Visualizing Huge Amounts of Fleet Data

using Shiny and Leaflet

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Smart Machines Europe

- A group at Samsung Semiconductor
- Founded in October 2018
- Focusing on advanced driver assistance systems

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- Data Scientist at Smart Machines Europe
- Prior:
    - Data Scientist at MAN Truck & Bus
    - Data Scientist at BFFT
- Released two R packages on CRAN (CreditMetrics and reliability)

Motivation

- Usage of R Shiny in combination with Leaflet:
  - To further investigate such data
  - To present a first prototype of a future data product to the user
- When using Leaflet, you can quickly exceed the volume of data that can be visualized efficiently
- A maximum of 10,000 data points for visualization seems appropriate here

Shiny Basic parts

Shiny applications have two components:

ui.R

defines the user interface

server.R

defines the server-side of the application

global.R (optional)

everything inside this file is run only on startup of the application

- Loading Data
- Constant Variables
- Database Connections
- ...

App using pure Leaflet

global.R

Some random gps data points (about 2,000) in and around Munich were created

```
library(data.table)
library(dplyr)
library(leaflet)

dat <- fread("data/route.csv")

dat.aug <- dat[, {
  data.table(lat=lat + rnorm(10) / 10000,
             lon=lon + rnorm(10) / 10000)
}, by = 1:nrow(dat)]
```

After augmentation leaflet has to render 20,000 data points

App using pure Leaflet

server.R

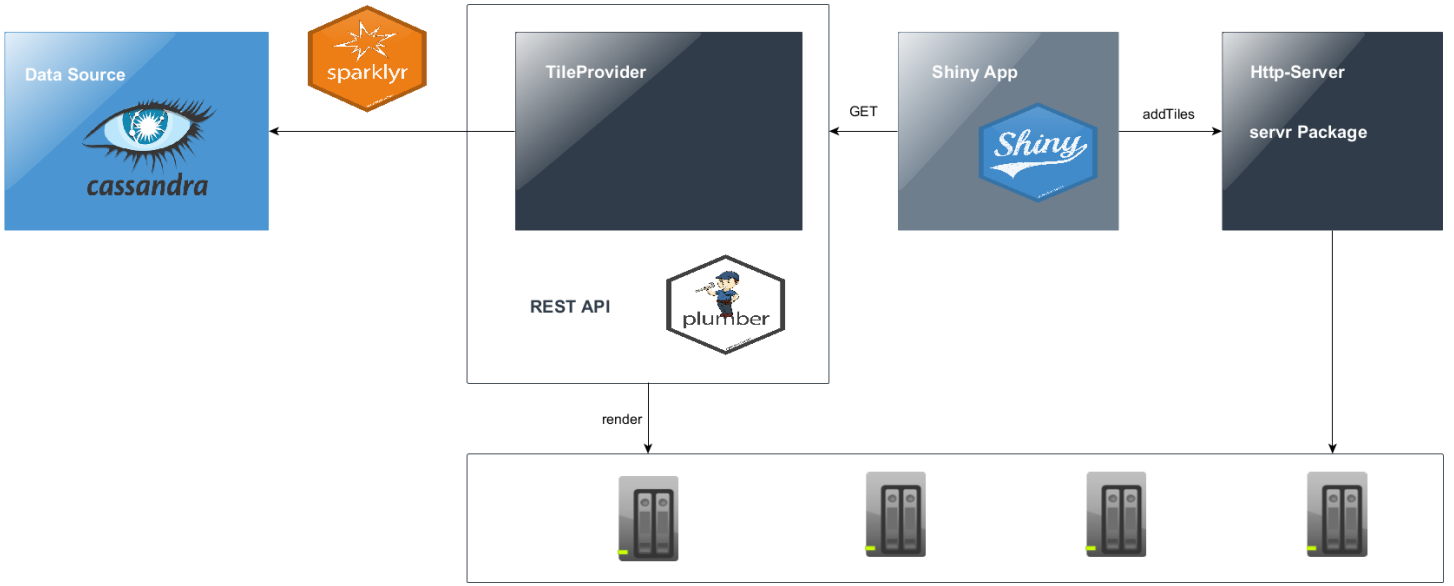
```
function(input, output, session) {

  # Create the map
  output$map <- renderLeaflet({
    leaflet() %>%
      addProviderTiles("CartoDB.DarkMatter") %>%
      addCircles(lng = dat.aug$lon, lat = dat.aug$lat) %>%
      setView(lng = 11.52284, lat = 48.15981, zoom = 10)
})

  output$text <- renderText({
    paste0("showing ", nrow(dat.aug), " points")
  })
}
```

Tile Layer based Approach

- Pure Leaflet seems not to work well with huge amounts of data
- Clustering could reduce/condense the data, but we cannot visualize the complete data
- **Alternative:** use a tile layer based approach



Data Source

- Import all data (about 2 million) into a NoSQL database, Apache Cassandra was chosen here.
- Calculate Mercator-Projection of all GPS data and use this in combination with the zoom level as partitioning key

```
CREATE TABLE IF NOT EXISTS density.points (
    zoom int,
    x int,
    y int,
    lat double,
    lng double,
    primary key ((zoom, x, y), lat, lng)
);
```

- A **Tile** is therefore defined by zoom, x and y

Create Spark Connection to Cassandra

```
library(sparklyr)
library(dplyr)

# fill config
config <- spark_config()
config[["sparklyr.defaultPackages"]] <-
  c("datastax:spark-cassandra-connector:2.3.0-s_2.11")
  config[["spark.cassandra.connection.host"]] <- host
  config[["spark.cassandra.connection.port"]] <- as.integer(port)

# create spark connection
private$sc <- spark_connect(master = "local[*]",
                            version = "2.3.0",
                            hadoop_version = 2.7,
                            config = config)

cass_tbl <- private$sc %>%
  spark_read_source(
    name = table,
    source = "org.apache.spark.sql.cassandra",
    options = list(keyspace = keyspace, table = table))
```

Calculate Tile and Position

```
## see geosphere::mercator
calcTile = function(zoom, lat, lon) {
  latRad <- pi/180 * lat
  n <- 2^zoom
  xTile <- n * ((lon + 180) / 360)
  yTile <- n * (1 - (log(tan(latRad) + 1 / cos(latRad)) / pi))
              / 2
  return(data.table(x=xTile, y=yTile))
}

calcPosition = function(dat, xx, yy) {
  dat[, x := x - xx]
  dat[, y := y - yy]
  dat[, y := 1.0 - y]

  ## tileSize = 256
  dat[, u := x * tileSize]
  dat[, v := y * tileSize]
  dat[, x := floor(u)]
  dat[, y := floor(v)]
}
```

Render Tile

```
renderTile = function(zoom, x, y)
{
  fileNameWithPath <- paste0("tile/", zoom, "_", x, "_", y, ".png")
  if (file.exists(fileNameWithPath)) {
    cat(paste0("chached zoom=", zoom, ", x=", x, ", y=", y, "\n"))
    return(NULL)
  }

  datTile <- private$calcTile(zoom, dat$lat, dat$lon)
  private$calcPosition(datTile, x, y)

  p <- ggplot(datTile) + geom_point(aes(x=x, y=y), colour = "blue",
    alpha=0.4, size=1.5) + ylim(1, private$tileSize) +
    xlim(1, private$tileSize)

  ## remove margins, labels and ticks from p

  png(fileNameWithPath, width=private$tileSize,
      height=private$tileSize, units="px", bg = "transparent")
  print(p)
  dev.off()
}
```

Web Services

REST Api

Create REST API to render tiles on port 7000

```
#' @get /render/<z>/<x_from>/<x_to>/<y_from>/<y_to>
render <- function(z, x_from, x_to, y_from, y_to) {
  tileCreator$render(z, x_from, x_to, y_from, y_to)
}
```

Http Server

Create Http Server for serving tiles on port 4321

```
library(servr)
httd()
```

App using Tile Layer based Approach

server.R

```
render <- reactive({
  bounds <- input$map_bounds
  zoom <- input$map_zoom
  if (!is.null(zoom) && !is.null(bounds)) {
    tileNortWest <- calcTile(zoom = zoom, lat = bounds$north,
                             lon = bounds$west)
    tileSouthEast <- calcTile(zoom = zoom, lat = bounds$south,
                              lon = bounds$east)
    x_from <- as.character(round(tileNortWest$x) - 1)
    x_to <- as.character(round(tileSouthEast$x) + 1)
    y_from <- as.character(round(tileNortWest$y) - 1)
    y_to <- as.character(round(tileSouthEast$y) + 1)
    url <- paste0("http://localhost:7000/render/", zoom, "/",
                  x_from, "/", x_to, "/", y_from, "/", y_to)
    httr::GET(url)
  }
  leafletProxy("map") %>%
    addTiles(
      urlTemplate = "http://localhost:4321/tile/{z}_{x}_{y}.png",
      options = tileOptions(maxZoom = 19))
```

Summary

- Alternatively to using pure Leaflet approach we can use a tile layer based one to render huge amounts of data.
- Depending on the size of data and the use case we have two possibilities:
  - Render tiles on-the-fly per request
  - Render tiles in a batch run
- Sometimes it can take some time to render all tiles, so it seems reasonable to use the new future package to handle such asynchronous tasks.

Thank you! Questions?

Demo: https://github.com/wittmaan/UseR2019

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Literature

- Go implementation: https://github.com/fogleman/density
- https://en.wikipedia.org/wiki/Mercator_projection
- https://rstudio.github.io/leaflet/
- http://spark.rstudio.com/