ACMT Example: Population density over distance

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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("~/workspace/setup-acmt.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",
  houston_city_hall="901 Bagby St, Houston, TX 77002",
  nashville_city_hall="1 Public Square #303, Nashville, TN 37201"

)
```

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)
}
```

```
geocoder_is_available<-as.data.frame(city_hall_to_address_list) %>% t() %>% as.data.frame() %>%
  rename(address=V1) %>%
  mutate(city_hall=row.names(.), geocoder_is_available=FALSE)

city_hall_lat_long<-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))

for(address in geocoder_is_available$address){
  tryCatch({geocode(address)
    geocoder_is_available$geocoder_is_available[geocoder_is_available$address==address]=TRUE}, error=fu
    print(condition$message)
    print("Geocoder not available: using stored address to lat/long mappings instead")
  })
}

# call geocoder if available, use hard coded info otherwise
city_hall_to_lat_long_list <- NULL
for(address in geocoder_is_available$address){
  city_hall_name<-geocoder_is_available$city_hall[geocoder_is_available$address==address]
  if(geocoder_is_available$geocoder_is_available[geocoder_is_available$address==address]==TRUE){

    city_hall<-list(address)
    names(city_hall)<-city_hall_name
    city_hall_to_lat_long_list<-append(city_hall_to_lat_long_list, convert_address_to_lat_long(city_hal
                                                                  }
  else(city_hall_to_lat_long_list<-append(city_hall_to_lat_long_list, city_hall_lat_long[names(city_hal
}
```

```
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
```

```
##
## $seattle_city_hall$rating
## [1] 0
##
##
## $los_angeles_city_hall
## $los_angeles_city_hall$latitude
## [1] 34.05397
##
## $los_angeles_city_hall$longitude
## [1] -118.2436
##
## $los_angeles_city_hall$rating
## [1] 2
```

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_radius_to_variable_to_measures_list <- vector(mode="list", length=length(city_hall_to_la
  names(city_hall_to_radius_to_variable_to_measures_list) <- names(city_hall_to_lat_long_list)

  for(city_hall in names(city_hall_to_radius_to_variable_to_measures_list)) {
    radius_to_variable_to_measures_list <- vector(mode="list", length=length(radius_vector))
    names(radius_to_variable_to_measures_list) <- as.character(radius_vector)
    for (radius in radius_vector) {
      print(city_hall)
      print(radius)
      # 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 = ra

      # 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
      }
      #radius_to_variable_to_measures_list[[which(radius == radius_vector)]] <- variable_to_measures_li
      radius_to_variable_to_measures_list[[as.character(radius)]] <- variable_to_measures_list
    }
    city_hall_to_radius_to_variable_to_measures_list[[city_hall]] <- radius_to_variable_to_measures_lis
  }
  return(city_hall_to_radius_to_variable_to_measures_list)
}
```

```
setwd('~/workspace')
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")  # the name of the variable in ACMT's returned result
codes_of_acs_variables_to_get <- c("B01001_001")  # speed up; ask ACMT to only query this variable from

start_time_get_variable_measures_from_acmt <- Sys.time()
city_hall_to_radius_to_variable_to_measures_list <- get_variable_measures_from_acmt(city_hall_to_lat_lo
end_time_get_variable_measures_from_acmt <- Sys.time()
```

```
print(city_hall_to_radius_to_variable_to_measures_list[1])
```

```
## $seattle_city_hall
## $seattle_city_hall$`1000`
## $seattle_city_hall$`1000`$total_pop_count
## [1] 20047.59
##
##
## $seattle_city_hall$`2000`
## $seattle_city_hall$`2000`$total_pop_count
## [1] 65734.34
##
##
## $seattle_city_hall$`3000`
## $seattle_city_hall$`3000`$total_pop_count
## [1] 124589.1
##
##
## $seattle_city_hall$`4000`
## $seattle_city_hall$`4000`$total_pop_count
## [1] 171715.4
##
##
## $seattle_city_hall$`5000`
## $seattle_city_hall$`5000`$total_pop_count
## [1] 212559.3
```

```
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 12.68853 mins
```

4. Calculate population density

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

```
add_density_measures <- function(city_hall_to_radius_to_variable_to_measures_list) {
  city_hall_to_radius_to_variable_to_measures_with_population_density_list <- city_hall_to_radius_to_va
  for (city_hall in names(city_hall_to_radius_to_variable_to_measures_with_population_density_list)){
    for(radius_character in names(city_hall_to_radius_to_variable_to_measures_with_population_density_li
      for(variable in names(city_hall_to_radius_to_variable_to_measures_with_population_density_list[[ci
        if(variable == "total_pop_count"){  # add other "if" statements if you want to compute other me
```

```r
          total_pop_count <- city_hall_to_radius_to_variable_to_measures_with_population_density_list[[c
          radius_numeric <- as.numeric(radius_character)
          population_density <-  total_pop_count/(pi*radius_numeric^2)
          city_hall_to_radius_to_variable_to_measures_with_population_density_list[[city_hall]][[radius_
        }
      }
    }
  }
  return(city_hall_to_radius_to_variable_to_measures_with_population_density_list)
}
```

```r
city_hall_to_radius_to_variable_to_measures_with_population_density_list <- add_density_measures(city_ha
```

```r
print(city_hall_to_radius_to_variable_to_measures_with_population_density_list[1])
```

```
## $seattle_city_hall
## $seattle_city_hall$`1000`
## $seattle_city_hall$`1000`$total_pop_count
## [1] 20047.59
##
## $seattle_city_hall$`1000`$population_density
## [1] 0.006381345
##
##
## $seattle_city_hall$`2000`
## $seattle_city_hall$`2000`$total_pop_count
## [1] 65734.34
##
## $seattle_city_hall$`2000`$population_density
## [1] 0.005230973
##
##
## $seattle_city_hall$`3000`
## $seattle_city_hall$`3000`$total_pop_count
## [1] 124589.1
##
## $seattle_city_hall$`3000`$population_density
## [1] 0.004406438
##
##
## $seattle_city_hall$`4000`
## $seattle_city_hall$`4000`$total_pop_count
## [1] 171715.4
##
## $seattle_city_hall$`4000`$population_density
## [1] 0.003416169
##
##
## $seattle_city_hall$`5000`
## $seattle_city_hall$`5000`$total_pop_count
## [1] 212559.3
##
## $seattle_city_hall$`5000`$population_density
## [1] 0.002706389
```

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_radius_to_variable_to_measures_with_populati
  city_hall_vector <- c()
  radius_vector <- c()
  variable_vector <- c()
  value_vector <- c()

  for(city_hall in names(city_hall_to_radius_to_variable_to_measures_with_population_density_list)){
    for(radius_character in names(city_hall_to_radius_to_variable_to_measures_with_population_density_li
      for(variable in names(city_hall_to_radius_to_variable_to_measures_with_population_density_list[[ci
        city_hall_vector <- c(city_hall_vector, city_hall)
        radius_vector <- c(radius_vector, as.numeric(radius_character))
        variable_vector <- c(variable_vector, variable)
        value_vector <- c(value_vector, city_hall_to_radius_to_variable_to_measures_with_population_dens
      }
    }
  }

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

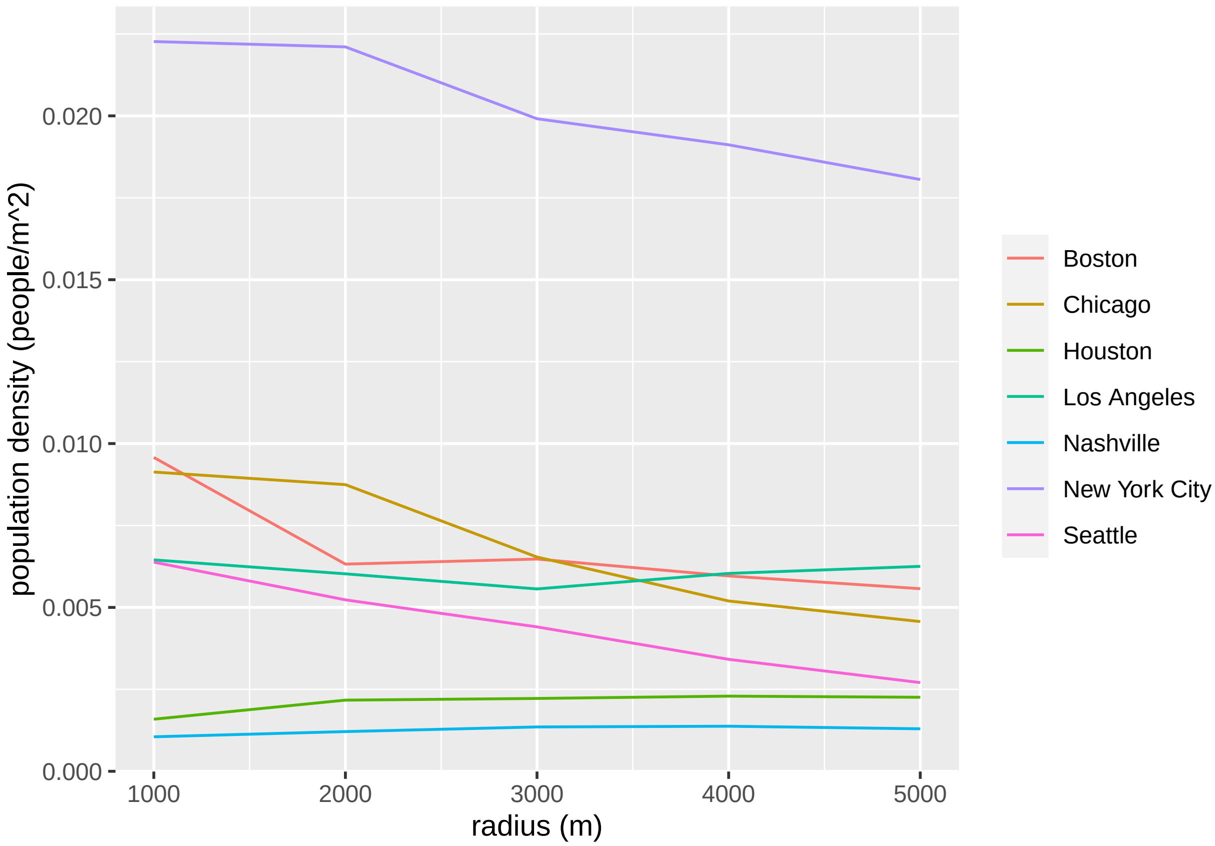
```
dataframe_for_plotting <- convert_to_dataframe_for_plotting(city_hall_to_radius_to_variable_to_measures_
```

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

```
##           city_hall radius           variable        value
## 1 seattle_city_hall   1000    total_pop_count 2.004759e+04
## 2 seattle_city_hall   1000 population_density 6.381345e-03
## 3 seattle_city_hall   2000    total_pop_count 6.573434e+04
## 4 seattle_city_hall   2000 population_density 5.230973e-03
## 5 seattle_city_hall   3000    total_pop_count 1.245891e+05
## 6 seattle_city_hall   3000 population_density 4.406438e-03
```

```
city_names <- c("seattle_city_hall"="Seattle",
"los_angeles_city_hall"="Los Angeles",
"chicago_city_hall"="Chicago",
"new_york_city_hall"="New York City",
"boston_city_hall"="Boston",
"houston_city_hall"="Houston",
"nashville_city_hall"="Nashville")

# Create a new column with city names
dataframe_for_plotting$city_hall <- city_names[dataframe_for_plotting$city_hall]
ggplot(dataframe_for_plotting[dataframe_for_plotting$variable == "population_density", ], aes(x=radius)
        geom_line(aes(y=value, col=city_hall)) +
        labs(y="population density (people/m^2)",
             x="radius (m)") +
  guides(color = guide_legend(title = NULL))
```



Results

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

However, this approach has a critical flaw. The population density is calculated by dividing the total population by a circular area. By doing so, we assume households are eventually distributed within the circular area. Nevertheless, this assumption can be problematic. For example, there is a significant amount of sea area near Seattle City Hall, and households are mostly in the land area. Thus, when calculating population density, the denominator should only be the land part of the circular area.

The problem is, ACMT does not naively provide land area and we need to import external data into ACMT.

In another example, we refine our analysis on population density and demonstrate how external data can be imported into ACMT. We show an example of importing National Walkability Index dataset, which includes land area data, into ACMT. We also include national walkability index in our analysis.