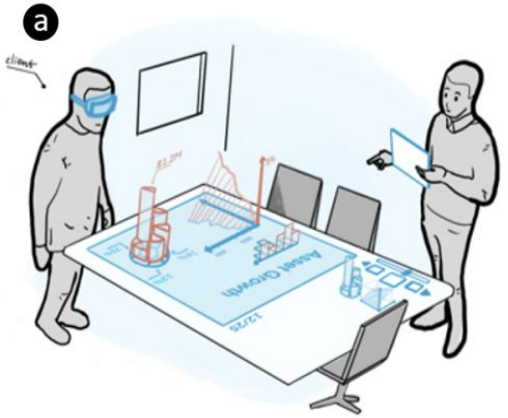


Immersion, presence, and engagement

- Having a more immersive system can make it easier for users and analysts to enter into a **flow state**, thus improving task performance as they become completely focused on their specific task
- VR/AR can also make learning about and understanding data more **engaging** to users, whether it be in a data story or in a live presentation
- A high degree of presence may also increase the **understandability and memorability** of the data and insights presented to audiences
  - Consider learning about the heights of skyscrapers by actually being able to feel the overwhelming visceral sensation of seeing them to scale in VR!





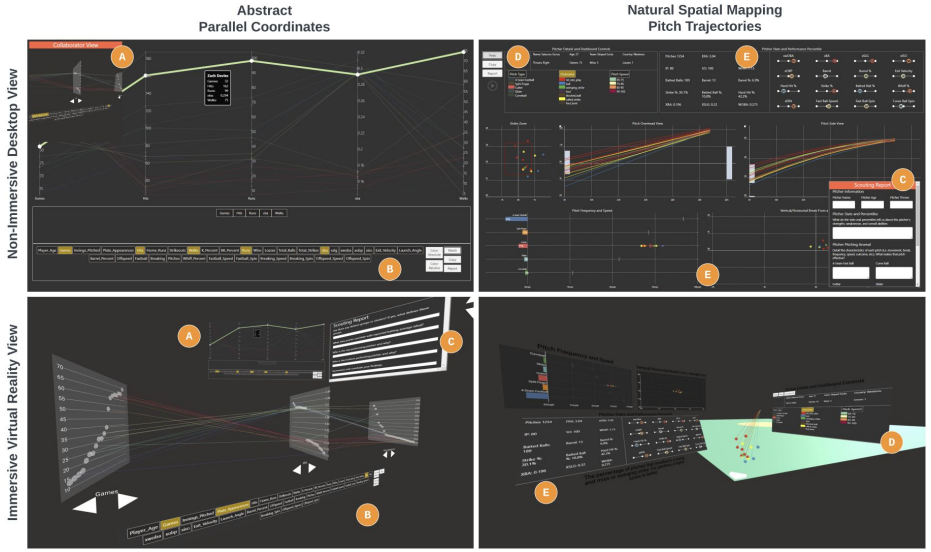


Collaborative immersive visualization (1)

- Groups of users are able to **share a virtual workspace** to perform collaborative visualization tasks in novel and potentially better ways
- **Virtual workspaces can be more freely defined** and adapted depending on the needs of the group
- Full-body tracking allows for **social cues** such as body language to be leveraged during the collaboration, especially if users are remote from one another

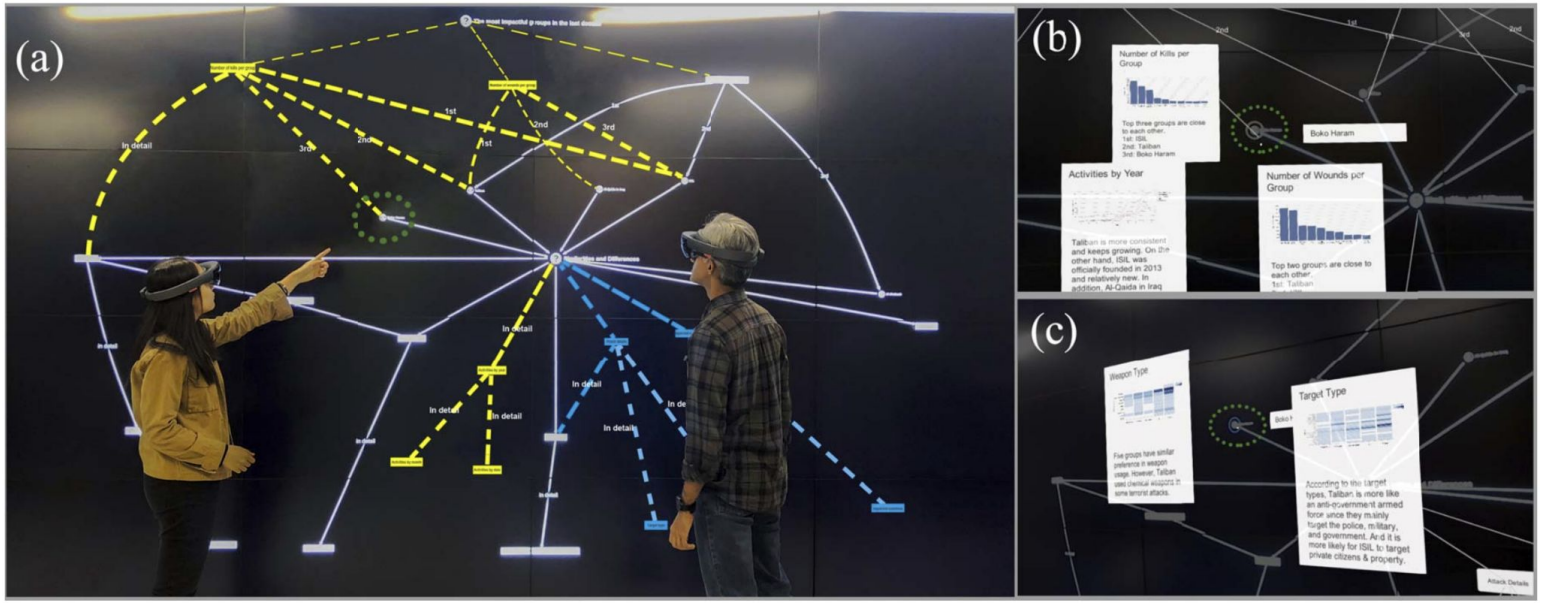
Collaborative immersive visualization (2)

- Each member of a collaborative session may also decide to use a different platform for their analysis, resulting in **asymmetric collaboration**
  - Consider one person using a VR HMD and another using their desktop
- While this approach allows for collaborators to choose the platform which best fits their needs and preferences the lack of common ground means that **cues need to be available to ensure group awareness** between people
  - Consider how the phrase “look at this trend line”, without any cues or context, becomes challenging to interpret due to its deictic nature



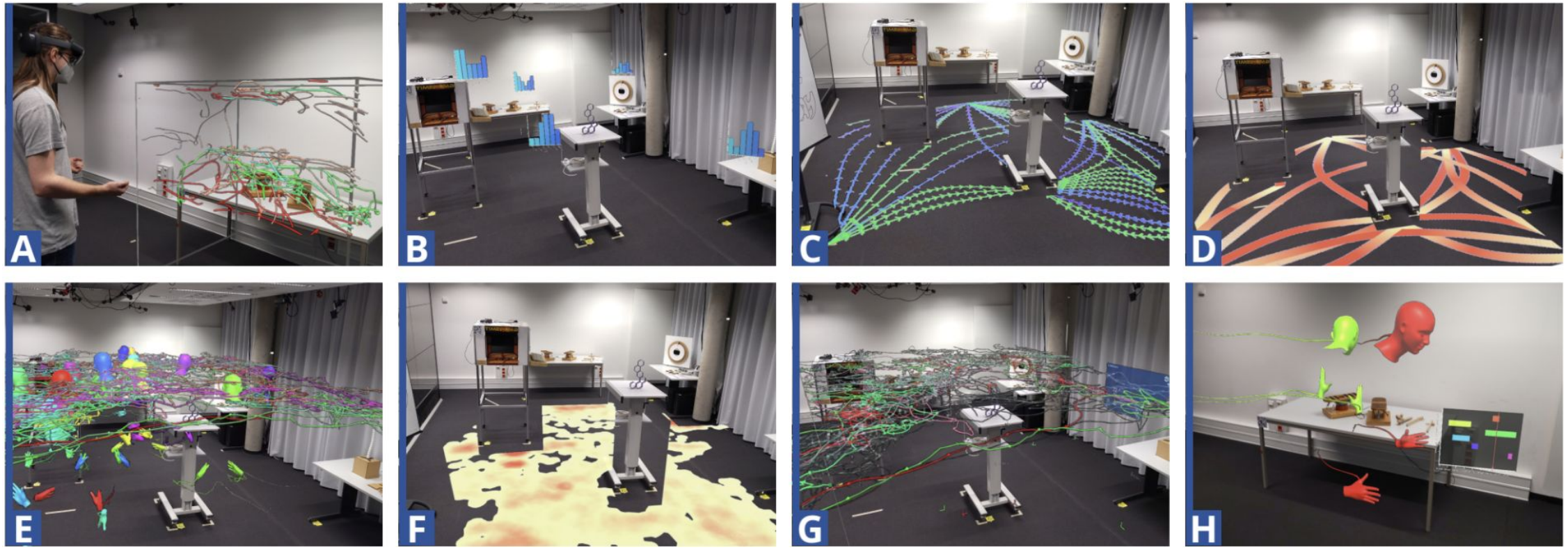
Collaborative immersive visualization (3)

- AR HMDs can also enable **workspace and information privacy** due to its display being limited to a single person
- Consider the following use cases:
  - Opening a sensitive document during a collaborative exercise which you do not want your collaborators to see
  - Doing additional analyses or information searching in a shared workspace, but in a manner which does not introduce visual clutter to others



In-situ visualization and analytics

- Data can be **visualized in-situ using AR**, wherein the visualizations provide additional information about areas and objects of interest in the real world
- By **embedding** visualizations directly onto the real world, data can be understood directly within its context without needing to refer to a separate screen or device



Is Immersive Analytics better than traditional visualization?

- It is challenging to compare the two due to the many differences between VR/AR and conventional devices
  - Is it fair to compare note-taking on paper versus a tablet?
- The more characteristics of VR/AR we leverage (e.g., embodiment, spatiality, novel input modalities), the further away from a baseline desktop comparison it gets and thus is harder to compare
- For now, extending existing desktop workflows with immersive technologies is likely the most realistic path forward
- Other factors also influence the uptake of immersive technologies, including ergonomics, cybersickness, and processing power

A glimpse into the future

- **Orion** from Meta and the **Snapchat Spectacles** offer a glimpse into what immersive technologies can and will be in the next decade
- Moving from bulky devices that are uncomfortable to wear for hours to lightweight devices that you can wear all the time
- How do you think these devices will change the way we visualize and analyze data?

In summary

- Immersive Analytics lies at the intersection of many fields, namely data visualization, human-computer interaction, and immersive display technologies (VR and AR)
- The range of use cases and applications of immersive analytics is vast, each with their own considerations in terms of both how to visualize data and how to interact with it. Even VR is very different from AR!
- As immersive headsets become more affordable, powerful, and ergonomic, perhaps we will see such immersive analytics applications reach mainstream use and appeal

Recommended reading

- Immersive Analytics (2018). K. Marriott, F. Schreiber, T. Dwyer, K. Klein, N. H. Riche, T. Itoh, W. Stuerzlinger, & B. H. Thomas (Eds.). Springer International Publishing. https://doi.org/10.1007/978-3-030-01388-2
- The VR Book (2015). J. Jerald. Association for Computing Machinery. https://doi.org/10.1145/2792790

Anu

Docs Examples API

Anu
Immersive Visualizations with Data-Driven Babylon

Create 3D and immersive data visualizations in Babylon.js with powerful data-driven scene manipulation patterns, pre-fabs, and interactions.

Get Started Examples

Data Binding

Use D3 style data binding patterns to create, select, and manipulate meshes in the Babylon scene graph.

Prefabs

Pre-fabricated 3D elements useful for quickly creating visualizations such as axes, text, maps and globes, etc.

Interaction

Quickly add XR spatial interactions to create dynamic data visualizations, animations, and more.

3. Developing immersive data visualizations with Anu.js