Don't Peek at My Chart: Privacy-preserving Visualization for Mobile Devices

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• Mobile data visualization is normally visible at both close and far viewing distances

• We propose a privacy-preserving mobile data visualization that is visible at a close distance but invisible at a far distance
Close Viewing Distance

Far Viewing Distance

Line chart
Background
Mobile Data Visualization
Shoulder-Surfing Attacks

It happens everywhere!
Challenges

• The **easy-to-view nature** of mobile data visualization is a double-edged sword; it's handy but also makes it **easy for others to peek**

• The **privacy-preserving** mobile data visualization must balance **readability and privacy protection**
The Goal of Mobile Vis Privacy Protection

How can we maintain visualization visibility for users at proximity while effectively concealing it from peekers at a distance?
Our Approach

Users can see the visualization
Peekers hardly see the visualization
Our Approach

Original

Viewing Distance
We propose a masking scheme to generate a privacy-preserving visualization.
Our method is inspired by the human vision system characteristics.
Coarse-grained level – Spatial Frequency

Spatial frequency relates to the frequency of color changes that humans perceive.
Coarse-grained level – Spatial Frequency

Spatial frequency relates to the frequency of color changes that humans perceive.
When viewing distance increases, the spatial frequency that humans perceive also increases.
Luminance contrast refers to the difference in brightness between the two colors.
The human vision system is affected by the coupling effect of both spatial frequency and luminance contrast.
The human vision system is affected by the coupling effect of both spatial frequency and luminance contrast.
Fine-grained level

![Points, Lines, Areas](image)

**Figure** Marks are geometric primitives.

Source: Visualization Analysis & Design [3]: Chapter 5 by Tamara Munzner

We utilized different schemes to process line-based marks and area-based marks!

Source: Visualization Analysis & Design [3]: Chapter 5 by Tamara Munzner
Masking Scheme for Area-based Marks

Area-based mask + Area-based marks = High-spatial frequency mark

Spatial domain

Frequency domain
Masking Scheme for Line-based Marks

(a) Area-based Mask

(b) Line-based Mask

(c) Stock Tendency

(d) Stock Tendency
Masking Scheme for Line-based Marks

(a) Area-based Mask

(b) Line-based Mask

(c) Stock Tendency

(d) Stock Tendency
Masking Scheme for Line-based Marks

(a1) Area-based Mask

(a2) Line-based Mask

(b) Stock Tendency

(c) Stock Tendency

(d) Stock Tendency
Masking Scheme for Line-based Marks

- We also apply the line-based mask on visualization axis and text because they are made of lines by nature
We change the luminance values of marks in the LAB color space.
Evaluation
Evaluation – Preliminary Study

• Human perception of visual indicators is affected by two elements: luminance contrast and spatial frequency

• To attain optimal privacy protection, we must identify the best combination of these two factors
Evaluation – Preliminary Study

We designed a 5-scale rating to evaluate participants’ effort and time needed to see the visualization processed by our method.

1: I cannot recognize any visual marks from the visualization.
2: I can identify a few visual marks from the visualization.
3: I can identify a large portion of the marks from the visualization.
4: I need some time and effort to identify all visualization marks from the visualizations.
5: I can easily recognize all the visual marks at a glance.
• Four popular visualization types\cite{3}: bar, pie, scatter, and line

Evaluation – User Study

• According to the preliminary study result, we selected the best combination of two factors and further conducted a user study.

• We recruited 18 participants to systematically assess the effectiveness of the method.
Evaluation – User Study

Baseline methods:

- **Original Visualization**: the original visualization is not processed by our approach.
- **Coarse-grained Visualization**: the visualization is processed by only the coarse-grained masking scheme in our method.

Our method:

- The visualization is processed by both the coarse-grained and fine-grained masking scheme.
We conducted a within-subject study where the participants viewed the test visualization at three different distances: 30cm, 60 cm and 90 cm.
Evaluation – User Study

• Visualization is composed of text, axes and visual marks\(^5\).

• Therefore, there are two tasks for rating: visual mark visibility rating and text readability rating.

• We utilize the same rating criteria the same as the preliminary study.

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Our method can achieve **good privacy protection** at a far distance.
Our fine-grained method can achieve better visibility at a close distance.
Evaluation – User Study

Our fine-grained method can achieve better privacy protection at a farther distance.
Take-away Message & QA

- Our method enables humans to see visualization at a close distance but hardly see it at a far distance.

- To this end, we utilize both the human vision system and visualization properties.

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