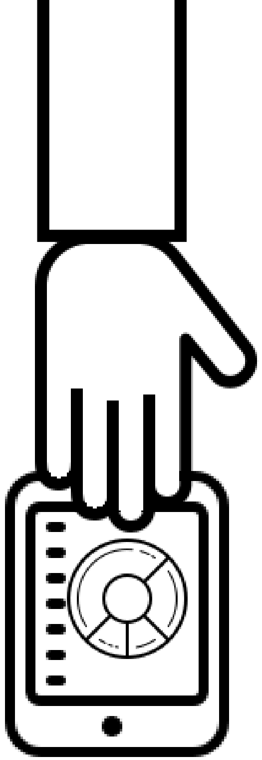
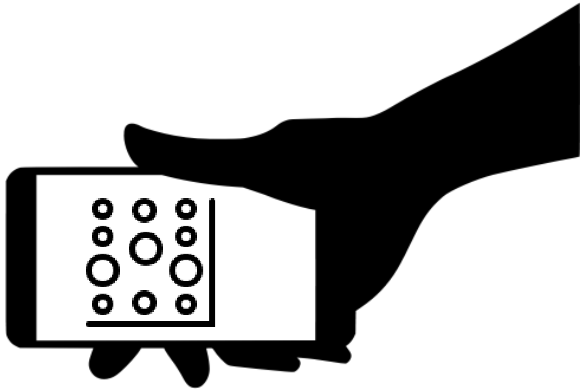
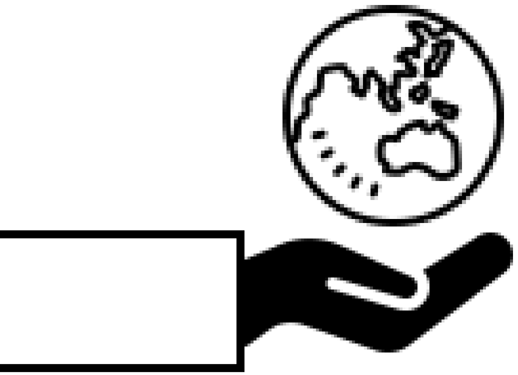


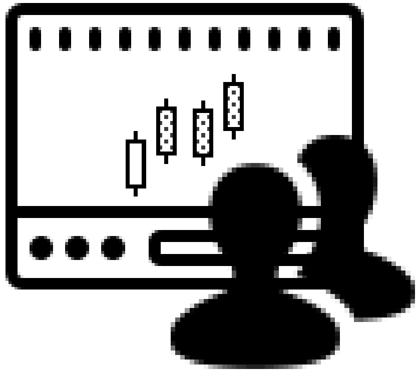


WHEN VISUALIZATION MEETS HCI…

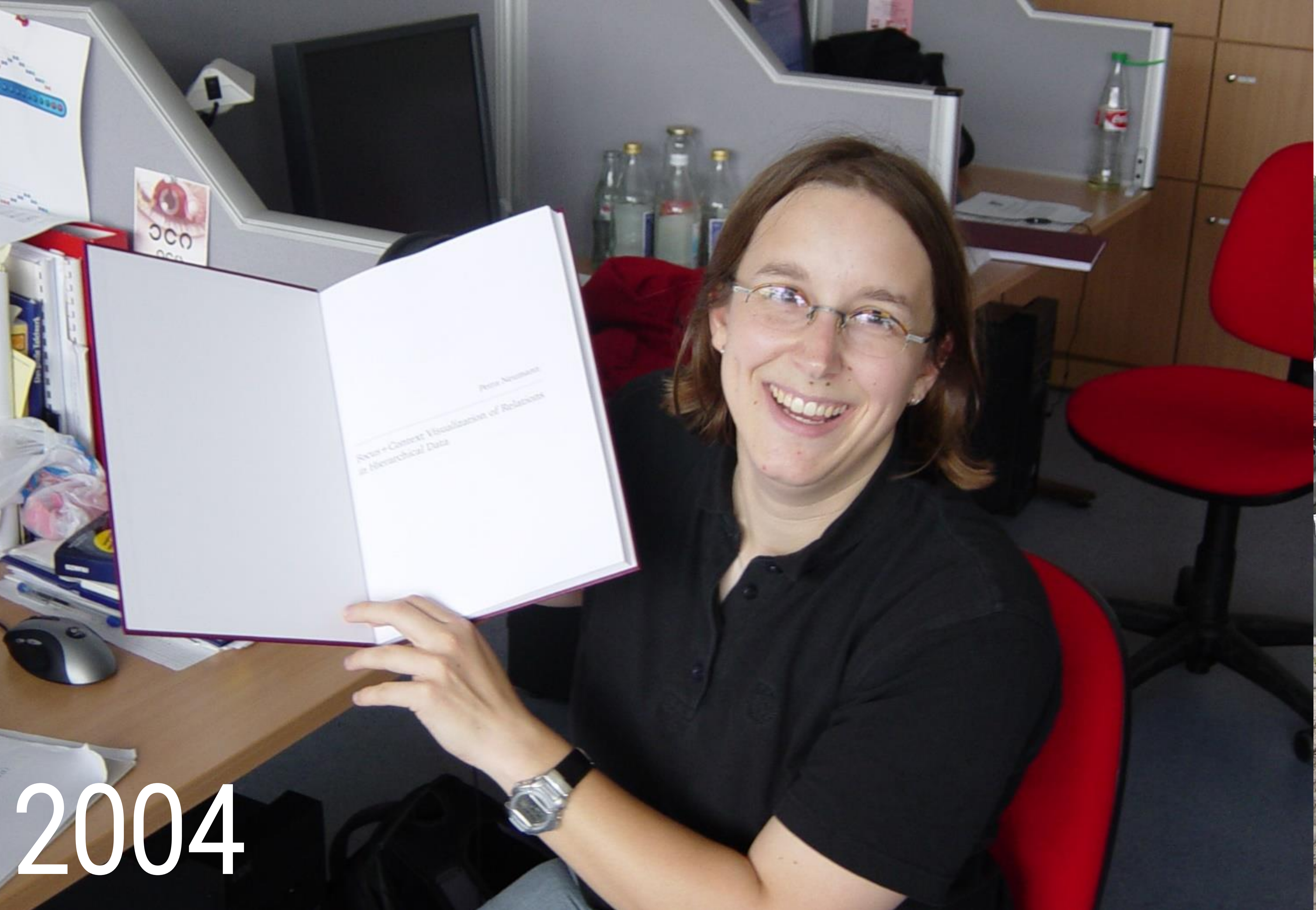
Petra Isenberg
@dr_pi petra.isenberg@inria.fr

Visual Analytics Project



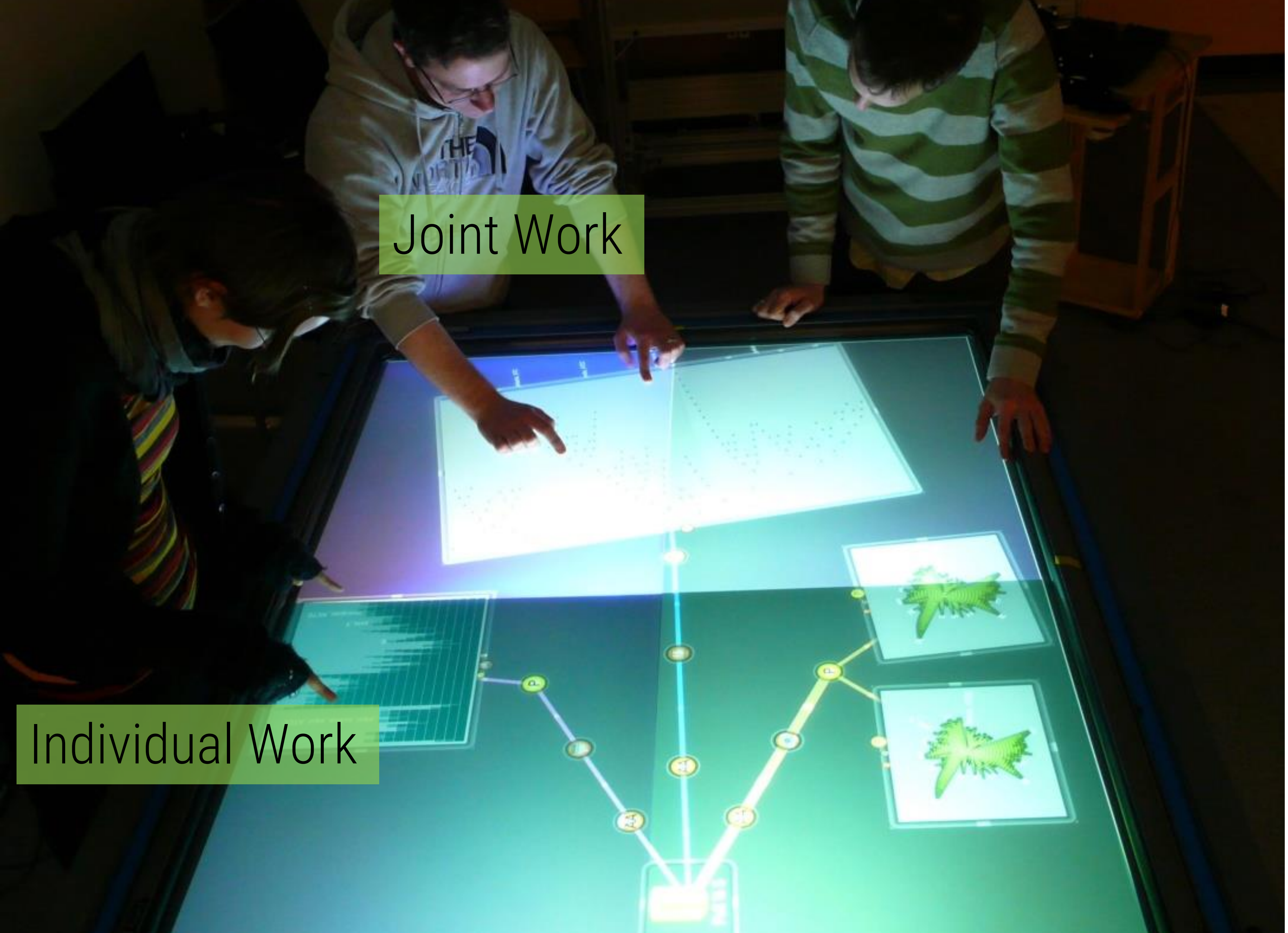


https://icons8.com/



My thesis advisor

Collaborative Information Visualization



THE UNIVERSITY OF CALGARY

Collaborative Information Visualization in Co-located Environments

by

Petra Isenberg

A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF COMPUTER SCIENCE

CALGARY, ALBERTA

DECEMBER, 2009

Collaborative Information Visualization

vs.

Computer Supported Collaborative Work

What’s the relationship?

Information Visualization
vs.
Human-Computer Interaction
What's the relationship?

Visualization

vs.

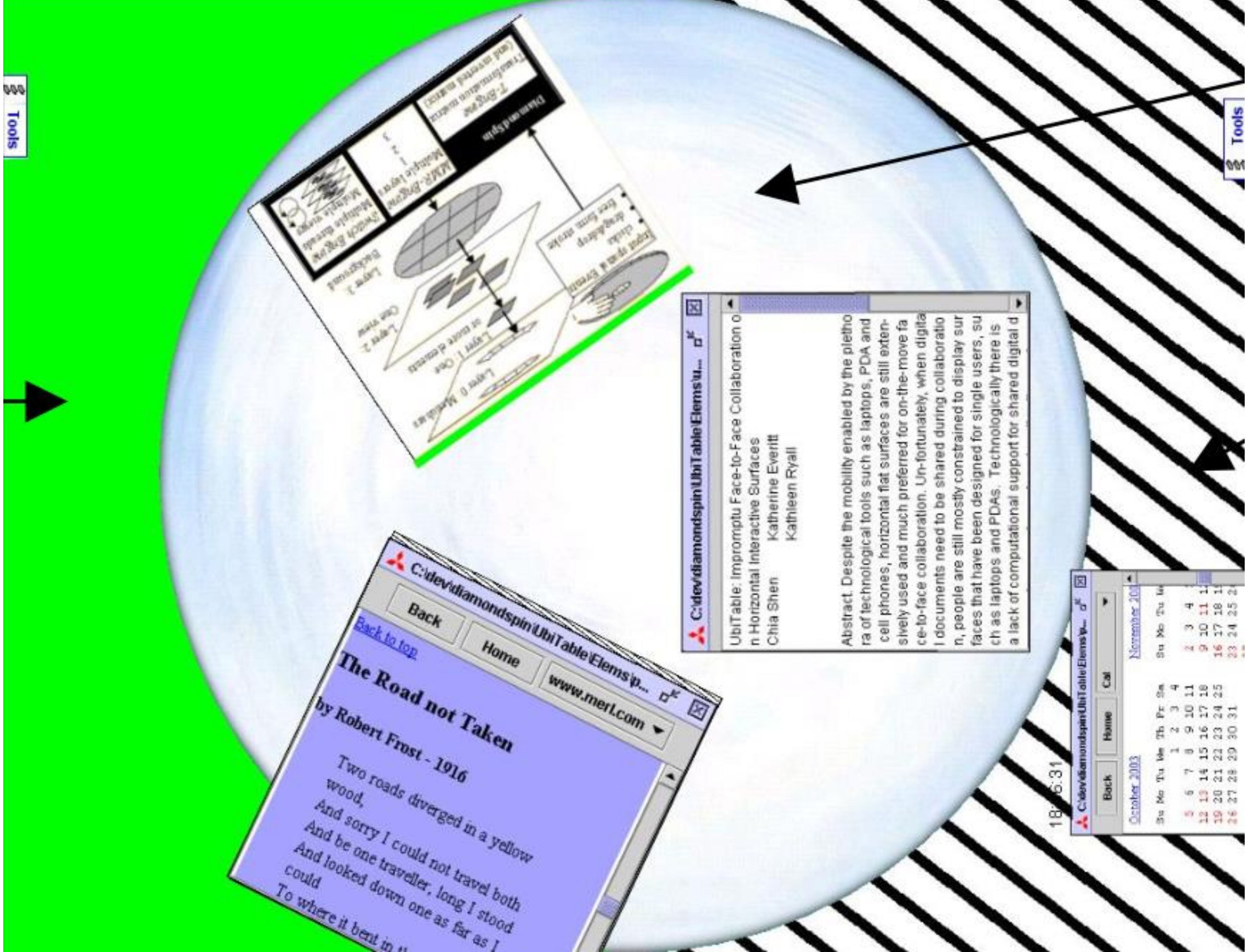
Human-Computer Interaction

What's the relationship?

Really?

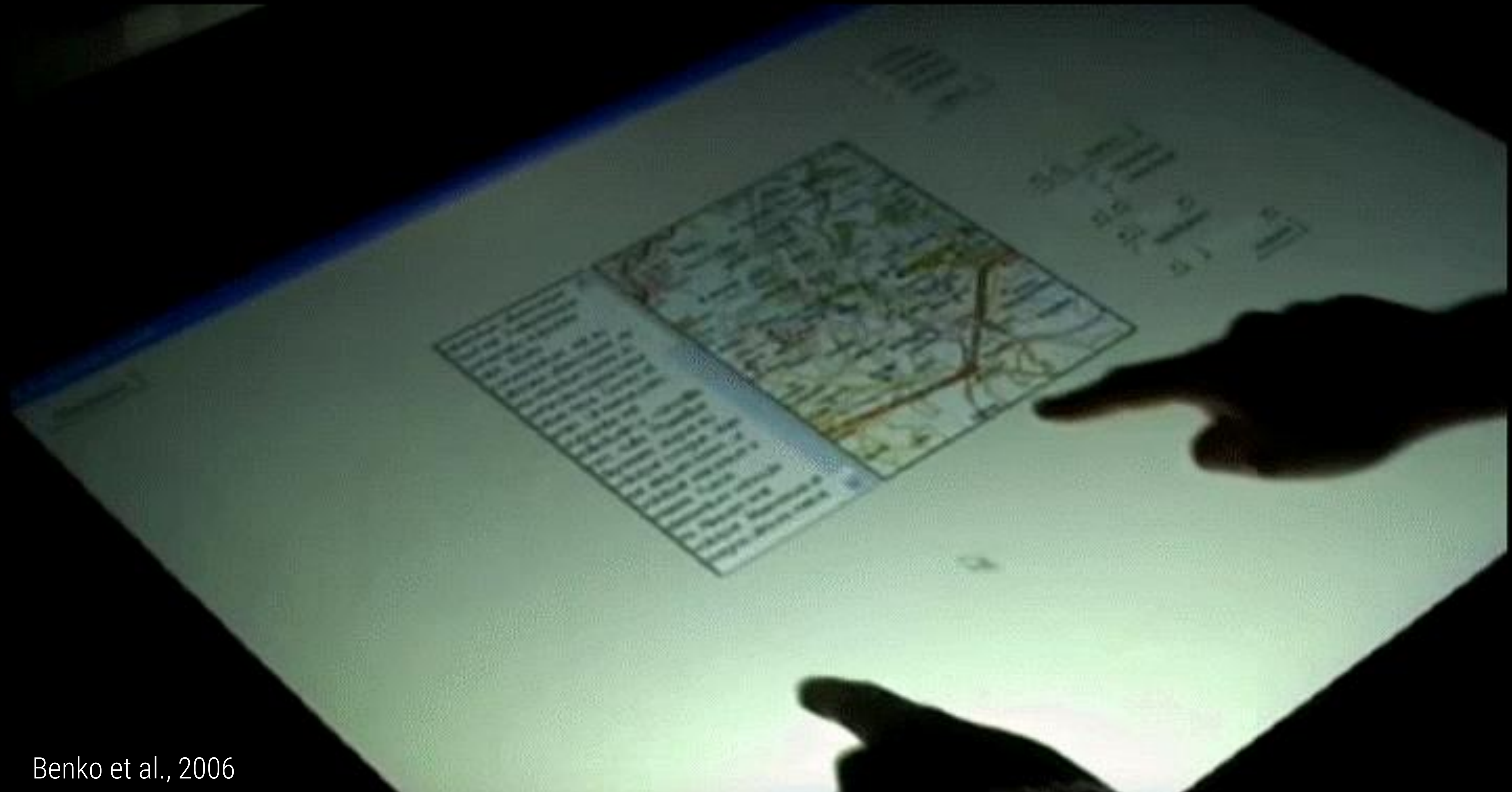
Isn't it obvious?

Vernier et al, 2002



Shen et al, 2003

TouchLight, Wilson, 2004



Benko et al., 2006

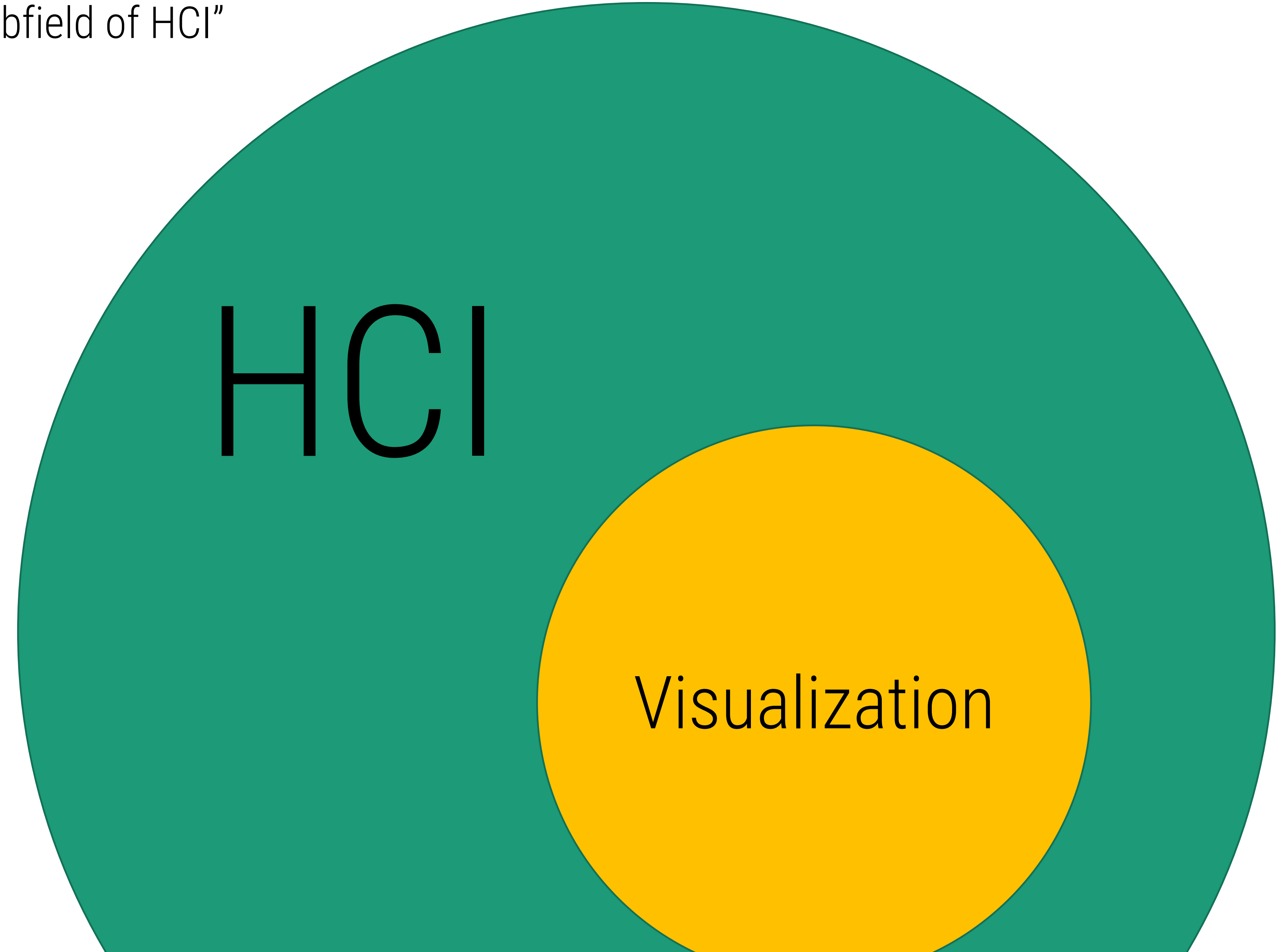
https://www.youtube.com/watch?v=X-GXO_urMow#t=408

https://www.youtube.com/watch?v=X-GXO_urMow#t=408

It's different

But how?

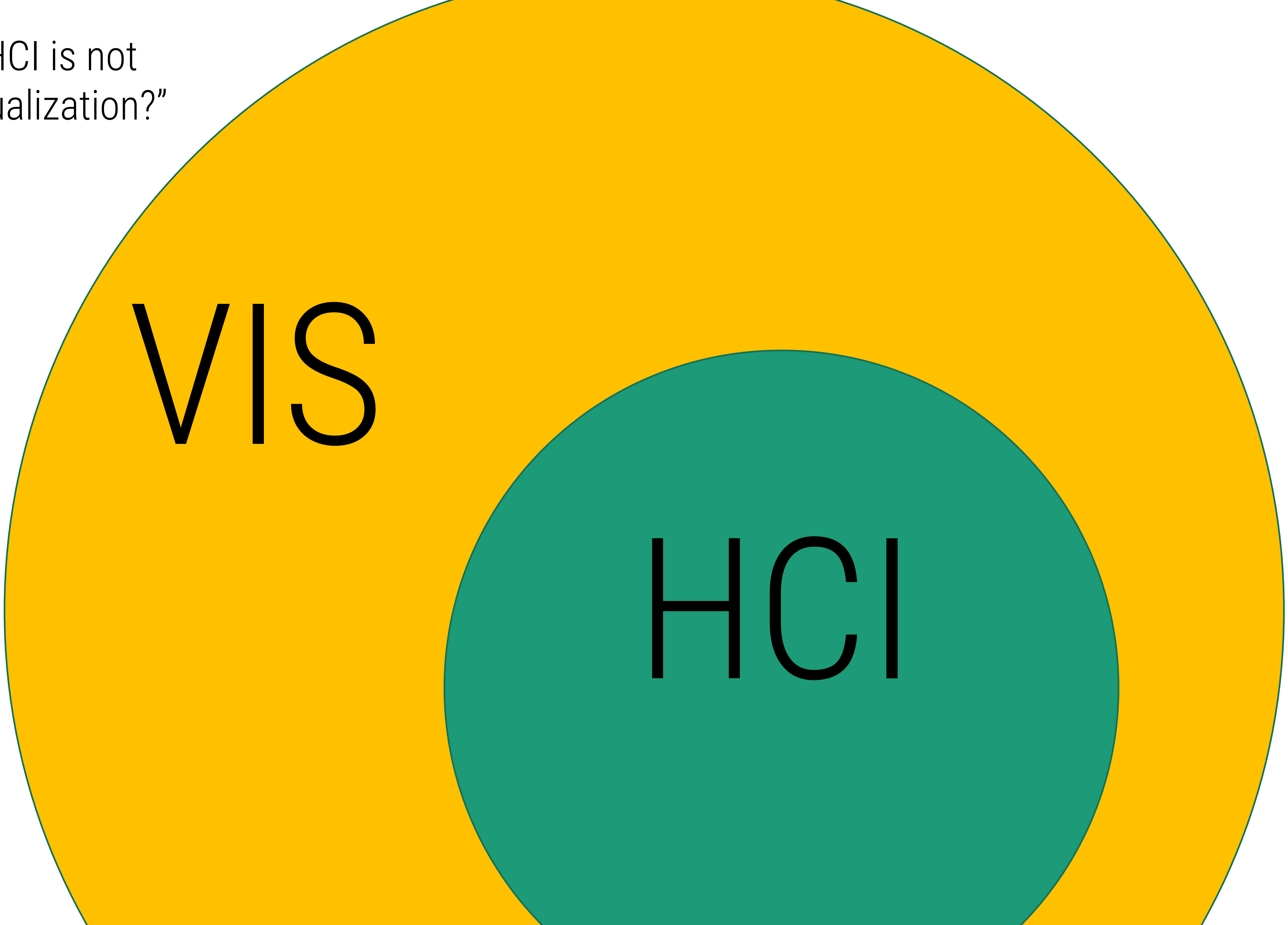
“Vis is a subfield of HCI”



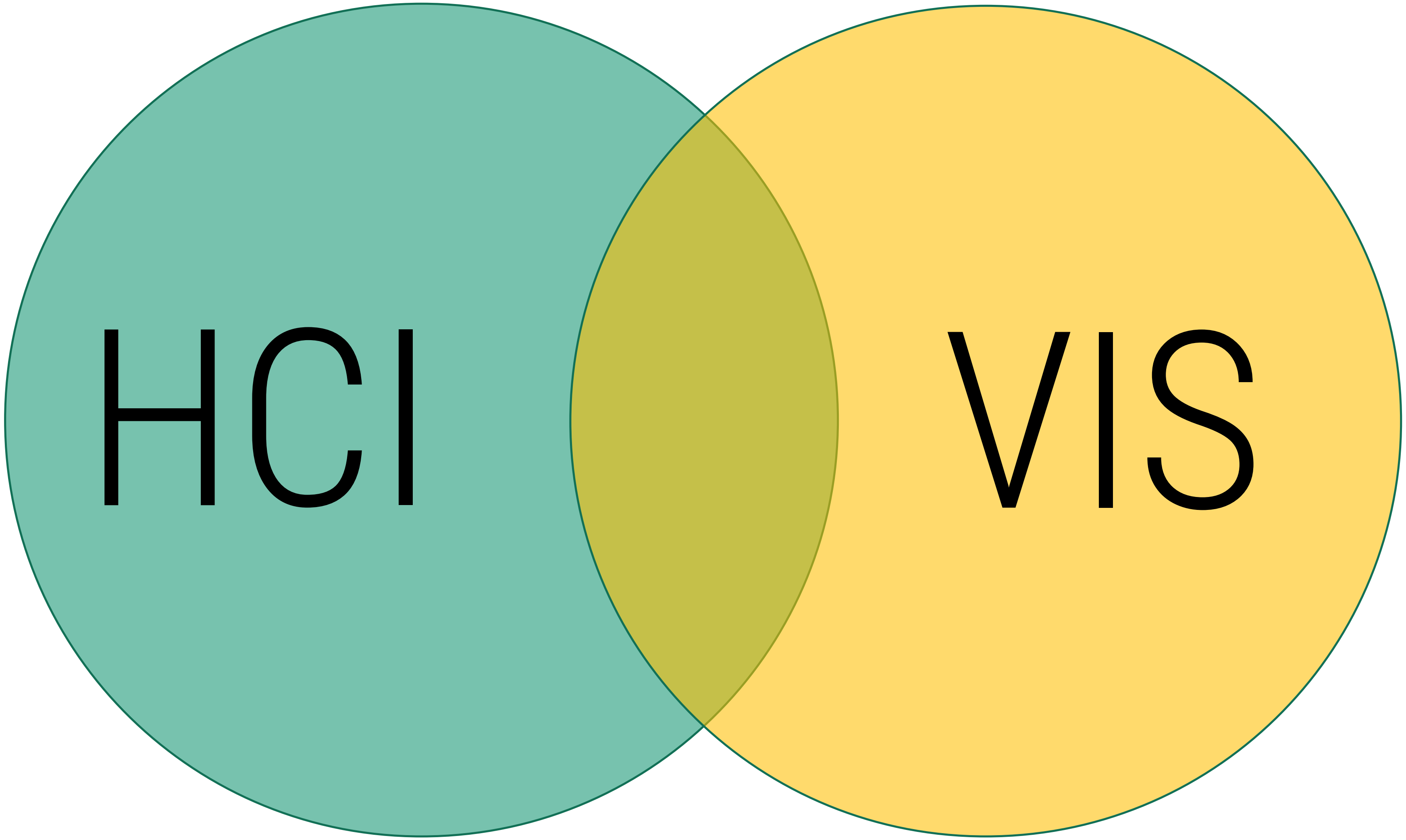
will Chair and serve on the subcommittee and if a subcommittee consists of multiple tracks. Subcommittees have been constructed with an eye to maintaining logically coherent clusters of topics.

- User Experience and Usability
- Specific Applications Areas
- Learning, Education, and Families
- Interaction Beyond the Individual
- Games and Play
- Privacy and Security
- Visualization
- Health
- Accessibility and Aging
- Design
- Interaction Techniques, Devices, and Modalities
- Understanding People: Theory, Concepts, Methods
- Engineering Interactive Systems and Technologies
- Critical and Sustainable Computing
- Computational Interaction

"What part of HCI is not relevant to visualization?"



“Each area has its specialties”

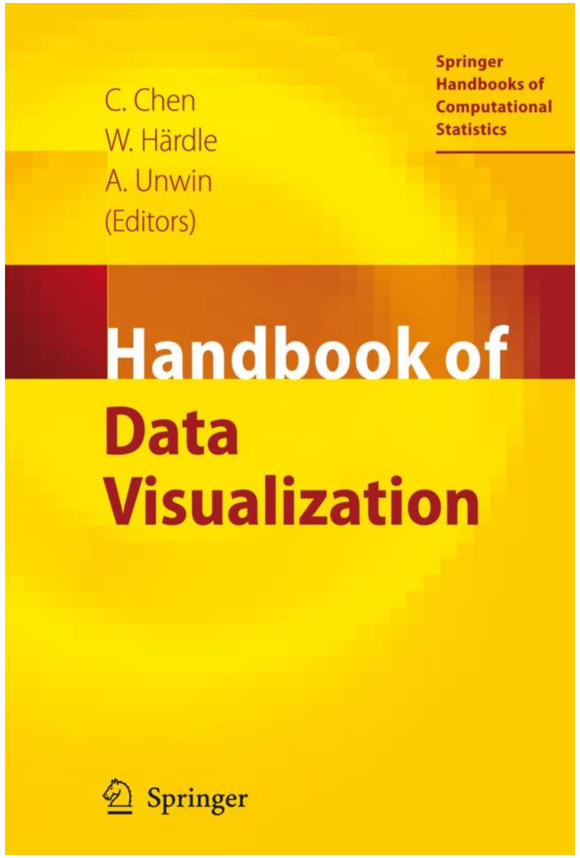


“the paper does seem to be more at home at an HCI venue”

[review quote from an IEEE VIS paper]

WHAT IS

VISUALIZATION?



III. Methodologies

The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations

Ben Shneiderman
Department of Computer Science,
Human-Computer Interaction Laboratory, and Institute for Systems Research
University of Maryland
College Park, Maryland 20742 USA
ben@cs.umd.edu

Abstract

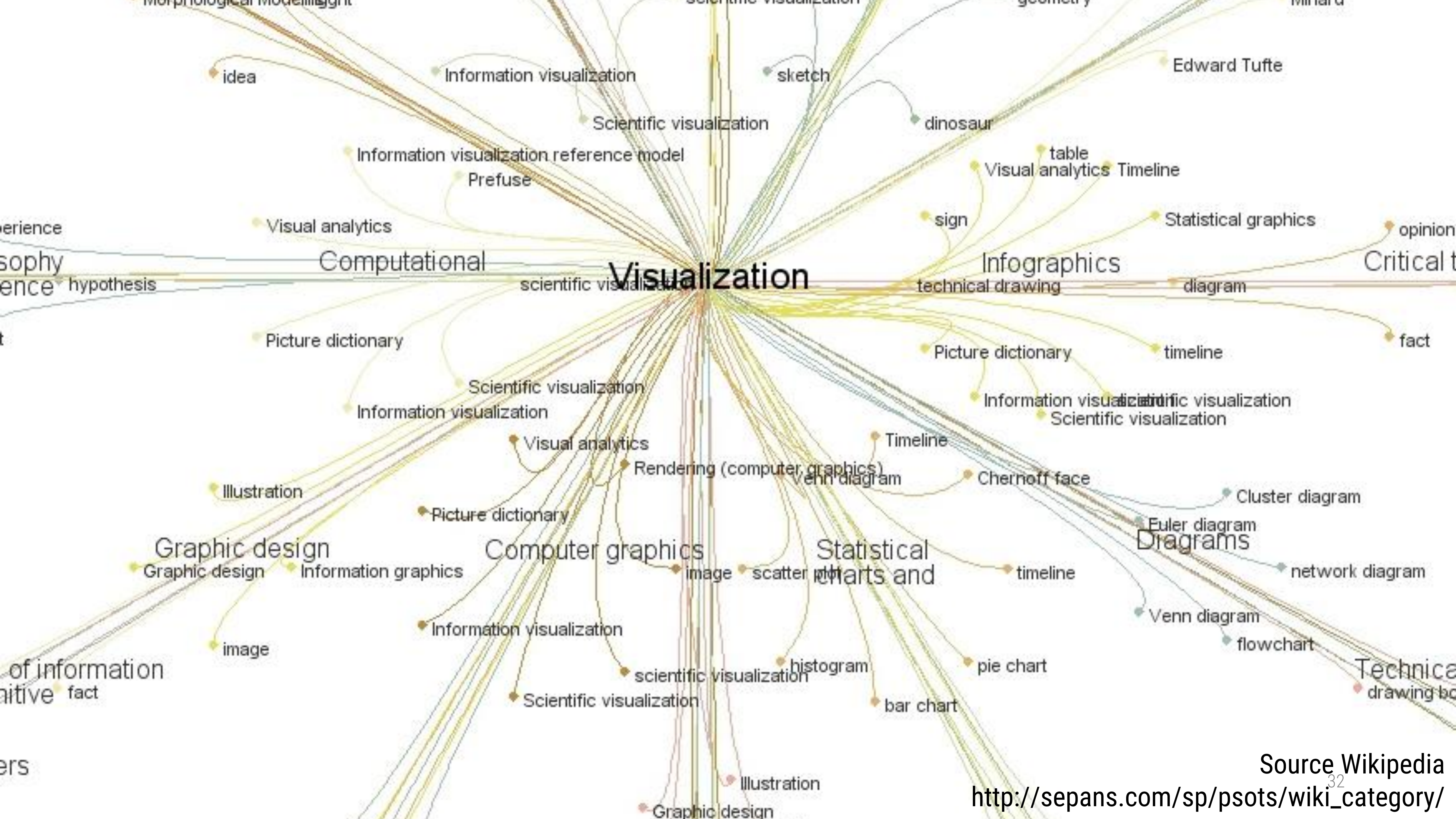
A useful starting point for designing advanced graphical user interfaces is the Visual Information-Seeking Mantra: overview first, zoom and filter, then details on demand. But this is only a starting point in trying to understand the rich and varied set of information visualizations that have been proposed in recent years. This paper offers a task by data type taxonomy with seven data types (one-, two-, three-dimensional data, temporal and multi-dimensional data, and tree and network data) and seven tasks (overview, zoom, filter, details-on-demand, relate, history, and extracts).

> Everything points to the conclusion that the phrase 'the language of art' is more than a loose metaphor, that even to describe the visible world in images we need a developed system of schemata.

keys), are being pushed aside by newer notions of information gathering, seeking, or visualization and data mining, warehousing, or filtering. While distinctions are subtle, the common goals reach from finding a narrow set of items in a large collection that satisfy a well-understood information need (known-item search) to developing an understanding of unexpected patterns within the collection (browse) (Marchionini, 1995).

Exploring information collections becomes increasingly difficult as the volume grows. A page of information is easy to explore, but when the information becomes the size of a book, or library, or even larger, it may be difficult to locate known items or to browse to gain an overview.

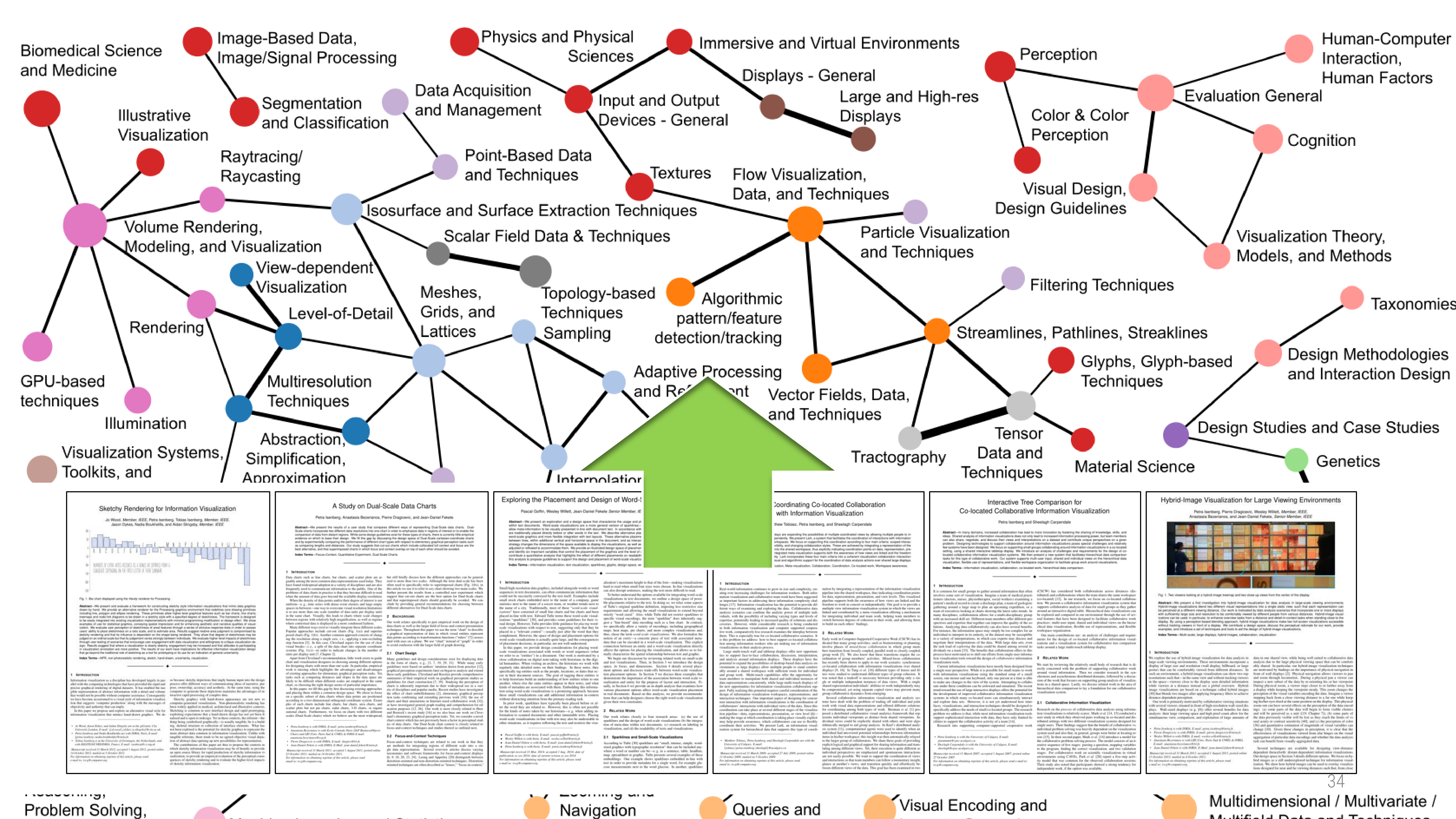
Designers are just discovering how to use the rapid and high resolution color displays to present large amounts of information in orderly and user-controlled ways. Perceptual psychologists, statisticians, and graphic designers (Bertin, 1983; Cleveland, 1993; Tufte, 1983, 1990) offer valuable guidance about presenting static information, but the



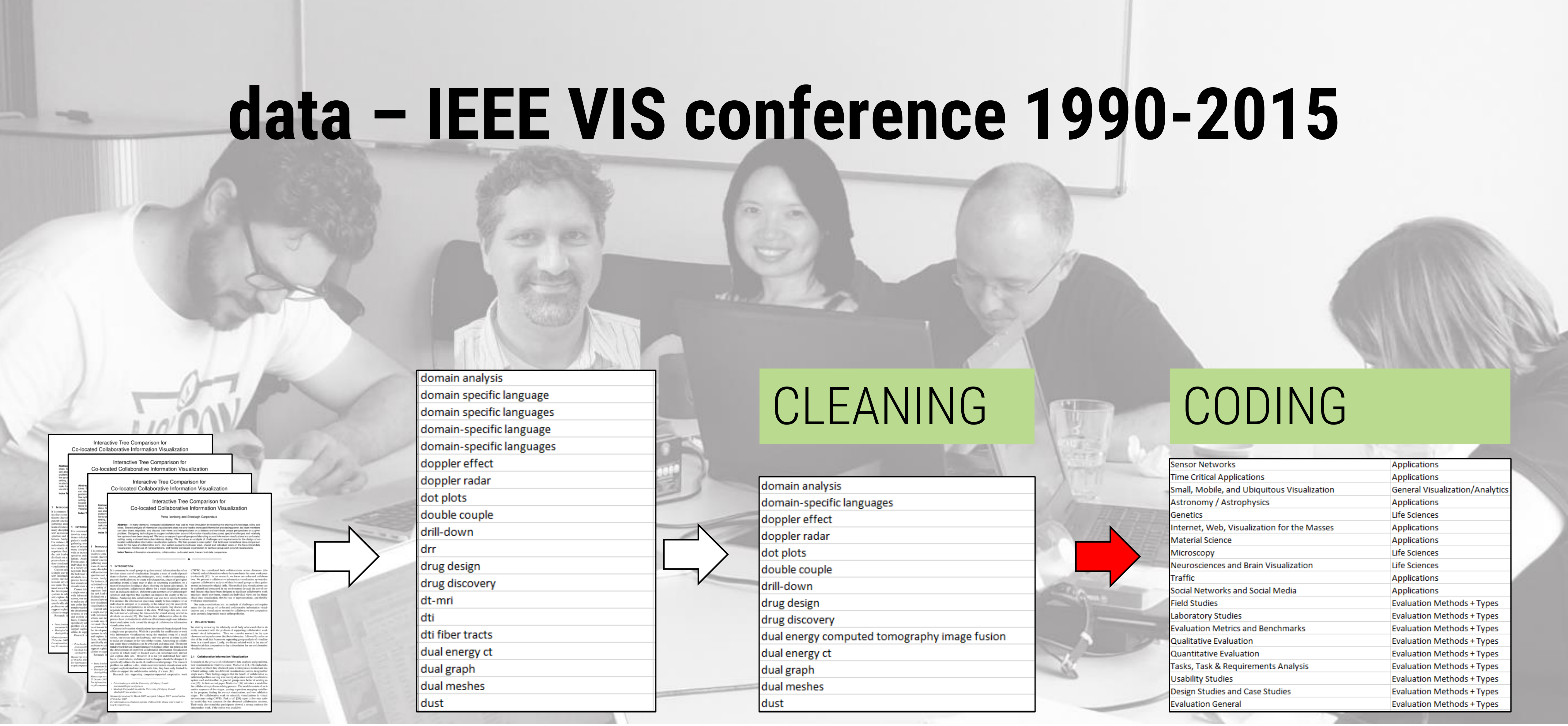
Source Wikipedia

http://sepans.com/sp/psots/wiki_category/


information visualization tools
Visualisation
DATA
Figure
Display Window
Profile Window
Menu
Data Visuali
Chart.js
Simple, clean and engaging charts for designers and developers
visual.ly
Wheel-Like Data Visualization With MooWheel
dygraphs
Polymaps


Biomedical Science and Medicine
Image-Based Data, Image/Signal Processing
Physics and Physical Sciences
Immersive and Virtual Environments
Perception
Human-Computer Interaction, Human Factors
Displays - General
Illustrative Visualization
Segmentation and Classification
Data Acquisition and Management
Input and Output Devices - General
Large and High-res Displays
Evaluation General
Color & Color Perception
Cognition
Raytracing/ Raycasting
Point-Based Data and Techniques
Textures
Flow Visualization, Data, and Techniques
Visual Design, Design Guidelines
Isosurface and Surface Extraction Techniques
Volume Rendering, Modeling, and Visualization
Scalar Field Data & Techniques
Particle Visualization and Techniques
Visualization Theory, Models, and Methods
View-dependent Visualization
Meshes, Grids, and Lattices
Topology-based Techniques
Algorithmic pattern/feature detection/tracking
Filtering Techniques
Level-of-Detail
Rendering
Sampling
Taxonomies
Streamlines, Pathlines, Streaklines
GPU-based techniques
Multiresolution Techniques
Adaptive Processing
Glyphs, Glyph-based Techniques
Design Methodologies and Interaction Design
Vector Fields, Data, and Techniques
Illumination
Tensor Data and Techniques
Design Studies and Case Studies
Abstraction, Simplification, Approximation
Visualization Systems, Toolkits, and
Tractography
Material Science
Genetics
Interpolation
Sketchy Rendering for Information Visualization
A Study on Dual-Scale Data Charts
Exploring the Placement and Design of Word-
Coordinating Co-located Collaboration with Information Visualization
Interactive Tree Comparison for Co-located Collaborative Information Visualization
Hybrid-Image Visualization for Large Viewing Environments
Problem Solving,
Navigation
Queries and
Visual Encoding and
Multidimensional / Multivariate /

data – IEEE VIS conference 1990-2015



2431 papers

domain analysis
domain specific language
domain specific languages
domain-specific language
domain-specific languages
doppler effect
doppler radar
dot plots
double couple
drill-down
drr
drug design
drug discovery
dt-mri
dti
dti fiber tracts
dual energy ct
dual graph
dual meshes
dust

4319 unique keywords

CLEANING

domain analysis
domain-specific languages
doppler effect
doppler radar
dot plots
double couple
drill-down
drug design
drug discovery
dual energy computed tomography image fusion
dual energy ct
dual graph
dual meshes
dust

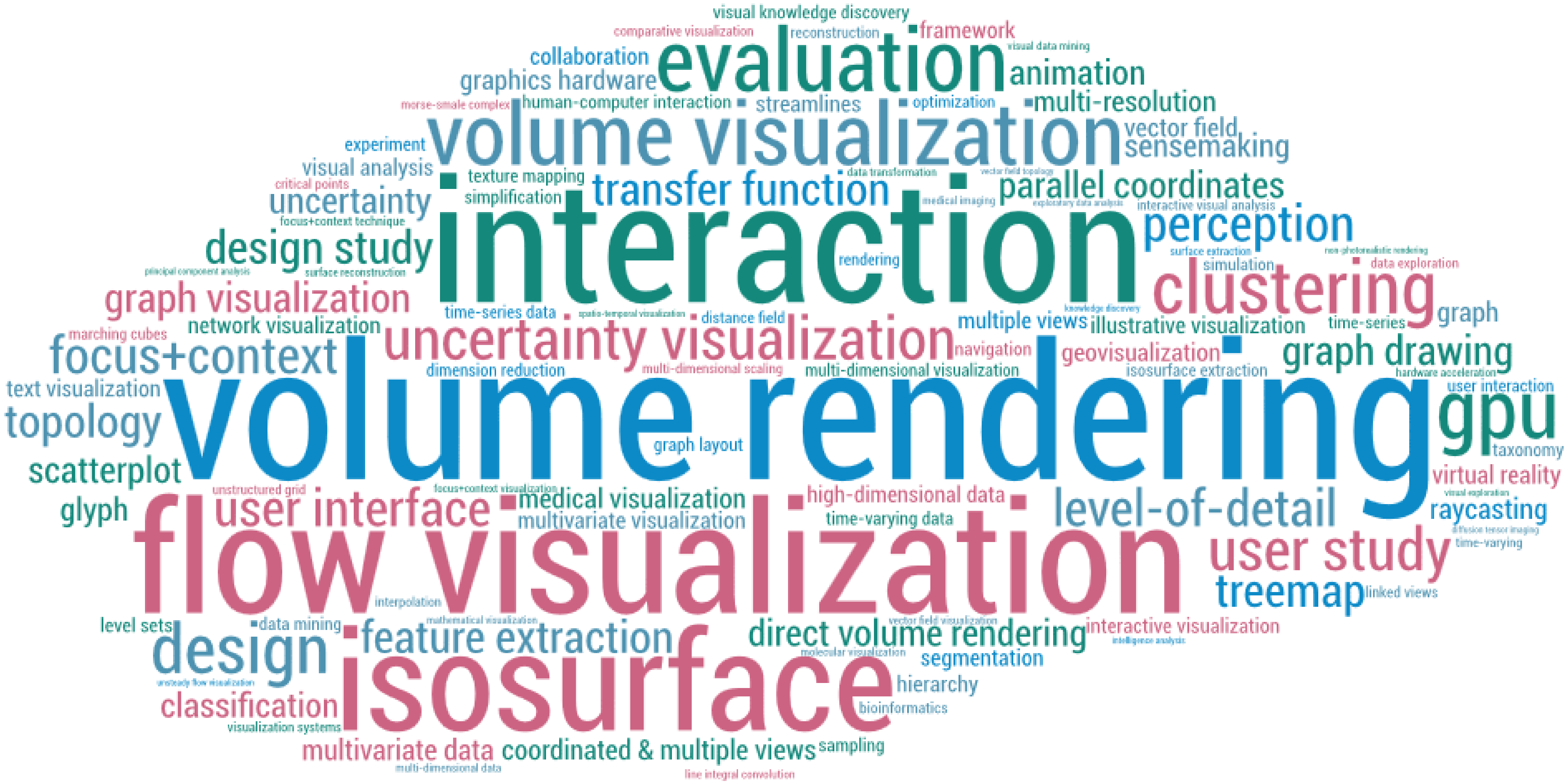
3952 unique cleaned keywords

CODING

Sensor Networks	Applications
Time Critical Applications	Applications
Small, Mobile, and Ubiquitous Visualization	General Visualization/Analytics
Astronomy / Astrophysics	Applications
Genetics	Life Sciences
Internet, Web, Visualization for the Masses	Applications
Material Science	Applications
Microscopy	Life Sciences
Neurosciences and Brain Visualization	Life Sciences
Traffic	Applications
Social Networks and Social Media	Applications
Field Studies	Evaluation Methods + Types
Laboratory Studies	Evaluation Methods + Types
Evaluation Metrics and Benchmarks	Evaluation Methods + Types
Qualitative Evaluation	Evaluation Methods + Types
Quantitative Evaluation	Evaluation Methods + Types
Tasks, Task & Requirements Analysis	Evaluation Methods + Types
Usability Studies	Evaluation Methods + Types
Design Studies and Case Studies	Evaluation Methods + Types
Evaluation General	Evaluation Methods + Types

180 topics
14 categories

Isenberg et al.: Visualization as Seen Through its Research Paper Keywords


visual knowledge discovery
comparative visualization
reconstruction
framework
visual data mining
collaboration
evaluation
graphics hardware
animation
morse-smale complex
human-computer interaction
streamlines
optimization
multi-resolution
experiment
volume visualization
vector field
sensemaking
visual analysis
texture mapping
data transformation
vector field topology
critical points
simplification
transfer function
parallel coordinates
uncertainty
medical imaging
exploratory data analysis
interactive visual analysis
focus+context technique
interaction
perception
design study
surface extraction
non-photorealistic rendering
principal component analysis
surface reconstruction
rendering
simulation
data exploration
clustering
graph visualization
time-series data
spatio-temporal visualization
knowledge discovery
distance field
multiple views
illustrative visualization
time-series
graph
network visualization
marching cubes
uncertainty visualization
navigation
focus+context
geovisualization
graph drawing
dimension reduction
multi-dimensional scaling
multi-dimensional visualization
isosurface extraction
hardware acceleration
text visualization
user interaction
volume rendering
topology
gpu
graph layout
taxonomy
scatterplot
virtual reality
unstructured grid
focus+context visualization
high-dimensional data
visual exploration
glyph
user interface
medical visualization
level-of-detail
raycasting
multivariate visualization
time-varying data
diffusion tensor imaging
flow visualization
time-varying
user study
interpolation
treemap
linked views
level sets
data mining
mathematical visualization
vector field visualization
interactive visualization
design
feature extraction
direct volume rendering
intelligence analysis
molecular visualization
segmentation
unsteady flow visualization
isosurface
hierarchy
classification
bioinformatics
visualization systems
multivariate data
coordinated & multiple views
sampling
multi-dimensional data
line integral convolution

MOST COMMON TOPICS

volume rendering, modeling, & vis (14% of papers)

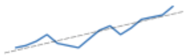
interaction techniques – general (11% of papers)

graph/network data & tech (8% of papers)

evaluation – general (8% of papers)

biomedical science & medicine (8% of papers)

SIGNIFICANT TEMPORAL TRENDS

interaction techniques—general 

evalua

machi

timese

multic

analys

graph

visual

data c

visuali

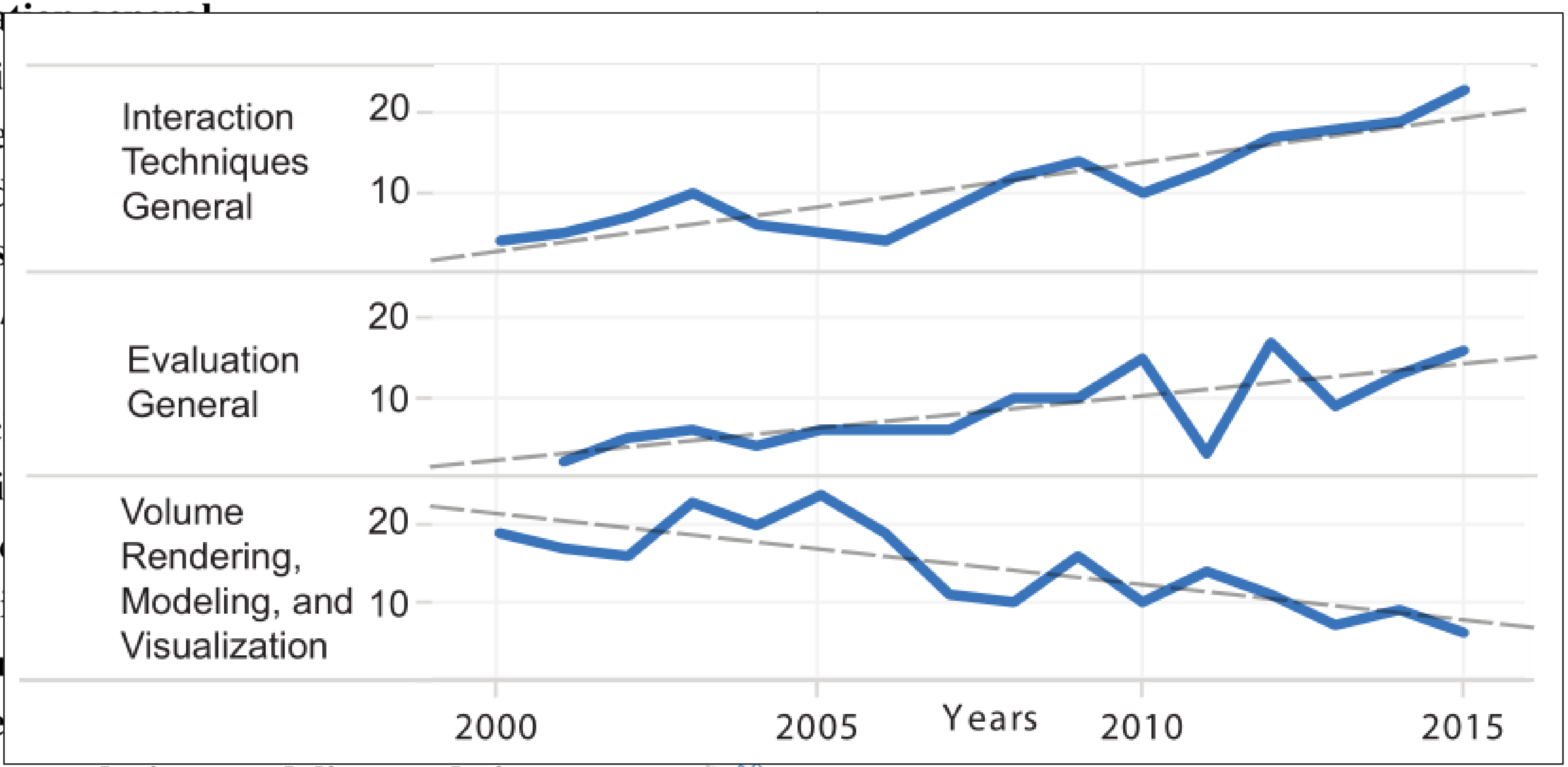
biomed

flow vi

numer

meshe

volume rendering, modeling, and vis.



Isenberg et al.: Visualization as Seen Through its Research Paper Keywords

OVERLAP AREAS

Design
Evaluation
Interaction

A MAIN DIFFERENCE

Vis focused on data & discovery*

* "discovery" in a broad sense of the term

OPPORTUNITIES FOR JOINT WORK

let’s not dwell on differences but look at what can be created

EMERGING AREAS IN VIS

and opportunities for collaboration in HCI

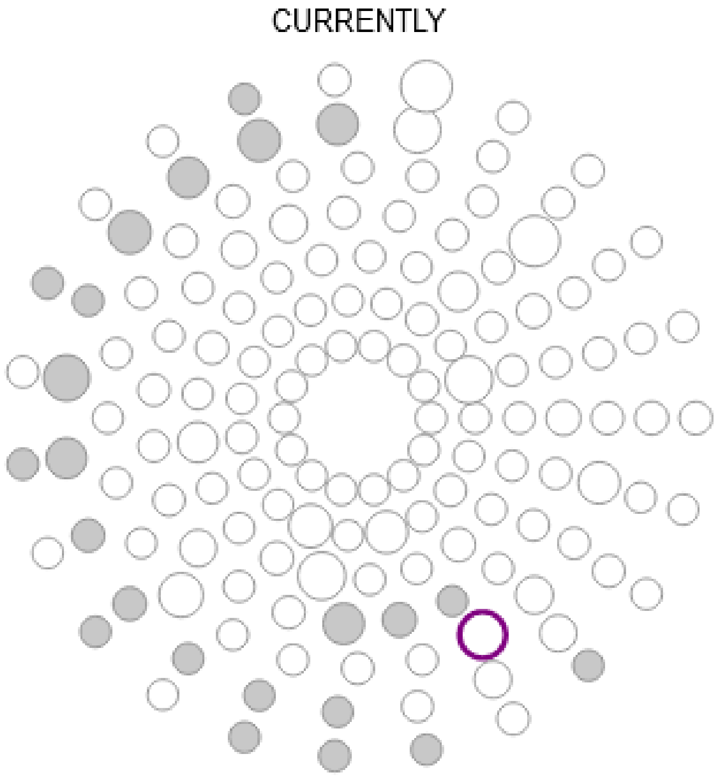
DATA PHYSICALIZATIONS

“A data physicalisation (or simply physicalization) is a physical artifact whose geometry or material properties encode data”

Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, Kasper Hornbæk. **Opportunities and Challenges for Data Physicalization**. CHI 2015 - Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, 2015.

DATA PHYSICALIZATION

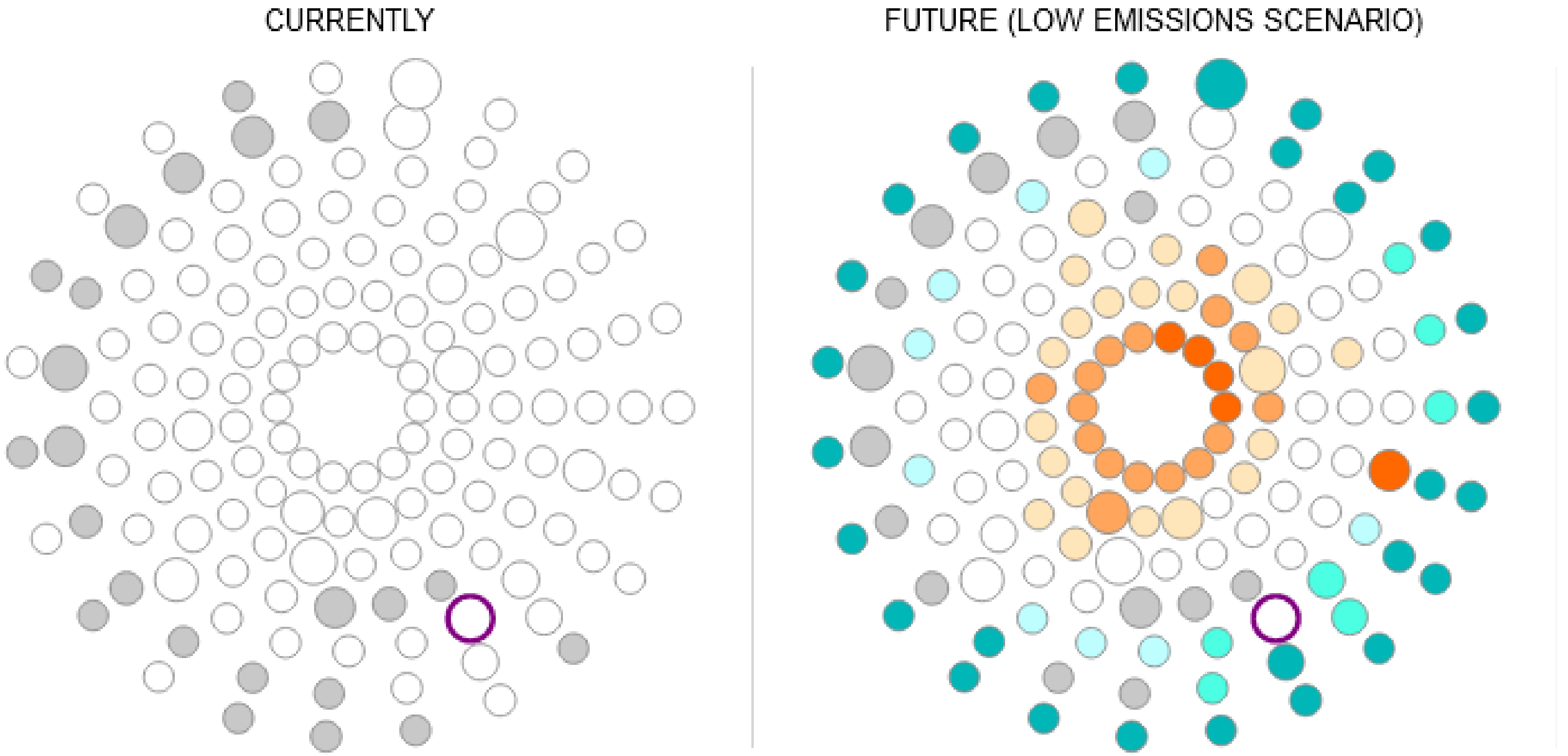
ORBACLES



http://minnlab.squarespace.com/orbacles/

DATA PHYSICALIZATION

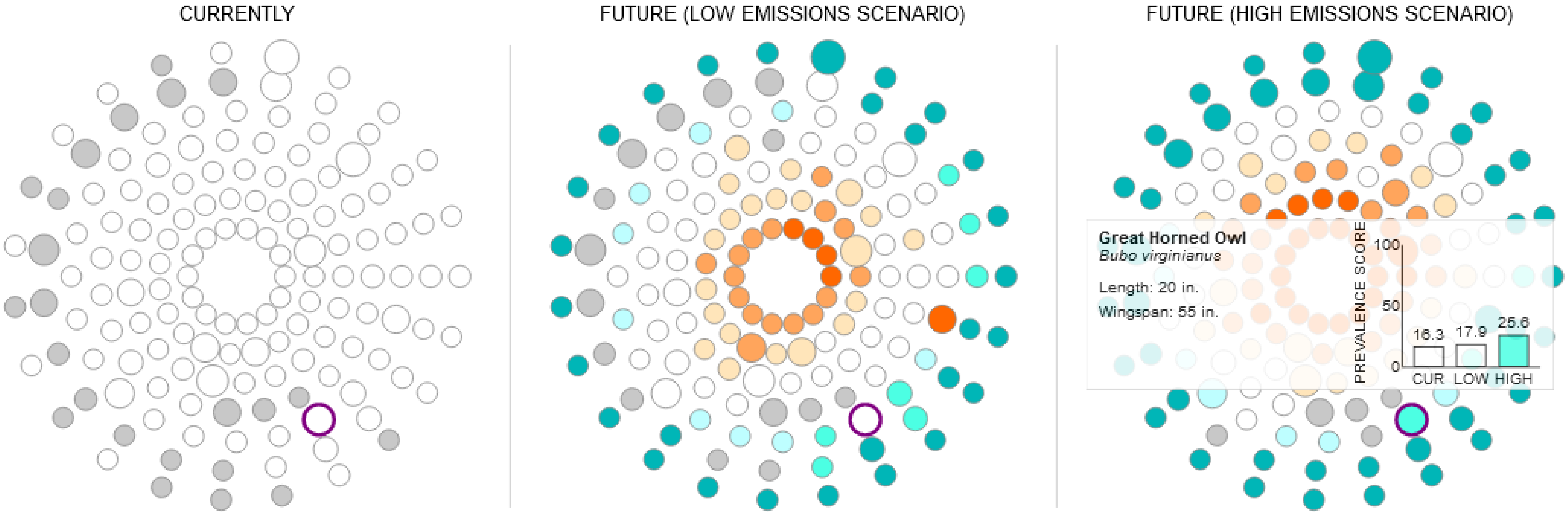
ORBACLES



http://minnlab.squarespace.com/orbacles/

DATA PHYSICALIZATION

ORBACLES

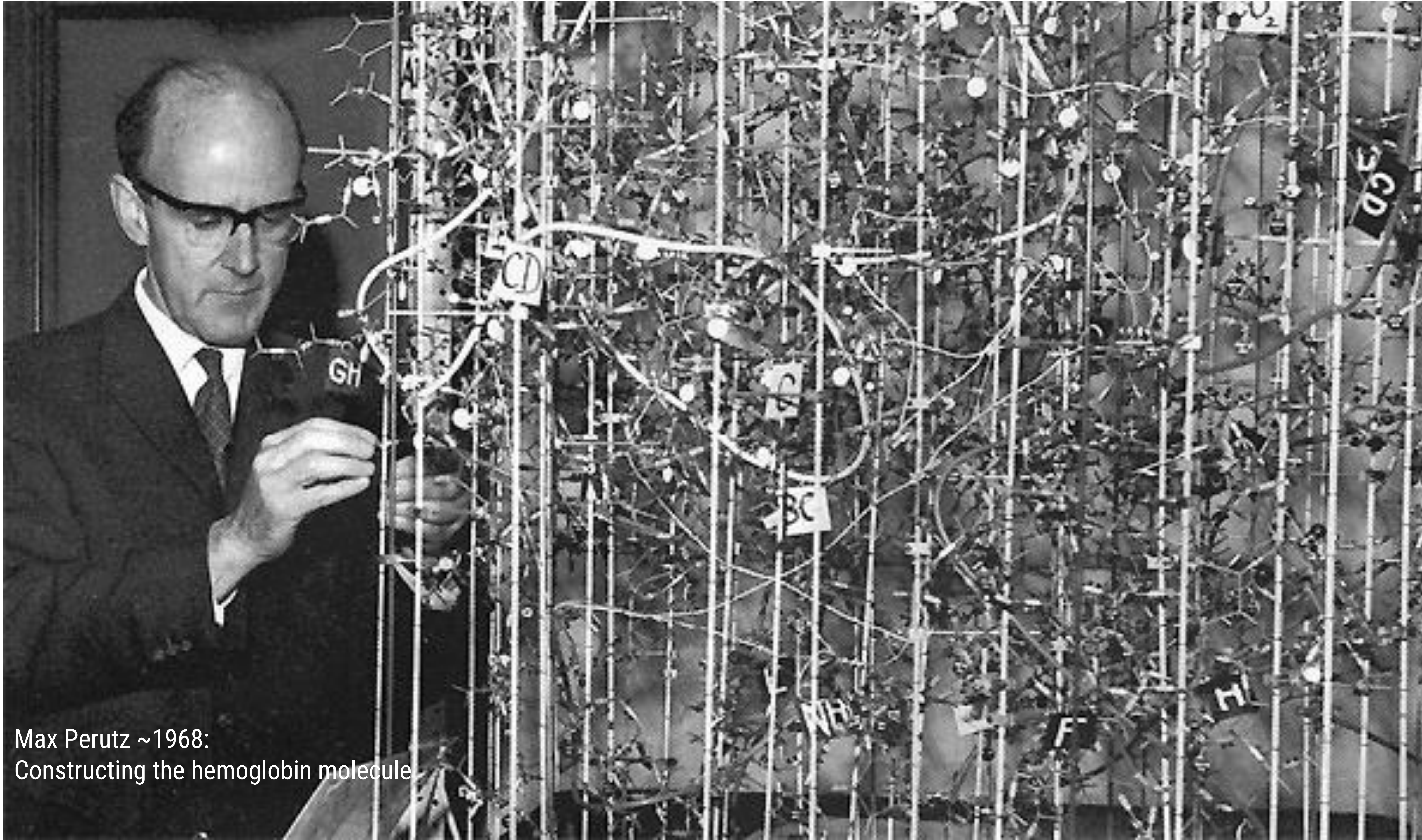


http://minnlab.squarespace.com/orbacles/

DATA PHYSICALIZATION

http://minnlab.squarespace.com/orbacles/

http://minnlab.squarespace.com/orbacles/



Max Perutz ~1968:
Constructing the hemoglobin molecule

http://dataphys.org/list/

The tempescope is a physical display that can simulate various weather conditions inside your living room.

https://www.tempescope.com/

http://dataphys.org/list/ Photo by Bompas & Parr.

SandScape device installed in the Children's Creativity Museum in San Francisco

Tangible Uis

AMBIENT DISPLAYS

Infotropism (Holstius, 2004)

SHAPE CHANGING INTERFACES

Relief (Leithinger et al, 2009)

FABRICATION

Open Opportunities

help people think about, explore, and share data
(not a complete list)

Build enabling technologies

(for making data physicalizations)

MakerVis

Build enabling technologies

(for physical data exploration and manipulation)

Mathieu Le Goc, Lawrence Kim, Ali Parsaei, Jean-Daniel Fekete, Pierre Dragicevic, Sean Follmer. **Zooids: Building Blocks for Swarm User Interfaces**. *UIST 2016*

Zooids: Building Blocks for Swarm User Interfaces

Mathieu Le Goc[1,3,4], **Lawrence H. Kim**[2], **Ali Parsaei**[2], **Jean-Daniel Fekete**[1,4] **Pierre Dragicevic**[1,4], **Sean Follmer**[2]
[1]Inria, [2]Stanford University, [3]Université Paris-Sud, [4]Université Paris-Saclay
{mathieu.le-goc, pierre.dragicevic, jean-daniel.fekete}@inria.fr, {lawkim, aparsaei, sfollmer}@stanford.edu

Figure 1. ***Zooids*** **can be held as tokens, manipulated collectively or individually, behave as physical pixels, act as handles and controllers, and can move dynamically under machine control. They are building blocks for a new class of user interface we call** ***swarm user interfaces*****.**

ABSTRACT
This paper introduces *swarm user interfaces*, a new class of human-computer interfaces comprised of many autonomous robots that handle both display and interaction. We describe the design of *Zooids*, an open-source open-hardware platform for developing tabletop swarm interfaces. The platform consists of a collection of custom-designed wheeled micro robots each 2.6 cm in diameter, a radio base-station, a high-speed DLP structured light projector for optical tracking, and a software framework for application development and control. We illustrate the potential of tabletop swarm user interfaces through a set of application scenarios developed with Zooids, and discuss general design considerations unique to swarm user interfaces.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords
Swarm user interfaces; tangible user interfaces.

INTRODUCTION
This article contributes to bringing closer to reality the vision of Ivan Sutherland for the Ultimate Display as *"a room within which the computer can control the existence of matter"* [70], and Hiroshi Ishii's vision of Radical Atoms where people can interact with *"a new kind of matter capable of changing form dynamically"* [26].

Several significant steps have been recently made towards Sutherland's and Ishii's visions, particularly through research on actuated tangibles [48, 50, 78] and shape displays [55, 56, 15]. However, current systems suffer from a number of limitations. First, actuated tabletop tangibles generally only support the manipulation and actuation of a few (e.g., 3–4) solid objects, which is not enough to emulate physical matter that can change form. On the other hand, shape displays try to achieve surfaces that can be deformed and actuated, but current implementations do not support arbitrary physical topologies. Furthermore, both types of systems traditionally use physical objects primarily as *input*, while *output* is almost always provided through separate pixel-based display technology. Although video-projected overlays allows input and output to spatially coincide [12], they provide only a limited sense of physicality [5]. Likewise, many such systems require heavy hardware or displays to function, and are thus primarily meant to be operated in sterile environments rather than embedded in our own physical world [24, 77].

Our research work fills this current gap in user interface technologies by introducing *Zooids* and *swarm user interfaces* (see figure 1). A *Zooid* is a hardware and software system: a small wheel-propelled robot with position and touch sensing capabilities that can be freely arranged and repositioned on any horizontal surface, both through user manipulation and computer control.

A Zooid is defined in Wikipedia as *"a single animal that is part of a colonial animal. Zooids are multicellular; their structure is similar to that of other solitary animals."* Zooids build on work from swarm robotics [10, 68], adding interaction and speed. *Swarm user interfaces* are interfaces built using

UIST 2016, October 16-19, 2016, Tokyo, Japan
ACM ISBN ...
DOI: http://dx.doi.org/10.1145/2984511.2984547

Dynamic Composite Data Physicalization Using Wheeled Micro-Robots

Mathieu Le Goc, Charles Perin, Sean Follmer, Jean-Daniel Fekete, Pierre Dragicevic

Fig. 1. Collaborative data exploration and analysis using a dynamic composite data physicalization.

Abstract— This paper introduces *dynamic composite physicalizations*, a new class of physical visualizations that use collections of self-propelled objects to represent data. Dynamic composite physicalizations can be used both to give physical form to well-known interactive visualization techniques, and to explore new visualizations and interaction paradigms. We first propose a design space characterizing composite physicalizations based on previous work in the fields of Information Visualization and Human Computer Interaction. We illustrate dynamic composite physicalizations in two scenarios demonstrating potential benefits for collaboration and decision making, as well as new opportunities for physical interaction. We then describe our implementation using wheeled micro-robots capable of locating themselves and sensing user input, before discussing limitations and opportunities for future work.

Index Terms—information visualization, data physicalization, tangible user interfaces

1 Introduction

This paper introduces *dynamic composite data physicalizations*, i.e.

can support cognition, communication, learning, problem solving and decision making" [39]. However, most existing physicalizations are

Refocus on output and exploration

(rather than input and manipulation)

The Future Role of Visual Feedback for Unobtrusive E-Textile Interfaces

Figure 1: We discuss how the promising research field of smart E-Textiles and emerging visual mobile displays can work together to achieve powerful and unobtrusive E-Textile controls.

Konstantin Klamka
Interactive Media Lab
Technische Universität Dresden
Dresden, Germany
klamka@acm.org

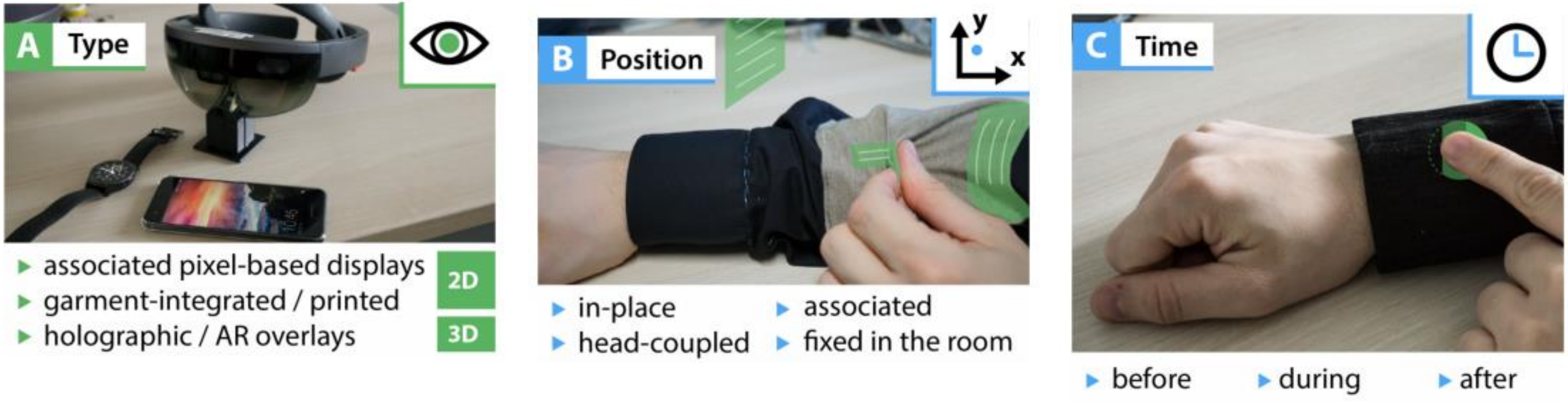
Raimund Dachselt
Interactive Media Lab
Technische Universität Dresden
Dresden, Germany
dachselt@acm.org

CHI'18 Workshop on (Un)Acceptable!?!—Re-thinking the Social Acceptability of Emerging Technologies, April 21, 2018, Montreal, QC, Canada.

Abstract
Emerging mobile interfaces are characterized by an increasing need for socially acceptable interaction supporting unobtrusive input. Simultaneously, they require rich visual feedback for many dynamic and complex mobile tasks. With this paper, we want to identify and discuss design options and parameters for body-centric and personal mobile interaction techniques that aim to be well-suited for both: social acceptability and rich functionality. Wearable E-Textiles are a promising research field for unobtrusive mobile computing since they allow novel, subtle and personal input controls. Therefore, we investigate, how they can be combined with high-quality Augmented Reality (AR) glasses to seamlessly provide visually augmented controls. For this, we question the role of visual feedback for unobtrusive mobile interfaces by classifying and discussing task- and context-depending visual feedback along the dimensions of the feedback type, position, time and visibility. Based on the sweet spots that we identified in our design classification, we conclude with two augmented E-Textile prototypes for future discussions.

Author Keywords
mobile interaction; wearable; social acceptability; AR glasses; E-Textile; augmented controls; smart fabric

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies, Interaction Styles;



First focus on visual feedback

REFERENCES
to get started on Data Physicalization

Pierre Dragicevic, Yvonne Jansen, Andrew Vande Moere. Data Physicalization. Jean Vanderdonckt. Springer Handbook of Human Computer Interaction, Springer, 2020
https://hal.inria.fr/hal-02113248v2

Yvonne Jansen, Pierre Dragicevic, Petra Isenberg, Jason Alexander, Abhijit Karnik, Johan Kildal, Sriram Subramanian, and Kasper Hornbæk. Opportunities and Challenges for Data Physicalization. CHI 2015
https://hal.inria.fr/hal-01120152

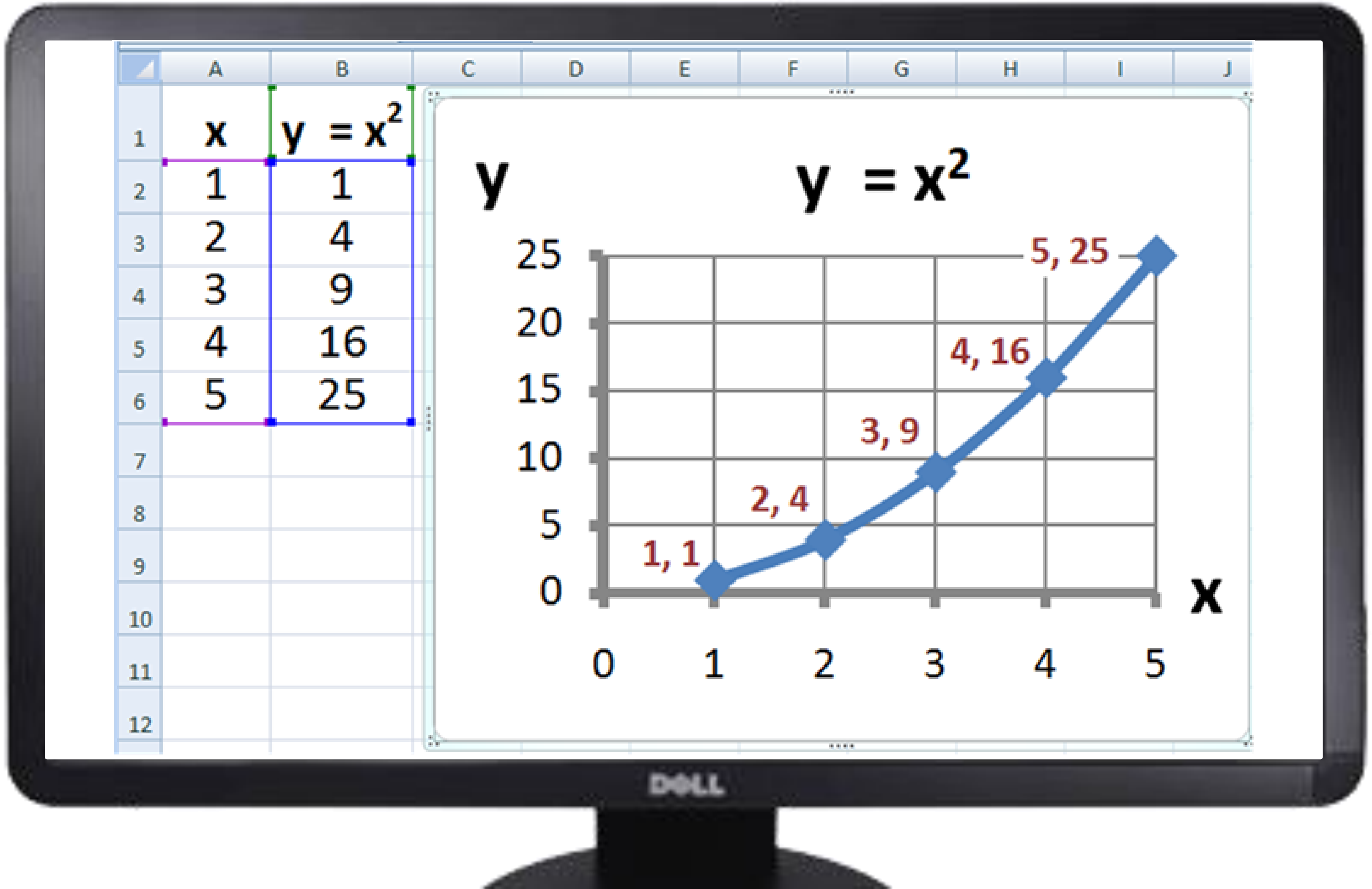
SITUATED & EMBEDDED VISUALIZATION

“representations of data that are deeply integrated with the physical spaces, objects, and entities to which the data refers”

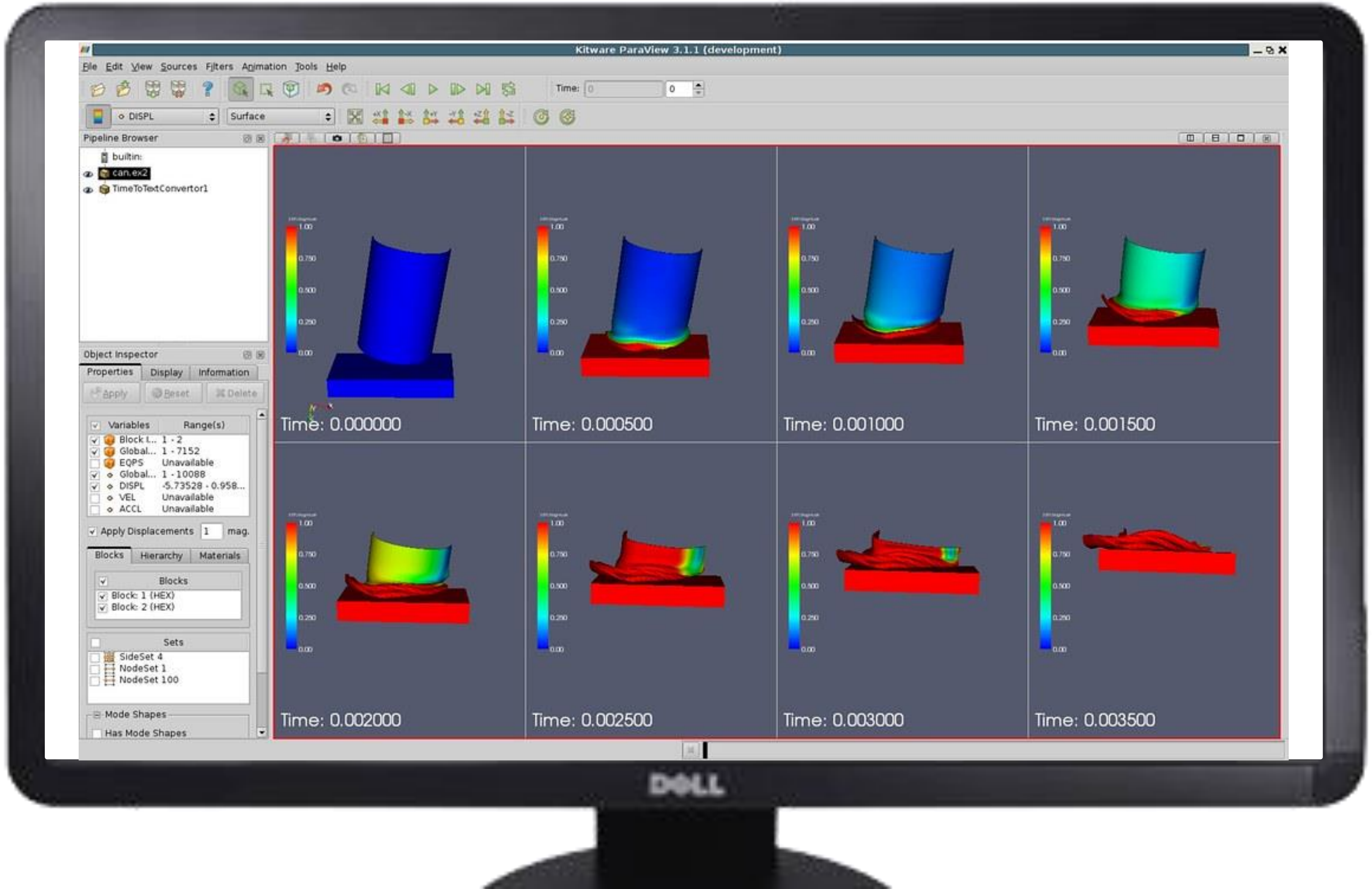
Wesley Willett, Yvonne Jansen, Pierre Dragicevic. Embedded Data Representations. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 2017, pp.461 - 470. ?10.1109/TVCG.2016.2598608

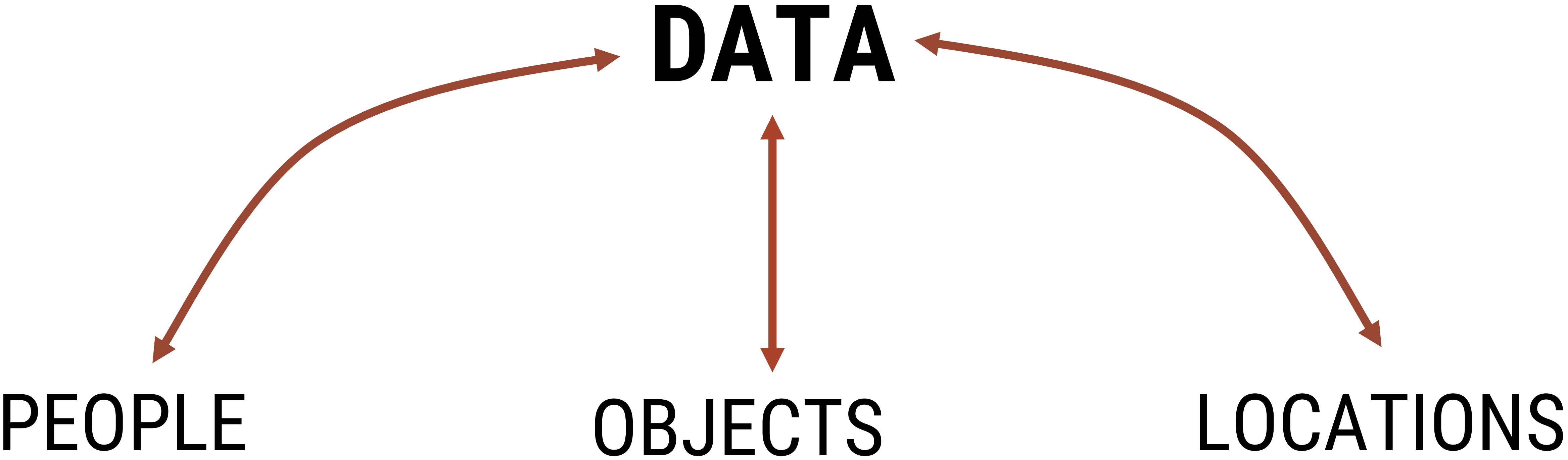
by Chris on Flickr

Data analysis software, simple statistics, …

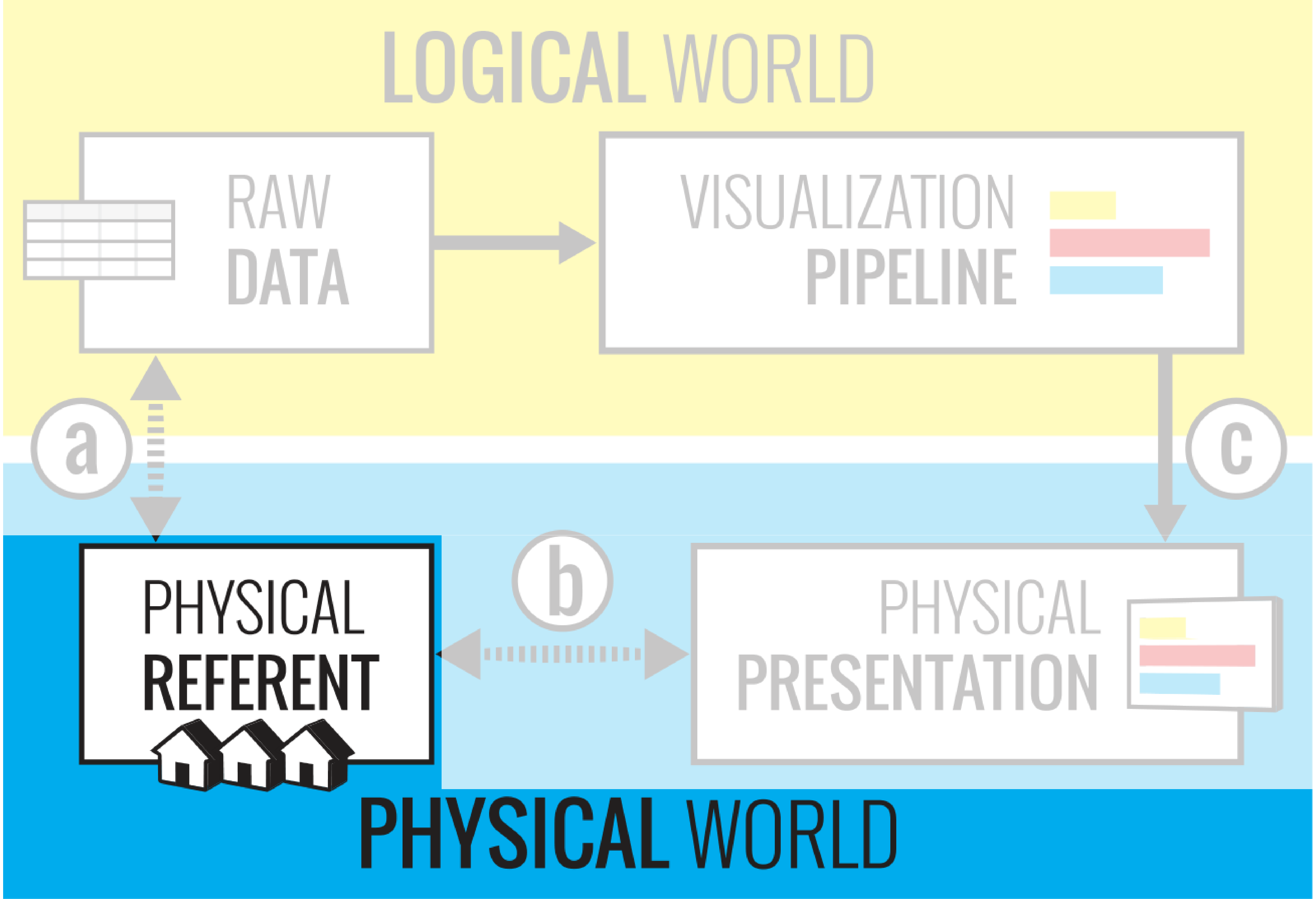


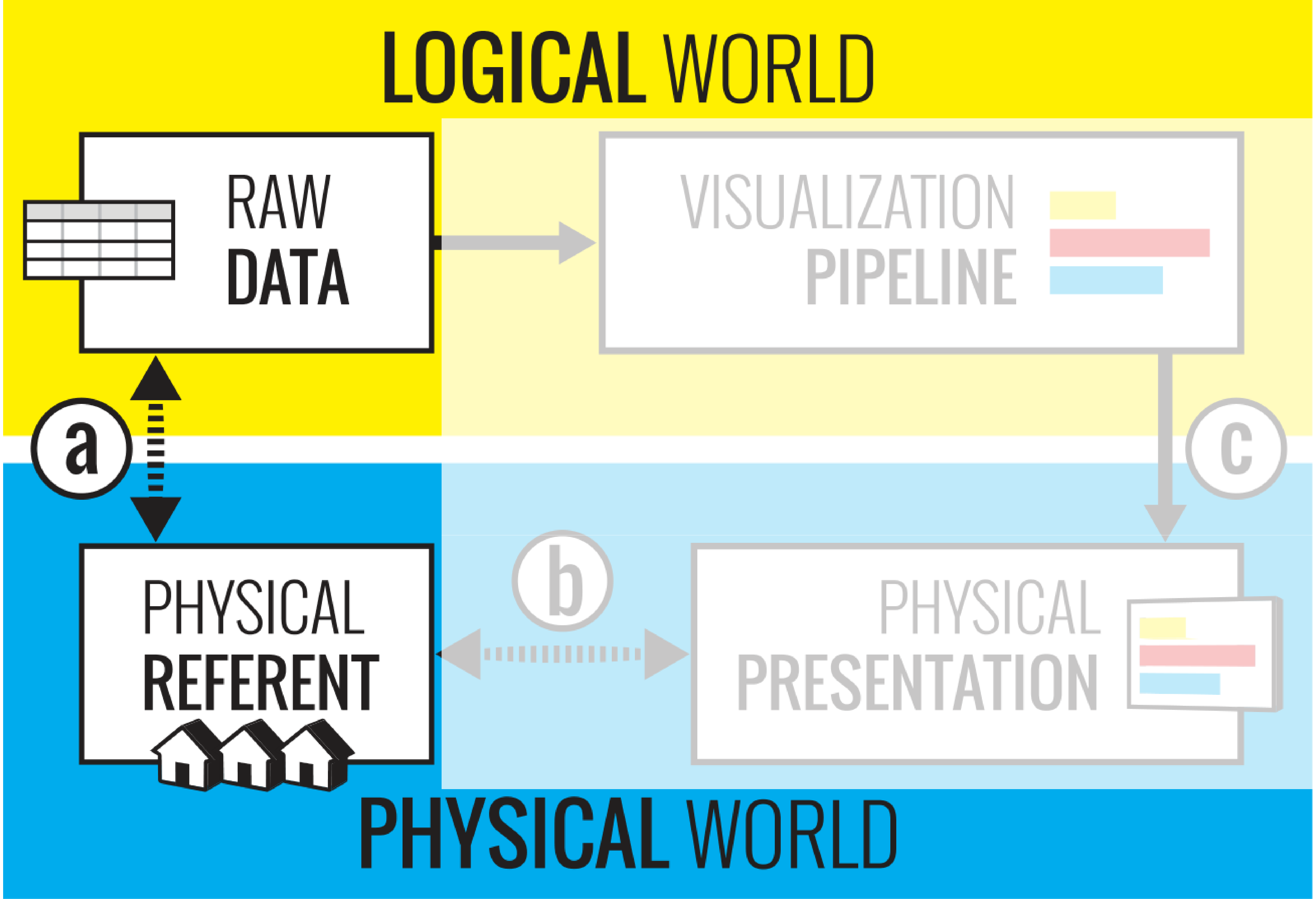
Tools for experts…



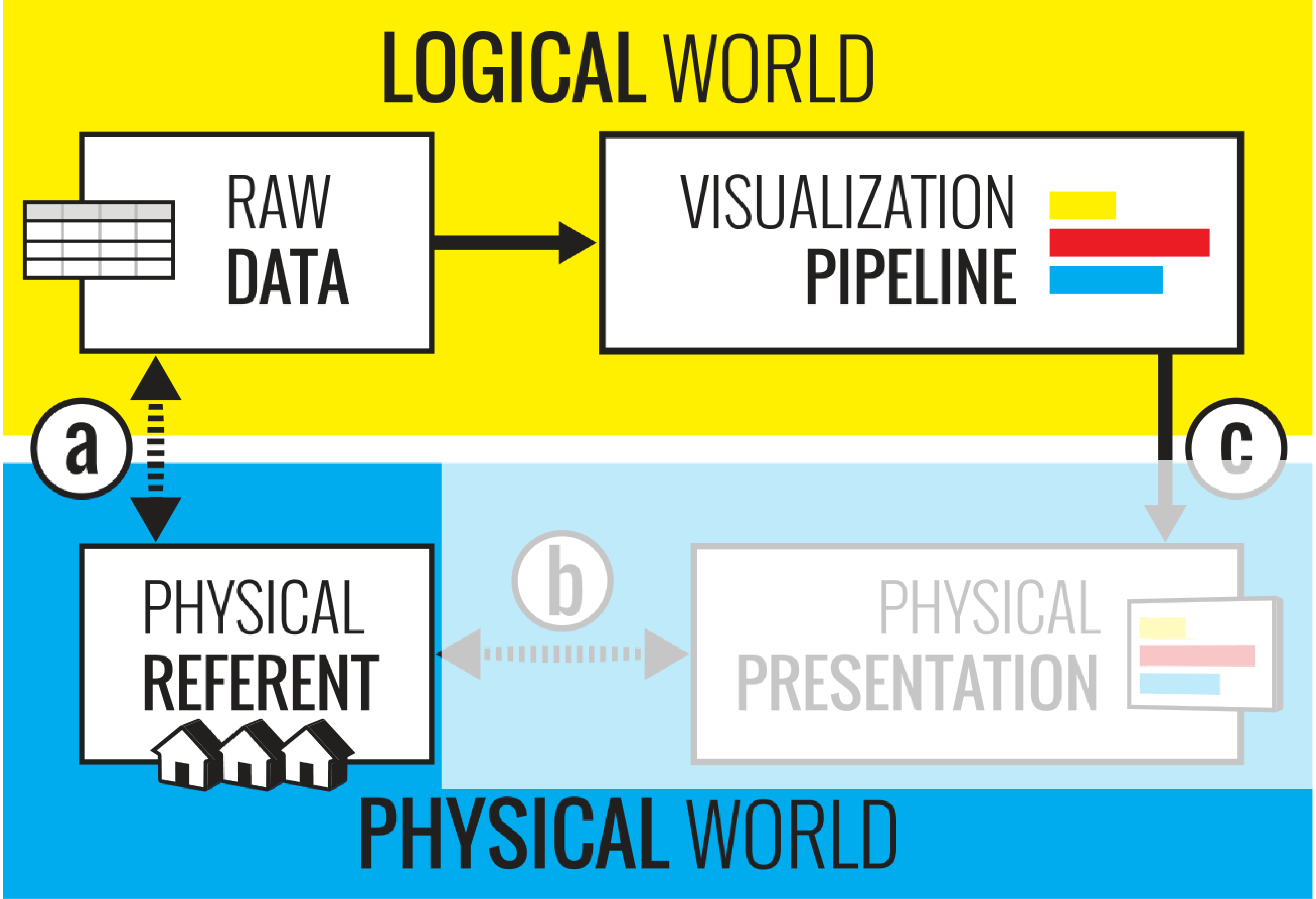

DATA
PEOPLE
OBJECTS
LOCATIONS

Wesley Willett, Yvonne Jansen, Pierre Dragicevic. Embedded Data Representations. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 2017, pp.461 - 470. ?10.1109/TVCG.2016.2598608

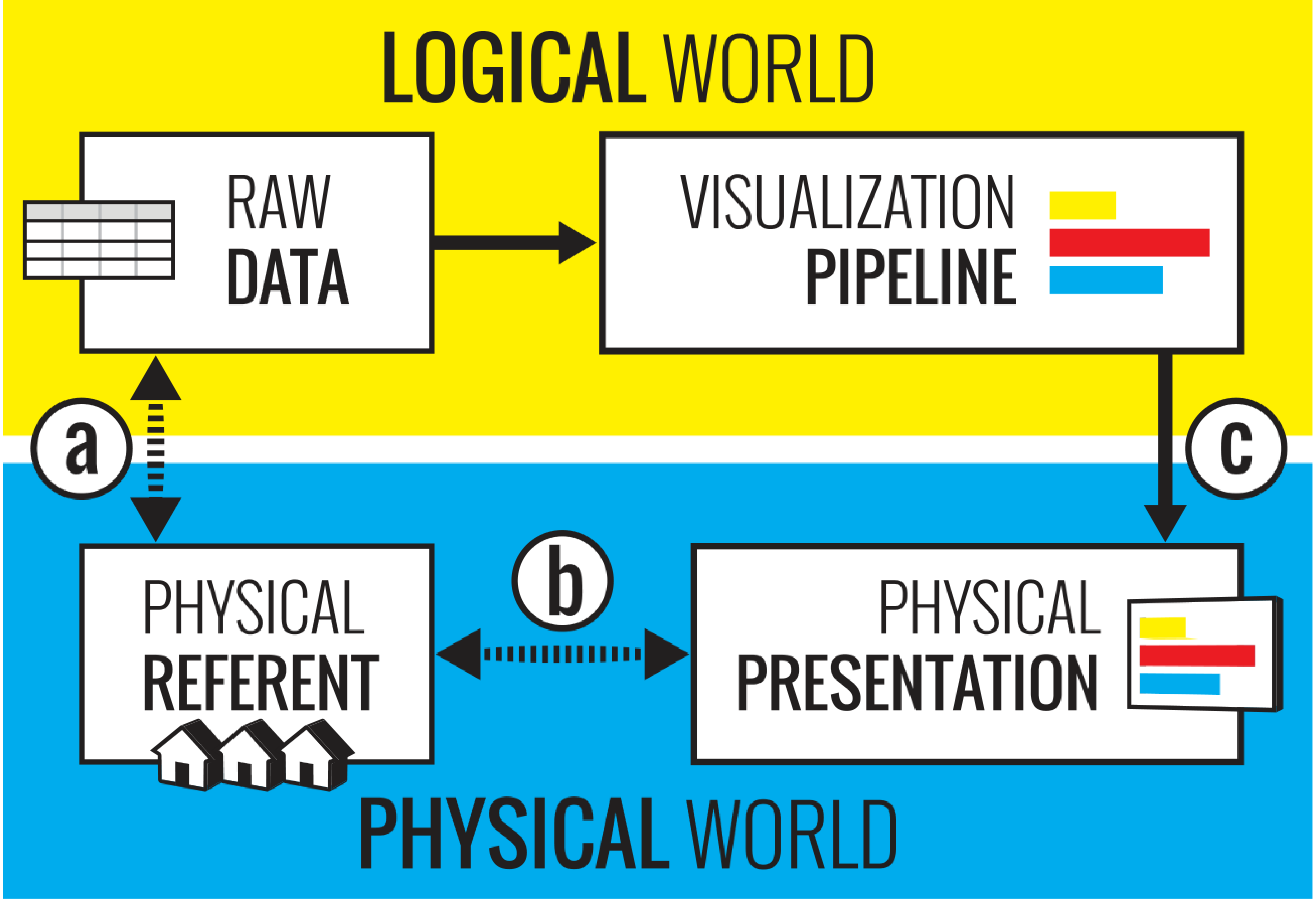




Wesley Willett, Yvonne Jansen, Pierre Dragicevic. Embedded Data Representations. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 2017, pp.461 - 470. ?10.1109/TVCG.2016.2598608



Wesley Willett, Yvonne Jansen, Pierre Dragicevic. Embedded Data Representations. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 2017, pp.461 - 470. ?10.1109/TVCG.2016.2598608



Wesley Willett, Yvonne Jansen, Pierre Dragicevic. Embedded Data Representations. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 2017, pp.461 - 470. ?10.1109/TVCG.2016.2598608

Infotropism (Holstius, 2004)

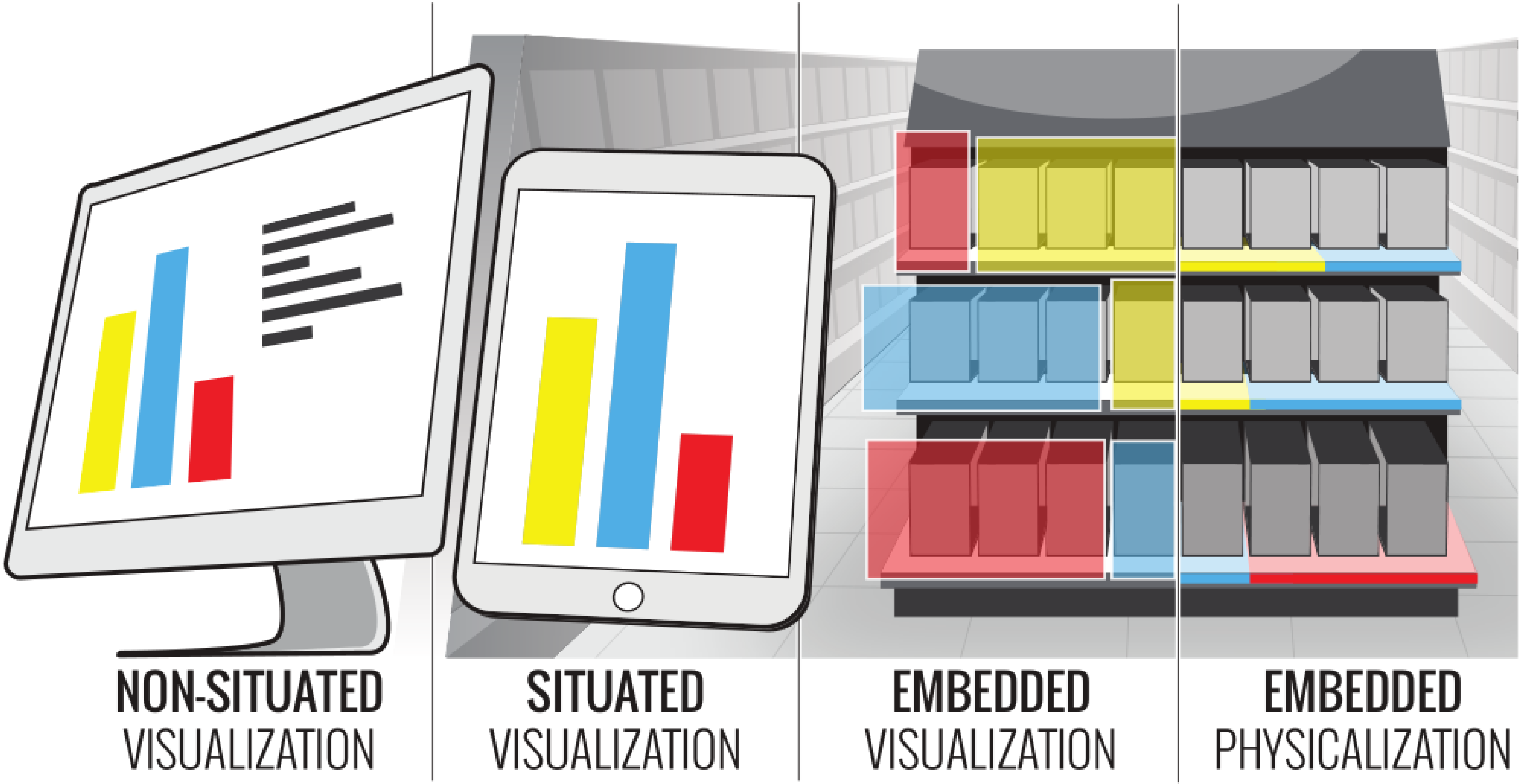

NON-SITUATED VISUALIZATION
SITUATED VISUALIZATION
EMBEDDED VISUALIZATION
EMBEDDED PHYSICALIZATION

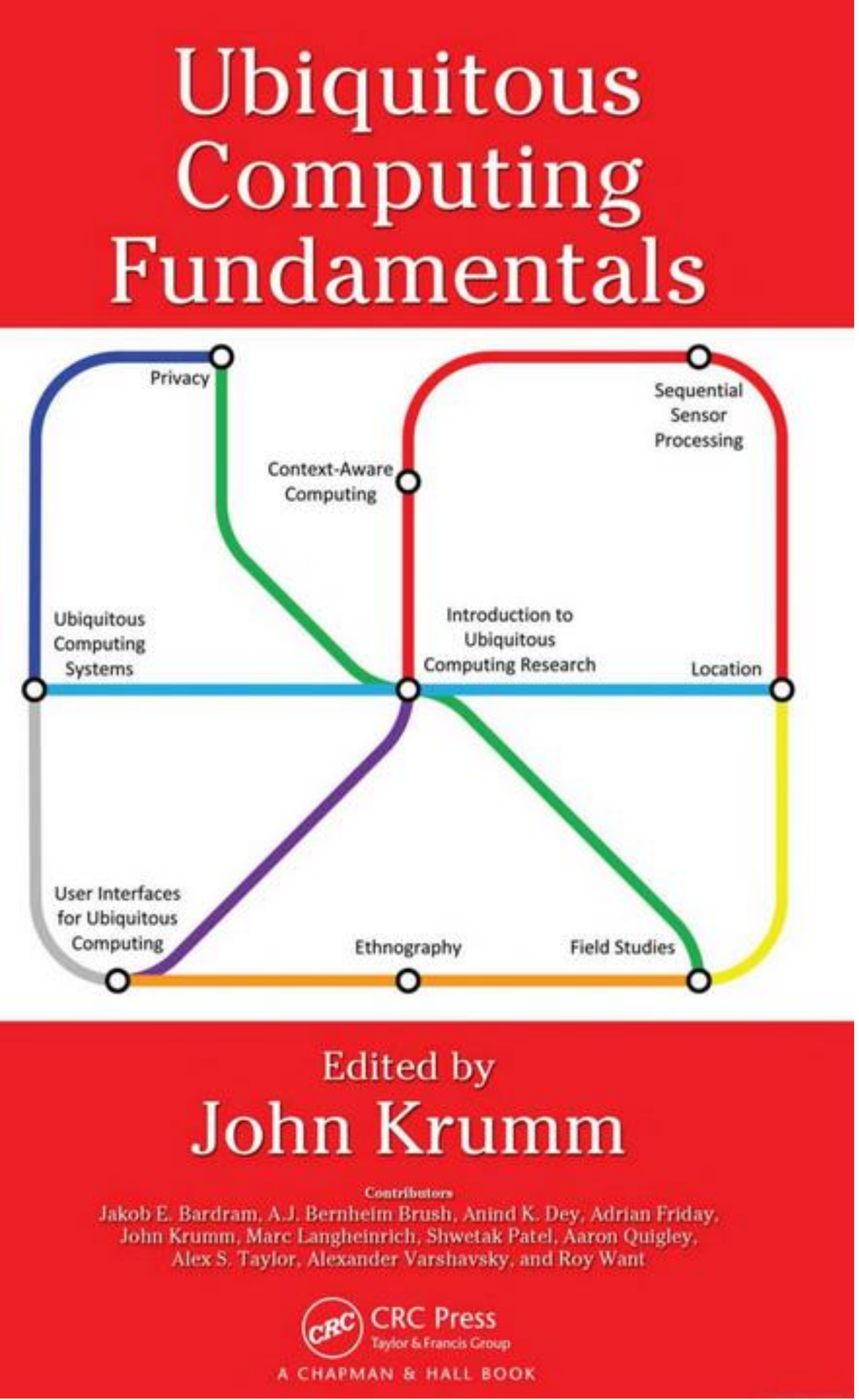
Image: DRIBBLE UP

RFIG Lamps (Raskar et al., 2004)

Data Jewelery

2014 – Silver Ring Shaped by DNA Profile

SiteLens (White and Feiner, 2009)

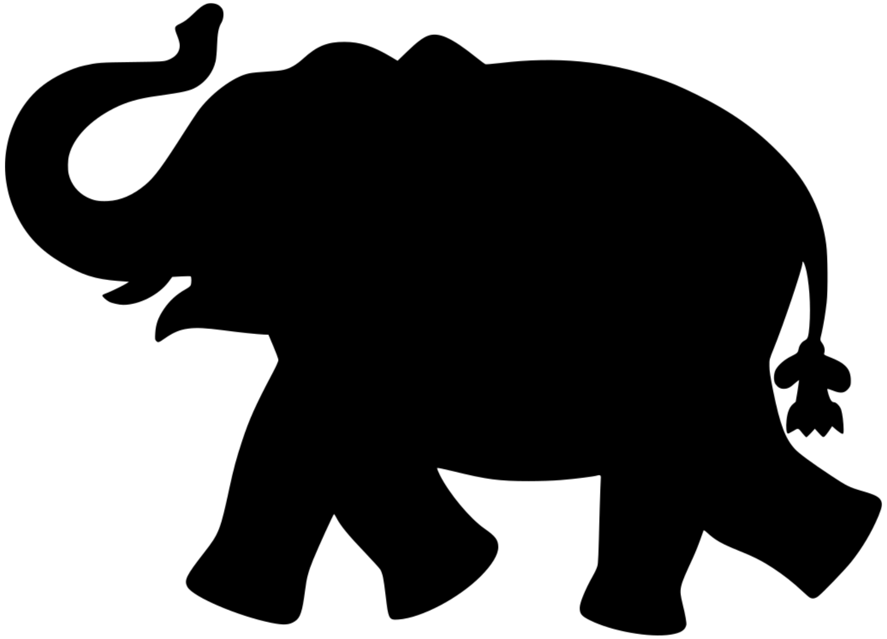


Bridging physical and digital worlds

Open Opportunities

help people think about, explore, and share data
(not a complete list)

When should embedded visualizations be used and in what ways might they be superior to or preferred over non-embedded visualizations?



Build enabling technologies

(for making situated visualizations)

PERSONAL FABRICATION

CurveBoards, 2020

Understanding experiences

with situated visualizations

Situated vs. non-situated experiences
Perception
Design

REFERENCE
to get started on Embedded and Situated Visualization

Wesley Willett, Yvonne Jansen, Pierre Dragicevic. Embedded Data Representations. IEEE Transactions on Visualization and Computer Graphics, Institute of Electrical and Electronics Engineers, 2017, pp.461 - 470. 10.1109/TVCG.2016.2598608

IMMERSIVE ANALYTICS

using VR/AR for data exploration and discovery

"Immersive Analytics investigates how new interaction and display technologies can be used to support analytical reasoning and decision making."

Chandler, T., Cordeil, M., Czauderna, T., Dwyer, T., Glowacki, J., Goncu, C., et al. (2015). "Immersive analytics," in *2015 Big Data Visual Analytics (BDVA)*, (Hobart, TAS: IEEE), 1–8.

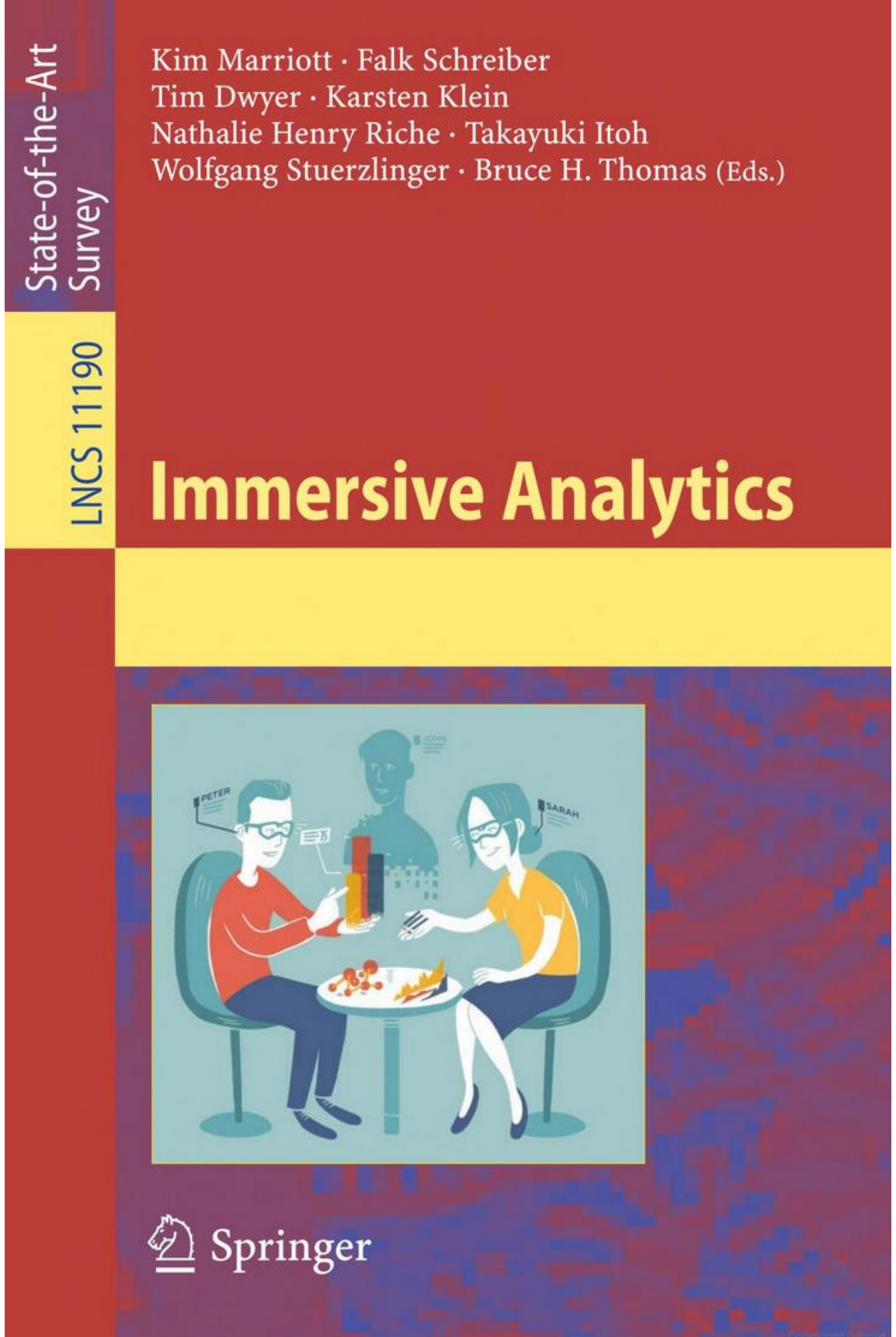
= a technology-based definition

Workshops on Immersive Analytics

- IA 2016
- IEEE BDVA 2016/17
- IEEE VR 2016
- ACM ISS 2016
- IEEE VIS 2017
- ACM CHI 2019
- ACM CHI 2020

2016


© SCHLOSS DAGSTUHL – LZI GMBH
licensed under Creative Commons License CC BY-NC-ND


State-of-the-Art Survey
LNCS 11190
Kim Marriott · Falk Schreiber
Tim Dwyer · Karsten Klein
Nathalie Henry Riche · Takayuki Itoh
Wolfgang Stuerzlinger · Bruce H. Thomas (Eds.)
Immersive Analytics
PETER
SARAH
Springer

“Immersive Analytics is the use of engaging, embodied analysis tools to support data understanding and decision making”

[Dwyer, Marriott, Isenberg, Klein, Riche, Schreiber, Stuerzlinger, Thomas: Immersive Analytics: An Introduction. In: Immersive Analytics, 2018]

Immersive analytics is the science of analytical reasoning facilitated by immersive human-computer interfaces.

- *Analytical reasoning:* computer-aided analytical reasoning as a partner with the human; foraging & sensemaking.

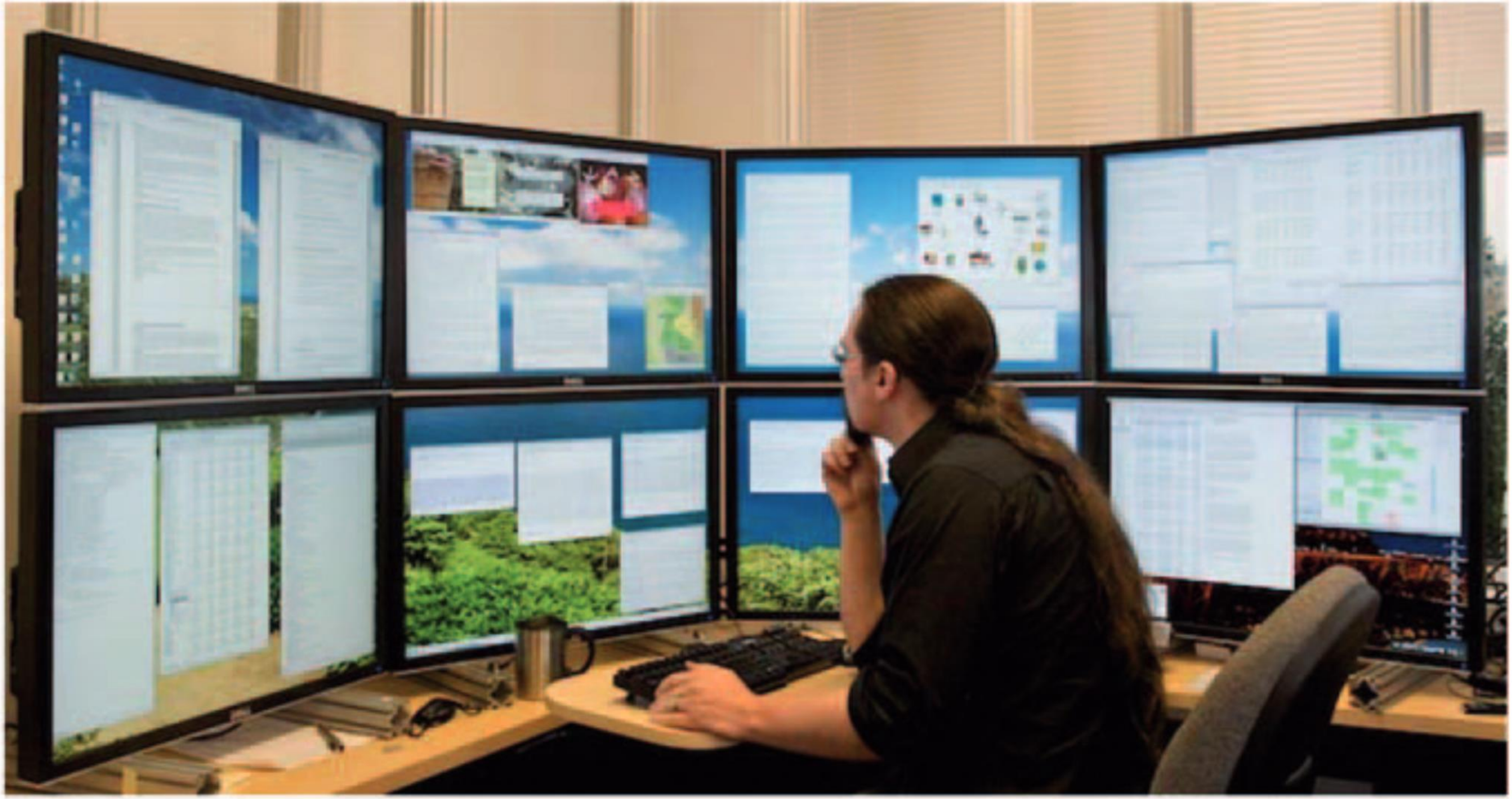
- *Immersive human-computer interfaces:* enable a user to interact with a system using additional or more-immersive displays and user interface techniques.

[Skarbez, Polys, Ogle, North, Bowman; Immersive Analytics: Theory and Research Agenda, Frontiers in Robotics and AI , 2019]

Why?

Some Potential Benefits:

- **Space to Think**
- Spatial understanding
- Rich interactions with data possible
- Rich sensory experiences with data



[Andrews et al. “Information Visualization on large, high-resolution displays: Issues, challenges, and opportunities”, Information Visualization, 2010]

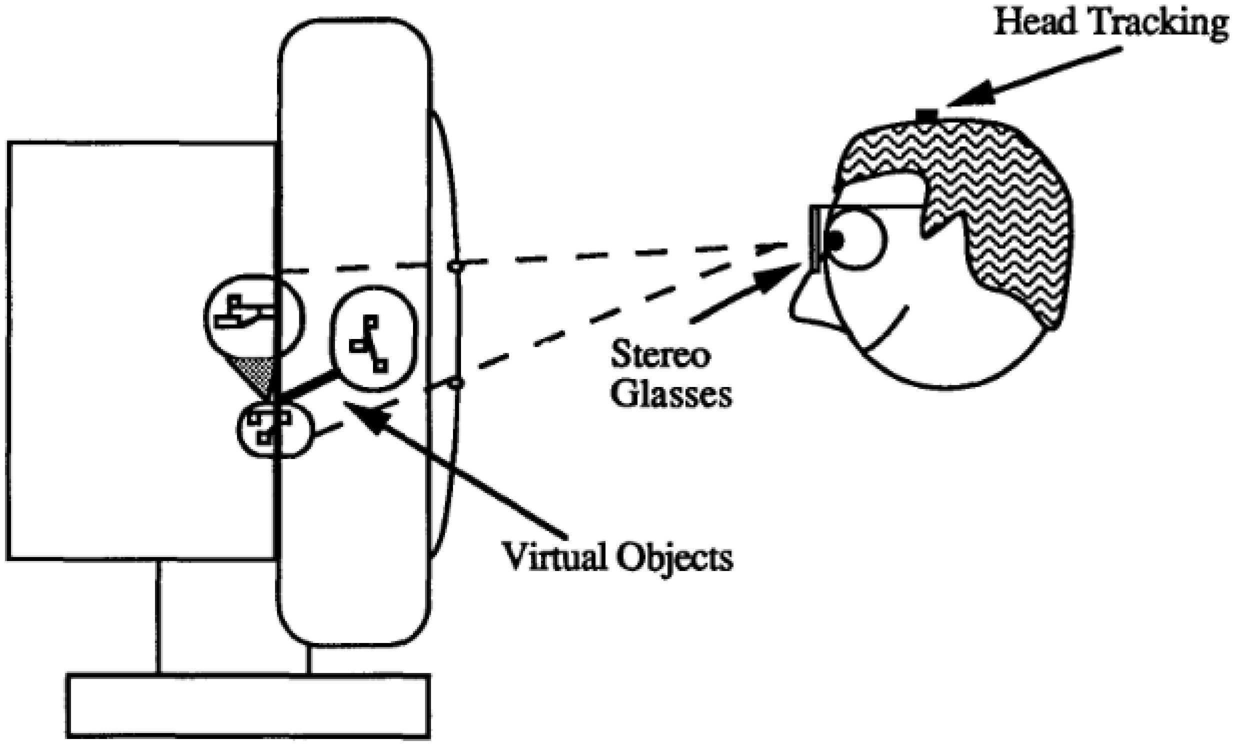
Image credit: https://www.makeuseof.com/tag/virtual-reality-desktops-save-money-space/

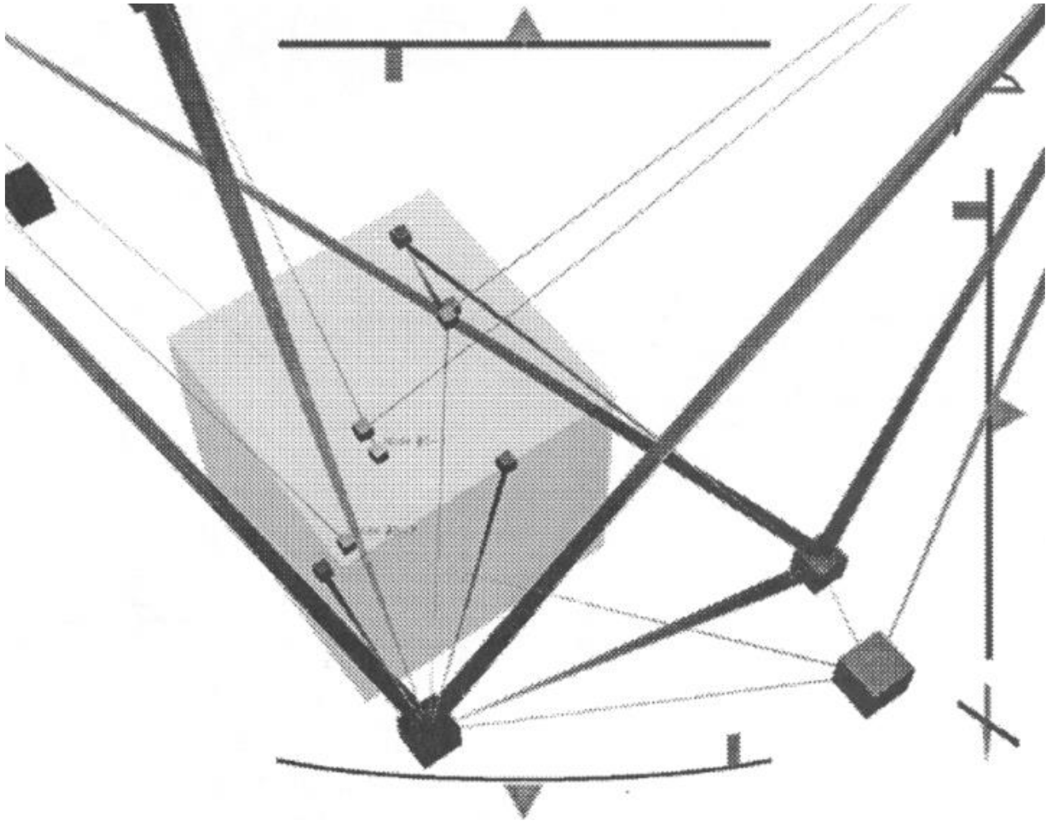
Responsive Workbench (1994)

- required glasses & gloves
  multi-user
- visualization applications

Krüger, W., Fröhlich, B.
The Responsive Workbench
IEEE Computer Graphics and Applications, 14(3), pp. 12-15, 1994

Fishtank VR





Ware et al.: 1993. Visualizing object oriented software in three dimensions.
In *Conference of the Centre for Advanced Studies on Collaborative research: software engineering - Volume 1* (*CASCON '93*). IBM Press, 612–620.

Survey of Immersive Analytics

Adrien Fonnet and Yannick Prié

Abstract—Immersive analytics (IA) is a new term referring to the use of immersive technologies for data analysis. Yet such applications are not new, and numerous contributions have been made in the last three decades. However, no survey reviewing all these contributions is available. Here we propose a survey of IA from the early nineties until the present day, describing how rendering technologies, data, sensory mapping, and interaction means have been used to build IA systems, as well as how these systems have been evaluated. The conclusions that emerge from our analysis are that: multi-sensory aspects of IA are under-exploited, the 3DUI and VR community knowledge regarding immersive interaction is not sufficiently utilised, the IA community should focus on converging towards best practices, as well as aim for real life IA systems.

Index Terms—Immersive analytics, survey, virtual environments, immersive environments, data visualization, information visualization, scientific visualization, visual data mining.

1 Introduction

IMMERSIVE analytics (IA) was defined in 2015 as "the applicability and development of emerging user-interface technologies for creating more engaging and immersive experiences and seamless workflows for data analysis applications" [1], and more recently as "the use of engaging, embodied analysis tools to support data understanding and decision making" [2].

The idea to use immersive technologies to carry out visual data analysis tasks is not new [3] and many proposals have been made since the early nineties. Indeed, the interest of researchers in the use of immersive technologies has been driven by the ability to represent 3D data in 3D, as well as the possibility to better exploit human perception capabilities, and to make use of embodied perception and interaction. The contemporary development and structuring of the field (attested by scholar meetings [4], [5] and conference workshops [6], [7], [8], [9] in the last years) is mainly related

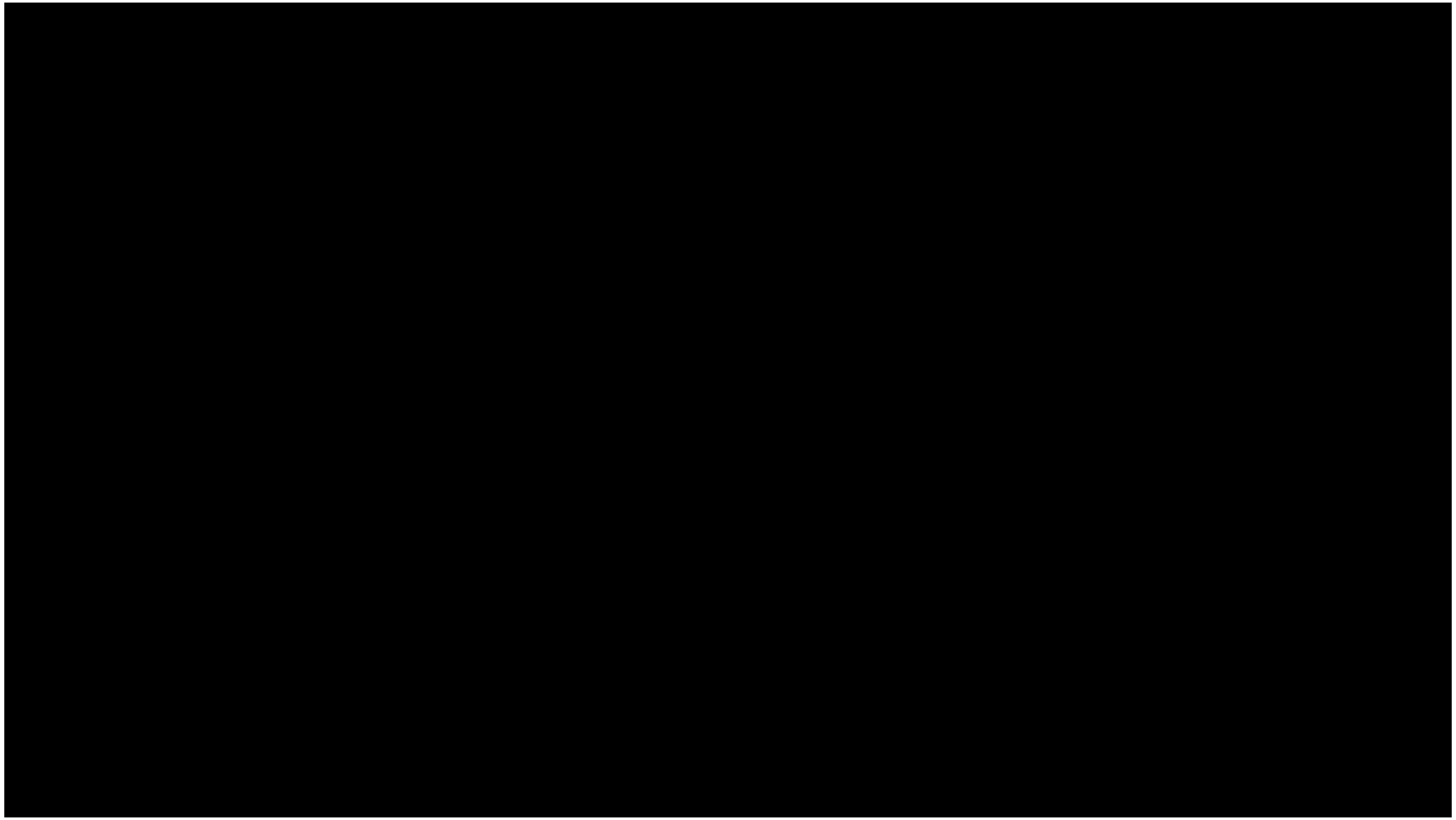
1.1 Method: corpus building and analysis

Since no clear IA domain had been established before 2015, no particular venues or keywords specifically gather contributions together. We therefore conducted a systematic but open investigation with the main scientific search engines (IEEE Xplore, ACM Digital Library, Science Direct, Springer Link, or Google Scholar), using search terms that cover both data analyze processes (e.g. visual data mining or data visualization) and immersive technologies (e.g. immersive environment or virtual reality). Specific journals, conferences, and workshops were also covered, such as TVCG, IEEE Vis, or IEEE VR, as well as the full bibliography of key scientists. The search stopped when papers' references were not bringing any new articles to the survey's collection.

The initial criterion for a paper to be included in our corpus was that it must contain a thorough description

A. Fonnet and Y. Prié, "Survey of Immersive Analytics," in *IEEE Transactions on Visualization and Computer Graphics*, doi: 10.1109/TVCG.2019.2929033.

ImAxes

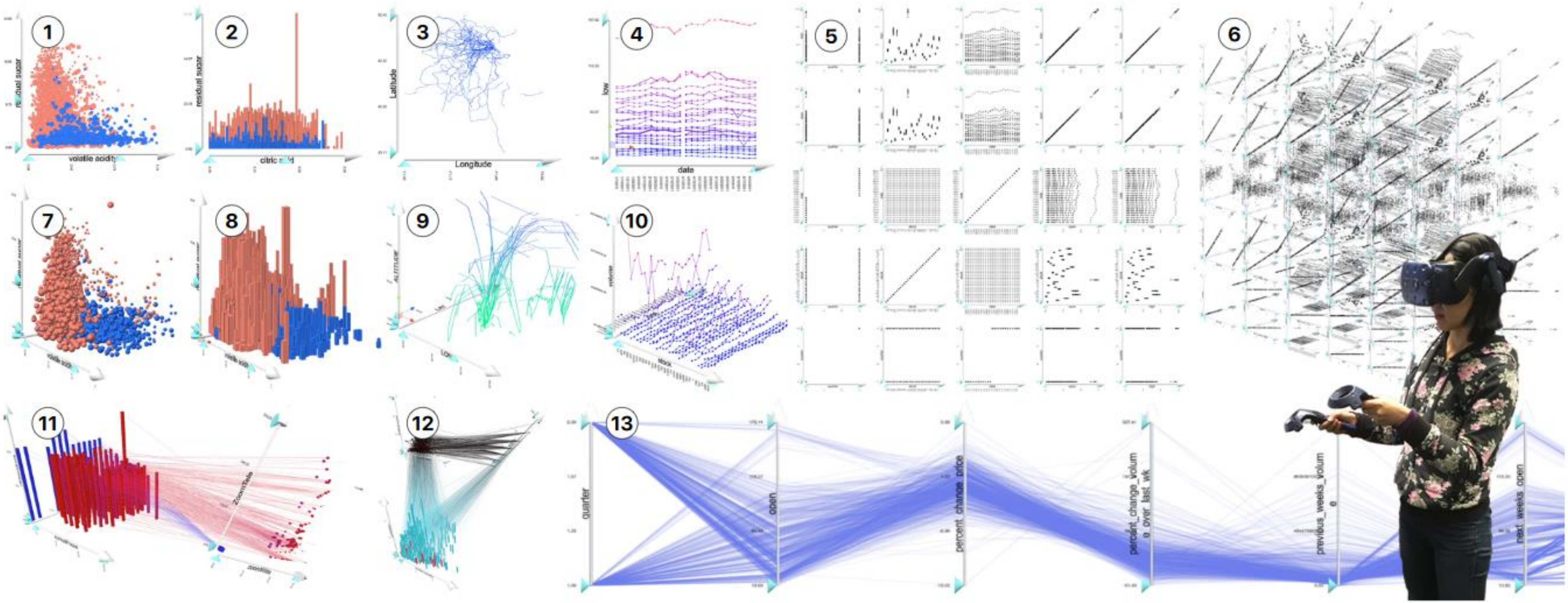


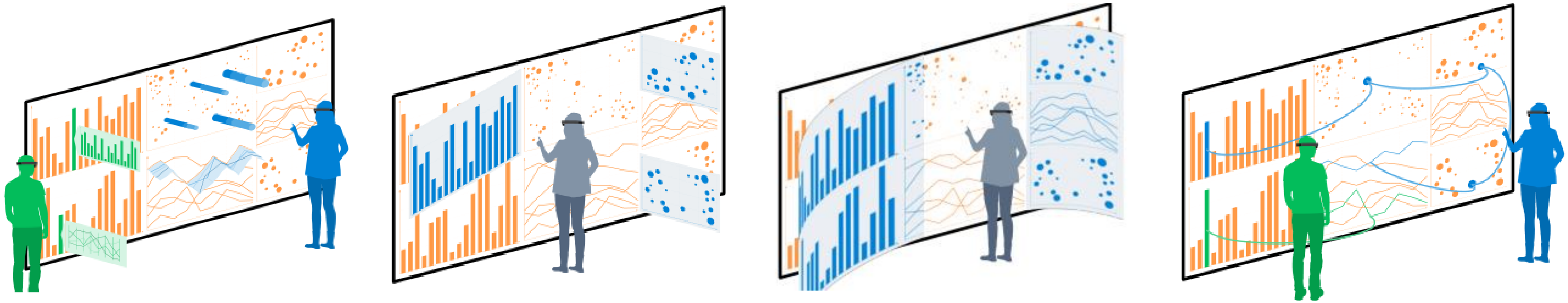
[Cordeil et al. 2017. ImAxes: Immersive Axes as Embodied Affordances for Interactive Multivariate Data Visualisation. UIST]

IATK: An Immersive Analytics Toolkit

Maxime Cordeil * Monash University
Andrew Cunningham † University of South Australia
Benjamin Bach ‡ Edinburgh University
Christophe Hurter § ENAC
Bruce H. Thomas ¶ University of South Australia
Kim Marriott ‖ Monash University
Tim Dwyer ** Monash University

https://github.com/MaximeCordeil/IATK





Personal Augmented Reality for Information Visualization on Large Interactive Displays

Patrick Reipschläger*, Tamara Flemisch*, Raimund Dachselt

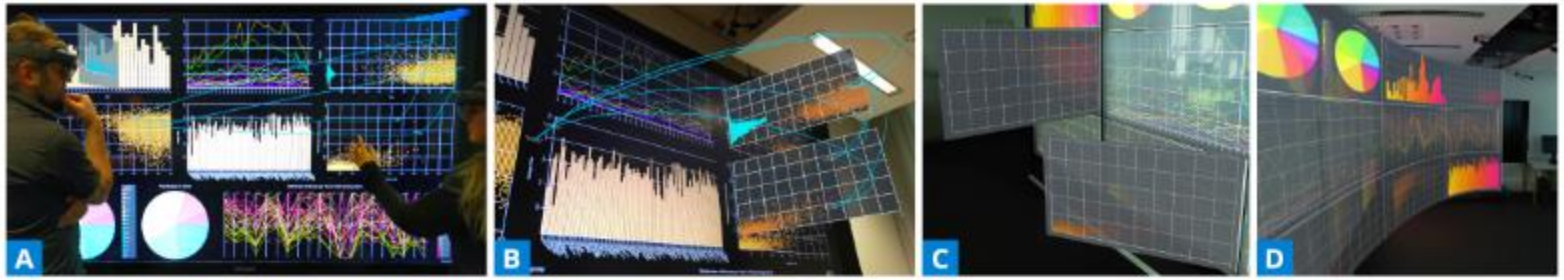
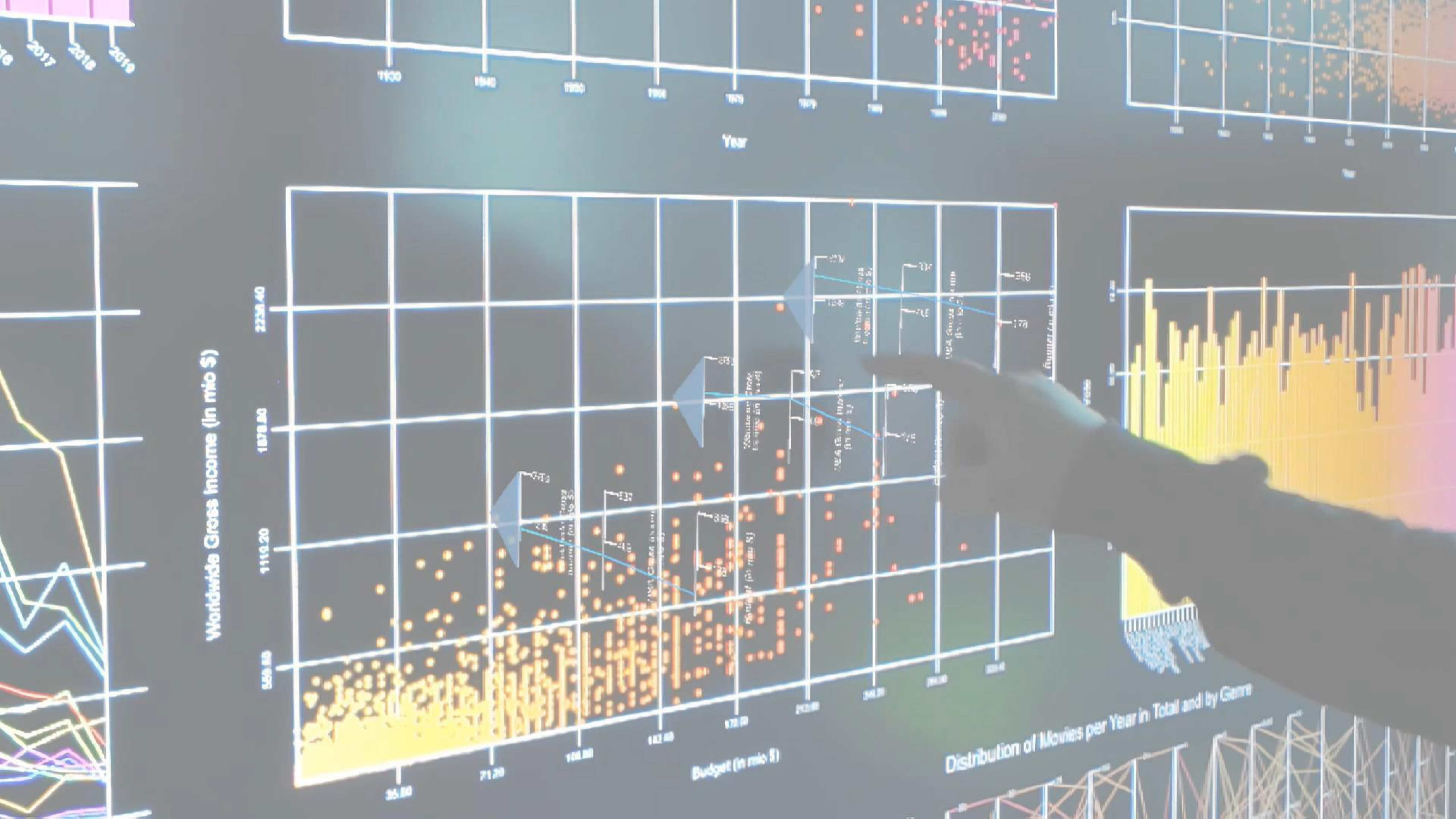


Fig. 1. Impressions from our prototype for extending visualizations with Augmented Reality: (a) Two analysts working with our environment, (b) display showing our *AR Brushing and Linking*, *Embedded AR Visualizations*, and *Extended Axis Views*, (c) *Hinged Visualizations* to improve perception of remote content, and (d) *Curved AR Screen* providing an overview of the entire display.

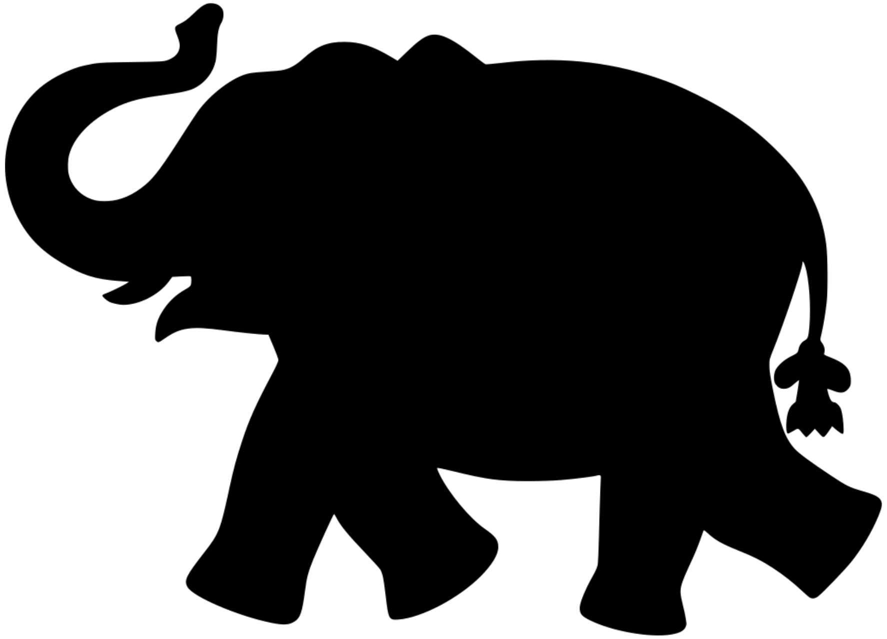
Abstract—In this work we propose the combination of large interactive displays with personal head-mounted Augmented Reality (AR) for information visualization to facilitate data exploration and analysis. Even though large displays provide more display space, they are challenging with regard to perception, effective multi-user support, and managing data density and complexity. To address these issues and illustrate our proposed setup, we contribute an extensive design space comprising first, the spatial alignment of display,


2017
2018
2019
Year
Worldwide Gross Income (in mio $)
Budget (in mio $)
Distribution of Movies per Year in Total and by Genre

Open Opportunities

help people think about, explore, and share data

Why should immersive technologies be used for visual analytics, and in what ways might they be superior to or preferred over other systems?



[Skarbez, Polys, Ogle, North, Bowman; Immersive Analytics: Theory and Research Agenda, Frontiers in Robotics and AI , 2019]

Immersive Data Stories

(Immersive Visual Storytelling with Data)

http://graphics.wsj.com/3d-nasdaq/

A 3-D View of a Chart That Predicts The Economic Future: The Yield Curve

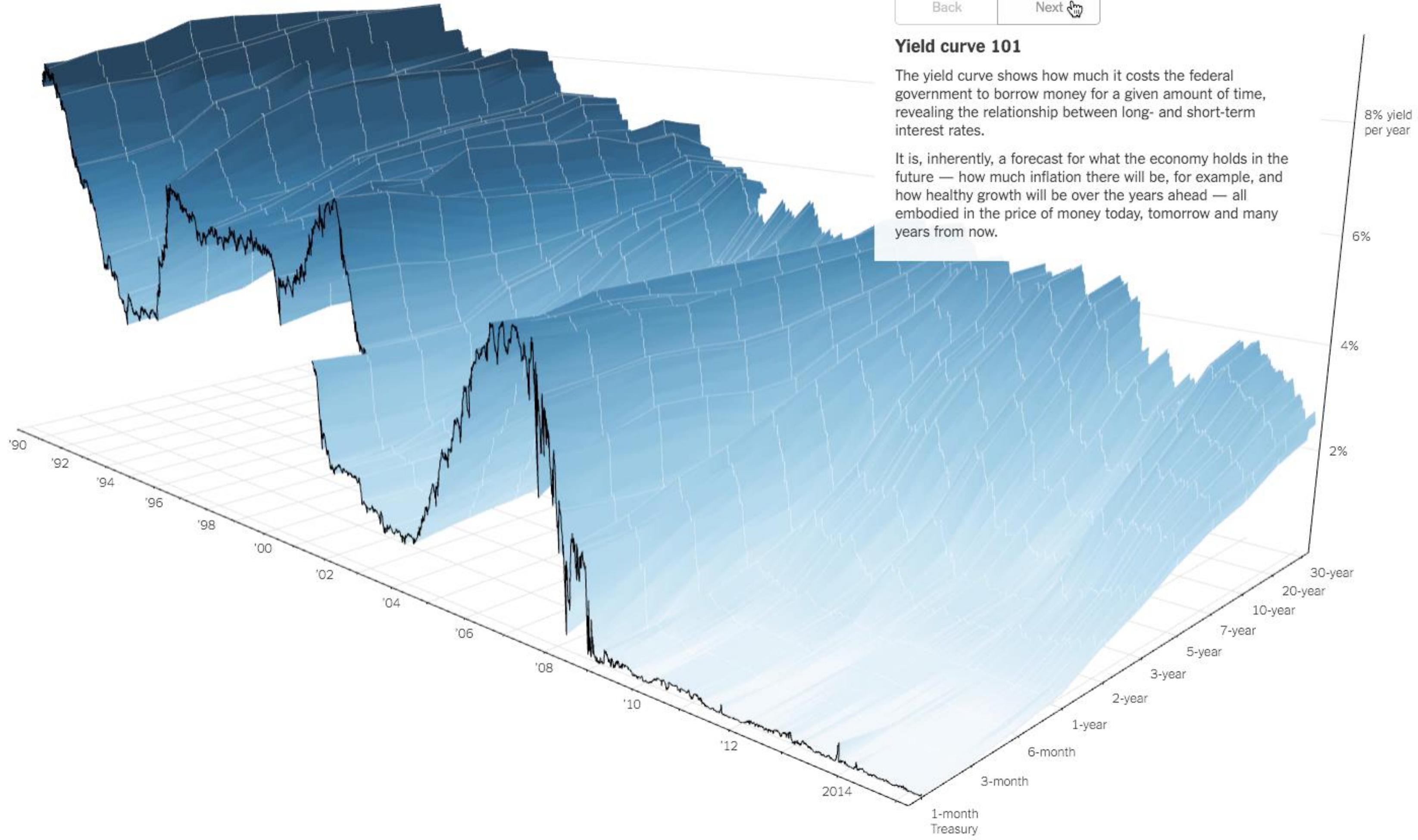
By GREGOR AISCH and AMANDA COX MARCH 18, 2015

Back Next

Yield curve 101

The yield curve shows how much it costs the federal government to borrow money for a given amount of time, revealing the relationship between long- and short-term interest rates.

It is, inherently, a forecast for what the economy holds in the future — how much inflation there will be, for example, and how healthy growth will be over the years ahead — all embodied in the price of money today, tomorrow and many years from now.



What is the role of the presentation medium?

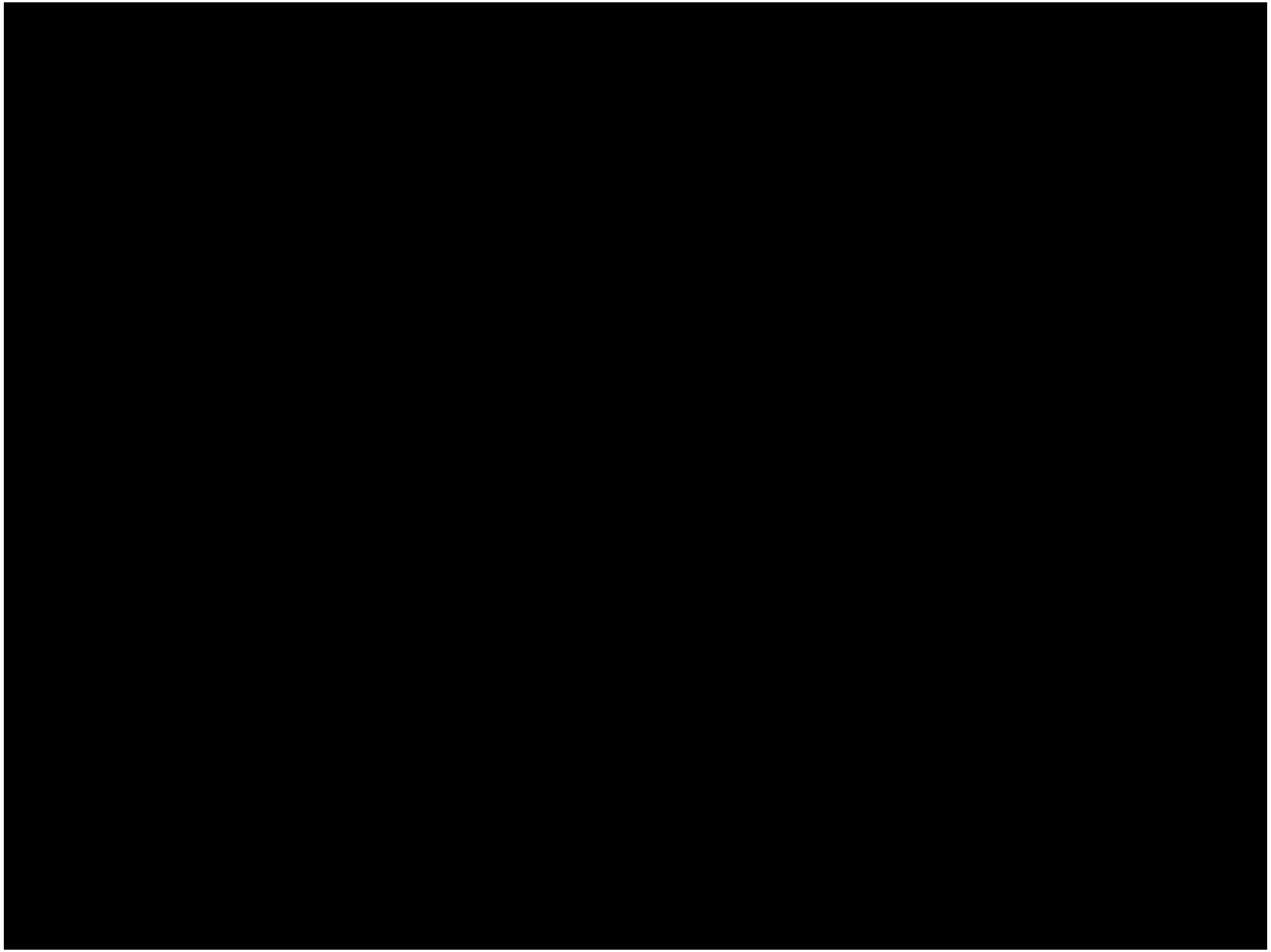
To what extent are references to the “real-world” necessary?

Can we create emotional involvement?

[Immersive Visual Data Stories. Isenberg et al. in “Immersive Analytics”, 2019]

Design

(how much immersive technology do we actually need)

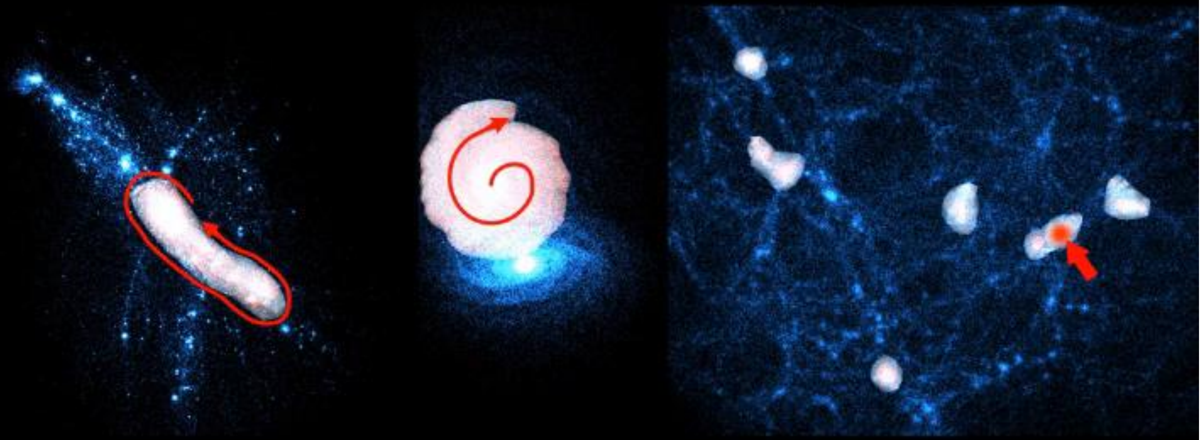


https://www.youtube.com/watch?v=fP-7rhb-qMg created by Wayne Lytle in 1993 at the Cornell Theory Center

Interaction with Data
in 3D Immersive Spaces

CAST: Effective and Efficient User Interaction for Context-Aware Selection in 3D Particle Clouds

Lingyun Yu
Konstantinos Efstathiou
Petra Isenberg
Tobias Isenberg



HANGZHOU DIANZI UNIVERSITY
university of groningen
informatics mathematics
Inria

contact: LingYun Yu <mail@yulingyun.com> and Tobias Isenberg <tobias.isenberg@inria.fr>

REFERENCES
to get started on Immersive Analytics

Immersive Analytics [Book]
edited by Kim Marriott, Falk Schreiber, Tim Dwyer, Karsten Klein, Nathalie Henry Riche, Takayuki Itoh, Wolfgang Stuerzlinger, Bruce H. Thomas 2018

Immersive Analytics: Theory and Research Agenda,
Skarbez, Polys, Ogle, North, Bowman; Frontiers in Robotics and AI , 2019

Survey of Immersive Analytics,
Fonnet and Prié, in *IEEE Transactions on Visualization and Computer Graphics*, doi: 10.1109/TVCG.2019.2929033.

DATA PHYSICALIZATION

SITUATED VISUALIZATION

IMMERSIVE ANALYTICS

PERSONAL DATA VISUALIZATION

MOBILE VISUALIZATION

should we care about the latest and greatest display technology…

HOW IMPORTANT IS DISPLAY TECHNOLOGY TO US?

http://pixabay.com/en/technology-informatics-computers-298256/

should we care about the latest and greatest display technology…

ABSOLUTELY

http://pixabay.com/en/technology-informatics-computers-298256/

Together we can shape…

WHAT THE FUTURE OF DATA EXPERIENCES WILL BE LIKE!

http://pixabay.com/en/technology-informatics-computers-298256/

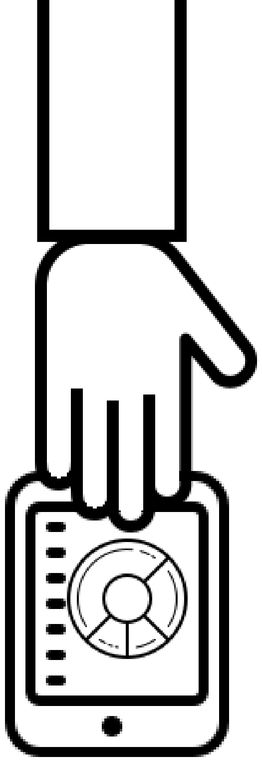
we need to empower people to…

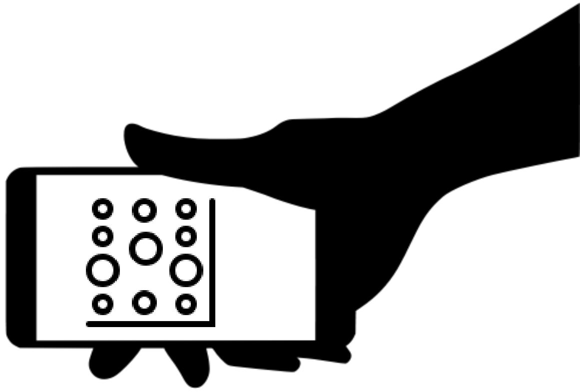
UNDERSTAND DATA
TO NAVIGATE THE(IR) WORLD

http://photos.jdhancock.com/photo/2012-06-14-051220-universal-hulk.html

BENEFITS OF JOINT HCI+VIS WORK

- new audiences
  (e.g. personal analytics, larger audiences, …)
- new social settings
- novel interactions
- more pixels (or less!)
- new constraints → inspiration!





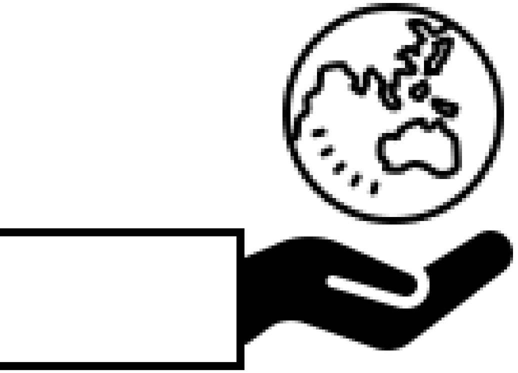
WHEN VISUALIZATION MEETS HCI…

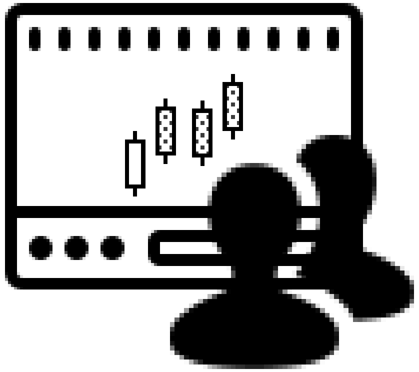
Petra Isenberg

@dr_pi petra.Isenberg@inria.fr

Inria

Aviz Visual Analytics Project





https://icons8.com/

Extra Slides

…just in case…

ACKNOWLEDGE THE PHYSICAL WORLD

SITUATED VISUALIZATIONS

https://vimeo.com/226488668

“everything is related to everything else, but near things are more related than distant things”

- In-situ data analysis (Ens & Irani)
  “access to situationally appropriate data at an ideal time and place”

- Situated visualization (Vande Moere & Hill 2012)
  “embedded in a real-world, physical environment”

- Situated visualization (White 2009)
  “a visualization that is related to its environment”
  “based on the relevance of the data to the physical context”

“representations of data that are deeply integrated with the physical spaces, objects, and entities to which the data refers”


Visualisierung von Relationen
in hierarchischen Daten
OTTO-VON-GUERICKE-UNIVERSITÄT MAGDEBURG
Diplomverteidigung
Petra Neumann, CV99
8. September 2004

Photo by rawpixel.com from Pexels

Photo by rawpixel.com from Pexels

Raja et al.: Exploring the Benefits of Immersion in Abstract Information Visualization. Immersive Projection Technology Workshop, 2004.