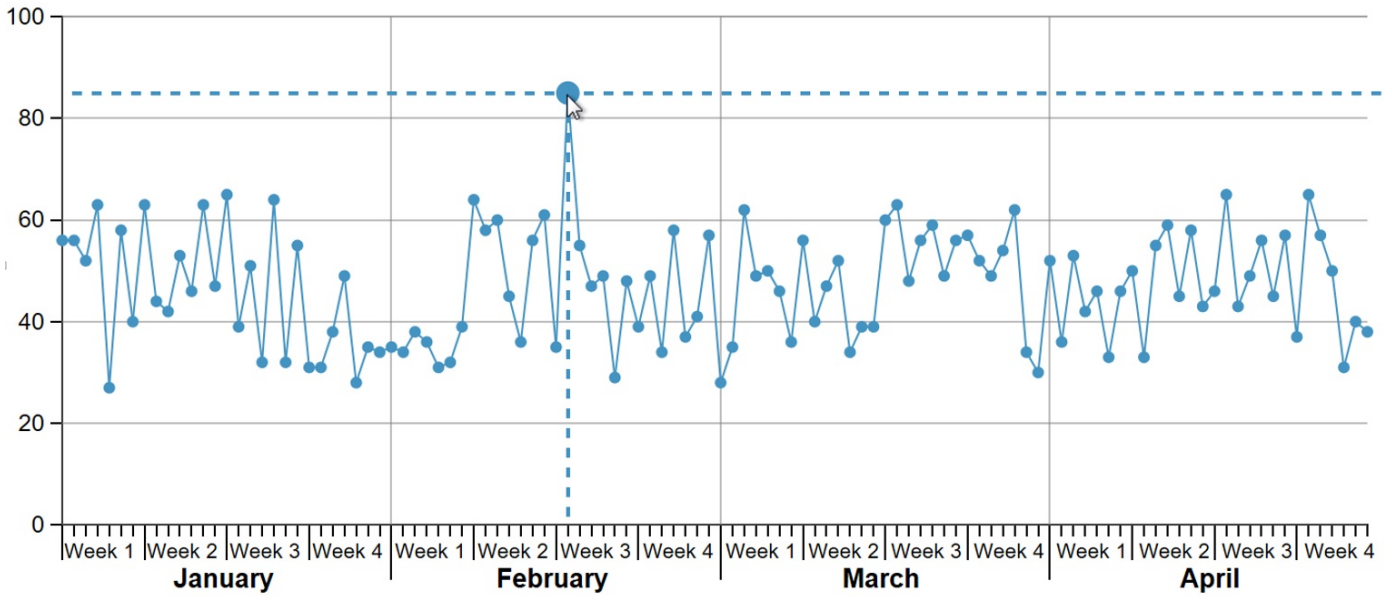
Investigating Time Series Visualisations to Improve the User Experience

Muhammad Adnan

Mike Just, Lynne Baillie

Motivation

- Time series visualisations widely used
- Example: Network security analysis
  - Time (horizontal), number of packets (vertical)



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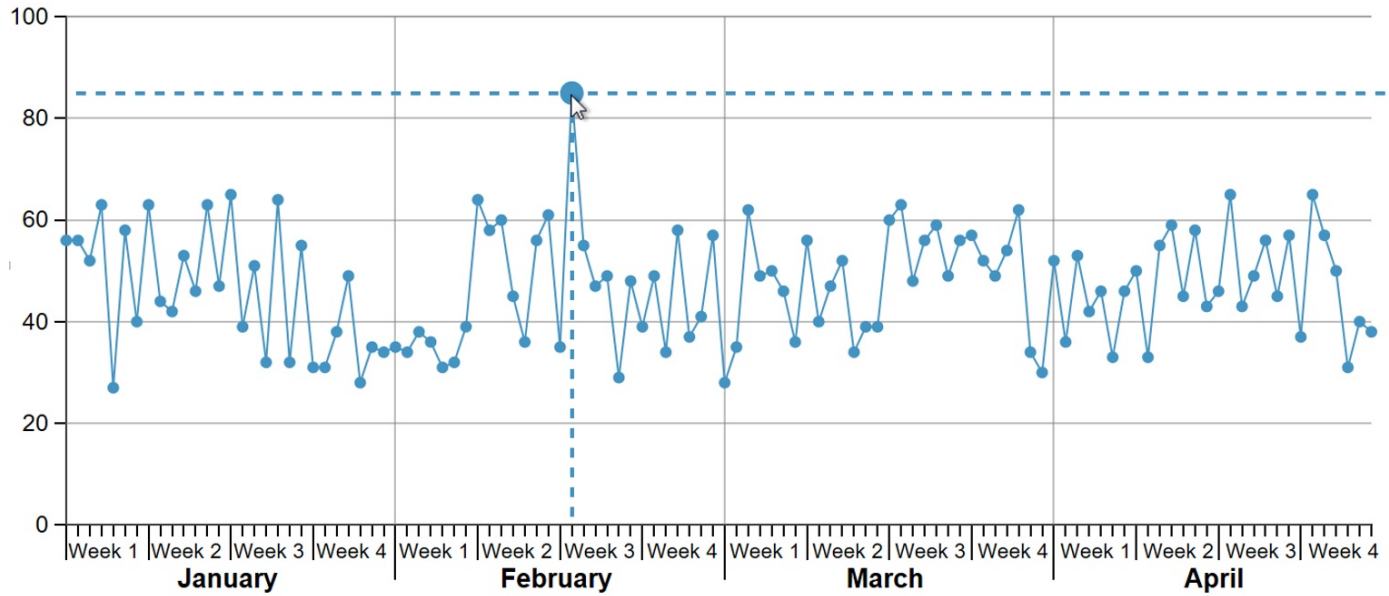

- Tasks such as maxima and comparison used to identify possible Denial of Service attacks

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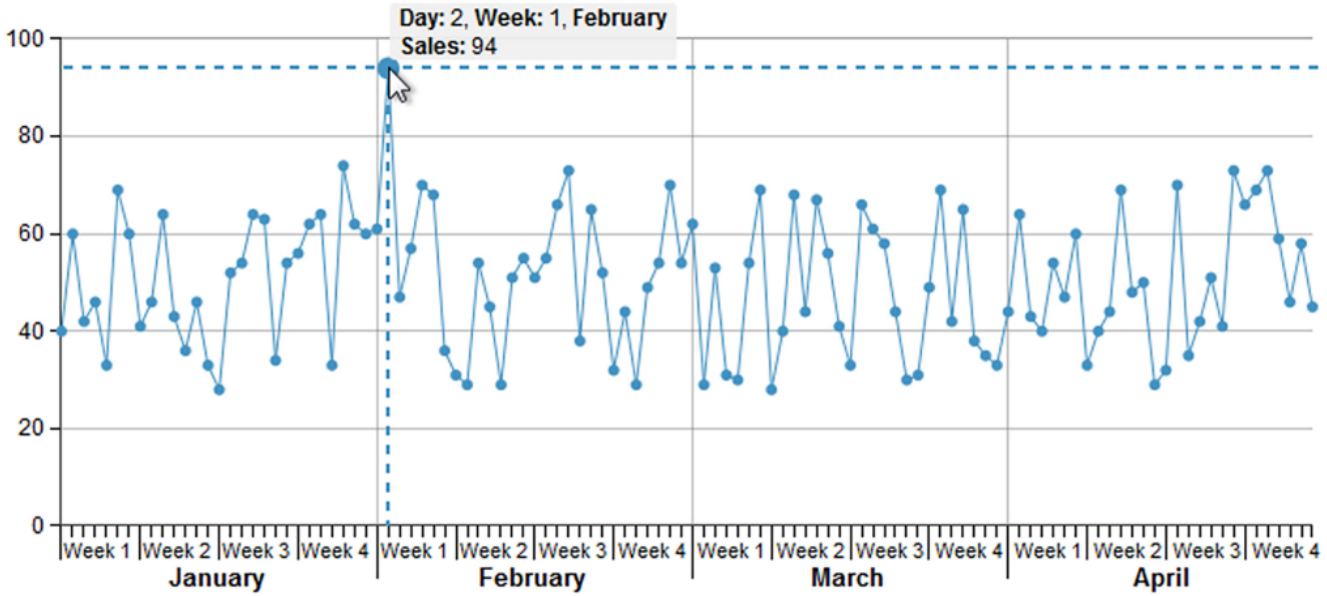
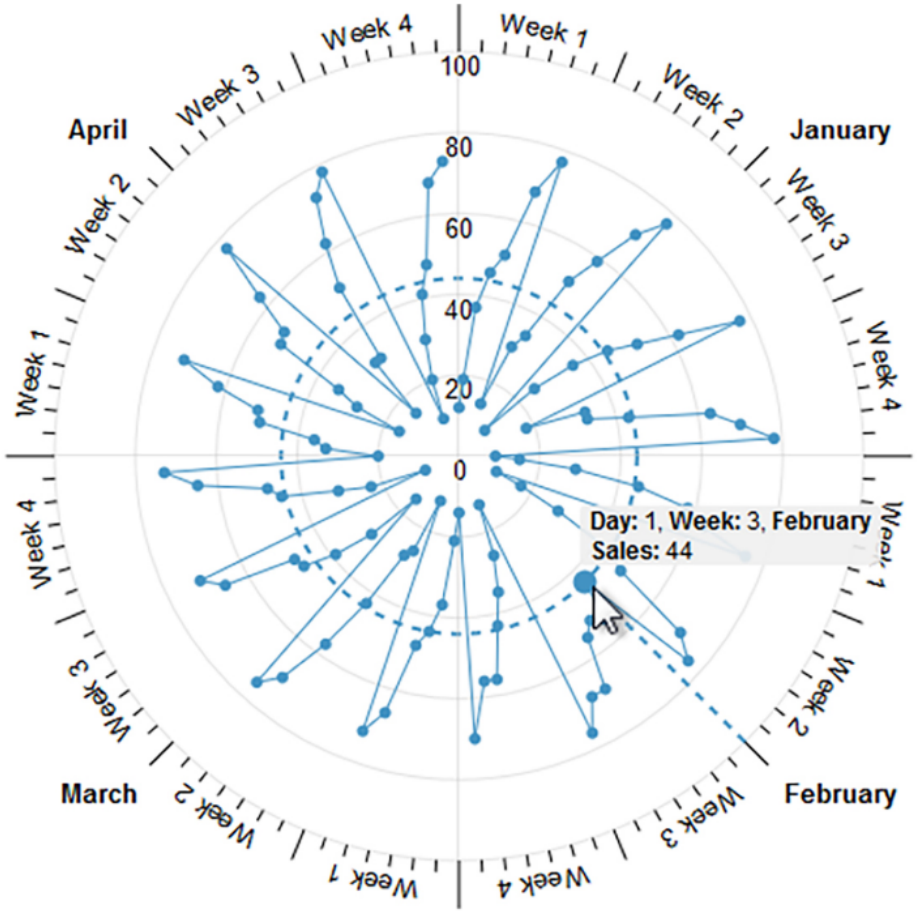


(a) Line chart

Motivation

- Several possible visual representations to use



(b) Radar chart

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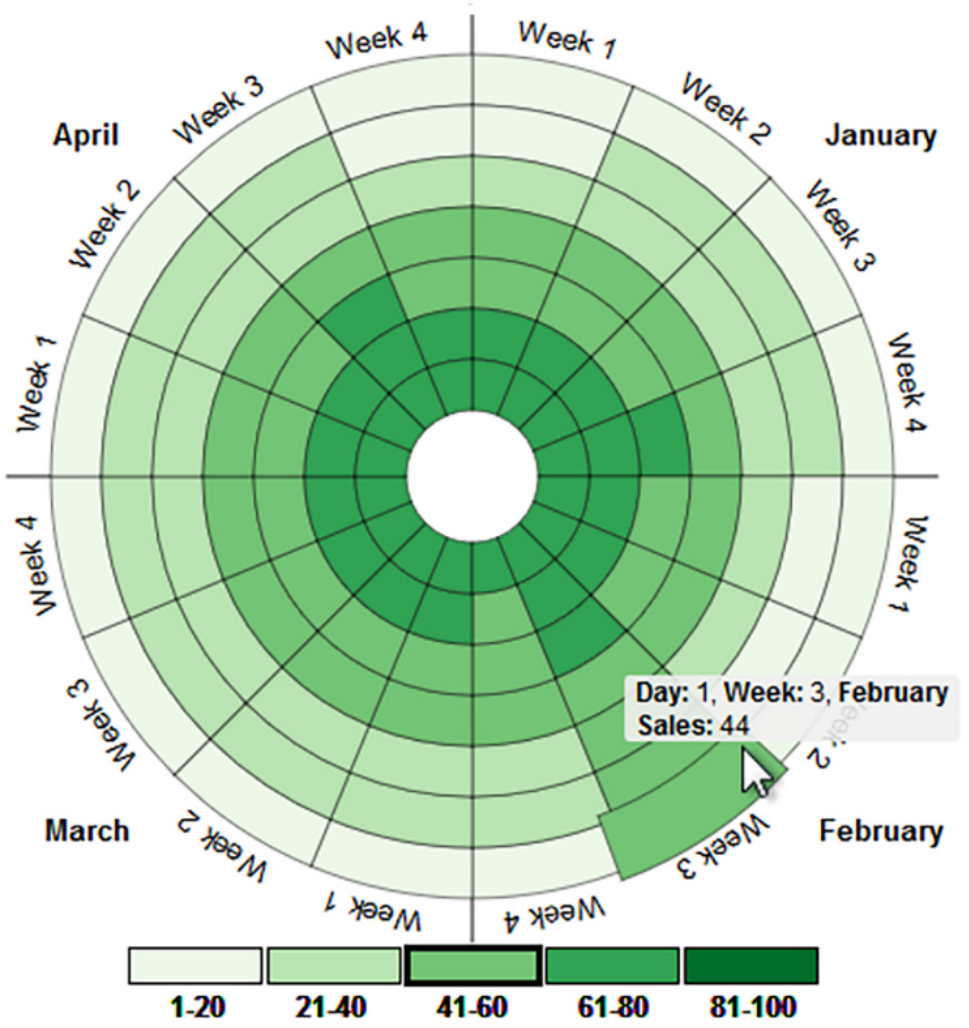

(d) Circular heatmap

Motivation

- Which visual representation to use?

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- What about user interaction?

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- Which visual representation to use?
- What about user interaction?
- Dozens of research papers since early 80s on visual representation and graphical perception
- Gaps re: some fundamental factors
  - Interaction techniques
  - Visual encodings
  - Coordinate systems

Background

Interaction techniques

Graphical perception studies commonly in **static setting**, limiting knowledge of **user experience**.

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Effectiveness within and across position and colour visual encodings, but **not area**.

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Coordinate systems

Limited empirical evidence on **Cartesian vs. Polar** coordinate systems for time series visualisations using different visual encodings.

Our Approach

- Graphical perception study

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  - 4 arrangements of two **interaction techniques**:

    No interaction Only tooltips
    Only highlighting Both highlighting & tooltips
  - 3 **visual encodings**:

    Position Colour Area
  - 2 **coordinate systems**:

    Cartesian Polar
  - 4 **study tasks**:

    Maxima Comparison
    Minima Trend detection

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  - 4 **study tasks**:

    Maxima Comparison
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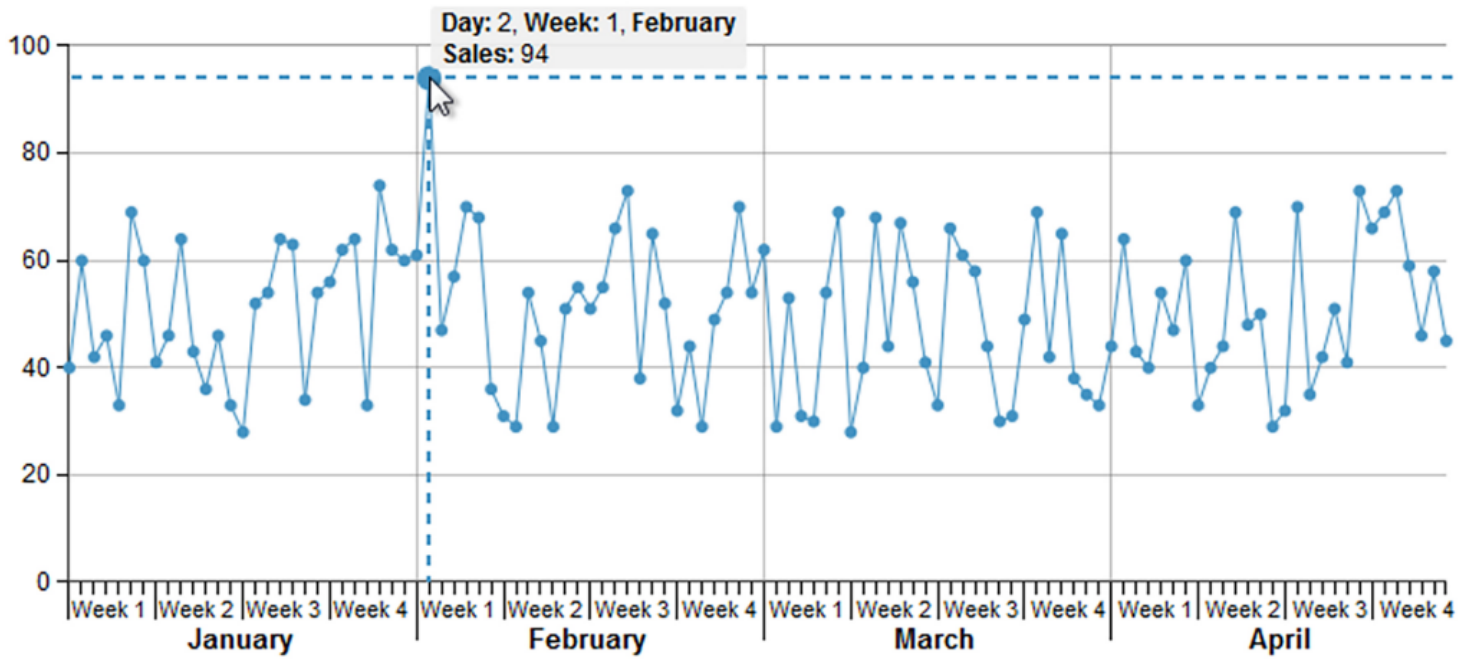
- 96 (4x3x2x4) experimental conditions

Visual Representations

- Visual encodings: Position, colour, and area
- For each, a Cartesian and polar coord. system
- Interaction techniques: highlighting & tooltips

Position encoding: Cartesian (line chart)



(a) Line chart

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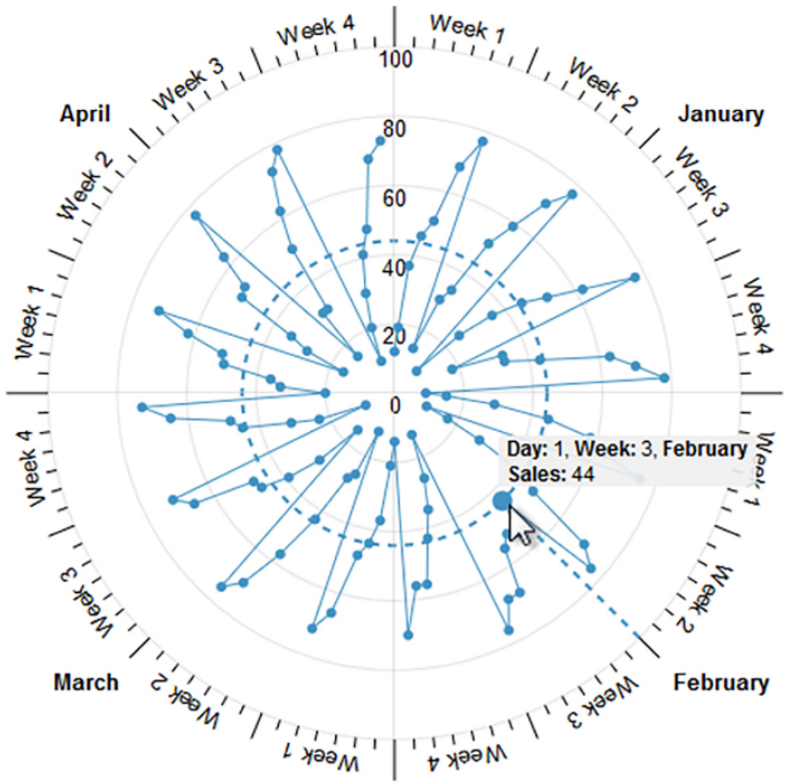
Position encoding: Polar (radar chart)



(b) Radar chart

Visual Representations

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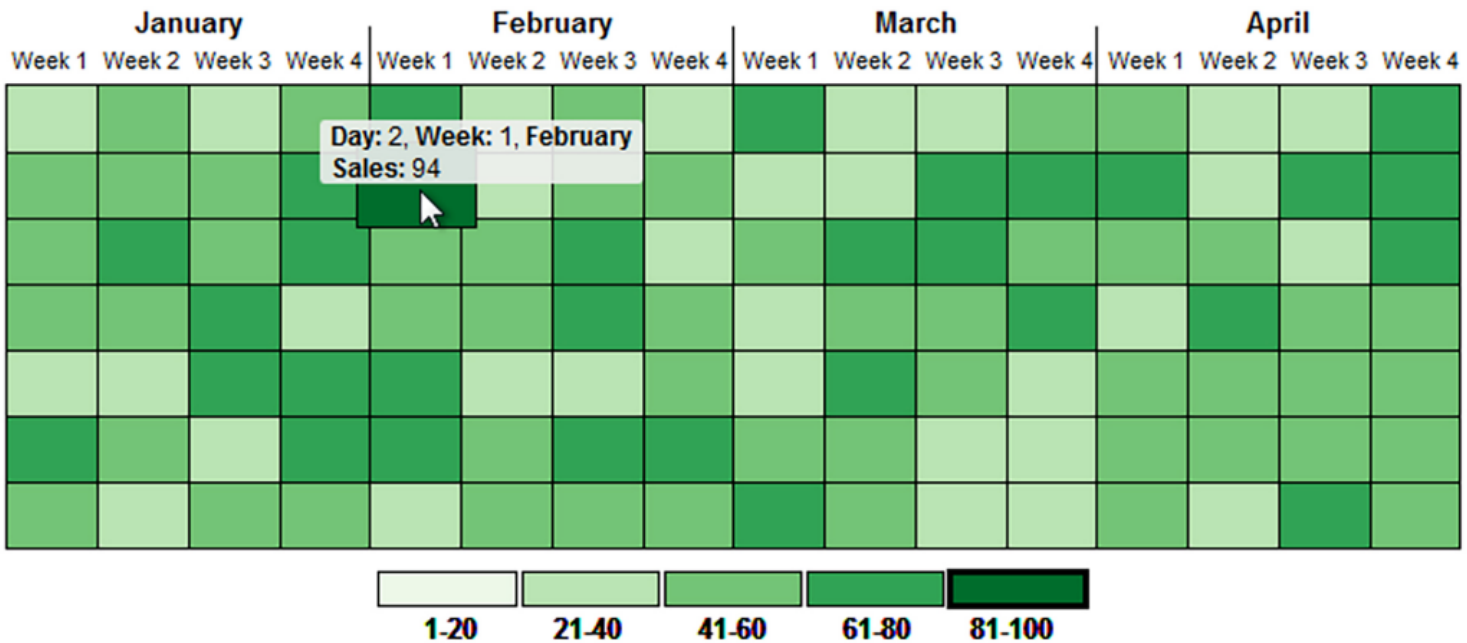
Colour encoding: Cartesian (rectangular heatmap)



(c) Rectangular heatmap

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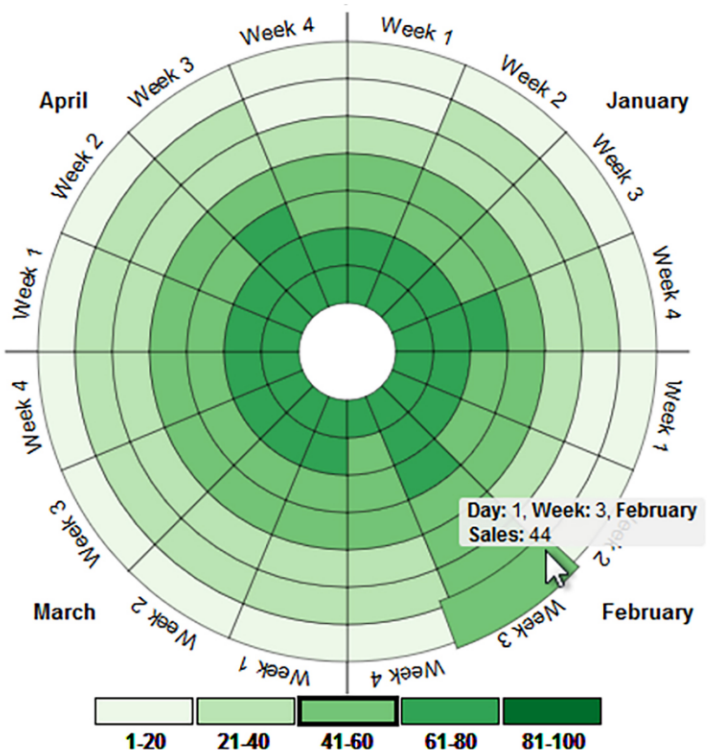
Colour encoding: Polar (circular heatmap)



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- Visual encodings: Position, colour, and area
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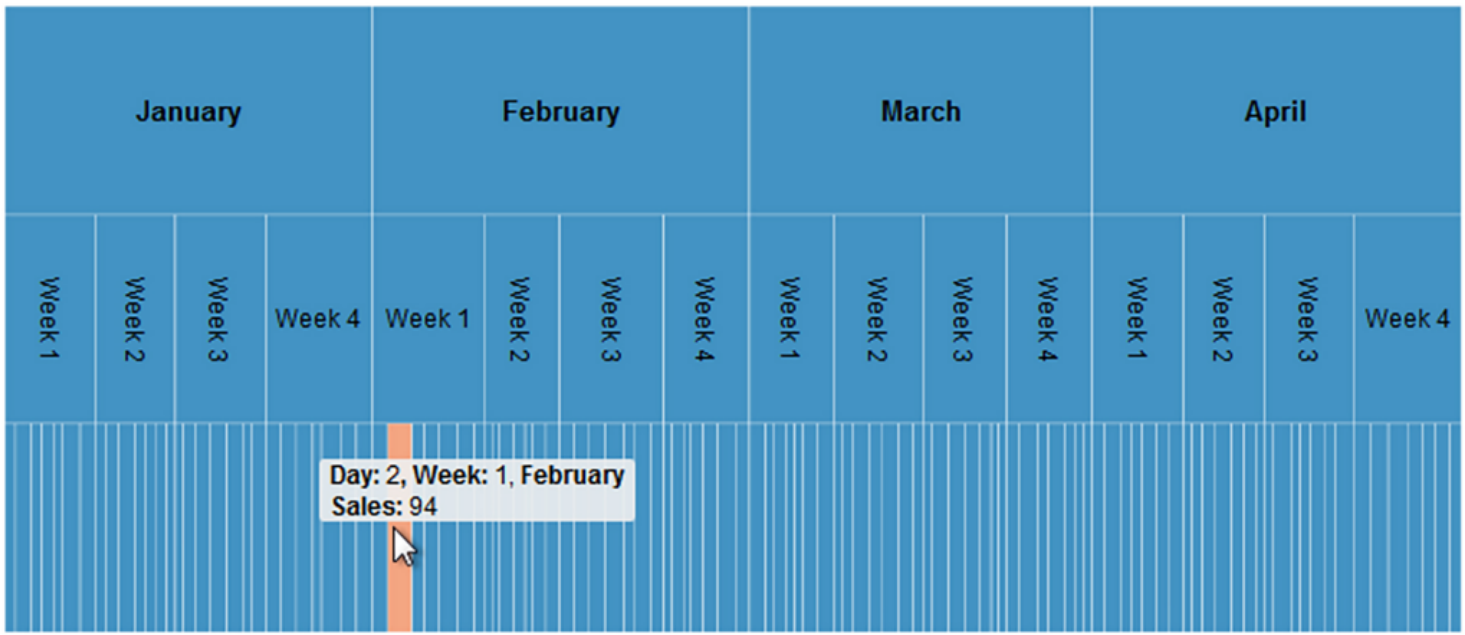
Area encoding: Cartesian (icicle plot)



(e) Icicle plot

Visual Representations

- Visual encodings: Position, colour, and area
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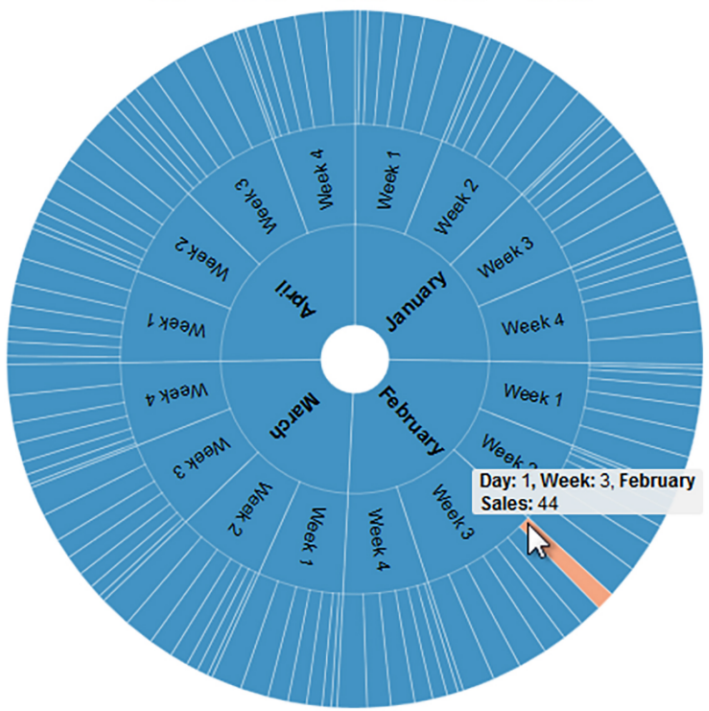
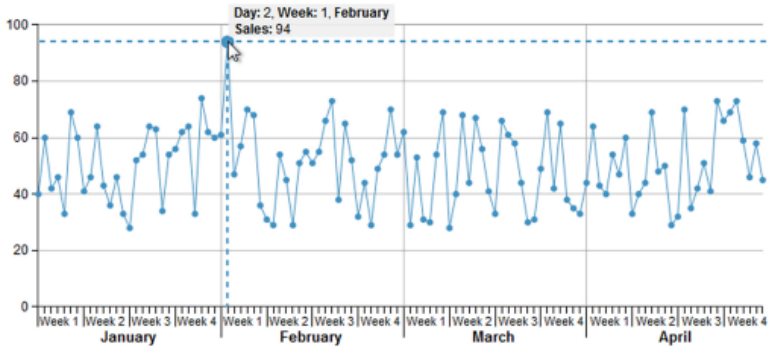
Area encoding: Polar (sunburst plot)



(f) Sunburst visualisation

Visual Representation Summary



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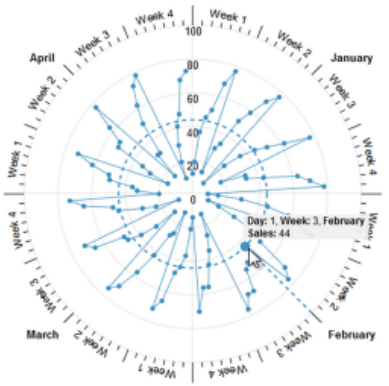

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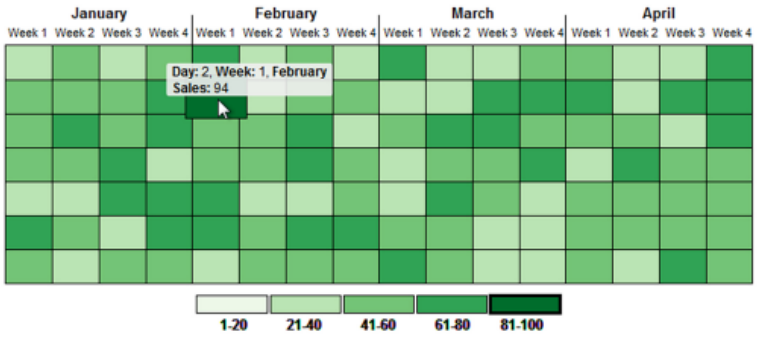

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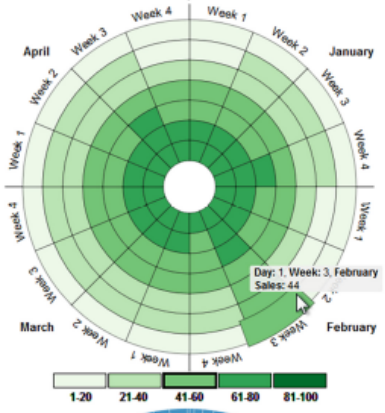

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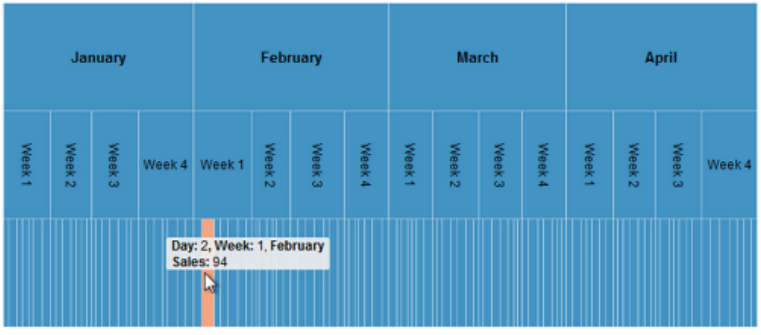

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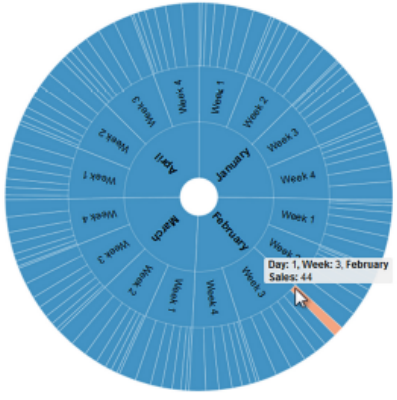

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Study Tasks

- Maxima
  - To identify the highest absolute value in a dataset
- Minima
  - To identify the lowest absolute value in a dataset
- Comparison
  - To compare two sets of data points to find out which set has the highest aggregated value
- Trend detection
  - To identify subset of data (i.e., a week) with lowest value increase (upward trend) within dataset

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Task scenario

Presented as sales data of a fictitious company

Study Design

- Study design
  - 24 study participants
    (14 male, 10 female; 18-44 years old)
  - Within-subject factorial design with 96 (4x3x2x4) experimental conditions for each participant
- Experimental conditions
  - Counterbalanced visualisations and interactions
  - Tasks ordered simple to complex
    (Javed et al., 2010)
- Data for visual representations
  - 96 distinct, synthetic time series datasets (one for each condition) following Fuchs et al. (2013)
  - Each dataset had 112 data points (1 per day) over 16 week period

Study Procedure

Stage	**Description**
Introduction	Greetings, consent, demographic questionnaire, study explanation
Maxima	Task training, 24 conditions
Minima	Task training, 24 conditions
Comparison	Task training, 24 conditions
Trend detect.	Task training, 24 conditions

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24 experimental conditions for each task
(3 visual encodings x 2 coord. systems x 4 interact.)

Study data collected

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- Completion of an experimental condition (sec)
- Accuracy of the given answer (binary)
- Confidence of the given answer (5-point Likert)
- Ease of use of a visualisation (5-point Likert)

Final two collected via questionnaire per condition

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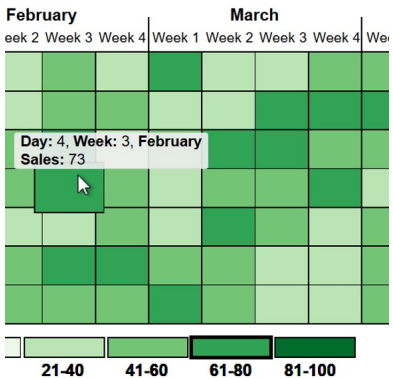

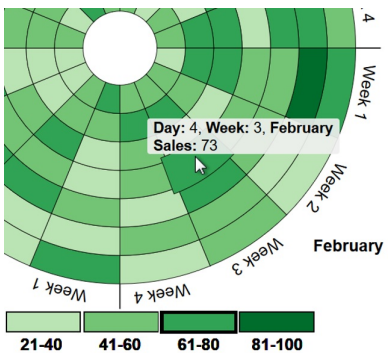

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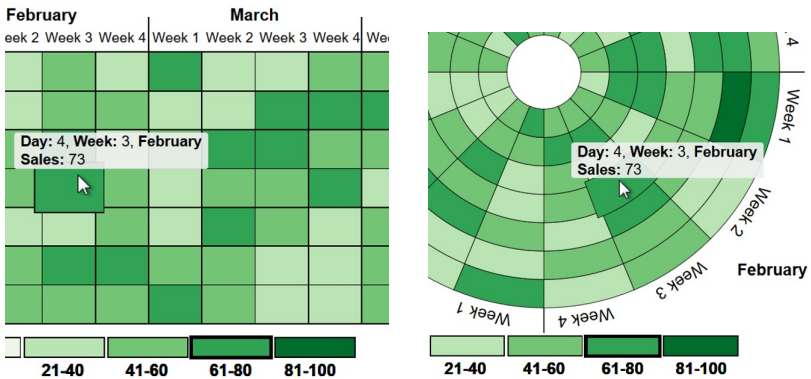

- Textual (tooltips) better than highlighting

Results: Visual Encodings

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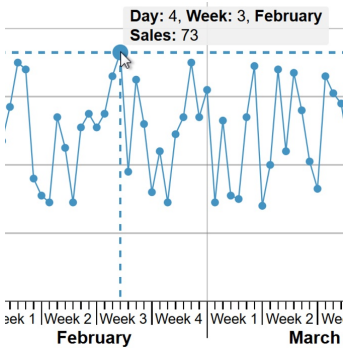
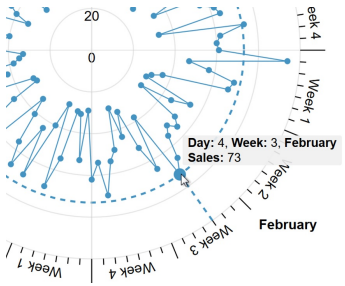
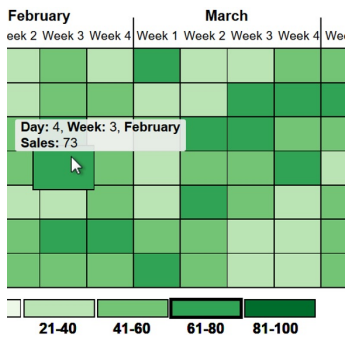
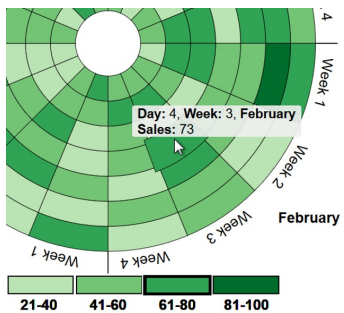
- Position & colour better: max, min, trend det.
  - Colour more accurate for minima









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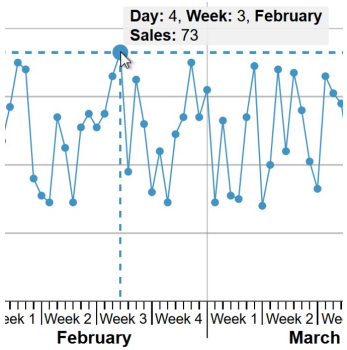
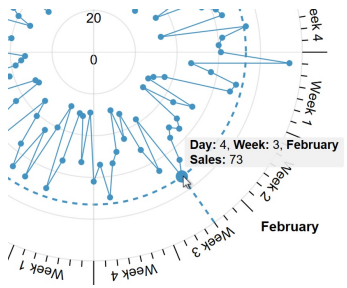
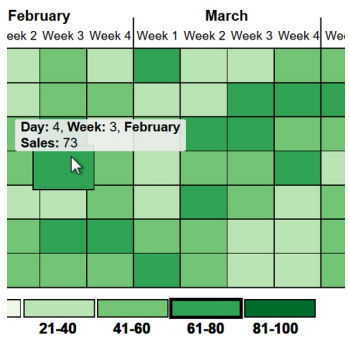
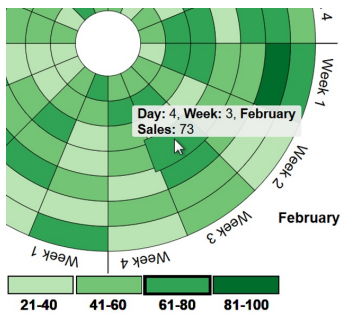
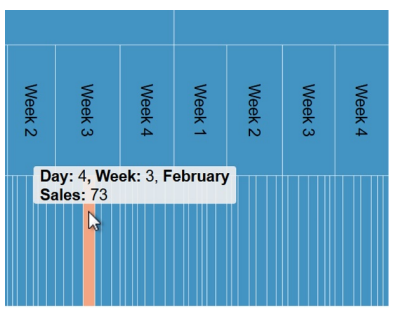


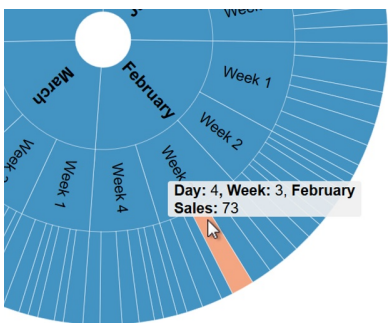






- Area more effective for comparison task





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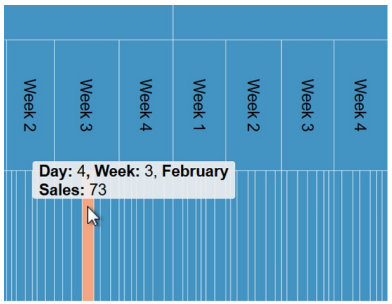

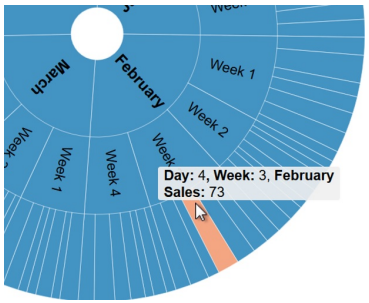

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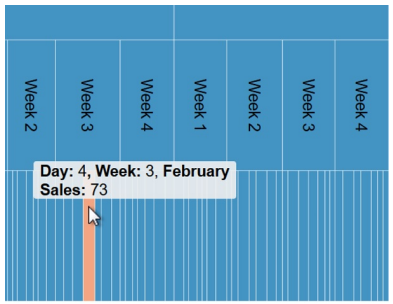
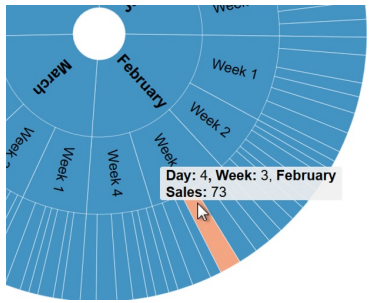
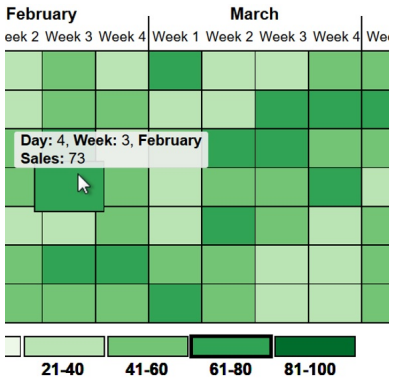
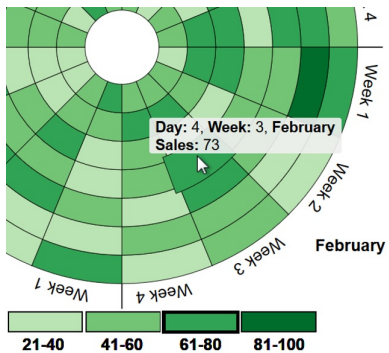




- Neglible effect of coordinate system for colour





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  - Improved confidence and ease of use, without a significant decrease in completion time or accuracy.
- No "one-size-fits-all"
  - The choice of a visual representation should be based on the type of tasks
- Generally, Cartesian is better
  - Cartesian coordinate systems are generally comparable or more effective than Polar, except for visualisations that use area for minima.

Looking Ahead

- Increased study of interactivity for time series visualisations
- Evidence of tradeoffs for different visual representations and tasks

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- Future work
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- Results applicable to domains that use time series visualisations
  - Currently studying visualisations for network security analysis

Contact

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PhD position in Usable Mobile Security

Where?	Heriot-Watt University, Edinburgh, UK Some travel to Microsoft Research, India
Supervisors	Lynne Baillie (Heriot-Watt University) Jacki O'Neil (Microsoft Research India) Mike Just (Heriot-Watt University)
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