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Hilby
Hilbert Interactive Prefix Plots

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Motivation: Understanding data linked to IP addresses or prefixes, e.g., …

Address allocations

What address space does an AS announce?

Security

How many IDS events do my managed machines get?

Resiliency

How many domains resolve to each IP address?

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Address allocations

What address space does an AS announce?

We will use this example in the remainder of this talk.

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How many IDS events do my managed machines get?

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Example: What address space does AS16509 announce?

First step, we get the data we are interested in from RIPE RIS.

Then, visualize the data in an intuitive and easy to consume way. How?

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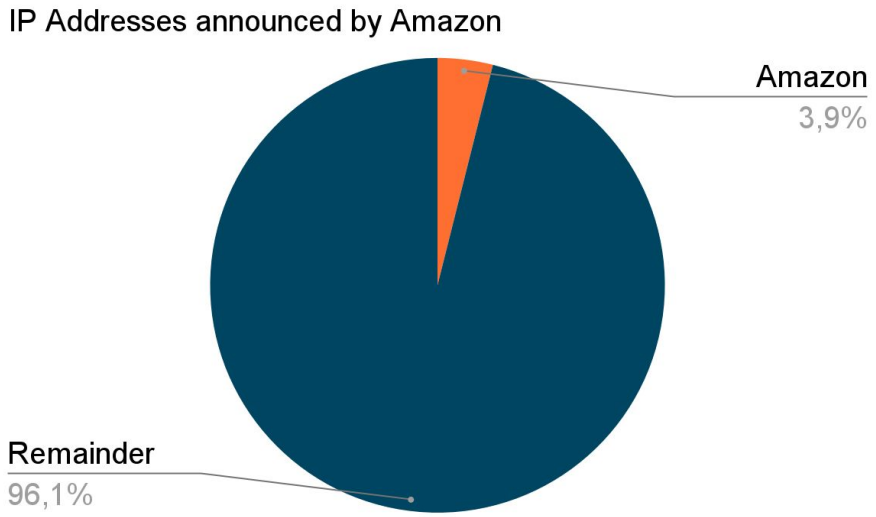
Then, visualize the data in an intuitive and easy to consume way. How?

Subnet	Announced space
3.0.0.0/8	100%
18.0.0.0/8	79.4%
54.0.0.0/8	64.4%
…	…

Option 1



Option 2

Example: What address space does AS16509 announce?

First step, we get the data we are … Then, visualize the data in an intuitive …

In cases like this most traditional data representations either:

Do not provide a good overview of the data,
or generalize the data too much to draw conclusions.

Displaying the IP address space as a “map” can convey details while still allowing for an intuitive overview.

…	…

Option 1

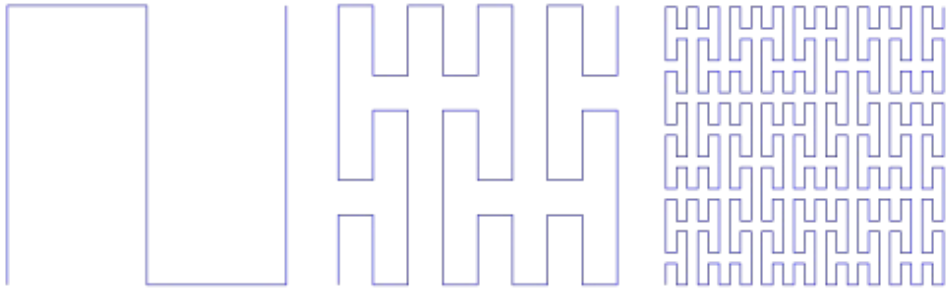
Option 2

Starting point: We want an image of the IP address space

The Problem: There is no natural way of "drawing a picture" of the one-dimensional IP address space.

Space-filling curves help to plot 1D data into a two dimensional space, by defining a formula for mapping each value to a coordinate.

Their iteration count controls the amount of 1D data points plotted into 2D.



First three iterations of the Peano curve construction, the first discovered space-filling curve.

Locality preservation is important for IP address data

For the resulting mapping to make sense, we require a second property: **preserving locality**

In case of the IP address space, preserving locality means **neighboring subnets will also be neighbors** in the resulting image.

This should also be true for each netmask value at the same time.

Locality preservation is important for IP address data

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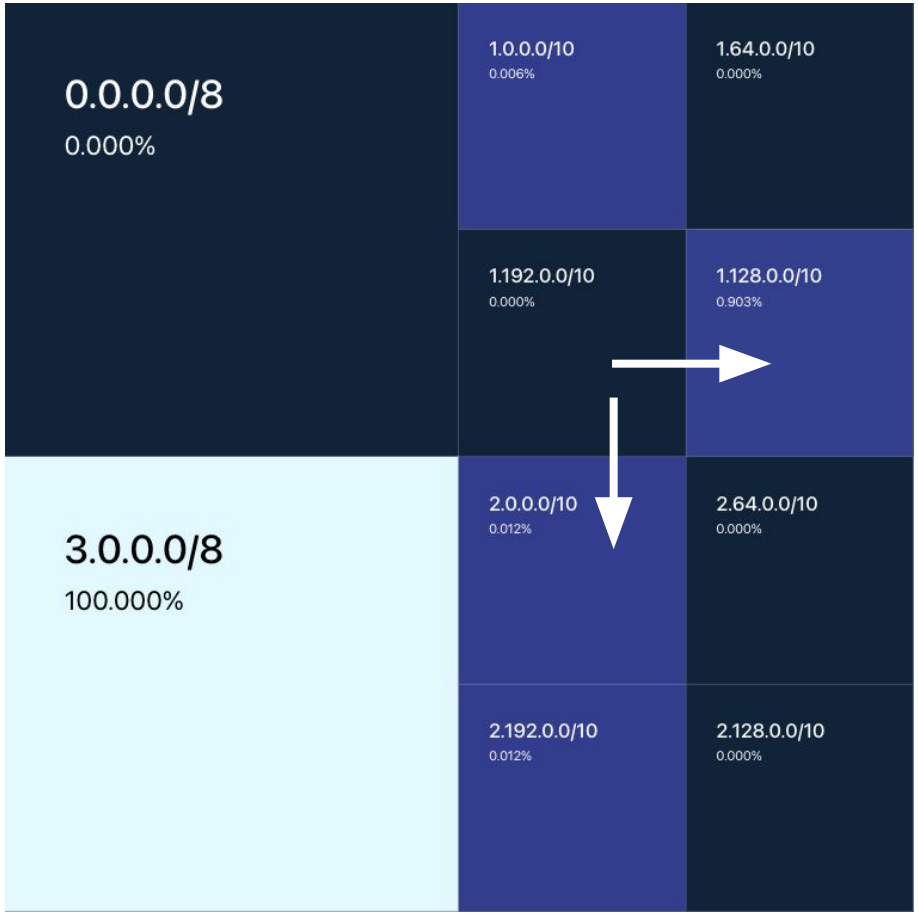
In case of the IP address space, preserving locality means **neighboring subnets will also be neighbors** in the resulting image.

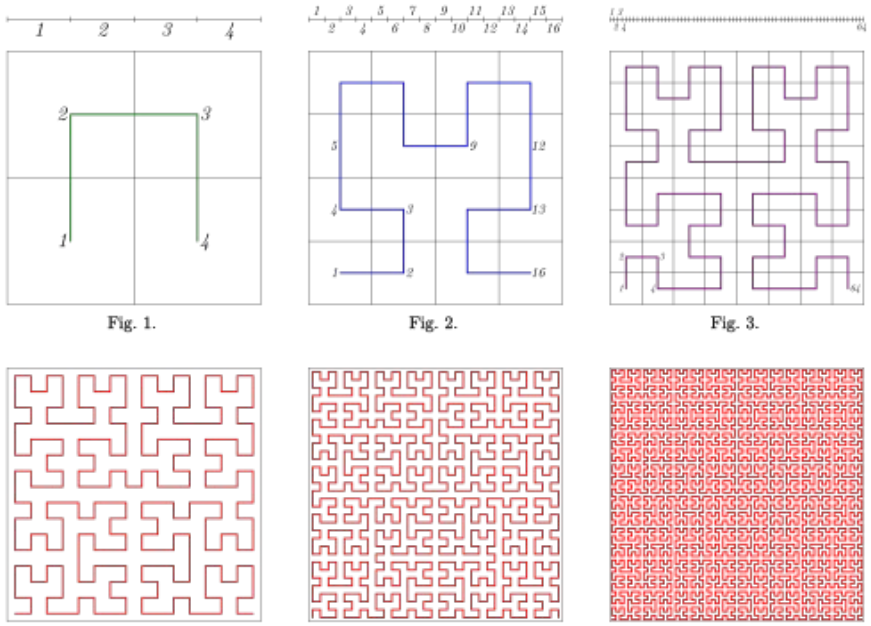
This should also be true for each netmask value at the same time. **Even across boundaries of less specific prefixes.**



Hilbert curves maintain the locality of the data.

Some curves, like the Hilbert curve, maintain the locality of the original data well.

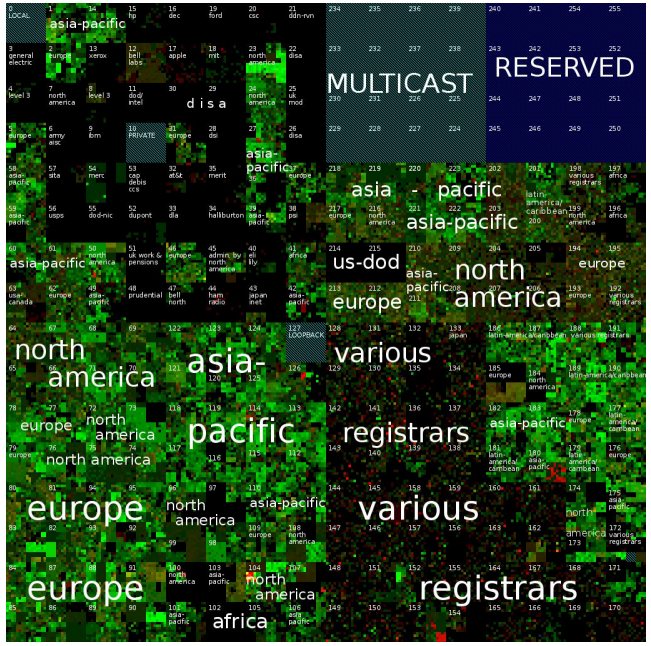
This makes them perfect for visualizing address space wide data.



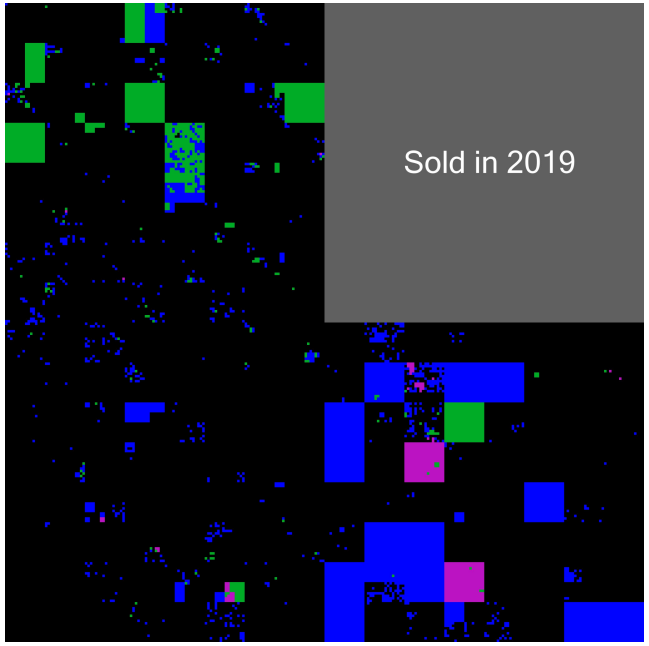
The first six iterations of the Hilbert Curve.

Hilbert curves to visualize IP address space

The original xkcd #195 shows the original allocations of the classful routing blocks.

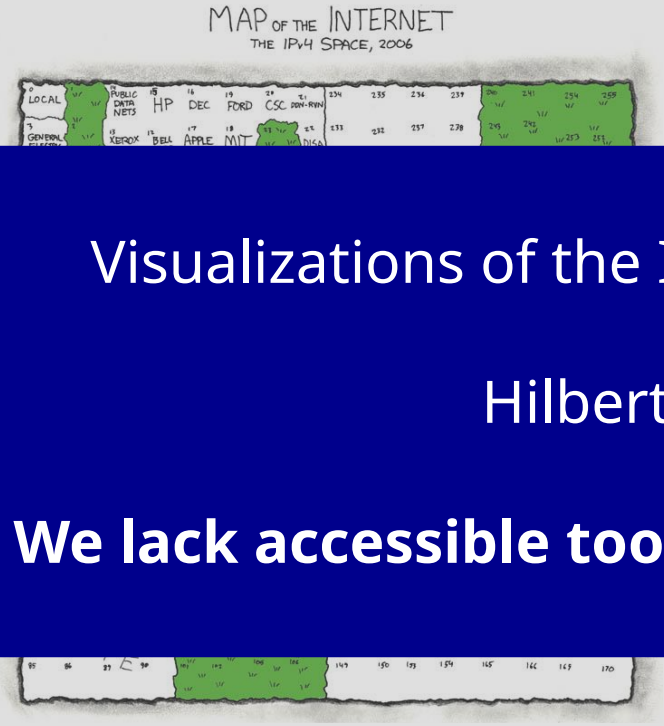


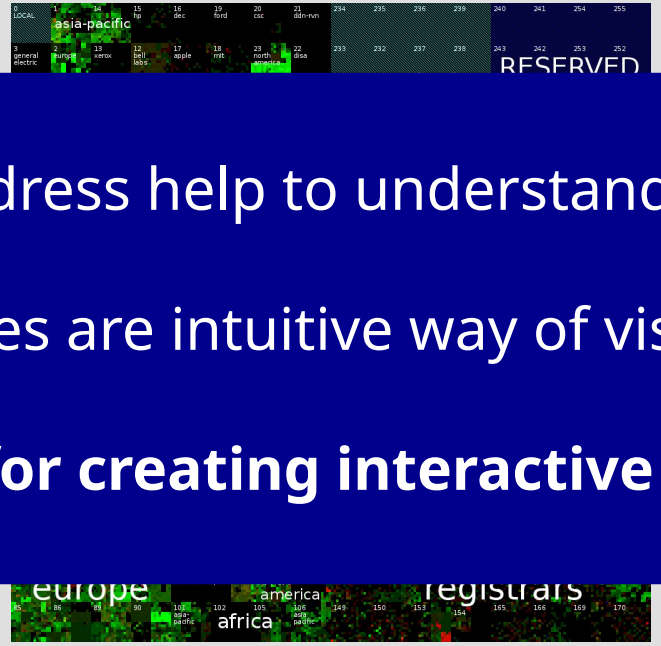
The ANT ISI internet census publishes images and an interactive viewer to explore responsive IP addresses.

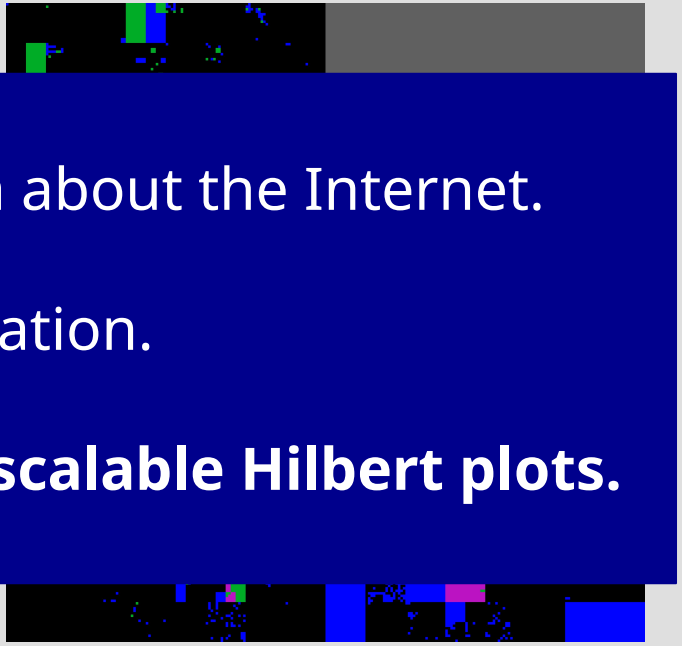


We visualized the capturing areas of the UCSD Network Telescope with the help of a hilbert curve.

Hilbert curves to visualize IP address space







Visualizations of the IP address help to understand data about the Internet.

Hilbert curves are intuitive way of visualization.

We lack accessible tooling for creating interactive and scalable Hilbert plots.

The original xkcd #195 shows the original allocations of the classful routing blocks.

The ANT ISI internet census publishes images and an interactive viewer for their collected data.

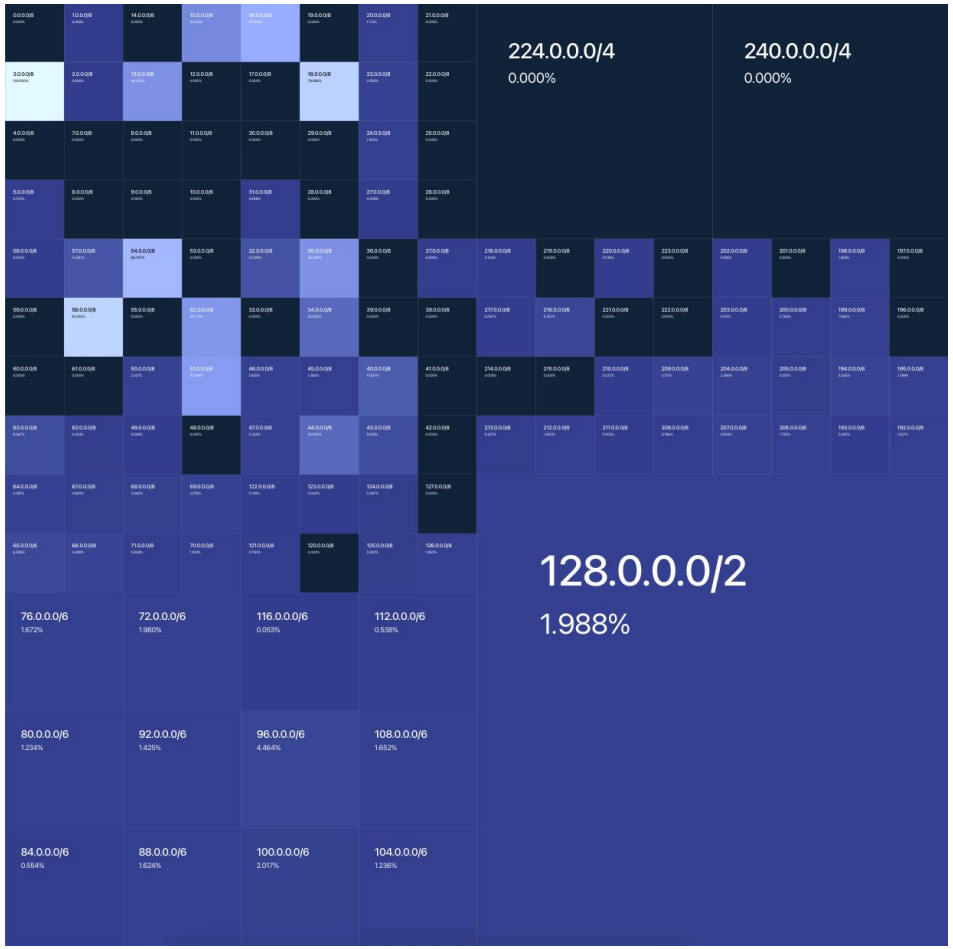
We visualized the capturing areas of the UCSD Network Telescope with the help of a hilbert curve.

Introducing: Hilby - Interactive prefix plots

Hilby is a React framework that abstracts away the complexity of setting up the Hilbert curve and any UI controls.

Key features of Hilby:

- Zooming and dragging controls
- Interactive expanding of subnets
- full CSS and content control over each subnet
- IPv6 capable
- on demand data fetching



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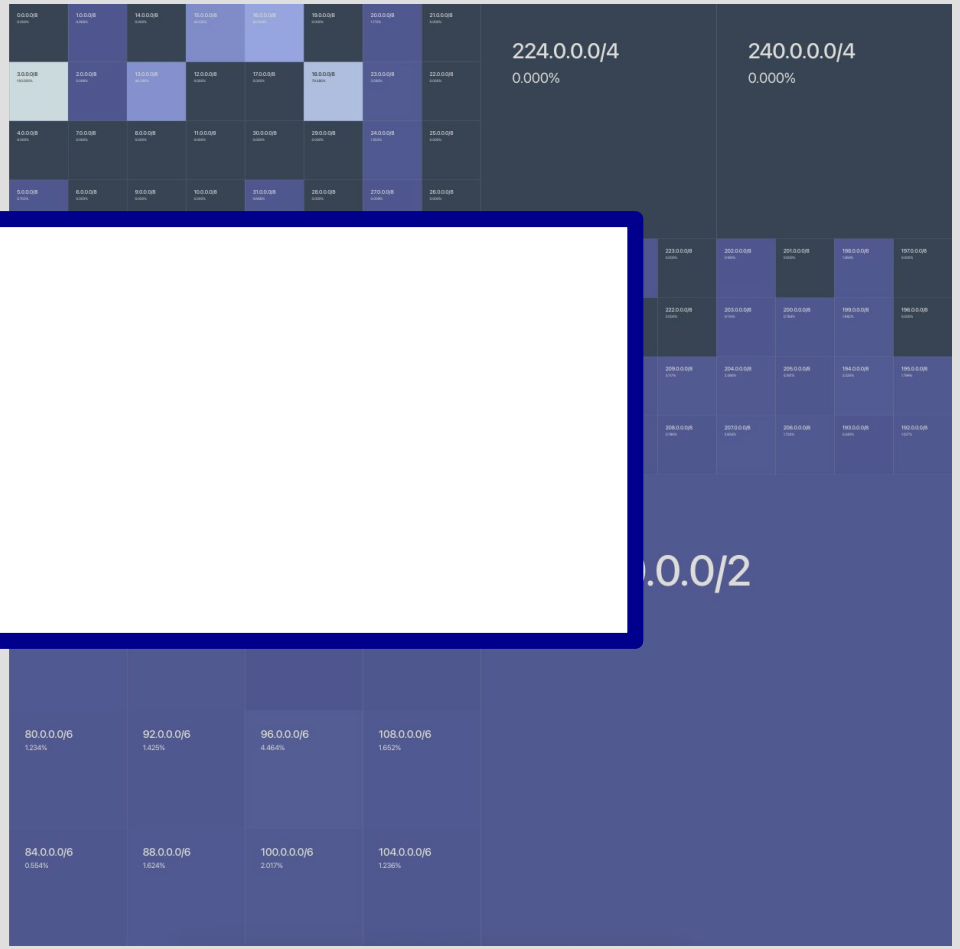
Demo time!

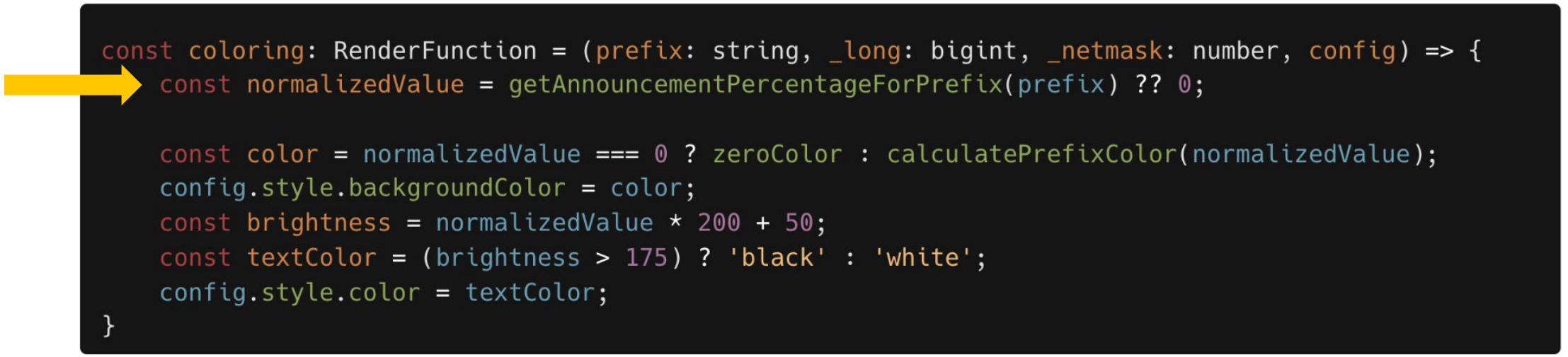
Follow along at
https://hilby.netd.cs.tu-dresden.de



Setting up Hilby for your data

You want to integrate Hilbert Curve into your website? Follow these steps!

1. Get your data and store it in a fast accessible way.
2. Implement a callback function that tells Hilby how to style a prefix when its rendered.



```
const coloring: RenderFunction = (prefix: string, _long: bigint, _netmask: number, config) => {
    const normalizedValue = getAnnouncementPercentageForPrefix(prefix) ?? 0;

    const color = normalizedValue === 0 ? zeroColor : calculatePrefixColor(normalizedValue);
    config.style.backgroundColor = color;
    const brightness = normalizedValue * 200 + 50;
    const textColor = (brightness > 175) ? 'black' : 'white';
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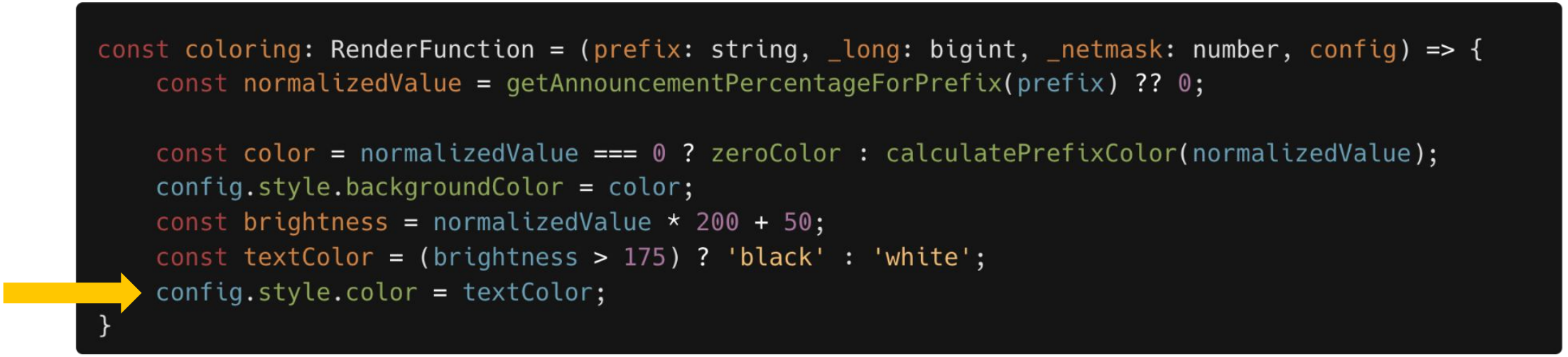

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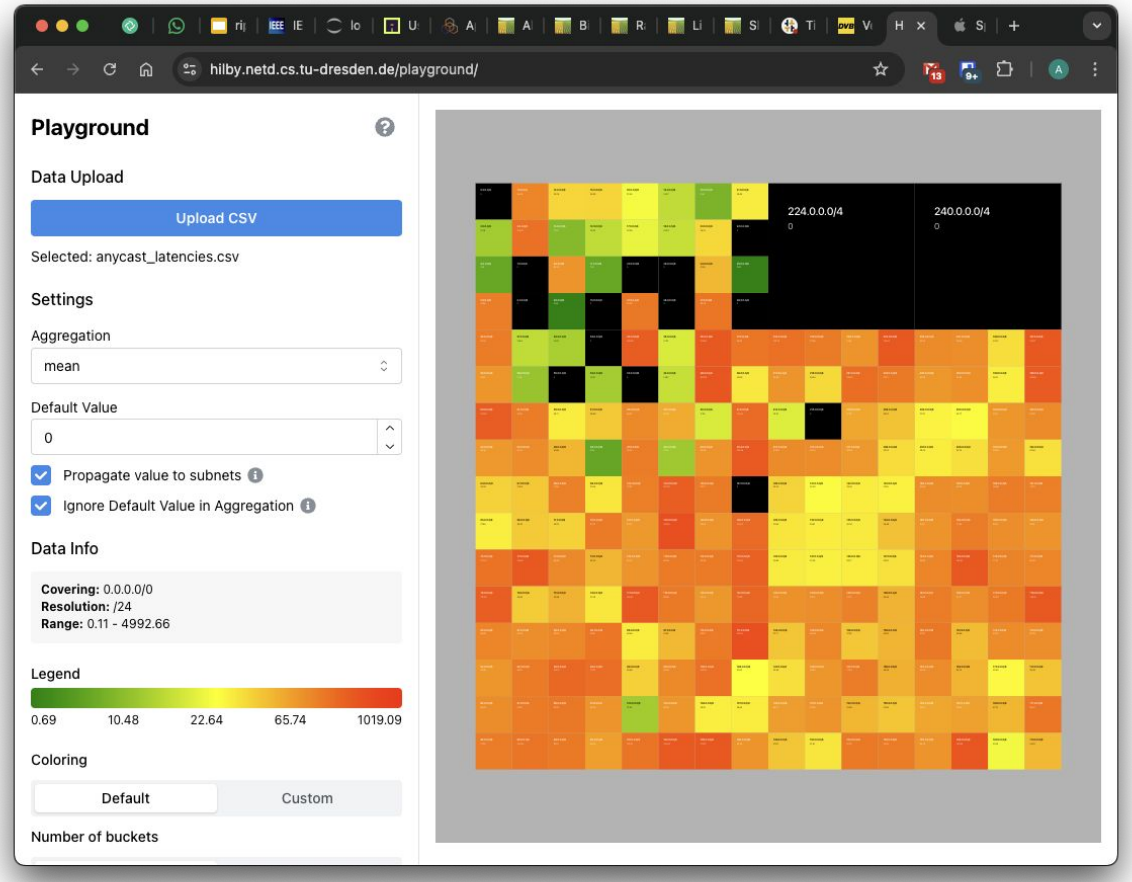
Experiment with your data? Use Hilby playground.

Using Hilby playground you can enter your data and experiment with a basic set of aggregations!

https://hilby.netd.cs.tu-dresden.de/playground

All calculations are done locally and no data is ever uploaded.



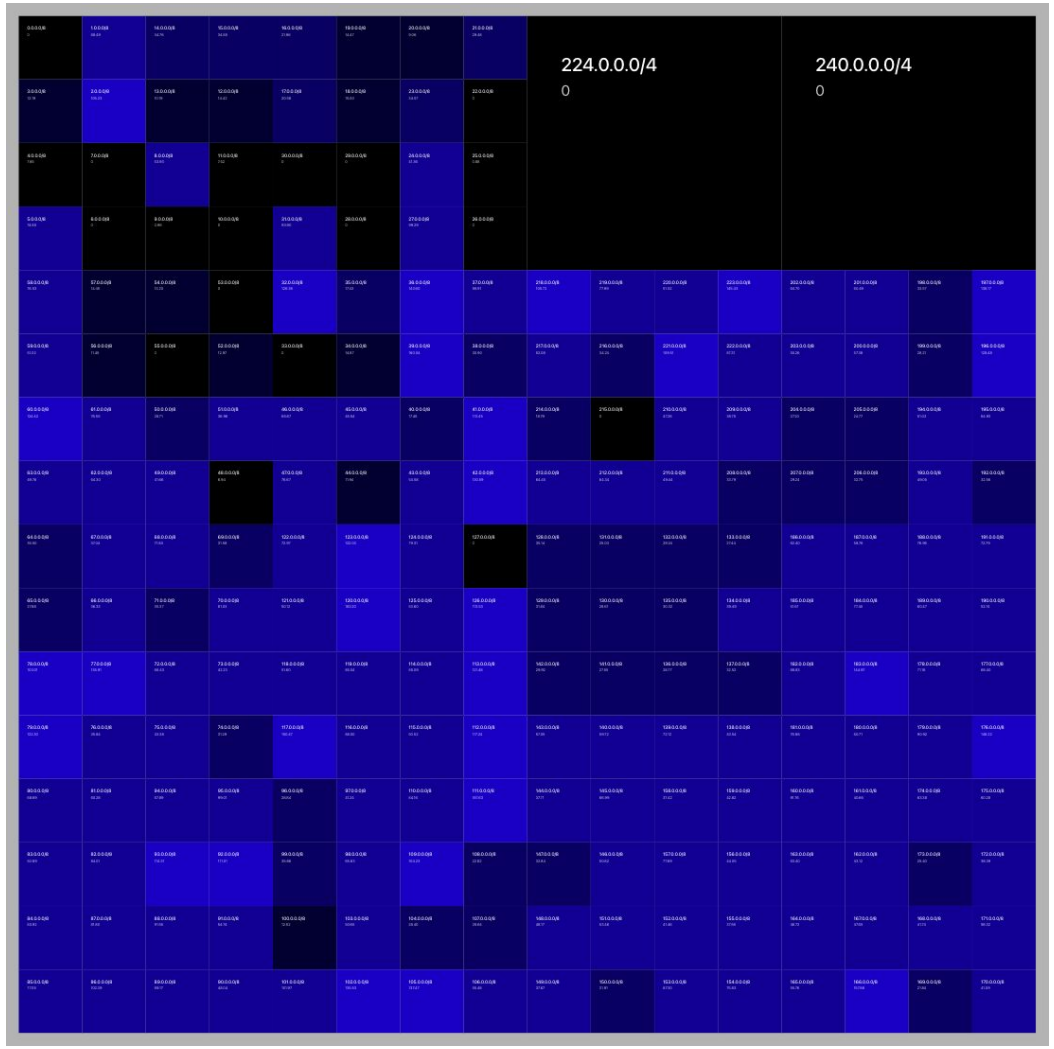
Interested?

Try out Hilby in the playground or add Hilby to your project via npm/yarn/pnpm:

```
npm install @netd-tud/hilby
```

Hilby is fully open source and on Github:
https://github.com/netd-tud/hilby

If you have any feature requests or issues, feel free to create a Github Issue or contact me via email!



References

[1] https://en.wikipedia.org/wiki/Space-filling_curve

[2] https://xkcd.com/195/

[3] https://ant.isi.edu/address/

[4] Alexander Männel, Jonas Mücke, K. C. Claffy, Max Gao, Ricky K. P. Mok, Marcin Nawrocki, Thomas C. Schmidt, and Matthias Wählisch. 2025. Lessons Learned from Operating a Large Network Telescope. In Proceedings of the ACM SIGCOMM 2025 Conference (SIGCOMM '25). Association for Computing Machinery, New York, NY, USA, 826–841. https://doi.org/10.1145/3718958.3754347