Final Year Project Report

SpaceKey: Exploring Patterns
in Spatial Databases

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Abstract

With the increasing demand of property, many property-searching applications have been developed. On these applications, users can apply many filters to the property in many aspects, for example price, number of guests, number of rooms. However, current applications do not support a method to include relative position of the desired property with other spatial objects, such as train station, school, and park. This paper will illustrate the solution to this issue using SPM algorithm, a spatial group keyword query. In addition, this paper also presents the design of the API built on the top of SPM algorithm. Furthermore, this paper also introduces a detailed implementation of a property searching web application with the query ability mentioned above. Using this website, the time needed for users to find a property is expected to improve. Currently, this website is already pretty mature in terms of development and it already can demonstrate the realization of SPM in real life.
Acknowledgement

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Last but not the least, I would like to thank my parents, my brothers and sister, as well as all my friends, especially my girlfriend who always be there to support me for the past one year. Although their support might not be directly support this project, but they helped me to maintain my mental health and kept encouraging me to finish this project.

I sincerely this project would be useful in house searching application, and any spatial group keyword algorithm problem. This project has been a valuable experience for me to learn more about team work and web development, as well as doing market research.
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List of Abbreviations

1. PoI: Point of Interest

2. SPM: Spatial Pattern Matching

3. API: Application Programming Interface
1. Introduction

The demand for property is steadily rising with the significant market size of real-estate across the world [1]. Together with this, many online property-searching applications have been developed for the users’ convenience.

After reviewing the existing property-searching applications, such as Airbnb and 28Hse.com, they have the similar main feature, that is, to search properties by applying some simple filters\(^1\) such as location, price, and number of room. However, in reality, user might have additional consideration, for instance, whether the property is located near a subway station. This additional consideration cannot be fulfilled directly by the existing websites. Only indirect method is available right now, for instance checking the address manually. Furthermore, it is only possible if the exact address of properties are provided by the website.

To address this problem, this paper suggests to add more advanced filter functionality, in which users can specify distance constraint between the property and the point of interests (PoI\(^2\)). Users should be able to find a house with a desired surrounding in a shorter time by using this filter compared to checking manually using Google Maps.

\(^1\) Simple filters here are defined as filters that applied using simple inputs and only applied to the property itself. For example, a filter based on price range.

\(^2\) Point of interest is a spatial objects in real life, such as subway station, school, and police station.
To implement this advanced filter, a recently developed spatial pattern matching (SPM) query algorithm will be utilized [2]. SPM query has spatial pattern as its input. As shown on Figure 1, spatial pattern is a graph in which the nodes represent spatial objects and its edges represent the distance constraint between two spatial objects. In particular, the distance constraint consists of the maximum and the minimum distances between two spatial objects. By integrating this with property-searching applications, we aim to solve the issue mentioned above.

![Spatial Pattern](image)

**Figure 1 Spatial Pattern**

This project will focus on promoting the practicability of SPM algorithm. An API that supports this high-level filter has been developed. Furthermore, a standalone web application to demonstrate the significance of this algorithm has been developed.

The remaining sections of this paper will be arranged as follows. First, in order to understand more about how this project, the detailed implementation of this project will be introduced. Then, it will followed by project methodologies. After that, the result is discussed. Lastly, the future work and conclusion will be presented.
2. Project Background
2.1 Available Options

This part will discuss about the existing property-searching applications that are available for Hong Kong. First, these websites feature will be discussed one by one in detailed. After that, their features’ summarize are presented.

2.1.1 28Hse.com

28Hse.com is one of a biggest Hong Kong property portal for buy / rent residential apartment. [3]

Figure 2 shows the interface of 28Hse.com location filter. It provides a detailed area of search specification. In addition it also provide a map search feature, as shown in Figure 3. Using this feature, while looking at the map, user can specify the area of search. Using either of these two features, it is really convenient for the users to narrow down the location.

28Hse.com also provides standard filters based on price, gross saleable area, number of bedrooms, and the age of the building.
Figure 2 Location Filter

Figure 3 Map Search Feature
2.1.2 Airbnb

Airbnb is an online hospitality platform that are available across the countries [4]. One of the service provided is properties rentals in short-term period. What this different to the other two is that Airbnb has a dates filter to specify the date of stay. This is just natural because the rental period is short. In addition, Airbnb provides many filter features such as the facilities they provide, the amenities, house rules, etc.

Last but not least, Airbnb also provide a map to show the approximate location of the properties they own.

![Airbnb Map](image.jpg)

*Figure 4 Airbnb Map*
2.1.3 Their Similarities

These two websites provide detailed location specification and a map to visualize the location. However, as described in the introduction, these websites only provide filters directly to the property itself, not to any of it surrounding.

2.2 Project Objectives

The main objective of this project is to integrate the existing housing applications features with the advanced searching feature by utilizing the SPM. By using this feature, users can filter available housing locations according to their interest in surround PoI such as subway station and supermarket. They also can specify the directional constraint and distance constraint between the desired properties and PoIs. In addition, user can specify a certain point in the map, for example to indicate user’s workplace to become PoI which can be used as an input. Then, it is expected to take less time for user to find a property that is close to user’s workplace.

The second objective is to promote SPM algorithm, which can be achieved by: (i) showing its real life implementation as mentioned in main objective part and (ii) building the SPM API so that a future developer can use SPM for other real life problems.
2.3 Deliverable Products

2.3.1 A standalone demo housing application

As mentioned in part 2.2, the main objective of this project is to integrate the existing housing applications with the advanced filter. To demonstrate the integration and SPM value, a house-searching website has been developed, named SpaceKey. It will have these functionalities:

- Searching based on location: similar with the existing websites, SpaceKey can search a property based on their location.
- Simple filters: properties can filtered based on its price, number of bedroom, and property size.
- Pattern Specification: As shown on Figure 6, SpaceKey provides an easy-to-use interface for user to specify the spatial pattern. Using this interface user can specify the Spatial Pattern (Figure 5) with ease. User can choose all the PolIs they are interested in as well the distance constraint. User also can specify the direction of the objection, for fengshui (风水) purpose for instance. Furthermore, can specify any unwanted object near the property, for example if the user does not want the property to be near school to avoid the noise during school day.
- Custom Object: Not only the default keyworded Pol, user also can make their own point of interest, called custom object. On figure 7, user included office to their input. In the end, this custom object will appear on the pattern specification (Figure 6). This feature enables the user to find a house in a certain area which is also as close as possible as user’s office.
- Query processing: SpaceKey then will process the user' query and return the result as desired. This request will be processed by the API in section 2.3.2.
- Results display: After the query is done, a comprehensible result will be displayed in a map (Figure 8). It will display all the results that satisfy the requirements from the users. At the same time, it also will display the results in a form list of properties (Figure 9).
**Figure 5 Spatial Pattern**

**Figure 6 Pattern Specification Input**
Figure 7 Custom Object Specification

Figure 8 Query Result (1)
2.3.2 SPM API

The second objective of this project is to promote SPM, which can be realized by implementing the supporting API, named SPM API, for the SpaceKey. The focus is on the spatial query algorithm, in particular SPM. Other existing algorithms are also implemented, such as top-k [5, 6], m-Closest Keywords (mCK) [7], minimum Spatial Keyword cover (minSK) [8], Collective Spatial Keyword Queries (CoSKQ) [9, 10]. This API has several basic functionalities:

- Build a dataset from local file
- Build custom data structure to support the spatial query algorithm, depending on the developer needs
- Answer various spatial keyword queries

This API also will be public to support any future developers.
2.3.3 Sample dataset

To make the SPM algorithm functional, some sample dataset required. In particular, the data needed are:

- Housing locations
- Spatial Information: latitude, longitude;
- Housing Information: price, house size, etc.
- Points of Interest (PoI) locations:
- Spatial Information: latitude, longitude;
- Keyword Information: A set of feature keywords for each object;
- Additional Information: ratings, reviews, etc.

For SpaceKey, we are using data gathered from other websites using data crawling method.

2.3.4 A project website

A simple website is developed to display information related to this project, which can be found at: https://i.cs.hku.hk/fyp/2018/fyp18050/. This website includes:

- The detail information of this project, including the objective and project’s progress;
- The documentation of the usage of the supporting API set;
- The demo of SpaceKey
- Files related to this project, such as project’s plan, interim report, and final report;
- Some other materials related to the project, such as the libraries used.

2.4 Project Scope

In the end of the day, the main purpose of this project is not to develop a website with advanced filter functionality itself. Instead, is to show the realization of SPM algorithm and to make other property-searching applications to adopt SPM algorithm for their applications.
3. Project Methodology

3.1. Introduction

This section will extensively explain the methodology of the project. It is divided into three parts; data collection, SPM API details, and web applications details. Although the API and the web application can be combined into one, we decided to separate it for several reasons. First, having a smaller chunk of codes will make it easier to maintain the software. Second, the main purpose of this project is to promote the SPM algorithm. By making an API specifically for this algorithm, we can let people in public to use this algorithm as well.

As the requirements of SPM’s algorithm, the data related to map and property must be stored in the machine where the algorithm runs. Thus, this is the first step of the project. After that, the filter API with distance constraints was built. This API is used on our application and also is available to the public. At the same time, we also built our front-end web application. We also finished implementing the back-end of SpaceKey.
3.2. System Architecture

![System Architecture Diagram]

**Figure 10 System Architecture of the Project**

The system architecture of this project is summarized at the figure above where:

- Users can search a property on the website front-end, for instance by specify the location, and request the query to the back-end via HTTP request.
- The back-end will fetch the data from the database when users run a query.
- The back-end will call the SPM API to handle the advanced filter queried by users.
- The SPM API will communicate with Database to fetch the data required by the algorithm.
- All the property data and PoI data are stored in MySQL database.
3.3 Data Collection and Preprocessing

For the purpose of this project, we attempted to crawl the data from map websites, such as Google Maps. Google Maps was chosen due to its credibility. Although buying the data will be preferable, but it seems impossible due to the budget constraint.

To obtain the PoI data, data scraper script was developed using Python libraries, such as Selenium, beautifulsoup4, and Scrapy. These libraries have a similar method to crawl the data by sending HTTP requests and translating the corresponding HTTP responses. Generally, having too many requests from the same machine within a short period might be treated as spam by the website. However, these libraries let users to specify the request rate, which ultimately help the users to break through the anti-spam barrier. We also attempted to scrap the data from 28Hse.com to collect property data.

After the dataset was collected, it was cleaned and formatted to fit the data types required by the algorithm, which the detail can be found in section 3.3.2. The data will be stored using a python library namely Pandas. Pandas provides a fully integrated tools which help users to increase their speed in data cleaning and data preprocessing.

This complete data set is the foundation of the SPM algorithm. To keep the data up-to-date, this datascraper is executed independently and regularly.
3.3.1 PoI Data

Here are the illustrations on how the data collection for PoI is carried out:

1. Build the list of PoI keywords, such as school, and supermarket. The list of keywords used is given in appendix B.

2. Build a list of starting points initiate the searching.

3. For each keyword:
   a. For each stating point:
      i. Send a request to find that keyword in google map
      ii. Inspect the HTML element of that object to find its properties
      iii. For each spatial object found, record its name, latitude, and longitude if it object has not yet been stored, to prevent data duplication.

![Visual Illustration on How PoI data is collected](image)
3.3.2 Property Data

Property data collection method has the similar step with PoI data collection method.

3.3.3 Data Storage

The data will have table as its format, where null value will be set as default for any missing data or illegal format. The uniqueness of a PoI is determined by the combination of the longitude, latitude, and spatial object’s name. On the other hand, the property’s uniqueness is determined by the redirecting URL. When a duplicated data found, an old record will be replaced by a new one. The database will be stored on AWS RDS\(^3\).

The complete format of the data can be found in appendix B.

\(^3\) AWS RDS is Amazon Relational Database Service, a web service that makes it easier to set up, operate, and scale a relational database in the cloud.
3.4 SPM API Details

This supporting API lets anyone to send an HTTP request and receive the corresponding HTTP response with the desired data. The request consists of a group of keywords, in which the maximum and minimum travel distance between two points can be specified. Since the current SPM algorithm was written in Java, we decided to use Java as our whole system. The back-end for this API will be developed using the Spring Framework, a Java RESTful API which provides interface to handle HTTP requests. The explanation about SPM is described in the next subsection.

3.4.1 SPM [2]

Given a set of keywords as an input, in general, spatial-keyword query (SKQ) will return as set of spatial objects that are close to each other and match with the input keywords.

Recently, there is a new type of SKQ that was developed, named SPM query. Instead of just set of keywords, distance between a pairwise keyword is also specified in the input. This input is represented as a graph where the nodes are the keywords and the edges are the distance between two nodes (See Figure 12). The distance can be specified using upper bound and lower bound. This SPM query then will return a graph that satisfy this condition.

![Figure 12 Spatial Pattern](image)

Figure 12 Spatial Pattern
3.5 Web Application Details

3.5.1 Front-end Development

For the client side, we will use the standard industry language, HTML, CSS, and JavaScript as these languages are easy to use and readily accepted by most internet browsers. To speed up the process, a well-known front-end framework named Semantic React UI is used.

In addition, a JavaScript library called ReactJs will be utilized. ReactJs is a library developed by Facebook, which is used to build user interfaces. ReactJs has a model-view-controlled architectural structure which enables creators to make separation layer between data and user interface [11]. Consequently, there is no strong dependency between data and user interface. Thus, it will be easier to maintain the website.

3.5.2 Back-end Development

The back-end is responsible to handle the request sent by users, which includes: fetching the data queried by users, sending HTTP request to the filter API. Similar to the filter API, the back-end will be developed using Spring Framework to deal with the HTTP requests and MySQL will be used for the database.
4. Result and Documentation

4.1 Dataset

In total, there are 399,090 PoI data and 24,114 property data.

4.2 SPM API

The SPM API was implemented and the request documentation is as follows:

<table>
<thead>
<tr>
<th>URL</th>
<th>Post/Get</th>
<th>Parameter</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>/data/property/all</td>
<td>get</td>
<td>-</td>
<td>to request for all properties in Hong Kong</td>
</tr>
<tr>
<td>/data/property/get</td>
<td>Get</td>
<td>• region: regionName</td>
<td>to request all properties in a specific region</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• type: “sell”/”rent”</td>
<td></td>
</tr>
<tr>
<td>data/poi</td>
<td>Post</td>
<td>• region: regionName with data</td>
<td>to request all the PoI listed in wantedObjects in a specific region</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• wantedObjects: wantedObjects</td>
<td></td>
</tr>
<tr>
<td>/agl/spm_simple</td>
<td>Post</td>
<td>• region: regionName</td>
<td>to request all the house that satisfy distance constraint between property and PoI.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• type: “sell”/”rent”</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>with data:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• wantedObjects: wantedObjects</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• customObjects: customObjects</td>
<td></td>
</tr>
</tbody>
</table>

Note: wanted object is the PoI that the user interested in.

The detailed format of regionName, wantedObject, and customObjects is presented in Appendix B.
4.3 SpaceKey

This section will show screenshot from SpaceKey website.

![SpaceKey Homepage](image)

**Figure 13** Homepage
Figure 14 Search Page

Figure 15 Searching Property in Causeway Bay
Figure 16 Adding Custom Object

Figure 17 Adding SPM Parameters
Figure 18 Result using SPM query
5. Conclusion & Future Works

As the current popular property searching applications only allow users to filter using some basic filter to query a property, there are improvements that can be made, for example, to include a feature to query with relationships between a house and the properties around it. By integrating recent spatial group keyword query called SPM to a property searching application, this issue can be addressed. This will allow the users to have more flexibility which is expected to improve the time required to find an accommodation.

This final report introduces our website, SpaceKey, which is a property-searching website that include the advanced filter. While this website is functionally working, there are still many areas that can be further improved. For example, instead of using distance constraint, time constraint using some sort of transport is more desirable as normally human measure distance using time.

This final report also includes the SPM API. There are still many rooms to be improved such as better documentation and better support to developer. Hopefully this SPM API could be further improved and would be useful for any future development.
Appendix A – Survey Result

We conducted a survey to about 80 people with age between 17 and 30 about their consideration when looking for a house and their experience with the existing searching-property websites. The survey result as follows:

A.1 Consideration When Renting a Property for a Long Term in Hong Kong

The Chart 1 suggests that people find price as the most important factor when deciding whether they will rent a property. In addition, location and neighborhood are also some of the most important factors that will affect their decision.

![Chart 1 Property Renting Consideration](image)
A.2 Users Opinion about Advanced Filter Feature

In addition to the result from Chart 1, Chart 2 shows that more than 75% of respondent rate 4 or more when they were asked whether advanced filter feature might be useful. It indicates that this filter will be a great feature to have for properties-searching websites.
Appendix B

B.1 List of Keywords for PoI Data

- Temple
- Beach
- Restaurant
- Fire Station
- Police Office
- Post Office
- Bank
- Hospital
- McDonald
- Mall
- Sport Center
- Supermarket
- Store
- School
- Parking Lot
- Gas Station
- Garden
- Park
- Bar
- ATM
- Theater
- University
- Bus Terminal

B.2 Format of Dataset

B.2.1 PoI Data
- PoI name (e.g. restaurant)
- spatial object name (e.g. restaurant A)
- address
- latitude
- longitude

B.2.2 Property Data
- type (sell/rent)
- selling price
- renting price
- number of bedroom
- gross area
- net floor area
- which floor of the building
- address
- post date
- latitude
- longitude
- post title
- region
- property name
- contact number
- image URL
- page URL
- agent name
B.3 Format of API Request

B.3.1 regionName

Region name is a string which can be chosen from below:

- Aberdeen  •  Kennedy Town  •  North Point  •  Southern District
- Ap Lei Chau  •  Kowloon Bay  •  North Point Mid  •  Tai Hang
- Baguio Villa  •  Kowloon City  •  Olympic  •  Tai Kok Tsui
- Causeway Bay  •  Kowloon Station  •  Pok Fu Lam  •  Tai Po
- Chai Wan  •  Kowloon Tong  •  Prince Edward  •  Tai Wai
- Cheung Chau  •  Kwai Chung  •  Quarry Bay  •  Taikoo Shing
- Cheung Sha Wan  •  Kwai Fong  •  Repulse Bay  •  Tin Hau
- Clear Water Bay  •  Kowloon Bay  •  Sai Kung  •  Tin Shui Wai
- Diamond Hill  •  Lai Chi Kok  •  Sai Wan Ho  •  To Kwa Wan
- Discovery Bay  •  Lai King  •  Sai Ying Pun  •  Tseung Kwan O
- Fan Ling  •  Lam Tin  •  San Po Kong  •  Tsim Sha Tsui
- Fortress Hill Road  •  Lok Fu  •  Sham Shui Po  •  Tsing Yi
- Fotan  •  Ma On Shan  •  Sha Tin  •  Tsuen Wan
- Happy Valley  •  Ma Wan  •  Shaukeiwan  •  Tsuen Wan Sham
- Heng Fa Chuen  •  Mei Foo  •  Shek Tong Tsui  •  Tseung
- Ho Man Tin  •  Mid-Levels  •  Sheung Shui  •  Tuen Mun
- Hung Hom  •  Mong Kong  •  Sheung Wan  •  Tuen Mun
- Jardine  •  Ngau Chi Wan  •  South Horizons  •  Sham Tseng Tung
- Jordan  •  Ngau Tau Kok  •  South Lantau Island  •  Chung
• Wan Chai    • Wong Chuk Hang    • Yau Tong
• Western mid-levels • Wong Tai Sin    • Yau Yat Tsuen
• Whampo • Yau Ma Tei • Yuen Long

B.3.2 wantedObjects

wantedObject is a list of wantedObject

where wantedObject = {keyword: keyword from appendix B1, dir: directionOption, lower: lowerBoundValue, upper: upperBoundValue}

directionOption is one of the following: “any”, “north”, “east”, “south”, “west”.

Infinity is represented using -1.

B.3.3 customObjects

wantedObject is a list of customObject

where wantedObject = {keyword: keyword from appendix B1, dir: directionOption, lower: lowerBoundValue, upper: upperBoundValue, lat: latitudeValue, lng: longitudeValue}

directionOption is one of the following: “any”, “north”, “east”, “south”, “west”.

Infinity is represented using -1.
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