Unlocking High Performance Maps

With Mapbox Studio and Mapbox Vector Tiles

Justin Miller • Mapbox

Personal Introduction

- Work at Mapbox since 2010
- Mostly do mobile SDK development
- Have help build large parts of GL native/mobile
- Have seen where Mapbox has been and what we have learned from the past
- Based in USA

Agenda

- Why vector tiles?
- How do we style them?
- How do we make them?
- Hands-on time

Considerations

- mapbox.cn is still being built
- Current Mapbox Studio performance in China
- Limits of my expertise (software development rather than GIS, data, or cartography)
- Limited time today

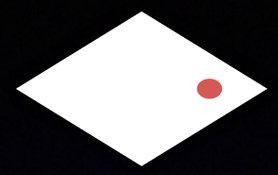
Assumptions

- Mercator projection
  - Square Earth, polar distortion
- Tiling
  - Doubling of map scale replaces each tile by four tiles of higher resolution
- OpenGL compatibility (WebGL and OpenGL ES)

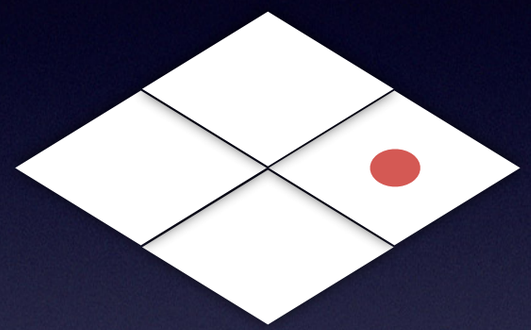
Why Vector Tiles?

“Slippy” Map Tiles

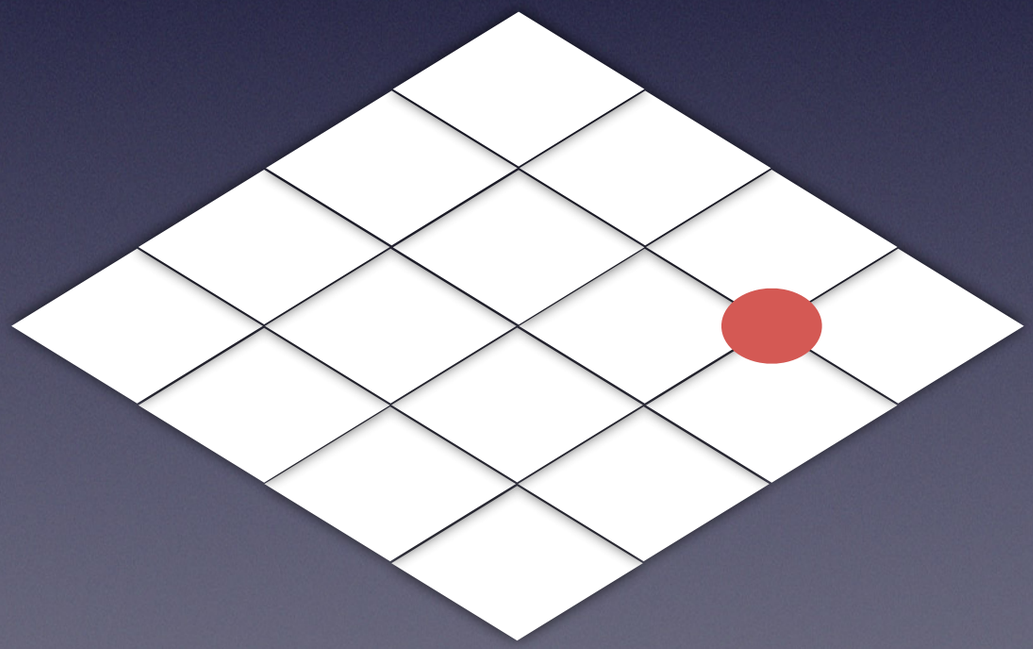
- Pioneered by Google Maps in 2005
- “Pyramid” structure for levels of detail
- Originally designed for raster imagery
- But also works great for vector tile data



z13



z14



z15

Vector Tiles

- Replacement of source data (SHP, KML, GeoJSON, PostGIS, etc.) with grid representation
- “Vector” refers to geometry, not actual vector math such as Bezier curves
- Rendered as primitives (lines, polygons, and symbols like icons or font characters)
- Rendered using the Mapbox GL standard

4096 points

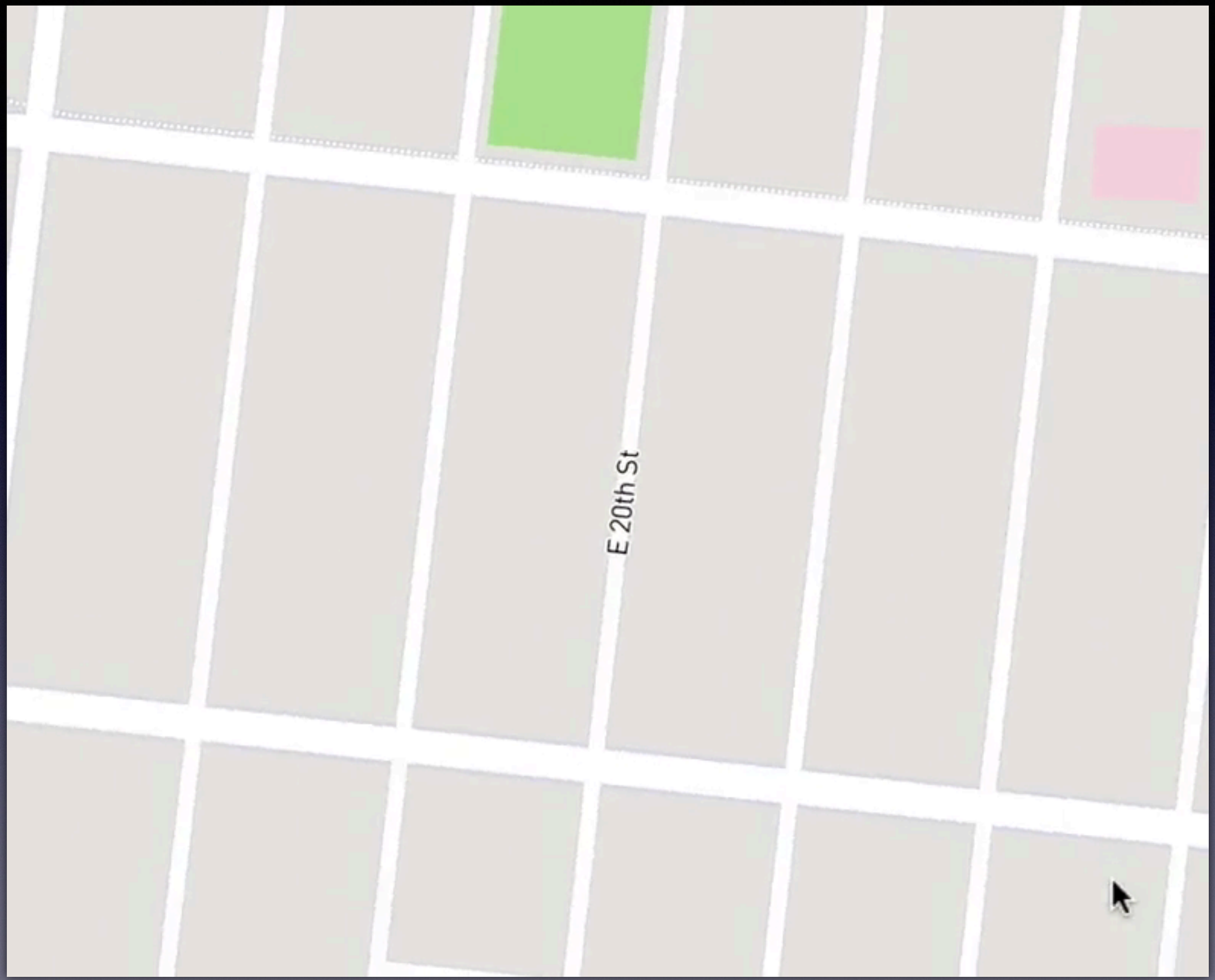
4096
points

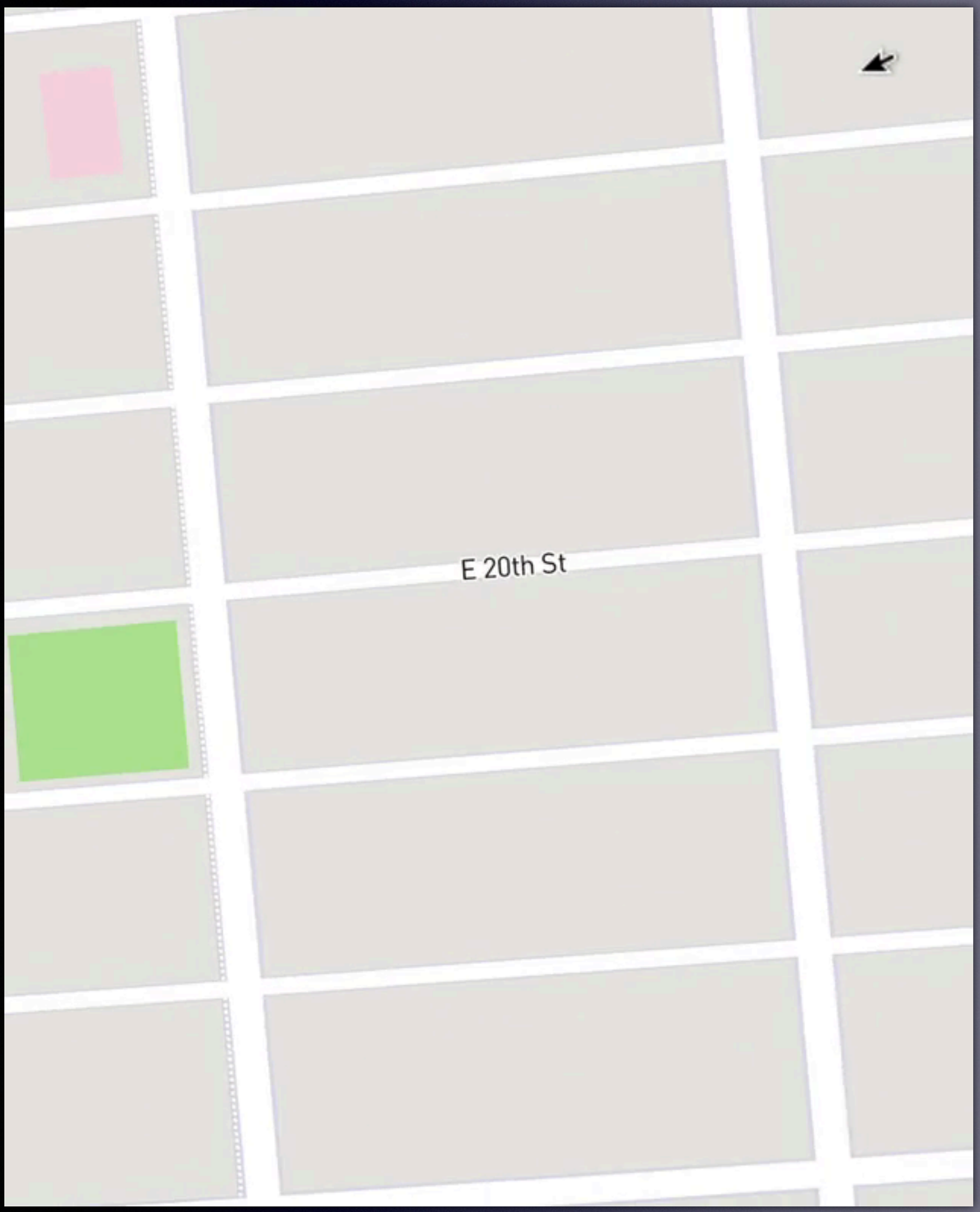
Allows Vector Rendering

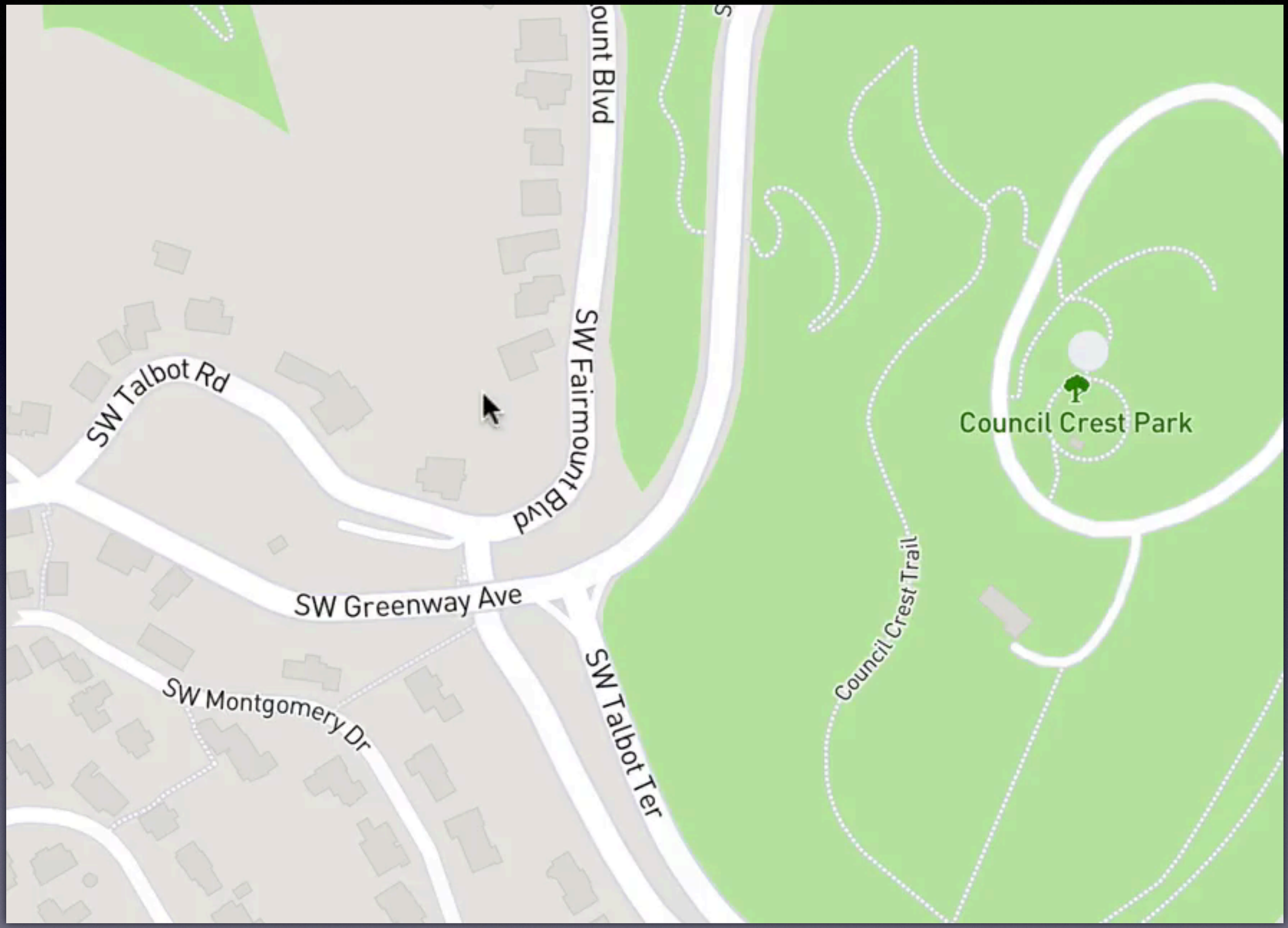
- Rendering happens on the client
- Drawing happens at 60 FPS (instant refresh)
- Makes possible animations and transitions

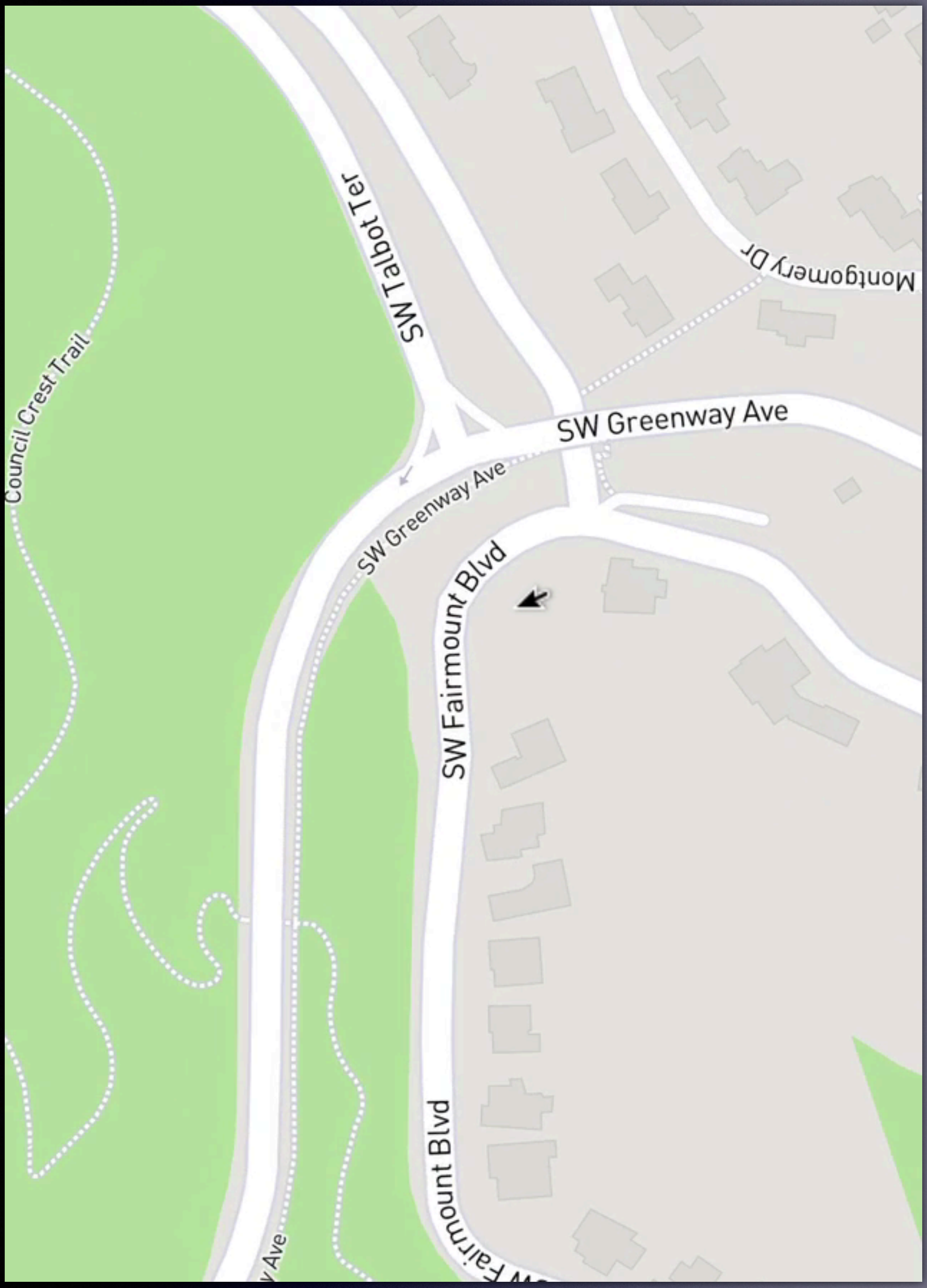
Rendering Advantages

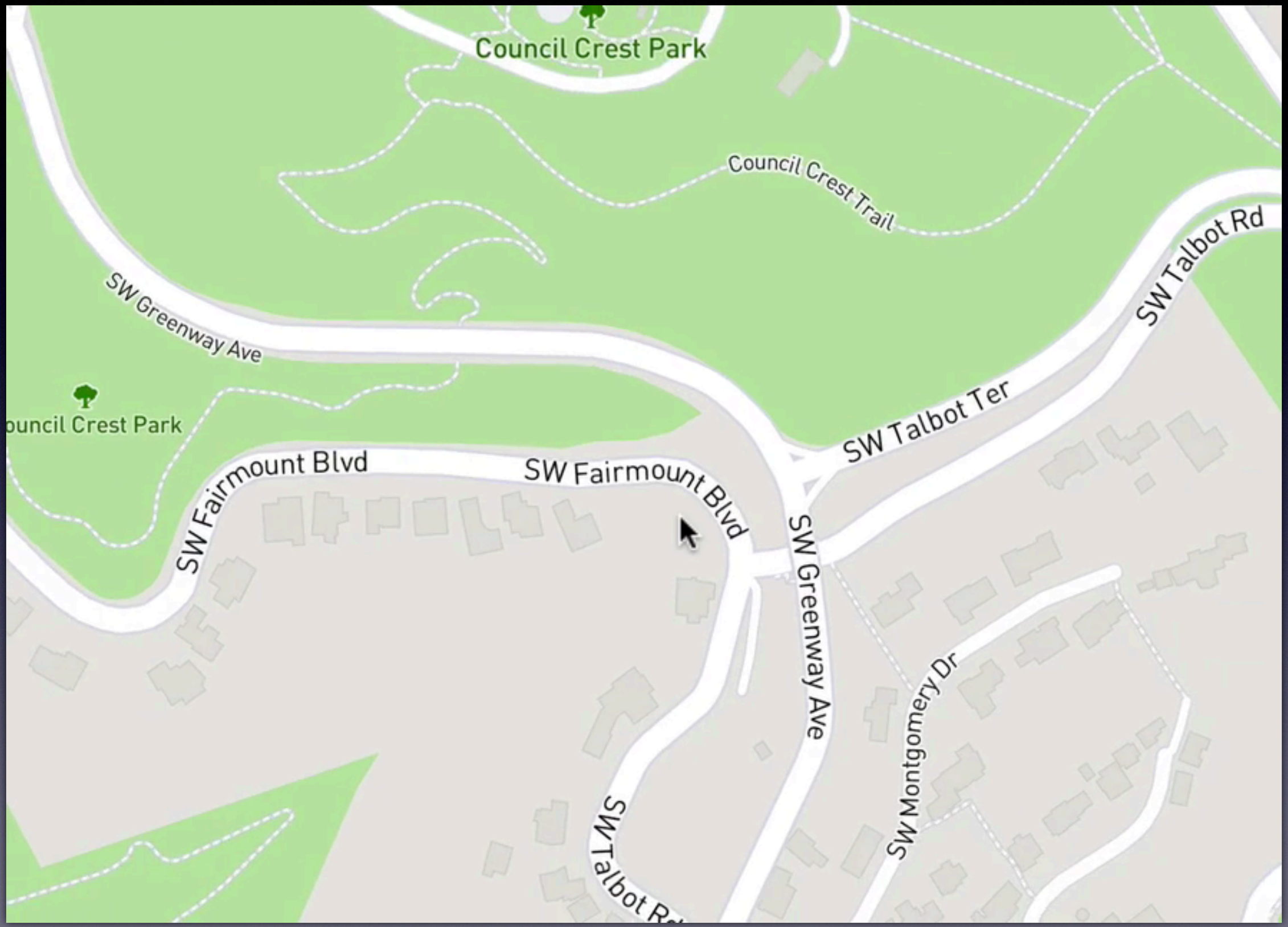
- Client-side, so performant and customizable
- Allows for advanced features
- Always-upright text
- Quickly change styling
- Zoom functions (style value as function of zoom level)
- Property functions (style value as function of property value)


E 20th St


E 20th St


SW Talbot Rd
SW Fairmount Blvd
SW Greenway Ave
SW Montgomery Dr
SW Talbot Ter
Council Crest Park
Council Crest Trail


Council Crest Trail
SW Talbot Ter
Montgomery Dr
SW Greenway Ave
SW Greenway Ave
SW Fairmount Blvd
SW Fairmount Blvd


Council Crest Park
Council Crest Trail
SW Greenway Ave
SW Talbot Rd
SW Talbot Ter
ouncil Crest Park
Fairmount Blvd
SW Fairmount Blvd
SW Greenway Ave
SW Montgomery Dr
SW Talbot R

How Do We Style Them?

Root
version
name
metadata
center
zoom
bearing
pitch
light
sources
sprite
glyphs
transition
layers

Light
anchor
position
color
intensity

Sources
Vector
Raster
GeoJSON
Image
Video

Sprite

Glyphs

Transition
duration
delay

Mapbox Style Specification

A Mapbox style is a document that defines the visual appearance of a map: what data to draw, the order to draw it in, and how to style the data when drawing it. A style document is a JSON object with specific root level and nested properties. This specification defines and describes these properties.

The intended audience of this specification includes:

- Advanced designers and cartographers who want to write styles by hand rather than use Mapbox Studio
- Developers using style-related features of Mapbox GL JS or the Mapbox iOS or Android SDKs
- Authors of software that generates or processes Mapbox styles.

Root Properties

Root level properties of a Mapbox style specify the map's layers, tile sources and other resources, and default values for the initial camera position when not specified elsewhere.

```
{
    "version": 8,
    "name": "Mapbox Streets",
    "sprite": "mapbox://sprites/mapbox/streets-v8"
```

color
intensity

Sources
Vector
Raster
GeoJSON
Image
Video

Sprite

Glyphs

Transition
duration
delay

Layers
Background
Fill
Line
Symbol
Raster
Circle
Fill-Extrusion

Types
Color
Enum
String
Boolean
Number
Array
Function
Filter

line

Layout Properties

`line-cap`

Optional enum. One of butt, round, square. Defaults to butt.

The display of line endings.

butt

A cap with a squared-off end which is drawn to the exact endpoint of the line.

round

A cap with a rounded end which is drawn beyond the endpoint of the line at a radius of one-half of the line's width and centered on the endpoint of the line.

square

A cap with a squared-off end which is drawn beyond the endpoint of the line at a distance of one-half of the line's width.

SDK Support	Mapbox GL JS	iOS SDK	Android SDK
basic functionality	>= 0.10.0	>= 2.0.0	>= 2.0.1

`line-join`

Optional enum. One of bevel, round, miter. Defaults to miter.

The display of lines when joining.

bevel

A join with a squared-off end which is drawn beyond the endpoint of the line at a distance of one-half of the line's width.

round

A join with a rounded end which is drawn beyond the endpoint of the line at a radius of one-half of the line's width and centered on the endpoint of the line.

miter

www.mapbox.com/mapbox-gl-style-spec/#types-filter

Mapbox Style Specification | Mapbox

color
intensity

Sources
Vector
Raster
GeoJSON
Image
Video

Sprite

Glyphs

Transition
duration
delay

Layers
Background
Fill
Line
Symbol
Raster
Circle
Fill-Extrusion

Types
Color
Enum
String
Boolean
Number
Array
Function
Filter

Open #types-boolean on this page in a new tab

Filter

A filter selects specific features from a layer. A filter is an array of one of the following forms:

Existential Filters

`["has", key]` ***feature[key]*** **exists**

`["!has", key]` ***feature[key]*** **does not exist**

Comparison Filters

`["==", key, value]` **equality:** ***feature[key]*** **=** ***value***

`["!=", key, value]` **inequality:** ***feature[key]*** **≠** ***value***

`[">", key, value]` **greater than:** ***feature[key]*** **>** ***value***

`[">=", key, value]` **greater than or equal:** ***feature[key]*** **≥** ***value***

`["<", key, value]` **less than:** ***feature[key]*** **<** ***value***

`["<=", key, value]` **less than or equal:** ***feature[key]*** **≤** ***value***

Set Membership Filters

`["in", key, v0, ..., vn]` **set inclusion:** ***feature[key]*** **∈ {*v0*, ..., *vn*}**

`["!in", key, v0, ..., vn]` **set exclusion:** ***feature[key]*** **∉ {*v0*, ..., *vn*}**

Combining Filters

`["all", f0, ..., fn]` **logical** `AND` **:** ***f0*** **∧ ... ∧** ***fn***

`["any", f0, ..., fn]` **logical** `OR` **:** ***f0*** **∨ ... ∨** ***fn***

Layout & Paint Properties

- Layout: earlier in render process, can be shared between layers using **`ref`** property
  - Examples: **`line-cap`**, **`line-join`**, **`visibility`**
- Paint: later in render process
  - Examples: **`line-opacity`**, **`line-color`**, **`line-width`**

Constant Values

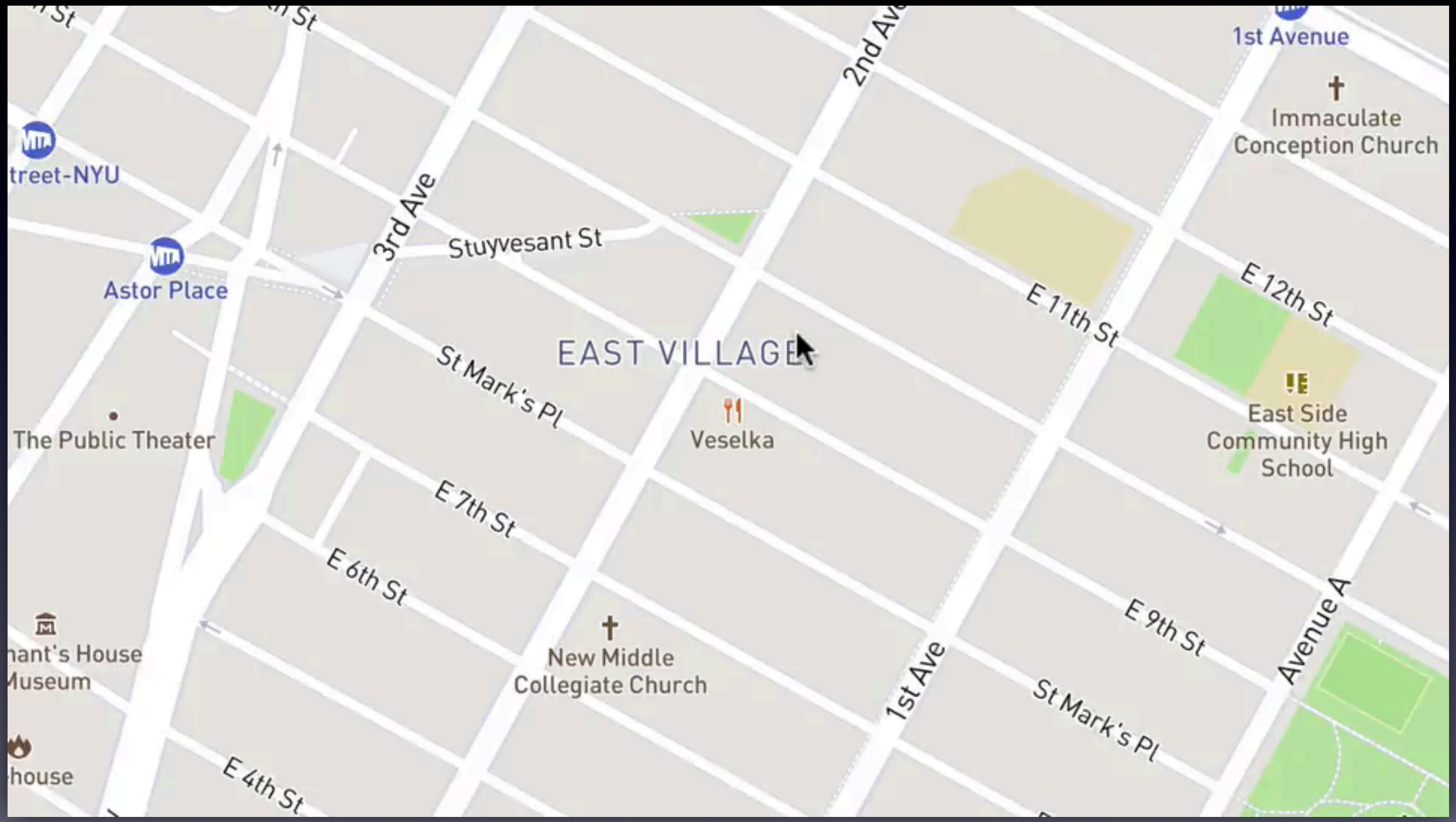
- Simple equality to numbers, strings, booleans, colors, etc.
- Fixed for every zoom level
- **`"circle-radius": 10`**

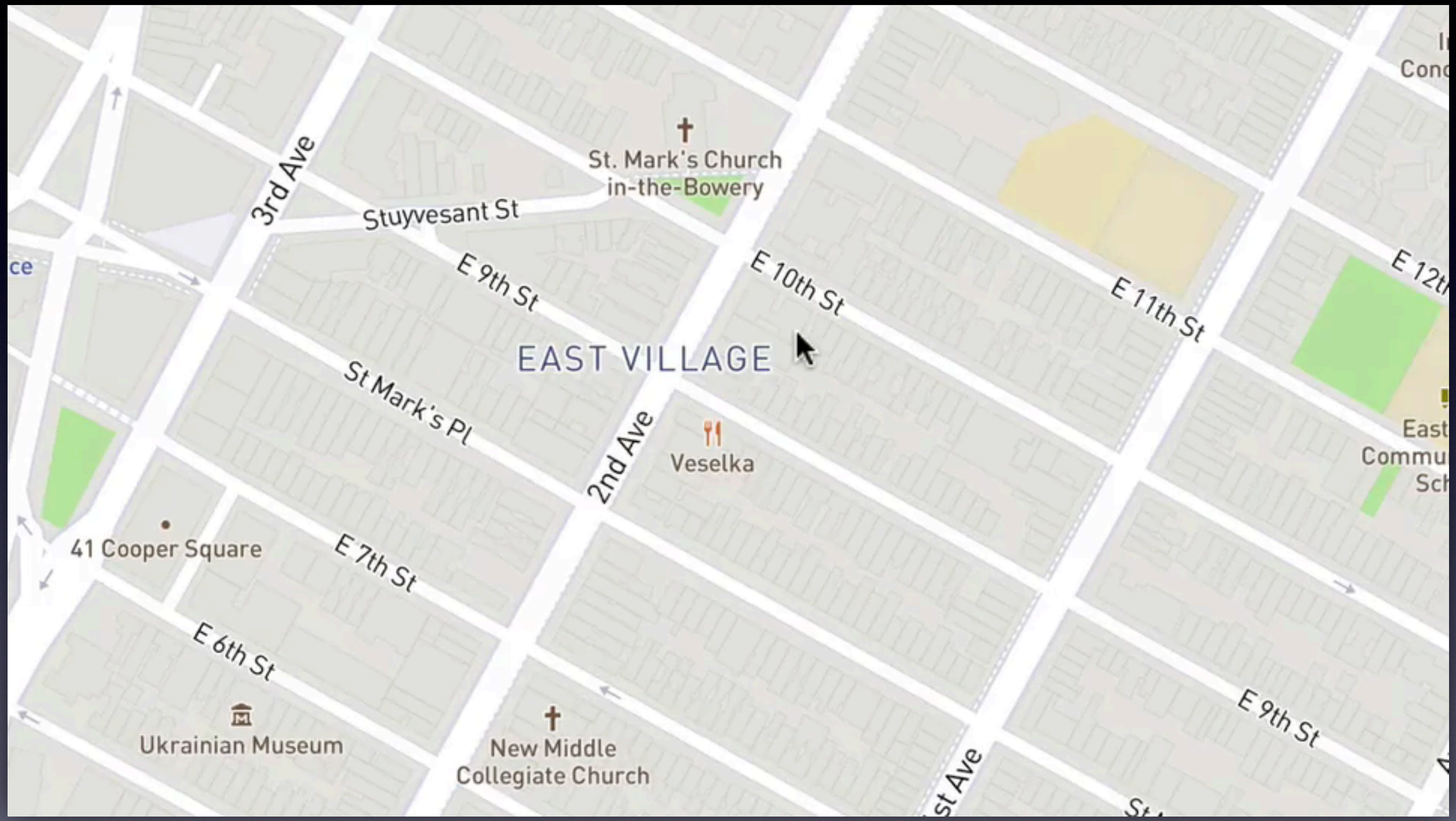
Function Values (Variable)

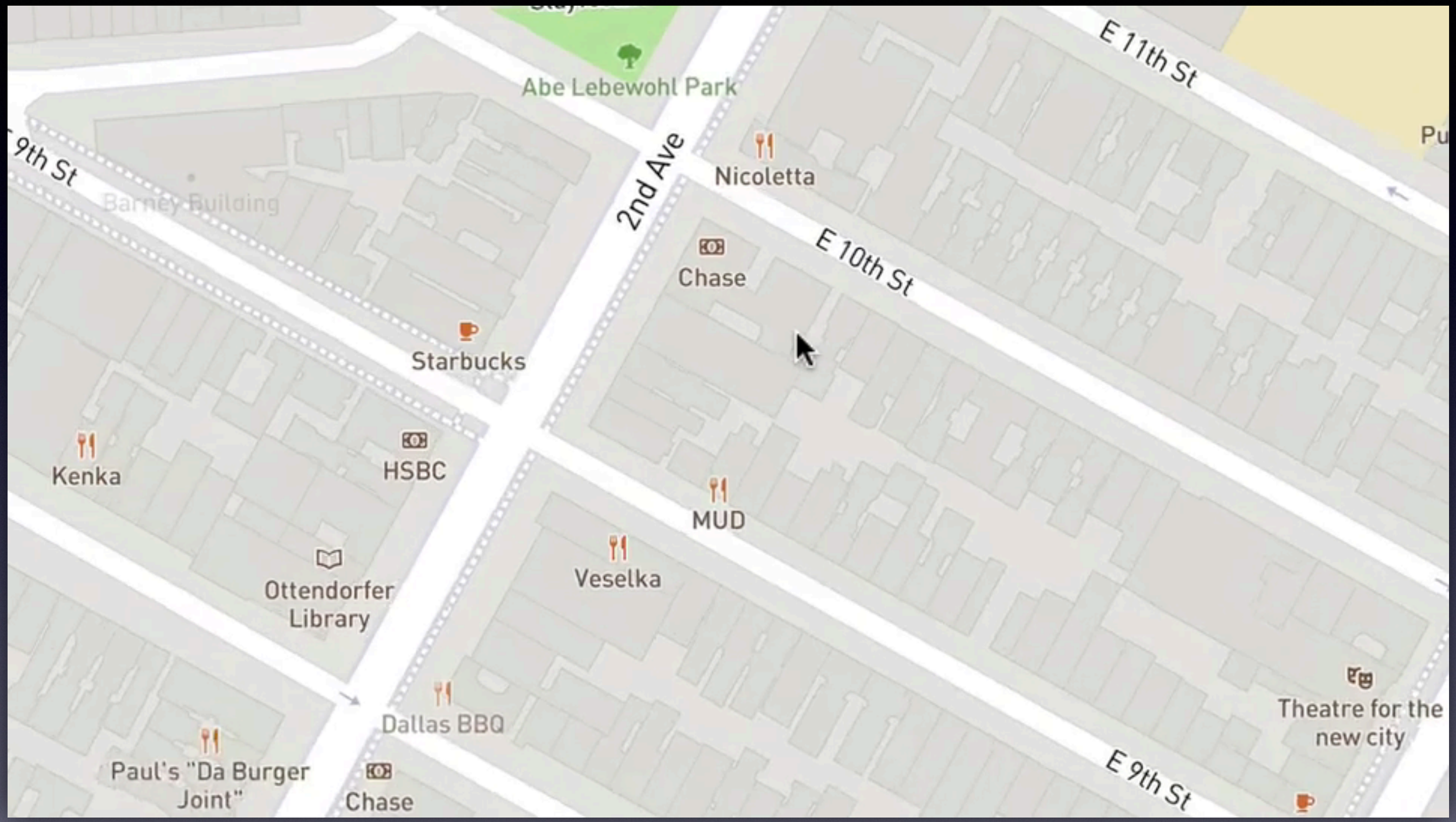
```
{
  "circle-radius": {

    "stops": [

      // zoom is 5 -> circle radius will be 1px
      [5, 1],

      // zoom is 10 -> circle radius will be 2px
      [10, 2]

    ]

  }

}
```

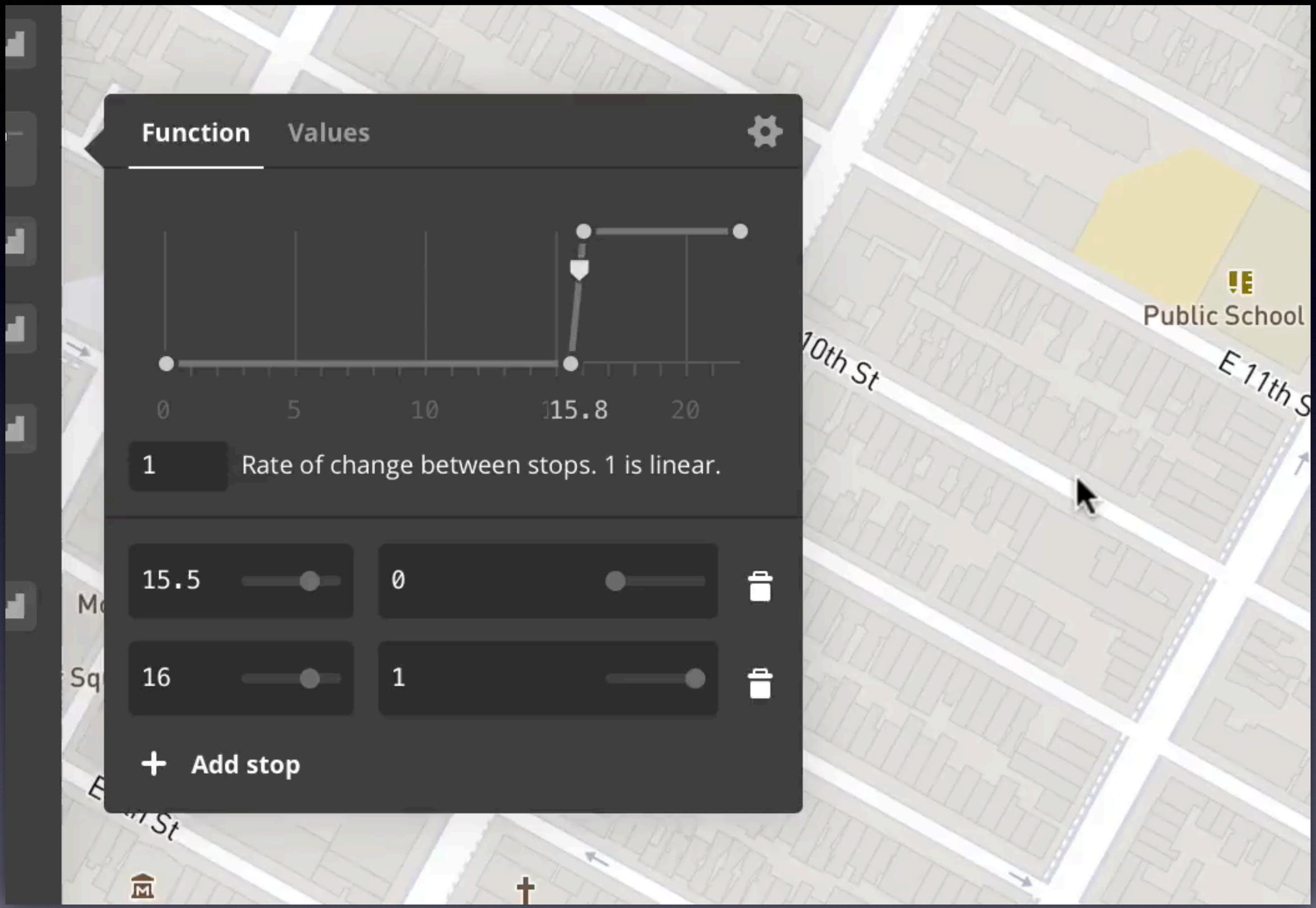
Function Values

- Discrete values for layout properties
  - Like previous **`circle-radius`** example
- Interpolated values for paint properties
  - Example: opacity constantly changes with zoom, every fractional zoom


1st Avenue
Immaculate Conception Church
treet-NYU
3rd Ave
Stuyvesant St
Astor Place
2nd Ave
E 11th St
E 12th St
EAST VILLAGE
St Mark's Pl
The Public Theater
Veselka
East Side Community High School
E 7th St
E 6th St
E 9th St
Avenue A
nant's House Museum
New Middle Collegiate Church
1st Ave
St Mark's Pl
house
E 4th St


St. Mark's Church
in-the-Bowery
3rd Ave
Stuyvesant St
E 9th St
E 10th St
E 11th St
EAST VILLAGE
St Mark's Pl
2nd Ave
Veselka
41 Cooper Square
E 7th St
E 6th St
Ukrainian Museum
New Middle
Collegiate Church
E 9th St


Abe Lebewohl Park
E 11th St
9th St
Barney Building
2nd Ave
Nicoletta
E 10th St
Chase
Starbucks
Kenka
HSBC
MUD
Ottendorfer Library
Veselka
Dallas BBQ
Theatre for the new city
Paul's "Da Burger Joint"
Chase
E 9th St


Function
Values
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15.8
20
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Rate of change between stops. 1 is linear.
15.5
0
16
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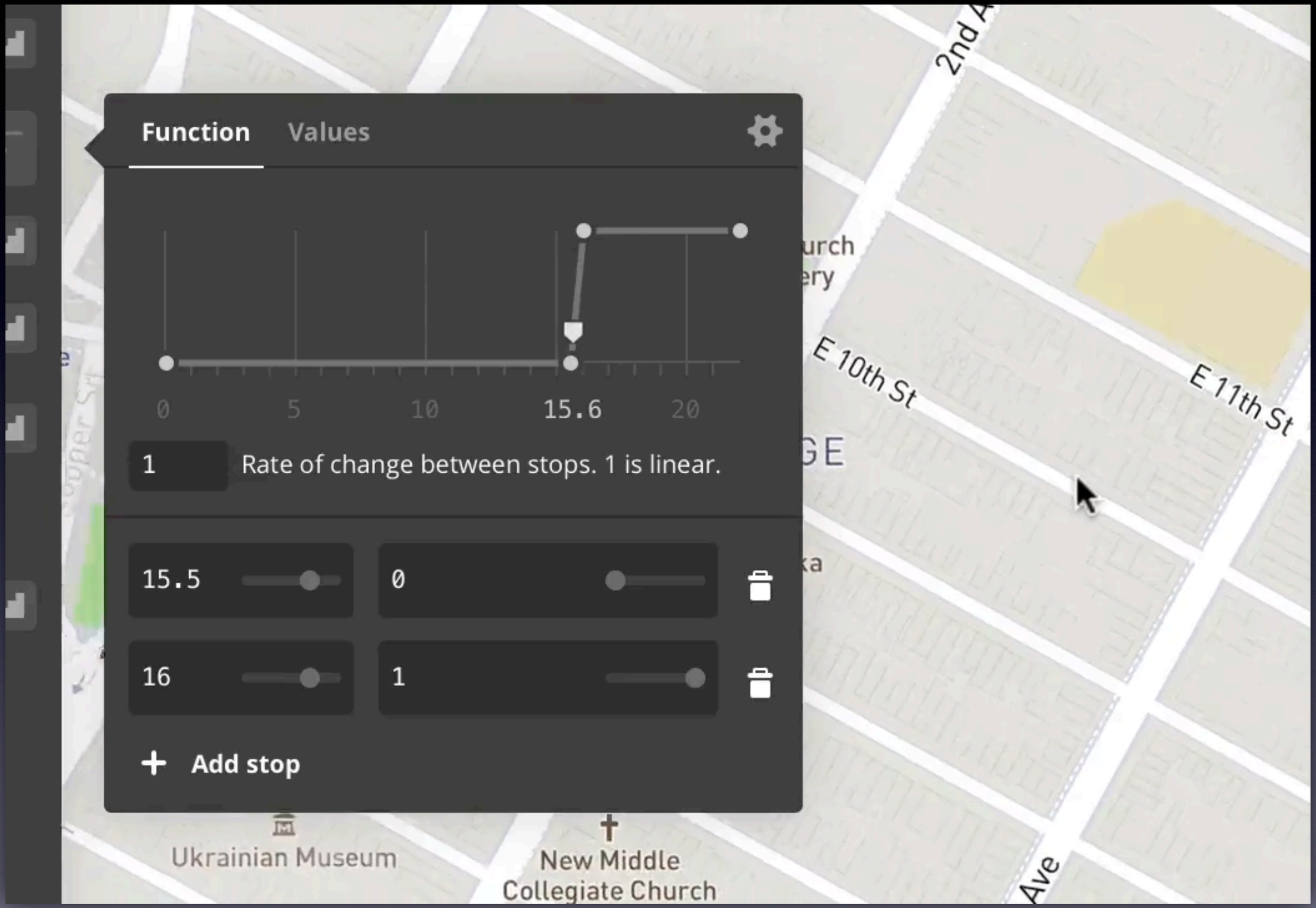
Add stop
Public School
E 11th S
10th St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Ukrainian Museum
New Middle
Collegiate Church
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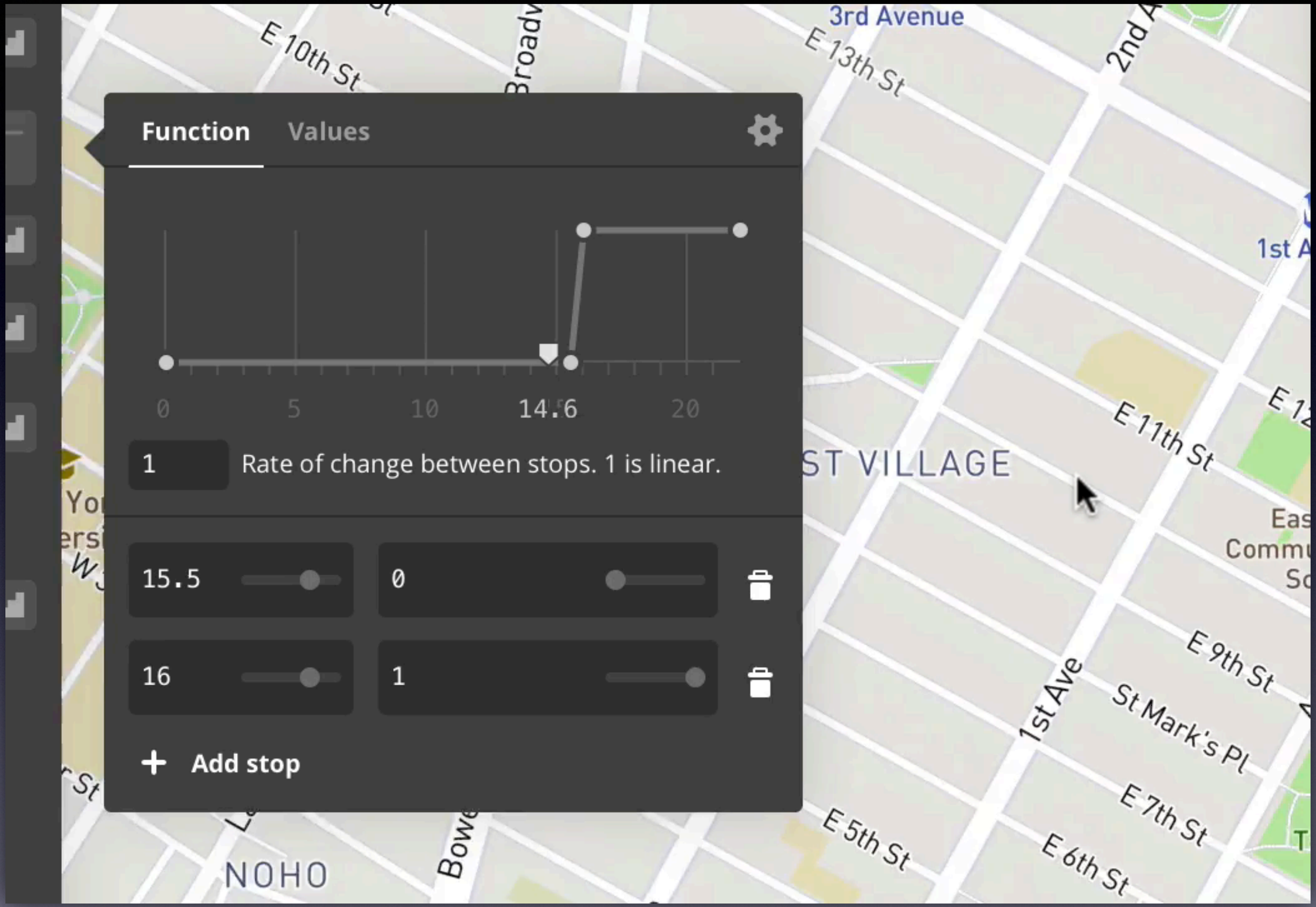
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Add stop
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E 13th St
1st A
E 11th St
ST VILLAGE
E 9th St
St Mark's Pl
1st Ave
E 7th St
E 6th St
E 5th St
NOHO

www.mapbox.com/blog/3d-features-in-mapbox-gl-js/

For example, when used with data-driven styling and the recent addition of building heights to Mapbox Streets, you can now render 3D buildings:

Hold control while clicking and dragging to tilt and rotate the map. On mobile? Tap here to see extrusions for GL JS in action.

The new extrusion properties together with data-driven styles make for a powerful combination. Beyond 3D buildings, they can be used for 3D elevation profiles, 3D indoor floorplans, and more.

When you're building 3D visuals, you'll want the flexibility to control the light source. That's why we

mapbox.com/blog/3d-features-in-mapbox-gl-js/

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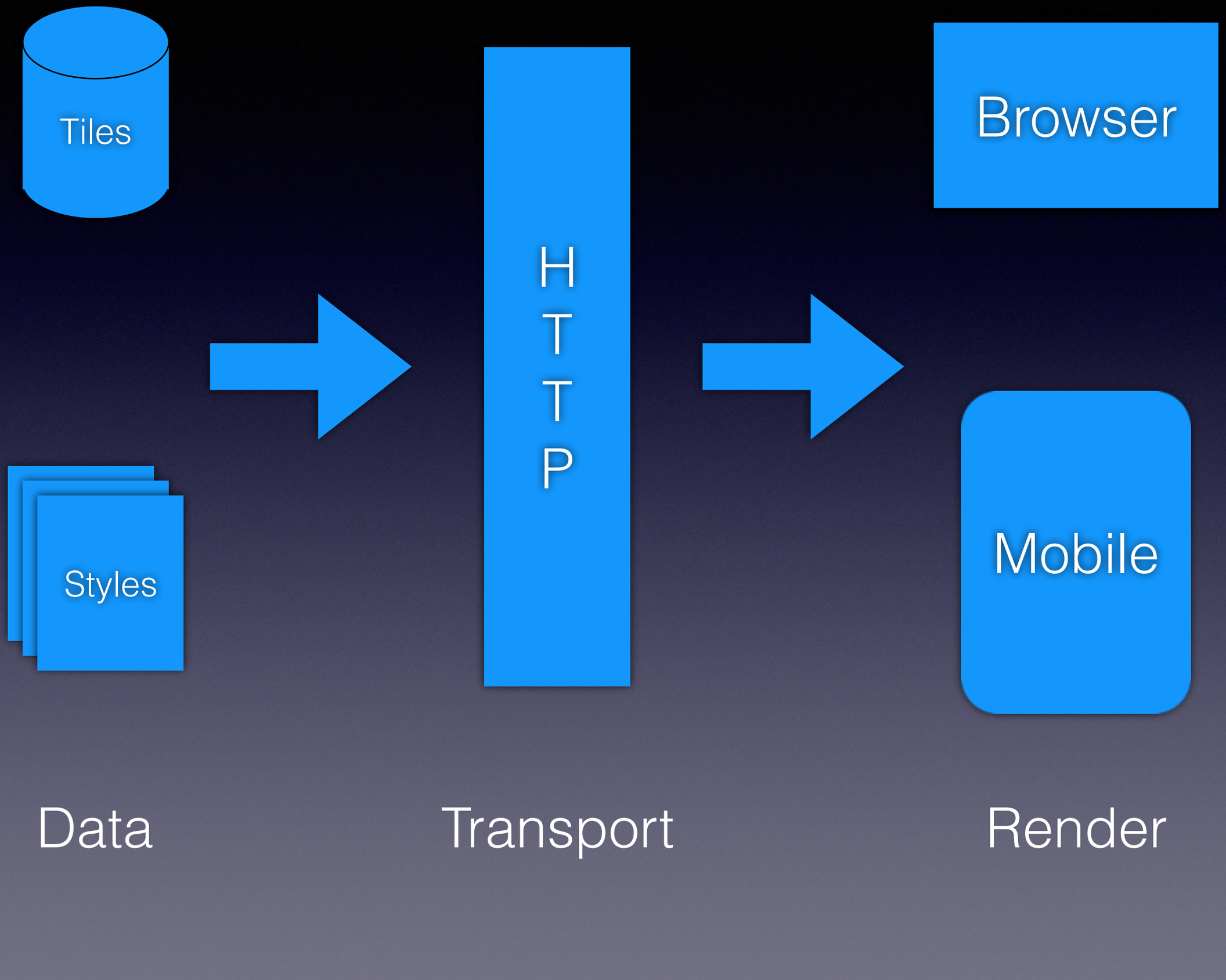
mapbox.com/blog/3d-features-in-mapbox-gl-js/

Ecosystem

- Tile creation (Studio, Mapnik, Tippecanoe)
- Tile hosting (HTTP assets)
- Styling (Studio)
- Style/font/icon hosting (HTTP assets)
- GL rendering
  - Web (WebGL clients such as Mapbox GL JS)
  - Mobile (native clients such as mobile SDKs)


Tiles
Styles
HTTP
Browser
Mobile
Data
Transport
Render

How Do We Make Them?

4096 points

4096
points

Simplify Shapes

- Reduce number of points in lines & polygons
- Reduce duplicate single points to one point
- Used where difference isn’t noticeable in rendering
- Allows for even more data size reduction
- Original shapes are lost permanently

Simplify Shapes

Simplify Shapes

Binary Format

- Able to be compressed more easily
- Able to be parsed faster by code
- Not necessary to be human-readable
- Uses Google Protocol Buffers (PBF) for storage

Delta Encoding

- Happens after projection into 4096 point tile
- Only store differences (deltas) between coordinates
  - Line from (64, 438) → (124, 447)
  - Encoded as (60,9)
  - Each tile stores one starting point plus many deltas per feature

GitHub, Inc. github.com/mapbox/vector-tile-spec

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Mapbox Vector Tile specification https://www.mapbox.com/vector-tiles/s... Edit

56 commits 4 branches 1 release 13 contributors

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jfirebaugh Remove incorrect comment ... Latest commit ab55f2b on Jun 6

1.0.0	update description alignment	2 years ago
1.0.1	Update README.md	2 years ago
2.0	Added back instructions to avoid linetos that do not result in the cu...	a year ago
2.1	Remove incorrect comment	7 months ago
CHANGELOG.md	Fix my inability to do math	a year ago
CONTRIBUTING.md	Initial version 2.0 Specification	a year ago
README.md	Add translation in README	10 months ago

README.md

Mapbox Vector Tile Specification

A specification for encoding tiled vector data.

矢量瓦片标准

本文档中的“**必须**”、“**必须不**”、“**必备**”、"**应该**"、“**不应该**”、“**建议**”、“**可以**”、“**可选**”的含义参照RFC 2119。

1. 目标

本文档规定了一种节省存储空间的矢量瓦片数据编码格式。这种格式应用于客户端或服务端高效渲染或查询要素信息。

2. 文件格式

矢量瓦片文件采用Google Protocol Buffers进行编码。Google Protocol Buffers是一种兼容多语言、多平台、易扩展的数据序列化格式。

2.1. 文件后缀

矢量瓦片文件的后缀**应该**为`mvt`。例如，`vector.mvt`。

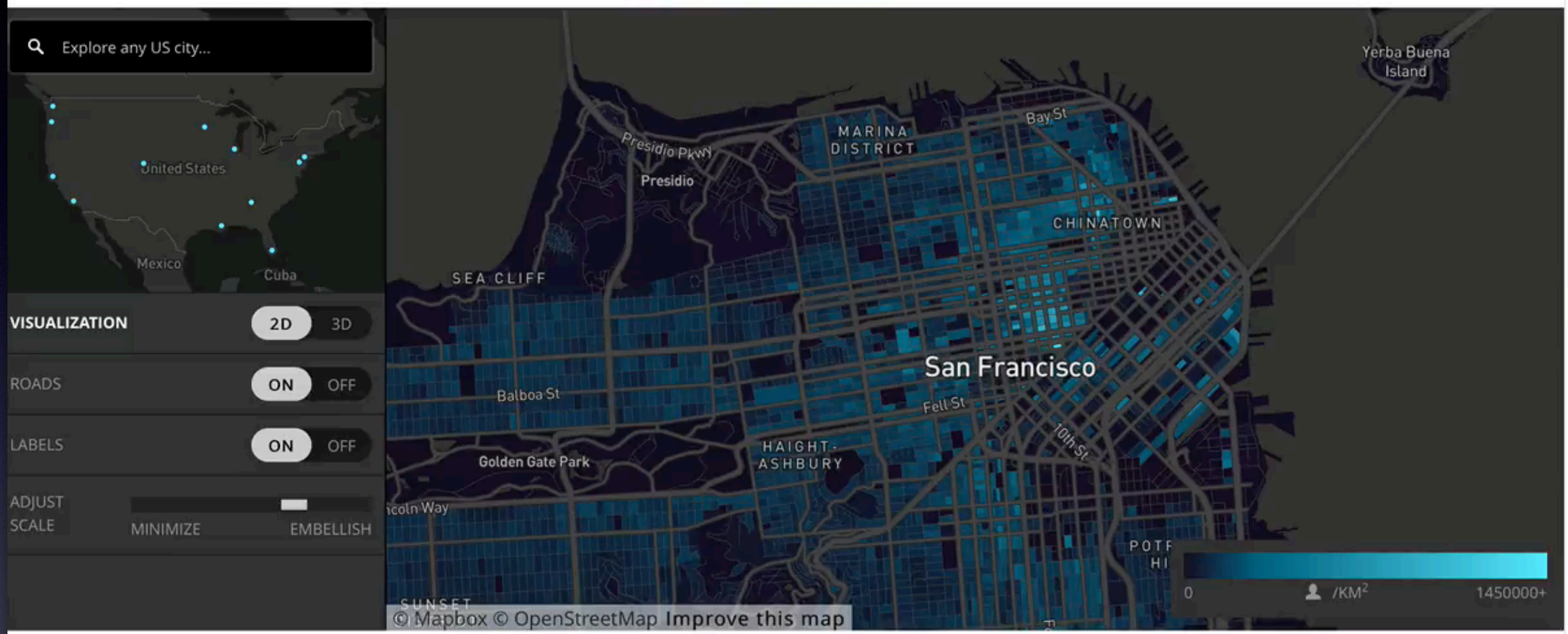
Feature Property Querying

- Source data properties are retained
  - Example: name, building number, POI details
- Unique property names and values are stored only once and correlated to features
  - Saves even more text and numeric space
- Able to be retrieved by client during queries

www.mapbox.com/blog/population-inspector/

fun using Mapbox GL JS's new 3D features and data-driven styling to show the remarkable concentration of people in areas like New York, where an average of over 27,000 people live in each square mile.

View full-screen demo | *Keep reading*



Use the sidebar to find any U.S. city, or toggle between two- and three-dimensional views of the data. Right-click drag (or hold down `control`*) to tilt and rotate the map. On mobile? Tap here to see extrusions for GL JS in action*

At first glance, these images of Chicago, New Orleans, and Manhattan look like skyscrapers, but

mapbox.com/blog/population-inspector/

Automatic Process

- Mapbox Studio's feature for creating "tilesets" is automatic
- Intelligent choices (compromises) are made
- Easiest for web-based uploading of data
- But can be done externally with other tools

More Custom Tools

- Mapnik backend (used by Studio)
- Tippecanoe (command-line tool with total control)
- JavaScript & Python libraries

GitHub, Inc. github.com/mapbox/mapnik-vector-tile

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Mapnik implemention of Mapbox Vector Tile specification

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912 commits 22 branches 69 releases 17 contributors BSD-3-Clause

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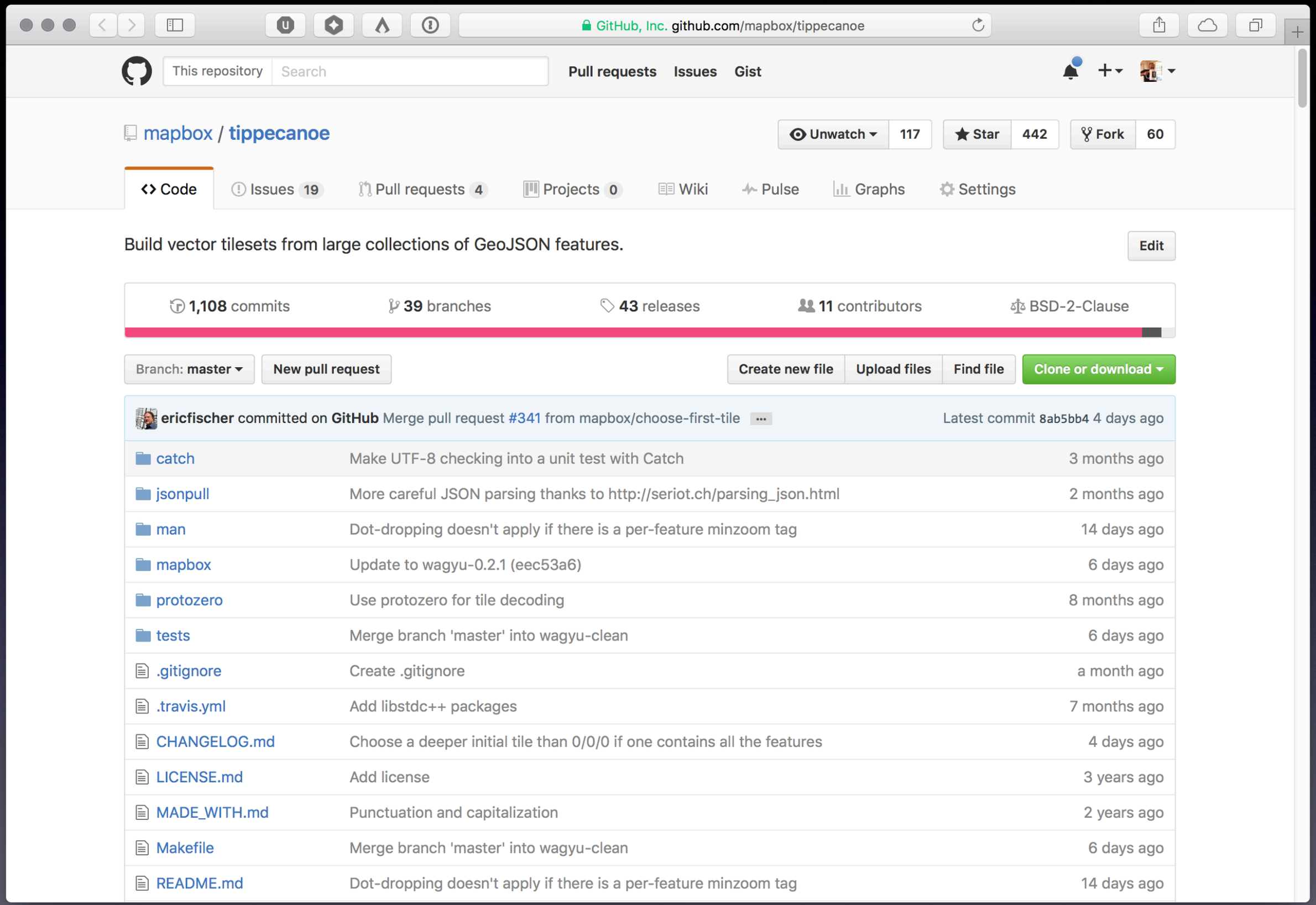
springmeyer bump to v1.2.2 Latest commit 4e29fec on Sep 10

bench	more fixes for open	9 months ago
bin	also fuzz fill types and extents	8 months ago
examples	Remove errors on debug mode by default by changing them to warnings. ...	a year ago
gyp	Add vtile-fuzz - refs mapnik/clipper#3	8 months ago
proto	pull in the vector tile v1.0.1 spec (+ experimental raster) + separat...	2 years ago
scripts	ccache+convert coverage to linux	9 months ago
src	port to protozero v1.4.2	3 months ago
test	port to protozero v1.4.2	3 months ago
.gitignore	Added make testpack, added mason to ignores	a year ago
.gitmodules	Add geometry visual tests for cutting geometries	a year ago
.npmignore	Added new npm ignore [skip ci]	9 months ago
.travis.yml	xutils dev for g++ build too	4 months ago
CHANGELOG.md	bump to v1.2.2	3 months ago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Star 442
Fork 60
Code
Issues 19
Pull requests 4
Projects 0
Wiki
Pulse
Graphs
Settings
Build vector tilesets from large collections of GeoJSON features.
Edit
1,108 commits
39 branches
43 releases
11 contributors
BSD-2-Clause
Branch: master
New pull request
Create new file
Upload files
Find file
Clone or download
ericfischer committed on GitHub Merge pull request #341 from mapbox/choose-first-tile
Latest commit 8ab5bb4 4 days ago
catch Make UTF-8 checking into a unit test with Catch 3 months ago
jsonpull More careful JSON parsing thanks to http://seriot.ch/parsing_json.html 2 months ago
man Dot-dropping doesn't apply if there is a per-feature minzoom tag 14 days ago
mapbox Update to wagyu-0.2.1 (eec53a6) 6 days ago
protozero Use protozero for tile decoding 8 months ago
tests Merge branch 'master' into wagyu-clean 6 days ago
.gitignore Create .gitignore a month ago
.travis.yml Add libstdc++ packages 7 months ago
CHANGELOG.md Choose a deeper initial tile than 0/0/0 if one contains all the features 4 days ago
LICENSE.md Add license 3 years ago
MADE_WITH.md Punctuation and capitalization 2 years ago
Makefile Merge branch 'master' into wagyu-clean 6 days ago
README.md Dot-dropping doesn't apply if there is a per-feature minzoom tag 14 days ago

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Parses vector tiles with JavaScript

Edit

84 commits 4 branches 14 releases 11 contributors BSD-3-Clause

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tmcw committed on GitHub Merge pull request #48 from nyurik/patch-2 ... Latest commit b7abef2 on Sep 26

lib	Make VectorTileFeature#id a public property	5 months ago
proto	initial commit	3 years ago
test	Make VectorTileFeature#id a public property	5 months ago
.eslintrc	Add eslint	11 months ago
.gitignore	add gitignore	3 years ago
.travis.yml	Drop all but node 4 from test matrix	7 months ago
CHANGELOG.md	1.3.0	5 months ago
LICENSE.txt	Update LICENSE.txt	3 months ago
README.md	Make VectorTileFeature#id a public property	5 months ago
fixtures.js	Classify polygon rings to distinguish inner polygon rings and multipo...	7 months ago
index.js	Expose all classes, not just VectorTile	3 years ago
package.json	Update package.json	3 months ago

README.md

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Parses vector tiles with Python

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21 commits 2 branches 0 releases 6 contributors BSD-3-Clause

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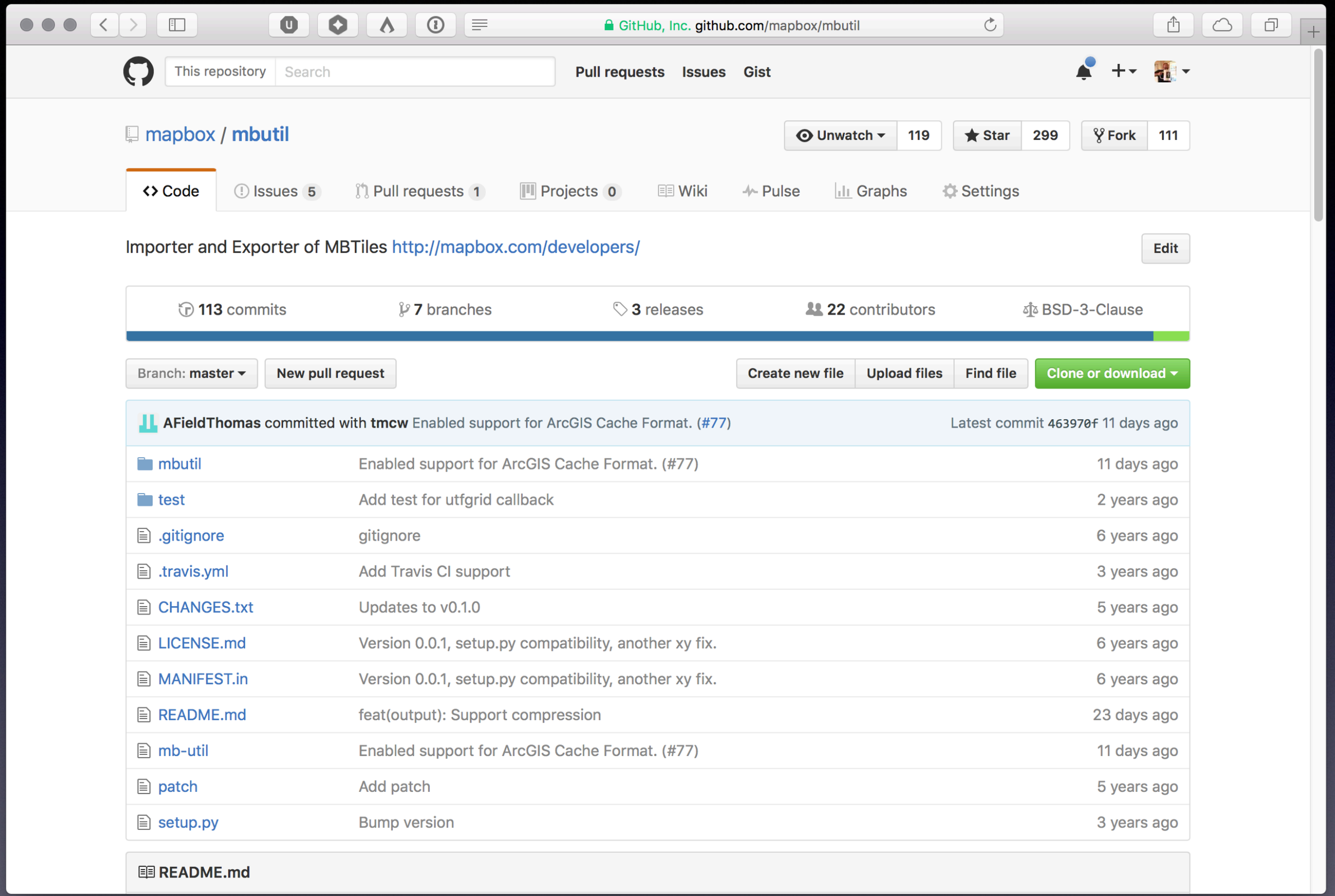
tmcw committed on GitHub Merge pull request #4 from AndreMiras/patch-1 ... Latest commit 342f7da on Jul 25

vector_tile	some vector tiles contain MultiLineString data. add support for these.	2 years ago
.gitignore	Initial commit	3 years ago
LICENSE.txt	GeoJSON to MVT PB2 functions and tool.	3 years ago
README.md	Update README.md	2 years ago
example.py	change VectorTile.to_geojson to return a dict, not a string	3 years ago
requirements.txt	Create requirements.txt	11 months ago
setup.py	GeoJSON to MVT PB2 functions and tool.	3 years ago
tests.py	Add more complete test for tile creation	3 years ago
tile-info.py	change VectorTile.to_geojson to return a dict, not a string	3 years ago
tile-raw-info.py	add a tile-info script showing raw pbf data	2 years ago

README.md

Tile Uploading & Transport

- MBTiles format is most efficient
- SQLite disk-based database of tile data
- Database key: **`x`**/**`y`**/**`z`** triad
- Data value: PBF vector tile data
- Easily capable of 10s of GB


GitHub, Inc. github.com/mapbox/mbutil
This repository
Search
Pull requests
Issues
Gist
mapbox / mbutil
Unwatch 119
Star 299
Fork 111
Code
Issues 5
Pull requests 1
Projects 0
Wiki
Pulse
Graphs
Settings
Importer and Exporter of MBTiles http://mapbox.com/developers/
Edit
113 commits
7 branches
3 releases
22 contributors
BSD-3-Clause
Branch: master
New pull request
Create new file
Upload files
Find file
Clone or download
AFieldThomas committed with tmcw Enabled support for ArcGIS Cache Format. (#77)
Latest commit 463970f 11 days ago
mbutil Enabled support for ArcGIS Cache Format. (#77) 11 days ago
test Add test for utfgrid callback 2 years ago
.gitignore gitignore 6 years ago
.travis.yml Add Travis CI support 3 years ago
CHANGES.txt Updates to v0.1.0 5 years ago
LICENSE.md Version 0.0.1, setup.py compatibility, another xy fix. 6 years ago
MANIFEST.in Version 0.0.1, setup.py compatibility, another xy fix. 6 years ago
README.md feat(output): Support compression 23 days ago
mb-util Enabled support for ArcGIS Cache Format. (#77) 11 days ago
patch Add patch 5 years ago
setup.py Bump version 3 years ago
README.md

Hands-On Time

Studio Overview

- Data sources (tilesets)
- Style layers
- Creates a (hosted) style file
- Creates (hosted) assets like fonts & icons
- Allows for easy mobile & HTML integration with a “style URL”

www.mapbox.com/studio/styles/justin/ciwpmahqb00ap2qqy2lky08jc/edit/

WeWork Sh... Publish

+ New layer

- Country labels 3 layers
- State labels 3 layers
- Marine labels 6 layers
- City labels 5 layers
- place-islands
- place-town
- place-village
- place-hamlet
- place-suburb
- place-neighbourhood
- place-islets-archipelago-aboriginal
- airport-label
- POI labels (scalerank 1) 2 layers
- Water labels 1 layer
- POI labels (scalerank 2) 2 layers
- Road labels 3 layers
- POI labels (scalerank 3) 2 layers
- waterway-label
- Admin boundaries 5 layers
- Bridges 34 layers
- Roads 27 layers
- Tunnels 24 layers
- building
- Aeroways 3 layers
- barrier_line-land-line
- barrier_line-land-polygon

Properties

7.5 120.922,31.350

Search
Map position
Debug
History
Help

沈高镇 丁伙镇 Taizhou Yangzhou Rugao Rudong 真州镇 Zhenjiang Yangzhong Nantong Binhai Park Jingjiang Nantong Haifu Town Jurong Jiangyin Haimen Changzhou Qidong 薛埠镇 Jintan 东港镇 Changshu 城桥镇 Shanghuang Town Wuxi 陈家镇 桥镇 Liyang 马山镇 Taicang Yixing Shezhu Town Suzhou Anting Shanghai Langxi 临湖镇 七都镇 西塘镇 青村镇 Guangde Huzhou Gaoyu Dayun Jiaxing 石化街道 五龙乡 Anji Tongxiang Deqing Haiyan Baofu 临平 衢山镇 Ganpu 岱东镇 太阳镇 Lin'an Hangzhou Cixi 师桥镇

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7.5 120.922,31.350

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water
water shadow
background

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Properties

water

Style | Select data

Basics

Color hsl(52, 85%, 49%)

Pattern none

Opacity 1

Antialias

1px stroke hsl(185, 2%, 10%)

Translate 0 px x / 0 px y

Translate anchor

Edit | Values

RGB | HSV

H 52

S 92

V 91

a 100

7.5 120.922,31.350

Search

Map position

Debug

History

Help

沈高镇 Taizhou Rugao Rudong Nantong Binhai Park Nantong Haimen Qidong 城桥镇 陈家镇 马山镇 Taicang Yixing Suzhou Anting Shanghai 临湖镇 七都镇 西塘镇 青村镇 Huzhou Dayun Jiaxing 石化街道 Tongxiang Deqing Haiyan 临平 Ganpu Lin'an Hangzhou Cixi 师桥镇

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- barrier_line-land-polygon

Properties

water

Style | Select data

Basics

Color hsl(353, 92%, 74%)

Pattern none

Opacity 1

Antialias

1px stroke hsl(185, 2%, 10%)

Translate 0 px x / 0 px y

Translate anchor

Edit | Values

RGB | HSV

H 353

S 48

V 98

a 100

7.5 120.922,31.350

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WeWork Shanghai Dark

Share your style with friends, integrate it into an application, or use it with other mapping software:

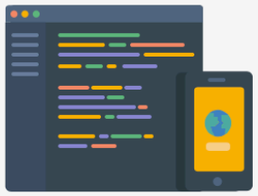
Share and preview

Share URL:

```
https://api.mapbox.com/styles/v1/justin/ciwpmahqb00ap2qqy2lky08jc.html?title=true&access_token=pk.eyJ1IjoianVzdGluIiwiYSI6Ijh1RmhSN2cifQ.-R7zSJ3glf2uXy5XzMWYnA#7.5/31.349522/120.922066/0
```

Share your design with your friends and coworkers. Everyone will be able to see the latest published version of this style through this **share URL** link.

Develop with this style



Mapbox | Leaflet

Style URL: mapbox://styles/justin/ciwpmahqb00ap2qqy…

Access token: pk.eyJ1IjoianVzdGluIiwiYSI6Ijh1RmhSN2cif…

Note the **style URL** and **access token** and select a platform to get started:

Preview

View style details

Edit style

Pick an access token

Default Public Token

Use tokens for better access control and analytics.

Attribution

© Mapbox © OpenStreetMap

When using this map style, you must include attribution. For details, read the FAQ.

```
var map = new mapboxgl.Map({
    container: 'map', // container id
    style: 'mapbox://styles/peterqliu/ciug032my008f2ipm1z1rf15q', //stylesheet location
    center: [-122.4232292175293,37.784282779035216], // starting position
    hash: false,
    zoom: 12, // starting zoom
    minZoom: 12,
    maxZoom:16,
      attributionControl: {
      position: 'bottom-left'
    }
});
```

```
map.styleURL = URL(string: "mapbox://styles/justin/ciwvnp7wi00bm2pm3c59c9l4b")
```


Rd
WILLAMETTE HEIGHTS
KINGS HEIGHTS
NW 23rd Ave
NW 21st Ave
NW 18th Ave
PEARL DISTRICT
NW Everett St
Portland
Eastbank Fwy
IRVINGTON
LLOYD DISTRICT
T. H. Banfield Fwy
HOLL
LAUR
E Burnside
SE Stark St
SE Grand Ave
CENTRAL EAST SIDE
BELMON
HA
SW Taylor St
Washington Park
UNIVERSITY DISTRICT
LADD'S ADDITION
SE Division St
SYLVAN
GREEN HILLS
PORTLAND HEIGHTS
MARQUAM HILL
SE 2
Mapbox

Thank You!

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