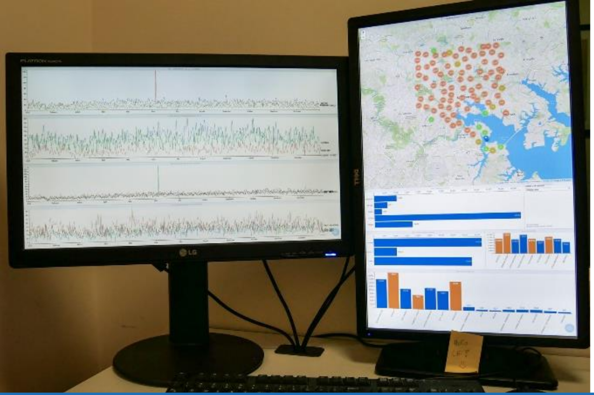
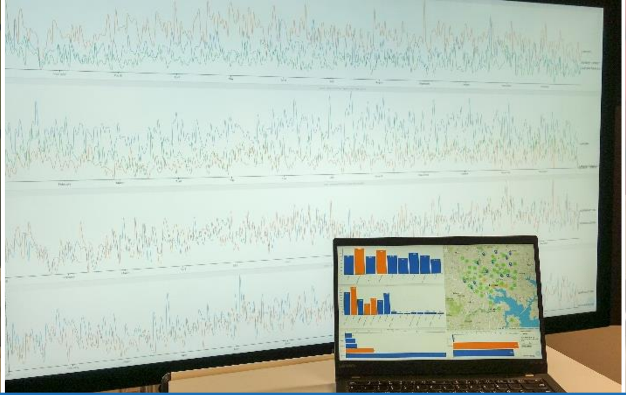
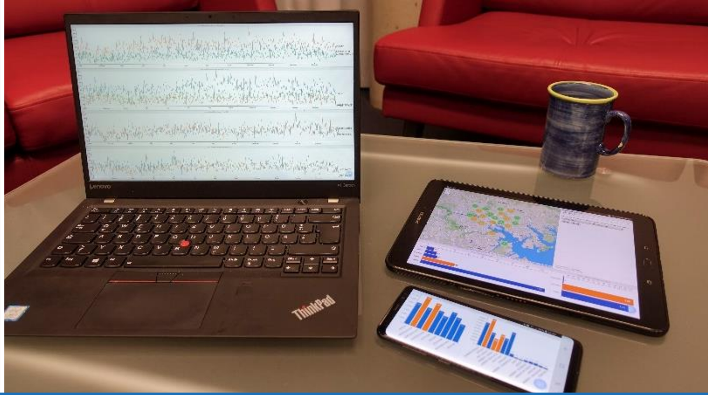


# Vistribute:
# Distributing Interactive Visualizations in Dynamic Multi-Device Setups

**Tom Horak**, Andreas Mathisen, Clemens N. Klokmose, Raimund Dachselt, Niklas Elmqvist

ACM CHI 2019
Glasgow, Scotland, UK

TECHNISCHE UNIVERSITÄT DRESDEN
INTERACTIVE MEDIA LAB DRESDEN
AARHUS UNIVERSITY
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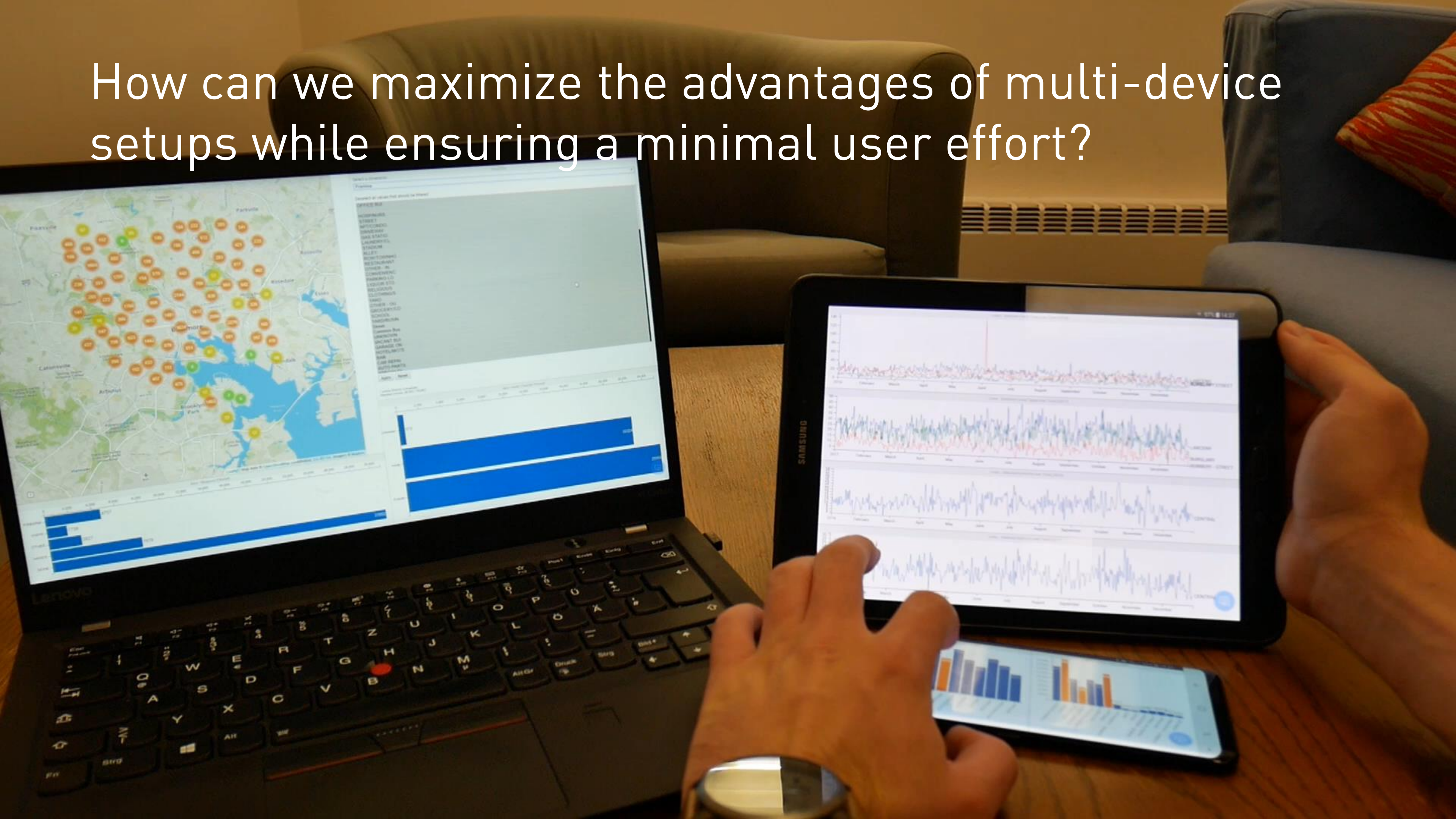
Nowadays, data analysis can take place in many different environments with various devices

How can we maximize the advantages of multi-device setups while ensuring a minimal user effort?



# What we know: devices can fulfill different roles during visual data analysis

Roles emerging from data exploration patterns,
e.g., overview+detail, focus+context

Roles emerging from multi-user constellations,
e.g., personal toolboxes, shared interaction space

So far:
- Only systems for specific device combinations
- Lacking support for flexibly placing visualizations
- Increasing configuration effort with many devices

Kister et al., CGF '17:
*GraSp*

Wozinak et al., NordiCHI '14:
*Thaddeus*

McGrath et al., AVI '12:
*Branch-merge-explore*

Horak et al., CHI '18:
*When David meets Goliath*


Plank et al., CHI '17:
*Is Two Enough?!*

Langner et al., VIS '18:
*VisTiles*

# What we know: various frameworks for cross-device development exist, but rarely focus on visualizations

## Synchronization frameworks:

Support for synchronizing elements or events across devices

Badam and Elmqvist 2014: *PolyChrome*
Badam et al. 2015: *Munin*
Houben & Marquardt 2015: *WATCHCONNECT*
Klokmose et al. 2015: *Webstrates*
Schreiner et al. 2015: *Connichiwa*

## Distribution frameworks:

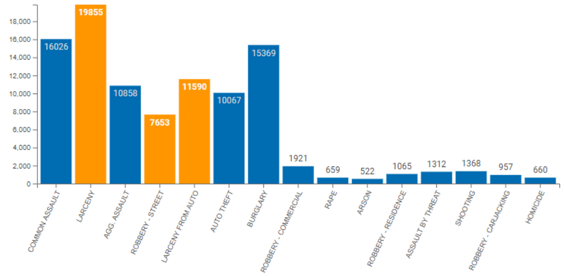
Automatic distribution of components based on manually defined constraints

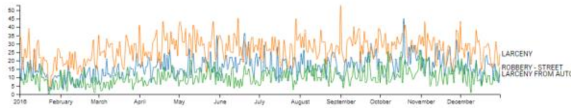
Yang & Wigdor 2014: *Panelrama*
Nebeling & Dey 2016, Nebeling 2017: *XDBrowser*
Husmann et al. 2018: *Out of Office Software Development*
Park et al. 2018: *AdaM*

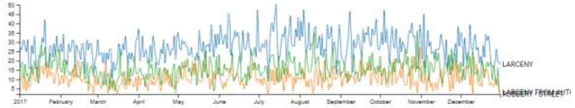
## So far, all frameworks…

- rely on additional input from developers or users
- do rarely consider visualization-specific aspects

# Visualizations are more than "just" views




Visualizations have a rich body of characteristics and certain relationships to other visualizations

Visualization Type

Encoding

Size

Data Points

Axis

Visual Density

Internal State

Data Source

Idea: Considering these aspects alongside device properties and user preferences

# We contribute the Vistribute framework

## Design Space

Exploring the properties and relationships between visualizations, devices, and the user

## 6 Heuristics

High-level constraints for deriving a view-sensitive distribution and layout

## Vistribute System

Open source implementation representing one possible instance of our heuristics

# Each heuristic contributes to different aspects of a distribution

## Grouping & alignment based on view relationships

- ★ 1 Visual Similarity
- ★ 2 Data Similarity
- ★ 3 Input Connectivity

## View adjustments and device assignments

- ★ 4 Data Density
- ★ 5 Device Suitability

## Allowing adaptations by users

- ★ 6 User Preferences

# Grouping & alignment based on view relationships

## ★1 Visual Similarity promotes comparison

*If two views are **visually very similar**, they should be both **juxtaposed and aligned**.*

## ★2 Data Similarity indicates alternative representations

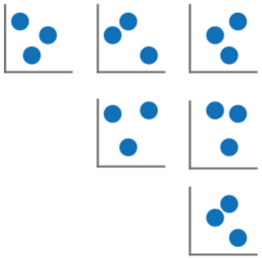
*If two views have a **high degree of data similarity** and a corresponding visual similarity, they should be **placed close to each other**.*

## ★3 Input Connectivity fosters the data exploration

*If an interface component serves as **data input for others**, it should be **placed close to the affected** components.*

Example: Small multiples

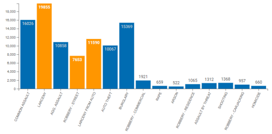
Example: Scatterplot matrix

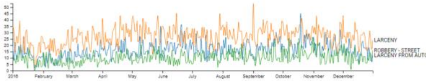


Example: Dashboard

# View adjustments and device assignments

4 **Data Density** influences the space requirement






> *A view should be **allocated space proportional** to the **number of data points** it encodes.*

5 **Device Suitability** differs for all visualizations

> *If devices are diverse, **view assignments** should be **guided by device suitability**.*

# Allowing adaptations by the user:

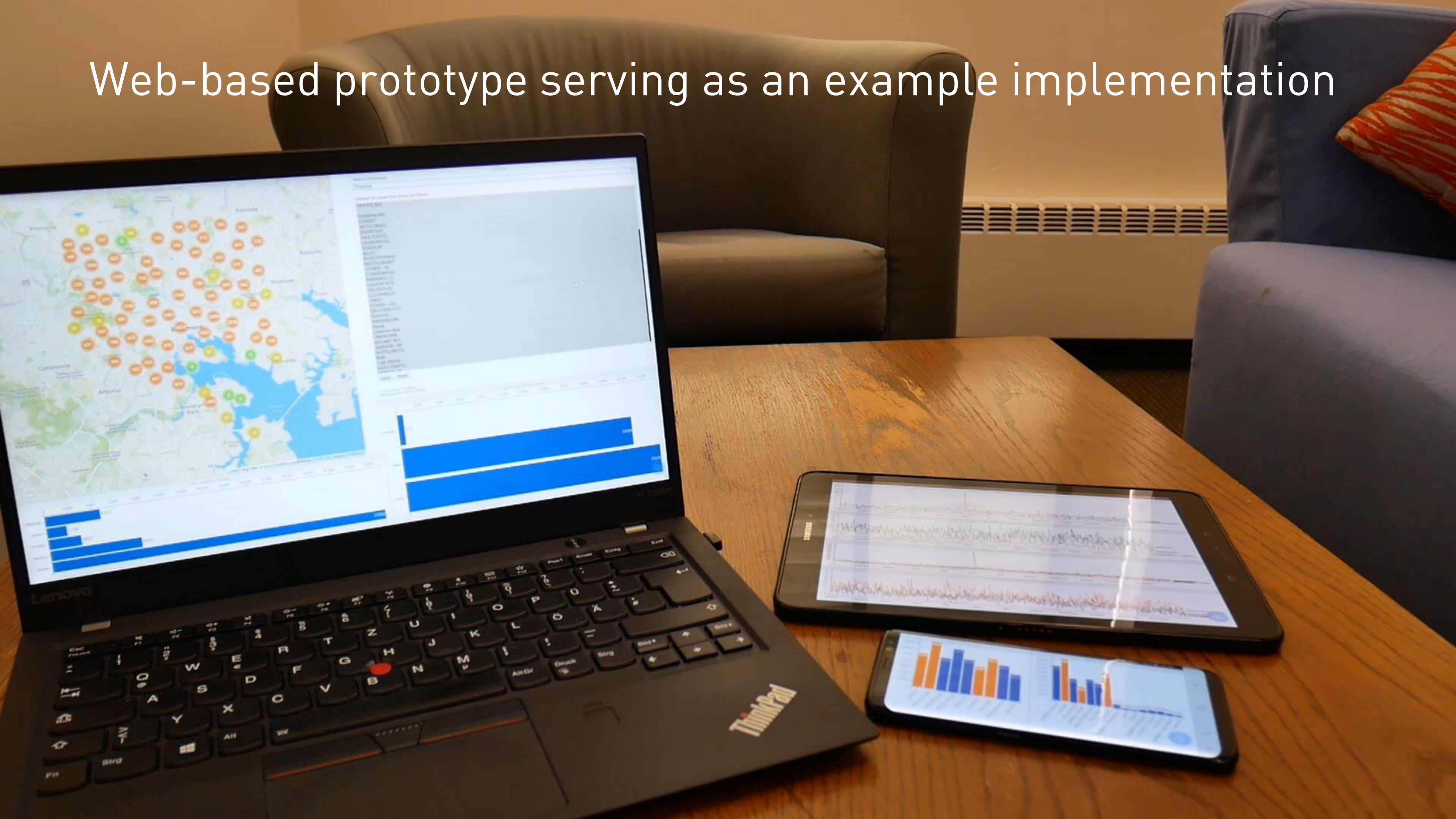
6 User preferences always exists

*If user **preferences** are applicable, they **outweigh all other heuristics**.*

Users can have **static** preference about specific distribution details

In the context of analysis tasks, **temporary** user interest can occur

# Web-based prototype serving as an example implementation



# User-created distributions versus Vistribute: a small-scale comparison study

- 6 participants (1 female, 5 male; active in the field > 3 years)
- 2 phases; approx. 60 minutes per session
- Think-aloud protocol

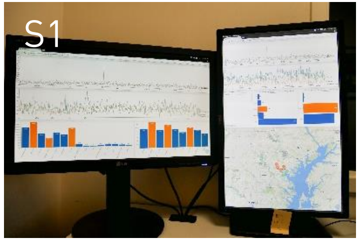
## Phase 1:

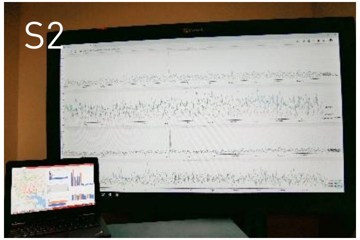
Manually distributing 10 visualizations in 3 different setups

## Phase 2:

Per setup, rating of 3 existing distributions

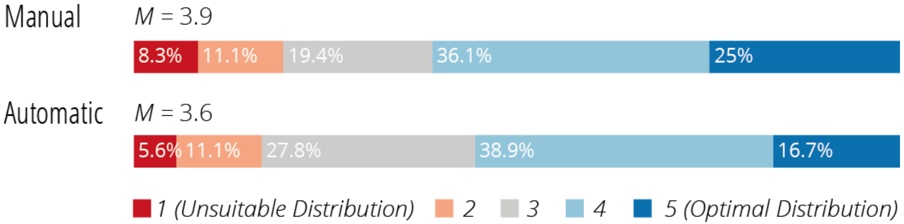
(2 created by other participants, 1 by Vistribute)

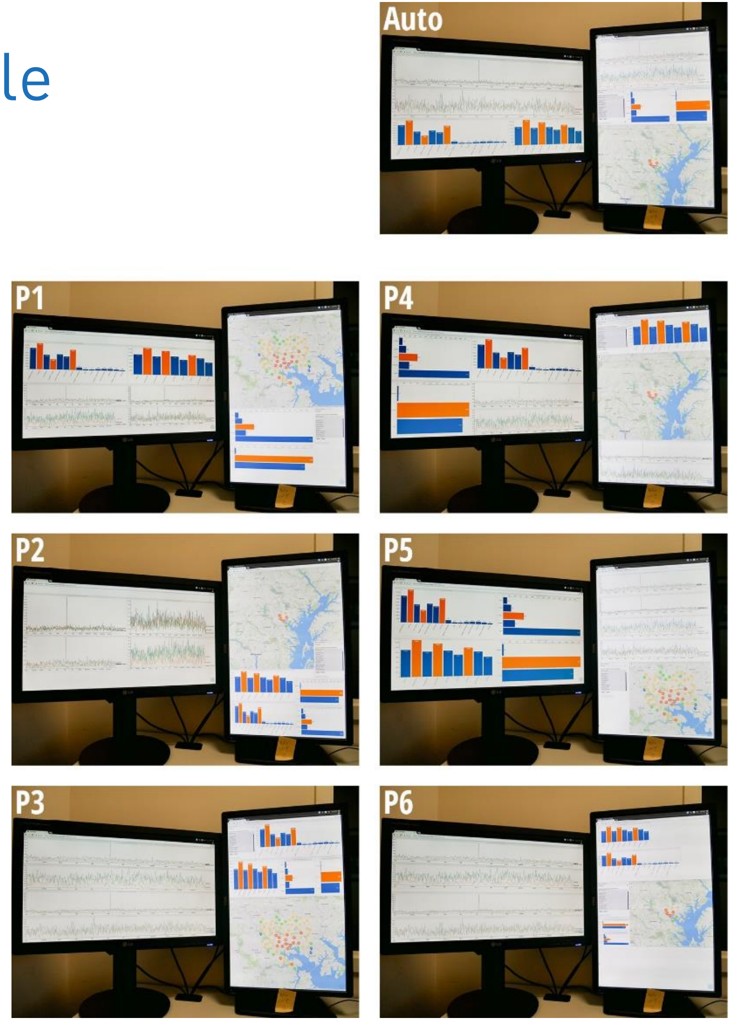



# In most cases, multiple reasonable distributions exist

- Personal preferences have a strong influence
- User considered similar aspects as our heuristics
- Manual distributions rated slightly better

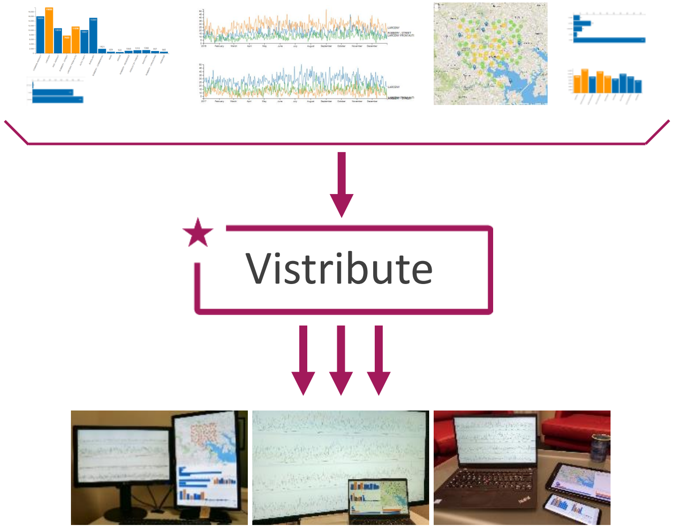


# Towards effortless multi-device environments

Manually distributing is *"exhausting"*,
*"there should be an optimization for this"*

On average, participants spent 8 minutes on one distribution



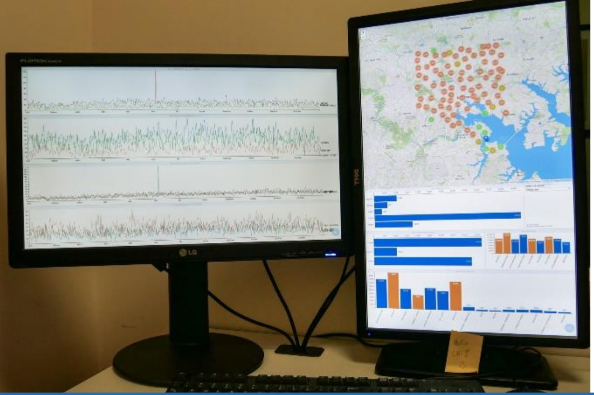

Vistribute provides reasonable distributions without requiring additional user input

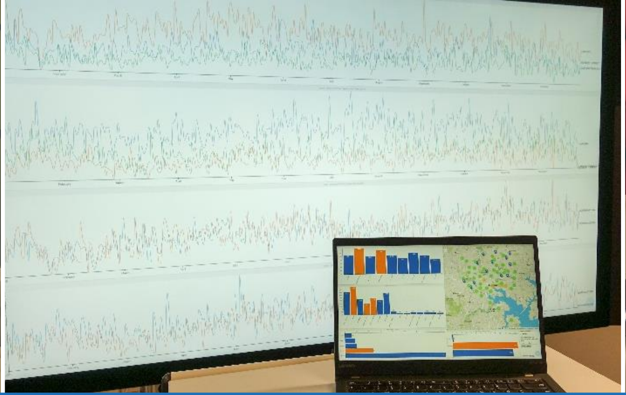
# Towards effortless multi-device environments

## Next: Investigating how analysts work in MDEs
Refinement of heuristics and investigate cross-device interactions

## From heuristics towards formalism
Incorporating AI mechanisms to further improve distributions

## From distribution towards visualization generation
Generating suitable visualization for the user’s current goals





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Tom Horak - Interactive Media Lab, Technische Universität Dresden – horakt@acm.org
Andreas Mathisen – Department of Computer Science, Aarhus University – am@cs.au.dk
Clemens N. Klokmose – Digital Design & Information Studies, Aarhus University – clemens@cavi.au.dk
Raimund Dachselt – Interactive Media Lab, Technische Universität Dresden – dachselt@acm.org
Niklas Elmqvist – College of Information Studies, University of Maryland – elm@umd.edu



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TECHNISCHE UNIVERSITÄT DRESDEN

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UNIVERSITY OF MARYLAND 1856

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