What is the IoT?

“The Internet of Things is the ever-expanding collection of connected devices that capture and share data. Any object, outfitted with the right sensors, can observe and interact with its environment.” Omes (1)
AR + IOT: Opportunities

- On the first look, plenty!
- Visualize physical location of data
- Quicker debugging
- Increased immersion
- Direct manipulation of IoT system (2-way communication)

AR can aid graph comprehension

1) Graph comprehension involves:
   a) Bottom-up processes in which people extract visual chunks (limited number of quantitative facts or relations) that are explicitly represented to those visual chunks must be computed by inferential processes that are difficult and error prone.
   b) Top-down processes in which knowledge of semantic content also influences viewer's interpretations of data. — Shah (3)

[Links]

AR + IoT: Challenges

- Lacking maturity of AR devices
  - Tablets
  - HMDs
  - Occlusion
- Lack of shared experiences
- Difficulty of setup
- Lack of voice control
- Lack of standards for data streams, software deployment, etc.

However...

It’s a chance!

- ...to advance data visualization theory!
- Develop data visualizations for
  - IoT debugging and optimization
  - IoT education and training

In summary

- AR is not foolproof
- AR is not established
- The IoT necessitates many kinds of literacies and skills
- Developing applications for AR + IoT is new terrain
- Difficulties related to
  - Skill
  - Technology
Example projects - Lifting the Veil

- Sentient Veil Boston (MA)
- February 2017
- Goal: Visualize actuation pattern in Sentient Veil sculpture
- Target audience: Visitors

Lifting the Veil App Development

- Lifting the Veil Virtual
  - Sensor 1 triggered
- Lifting the Veil AR
  - Sensor 2 triggered

INDIANA UNIVERSITY
Facilitating on Promise
Example projects – Dendrite Moth field array

- VIS Lab
- November 2017 – present
- Core: Create small-scale IoT setup for debugging & visualization development
- Target audience: makers

http://cns.iu.edu/photos.htm

See https://github.com/pbarch/1714-IU-Summer-Camp-for-code

Dendrite Field Array Schematics
Demo: Tablet-based AR with IoT

Example projects – Amatria 24h data stream
- Amatria
- May 2018
- Goal: Visualization for experience
- Examining data, feedback, vehicle access
- Target audience: makers

Example projects – Amatria 24h data stream (cont’d)
- How could AR improve the visualization?
  - For tourists:
    - Increased immersion
  - For students:
    - Improved understanding
  - Jobs:
    - Improved workflow

Tavola
- Movement: people
- Goal: Balance a market table
- Enhance visitor experience
  - Rich, engaging environment
Demo time!

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<th>Data scale</th>
<th>Analysis</th>
<th>Vis type</th>
<th>Graphic var type</th>
<th>Graphic symbol type</th>
<th>Interaction type</th>
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</thead>
<tbody>
<tr>
<td>Compare</td>
<td>Nominal</td>
<td>Temporal</td>
<td>Color bar</td>
<td>Volume</td>
<td>Time</td>
<td>Zoom</td>
</tr>
<tr>
<td>Locate</td>
<td>Temporal</td>
<td>Map</td>
<td>Shape</td>
<td>Area</td>
<td>Filter</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion & outlook
- Essential for academia: integrate AR into existing data visualization frameworks
  - Deconstruct
  - Develop
  - Test, test, test

- Essential for industry:
  - Offer unified solutions for development and deployment
  - Develop affordable hardware & software

- Essential for educators:
  - Include AR (and VR) into curriculums for STEM students

References (Excerpt)
Image Sources

All images are the property of their respective owners, unless marked otherwise:

- Sentient Veil, 2017, Sentient Veil, Boston, MA. Photography by Andreas Bueckle
- Sentient Chamber, 2016, National Academy of Sciences, Washington, D.C. Photography by Andreas Bueckle
- Sentient Schematic Drawings, Philip Beesley Architect Inc., Toronto, ON (Canada)
- Sentient Veil Schematic Drawings, Philip Beesley Architect Inc., Toronto, ON (Canada)
- Andreas Bueckle, XRay App, Misc.
- Andreas Bueckle, Tavola App, Misc.
- Philip Beesley, Archinect Inc., Misc.
- Matthew Spremüli, photo (CA)

[Image of Matthew Spremüli]