# Making Vector Tiles: For Pleasure and Profit

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## Summary

Vector Tiles are a great new way to serve geographic data via web maps. They provide significant improvements over traditional methods of creating web maps but are a little more complicated to set up.

This tutorial explains how to use Vector Tiles for both base maps but more importantly, how to create your own vector tile layers. It also explains how to do this using completely free software and avoiding licencing or subscription fees.

In this tutorial, we will cover going from a source geographic file format to viewing tiles on your website using Mapbox GL JS. To achieve this, we will only use free open source tools provided by Mapbox and others. The documentation, we feel requires some improvement for someone to accomplish this, hence this blog post.

## Introduction

Web maps (Haklay et al. 2008) are a great way to present your data; they allow for interactivity, and for users to zoom into their area of interest. But they have a problem with large datasets; they become slow and unresponsive. This decline in performance is because you must download all your data before it is put onto the map. The solution was to tile the data.

### Tiling – What it is and why it matters

Tiling breaks your data into many small square datasets (tiles) than can then be downloaded individually. This means that you only have to download the tiles in the area you interested in rather than the whole dataset. This both reduces the amount of data that the webserver has to send to the user and reduces the amount of data the user's computer must hold in memory.

Tiling was first implemented for raster data with each tile being a 256 x 256 pixel PNG image. It works well for basemaps and is still used by many websites today such as https://www.openstreetmap.org/. Tiles exist in a pyramid structure; at the top of the pyramid (zoom level 0), the whole world is a single tile. Each step down the pyramid (zoom levels 1,2,3, etc.) increases the number of tiles by a factor of 4. Tilesets typically go down to about zoom level 19 at which point one tile covers an area about the size of a single building.

<img src='images/tiles.png'/>

Raster tiles have two significant limitations:

1. They are static – you can't click on an image to get extra information or dynamically change the styling of the map.

2. They are large – while each tile is small, hosting all the tiles uses up a lot of space on your server. For example, a tileset for the UK is around 15 GB.

Due to these limitations, raster tiles are mostly used for base maps and are served by third party services.

### Introducing Vector Tiles

Vector Tiles are a newer take on the idea of tiling, instead of many images the tiles are lots of tiny vector datasets. These vector tiles are usually smaller, as not all pixels need to be coded.

## Prerequisites

Most of the tools in this tutorial are Linux command line applications. So you will need a Linux computer with permission to install the software. If you do not have a Linux computer, you can.

1. Create a virtual machine using software such as [Virtual Box](https://www.virtualbox.org/)

2. On Windows 10, use the [Windows Subsystem for Linux](https://docs.microsoft.com/en-us/windows/wsl/install-win10)

3. Some of the tools are supported on Mac if you have a Mac check documentation

### Software

This tutorial uses a range of different software; not all software is required for every workflow. The flowcharts below highlight which tools are needed to perform each task.

\*\*[tippecanoe](https://github.com/mapbox/tippecanoe)\*\*

Tippecanoe is free software from Mapbox which converts `.geojson` files into vector tiles. It is also supported on Mac.

\*\*[mb-util](https://github.com/mapbox/mbutil)\*\*

Tippecanoe is free software from Mapbox which converts `.mbtiles` files into a folder of `.pbf` vector tiles.

\*\*A text editor\*\*

We will be editing some files, and a simple text editor will be required.

\*\*A HTML Server\*\*

This tutorial was written with [Apache](https://httpd.apache.org/) in mind, but any modern HTML server will do.

\*\*An FTP client\*\*

You will need to upload files to your server. Usually, this is done with an FTP client such as [Filezilla](https://filezilla-project.org/)

\*\*GIS Software\*\*

You will need to project your dataset to `epsg:4326` and convert them into the `.geojson` format. This can be done in a wide range of free GIS software such a [QGIS](https://qgis.org/en/site/). QGIS is available for Windows, Mac, and Linux.

\*\*[openmaptiles](https://github.com/openmaptiles/openmaptiles)\*\*

If you wish to generate your own basemap tiles, you will need to use \*\*openmaptiles\*\*. Alteritvily you can download premade tiles which may be free or may require a one-off payment. openmaptiles is available for Windows, Mac, and Linux (see below).

\*\*[docker](https://www.docker.com/)\*\*

\*\*openmaptiles\*\* requires docker. Docker is available for Windows, Mac, and Linux.

## Part 1: Making Vector Titles

<img src='images/gen\_flowchart.png'/>

### To gzip or not to gzip

Before generating the vector tiles, you must make a decision on if they will be gzipped or not. [gzip](https://en.wikipedia.org/wiki/Gzip) is a compression standard which is supported by all modern browsers. The compressed `.pbf` files are about 25% of the size of the uncompressed ones. This saves storage space on your server and speeds up the download of the tiles, giving your users a better experience.

So gzipped `.pbf` files are better. But to use the gzipped files, you must modify the [HTTP Headers](https://en.wikipedia.org/wiki/List\_of\_HTTP\_header\_fields) to include:

```

Content-Encoding: gzip

```

This will tell the user's browser that the files are gzipped and to ungzip them before trying to use them. Without this HTTP Header, the browser will be unable to read and render the tiles. So gzipping is only a good idea if you are able to modify the HTTP Headers on your server.

The sections below will outline how to generate tiles with and without gzipping and how to modify HTTP headers when using [Apache](https://httpd.apache.org/) server. If you are using a different server software, check for a tutorial on how to modify HTTP headers.

### Making a Basemap

To have a basemap, you have three main choices:

1. Get your basemap from a 3rd party service such as Mapbox, depending on your usage you may need to pay.

2. Get premade tiles from OpenMapTiles, free for non-profit uses but a $1000 fee for commercial projects

3. Generate your own tiles, free but most difficult.

#### Using OpenMapTiles

You can sign up for a free account at www.openmaptiles.com

You can download tiles for the whole [planet](https://openmaptiles.com/downloads/planet/) or just a [country](https://openmaptiles.com/downloads/europe/great-britain/england/) or [region](https://openmaptiles.com/downloads/europe/great-britain/england/leeds/). OpenMapTiles allow for free download of tiles for education and evaluation purposes but charge up to $1,000 for a onetime download for commercial projects.

The download will be a single `.mbtiles` file.

To convert to a folder of gzipped tiles, we will use \*\*mb-util\*\*

```sh

./mb-util --image\_format=pbf countries.mbtiles countries

```

you can convert the gzipped files to ungzipped files with the following bash commands:

```sh

gzip -d -r -S .pbf \*

find . -type f -exec mv '{}' '{}'.pbf \;

```

#### Generating your own Basemap

To generate your own basemap you will need to install Docker and `openmaptiles` there are installation instructions [here]( <https://openmaptiles.org/docs/generate/generate-openmaptiles/>). The OpenMapTIles can easily built for an individual country or region using the [quick start]( <https://github.com/openmaptiles/openmaptiles/blob/master/QUICKSTART.md>) guide.

OpenMapTiles uses [Geofabrik](<http://download.geofabrik.de/index.html>) regions, so you can build a tile layer for any one of those regions with minimal effort. OpenMapTitles also draws in some low-resolution data for the rest of the world, so your map does not appear to be floating in a sea of nothing.

### Making Tiles from your own Data

#### Converting your data to GeoJSON

The tools we use to create Vector Tiles require the input data to be in the `.geojson` format and to be using the `epsg:4326` coordinate reference system.

Converting a shapefile into tile:

An example file in question would be the UK MSOA boundaries which are roughly ~600M in size when converted to plain `.geojson` file.

This could be achieved in R for instance:

```R

# get LAs

folder = "/tmp/Counties\_and\_UA"

if(!dir.exists(folder)) {

dir.create(folder)

}

url = "https://opendata.arcgis.com/datasets/f341dcfd94284d58aba0a84daf2199e9\_0.zip"

msoa\_shape = list.files(folder, pattern = "shp")[1]

if(!file.exists(file.path(folder, msoa\_shape))) {

download.file(url, destfile = file.path(folder, "data.zip"))

unzip(file.path(folder, "data.zip"), exdir = folder)

msoa\_shape = list.files(folder, pattern = "shp")[1]

}

library(sf)

msoa = st\_read(file.path(folder, msoa\_shape))

st\_write(msoa, "~/Downloads/msoa.geojson")

```

We have not tested Python but there has to be [packages](https://pypi.org/project/pyshp/1.1.7/) that can read shapefiles and interpret them into GeoJSON. If you have GDAL [installed](https://tracker.debian.org/pkg/gdal) then oneline would achieve the same thing, if you already have downloaded the shapefile. So the above can be done as:

```sh

ogr2ogr -f GeoJSON msoa.geojson /tmp/Counties\_and\_UA/Counties\_and\_Unitary\_Authorities\_December\_2017\_Full\_Extent\_Boundaries\_in\_UK\_WGS84.shp -lco RFC7946=YES

```

#### Converting GeoJSON to Vector Tiles

##### Converting to a single mbtiles file

Let us convert this to a format called `.mbtiles` which is essentially an SQLite zipped formatted the way Mapbox (hence the mb part) can read it.

We will use [`tippecanoe`](https://github.com/mapbox/tippecanoe) repo/package to achieve this.

```sh

tippecanoe -zg -o out.mbtiles --drop-densest-as-needed msoa.geojson

```

//TODO use the mbtile viewer to view the tiles we generated.

We [can now serve](mapbox.mapbox-streets-v8) the `.mbtiles` in a Mapbox JS instance. The drawback here, is an initial lag in downloading the whole file by the client (browser), the pro is, as you probably guess, is this happens only once. It was perhaps developed for mobile apps and works perfectly for such cases.

//TODO add html example with mbtiles

//TODO test servers and CORS

However, not everyone can do this as the size of the package could be large and slower connection clients would be punished harshly. It is important to shorten the ["time to first byte"](https://en.wikipedia.org/wiki/Time\_to\_first\_byte). That is why we should consider unzipping the package into single `pbf` tiles. Protocol buffers (pbf) is a language-neutral [serialaization](https://developers.google.com/protocol-buffers) by Google.

We can do this by:

##### Converting to a folder of pbf files

Converting to a folder of `.pbf` tiles with gzip compression

```sh

tippecanoe -zg --output-to-directory=mytiles --drop-densest-as-needed msoa.geojson

```

If you don't want to use gzipped `.pbf` files then you can generate uncompressed files with tippecanoe by:

```sh

tippecanoe -zg --output-to-directory=mytiles --drop-densest-as-needed --no-tile-compression msoa.geojson

```

## Part 2: Hosting Vector Tiles

When hosting vector tiles on your own server, you have two main choices:

1. Install a specialist tile hosting server such as TileServer and use a `.mbtiles`

2. Generate individual `.pbf` tiles and then upload them to a folder on your server.

### Hosting using a mbtiles file

See documentation at https://openmaptiles.org/docs/

### Hosting a folder of individual titles

This method is very simple and does not require the installation of specialist software on your server. This means you can even host the tiles on file servers such as Amazon S3. It should also improve the hosting performance as your server does not need to do any processing, simply serve the requested files. The downside is that you get no support or helpful features included in your chosen software. It is also less suited to hosting datasets that you expect to update regularly.

#### Uploading your tiles

Once you have created your tiles simply upload them to your server using an FTP client such as [Filezilla](https://filezilla-project.org/)

#### Modifying HTML Headers

There are two reasons you may want to modify HTML headers.

1. To enable gzip compression (see above)

2. To enable [CORS](https://en.wikipedia.org/wiki/Cross-origin\_resource\_sharing)

Cross Origin Resouce Sharing (CORS) is required if you wish to host the tiles on a different server from the one that will serve your website. Common use cases are:

1. You are using separate servers for tile hosting (e.g. Google Cloud or Amazon S3) than for web hosting.

2. You wish to use the [Maputnik](https://maputnik.github.io/) style editor to build your `style.json` file (see below).

If you are using Apache server, HTML headers can be simply modified by adding a `.htaccess` file into the folder containing your vector tiles. The `.htaccess` file will apply to all the subfolders below the file, so storing all your tiles in a single folder is a good idea.

\*\*Example folder structure\*\*

```

/index.html

/tiles

.htaccess

/basemap

/mytiles1

/mytiles2

```

\*\*Example `.htaccess` file\*\*

```

Header add Access-Control-Allow-Origin "\*"

Header add Access-Control-Allow-Methods: "GET, POST"

Header set Content-Encoding: gzip

```

If your `.htaccess` file is not working you may need to [enable this feature](https://stackoverflow.com/questions/12202387/htaccess-not-working-apache) in your server config file.

### Hosting Fonts

If your map includes text tables, such as road of country names you will need to provide the fonts you wish to use. You can download a selection of fonts [from this repo]( https://github.com/ITSLeeds/VectorTiles/releases) and upload them to your server in a folder called fonts. You will need to unzip the files and uploaded them in the file structure shown below.

\*\*Example folder structure\*\*

```

/index.html

/fonts

/metropolis

Metropolis-Black.pbf

Metropolis-BlackItalic.pbf

/noto-sans

NotoNaskhArabic-Bold.pbf

/mytiles2

```

## Part 3: Visualising Vector Tiles

There are many ways to view vector tiles, but when building a website, we recommend using Mapbox GL JS. Mapbox GL JS is a Javascript library which takes advantage of [WebGL](https://en.wikipedia.org/wiki/WebGL) this means the library can use both the GPU and the CPU to render your maps rather than just the CPU as was the case with older libraries such as [leaflet]( https://leafletjs.com/). The use of the GPU means that you can render larger and more complex datasets such as 3D maps, animations, and other advanced features.

Although Mapbox GL JS is open source, it is maintained by Mapbox and most of the documentation steers you towards using Mapbox's paid services. However, it works equally well with vector tiles hosted from any location.

Mapbox GL JS has good [documentation](https://docs.mapbox.com/mapbox-gl-js/api/) and lots of [examples](https://docs.mapbox.com/mapbox-gl-js/examples/) to this tutorial will focus on the changes required for hosting your own vector tiles and supporting multiple vector tile layers.

<img src='images/vis\_flowchart.png'/>

This example is based on the Mapbox getting started [example](https://docs.mapbox.com/mapbox-gl-js/example/simple-map/).

```html

<!DOCTYPE html>

<html>

<head>

<meta charset="utf-8" />

<title>Display a map</title>

<meta name="viewport" content="initial-scale=1,maximum-scale=1,user-scalable=no" />

<script src="https://api.mapbox.com/mapbox-gl-js/v1.9.0/mapbox-gl.js"></script>

<link href="https://api.mapbox.com/mapbox-gl-js/v1.9.0/mapbox-gl.css" rel="stylesheet" />

<style>

body { margin: 0; padding: 0; }

#map { position: absolute; top: 0; bottom: 0; width: 100%; }

</style>

</head>

<body>

<div id="map"></div>

<script>

mapboxgl.accessToken = 'NotNeeded';

var map = new mapboxgl.Map({

container: 'map', // container id

style: 'https://www.mysite.com/tiles/style.json', // stylesheet location

center: [-1, 53], // starting position [lng, lat]

zoom: 9 // starting zoom

});

</script>

</body>

</html>

```

The key changes from the Mapbox example are; that `mapboxgl.accessToken` must be defined but is not used as we are not connecting to the Mapbox services, and the location of the `style.json` has been changed to a URL on your server.

### Constructing the style.json file

You will notice that in the HTML example above, we made no reference to where our vector tiles are of how they should be displayed. This is because all this information is contained within a stylesheet `.json` file. The full specification for the stylesheet can be found [here](https://docs.mapbox.com/mapbox-gl-js/style-spec/), but a simplified structure is shown below.

```json

{

"version": 8,

"name": "Basic",

"metadata": {

"openmaptiles:version": "3.x"

},

"sources": {

"openmaptiles": {

"type": "vector",

"tiles": ["https://www.mysite.com/tiles/basemap/{z}/{x}/{y}.pbf"]

},

"msoa": {

"type": "vector",

"tiles": ["https://www.mysite.com/tiles/msoa/{z}/{x}/{y}.pbf"

]

}

},

"glyphs": "https://www.mysite.com/fonts/{fontstack}/{range}.pbf",

"layers": [

{

"id": "background",

"type": "background",

"paint": {

"background-color": "hsl(47, 26%, 88%)"

}

},

{

"id": "landuse-residential",

"type": "fill",

"source": "openmaptiles",

"source-layer": "landuse",

"filter": [

"all",

[

"==",

"$type",

"Polygon"

],

[

"in",

"class",

"residential",

"suburb",

"neighbourhood"

]

],

"layout": {

"visibility": "visible"

},

"paint": {

"fill-color": "hsl(47, 13%, 86%)",

"fill-opacity": 0.7

}

},

{

"id": "msoa\_layer",

"type": "fill",

"source": "msoa",

"source-layer": "msoa",

"layout": {

"visibility": "visible"

},

"paint": {

"fill-color": "hsl(105, 13%, 86%)",

"fill-opacity": 0.7

}

}

],

"id": "basic"

}

```

### Dynamically adding vector tile layers

The `style.json` file is good for vector tiles that you always want to show such as basemaps, but is not dynamic. If you have layers that you wish to toggle on and off then you need a more dynamic method to style the vector tiles.

Another [Mapbox example]( https://docs.mapbox.com/mapbox-gl-js/example/third-party/) is useful:

```js

map.on('load', function() {

map.addSource('msoa', {

'type': 'vector',

'tiles': ["https://www.mysite.com/tiles/msoa/{z}/{x}/{y}.pbf"],

'minzoom': 6,

'maxzoom': 14

});

map.addLayer(

{

'id': 'msoa',

'type': 'fill',

'source': 'msoa', // must match name in .addSource

'source-layer': 'msoa', // must match layer name given when titles were created check metadata.json

"paint": {

"fill-color": {

"property": "population",

"stops": [

[ 1000, "#053061"],

[2000, "#053061"],

[3000, "#2166ac" ],

],

"type": "exponential"

},

"fill-opacity": 0.7

}

}

});

```

## References:

Haklay, Muki, Alex Singleton, and Chris Parker. "Web mapping 2.0: The neogeography of the GeoWeb." Geography Compass 2.6 (2008): 2011-2039.