

Method and Apparatus for Creating Map Data for Calculating Commute Time Using Public Transit Information

Field of Invention

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The present invention relates to a method and apparatus for creating map data using public transit information to calculate commute time and presenting alternatives within a geographical area in accordance with user's search query and preferences. Particularly, the present invention relates to using the public transit information to create the map data for use in calculating commute time in accordance to a commute mode which is not limited to public transit mode.

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Background

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When people search for alternatives such as jobs or properties, location is a key consideration. While distances between locations provide certain indication to users performing location-based searches, they are insufficient. For example, a smaller distance may actually require a longer travel time. The amount of time it takes to travel to the alternative is thus a better indicator. Some map service providers, such as Google Map, have already provided services of computing commute time between any two specified locations. However, they are unable to present to the users a qualified region that can be reached from a specific location by a specific commute mode within a specific commute time.

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One of the difficulties in providing the above feature is that the required computation resources are huge so that it usually takes a significant amount of time to generate the qualified region. The travel map built according to the entire road networks in the cities is extremely large because of the various commute modes and the numerous roads available.

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There is a need for a method and apparatus capable of computing commute time efficiently.

Summary

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The invention is defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

In one exemplary technique of the present disclosure, there is provided a method for creating map data for calculating commute time between locations with respect to a specific commute mode, the method comprising steps of obtaining public transit information; generating a directed graph of the public transit; creating, for the specific
5 commute mode, map data for calculating commute time between locations using the directed graph of the public transit; and storing the map data for the specific commute mode.

The map data for calculating commute time between locations for the specific commute
10 mode may be created by modifying the directed graph of the public transit in accordance with the specific commute mode.

The public transit information may include public transit stations and routes between public transit stations, each route being associated with a mode of public transit and a
15 travel time by the mode of public transit.

The directed graph of the public transit may include nodes representing the public transit stations and edges connecting the nodes representing the routes between public transit stations, each edge being associated with the mode of public transit for the corresponding
20 route and a weight representing the travel time by the mode of public transit for the corresponding route.

The mode of public transit may be one of bus, subway, ferry and light rail.

The specific commute mode may be one of using public transit, walking, cycling and
25 driving.

When the specific commute mode is walking or cycling, the step of creating the map data may include removing edges that are not allowed for walking or cycling from the directed
30 graph of the public transit and modifying the weight of each remaining edge to represent a travel time by walking or cycling.

When the specific commute mode is driving, the step of creating the map data may include removing edges in which the mode of public transit is not bus from the directed
35 graph of the public transit and merging a graph of highways with the directed graph having only edges in which the mode of public transit is bus.

In another exemplary technique of the present disclosure, there is provided a method for calculating a commute time from a first location to a second location with respect to a specific commute mode, the method comprising steps of creating map data for the specific commute mode; and calculating a commute time from the first location to the second location using the map data.

The map data for the specific commute mode may include nodes and edges connecting the nodes, the edges representing routes for the specific commute mode and each edge having a weight representing a travel time by the specific commute mode, and the calculating step may comprise adding a first location node and a second location node to the map data, the first location node representing the first location and the second location node representing the second location; selecting a set of first nodes and a set of second nodes from the nodes of the map data, the first nodes being nodes within a predetermined distance from the first location node and the second nodes being nodes within a predetermined distance from the second location node; adding edges connecting the first location node to each of the first nodes and edges connecting each of the second nodes to the second location node to the map data, each added edge having a weight representing a travel time by the specific commute mode; and calculating a shortest commute time from the first location to the second location using the map data having the added nodes and the added edges.

In another exemplary technique of the present disclosure, there is provided a method of providing location-based alternatives in a region specified by a user, comprising steps of receiving input of a first location, a first commute mode and a first commute time from the user; and generating a first region reachable from the first location by the first commute mode within the first commute time using map data created for the first commute mode, the map data being created using a directed graph of public transit and the first region being the region specified by the user.

The method may further comprise steps of receiving input of a second location, a second commute mode and a second commute time from the user; generating a second region reachable from the second location by the second commute mode within the second commute time using map data created for the second commute mode, the map data being created using the directed graph of public transit; and obtaining an intersection or a union of the first region and the second region as the region specified by the user.

The method may further comprise steps of obtaining location-based alternatives in the region specified by the user; receiving input of matching criteria from the user; calculating, for each location-based alternative in the region specified by the user, a matching score indicating a degree of match with the matching criteria.

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The matching score may be calculated considering learned preferences of the user based on user behaviors.

10 In another exemplary technique of the present disclosure, there is provided an apparatus for creating map data for calculating commute time between locations with respect to a specific commute mode, comprising a processor configured to obtain public transit information, generate a directed graph of the public transit, and create, for the specific commute mode, map data for calculating commute time between locations using the directed graph of public transit; and a data storage medium configured to store the map
15 data for the specific commute mode.

Brief Description of the Drawings

Embodiments of the method and the apparatus will now be described with reference to
20 the accompanying figures in which:

Fig. 1 shows a schematic diagram of a system that enables a user to search for location-based alternatives within a qualified region that is reachable from a specific location by travelling on a specific commute mode within a specific commute time;

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Fig. 2 is an example of a screen display displayed to a user who is searching for alternatives using the system;

Fig. 3 is an example of a location selection screen display that allows the user to specify a
30 location, a commute mode and a commute time for the generating of a qualified region;

Fig. 4 is a flowchart illustrating an example of a method of using public transit information to create map data for calculating commute time with respect to a commute mode and calculating commute time using the map data;

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Fig. 5 shows an example of a part of a directed graph generated using the public transit information;

Fig. 6 shows an example of a part of data map for driving including information of highways.

5 Fig. 7 illustrates three components for computing commute time by public transit between locations A and B;

Fig. 8 is an example of a screen display showing an overlapped region reachable from two locations by travelling on respective commute modes within respective commute times;

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Fig. 9 is an example of a screen display showing a region that can be reached from a selected subway station by walking within 20 minutes;

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Fig. 11 illustrates an example of two separated portions of a qualified region;

20 Fig. 12 illustrates another example of two separated portions of a qualified region;

Fig. 13 shows an example of receiving user's preferences;

25 Fig. 14 is an example of a screen display displaying a list of alternatives found within the qualified region;

Fig. 15 is an example of a preference input screen display illustrating how a user may input his and her preferences and rank the alternatives shown in Fig. 14;

30 Fig. 16 is an example of another preference input screen display in which a number of criteria are selected for determining a matching score for each alternative; and

Fig. 17 is an example of a screen display displaying the alternatives with the matching scores calculated in accordance with the number of criteria selected in Fig. 16

35 **Detailed Description**

Fig. 1 shows a schematic diagram of an exemplary system 100 that enables a user to search for location-based alternatives, for example, properties or jobs, in a qualified region that is reachable from a specific location by travelling on a specific commute mode within a specific commute time. Based on the user's preferences, the system 100 also produces a matching score for each of the alternatives in the qualified region indicating the degree of match with the user's preferences.

The system 100 comprises one or more servers 102 coupled to a plurality of electronic devices 104 via wired or wireless networks 110, for example, the Internet and the Ethernet based on Local Area Network, Wide Area Network Technologies and the like. The server 102 is configured to communicate with the plurality of electronic devices 104 through the networks 110. The server 102 may be any type of device capable of receiving and sending data, and performing data processing. The data processing includes processing of creating map data for calculating commute time between any two locations, generating a qualified region according to a user's input of a specific location, a specific commute mode and a specific commute time, and calculating a matching score for each of the alternatives in the qualified region in accordance with the user's preferences. The server 102 may be a cloud-computing platform so that the processing load is distributed among the cloud.

The system 100 comprises a memory, for example, a database 106 that is accessible to the one or more servers 102. The database 106 stores data required for processing performed by the server 102 and data resulted from the processing, such as data pertaining to public transit information, map data for calculating commute time, data pertaining to the alternatives, and steps and parameters for calculating matching scores. The database 106 may comprise a plurality of databases or memories.

The electronic device 104 may be a personal computer, a notebook, a touch-pad device, a tablet device, a smart phone, a personal digital assistant and the like. The electronic device 104 accepts a user's input and transmits the input to the server 102. The electronic device 104 also receives the processed data from the server 102 and displays information of processed data to the user.

The server 102 contains software, such as one or more computer programs for instructing the server 102 to communicate with the electronic devices 104, access the database 106 and perform the data processing. Each of the one or more servers 102 may be a computer.

The computer function as the server 102 may comprise a processor for executing the one or more computer programs, and may include input modules such as a computer mouse, keyboard/keypad, and/or a plurality of output devices such as a display. The computer may comprise a memory which functions as the database 106.

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The processor may be connected to the networks 110, for instance, the Internet, via a suitable transceiver device (i.e. a network interface), to enable access to e.g. the Internet or other network systems such as a wired Local Area Network (LAN) or Wide Area Network (WAN). The processor may also be connected to one or more external wireless communication enabled devices via a suitable wireless transceiver device e.g. a WiFi transceiver, Bluetooth module, Mobile telecommunication transceiver suitable for Global System for Mobile Communication (GSM), 3G, 3.5G, 4G, 5G or any emerging telecommunication systems, or the like.

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One or more of the computer programs may be stored in any machine readable medium. The machine readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a general purpose computer. The computer program when loaded and executed on such a general-purpose computer effectively results in a system (e.g. 100) that implements the steps of the data processing in examples described later.

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Fig. 2 shows an example of a screen display 200 displayed to a user who is searching for alternatives, for example, properties for rental as shown, using one electric device 104 of the system 100. The user is able to specify a desired region by clicking a button 202 provided on the screen display 200 which leads to a location selection screen display 300 as shown in Fig. 3.

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In the location selection screen display 300, a text box 302 is provided for the user to specify a location of an origin of travel; a mode selection box 304 is provided for the user to specify a commute mode; and a time selection box 306 is provided for the user to specify a commute time. As shown in Fig.12, the user specifies driving as the commute mode and 10 minutes as the commute time. Other commute modes that can be selected by the user include using public transit, walking, cycling, etc., and the commute time may be specified in the order of 5 minutes. An approximate commute time, in the order of 5 or 10 minutes, is used in the embodiment of the present invention as such approximation

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results in computational efficiency and still provides sufficient information to the users to make decisions.

After the user has input the required information, the user's input is sent to the server 102.

5 Data processing is performed by the processor of the server 102 to obtaining a qualified region that is reachable from the selected location by travelling on the selected commute mode within the selected commute time. The electronic device 104 receives data of the qualified region and displays the qualified region 310 as shown in Fig. 3. The origin of travel is indicated by a marker 312.

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According to an embodiment of the present invention, commute time is computed based on data of public transit information. Map data for calculating commute time with respect to a particular commute mode is built on information of public transit which includes bus, subway, light rail, ferry, and other similar types of transport available to the public. Fig. 4 is a flowchart illustrating an example of a method 400 of using public transit information to create map data for calculating commute time with respect to a commute mode and calculating commute time using the map data. The steps of the method 400 may be executed by the processor of the server 102.

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20 In step 402, the public transit information is obtained, including public transit stations, routes between public transit stations, a mode of public transit and a travel time by the mode of public transit for each route, etc. Such public transit information may be obtained from the public transit providers.

25 In step 404, a directed graph of the public transit is generated using the public transit information. The directed graph includes nodes representing public transit stations and edges between the nodes. Each edge represents a mode of public transit that directly connects the corresponding two nodes, and is associated with a weight representing a travel time between the corresponding two nodes by the corresponding mode of public transit. Fig. 5 shows an example of a part of a directed graph 500 generated using the public transit information. The nodes 502 represent bus stops and subway stations and each edge 504 is associated with a travel time by bus or subway, i.e. a mode of public transit. For example, from station N1 to station N2, there are bus line 506 and subway line 508 with respective travel times of 7 minutes and 3 minutes. Thus, two edges are constructed from node N1 to node N2, one having a weight of 7 minutes and the other having a weight of 3 minutes. The mode of public transit includes bus, subway, ferry, light rail, and any other mode of public transit available. The directed graph constructed using

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public transit information gives a good estimate of the road network of a city because public transit usually covers all main roads of the city in practice.

In step 406, for a specific commute mode which is an available option to the user, map data for calculating commute time between any two locations is created by using the directed graph of public transit.

For the commute mode of using public transit, the directed graph of the public transit generated in step 404 is used as map data for calculating commute time. For other commute modes, the map data (i.e. a directed graph) for calculating commute time is created by modifying the directed graph of the public transit in accordance with the specific commute mode.

For the commute mode of walking or cycling, the directed graph of the public transit generated in step 404 is modified by first removing edges for which pedestrians are not allowed (i.e. removing edges that are not allowed for walking or cycling from the directed graph) and then modifying weights associated with the remaining edges to create map data for calculating commute time by walking or cycling. The edges representing subway and ferry lines, and the edges representing bus routes passing highways are removed as they are not accessible by walking or cycling. The weights representing the travel times by the mode of public transit are changed to travel times by walking or cycling by dividing the distance between any two nodes by the average walking or cycling speed of a human being. The distance between the two nodes may be the actual travel distance or an estimated distance obtained by multiplying the average speed of the mode of public transit (e.g. bus or subway) with the travel time by the mode of public transit for the edge connecting the two nodes.

For the commute mode of driving, the directed graph of the public transit is modified by keeping the edges that correspond to bus routes only and adding information of highways or expressways. The edges representing other modes of public transit, such as ferry lines and subways, are removed from the directed graph of the public transit and nodes representing highway exits are added to the directed graph. Two of these additional nodes are connected by an edge if they are adjacent along the highways. This highway graph is then merged with the graph of public transit by connecting the nodes corresponding to highway exits with the nodes in the graph of public transit that are adjacent. As shown by an example of a part of data map for driving 600 in Fig. 6, the two nodes E1 and E2 represent two adjacent highway exits and are connected with an edge

602. The two nodes E1 and E2 are connected with the adjacent nodes of the directed graph of public transit by edges (i.e. darkened edges). The weights on the edges of the merged graph are changed to the driving time by dividing the distance between any two nodes by the average driving speed of a human being. The distance between the two nodes may be the actual travel distance or an estimated distance obtained by multiplying the average speed of the mode of public transit with the travel time by the mode of public transit for the edge connecting the two nodes.

In step 408, the map data (i.e. a directed graph) created for each possible commute mode is stored in the database 106. The commute time between any two locations for a particular commute mode may be calculated using map data for the particular commute mode stored in the database 106 by the server 102 in step 410. The shortest path between any pair of nodes in the map data, which corresponds to the smallest commute time, can be easily commuted using existing algorithms, for example, Dijkstra's algorithm.

To calculate commute time between any two locations using public transit, the directed graph constructed with public transit information, i.e. the map data for calculating commute time for public transit, is used.

An example of calculation is illustrated with locations A and B as shown in Fig. 5. First, the public transit stations which are close to locations A and B are found respectively. For example, by computing geographic distances between the nearby public transit stations and locations A and B, a set of public transit stations N1...Nj (i.e. nodes N1 to Nj) which are within a certain distance D from the location A are selected and a set of public transit stations M1...Mk (i.e. nodes M1 to Mk) which are within a certain distance D from location B are selected as shown in Figs. 5 and 7. In residential areas where public transit services are rather dense, 1 km to 2 km may be a reasonable value of the distance. Other values of distances may be used depending on the density of public transit. The geographic distances between the nearby public transit stations and locations A and B are then divided by the average walking speed of a human being to obtain travel times which are good estimates for walking times to the nearby public transit stations from locations A and B.

The commute time by using public transit between locations A and B is then computed with three components as illustrated in Fig. 7: the walking time from location A to a nearby public transit station N, the fastest public transit time from that transit station N to another

transit station M that is close to location B, and the walking time from the another transit station M to location B.

To compute the shortest path (i.e. the path having the shortest commute time) between locations A and B using the directed graph built on public transit data (i.e. the public transit graph between $N_1 \dots N_j$ and $M_1 \dots M_k$), locations A and B are added to the directed graph as two new nodes in accordance with their geographical locations. Edges connecting node A to those nearby stations of A (i.e. nodes $N_1 \dots N_j$) and edges connecting those nearby stations of B (i.e. nodes $M_1 \dots M_k$) to B are also added to the directed graph. Each added edge has a weight denoting the travel time for the specific commute mode. After constructing this new graph, a shortest path from A to B can be computed by using well known algorithms.

In addition, following information may be added in the calculation of the commute time by public transit: bus stop times at a bus stop, subway stops time at a subway station, the average waiting time for bus, the average waiting time for subway, etc.

To calculate commute time between any two locations by walking or cycling, the map data (i.e. the directed graph) for calculating commute time for walking or cycling is used. The commute time between any two locations by walking or cycling is computed by a similar approach as above as the weights associated with the edges in the map data for walking or cycling have already been converted to travel times by walking or cycling at the step of creating the map data for walking or cycling. To calculate commute time between any two locations by walking or cycling, the geographic distances between the nearby public transit stations and locations A and B are divided by the average walking or cycling speed of a human being to obtain walking or cycling times to the nearby public transit stations from locations A and B.

To calculate commute time between any two locations by driving, the map data (i.e. the directed graph) for calculating commute time for driving is used. The commute time between any two locations by driving is computed by a similar approach as above as the weights associated with the edges in the map data for driving have already been converted to travel times by driving at the step of creating the map data for driving. The geographic distances between the nearby public transit stations and locations A and B are divided by the average driving speed of a human being to obtain driving times to the nearby public transit stations from locations A and B.

Using the above map data and the above method of calculating commute time, the system 100 is capable of generating a qualified region that is reachable from a location by travelling on a commute mode within a commute time selected by the user. Upon receiving a location, a commute mode and a commute time from the user, a qualified region reachable from the location by the commute mode within the commute time is calculated using map data created for the received commute mode. For example, in Fig. 3, when a user specifies a location of 413 Serangoon Central in Singapore, a commute mode of public transit, and a commute time of 10 minutes, the brighter region 310 on the map is the qualified region that can be reached from the original of travel by using public transit within 10 minutes.

The system 100 is capable of generating an overlapped region of two qualified regions which can be reached from the two selected locations by travelling on respective selected commute modes within respective selected commute times which are input by the user.

Fig. 8 is an example of a screen display 800 showing an overlapped region 802 reachable from two locations by travelling on respective commute modes within respective commute times. For example, the user has input two locations X and Y, and selected driving within 30 minutes for location X and using public transit within 20 minutes for location Y as the commute modes and commute times as shown in Fig. 8. The respective qualified regions 804, 806 are generated and shown, and their intersection, i.e. the overlapped region 802, is highlighted as the brightest region on the map. The overlapped region 802 helps users to identify what are the alternatives available in the geographical area within a 10-minutes driving range from the two selected locations. It is useful when the user is looking for alternatives which are reachable within comparable commute times from two locations, for example, the user's working place and the school that the user's child is attending. In the example shown in Fig. 8, the user is notified that there are 8 properties for rental in the overlapped region 802.

It is also possible to generate a joint region (i.e. a union) of two qualified regions using the system 100, providing the user with more options. Fig. 9 is an example of a screen display 900 showing a region 902 that can be reached from a selected subway station 904 by walking within 20 minutes; and Fig. 10 shows a screen display 1000 of two joint regions 1002 that can be reached from two selected adjacent subway stations 1004, 1006 by walking within 20 minutes. Different commute modes and different commute times can be selected when the user is interested in joint regions.

In the above examples, the user may input two sets of information about the location, the commute mode and the commute time to generate an intersection or a union of two

qualified regions. However, the system 100 is not limited to this as it is capable of receiving more sets of information about the location, the commute mode and the commute time from the user and generating an intersection or a union of all qualified regions.

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Using the map data and the method of calculating commute time described above, it is possible that the qualified region shown is not continuous. As illustrated in each of Figs. 11 and 12, two separated portions 1102, 1104 and 1202, 1204 of a qualified region that are reachable from a selected location by travelling on a selected commute mode within a selected commute are shown in the respective screen displays 1100, 1200. The two portions of the qualified region do not join because the area between the two portions is not accessible by using public transit within the selected 20 minutes in Fig. 11 and by driving within the selected 10 minutes in Fig. 12. It takes a longer time to reach the area probably because the area is further away from highway exits than the small portion of the qualified region though the area is nearer from the original of travel on the map.

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The above method of creating road map for use in the calculation of commute time based on the public transit information is simple and efficient. The data structure of the created road map is extremely simple and small in size because the number of public transit routes in a city is usually significantly less than the number of all travel routes in the city. Using such road map, the calculation of commute time and computation of qualified regions are extremely fast. The system 100 can be easily used by small enterprises or individuals whereas a system building on a road map graph taking into consideration of all travel routes in the city is excessively complicated and expensive and may require several months to construct.

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The system 100 based on the map data created using the public transit information is robust. In a conventional road map graph, if a new road is introduced or a route is redirected, the whole data set needs to be rebuilt, and thus, it cannot capture the dynamics of changes in the city. However, relying mainly on the public transit information, the system 100 is very easy to maintain and update.

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Since the map data used in the system 100 is built mainly on the public transit information, the commute time calculated using the map data is an approximation, typically in the range of 5 minutes. In most applications of location-based searches for alternatives, such as searches for jobs and properties, users do not care about the precise commute time. A rough time range is sufficient to help users to make decisions. Calculating approximated

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commute time using the map data built on public transit information improves computational efficiency greatly without any compromise of user satisfaction.

In addition to the quickness in generating the qualified region using simpler map data, the system 100 allows the user to rank the alternatives in the qualified region by computing a matching score for each of the alternatives in accordance with the user's preferences. The matching score for an alternative indicates a degree of match with the user's preferences. A user inputs his or her preferences via the electronic device 104 of the system 100 which then transmits the input to the server 102. The server 120 calculates a matching score for each of the alternatives in the qualified region based on the user input received from the electronic device 104 and the relevant data stored in the database 106 including the data pertaining to the alternatives, and the steps and the parameters for calculating matching scores. The electronic device 104 receives the matching scores from the server 102 and displays the information to the user.

According to an embodiment of the present invention, a matching score for an alternative may be computed with respect to the following three parameters or matching criteria:

1. the commute time between the selected location and the alternative;
2. the commute mode and/or the mode of public transit; and
3. the amount of commute transfers.

Each parameter is assigned with a non-negative weight w_1 , w_2 and w_3 , respectively, where $w_1 + w_2 + w_3 = 1$. Without input of user's preferences, the weights w_1 , w_2 and w_3 are assigned with a default value, for example, $1/3$ for each weight. When the user indicates his or her preferences, for example, by placing ticks in the relevant boxes 1302 in Fig. 13 which shows an example of receiving user's preferences through the electronic device 104 of the system 100, the weight for the parameter chosen by the user as important will be assigned a larger value compared with the weight for the parameter which is not selected as important.

For each parameter, a score in the range of $[0, 1]$ is assigned according to the contents of the parameter. The matching score of an alternative is computed as a linear combination of the scores for the three parameters weighted by w_1 , w_2 , and w_3 , respectively. The alternatives may be ranked according to the matching scores.

Accordingly, the user is able to indicate his or her references and review the alternatives based on the matching scores calculated in accordance to his or her references. For

example, when the user indicates that he or she prefers to take subway and fewer transfers, an alternative associated with a few more subway stations may be given a higher matching score than an alternative that needs transfer to buses, although the former may have a longer travel distance or commute time.

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In addition to commute time, commute mode and commute transfers, other conditions and parameters of an alternative may be taken into consideration when computing the matching scores, such as nearby places of interest, living environment, etc.

10 For example, the following matching criteria may be considered as other conditions and parameters when computing matching scores for properties for rental or purchase in a qualified region:

C1. Price

C2. Size

15 C3. Convenience to subway stations

C4. Convenience to places of interest

C5. Commute time to specific location(s)

C6. Living environment

C7. Move in date

20 C8. Listing date

C9. Publisher score

For each of the above criteria, a module or an algorithm is developed to compute a score in which:

25 For C1, a module is built to compute a score s_1 for each property that denotes its price compared to the search query specified by users;

For C2, a module is built to compute a score s_2 for each property that denotes its size compared to the search query specified by users;

30 For C3, a module is built to compute a score s_3 for each property that denotes its convenience to subway stations;

For C4, a module is built to compute a score s_4 for each property that denotes its convenience to a number of places of interest, including but not limited to supermarket, food court, shopping mall, kindergarten, school, clinic, hospital and park;

35 For C5, a module is built to compute a score s_5 for each property that denotes its convenience of using public transport to specific location(s), including but not limited to factors of commute time, commute mode (e.g., bus, subway), and commute transfers;

For C6, a module is built to compute a score s_6 for each property that denotes its living environment, including but not limited to factors of property condition, furnishing, amenities, and year of completion;

For C7, a module is built to compute a score s_7 for each property that denotes how well it matches between the move in date specified by users and available date specified by publishers;

For C8, a module is built to compute a score s_8 for each property that denotes how long it has been posted; and

For C9, a module is built to compute a score s_9 for the publisher of a property, including but not limited to factors of his or her performance, responsibility, reputation and ranking.

The final matching score for a property is computed according to the following formula:

$$\text{matching score} = w_1*s_1 + w_2*s_2 + \dots + w_8*s_8 + w_9*s_9$$

where $w_1, w_2 \dots w_9$ are weights determined according to user's preferences.

Without input of user's preferences, the weights $w_1, w_2 \dots w_9$ are assigned with a pre-determined value, for example, $1/9$ for each weight.

Two further modules or algorithms may be used to refine the parameters $s_1, s_2 \dots s_9$. The first module is a learning algorithm that automatically learns the preferences of a user when he or she explores on the website, i.e. learning based on user behaviors. The second module is to let the user specify the factors among the above criteria of C1, C2...C6 that are the most important. The two modules yield refined parameters $s_1, s_2 \dots s_9$ and the matching score is computed according to the above formula with refined parameters.

To compute the matching score of the properties, the following information or variables may either be stored in the databased 106 as the data pertaining to the alternatives or be obtained from the user: locations of the properties, locations of places of interest (such as food courts, supermarkets, shopping malls, clinics, schools, kindergartens, parks, etc.), and other criteria of the properties (such as price, number and size of bedrooms, number and size of bathrooms, furnishing, etc.), user's preferences (through the learning algorithm and or user's specification) and publishers' performance score.

Mathematical models other than a weighted linear combination of the parameters as disclosed above may also be used in computing matching scores considering the same criteria.

5 The calculation of matching scores for properties is illustrated with the example of a user searching for properties for rental in a desired region illustrated in Figs. 2 and 3 earlier. When the qualified region 310 is displayed, the properties in qualified region 310 are identified and the number is displayed as well as shown in Fig. 3. When the user confirms the selection of the qualified region, a screen display 1400 is shown in Fig. 14, displaying
10 a list of the 16 properties found in the qualified region 310. The user is able to input his or her preferences by clicking a button 1402 which leads to a preference input screen display 1500, an example of which is shown in Fig. 15.

Fig. 15 illustrates how a user may input his and her preferences and rank the 16
15 properties shown in Fig. 14. The user is able to select from a list of the criteria 1502 including convenience to public transportation, budget, convenience to subway stations, convenience to shopping malls, convenience to supermarkets, convenience to food courts, convenience to kindergartens or childcare centers, convenience to a specific location, living environment with respect to quite level, amenities or facilities and apartment or
20 room conditions. In Fig. 15, the criterion of "convenience to public transportation" is selected as one important consideration for determining a matching score for each of the 16 properties.

Fig. 16 shows another preference input screen display 1600 in which a number of criteria
25 1602 are selected for determining a matching score for each of the 16 properties. The matching score for a property that indicates how well the property matches all of the selected criteria may be calculated with methods discussed earlier. Fig. 17 shows a screen display 1700 displaying the 16 properties with the matching scores calculated in accordance with the criteria 1602 after the user confirms the selection of the criteria in Fig.
30 16.

The above examples of calculating a matching score for alternatives in a qualified region takes into consideration a number of factors including the commute time in accordance with user's preferences. The matching score serves as a one dimensional metric that
35 helps users to decide which alternative is more preferred among a plurality of alternatives.

Whilst there has been described in the foregoing description embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

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Claims

1. A method for creating map data for calculating commute time between locations with respect to a specific commute mode, comprising steps of

5 obtaining public transit information;

generating a directed graph of the public transit, the directed graph of the public transit including nodes and edges connecting the nodes, wherein each edge represents a route between two nodes travelled by a mode of public transit and being associated with a weight;

10 creating, for the specific commute mode, map data for calculating commute time between locations using the directed graph of the public transit; and

storing the map data for the specific commute mode,

wherein the specific commute mode includes driving, and the step of creating the map data for driving includes:

15 removing edges in which the mode of public transit is not bus from the directed graph of the public transit to obtain a modified directed graph having only edges in which the mode of public transit is bus; and

merging a graph of highways with the modified directed graph of the public transit by connecting nodes corresponding to highway exits with nodes in the modified directed graph of public transit that are adjacent the nodes corresponding to highway exits.

2. The method according to claim 1, wherein the map data for calculating commute time between locations for the specific commute mode other than driving is created by modifying the directed graph of the public transit in accordance with the specific commute mode other than driving.

3. The method according to claim 1 or 2, wherein the public transit information includes public transit stations and routes between public transit stations, each route being associated with a mode of public transit and a travel time by the mode of public transit.

4. The method according to claim 3, wherein the nodes representing the public transit stations and the edges connecting the nodes representing the routes between public transit stations, each edge being associated with the mode of public transit for the corresponding route and a weight representing the travel time by the mode of public transit for the corresponding route.

5. The method according to claim 3 or 4, wherein the mode of public transit is one of bus, subway, ferry and light rail.

6. The method according to any one of claims 1 to 5, wherein the specific commute mode further includes one of using public transit, walking, and cycling.

7. The method according to claim 6, wherein when the specific commute mode is walking or cycling, the step of creating the map data includes removing edges that are not allowed for walking or cycling from the directed graph of the public transit and modifying the weight of each remaining edge to represent a travel time by walking or cycling.

8. The method according to any one of the preceding claims, the method comprising: calculating a commute time from a first location to a second location with respect to the specific commute mode using the map data created.

9. The method according to claim 8, wherein the map data for the specific commute mode includes nodes and edges connecting the nodes, the edges of the map data for the specific commute mode representing routes for the specific commute mode and each edge having a weight representing a travel time by the specific commute mode, and the step for calculating the commute time from the first location to the second location comprises:

selecting a set of first nodes and a set of second nodes from the nodes of the map data for the specific commute mode, the first nodes being nodes within a predetermined distance from a node of the first location and the second nodes being nodes within a predetermined distance from a node of the second location;

computing edges connecting the node of the first location to each of the first nodes and edges connecting each of the second nodes to the node of the second location, each of the computed edges having a weight representing a travel time by a second specific commute mode; and

calculating a shortest commute time from the node of the first location to the node of the second location by considering the weights of each of the computed edges and weight of each edge representing a route between each of the first nodes and each of the second nodes.

10. The method according to any one of the preceding claims, wherein the directed graph of public transit for calculating commute time between locations with respect to the specific commute mode is used to determine location-based alternatives in a region reachable from a first location within a first commute time by the specific commute mode,

wherein the first location, the specific commute mode and the first commute time are specified by a user.

11. The method according to claim 10, wherein the directed graph of public transit for calculating commute time between locations with respect to a second commute mode is used to determine a second region reachable from a second location within a second commute time by the second commute mode, wherein the second location, the second commute mode and the second commute time are specified by the user, the method further comprising obtaining an intersection or a union of the first region and the second region as a qualified region which can be reached from the first location and the second location by commuting on respective commute modes within respective commute times specified by the user.

12. An apparatus for creating map data for calculating commute time between locations with respect to a specific commute mode, comprising

a processor configured to:

obtain public transit information;

generate a directed graph of the public transit, the directed graph of the public transit including nodes and edges connecting the nodes, wherein each edge represents a route between two nodes travelled by a mode of public transit and being associated with a weight; and

create, for the specific commute mode, map data for calculating commute time between locations using the directed graph of public transit; and

a data storage medium configured to store the map data for the specific commute mode,

wherein the specific commute mode includes driving, and the step of creating the map data for driving includes:

removing edges in which the mode of public transit is not bus from the directed graph of the public transit to obtain a modified directed graph having only edges in which the mode of public transit is bus; and

merging a graph of highways with the modified directed graph of the public transit by connecting nodes corresponding to highway exits with nodes in the modified directed graph of the public transit that are adjacent the nodes corresponding to highway exits.