Developing and Implementing a Spatial Analysis Tool for health-advocating amenities in Singapore

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1. Introduction

Living a healthy lifestyle can help prevent chronic diseases, long-term illnesses, and are lastly important for self-esteem and self-image. This can be accomplished by maintaining a regular exercise routine, being conscious of individual diet, or getting more exposure to nature and greenery as compared to the urban and concrete jungle. We have thus segmented healthier living into three main facets, mainly healthy eating, exercise, and natural exposure.

To encourage healthier living amongst residents anywhere, there naturally has to be a presence of healthy living amenities within the residents' living community. This paper reports on our development efforts in designing and implementing a geospatial analytics tool for use by urban planners or potential business owners in the spatial visualization and analysis of these healthy amenities.

2. Motivation and Objectives

Currently, there are no applications that employ geospatial analysis techniques (e.g. raster density maps) to assess the presence, accessibility, or patterns of health-advocating amenities from all the three main aspects as mentioned above. Hence, we are motivated to produce an application that will provide an easy to understand and user-friendly GUI, but will also contain a degree of technical depth such that urban planners can gain a general grasp of healthy living facilities in Singapore, and possibly resolve any potential lapses or identify areas of improvement.

We aim to use geospatial intelligence in exploring demand and supply, accessibility of residents, and spatial patterns towards amenities that advocate a healthier lifestyle. The scope of our analysis will involve the aforementioned facets of a healthier lifestyle - Amenities such as eateries, gyms, and parks.

Our objectives are listed as follows:

- Build an interactive GIS tool using R Shiny with adjustable variables.
- Within each subzone, visualize and analyse the demand (population of subzone) and supply (number of healthy living amenities in each subzone);
- Within each region, visualize and analyse the density of healthy living amenities.
- Within each planning area, plot and analyse the spatial distribution of healthy living amenities.
- Modelling the spatial accessibility of healthy amenities to residential areas.
- Evaluate results of analysis, identify lapses or improvements, and provide recommendations to urban planners to further extend the

options available for residents to live a healthier lifestyle.

3. Visualization and Analysis Methods

a. Point Mapping

The map allows users to visualise pre-defined areas with coloured or patterned in the proportion of a number. Point maps allow users to have a better understanding of how a variable varies across a geographic area and show the different level of variability of a region. Choropleth maps are useful when we want to show the regional pattern from the data. Hence, users can easily identify which region has more gyms, healthy eateries or etc.

b. Spatial Point Pattern Analysis

The concept of the first order and second order are important. This is because it underlies the basic principles of spatial point pattern analysis.

i. First Order (Kernel Density)

Kernel density calculates the density of points around each output raster cell. Each point is smoothly fitted to each point. How it works is that, when none is specified, the density of each output raster cell is being calculated and added to the values of all the kernel surfaces. It will overlay the raster cell centre.

Kernel density can calculate the density of linear features of the neighbourhood of each output raster cell. The surface of the map is defined therefore the volume under the surface equals the product of line length. Also, the population field value. Users can control the density units for points and lines by selecting the appropriate factors.

ii. Second Order

Second-order neighbourhood analysis is used to identify clusters at various spatial scales. The theoretical model shows the degree of clusters in a Poisson process from a perspective of each individual point. Second order has different functions to measure the spatial point process analysis.

c. Accessibility Analysis

Geographical accessibility to nearby facilities is one of the important analyses. With the accessibility analysis, we can understand how accessible the facilities are from the HDB. The aim of the study will be developing precise, context specific estimation of geographic accessibility to care the rural districts in Singapore and design and implement how Singapore can further improve the accessibility in Singapore.

i. Hansen Accessibility

Hansen is the accessibility that is defined as the potential of opportunities for interaction and it allows land-use and transport systems to enable each location to reach destinations by means of a transport mode. Hansen accessibility also allows us to analyse and generate the population or houses reaching across distances.

4. Approach

a. Data Collection

Healthier Eateries

Dataset for healthier dining partners as eating well is fundamental to good health and well-being. Healthy eating will help

Singapore to maintain a healthy body.

Bbike
Dataset allow us to identify safe and short bike routes in Singapore

Gyms@SG
Location dataset of exercise facilities around Singapore. Gym helps to increase cardiovascular fitness, stronger muscles and maintain a healthy body.

Singapore Planning Subzone
Singapore map out at a planning subzone level

Singapore Residents by Planning AreaSubzone, Age Group, Sex and Type of Dwelling, June 2011-2020
Dataset to identify the residents' details by subzone

b. Data Cleaning

Dataset for Bike locations that are outside the singapore region. Hence, we had to filter those points out and input. For the Healthier eateries, they have a list of eateries with fast food chains such as macdonald, pizza hut etc. Hence, we needed to clean the dataset in order to filter only healthier eateries.

5. Technology

a. System Architecture

Our application is deployable by R Studio, to a remote instance hosted and managed by Shinyapp.io. Users are then able to view and interact with it online using their preferred browser. While our application currently does not require scaling and load balancing, these can also be handled easily by Shinyapp.io just a few clicks via their portal. A few examples of system architectures constructable by Shinyapp.io are illustrated in the image below.

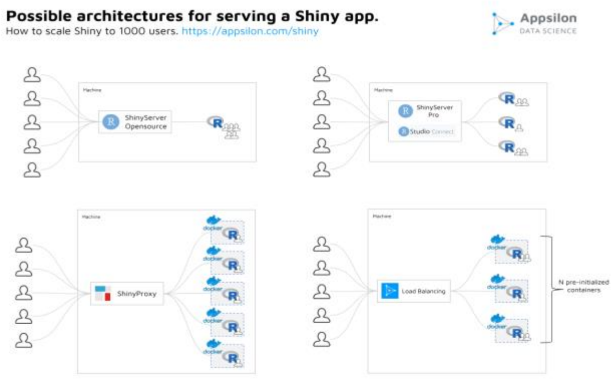


Figure 1. Possible architectures for scaling and serving a Shiny app

b. Software Architecture

The user interface of our application (i.e., how your app will be displayed to your user in a web browser) is described by the ui.R file. Similar to R Markdown, it renders and converts R content such as text or graphics as native web format. However, it also allows us to create widgets, which are interactive controls that affect our application. The ui.R file is populated with information from an R session , which is configured via the server.R file. The Shiny architecture therefore allows us to pass information back and forth between the user-interface and the server.

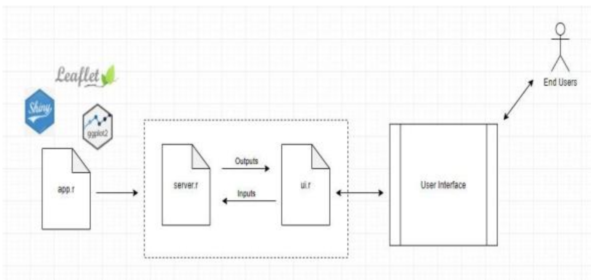


Figure 1. Flow of data and information between R files to end user

c. Libraries Used

ui.R	server.R
shiny, shinythemes, leaflet, shinycssloaders, DT	rdgal, sf, sp, spdep, tmap, dplyr, tidyverse, maptools, raster, broom, spatstat, shiny, leaflet, spData, DT

6. Application

a. App Interactivity

Having a useful interactivity allows users to engage with our website and be memorable. This is because even with the excellent analysis and map images, if the interactivity does not allow the user to find and understand the analysis, it will become meaningless. With the good interactive functions, users can experience easier and allow them to focus on the current website environment they are interacting with. Therefore, our group will be adding several important interactivities functions into your shiny app for user to have better understanding of our findings

b. User Interface Design

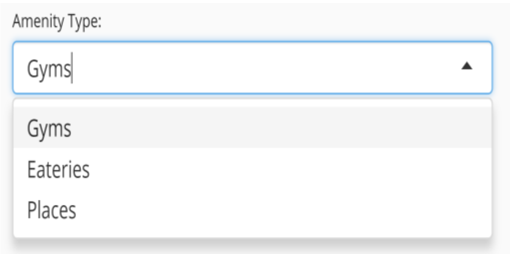
Our application consists of four unique modules, each describing a different variety of visualization/analysis as illustrated in Section 3 (Choropleth Mapping, Spatial Point Pattern Analysis, Accessibility Analysis), and an additional module that visualizes the cleaned and processed input data in un-analyzed forms for general viewing - Data tables and simple Point Map visualization.

c. Components and Filters

Besides the main panel that illustrates a relevant plot/map/graph/table, each module is also equipped with a sidebar filled with tools that empowers the user to dynamically adjust their analysis or visualizations of the main panel on the fly. These could potentially change the way the user interpretes or understands the results of the analysis.

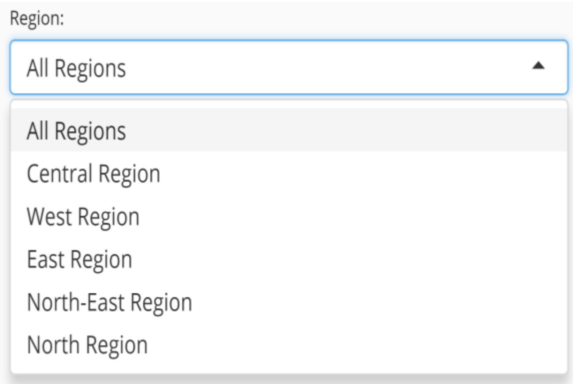
d. Amenity Selection Dropdown

We have added dropdown to allow users to have amenity selection. A drop-down list is a useful graphical control element which is similar to a list box. This allows the user to choose the value of their preference from the list. From the list, users can select gyms, eateries and cycle places.



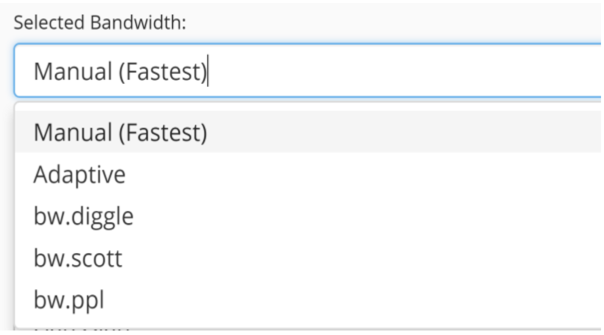
e. Region/Planning Area Filter

Users can further filter the Singapore region. They can either choose all regions, or specific regions such as central, west, east, north-east and north regions based on their preferences. Once a user selects a region, the map will change accordingly.



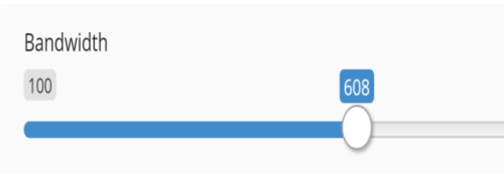
f. Bandwidth Filter

Users can filter bandwidth of the map from the dropdown list.



g. Kernel Distance Slider

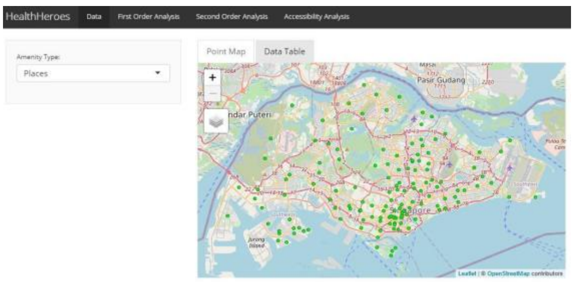
We have also added a bandwidth slider for users to choose from 100 to 1,000. Hence, users can slide the range to understand the kernel map in more detail.



1. Results

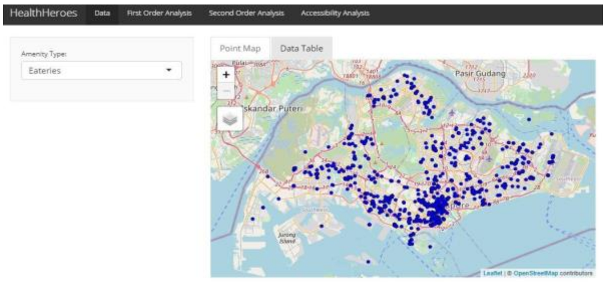
a. Point Map

Places



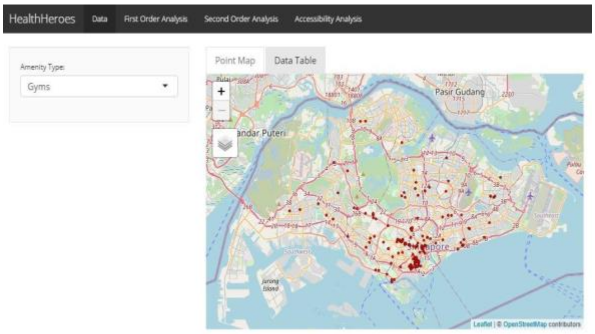
"Places" represents the locations of people who can cycle. Based on this point map, the locations are well spread among Singapore. However, most of them are concentrated towards the central region.

Eateries



As opposed to "Places", "Eateries" have more locations for Singaporeans to visit. They are equally distributed in the West, North, and East areas of Singapore. In contrast, The central region tends to have more "Eateries".

Gyms



Unlike "Places" and "Eateries", "Gyms" is not well distributed in Singapore. Most gym facilities are located in the central region with very few located in the West, North, and East regions which can be observed from the Point map.

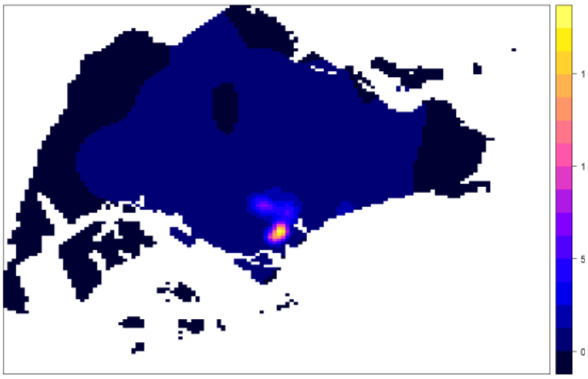
From the point map, we can analyse that most of the users can easily identify the exact locations of the healthy places, where most are concentrated in the central region of Singapore.

b. Spatial Point Pattern Analysis

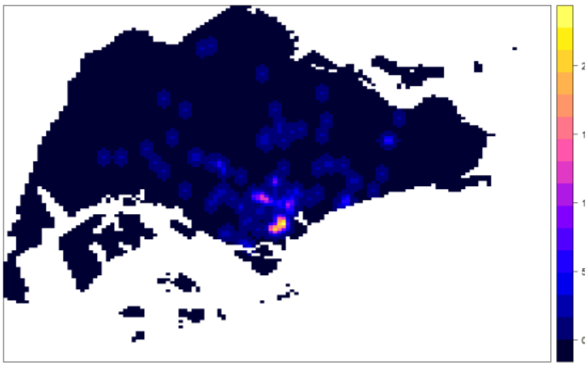
a) First Order (Kernel Density)

1. Gym

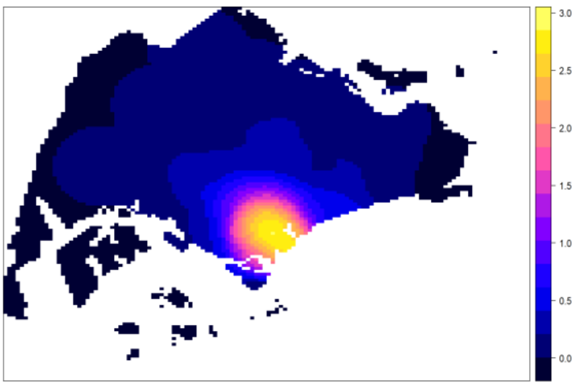
Adaptive



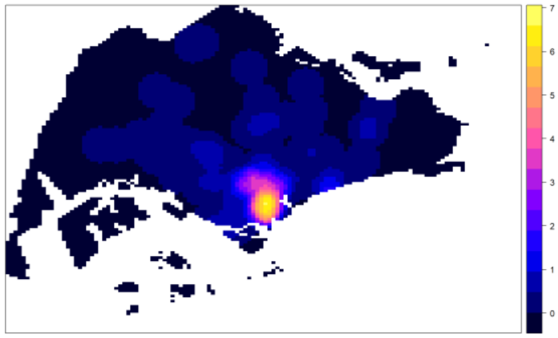
Bw.diggle



Bw.scott



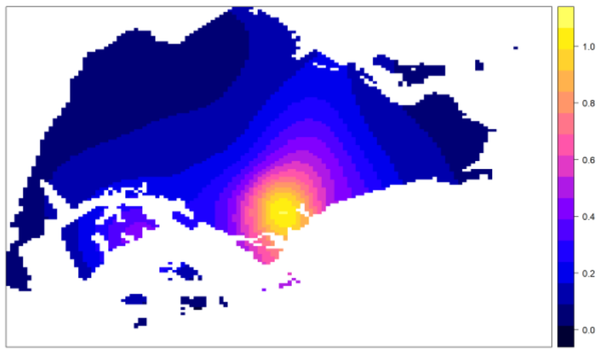
Bw.ppl

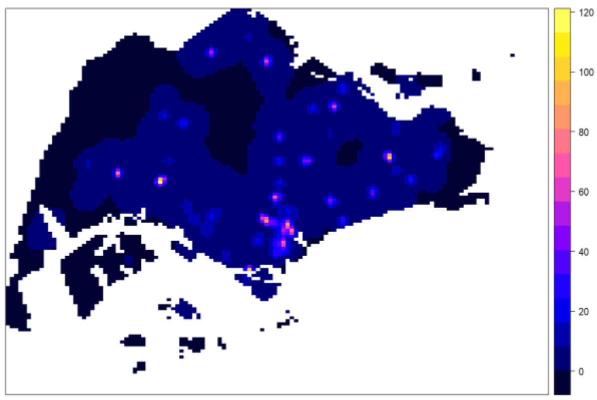


After computing Kernel Density Estimation (KDE), we can highlight that the gyms are concentrated in the South part of Singapore. Though Adaptive and Bw.diggle show similar results, Bw.diggle represents the locations of the “Gym” in more detail. Bw.scott visually maps the concentration rate as it gradually spreads from the South region to the North. To allow Singaporeans to have convenient access to gyms, it will be better if more gyms can be located in the West, North, and East regions instead of clustering in the South part of Singapore.

2. Eateries

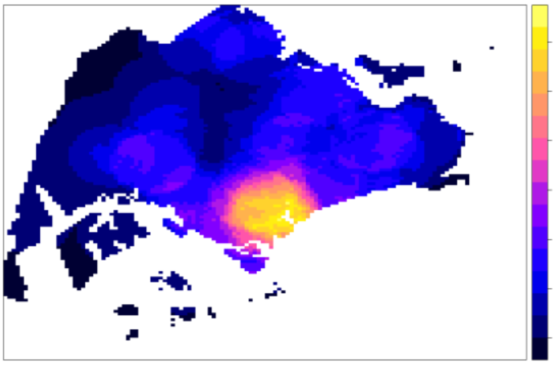
Adaptive



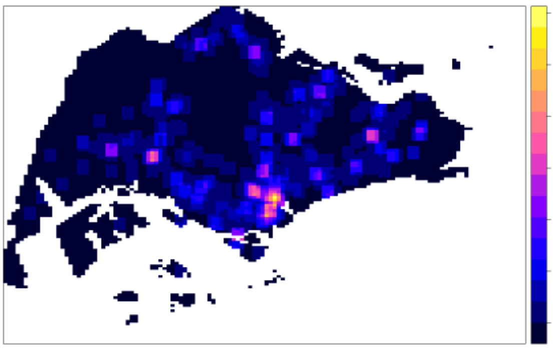


Bw.diggle

Bw.scott



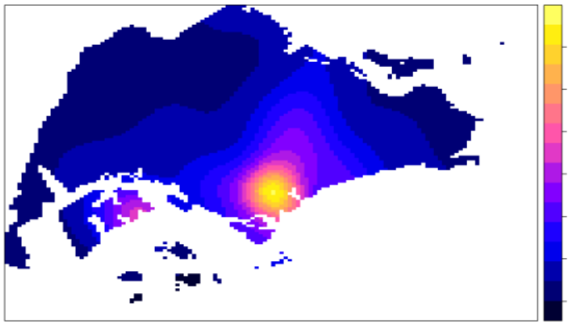
Bw.ppl



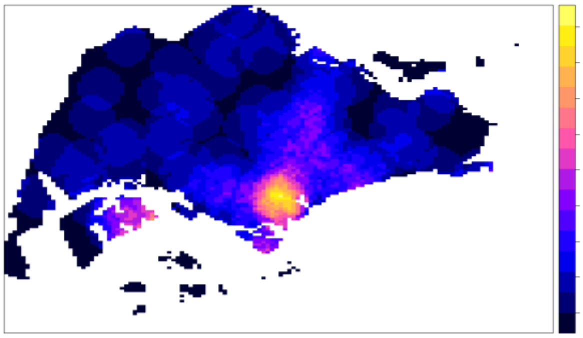
For “Eateries”, it is generally well spread with and most of them clustered in the southern part of Singapore. Based on Adaptive and Bw.scott, eateries are mainly concentrated in the southern part. For Bw.diggle and Bw.ppl, eateries are located all over Singapore. Therefore, healthy eateries are well spread in Singapore. However, it will be better for Singapore to have more healthy eateries towards the West and North parts of Singapore.

3. Places

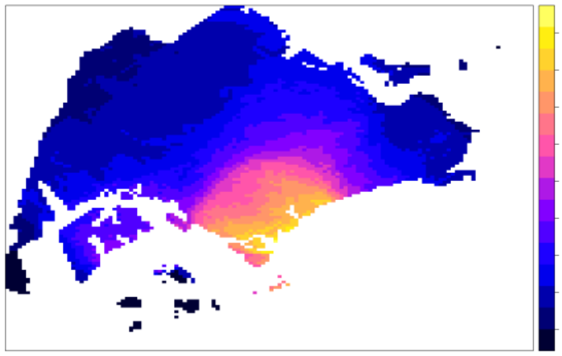
Adaptive



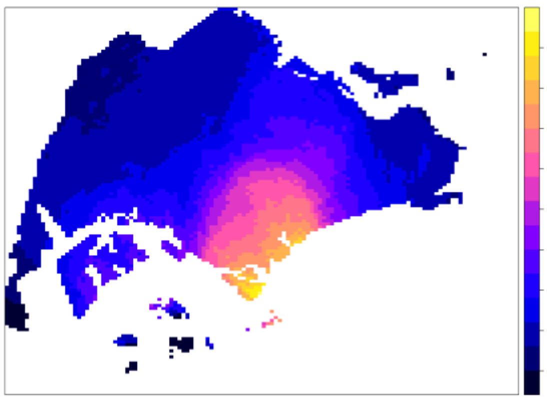
Bw.diggle



Bw.scott



Bw.ppl

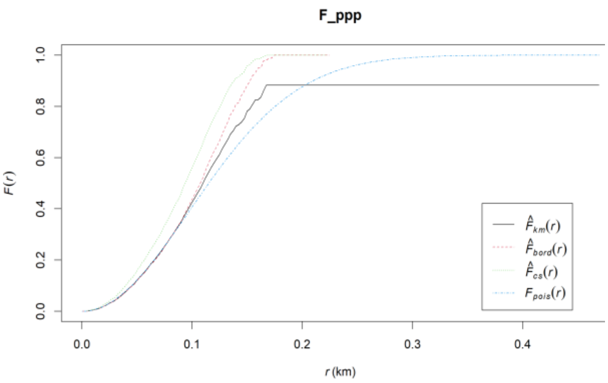


Similar to “Gym” and “Eateries”, “Places” are mainly located in the South part of Singapore as well. We can also understand that places are spread towards the South East area. We can further deduce that the North West area does not have sufficient places for people to cycle. Therefore, more places for cycling can be implemented towards the West and North regions to encourage more Singaporeans to cycle.

b) Second Order

A closer look at Orchard reveals that most of the healthy places are located in the central region of Singapore.

F-Function



F Function allows us to estimate the empty spaces function F(r) or their hazard rate h(r) from the point pattern in a window of arbitrary shape.

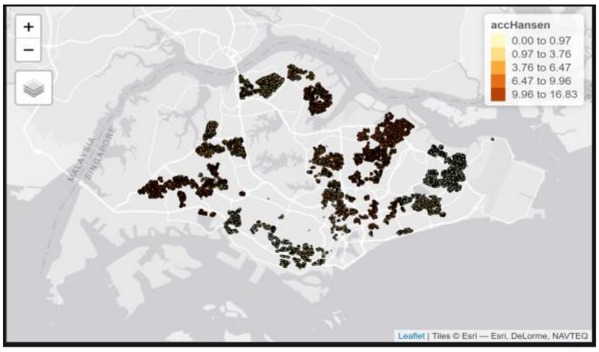
Ho = The distribution of “Places” listings in Orchard is randomly distributed.
H1= The distribution of “Places” listings in Orchard are not randomly distributed.

From the chart above, we can observe that the data is below the theoretical line. The line envelope is from r ~ 0.1. This means that the point pattern is not consistent with the null hypothesis. Therefore, we will reject the null hypothesis at r = 0.1. We can conclude that “Places” listings in Orchard are not randomly distributed and have a clustered pattern.

c. Accessibility Analysis

a) Hansen Accessibility

1. Gym



2. Eateries

By using Hansen accessibility model, we can analyse geographical accessibility. Accessibility is an important element for us to understand cities and public services. From the analysis, we were able to find out accessibilities for gym and eateries from HDB. We used QGIS to calculate the OD distance. From the distance data, we used R Hansen accessibility libraries to calculate the accessibility.

Conclusion/ Limitation

The analysis and visualisation can be further improved due to its limitless potential. First, due to the limited memory an application can have, the accessibility map was not able to be deployed into the website. However, it can still run locally. Therefore, in future, we will research to identify the maximum amount memory that the application can process, and work based on that.

Our visualisation focuses on the locations, kernel, and accessibility of the gym, eateries, and places where people can cycle. We hope that the Singapore government is willing to take our findings into consideration to drive Singapore in becoming a more health-conscious society.

References

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