Visualization in the Real World: Confluence of Visualization and Augmented Reality

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What Makes Augmented Reality Interesting?

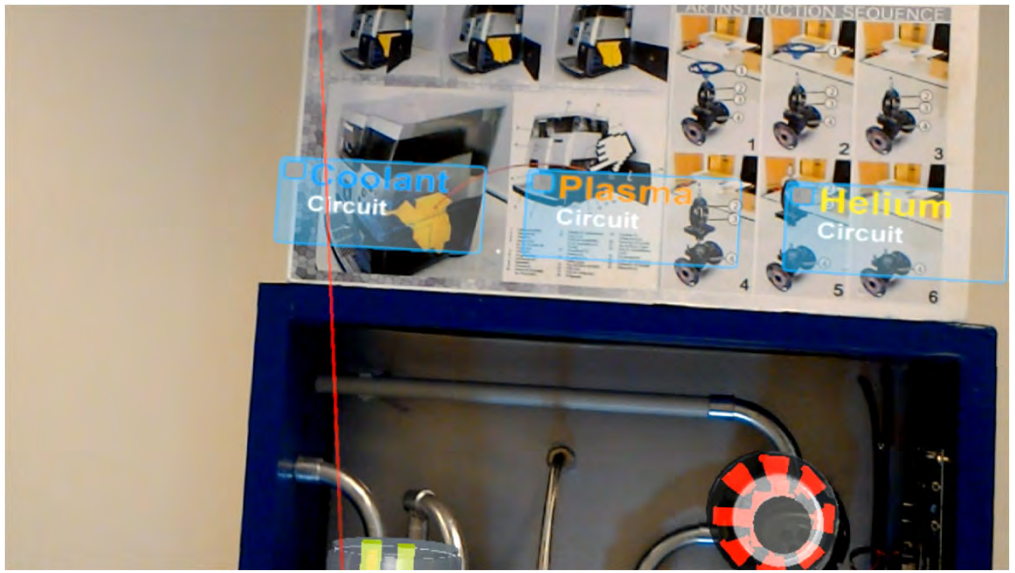
- Overlays real world with computer graphics
- Runs with headsets, handhelds, projectors
- Low latency, tracked, blended graphics
- Work anywhere, indoors + outdoors
- Natural user interface, ease of use

Epson

Magic Leap

Microsoft

[Langlotz, Ngyuen, Schmalstieg, Grasset, 2014]



What Makes Visualization Interesting?

- VIS provides **insight**
  - Abstract data made visually accessible
  - Information workers, support cognition

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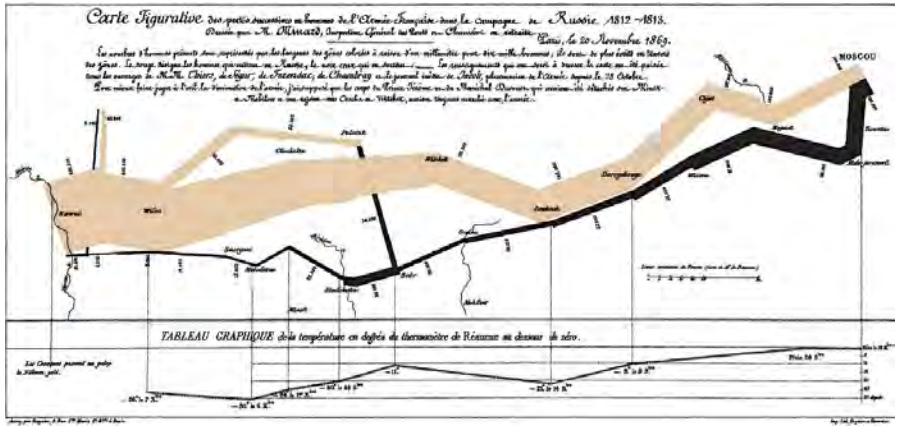


(Sankey diagram, Minard 1869)

- Not so much about **presence** (being there)
- Rather about **cognition** (perceiving, understanding, deciding)
- But: **spatial understanding** is an important part of cognition
  - Spatial understanding aids cognition
  - Need for spatial understanding motivates the use of VR/AR!

Slide 3

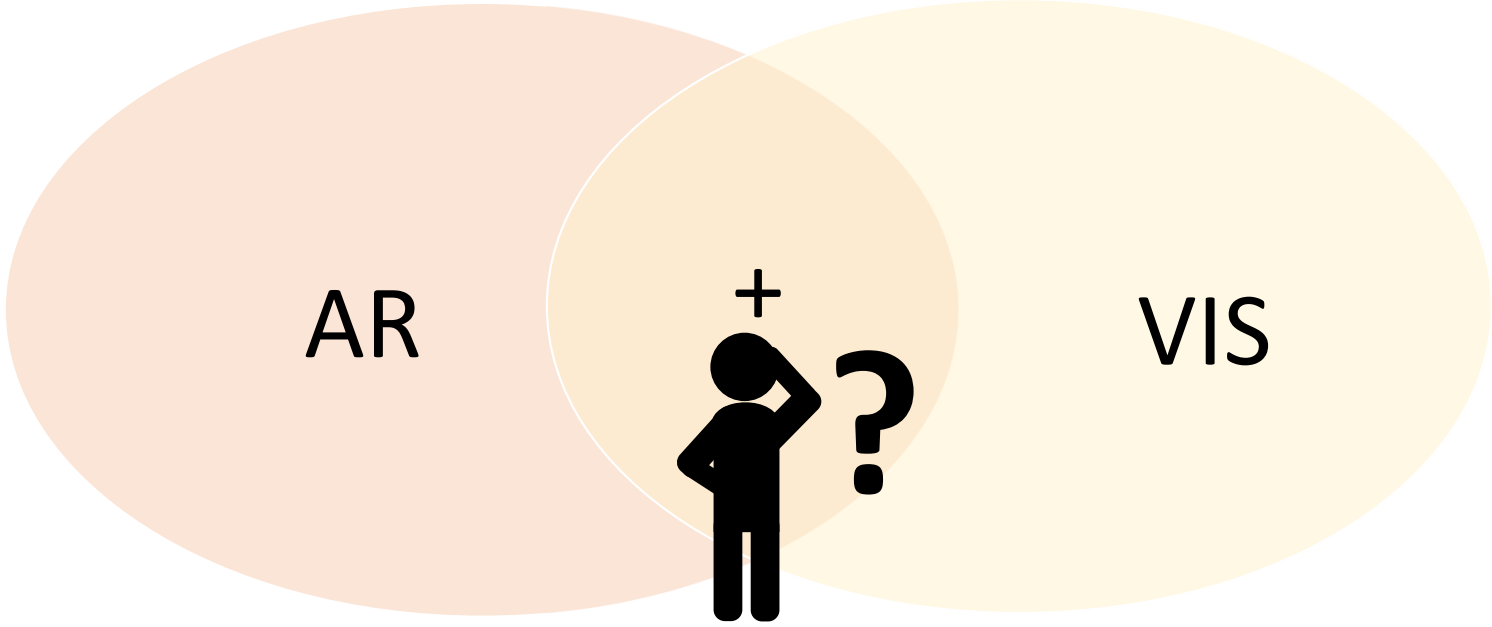
s1 schmalstieg@tugraz.at, 8 Feb 2021

How are AR and Visualization Connected?

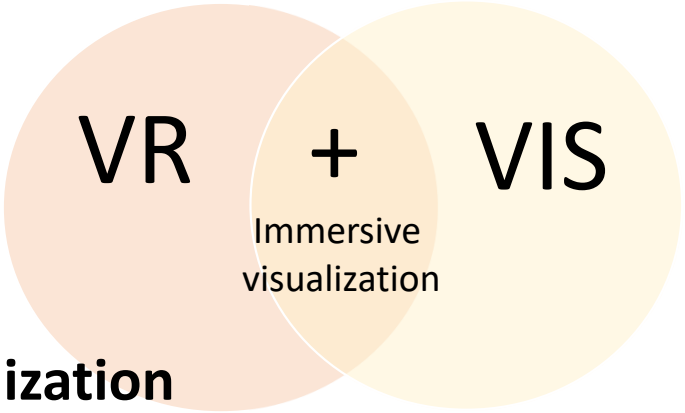
- Focus on **intelligence amplification** (IA) rather than **artificial intelligence** (AI)
  - W. Ross Ashby: *Introduction to Cybernetics,* 1956
  - IA sometimes also called **cognitive augmentation**
- Where is IA used?
- IA as killer app for mobile phones
  - Wikipedia, mobile google search, maps, QR codes
- IA as killer app for AR
  - AR as a **natural** user interface (not a **symbolic** user interface, as on desktop)
  - AR as a **medium** that makes us appear (or actually be) smart
  - No more need to take out your phone and swipe through the app list

What is the Overlap of AR and VIS?

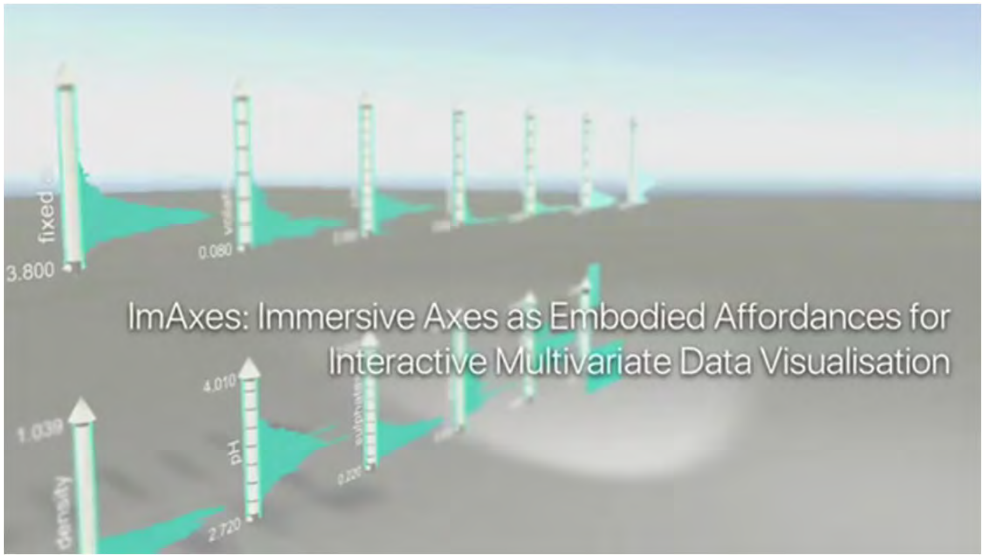
How can we realize the intelligence amplification using AR + VIS?



Immersive Visualization



- Let‘s first combine VIS and VR
- We get a **spatially registered visualization**
  - Left is left, right is right
  - Can reach out and touch the data
  - Can use sense of body, proprioception
  - Can use 3D direct interaction
- But **meaning** of physical space is **arbitrary**
  - Visualization only relates to itself
  - Hence, we call it **virtual** or **immersive**



ImAxes [Cordeil, Cunningham, Dwyer, Thomas, 2017]

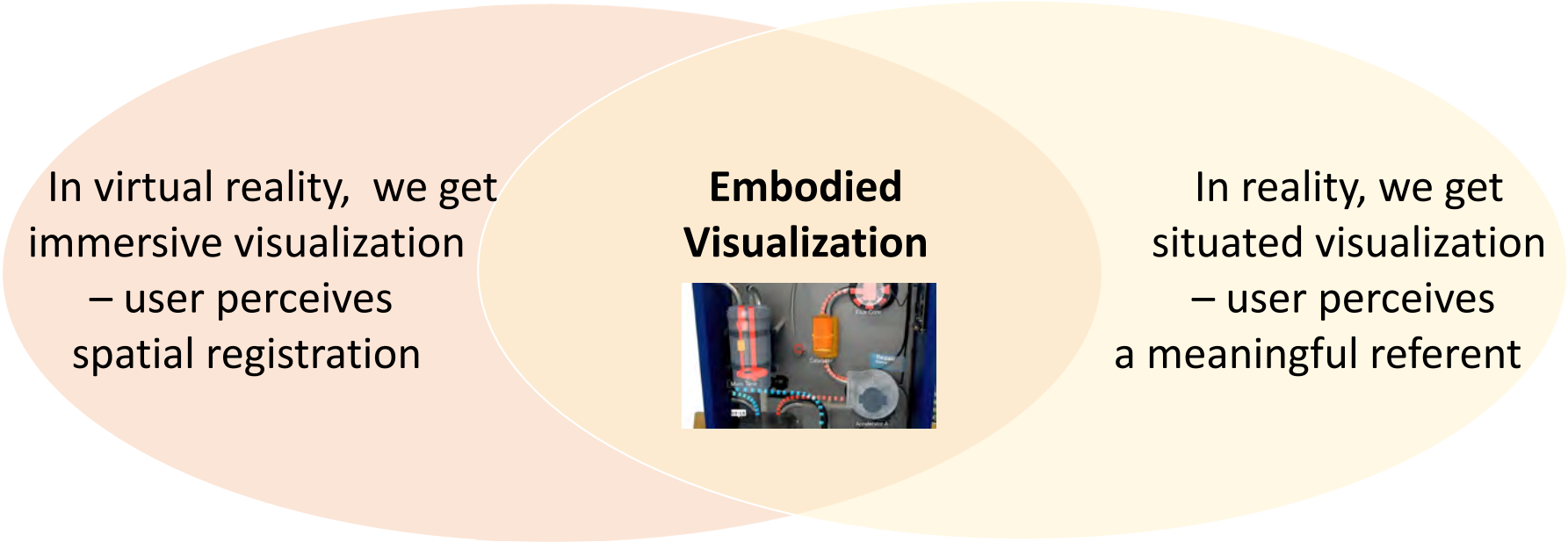
Situated Visualization

- In reality, user perceives **referents** [Willet, Jansen, Dragicevic, TVCG 2016]
- Referent = **physical object/locale with meaning**
- Referent must be visible
  - Not in opaque VR headsets
  - Includes location-based apps, tangible interfaces, IoT...

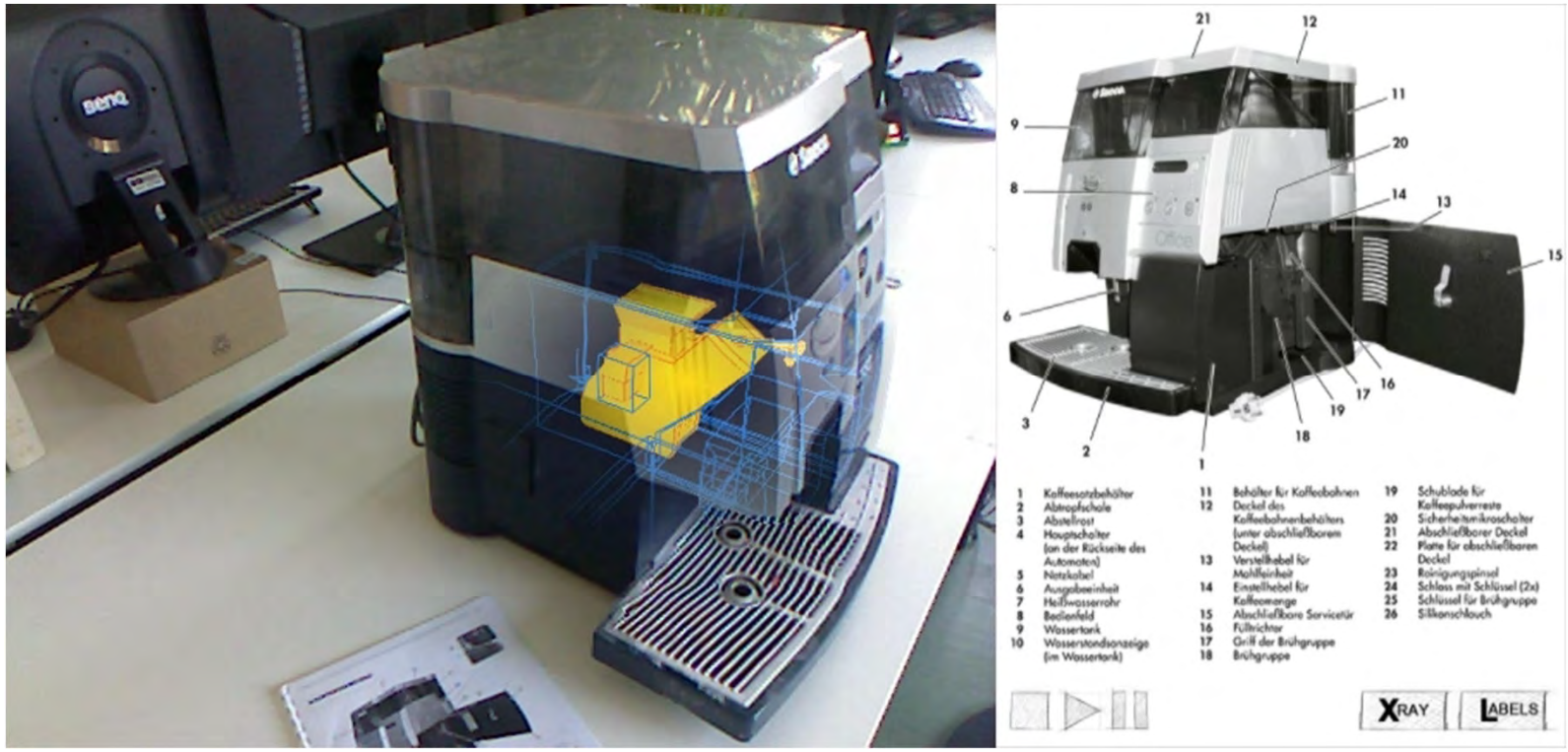
- Visualization that is perceived **simultaneously** with a referent is called **situated visualization**
- SitVis can use AR, but also mobile displays, embedded displays...

Embodied Visualization in Augmented Reality

- AR combines virtual + real
- Spatially registered interaction with a meaningful referent = **embodied visualization**



X-Ray: Referent is Hidden Inside Machine

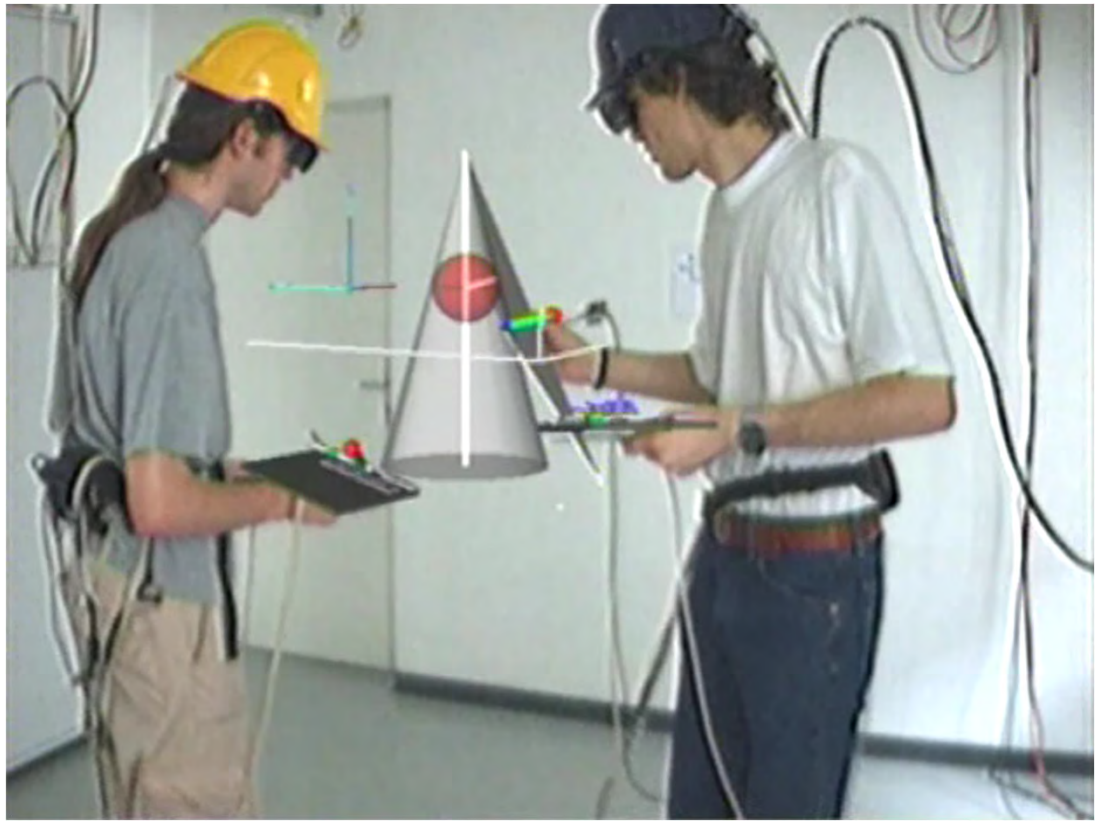


[Mohr, Kerbl, Kalkofen, Schmalstieg, CHI 2015]

Wearable Displays: Referent is Own Body

[Grubert, Heinisch, Quigley, Schmalstieg, CHI 2015]

Collaboration: Referent is Other Person



[Kaufmann, Schmalstieg, c&g 2003]

Embodied Visualization

- Casual – association by looking
- Requires only basic visual encoding
- Requires **perceptual methods**
  - Legibility
  - Label placement
  - Details on demand
  - Focus+context
  - Layout optimization
- Requires **environmental AI**
  - Object detection
  - Scene understanding

Label Placement: Temporal Coherence

- Casual – association by looking
- Requires only basic visual encoding
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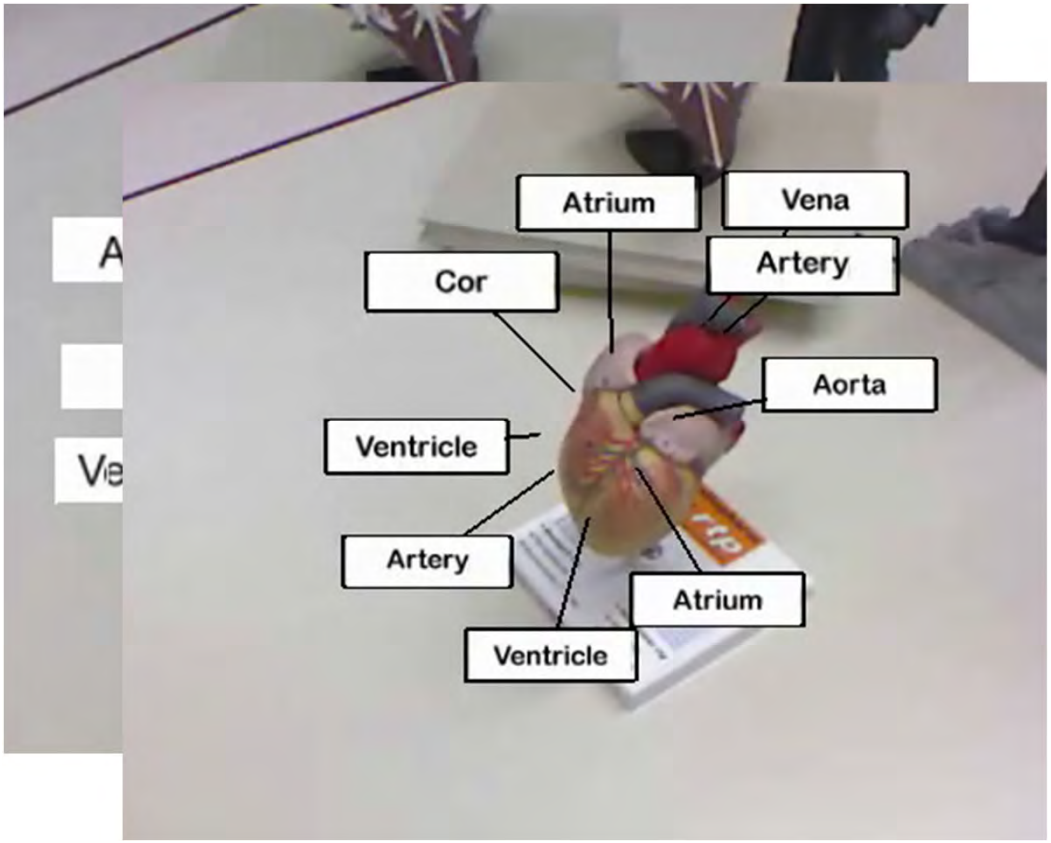

[Tatzgern, Kalkofen, Grasset, Schmalstieg,, VR 2014]

Details on Demand: Icon Hierarchy

- Casual – association by looking
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- Requires perceptual methods
  - Legibility
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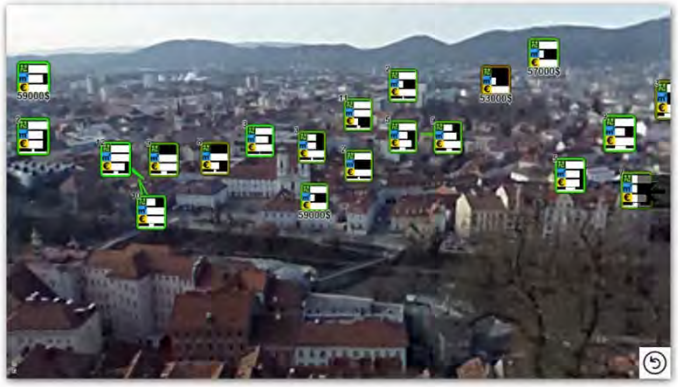
Adaptive Information Density Display



We present an **information density display** that selects the presented items based on **user preferences**. At the same time it avoids visual clutter by **balancing** the presented **information** against the available **screen space**.

[Tatzgern, Orso, Kalkofen, Jacucci, Ghamberini, Schmalstieg, TVCG (VR) 2016]

Focus+Context: X-Ray Vision

- Casual – association by looking
- Requires only basic visual encoding
- Requires perceptual methods
  - Legibility
  - Labeling placement
  - Details on demand
  - **Focus+context**
  - Layout optimization
- Requires environmental AI
  - Object detection
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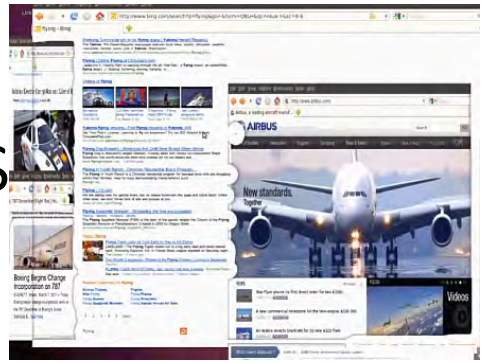
[Erat, Isop, Kalkofen, Schmalstieg, TVCG (VR) 2018]

Layout Optimization: 2D Windows



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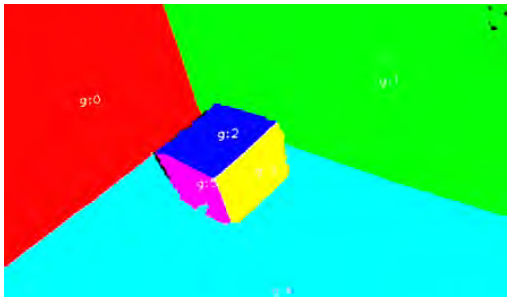
[Steinberger, Waldner, Schmalstieg,, CFG (Eurographics) 2012]

Scene Understanding: Geometry



[Nguyen, Reitmayr, Schmalstieg, TVCG 2016]

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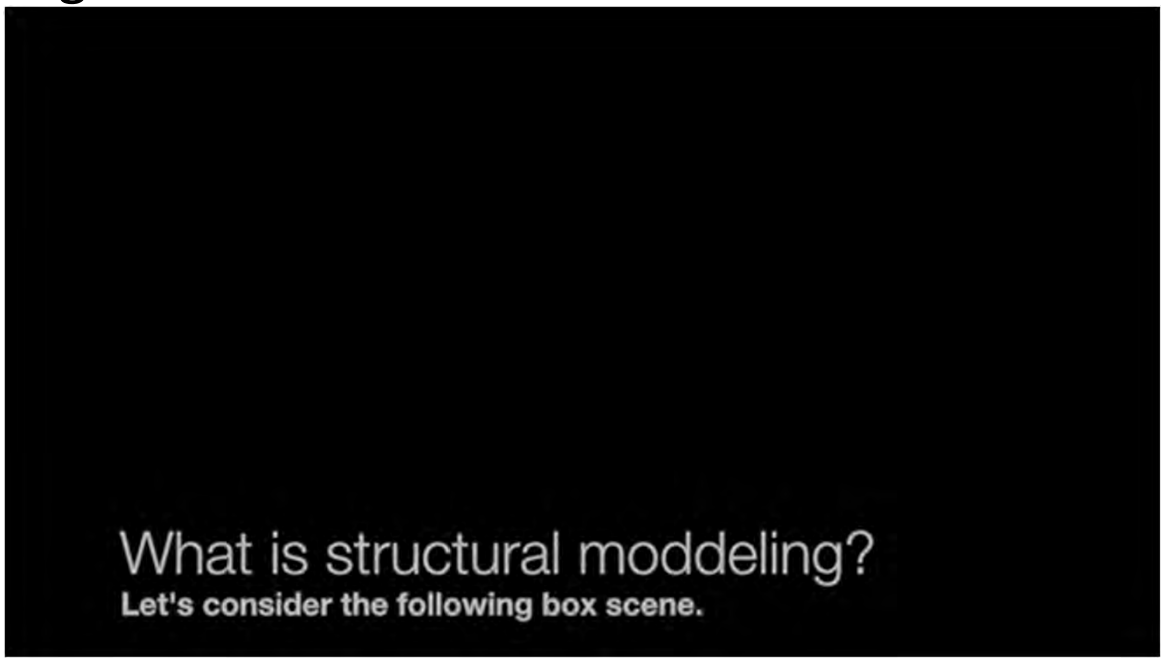

Scene Understanding: Semantics

- Casual – association by looking
- Requires only basic visual encoding
- Requires perceptual methods
  - Legibility
  - Labeling placement
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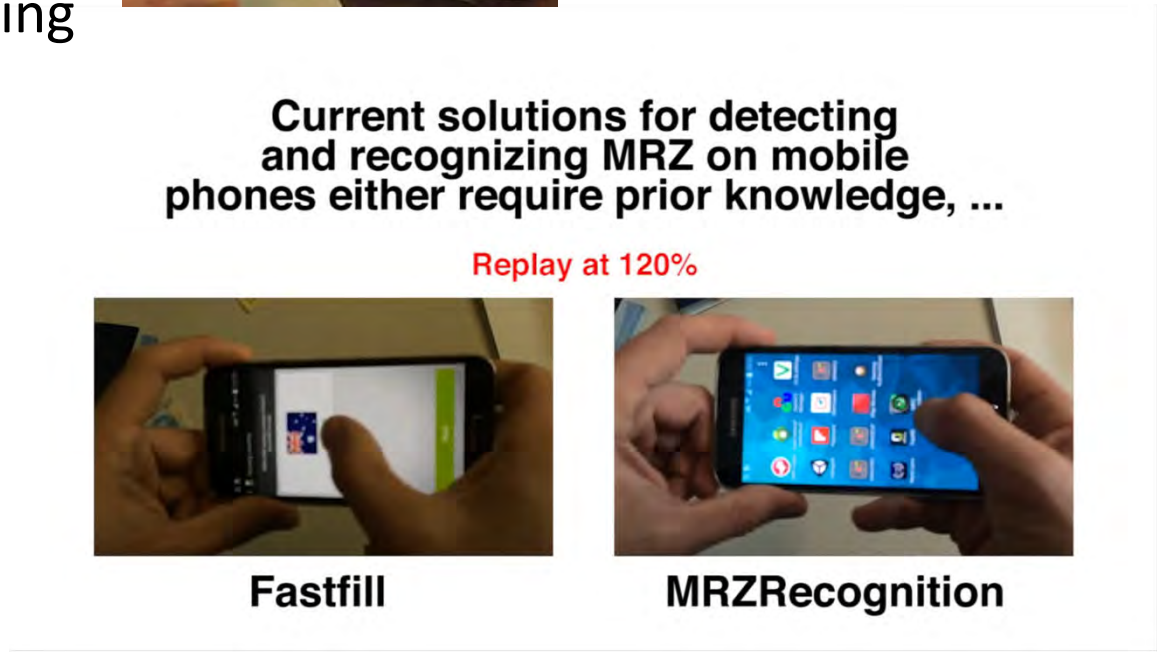
  - Layout optimization
- Requires environmental AI
  - Object detection
  - **Scene understanding**



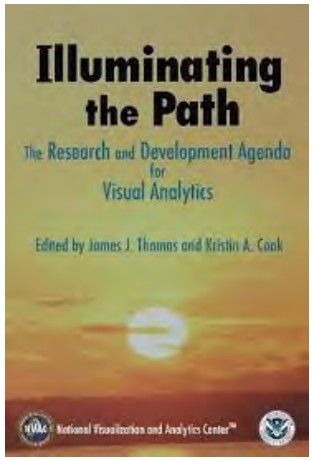
[Hartl, Arth, Schmalstieg, VISAPP 2015]

From Visual to Embodied Analytics

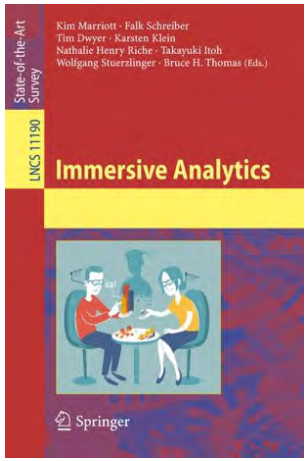
- Visual analytics: "*Science of analytical reasoning facilitated by interactive visual interfaces*"

- Embodied Analytics in AR
  - Study complex data close to a referent
  - E.g., diagnosing a faulty machine in a factory

[Thomas, Welch, Dragicevic, Elmquist, Irani, Jansen, Schmalstieg, Tabard, ElSayed, Smith, Willet 2018]



[Cook, Thomas, 2005]



[Marriott et al., 2018]

Embodied Analytics

- Support complicated work with AR
  - E.g., diagnosing a faulty machine in a factory
- The **authoring problem**
  - Where does the "smart" content come from?
  - Huge semantic gap digital←→real
- How can we close the semantic gap?
  - Teleassistance (*Wizard of Oz* in real life)
  - Data-driven authoring (from printed manuals)
  - Authoring by example

Authoring from Legacy Data: Printed Manuals

- Support complicated work with AR
  - E.g., diagnosing a faulty machine in a factory
- The authoring problem
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- How can we close the semantic gap?
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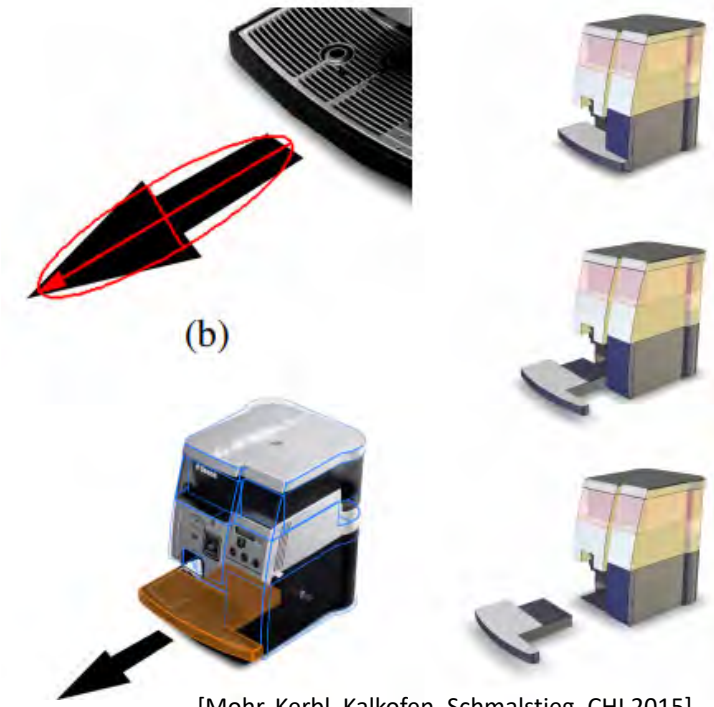
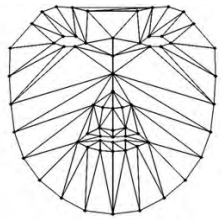
  - **Data-driven authoring**
  - Authoring by example



[Mohr, Kerbl, Kalkofen, Schmalstieg, CHI 2015]

Authoring by Example: Youtube



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[Mohr, Mandl, Tatzgern, Veas, Schmalstieg, Kalkofen, CHI 2016]

Authoring by Demonstration

- Support complicated work with AR
  - E.g., diagnosing a faulty machine in a factory
- The authoring problem
  - Where does "smart" content come from?
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- How can we close the semantic gap?
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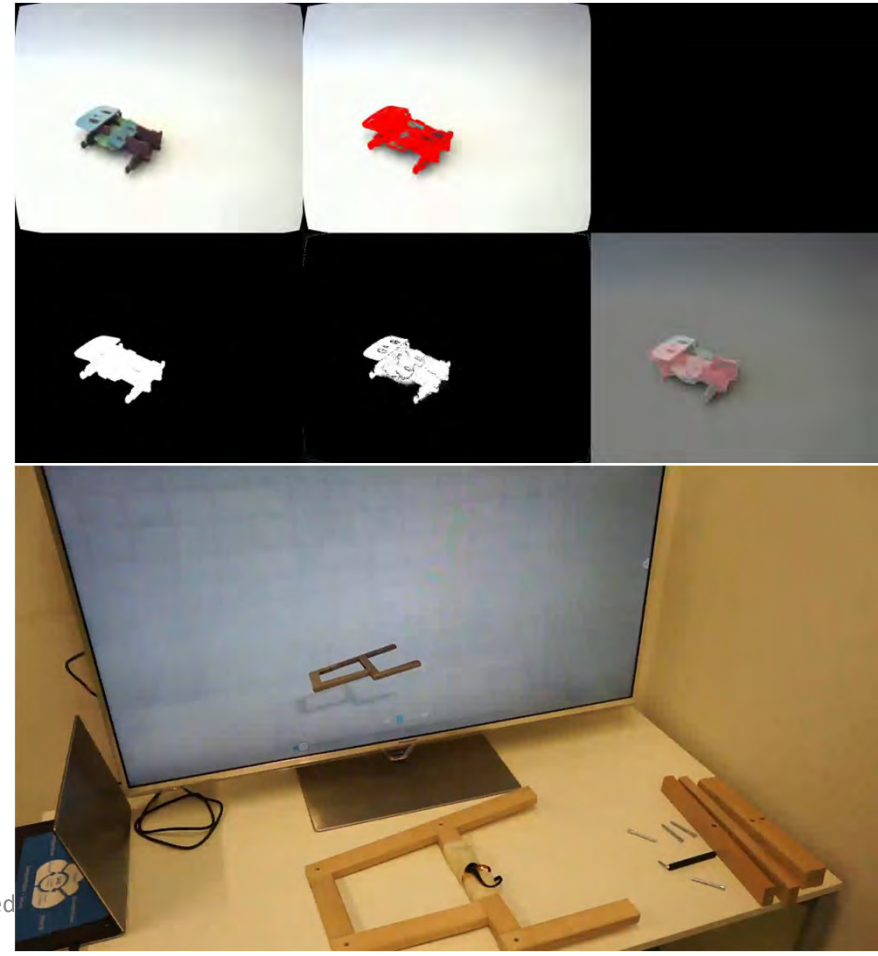


Several Deeper Questions Emerge

- When does embodiment lead to greater effectiveness?
  - Task performance, learning, engagement, adoption, or satisfaction?
- How much embodiment is needed/justified?
- Is cognitive load reduced by embodied visualization?
- Spatialization: How to map data/attributes to the environment?
- How can we design selection and manipulation techniques to work within and across a physical environment?
- What techniques work best to navigate (non-spatial) data in embodiement visualization?

[Skarbez, Polys, Ogle, North, Bowman, Frontiers AI/R 2019]

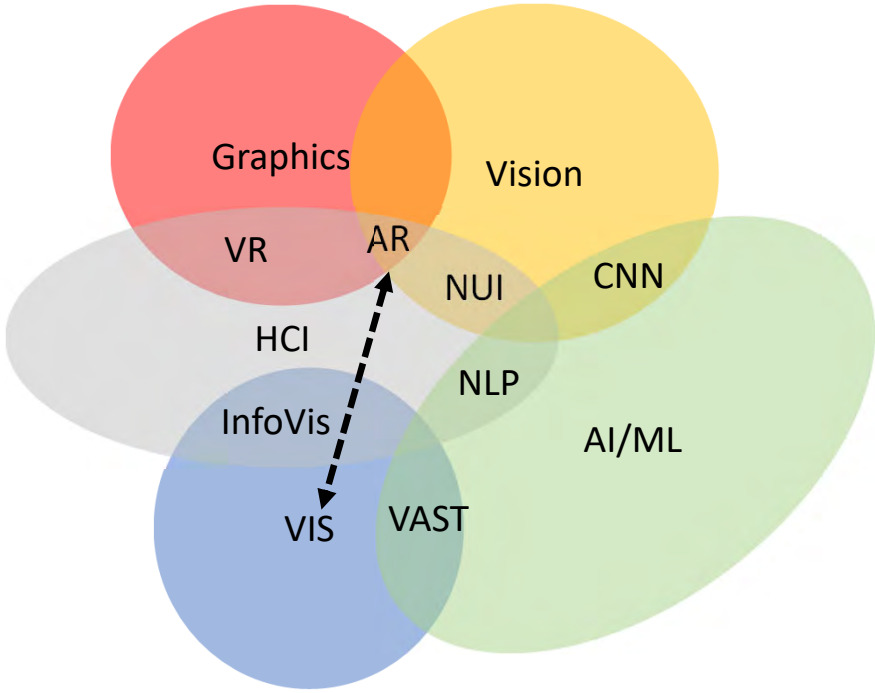
Research Agenda: Much To Do

- Important new field: Embodied Vis takes AR beyond (only) entertainment

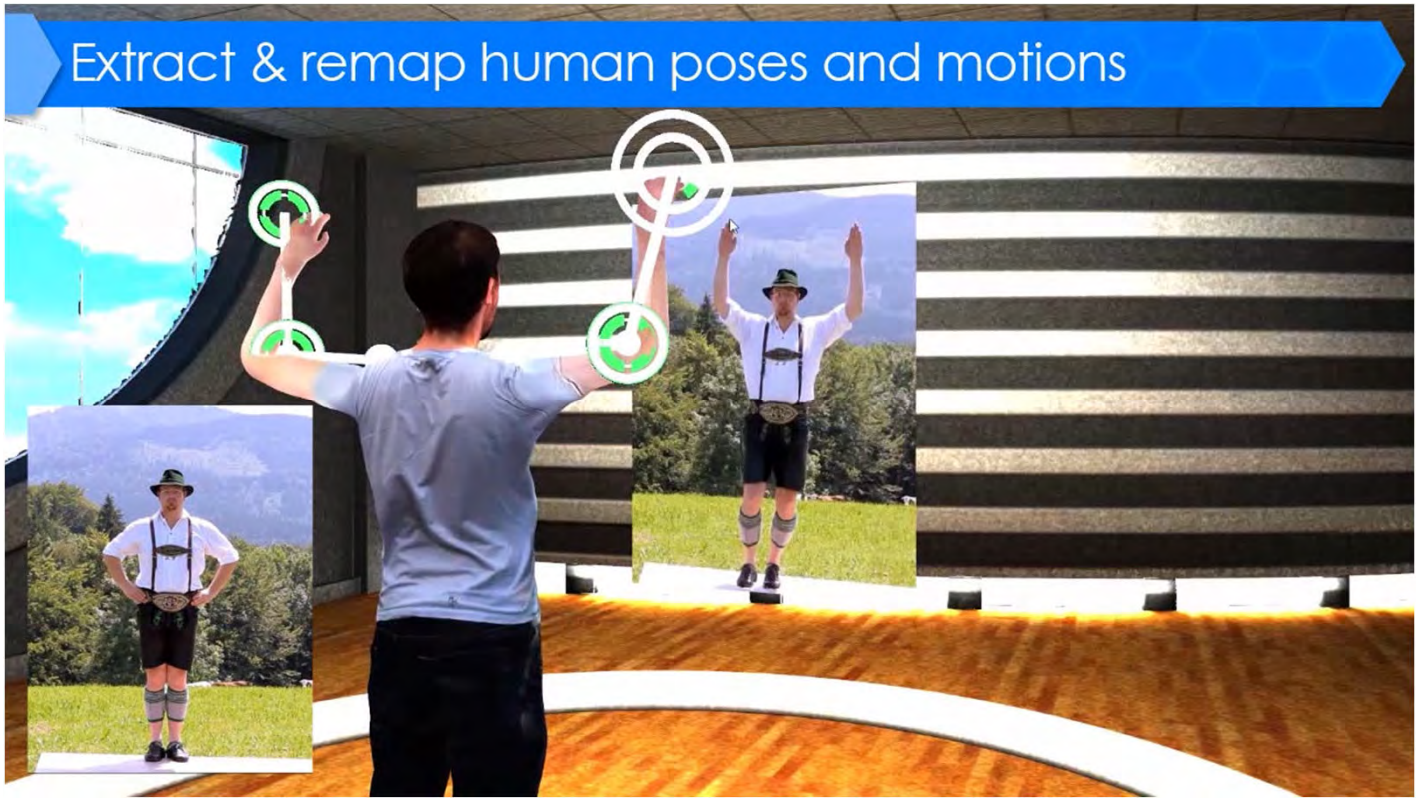
- Embodied Vis will need
  - **Better displays**: vergence-accomodation conflict, FOV
  - **Scalability**: cloud computing, latency-hiding
  - **Visualization literacy in AR**: Styles, conventions, best practices
  - **Software frameworks**: the VTK/SVG/D3 of AR(?)
  - **Flexible standards**: „Responsive design“ for AR

Is the Relationship of AR and Vis Too Complicated?

- I hope I have convinced you otherwise!
- There is a lot of common ground
- But there is also a distance to cross
- Exploring the overlap of AR and VIS can lead to radical research innovations!
- *All these communities should definitely interact more!*



Thank You!



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