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On the Development of a Software Suitable to Support Natural Area Hikers in the Selection of Paths

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Abstract: Hiking can provide rural economic development as well as a variety of physical benefits on the community of walkers. The present short study discusses relevant issues linked to the implementation and management of a modern service suitable to overcome the limits of the existing web sites about trials. The proposed solution, fully based on open source software, intercepts the understandable expectations of the natural area hikers that wish to be supported in the selection of paths that best fit their profile and motivations, hopefully by keeping away from accident hazards and/or health risks during the excursion.

Key words: Hiking, personalized hiking service, spatial database, implementation, mobile webGIS, open source software, SQL

INTRODUCTION

Government agencies and private organizations should provide adequate support to the expanding community of hikers to exploit the vast natural beauty that most countries in the world can boast with important economic returns and benefits on the physical well-being of citizens (Mayer *et al*., 2010; Bowker *et al*., 2007; Litman, 2004). Di Felice (2014) mentions many sources that quantify the positive effects of the environmental hiking on the economy of the rural areas where such activities take place as well as studies that give empirical evidences that walking can provide comparable health benefits as vigorous exercise but with fewer risks.

Nowadays, the more widespread way of serving hikers consists in the development of web sites about trials. Di Felice (2014) remarks that the existing sites are unsatisfactory because they display in a sort of digital shop window, all the paths surveyed leaving to the hikers the decision of choosing one. Di Felice (2014) constitutes a novel contribution in the direction of replacing this kind of public offer with an intelligent software engine able to select the set of paths that best fit the profile and motivations of the hikers, hopefully by preventing that they run into accident hazards and/or health risks during the excursion. In detail, Di Felice gives two original contributions. First, he makes the conjecture that two factors (called human and motivational Table 1) are relevant in the hiking domain; then building on such an assumption, he proposes a general method which constitutes the basic building block on which it would be possible to implement a personalized hiking service to the growing community of hikers in natural areas.

Table 1: The factors of the hiking domain vs. the issues as they emerge from the state of the art. Di Felice (2014)

Factors	Issues
Human	Physical well-being; Health hazards; Risks of accidents
Motivational	Hiker satisfaction

MATERIALS AND METHODS

Background: The background of the present study is the novel method suitable to select paths tailored on the user profile and motivations appeared by Di Felice (2014). This section recalls the basis of such a method in order to facilitate the comprehension of the remaining part of the present contribution.

Let us denote with N and M the total number of paths (P) and hikers (H), respectively. Formally, $P = \{p_1, p_2, ..., p_N\}$ and $H = \{h_1, h_2,..., h_M\}$ while p and h denote in order, the generic path and the generic hiker. The method by Di Felice (2014) selects a sub-set (eventually empty) of paths from P suitable to a specific hiker ($h \in H$) by mapping the two factors of the hiking domain into quantitative parameters identified with respect to the space of paths and the space of hikers, i.e., two 2D spaces whose dimensions take the names from those two factors.

Human dimension: We call stretch of p each portion of the path delimited by a variation of the gradient of the terrain. We use the parameter E (xertion) (expressed in kilometers) to quantify the human dimension. In the space of paths, E_p defines the inherent (alias technical) difficulty of each trail. The quantification of E_p is obtained by means of Eq. 1:

$$E_p = \sum_{i=1}^{Q} (L_i + D_i/L_i) \text{ if } D_i < 0, \text{ set } D_i/L_i = 0 \qquad (1)$$

Where:

Q = Denotes the number of stretches of path p
L_i = The length of the generic stretch of p (expressed in kilometers)
D_i = Its altitude variation (expressed in kilometers)

With regard to the hiker space, the human dimension is quantified by the hiker maximum sustainable exertion (E_h) calculated by taking into account his age, weight, height and training, according to Eq. 2:

$$E_h = (v_a \times v_w \times v_t) \times E_{nom} \qquad (2)$$

where, E_{nom} the maximum nominal exertion that hiker h can afford in a day-walk while v_a, v_w and v_t are the values returned by the functions V_a, V_w and V_t linked in sequence, to the age, physical well-being and training of h. For a given hiker, the three functions assume a value between 0 and 1.0, the lower extreme not included. The purpose of Eq. 2 is to adapt the value of E_{nom} to the characteristics of the hiker. The value of E_{nom} is set to 24 km by Di Felice (2014) but such a value may be changed without affecting the method.

A hiker with human factor equal to HF(h) = E_h can face paths characterized by a human factor HF(p) = E_p such that condition holds:

$$E_p \leq E_h \qquad (3)$$

To evaluate this Eq. 3, functions V_a, V_w and V_t have to be chosen. The definition of those three functions is given by Di Felice (2014).

Motivational dimension: Let:

- MF = {mf_1, mf_2, ..., mf_f} be the set of the possible reasons why a hiker might want to take a route
- MF (p)⊆MF be the set of the attributes of path p
- MF (h)⊆MF be the reasons why hiker h wants to walk along path p

Then, path p is of interest of hiker h if and only if:

$$MF(h) \subseteq MF(p) \qquad (4)$$

Determination of the set of paths suitable for a hiker: First of all it is necessary to compute:

$$(HF(p), MF(p)) \; \forall p \in P \text{ and } HF(h), MF(h)$$

then the paths to be returned to hiker h is the set composed of those satisfying the following conditions:

$$\left(HF(p) \leq HF(h) \wedge MF(p) \supseteq MF(h)\right)\left(\forall \; p \in P\right) \qquad (5)$$

The software architecture to be implemented and the roles to be involved: Figure 1 sketches a general software architecture of a service (accessible via web) suitable to support a generic hiker in the choice of the route to be taken and the roles to be involved to implement and effectively manage such a service.

The relevant building blocks of the software architecture of Fig. 1 are the SDB about paths, POints of Interests (POIs are sites that people find useful or interesting, e.g., ruins, waterfalls, springs, lakes, fortresses, mountain tops, viewpoints, refreshment areas, etc.) and users/hikers, controlled by a Management System featuring a spatial extension, the webGIS and a spatial viewer. In the implementation of the software architecture of Fig. 1, we adopted PostgreSQL/PostGIS as DBMS, QGIS as spatial viewer while Walk is the name of the webGIS developed by us. The effectiveness of using PostgreSQL/PostGIS as spatial DBMS is testified by its adoption in the implementation of many relevant problems (Karthikeyan *et al*., 2012).

Figure 1 shows also, the actors to be involved and the way they interact each other and with the SDB. The DB Designer (DBD) and the DBA interact directly with the

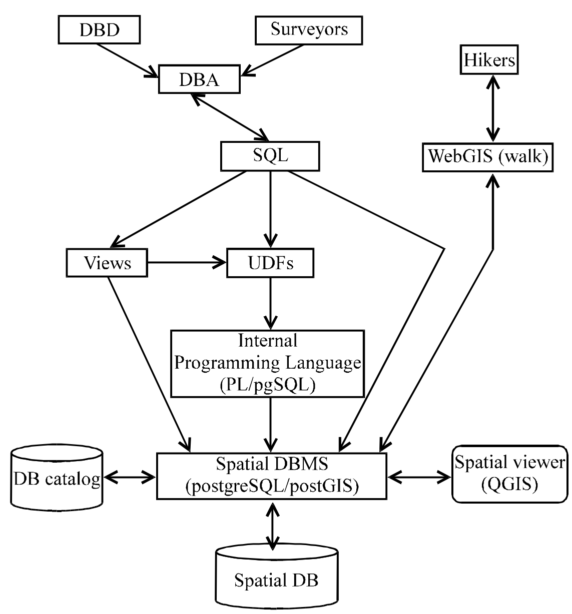

Fig. 1: Software architecture and roles involved

spatial DBMS while the hikers interact with the spatial DBMS through the ad hoc interface of the webGIS. The DBD, DBA and the surveyors likely are part of the organization offering the service (municipality, province, agency, ...) while the hiker is any user registered to the service.

Completed the design and realization of the SDB, the surveyors play a crucial role because they have the responsibility of the collection of the data about paths and POIs. Their research determines the quality of the information provided to the hikers. When available, those data are passed to the DBA who proceeds to update the state of the database.

Structure of the spatial database: Figure 2 shows the structure of the (minimal) SDB suitable to implement the method proposed by Di Felice (2014). Of course, on specific requirements of the institution that expresses the intention of providing the service to the hikers it may become necessary to enrich the structure of the SDB by adding additional attributes/tables. This task must involve the DBD and the DBA.

Of the six tables that comprise the database, two (point and route) are spatial since they host a spatial attribute (GeoPosition and shape, respectively both of type geometry). The implementation of the SDB of Fig. 2 was carried out with the usual SQL CREATE TABLE command.

Implementation of the method: By processing the values stored in the attribute Shape of the table route, it is possible to calculate for a generic path (p): the point of departure and arrival, the length and the height variations, data (the latter) to be used for the calculation of the value of the Exertion (E_p) necessary to complete p (Eq. 1). The values of the functions about the age (V_a) and physical

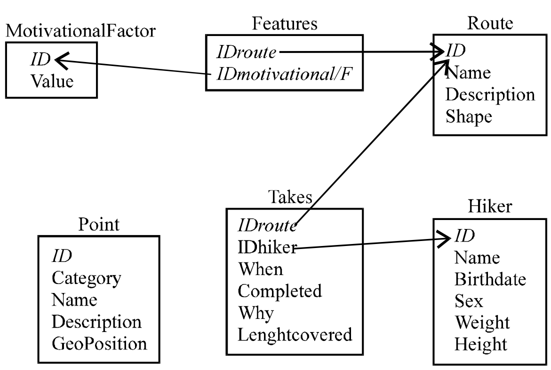

Fig. 2: Structure of the SDB. Italic attributes denote the tables' primary key while the arrows explicit the join paths that is the link between a primary key and the corresponding foreign key

well-being (V_w) of a given hiker (h) can be calculated from the values of the attributes (BirthDate, Weight and Height) of the table hiker. While the value of the function about the training (V_t) is computed from the contents of the table takes that holds the history of the routes traveled by each hiker. In summary this portion of the database contains the data necessary for the calculation of the maximum physical effort (E_h) faceable by h (Eq. 2). Computed E_p and E_h, it is equivalent to have taken into account the human dimension.

From the contents of tables route, features and motivational Factor, it is possible to compute the motivational dimension, i.e., it is possible to compare the POIs along each path against the interests expressed by the hiker.

Technically, the implementation of the method proposed by Di Felice (2014) was carried out by coding a certain number of PL/pgSQL User Defined Functions (UDFs) on top of the PostgreSQL spatial database. The writing of the UDFs benefited from the package about metric-topological operators part of the specifications of the Open Geospatial Consortium (OGC, 2005). In numbers, the implementation can be summarized as follows: 12 UDFs were necessary to implement the (human and motivational) dimensions of the hiking domain while additional 16 UDFs were coded to facilitate the database querying. So far, the following user requests are supported:

- Departure from a specific location/point
- Departure from and arrival to specific locations/points
- Passage in proximity of a set of POIs
- Maximum duration (in hours) of the excursion
- Maximum length (in kilometers) of the excursion
- Maximum gradient (in meters) of the excursion

As an example, below it is shown the code of the (near_by()) UDF that returns the identifiers of the set of routes that touch the POIs of a given category (let say for instance: cultural). The 100 m is the distance threshold value used in the query below to implement the vague notion of touch:

```
CREATE FUNCTION near_by (id integer)
    RETURNS SETOF integer AS
    $$
        SELECT r.id
        FROM   route AS r, POI AS p
         WHERE  ST_Distance(r.Shape, p.GeoPosition, false)<100 AND
             p.id = $1;
    $$
LANGUAGE sql;
```

The DBA and the hikers both may take advantage of the availability of those predefined UDFs but they do so through different paths (Fig. 1). For the hikers, the interaction with the SDB takes place by invoking the predefined database objects (either views and/or UDFs) through the interface of the webGIS that mask to them all the internal encoding details. The DBA, vice versa, interacts primarily through the console of the DBMS and/or the QGIS spatial viewer. However, independently of the path followed, the interaction with the SDB implies always the execution of SQL queries Table 2 linkes the role shown in Fig. 1 to the corresponding skill.

Loading of the database: A fundamental and also propaedeutical step to the supply of the service of selection of personalized routes consists in loading into the SDB an as large as possible number of paths whose data have to be acquired on the field by one or more surveyors as well as the data about the POIs.

The loading of the SDB is also essential because the DBA can verify the correctness of the implementation of the method of selection of paths based on the profile of the users and their motivations. In this sense, it is necessary and sufficient to load:

- In the (table hiker of the) database a limited number users of fantasy with profile quite different each other (Table 3)
- In the (table motivationalFactor of the) database a certain number of values. We entered the following values: {peak, cultural, naturalistic, religious, panoramic}

About the paths and the POIs we did the following. In (table route of the) database were loaded thirteen paths, having average length of 7.3 km very differentiated in the extension (ranging from 1.8-17.3 km 2nd column of Table 4) and in the difficulty (the minimum (maximum) height difference is equal to 130 m (1396 m) 3rd column of Table 4). The routes are referred to a geographic area surrounding the massif of Terminillo (2217 m above the sea level, being part of the Abruzzo Reatini group of mountains, 100 km away from Rome, Italy).

The POIs are 20, divided into the following seven categories: peak, water, cultural, naturalistic, religious, panoramic and receptive structure.

As a general remark, it is worthwhile to notice that a complex and delicate task concerns the loading of the geometry of the routes (into the attribute Shape) and the POIs (into the attribute GeoPosition). We acquired these data on the ground with the Thales MobileMapper reveiver (http://auto.manualsonline.com/manuals/) then exported them in the shape format through the MobileMapper Office software running on a PC and lastly, we imported (with the shp2pgsql PostGIS command) the shapes into the tables (route and POI) of the database. Figure 3 shows the (QGIS) map of the routes and the POIs.

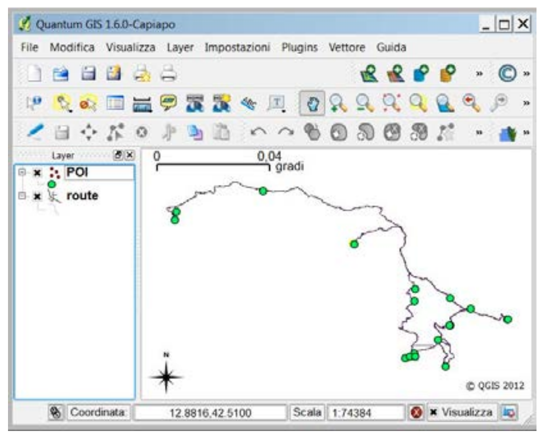

Fig. 3: The (QGIS) map of routes and POIs loaded into the SDB (notice that the latter are not all visible at the scale of display)

Table 2: The involved roles and their skills

Roles	Skills
DBD	Design of a spatial database
DBA	SQL, PL/pgSQL
Surveyor	Paths' data collection on the field
Programmer	webGIS app developer

Table 3: The data about four hypothetical hikers we loaded into the SDB. The Age values are computed from the birth date (stored in the database)

Hikers	Age	Sex	Height	Weitgh (kg)	Nh
1	28	M	1.85	95	20
2	57	M	1.75	88	5
3	24	F	1.70	65	10
4	13	M	1.50	43	0

Table 4: Data about the 13 routes loaded in the SDB

Routes	Length (km)	Altitude variation (m)	Exertion (Ep) (km)
1	2.8	144	4.2
2	2.6	144	4.1
3	17.3	1051	27.8
4	3.2	388	7.1
5	5.5	518	10.6
6	10.4	801	18.4
7	7.0	130	8.4
8	7.7	518	12.9
9	5.6	412	9.7
10	3.2	243	5.6
11	11.4	692	18.3
12	16.4	1396	30.3
13	1.8	236	4.2

The values of the length and altitude variation columns were calculated from the attribute Shape of table route. While those of the exertion column were calculated by using Eq. 1. The altitude variation column denotes the maximum path gradient

WALK (a mobile webGIS application): Walk is a webGIS software accessible by the hiker (Fig. 1) from any smartphone that supports a web browser and is connected to the Internet. The web pages, written in HTML5, JavaScript and CSS are independent of the operating system of the device. The software technologies used to implement Walk are listed below:

- The client-side library OpenLayers (ver. 2.11, available at http://openlayers.org.) for creating interactive web maps. On the server side, researchers used Google Map Server
- The jQuery JavaScript library (http://jquery.com/) and relative plugin jQTouch (http://www.jqtouch.com/) to manage HTML document traversing, event handling, animation and Ajax interactions
- The JavaScript Object Notation (http://www.json.org/) as data-interchange language between the client and the server
- GeoJSON (http://www.geojson.org/) to manage the geometry of geographic features (i.e., paths and POIs). GeoJSON (ver. 1.0) supports the following geometry types: Point, LineString, Polygon, MultiPoint, MultiLineString, MultiPolygon and GeometryCollection
- The SpinningWheel javascript library to implement the direct manipulation style largely used in smartphone applications
- The HTML5 to take advantage of the Geolocation API that allows to track the current location of a moving subject

RESULTS AND DISCUSSION

This study discusses in sequence, the way the DBA and a generic hiker interact with the SDB.

From the side of the DBA: The DBA has a key role in the development and monitoring of the service to the community of hikers (Fig. 1). In fact, he has several responsibilities including the following: implement and populate the SDB, implement the method of selection of paths, validate the correct implementation of such a method, perform periodic analysis about the choice of paths by the users of the service. The job of the DBA consists in the formulation of SQL query against the SDB. This task is tremendously facilitated by the possibility of invoking some of the many UDFs that have been implemented. For example, the query:

```
SELECT      id AS hiker, Hf (id) AS route
FROM        hiker
ORDER BY    id, Hf (id)
```

returns a list of pairs <hiker id, set of paths id> that is the query lists, for each hiker (identified by the integer id) in the database, the (identifiers of the) paths (present in the database) suitable to him (i.e., the trails such that condition $E_p \leq E_h$ holds). The formulation of the previous query looks quite trivial simply because it makes recourse to the UDF Hf (id) that implements the human factor.

From the side of the hiker: Through Walk, hikers/users can carry out the following tasks: start the web app; register to the service; log in; search (two options are currently available: by entering the date of departure and the place of departure (arrival); by entering further path search criteria (optional): motivations and/or POIs); visualization of paths, information about them, navigation and log out.

Hereafter, it follows a brief commentary about the registration phase and the search of paths in sequence. Registration is the first operation that the user must perform. It is devoted to enter in the SDB his initial profile based on the physical characteristics (height, weight, date of birth and gender) and the technical skills.

Any registered user has the possibility to communicate the date and place of departure and (optionally) the place of arrival, one or more motivations, one or more POIs that he would like to meet along the way. In turn, walk queries the SDB taking into account

Fig. 4: The paths (percorsi in the screenshot) returned by walk in reply to the user's request (motivational factor) and his profile (human factor)

the criteria set and the user currently logged on. Figure 4 shows the routes proposed by the system when the hiker enters the following values:

- Departure: fontanella campoforogna
- Arrival: fontanella campoforogna
- Motivations: panoramic

The color of the paths reflects their technical difficulty: low (green), medium (yellow), high (red). In Fig. 4 the green path is the easiest because it is the shortest; it returns to the initial point through a loop. The other two paths extend for a certain length, hence they have to be walked back till the starting point is reached. Of the two, the longest and therefore the most challenging, is the red one, partly covered by the yellow path in Fig. 4.

Note that the three paths of Fig. 4 are all suitable to the profile of the hiker in the sense that they satisfy the conditions of the method proposed by Di Felice (2014), i.e., they have $E_p \leq E_h$, moreover they offer the POIs selected by the hiker.

When the user selects a specific path (among those returned to him) Walk displays the information about it stored into the SDB including the elevation profile. During the excursion, the hiker can get information about his position along the route (thanks to the GPS sensor in the smartphone) (Fig. 5).

Starting at the top-left of Fig. 5 and proceeding counterclockwise, the icons that appear in the three screens allow: the usual operations of zoom-in/-out, the activation of the GPS sensor, to have information about the exact position of the hiker along the path, to select the Google map to be used as background.

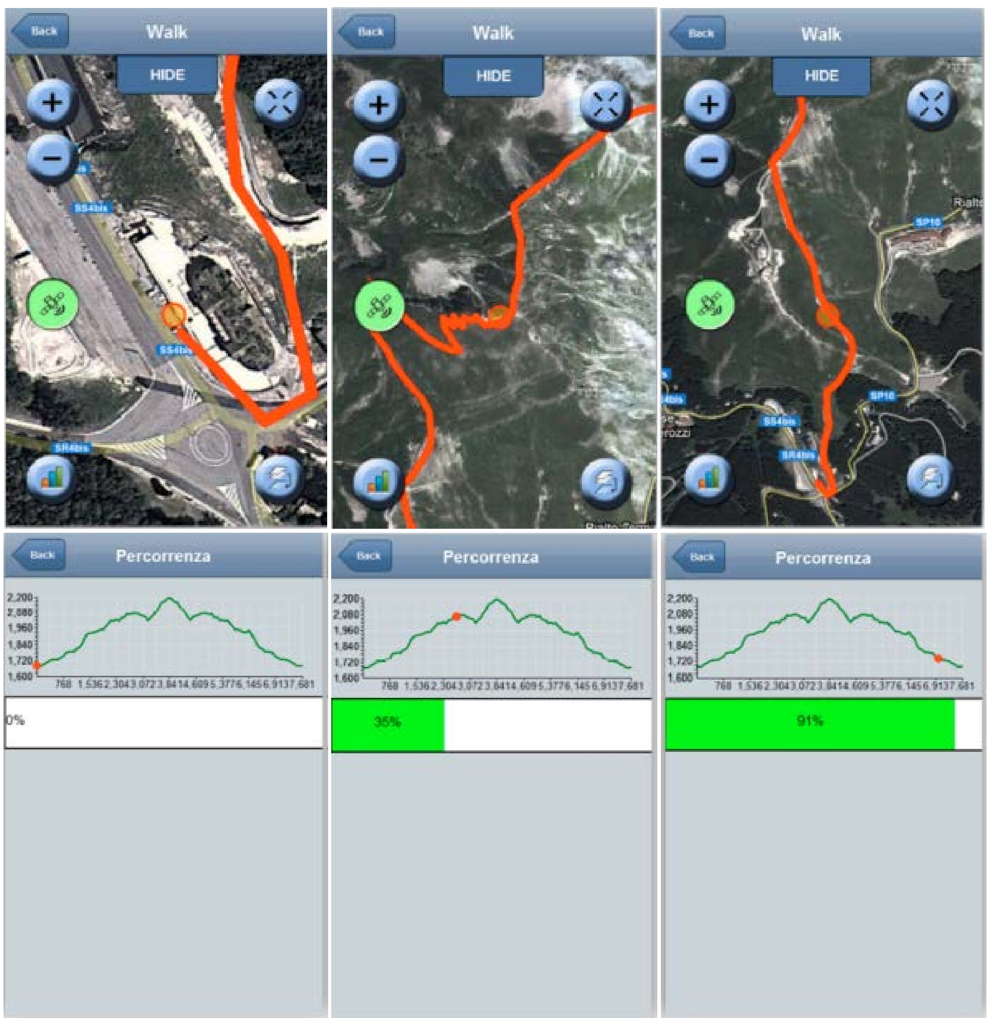

Fig. 5: Three different positions (percorrenza in the screenshot) of the hiker along the path: at the departure, at 35 and at 91% of the whole path

Completion of the excursion and database update: Once the hiker has completed an excursion, walk stores on the mobile device the date, the hiker Id and the Id of the route itself. These data are not immediately transferred to the server to prevent the risk of losing them because of lack of coverage (which is common especially in natural areas). The upload into the database will take place at the next user log in.

CONCLUSION

This study has focused on the major issues that the operators with responsibility of management and development of regional territories should be taken into account in order to set out a personalized hiking service to the growing community of hikers of natural areas.

After successful completion of the implementation phase, researchers are able to state that with a short development time and zero investment for the acquisition of the software technologies (entirely open source) it is within the reach of any administration to take charge of providing such a service. The software developed by us, together with the structure of SDB are available to anyone who requests it. From this material, to develop a custom solution will be further facilitated.

A very important action that the DBA should conduct periodically, on behalf of the institution that offers the service, concerns statistical surveys devoted to the understanding of the choices more frequently taken by the hikers in order to be able to take strategic decisions on future actions to be implemented such as for instance the activation of medical facilities along certain routes or refreshment stands or stores of local products etc. It follows a partial list of surveys that might be implemented with the writing of simple SQL queries: which trails have been chosen more frequently in a given period of the year? How many trails with extension greater than a given value, were walked in a given period of time? What is the average size of the trails selected by the hikers? Which hikers (if any) have retraced, in a given period of time, the same trail and how many times? What is the average age of the hikers in relation to the trails' maximum extension and maximum altitude variation? Which are the POIs most frequently selected by the hikers? etc.

RECOMMENDATIONS

An open issue: It remains open the validation of the method proposed by Di Felice (2014) because it can take place only downstream of a sufficient amount of time of usage of the service by a large number of subjects. The central issue to be investigated is whether the values of E_p and E_h are appropriate or they need an adjustment. In this sense, the WALK webGIS app allows to the registered users not only the choise of the paths between those being offered but also to communicate whether the chosen path has been completed in full or not and in the latter case, to explain the cause of the withdrawal as well as the covered percentage of the path. These information are hosted in the following three attributes of the table takes (Fig. 2): completed-true/false, why-free text and lenghtCovered-a decimal value.

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