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Design and development of a web-based GIS application for rating residential properties

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Abstract

In the real estate business, it is a common understanding that the value and potential of a property are fundamentally determined by its location and surrounding environment, like the proximity to services and facilities. Depending on buyer/tenant preferences or on the stage of a person life cycle, surrounding preferences may vary, such as families with young children are interested in properties located near parks, playgrounds or schools, whereas young people and students want to be near entertainment venues. In this paper, we present "Rate your Place", a web-based GIS that allows buyers/tenants to define their preferences regarding the types of facilities that they want to have near or far from their ideal property and returns a ranked list of the most suitable properties. Ranking mechanism is based on a multi-criteria geospatial analysis methodology that employs: (a) routing methods, for calculating road network distances, (b) a Ratio Estimation Procedure, for assigning weights to types of facilities, (c) Score Range Procedure, for distance normalization and (d) a Simple Additive Weighting (SAW) index for calculating the final score of each property. The methodology is supported by an integrated web-based GIS developed exclusively with the use of open source software. As a case study, an application has been implemented for the city of Chios, Greece.

Keywords: webGIS; spatial database; multicriteria analysis; real estate

1. Introduction

Searching for the most appropriate or ideal house is an important and difficult process for everyone, closely depended to the stages of the household life cycle (McCarthy 1976; Doling, 1976). Besides price, location implicating environment in physical and social spaces, is a premier factor that affects decision making in residential property selection (Zeng& Zhou, 2001). For example, families with young children want to live near parks, playgrounds and schools, while people, after their children have grown, might prefer to be close to theaters and restaurants. At the same time, the price of a property is primarily determined by its location and its relationship to geographical features and services in the natural and man-made environment (Pagourtzi et al., 2003; Pagourtzi et al., 2006). Therefore, a number of GIS, webGIS and spatial decision support systems have been developed during the last twenty years to assist house purchasers.

This kind of systems allows the definition of search criteria on the characteristics of the property (like price, number of rooms, size, buildings' age, etc.) and offer mapping services for location visualization. Some of them, like walkscore® (Duncan et al., 2011), computes a score for each available property expressing its proximity to facilities (like supermarkets, transportation stations, schools, etc). Candidate purchasers may set walking and bicycling time or commuting thresholds to reach these services. In addition to this, other systems enable the definition of acceptable levels of spatial environmental factors, like noise and air quality (Albacete et al., 2012). For criteria modeling selection and available dwellings ranking, different approaches have been proposed, like multi-criteria decision support systems (Rinner&Heppleston, 2006; Natividade-Jesus, 2007), ontologies (Malczewski & Jelokhani-Niaraki, 2012), fuzzy theory (Zeng & Zhou, 2001; Pagourtzi et al., 2006; Aliyeva, 2017), functional learning models and unified probabilistic optimization (Fu et al., 2015) or visual analytic methods (Sun et al., 2013; Li et al., 2018).

In this work we present "Rate your Place", a web-based decision-making GIS application to support home buyers/tenants to find a property. The application evaluates the available properties in two stages. Initially, the residential properties that meet non-distance criteria set by the buyer/tenant (such as number of rooms, price etc.) are selected. Afterwards, the selected properties are ranked according to their distance from facilities that were previously rated by the buyer/tenant. In this way, the users of the application are able to express their personal preferences to particular types of facilities.

Our work contributes to the domain of residential properties ranking by a couple of features that are missing from existing systems: (a) buyers/tenants may designate facilities that they want to be not only close, but also away from their new home, and (b) buyers/tenants may introduce new locations, not existing in the system (like workplace, parents' residence, disturbing activity etc.).

The proposed ranking methodology:

- Uses the Ratio Estimation Procedure, a rating method to assign grades to facilities, that the user wants to be close or far away from his future property.
- Uses the Score Range Procedure, a linear scale transformation method to convert the kilometric distance between properties and facilities type to a comparable unit.
- Uses the Simple Additive Weighting, a Multi-Attribute Decision Making (MADM) method, to evaluate and rank the properties in descending order. The MADM method evaluates each property using the (a) assigned by the user grades for each facility and (b) calculated distances between properties and facilities. This approach is often used to make decisions according to many different spatial characteristics and is based on the weighted average logic (Malczewski, 1999).

Particular attention was given so as:

- To calculate the actual length on the road, network distance. It is particularly important that the distances are real, in order to avoid the disadvantages that arise from the use of Euclidean distance.
- To visualize the location of real estate properties and facilities on a map so that the interested person understands the surrounding environment
- To easily adapt to new areas and new types of facilities

The rest of the paper is organized as follows: Section 2 presents the geospatial decision making methodology employed by the proposed system. Section 3 describes the implementation details of the web-based GIS, namely the different incorporated open source software and the overall system architecture. Section 4 demonstrates the operation of the application, while section 5 concludes the paper and presents future work.

2. Geospatial Analysis

In this section we present the geo-spatial analysis methodology that we developed in order to deal with the house selection problem. The methodology allows buyers/tenants to assign grades on different types of facilities (e.g., supermarkets, schools, etc.) that they want to be located close or far away from the desired property, and calculates a score for each available property. This score takes into account the user-defined preferences (grades on facility types) and the properties/facilities network distances. Properties with higher scores are more suitable for the specific user according to the specified preferences. The proposed methodology is comprised of three parts: (a) user grading on facilities based on his preferences and normalization (b) calculation of the network distances between property and facilities and (c) properties score calculation.

2.1 Rating facilities- Normalization of weights

In this section we describe the part of the methodology where the buyer/tenant expresses his preference to be close or far away from different facility types. In this part we employ the rating method named Ratio Estimation Procedure. This method is comprised of the following steps:

1. Assignment of grades to different facility types, based on buyer/tenant's preferences.
2. Calculation of original weights.
3. Normalization of weights.

Initially, the buyer/tenant expresses his/her preference for the different types of facilities by assigning a positive or a negative grade to them, from a predetermined scale from -100 to 100. The assignment of the negative or positive grade indicates whether the buyer/tenant wishes to have the particular facility close (positive) or far away (negative) from his new property.

The method starts by assigning an arbitrary grade value to the most attractive facility type as it was defined by the buyer/tenant. The arbitrary grade of 100 is assigned to the facility type that the buyer/tenant wants to be closest to him. Proportionally smaller grades are given to facility types lower in order. The procedure is continued until a grade is assigned to every facility type (column "Ratio Scale", Table 1). Next we calculate the original weights using the grade for the least important criterion (criterion 3). That is, $w_1/w_3 = 50/10 = 5.0$, $w_2/w_3 = 75/10 = 7.5$, and so on. Finally, these weights are normalized by dividing each weight with the total and their sum is 1.0. (See Table-1).

Table 1. Assessing weights by the Ratio Estimation Procedure

Criterion	Straight Rank	Ratio Scale	Original weight	Normalized weight
One	4	50	5.0	0.168
Two	2	75	7.5	0.252
Three	5	10	1.0	0.034
Four	1	100	10	0.335
Five	3	63	<u>6.3</u>	<u>0.211</u>
			29.9	1.000

Close to: 1, Pharmacies; 2, Entertainment places; 3, Schools; 4, Supermarket; 5, Workplace.

2.2 Distance calculation and distance normalization

In this part of the methodology, we calculate the network distances between properties and facilities using the Dijkstra algorithm. We should note that the distances are calculated only for the residential properties that met non-distance criteria, set initially by the buyer/tenant. We will refer to this subset of all the available properties as “selected properties”. Then, we use the Score Ranging Procedure to normalize the kilometric distances between properties and facilities to a range from 0-1. This is needed as we want to bring distance values into the same range as the assigned weights.

Given that the buyer/tenant has the option to choose whether he wants to have a type of facility close or far away from his future property, he can grade a facility with negative or positive grade. If for example the potential buyer wants his future house to be located far away from entertainment places (and thus assigns a negative grade to this facility type), the methodology normalizes the distance between the property and the facilities of the specific type using the equation (1).

$$y = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (1) \text{ Normalization of maximum distance}$$

X is the maximum distance between one property and facility type, x_{min} is the minimum distance that is calculated between selected properties and facility type and x_{max} is the maximum distance that is calculated between selected properties and facility type. The equation (1) states that as the x is moving away from x_{min} y tends towards to 1.

Otherwise, when user assigns a positive grade to a facility type, the methodology normalizes the kilometric values using equation (2).

$$y = \frac{x_{max} - x}{x_{max} - x_{min}} \quad (2) \text{ Normalization of minimum distance}$$

X is the minimum distance between one property and facility type. The equation (2) states that as the x is moving away from x_{max} y tends towards to 1.

2.3 Property Score Calculation

The last step of the methodology refers to the calculation of a score for each property. For the calculation of the score we use the Simple Additive Weighting (SAW), a simple and a well-known method for multi-attribute decision making. It is also known as weighted linear combination and is based on the weighted average (Malczewski, 1999). The score is estimated for each property by multiplying the normalised weight assigned for each facility type to the normalized property/facility distance. Finally, the result of multiplication is summed up, the final scores for the selected properties is calculated (equation 3) and a ranked list of properties is generated.

$$Score = \sum weight_i \times distance_j \quad (3)$$

Where i is the assigned normalized weight for a facility type and j is the normalized minimum or maximum distance between a property and one facility type.

3. "Rate your Place" System

"Rate your Place" is an integrated GIS that is customized to real estate business for recommending properties to interested buyers/tenants. The development of the system is based exclusively in open source software. Open source approaches benefit from: (a) the reduced or no software purchase costs and (b) the liberty for modifications on source code that allows the development of tailor-made environments. However – as Song mentions (Song et al., 2005) – the deployment of an open source system architecture does not mean zero costs. It requires the installation, configuration, development and orchestration of the selected software. These tasks are time consuming, especially for non-technical users or users unfamiliar with these software. Since "Rate your place" team had the necessary technical background we adopted an open software solution. The software stack used for the development of "Rate your Place" system is presented below:

PostgreSQL: PostgreSQL is a Relational Data Base Management System (RDBMS). An RDBMS software provides full supporting for data management. The main reasons for selecting PostgreSQL for the "Rate you Place" system are: a) it is open source, b) supports spatial data and c) supports routing algorithms. The main functions of the PostgreSQL in the "Rate your Place" system are:

- *Storage of Data.* "Rate your Place" data mainly concern properties, facilities and street network. These data are stored as tables in PostgreSQL. For example, the table "Properties" contains information such as the location (geo-spatial points) and descriptive attributes like the size, rooms number, address and availability of each property. Likewise, the "Facilities" table contains information such as the location (geo-spatial points), the address and the type of each facility i.e. supermarket, school, pharmacy and entertainment. The "Street" table contains the road network (geo-spatial lines) for the city of Chios.
- *Management of spatial data.* Spatial Data define the location of each object and is a kind of data that require special handling. The management of spatial data (e.g. storage and spatial queries) is possible by the PostgreSQL extension, called PostGIS.
- *Routing Algorithms.* "Rate your Place" uses routing algorithms for calculating the distances between properties and facilities based on the street network. These algorithms (e.g. Dijkstra) are supported by the PostgreSQL extension, called pgRouting.
- *Application Logic.* "Rate your Place" require a programming environment for the implementation of functions such as the calculation of the properties-facilities distances, the assignment of weights and the calculation of the final scores for each property. These functions were implemented as stored procedures on the PostgreSQL native programming language, called PL/pgSQL. PL/pgSQL incorporates basic programming capabilities (like looping and control elements) and it was preferred over other programming languages (such as Java, Python etc) because it is simple and it can be executed inside the PostgreSQL environment.

QGIS: QGIS is an open source Desktop GIS that supports the processing, analysis and visualization of spatial data. QGIS in the "Rate your Place" system is used as the main entry point for realtors for tasks like property and facility insertion, deletion and editing.

WebGIS Application: The webGIS application is the contact point of the buyer/tenant with the system. It is an online application accessible through a web browser. The webGIS application was developed using JSP (Java Server Pages) and Java Servlets for the interaction with the database. The map functionality was developed with the open source OpenLayers API which is a Javascript API for managing spatial data on web applications. Google maps were used as the cartographic background of the map. The WebGIS application is hosted in Apache Tomcat Server.

GeoServer: GeoServer is an open source Map Server for distributing and visualizing spatial data on the web as Web Map Services (WMS). It provides a user-friendly interface for creating WMS by directly reading the data stored in the PostgreSQL. GeoServer serves three WMS, namely properties, facilities and streets, which are integrated easily in the WebGIS application using the OpenLayers API. Adopting GeoServer for serving spatial data over the web was the preferred solution since otherwise we would have to retrieve spatial data from files which would require their constant synchronization with the database or directly from the database which would require the writing of more code.

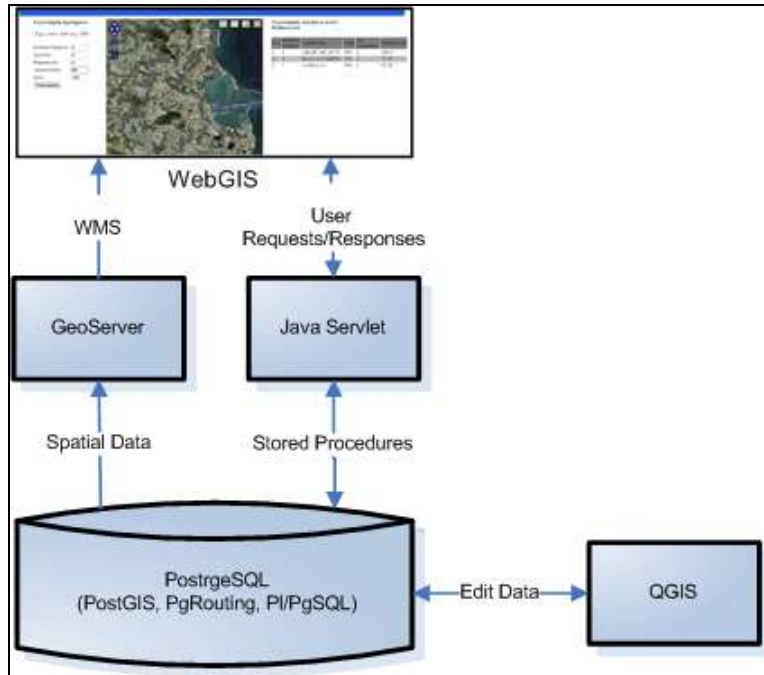


Fig. 1. Rate your Place System Architecture

The overall "Rate your Place" system architecture is illustrated in Fig. 1. PostgreSQL stores "Rate your Place" data. Realtors can edit data by using QGIS. GeoServer reads spatial data from PostgreSQL and serves them to the WebGIS as WMS. Finally, Java Servlets accept user requests from the webGIS application, process the stored procedures and return the responses back to the user. The presented architecture and software tools ensure flexibility in data management and efficiency in data processing, while not incurring software license costs.

4. Demonstration

In this section we present the WebGIS application which implements the methodology described in section 2. The application was developed for the city of Chios for which there were available data regarding the road network and the location of facilities related to entertainment, schools, pharmacies and supermarkets. The prices and locations of the available for rent real estate properties were all fictitious. The buyer/tenant interacts with the application in two stages. In the first stage the user searches for a property based on a price criterion (e.g. max price 350 euros) and number of rooms (Fig.2).As a result the location of the properties that meet his criteria is returned and visualized on a map (Fig.3).



The screenshot shows a web form titled "Find your Place" with a blue header bar. Below the title, there are two input fields: "Price (max)" with the value "350" and "Available Rooms" with the value "0". To the right of the "Available Rooms" field is a minus sign and another empty input field. Below these fields is a "Next" button.

Fig 2. Entering non-spatial criteria

In this screen the buyer/tenant chooses which facility types he wishes to have close or far away and assigns the desired grades for each facility type. It is also possible to pin a new location on the map that signifies a user defined place (e.g. buyer/tenant's workplace). The range of grades for each facility type can be a value between -100 and 100. The selection of the negative or positive grade indicates whether the user wishes to have the particular facility type at short or long distance. In the below example a buyer/tenant would prefer a property that is located near to Super Markets and Pharmacies (and thus assigns a grade of 50 to each) and far from entertainment facilities and thus assigns a grade of -30. By clicking on the "sort" button, the system returns a list of the most suitable properties, ranked by their score and presents their location on the map.

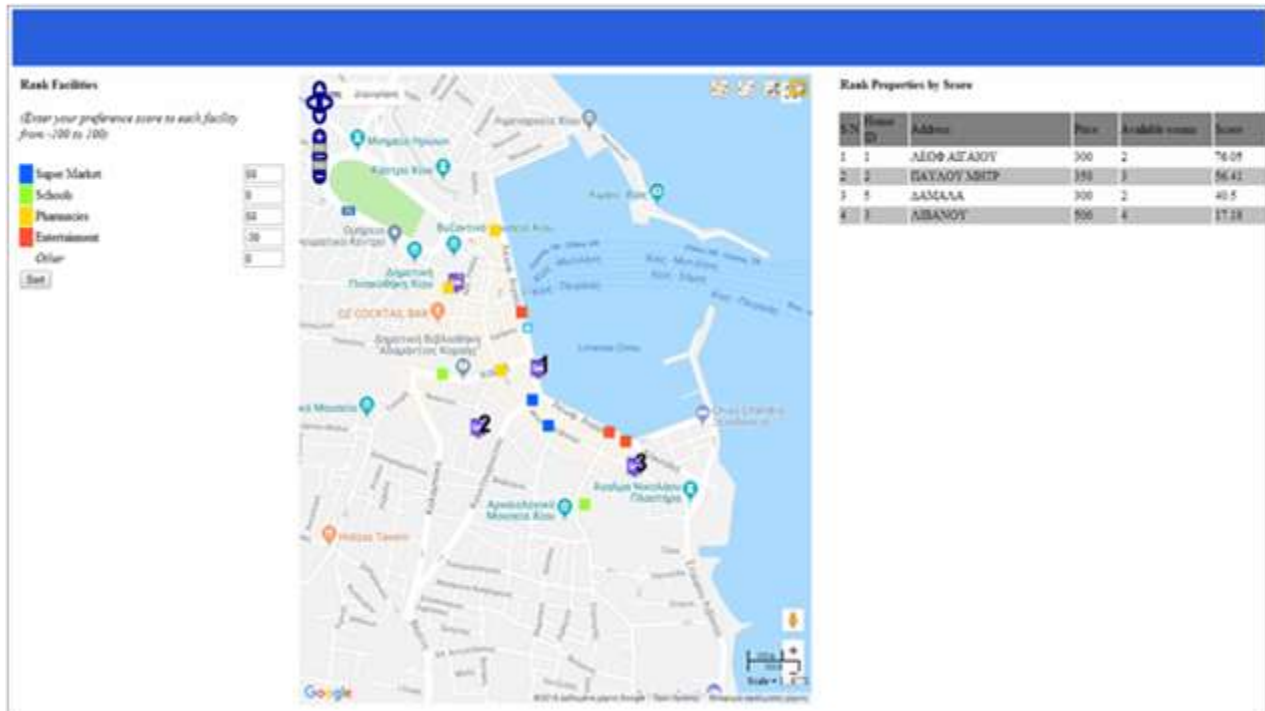


Fig 3. Entering spatial criteria and getting properties scores

5. Conclusions – Discussion

In this work we have presented a webGIS-based application named Rate your Place that combines Geographic Information Systems and spatial multi-criterion analysis methods to support decision making in the field of residential property selection. The aim of the application is to enable interested persons to evaluate their new house selection according to descriptive criteria (such as number of rooms and price) and the proximity or remoteness to/from stored and user-defined facilities that are previously rated by them. In this way home buyers/tenants are able to express their needs as stated by their stage in the life cycle. The resulting available houses are ranked and visually displayed on a map, jointly with the adjacent facilities.

“Rate your Place” incorporates some novel features compared with other property recommendation application. For instance, particular attention was given to the calculation of the network distances and not the Euclidean between properties and facilities. Also, buyers/tenants may define facility types that they want to be not only close, but also far away from their new home. For the calculation of the property scores we used geo analysis and multi-criteria methods such as routing algorithms, the Simple Additive Weighting (SAW), Score Range Procedure and Ratio Estimation Procedure methods. We are aware of some of the methods limitations. For example, assigning weights using the Ratio Estimation Procedure can be criticized for the lack of theoretical foundations. The meaning of the weights assigned to the criteria might be difficult to justify. On the other hand it presents some advantages like it is easy in use, cost effective and fast. Finally we should note that the integrated Web based GIS System was developed using exclusively open source software platforms that reduces the licensing costs and permits the customization of its functionality.

As a final word we would like to note that the distance from services is not the only criterion for finding the ideal place of residence. The spatial factors influencing the final decision are many, such as the climate of the area, the pollution and air quality, the view etc. Our future plans include the incorporation of more spatial criteria in our analysis methodology. In addition, the number of instances for each type of service located near/remote to a property, will also participate to the evaluation and ranking calculations.

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