Bing Maps Tile System

Bing

Bing Maps provides a world map that users can directly manipulate to pan and zoom. To make this interaction as fast and responsive as possible, we chose to pre-render the map at many different levels of detail, and to cut each map into tiles for quick retrieval and display. This document describes the projection, coordinate systems, and addressing scheme of the map tiles, which collectively are called the Bing Maps Tile System.

Map Projection

To make the map seamless, and to ensure that aerial images from different sources line up properly, we have to use a single projection for the entire world. We chose to use the **Mercator projection**, which looks like this:

Although the Mercator projection significantly distorts scale and area (particularly near the poles), it has two important properties that outweigh the scale distortion:

1. It's a **conformal** projection, which means that it preserves the shape of relatively small objects. This is especially important when showing aerial imagery, because we want to avoid distorting the shape of buildings. Square buildings should appear square, not rectangular.

2. It's a **cylindrical** projection, which means that north and south are always straight up and down, and west and east are always straight left and right.

Since the Mercator projection goes to infinity at the poles, it doesn't actually show the entire world. Using a square aspect ratio for the map, the maximum latitude shown is approximately 85.05 degrees.

To simplify the calculations, we use the spherical form of this projection, not the ellipsoidal form. Since the projection is used only for map display, and not for displaying numeric coordinates, we don't need the extra

precision of an ellipsoidal projection. The spherical projection causes approximately 0.33% scale distortion in the Y direction, which is not visually noticeable.

Ground Resolution and Map Scale

In addition to the projection, the ground resolution or map scale must be specified in order to render a map. At the lowest level of detail (Level 1), the map is 512 x 512 pixels. At each successive level of detail, the map width and height grow by a factor of 2: Level 2 is 1024 x 1024 pixels, Level 3 is 2048 x 2048 pixels, Level 4 is 4096 x 4096 pixels, and so on. In general, the width and height of the map (in pixels) can be calculated as:

$$\text{map width} = \text{map height} = 256 * 2^{\text{level}} \text{ pixels}$$

The **ground resolution** indicates the distance on the ground that's represented by a single pixel in the map. For example, at a ground resolution of 10 meters/pixel, each pixel represents a ground distance of 10 meters. The ground resolution varies depending on the level of detail and the latitude at which it's measured. Using an earth radius of 6378137 meters, the ground resolution (in meters per pixel) can be calculated as:

$$\text{ground resolution} = \cos(\text{latitude} * \pi/180) * \text{earth circumference} / \text{map width}$$

$$= (\cos(\text{latitude} * \pi/180) * 2 * \pi * 6378137 \text{ meters}) / (256 * 2^{\text{level}} \text{ pixels})$$

The **map scale** indicates the ratio between map distance and ground distance, when measured in the same units. For instance, at a map scale of 1 : 100,000, each inch on the map represents a ground distance of 100,000 inches. Like the ground resolution, the map scale varies with the level of detail and the latitude of measurement. It can be calculated from the ground resolution as follows, given the screen resolution in dots per inch, typically 96 dpi:

$$\text{map scale} = 1 : \text{ground resolution} * \text{screen dpi} / 0.0254 \text{ meters/inch}$$

$$= 1 : (\cos(\text{latitude} * \pi/180) * 2 * \pi * 6378137 * \text{screen dpi}) / (256 * 2^{\text{level}} * 0.0254)$$

This table shows each of these values at each level of detail, **as measured at the Equator**. (Note that the ground resolution and map scale also vary with the latitude, as shown in the equations above, but not shown in the table below.)

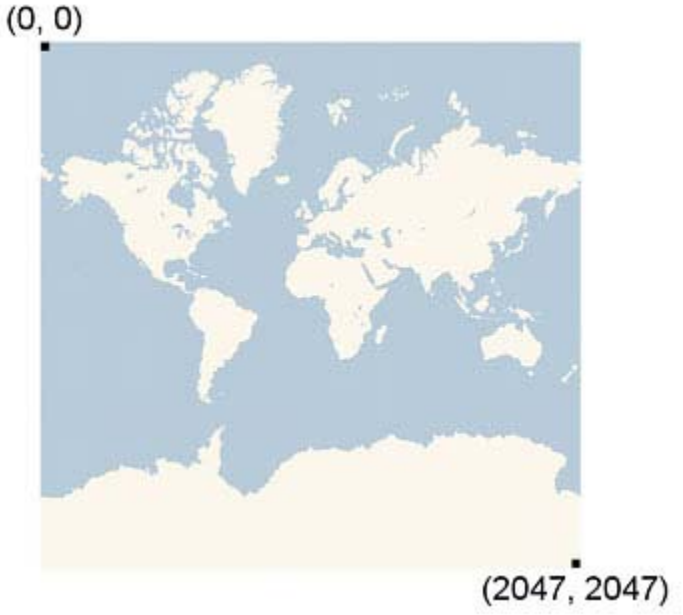
Level of Detail	Map Width and Height (pixels)	Ground Resolution (meters / pixel)	Map Scale (at 96 dpi)
1	512	78,271.5170	1 : 295,829,355.45
2	1,024	39,135.7585	1 : 147,914,677.73
3	2,048	19,567.8792	1 : 73,957,338.86
4	4,096	9,783.9396	1 : 36,978,669.43

5	8,192	4,891.9698	1 : 18,489,334.72
6	16,384	2,445.9849	1 : 9,244,667.36
7	32,768	1,222.9925	1 : 4,622,333.68
8	65,536	611.4962	1 : 2,311,166.84
9	131,072	305.7481	1 : 1,155,583.42
10	262,144	152.8741	1 : 577,791.71
11	524,288	76.4370	1 : 288,895.85
12	1,048,576	38.2185	1 : 144,447.93
13	2,097,152	19.1093	1 : 72,223.96
14	4,194,304	9.5546	1 : 36,111.98
15	8,388,608	4.7773	1 : 18,055.99
16	16,777,216	2.3887	1 : 9,028.00
17	33,554,432	1.1943	1 : 4,514.00
18	67,108,864	0.5972	1 : 2,257.00
19	134,217,728	0.2986	1 : 1,128.50
20	268,435,456	0.1493	1 : 564.25
21	536,870,912	0.0746	1 : 282.12
22	1,073,741,824	0.0373	1 : 141.06
23	2,147,483,648	0.0187	1 : 70.53

Pixel Coordinates

Having chosen the projection and scale to use at each level of detail, we can convert geographic coordinates into pixel coordinates. Since the map width and height is different at each level, so are the pixel coordinates. The pixel at the upper-left corner of the map always has pixel coordinates (0, 0). The pixel at the lower-right corner of the map has pixel coordinates (width-1, height-1), or referring to the equations in the previous

section, (256 * 2^{level}–1, 256 * 2^{level}–1). For example, at level 3, the pixel coordinates range from (0, 0) to (2047, 2047), like this:



Given latitude and longitude in degrees, and the level of detail, the pixel XY coordinates can be calculated as follows:

```
sinLatitude = sin(latitude * pi/180)
```

```
pixelX = ((longitude + 180) / 360) * 256 * 2^level
```

```
pixelY = (0.5 – log((1 + sinLatitude) / (1 – sinLatitude)) / (4 * pi)) * 256 * 2^level
```

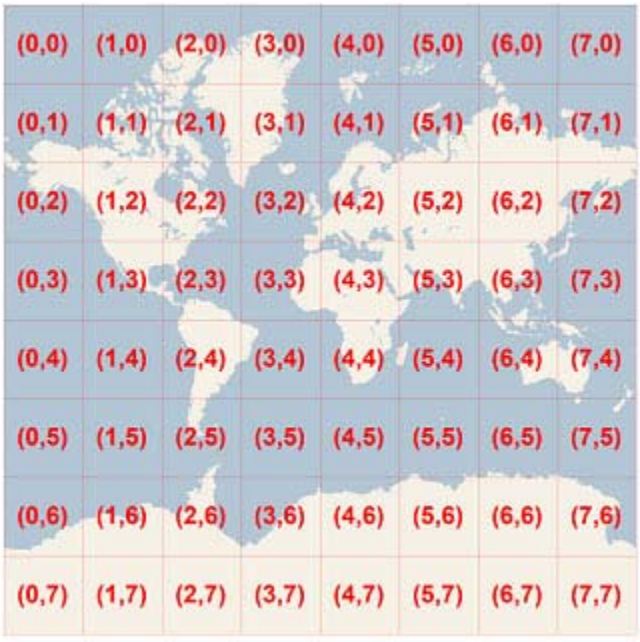
The latitude and longitude are assumed to be on the WGS 84 datum. Even though Bing Maps uses a spherical projection, it's important to convert all geographic coordinates into a common datum, and WGS 84 was chosen to be that datum. The longitude is assumed to range from -180 to +180 degrees, and the latitude must be clipped to range from -85.05112878 to 85.05112878. This avoids a singularity at the poles, and it causes the projected map to be square.

Tile Coordinates and Quadkeys

To optimize the performance of map retrieval and display, the rendered map is cut into tiles of 256 x 256 pixels each. As the number of pixels differs at each level of detail, so does the number of tiles:

```
map width = map height = 2^level tiles
```

Each tile is given XY coordinates ranging from (0, 0) in the upper left to (2^{level}–1, 2^{level}–1) in the lower right. For example, at level 3 the tile coordinates range from (0, 0) to (7, 7) as follows:



Given a pair of pixel XY coordinates, you can easily determine the tile XY coordinates of the tile containing that pixel:

```
tileX = floor(pixelX / 256)

tileY = floor(pixelY / 256)
```

To optimize the indexing and storage of tiles, the two-dimensional tile XY coordinates are combined into one-dimensional strings called quadtree keys, or "quadkeys" for short. Each quadkey uniquely identifies a single tile at a particular level of detail, and it can be used as an key in common database B-tree indexes. To convert tile coordinates into a quadkey, the bits of the Y and X coordinates are interleaved, and the result is interpreted as a base-4 number (with leading zeros maintained) and converted into a string. For instance, given tile XY coordinates of (3, 5) at level 3, the quadkey is determined as follows:

$tileX = 3 = 011_2$

$tileY = 5 = 101_2$

$quadkey = 100111_2 = 213_4 = \text{“213”}$

Quadkeys have several interesting properties. First, the length of a quadkey (the number of digits) equals the level of detail of the corresponding tile. Second, the quadkey of any tile starts with the quadkey of its parent tile (the containing tile at the previous level). As shown in the example below, tile 2 is the parent of tiles 20 through 23, and tile 13 is the parent of tiles 130 through 133:

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