ACMT Example: Population density over distance

Weipeng Zhou

2/22/2021

Introduction

Automatic Context Measurement Tool (ACMT) is a convenient tool for studying neighbourhoods in the United States. Based on the user-provided address and radius, ACMT locates a geographical area and outputs context measurements (population, education level, commute time, etc.) for the area. ACMT is easy to install, highly reproducible and works consistently across computer platforms.

There are various ways of using ACMT and here we show one example – 5-city comparison of population density decay as function of distance from City Hall.

We use ACMT to get population densities for 5 cities (Seattle, Los Angeles, Chicago, New York and Boston) over 5 radiuses (1000, 2000, 3000, 4000, 5000). We consider the center of a city to be the location of its City Hall. After getting the densities, we make a plot of density over radius, categoried by cities; and we will be able to tell which city is the most populated across space.

We take the following steps:

1. Find the addresses of each city's City Hall
2. Use ACMT's geocoder to convert the addresses to coordinates
3. Use ACMT to get the population measurement for each coordinate over 5 radiuses (1000, 2000, 3000, 4000, 5000)
4. Calculate population density
5. Plot density vs. radius, categoried by cities

Example

1. Find the addresses of each city's City Hall

We have gathered the City Hall addresses for Seattle, Los Angeles, Chicago, New York and Boston from Google.

```r
source("RefreshAPIKey.R")
source("GeocoderACMT.R")

library(ggplot2)
city_hall_to_address_list <- list(
  seattle_city_hall="600 4th Ave, Seattle, WA 98104",
  los_angeles_city_hall="200 N Spring St, Los Angeles, CA 90012",
  chicago_city_hall="121 N LaSalle St, Chicago, IL 60602",
  new_york_city_hall="City Hall Park, New York, NY 10007",
  boston_city_hall="1 City Hall Square #500, Boston, MA 02201"
)
```

2. Use ACMT's geocoder to convert the addresses to coordinates

ACMT comes with a handy geocoder that converts addresses to latitude/longtitude coordinates. We check if geocoder is available in the version of ACMT you installed; if it is not available, we use the pre-computed coordinates.

```
convert_address_to_lat_long <- function (city_hall_to_address_list) { # function to get get lat/long fo
  city_hall_to_lat_long_list <- vector(mode="list", length=length(city_hall_to_address_list))
  names(city_hall_to_lat_long_list) <- names(city_hall_to_address_list)
  for (name in names(city_hall_to_address_list)){
    city_hall_to_lat_long_list[[name]] <- geocode(city_hall_to_address_list[[name]])
  }
  return(city_hall_to_lat_long_list)
}
```

```
# is geocoder available?
geocoder_is_available <- FALSE
tryCatch({  # note that codes in try is not inside a new function, just treat it as normal R code
  geocode("1959 NE Pacific Street, Seattle, WA 98195")
  geocoder_is_available <- TRUE
}, error = function(condition) {  # note that in error handler, the codes is inside a new function; thi
  print(condition$message)
  print("Geocoder not available: using stored address to lat/long mappings instead")
})

city_hall_to_lat_long_list <- NULL
# call geocoder if available, use hard coded info otherwise
if (geocoder_is_available) {
  city_hall_to_lat_long_list <- convert_address_to_lat_long(city_hall_to_address_list)
} else {
  city_hall_to_lat_long_list <- list(
    seattle_city_hall=list(latitude=47.60328, longitude=-122.3302),
    los_angeles_city_hall=list(latitude=34.05397, longitude=-118.2436),
    chicago_city_hall=list(latitude=41.88334, longitude=-87.63229),
    new_york_city_hall=list(latitude=40.66392, longitude=-73.93835),
    boston_city_hall=list(latitude=42.35773, longitude=-71.05919)
  )
}
```

```
print(city_hall_to_lat_long_list[1:2])
```

```
## $seattle_city_hall
## $seattle_city_hall$latitude
## [1] 47.60328
##
## $seattle_city_hall$longitude
## [1] -122.3302
##
##
## $los_angeles_city_hall
## $los_angeles_city_hall$latitude
## [1] 34.05397
##
```

```
## $los_angeles_city_hall$longitude
## [1] -118.2436
```

3. Use ACMT to get the population measurement for each coordinate over 5 radiuses (1000, 2000, 3000, 4000, 5000)

We create a function for querying ACMT measurements for a list of coordinates and radiuses. We are interested in the variable `total_pop_count`.

```
# function to get the environmental measures for the variables we are intersted
get_variable_measures_from_acmt <- function (city_hall_to_lat_long_list, radius_vector, year, names_of_v
  city_hall_to_distance_to_variable_to_measures_list <- vector(mode="list", length=length(city_hall_to_l
  names(city_hall_to_distance_to_variable_to_measures_list) <- names(city_hall_to_lat_long_list)

  for(city_hall in names(city_hall_to_distance_to_variable_to_measures_list)) {
    distance_to_variable_to_measures_list <- vector(mode="list", length=length(radius_vector))
    names(distance_to_variable_to_measures_list) <- as.character(radius_vector)
    for (distance in radius_vector) {
      print(city_hall)
      print(distance)
      # get lat/long
      latitude <- city_hall_to_lat_long_list[[city_hall]]$latitude
      longitude <- city_hall_to_lat_long_list[[city_hall]]$longitude

      # get environmental measures for all variables
      environmental_measures <- get_acmt_standard_array(long=longitude, lat=latitude, radius_meters = di

      # get environmental measures for the variables are interested
      variable_to_measures_list <- vector(mode="list", length=length(names_of_variable_to_get))
      names(variable_to_measures_list) <- names_of_variable_to_get
      for (name_of_variable in names_of_variable_to_get) {
        value_of_variable <- environmental_measures[environmental_measures$names == name_of_variable, ]$
        variable_to_measures_list[[name_of_variable]] <- value_of_variable
      }
      #distance_to_variable_to_measures_list[[which(distance == radius_vector)]] <- variable_to_measures
      distance_to_variable_to_measures_list[[as.character(distance)]] <- variable_to_measures_list
    }
    city_hall_to_distance_to_variable_to_measures_list[[city_hall]] <- distance_to_variable_to_measures_
  }
  return(city_hall_to_distance_to_variable_to_measures_list)
}
```

```
city_hall_to_lat_long_list <- city_hall_to_lat_long_list
radius_vector <- c(1000, 2000, 3000, 4000, 5000)
year <- 2017
names_of_variable_to_get <- c("total_pop_count")

start_time_get_variable_measures_from_acmt <- Sys.time()
city_hall_to_distance_to_variable_to_measures_list <- get_variable_measures_from_acmt(city_hall_to_lat_l
end_time_get_variable_measures_from_acmt <- Sys.time()
```

```
print(city_hall_to_distance_to_variable_to_measures_list[1:2])
```

```
## $seattle_city_hall
## $seattle_city_hall$`1000`
```

```
## $seattle_city_hall$`1000`$total_pop_count
## [1] 19913.15
##
##
## $seattle_city_hall$`2000`
## $seattle_city_hall$`2000`$total_pop_count
## [1] 66370.01
##
##
## $seattle_city_hall$`3000`
## $seattle_city_hall$`3000`$total_pop_count
## [1] 124443
##
##
## $seattle_city_hall$`4000`
## $seattle_city_hall$`4000`$total_pop_count
## [1] 171655.8
##
##
## $seattle_city_hall$`5000`
## $seattle_city_hall$`5000`$total_pop_count
## [1] 212616
##
##
##
## $los_angeles_city_hall
## $los_angeles_city_hall$`1000`
## $los_angeles_city_hall$`1000`$total_pop_count
## [1] 20238.99
##
##
## $los_angeles_city_hall$`2000`
## $los_angeles_city_hall$`2000`$total_pop_count
## [1] 75561.93
##
##
## $los_angeles_city_hall$`3000`
## $los_angeles_city_hall$`3000`$total_pop_count
## [1] 157296.7
##
##
## $los_angeles_city_hall$`4000`
## $los_angeles_city_hall$`4000`$total_pop_count
## [1] 303411.8
##
##
## $los_angeles_city_hall$`5000`
## $los_angeles_city_hall$`5000`$total_pop_count
## [1] 490890.9
```

```r
print("Between start and end of getting ACMT measures: ")
```

```
## [1] "Between start and end of getting ACMT measures: "
```

```
print(end_time_get_variable_measures_from_acmt - start_time_get_variable_measures_from_acmt)
```

```
## Time difference of 43.88949 mins
```

4. Calculate population density

We create a function for computing population density for the given radiues.

```
add_density_measures <- function(city_hall_to_distance_to_variable_to_measures_list) {
  city_hall_to_distance_to_variable_to_measures_with_population_density_list <- city_hall_to_distance_to
  for (city_hall in names(city_hall_to_distance_to_variable_to_measures_with_population_density_list)){
    for(distance_character in names(city_hall_to_distance_to_variable_to_measures_with_population_densi
      for(variable in names(city_hall_to_distance_to_variable_to_measures_with_population_density_list[
        if(variable == "total_pop_count"){  # add other "if" statements if you want to compute other me
          total_pop_count <- city_hall_to_distance_to_variable_to_measures_with_population_density_list
          distance_numeric <- as.numeric(distance_character)
          population_density <-  total_pop_count/(pi*distance_numeric^2)  # distance is radius
          city_hall_to_distance_to_variable_to_measures_with_population_density_list[[city_hall]][[dista
        }
      }
    }
  }
  return(city_hall_to_distance_to_variable_to_measures_with_population_density_list)
}
```

```
city_hall_to_distance_to_variable_to_measures_with_population_density_list <- add_density_measures(city_
```

```
print(city_hall_to_distance_to_variable_to_measures_with_population_density_list[1:2])
```

```
## $seattle_city_hall
## $seattle_city_hall$`1000`
## $seattle_city_hall$`1000`$total_pop_count
## [1] 19913.15
##
## $seattle_city_hall$`1000`$population_density
## [1] 0.006338554
##
##
## $seattle_city_hall$`2000`
## $seattle_city_hall$`2000`$total_pop_count
## [1] 66370.01
##
## $seattle_city_hall$`2000`$population_density
## [1] 0.005281557
##
##
## $seattle_city_hall$`3000`
## $seattle_city_hall$`3000`$total_pop_count
## [1] 124443
##
## $seattle_city_hall$`3000`$population_density
## [1] 0.004401271
##
##
```

```
## $seattle_city_hall$`4000`
## $seattle_city_hall$`4000`$total_pop_count
## [1] 171655.8
##
## $seattle_city_hall$`4000`$population_density
## [1] 0.003414984
##
##
## $seattle_city_hall$`5000`
## $seattle_city_hall$`5000`$total_pop_count
## [1] 212616
##
## $seattle_city_hall$`5000`$population_density
## [1] 0.002707111
##
##
##
## $los_angeles_city_hall
## $los_angeles_city_hall$`1000`
## $los_angeles_city_hall$`1000`$total_pop_count
## [1] 20238.99
##
## $los_angeles_city_hall$`1000`$population_density
## [1] 0.006442271
##
##
## $los_angeles_city_hall$`2000`
## $los_angeles_city_hall$`2000`$total_pop_count
## [1] 75561.93
##
## $los_angeles_city_hall$`2000`$population_density
## [1] 0.006013028
##
##
## $los_angeles_city_hall$`3000`
## $los_angeles_city_hall$`3000`$total_pop_count
## [1] 157296.7
##
## $los_angeles_city_hall$`3000`$population_density
## [1] 0.005563233
##
##
## $los_angeles_city_hall$`4000`
## $los_angeles_city_hall$`4000`$total_pop_count
## [1] 303411.8
##
## $los_angeles_city_hall$`4000`$population_density
## [1] 0.006036186
##
##
## $los_angeles_city_hall$`5000`
## $los_angeles_city_hall$`5000`$total_pop_count
## [1] 490890.9
##
```

```
## $los_angeles_city_hall$`5000`$population_density
## [1] 0.006250217
```

5. Plot density vs. radius, categoried by cities

We create a function for converting the data we have so far to ggplot friendly format. We then use ggplot to create our plot.

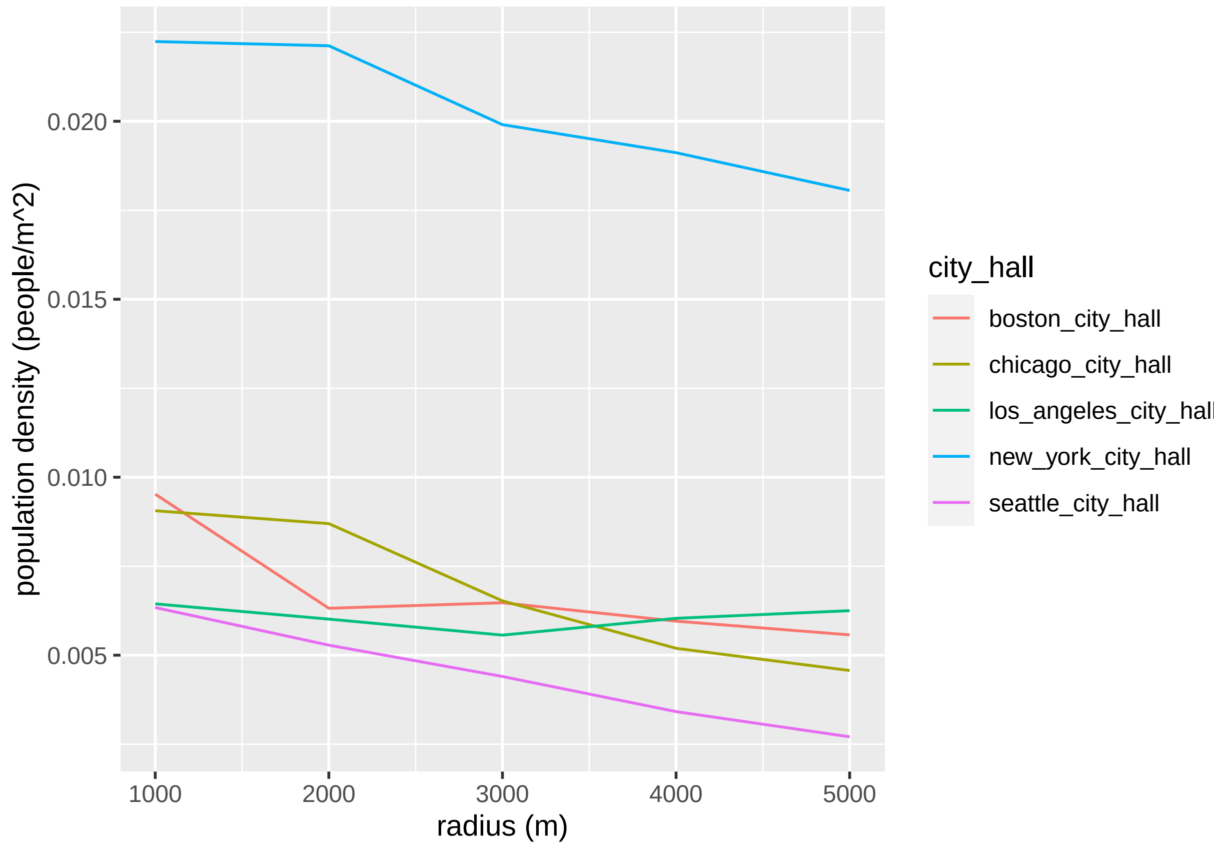
```
convert_to_dataframe_for_plotting <- function (city_hall_to_distance_to_variable_to_measures_with_popula
  city_hall_vector <- c()
  radius_vector <- c()
  variable_vector <- c()
  value_vector <- c()

  for(city_hall in names(city_hall_to_distance_to_variable_to_measures_with_population_density_list)){
    for(distance_character in names(city_hall_to_distance_to_variable_to_measures_with_population_densi
      for(variable in names(city_hall_to_distance_to_variable_to_measures_with_population_density_list[
        city_hall_vector <- c(city_hall_vector, city_hall)
        radius_vector <- c(radius_vector, as.numeric(distance_character))
        variable_vector <- c(variable_vector, variable)
        value_vector <- c(value_vector, city_hall_to_distance_to_variable_to_measures_with_population_de
      }
    }
  }

  dataframe_for_plotting <- data.frame(city_hall_vector, radius_vector, variable_vector, value_vector, s
  names(dataframe_for_plotting) <- c("city_hall", "distance", "variable", "value")
  return(dataframe_for_plotting)
}
```

```
dataframe_for_plotting <- convert_to_dataframe_for_plotting(city_hall_to_distance_to_variable_to_measure
```

```
print(head(dataframe_for_plotting))
```

```
##           city_hall distance           variable        value
## 1 seattle_city_hall     1000    total_pop_count 1.991315e+04
## 2 seattle_city_hall     1000 population_density 6.338554e-03
## 3 seattle_city_hall     2000    total_pop_count 6.637001e+04
## 4 seattle_city_hall     2000 population_density 5.281557e-03
## 5 seattle_city_hall     3000    total_pop_count 1.244430e+05
## 6 seattle_city_hall     3000 population_density 4.401271e-03
```

```
ggplot(dataframe_for_plotting[dataframe_for_plotting$variable == "population_density", ], aes(x=distanc
        geom_line(aes(y=value, col=city_hall)) +
        labs(y="population density (people/m^2)",
             x="radius (m)")
```



Results

We see that New York has a much higher population density, and its density does not reduce much over distances.