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quadkeyr: Tools for converting QuadKey-identified datasets (Microsoft's Bing Maps Tile System) into raster images and analyzing Meta (Facebook) Mobility Data

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Software

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Summary

The quadkeyr R package presents a comprehensive toolkit for generating raster images from Quadkey-Identified data within Microsoft's Bing Maps Tile System (Schwartz, 2022). Designed to integrate Quadkey-Identified data into R workflows, this package facilitates the creation of QuadKey grids and raster images and introduces specialized functions for the processing of Meta (also known as Facebook) Mobility data (*Data for Good at Meta Website*, 2024).

The goal of quadkeyr is to:

1. **Convert a QuadKey to a Simple Features data.frame (and more):** quadkeyr provides functions to convert QuadKeys to an sf POINT data.frame or sf POLYGON data.frame (Pebesma, 2018) (Figure 1). Additionally, it offers all the R functions described in the official documentation (Schwartz, 2022) for converting QuadKeys to and from tiles, pixels, and geographic coordinates.

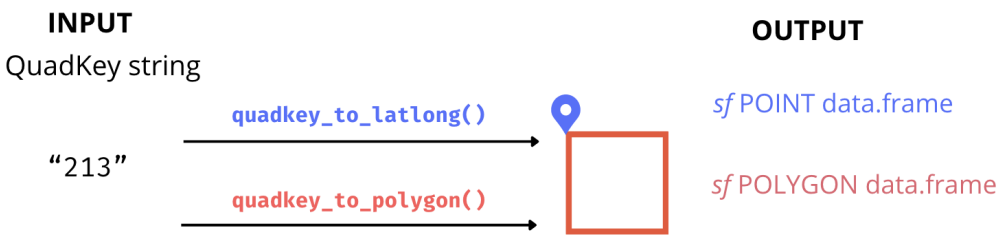

Figure 1: Convert a QuadKey to a Simple Features data.frame.

2. **Generate Raster Images from Quadkey-Identified Data:** Complete a grid of QuadKeys within a specified area and zoom level, and create a stars raster (Pebesma & Bivand, 2023). You can also directly convert QuadKeys in a data.frame column into an sf POLYGON data.frame (Figure 2).

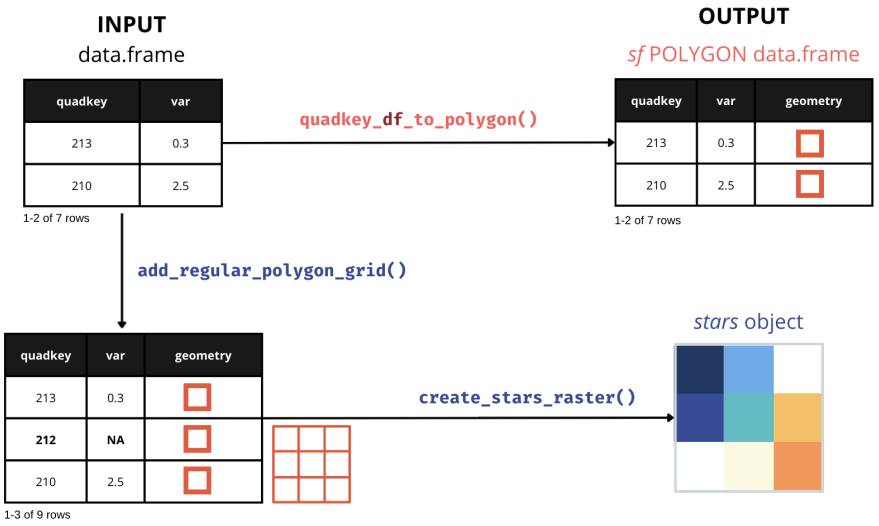

Figure 2: Generate an `sf` POLYGON data.frame or a `stars` object from Quadkey-Identified datasets

3. **Convert Meta (Facebook) Mobility QuadKey-Identified Datasets into Raster Files:** Convert Meta (Facebook) mobility data `.csv` files into `.tif` files by day and hour reported (Figure 3).

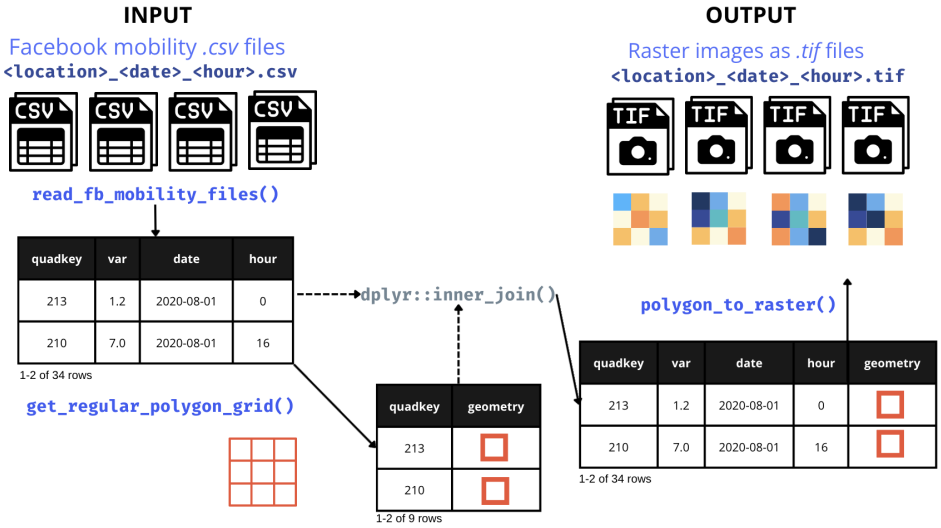

Figure 3: Convert Meta (Facebook) Mobility QuadKey-Identified Datasets into Raster Files.

4. **Offer an App for visualizing QuadKeys on a map:** Introduce a QuadKey visualization application enabling users to validate function outcomes.

Statement of need

What are QuadKeys in Tile Maps?

Tile maps divide the Earth's surface into a grid of tiles, with each tile corresponding to a specific geographic area at various zoom levels.

QuadKeys represent a location on a map by encoding its hierarchical spatial position as a sequence of characters (Figure 4). They provide an efficient method to address and retrieve

specific map tiles, facilitating rapid display within mapping applications.

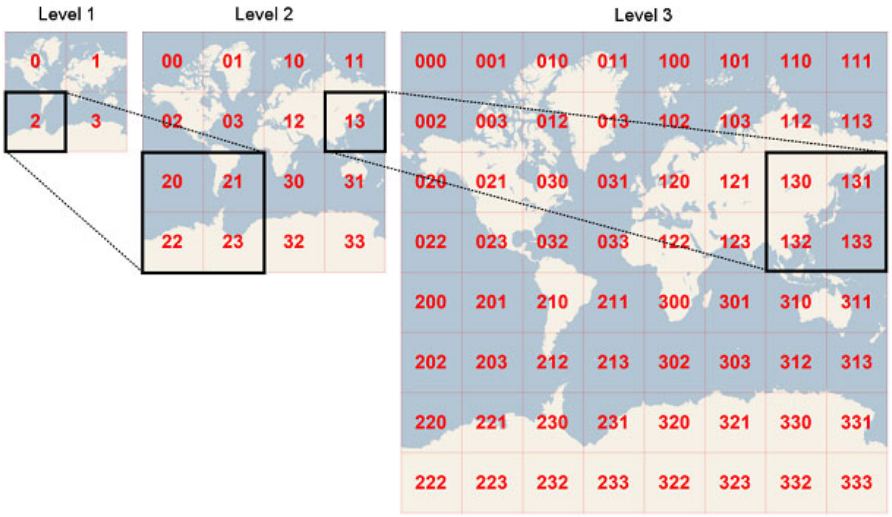

Figure 4: The QuadKey of any tile starts with the QuadKey of its parent tile (the containing tile at the previous level). Image extracted from Microsoft's Bing Maps Tile System webpage.

QuadKeys, tiles, pixels and geographic coordinates

Tile maps are composed of pixels that are grouped into tiles. Later, the tiles are converted to QuadKeys to optimize map performance, among other benefits described in detail in the official documentation (Schwartz, 2022).

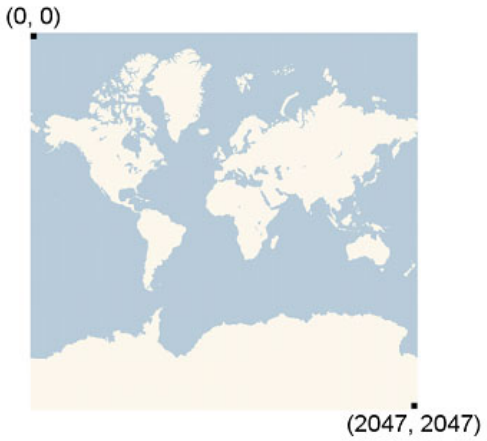

Figure 5: Pixels (0, 0) and (2047, 2047) for a map with zoom level 3. Image extracted from Microsoft's Bing Maps Tile System webpage.

Pixels and tiles are expressed as two-dimensional coordinates, (`pixelX`, `pixelY`) and (`tileX`, `tileY`), but QuadKeys are one-dimensional numeric strings. This is important to understand how the conversion works.

Each geographic pair of coordinates (latitude/longitude) will belong to a specific pixel referenced by coordinates (`pixelX`, `pixelY`) for each zoom level. In Figure 5, you can see pixels (0, 0) and (2047, 2047) for zoom level 3.

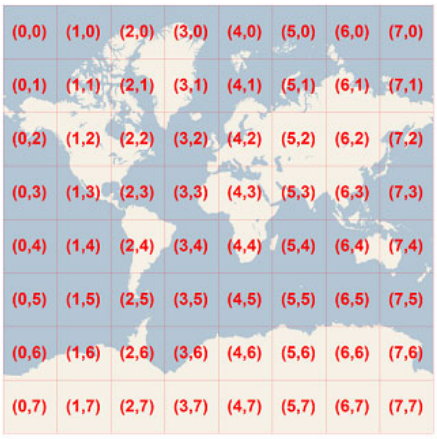

Figure 6: Tile coordinates. Image extracted from Microsoft's Bing Maps Tile System webpage.

For instance, a pixel for zoom level 3 represented by the coordinates `pixelX = 255` and `pixelY = 12` is part of the tile with coordinates `tileX = 0` and `tileY = 0`. The pixel with coordinates (0,0) belongs to tile (0,0), and the pixel (2047, 2047) is part of tile (7,7). You can verify this by comparing Figure 5 and Figure 6.

Converting QuadKeys to and from tiles, pixels, and geographic coordinates

The conversion from QuadKey to geographic coordinates involves a series of smaller transformations that relate to the structure of Tile Maps. All of these intermediary functions, as well as those facilitating the reverse conversion, are available for use within the `quadkeyr` package.

There are different tools in Python, R and other programming languages that help to convert Quadkeys to tiles, pixel or geographic coordinates as well. The package `slippymath` (McBain & Sumner, 2019) is the sole package in the R ecosystem dedicated to analyzing tile maps. Despite some similarities between `quadkeyr` and `slippymath`, the packages were developed with different objectives.

The goal of `quadkeyr` is to provide a new tool to facilitate the analysis of Meta (Facebook) Mobility Data, so it has specific functions tailored for this purpose and is based solely on Microsoft's Bing Tile Maps documentation. On the other hand, `slippymath` is a mature and smaller package featuring general functions for processing tile maps. It was designed to be easily incorporated as a dependency of higher-level tools.

Raster Images

Recent changes in the geospatial R ecosystem such as the retirement of `rgdal` (Bivand et al., 2023), `rgeos` (Bivand & Rundel, 2022) and `maptools` (Bivand & Lewin-Koh, 2022), affected packages that relied on them, as `sp` (Bivand et al., 2013) and `raster` (Hijmans, 2023), which have recently ceased being updated (Bivand et al., 2024; Pebesma & Bivand, 2022). The `quadkeyr` package addresses this issue by adopting the more modern R `stars` package (Pebesma & Bivand, 2023), which converts the `sf` POLYGON data.frame provided as input to a `stars` object. This object can then be saved as a raster image.

Meta (Facebook) Mobility Data and Data for Good

Meta (formerly Facebook) provides datasets in their program Data for good that are QuadKey-Identified, such as the citizen mobility dataset (*Data for Good at Meta Website*, 2024). To facilitate the processing of these data, `quadkeyr` offers specific functions designed to analyze the `.csv` files by date and hour provided and generate `.tif` raster images using no more than

three functions. So far, we are not aware of any other open-source package that provides these functionalities.

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