CITY WITHOUT BARRIERS, ICT TOOLS FOR THE UNIVERSAL ACCESSIBILITY. STUDY CASES IN BARCELONA

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Abstract

This paper is the presentation of the results and developed tasks in the framework of the research project titled City without barriers. Tool for the evaluation and visualization of the accessibility into public space, using TLS, GIS and GPS Technologies,[1] developed during 2014 and 2015 by the authors and others researchers and technicians in the Centre of Land Policy and Valuations (CPSV) and the Virtual City Modelling Lab (LMVC) of the Technical University of Catalonia (UPC)

The main goal of the applied research project was the development of a tool to assess the degree of accessibility and calculate optimal routes in public space, and above all their incorporation into an integral system (tool), with accessibility information, services, and support's content.

This tool has been developed in two formats, Web platform and App, and the App can be downloaded in situ and remotely via Web.

This has been achieved, by steps, and the first one has been the development of a methodology to facilitate universal access to public space, evaluating and obtaining optimal routes for the users. This methodology has been based in the use of ICT, specifically the

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terrestrial laser scanner (LTS), a tool of high precision that allows obtain information of the space with a high degree of accuracy and high quality and get measurable information directly, combined with Geographical Information Systems and GPS.

The starting premises were:

1. Increasing the information about accessibility to urban spaces, based on new demands, demographic changes, legal requirements or elder people and moving/visual disabilities needs.

2. Developing technological and strategic progresses in order to highlight universal accessibility and its associated information, as a need and an added value to the city.

Background and literature review

One of the main objectives of any society should be providing an accessible and barrier free environment, to all persons with any physical handicap or functional diversity, in order that they can move with freedom and without any kind of annoyance. Regarding the possibility of use of the public space, others studies have advanced in the need that any disabled or aged person must not be excluded from accessing to any place, neither in "physical terms" nor in "knowledge terms." for example to the build heritage. (Alonso, 2010: Del Moral et al, 2010)

The importance of groups of people with disabilities or motor disabilities, and the elder people is increasing, so supply and existing services in urban areas, must adapt to the new requirements, but should also consider the group with visual disabilities, often not considered when looking for solutions to urban accessibility. Also do not forget that this issue is not a problem unique to these groups, but should be seen as a general problem for all people.

In quantitative terms, according to the census of 2011 Spain has a population of 46.8 million of inhabitants, of which over 3.5 million suffer permanent disabilities, almost 8 million are over 70 years and nearly 8.5 million suffer from disabilities or temporary decrease (INE, 2001), which means that almost 35% of the population faces accessibility barriers on a daily basis, that percentage may be increased in the coming decades, if deemed progressive aging of the population of our country. In addition it is estimated that there are over 65,000 people with vision problems (ONCE), but keep in mind that "are for different reasons and at different levels," and order two million Spaniards with poor eyesight to retinal diseases. In the European context in general the situation is similar; Europe's population tends towards a functional, cultural and territorial diversity. (ECA, 2003)

The existence of physical barriers is a problem not only for these groups, but for all citizens and therefore should be avoided. In all cases the barriers cause limitations and exclusions of certain groups of people, constituting a non-acceptable "indirect discrimination." (Ley 51/2003)[2] The removal of barriers physically and through of information, are fundamental in the new technical developments. Also is important the improvement in the case that is not possible the access to some specific place. In this order the same Law forces since 2011 to meet the basic conditions of accessibility to all existing products and services that are capable of "reasonable adjustment."

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[2] LIONDAU (2003) Spanish *Law on Equal Opportunities, non-discrimination and universal accessibility for Persons with Disabilities*

(Roca, 2013) in this context and applications to evaluate accessibility and give alternatives or solutions acquire great significance.

From that perspective, in necessary consider the need that the offer and the services in the urban space should fit those new needs, but also including the group with visual disabilities, often excluded when researching urban accessibility solutions.

Traditionally the evaluation of accessibility towards people with disabilities has been based on audits as a tool, using the check-list to check compliance with accessibility requirements, in most cases matching with the regulations. (Biere et al, 2010) One of the most obvious disadvantages of this type of methodology is that it not take into account the quality of access, and the diagnosis is reduced to an absolute value: accessible or not, without indicating how accessible. To overcome the limitations of this approach yes/no, have defined methods, such as the framework for the assessment of accessibility developed by Church and Marston in 2003, in which, in addition to verification of compliance, including a series of classical forms to assess the accessibility and determining a "relative accessibility." This methodology provided a more systematic and accurate measurement and assumed a tool to measure the impact of accessibility improvements assuming an aid to decision making. (Biere et al, 2010) One of the most interesting innovations of this methodology for application in heritage sites, is the fact that the measure of the 'Attractiveness' to assess the accessibility of persons with disabilities is included for the first time. Consider this value is critical when accessibility historically unique cultural assets are valued. The translation of this methodology to the field of construction carried out under the POLIS project (Sakkas and Perez, 2006).

The theoretical and technical-scientific previous investigation made in our centre has been the start point for this project. The most important experience was developed in the context of the PATRAC Project,[3] in which two analysis tools were developed, one indoor and the other urban. In both cases working on 3D models obtained with TLS, calculating the optimal route regarding specific routes previously defined in the case of the building and over a mesh routing (also predefined) in the urban case.

In the case of the building, the tool used the RV (combined with GIS) to present information more accessible to the user, making diagnosis easier and understandable. With the introduction of the databases in the workflow (with weighting values of accessibility for each element of the route), the tool was able to be useful for different historical buildings that can be integrated into the tool, following the designed protocol of data generation. (Biere et al, 2010)

In the urban case the result enables to the user make a query for optimal route between two existing points of interest in the old town of *Tossa de Mar*, and get a result in the form of itinerary that allows to take into account the parameters of physical accessibility that himself has entered at the system to do the consultation. (Queralto and Valls, 2010) The result is obtained, from the pre elaborated Formula to calculate the best route, considering all the parameters of the system; distance, maximum slope, street width, etc.

Images of both applications are shown in the next figures.

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[3] http://www.patrimonioaccesible.com Financed in the framework of the Call INNPACTO projects of 2007, by the Spanish Ministry of Science and Innovation and FEDER.

Figure 1. Interface of the tool analysis of accessibility in interiors routes
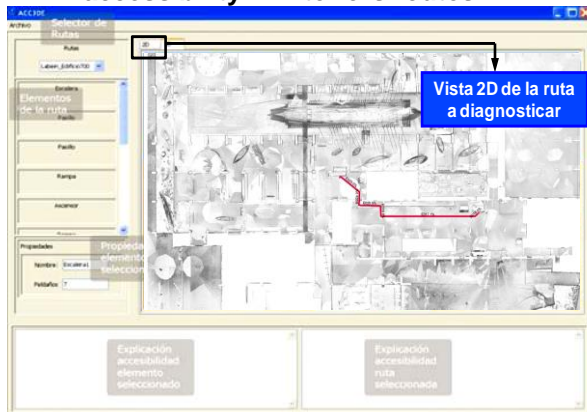
Figure 2. Web Interface tool of urban accessible optimal routes

Source: Own elaboration of the authors, based in previous research projects of the CPSV

Development

With all these previous considerations, it was considered to work using the Terrestrial Laser Scanner (TLS) -a high precision tool that allows to do real physic uprisings in a precise and high quality way and to obtain measurable information directly- and the Geographic Information Systems and GPS. It was considered that these technologies had to be integrated, as well as developing an integral methodology to evaluate physical accessibility, under the "Design for everyone" frame, that allows to diagnose problems of accessibility and to provide added information about physic environment to the users.

In order to develop this methodology, it was necessary to integrate to the 3D models –obtained from TLS- the ponderation parameters of the difficulty of each point, furnishing and trees on the terrain –among others- by identifying the elements and the value load in each case and for each detected kind of user.

In order to achieve the objective of the project and specially *the basic product, the evaluation tool*, was decided to work on two cases that would serve as prototypes: *Lesseps square and Fossar de les Moreres*. But it was also considered a previous *step of diagnostic, applicabilities and global specification* for the cases, which goal was to rethink the cases and identify the most appropriate that could improve the final results.

In this way –as it was reported in the annual report of the first year of the project- regarding the first case, Lesseps square, due to the problems to get data –it was under works- one considered as an alternative the Parc Güell, but the authorization was not achieved. It caused to decide *the access to Castell de Montjuïc* (Figure 3), because of its importance for the city, its complex accessibility and routes –with specific conditions- and green and tree areas. For the second case, el *Fossar de les Moreres* (Figure 4), we verified the validity, but we considered a bigger scope with a route from *Plaça de l'Àngel, to Marquès d'Argenteria street, to Passeig del Born and to Mercat.* (Figure 5)

Figure 3. Montjuïc, Figure 4. Original case, Figure 5. Extended case, with urban route

Source: Own elaboration of the authors in the framework of the PATRAC Project. (MICINN 2007 - 2009)

Diagnostic, applicability, and global specification

The first of the definitions in this sense was the rethink of the initial studied cases and the identification of the fittest cases that could improve the final results. As it has been explained in the previous section, the case of Lesseps square had to be removed by the access to Monjuïc Castle and it was decided to extend the case of Fossar de les Moreres to a route from Plaça de l'Àngel, Marquès de l'Argenteria street, Passeig del Born and Mercat.

Likewise, in order to diagnose the specific needs, we developed activities to identify, analyse and define the user's requirements and the evaluation criteria of the needs and accessibility traits. Based on these it was lately developed the assignation of values to weigh the accessibility, to each pixel of the 3D model, for each kind of user.

Once defined the cases was made the process of scanning, following the previous developed methodology by the LMVC, and after was developed the process of classification, including detection of elements, furniture, trees, etc. This process required the detection, at the same time, of zones with problems or lack of information (Figure 6), because these cause the sidewalks and tree wells are poorly defined. That situation requires a solution to complete the empty data, with additional scanning, because If we want to analyse the accessibility to scan through all traffic areas. For that reason is necessary take new scan positions.

Figure 6. Areas with lack of information
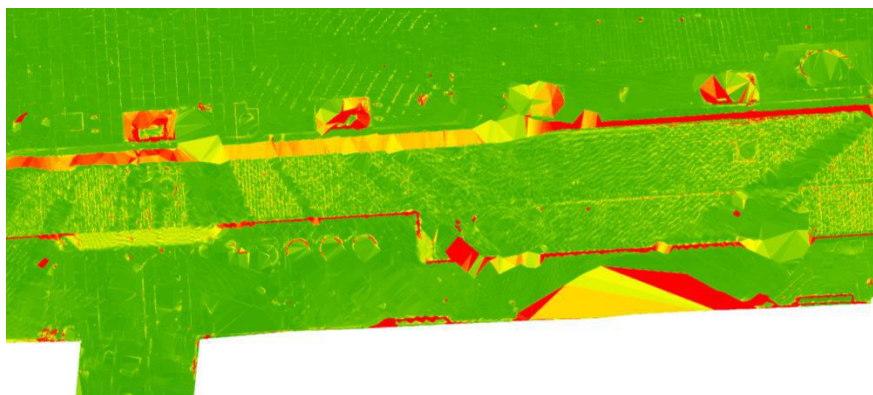
Source: LMVC's own elaboration in the framework of the PATRAC Project. (MICINN 2007 - 2009)

Once are finished the 3D models the classification process can be finished, in a different steps, including elements vectorization (Figure 7) or definitions of specific geometries, for exemple cylindrical (Figure 8).
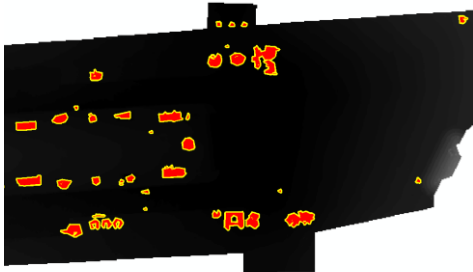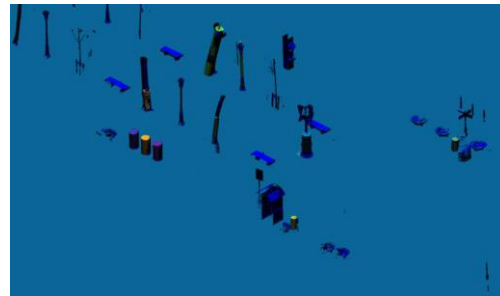
Figure 7. Classified furniture vectorised   **Figure 8. Cylindrical elements**

Source: LMVC's own elaboration in the framework of the PATRAC Project. (MICINN 2007 - 2009)

I in the case, of cylindrical elements, was used the next parameters to make the identification:

- Words (Trash containers): 21cm <Radi < 25cm // h_max = 1m
- Low pylons: 11cm <Radi < 15cm // h_max = 40cm
- PilonHigh Pylons: 4cm <Radi < 5cm // h_max = 90cm
- lights: Xcm <Radi < Xcm // h_max = Xm
- Ventilation: 33cm <Radi < 34cm // h_max = 1.35m

To generate the evaluation formula, in both cases (Montjuïc and Born) we have worked on specific features for three types of users: pedestrians –without movement disabilities or minimal degrees-, disabled –people with movement disability, elder people, mothers with baby strollers, etc. - and wheelchair users. For all those, we have incorporated the difficulty degree, proximity or remoteness to the elements, on the base of the ponderation methodology developed by Consuelo Del Moral (2010). Regarding this was necessary an adaptation about the criteria in order to adapt concepts regarding facilitator objects, no facilitator ones, and handicaps.

Once identified and separated each group of elements was assigned the values to calculate the accessibility, for each one. In the next table are detailed the values for the parameter slope.

Table 1. Values assigned for the parameter slope

Classificació	Descripció	Mobilitat total	Mobilitat reduïda	Mobilitat rodada
Obstacles negatius				
0	Resta	0	0	0
1	1m	25	25	25
2	30cm	50	100	100
3	Element	NoData	NoData	NoData
Obstacles positius				
0	Resta	0	25	0
1	1m	0	0	0
2	30cm	50	100	100
3	Element	NoData	NoData	NoData
Obstacles graons				
1	Element	-	-	NoData

Pendents				
1	< 6%	1	1	1
2	6% - 12%	5	5	10
3	12% - 20%	10	25	100
4	20% - 75%	25	100	NoData
5	> 75%	NoData	NoData	NoData
Centre via				
1	< 0,3m	NoData	NoData	NoData
2	0,3m - 0,5m	100	100	NoData
3	0,5m - 1m	25	50	100
4	1m - 2m	15	25	50
5	2m - 3,5m	10	10	20
6	3,5m - 5,5m	5	5	5
7	5,5m - 8m	3	3	3
8	> 8m	1	1	1

Source: LMVC's own elaboration in the framework of the PATRAC Project. (MICINN 2007 - 2009)

In addition, for each Kind of potential users we defined their own parameters, such as the width of the road space, as you can usually considered a pedestrian walking in the middle of a rather large space, but another pedestrian impaired vision prefer circulate near the facades of buildings, or elderly citizens would appreciate finding banks to rest along their journey.

These values were finally incorporated to the 3D models to be able to calculate based on an automatic formulation, defining any initial point and several destinations. For example, for the case for Argenteria-Born, the Market itself, Santa Maria de Mar, or el Fossar de les Moreres, etc. One of the validation tests of the tool was made with Professor Del Moral to verify the implemented calculation process and to test the app in situ.

Data collection and post process to the studied environments

A survey on the studied cases has been done by using the technology of scanning the surface, which has allowed documenting the pre-existence in both places. In order to be able to work lately with GNSS (Global Navigations Satellite Systems), it has to be done a geo-reference of the information by using control points. This technology allowed to obtain a cloud of points that contains information of the X, Y and Z coordinates for each one; the colour RGB (Red, Green and Blue); and the coordinates of the normal vector to the plane that form a point with his neighbours.

On its side, during the second year of the Montjuïc records, because of the complexity -as for example its slopes-, we had to consider other variables. The distance between the positions could not be the same for all the cases –we had to approach till 5 m of distance in certain points-, the alignment had to respond to different parameters as well, etc.

In the case of the Born as in Montjuïc, although programmed positions of the scanner to achieve a full pattern, with no hollows nor mistakes, we had to view additional positions to correct small mistakes in the models.

Once the data collection work was ended, post process began. Its particularity and its new is that once the 3D model for each case is ended (cleaned, depurated, fixed, etc.), the work for the generation of the MDT began. From the point clouds obtained by scanning, the plane of earth

was classified by the RANSAC (Random Sample Consensus) algorithm, where the major plane matches the pavement, and the rest are possible obstacles to the circulation.

During a first phase, we made a net of routes, in order to work the evaluation of the accessibility, on a vector format, but lately we decided that those had to be obtained directly from the traits of each terrain and taking in account their particularities, furnishings, trees, etc.

Development of the tool to evaluate urban environments

We worked at the same time with the generation of data of the previous phase. And, in fact, much of the evaluation values and calculations were incorporated to the pixels of the 3D models, from and advanced step of the post process done during this phase and which identified the elements and separated them in different models, to which lately values for weighting were added.

In a first step, we proved several software and we began the process of generation of processed information from TLS in order to introduce it to the routes in SIG. At the same time, we worked on designing the module of optimal routes. But, finally, we worked on the MDT of every case, by evaluating the optimal routes without the need of generating them previously in vector format, as the routes could be automatically obtained by identifying the elements separately, defining the slopes values, identifying the obstacles and assigning values, all these calculated taking into account all points of the model instead of previously defined routes.

In order to introduce the cloud of points into a GIS (Geographic Information System), they have had to transform into a LAS format, used to store aerial LIDAR data. Once they have been incorporated to the system, the clouds of soil points have been rasterized and, so, reclassified by slopes and the cloud of points, being positive if they ease mobility or negative if they don't.

When one compares the height difference between the two raster layers (pavement and obstacles), one gets the height of the obstacles, and then only those who affect users remain (below 2 m). In order to calculate the optimal route, it has been weighted the usability of the different pavements by giving weights (the higher the more difficult), according to the studied users. So, it has been stablished a weight for light slopes up to 6%, mid slopes up to 12%, high slopes up to 18% and scales, slopes between 45% and 100%.

Regarding obstacles, the weighs have been stablished according to the distance. So, the closer positive obstacles, the lesser weight assigned, and the closer negative obstacles, the higher one. Finally, taking into account the obtained weighs (slopes, positive and negative obstacles), we have final weighs for each of the users, which have allowed to get the following direction from any point to the different stablished destinies.

It is important to mention that the calculation work of the optimal routes, different to each of the three kind of described users (pedestrians, disabled people and wheelchair users), can be done in an automatic way as a direct consequence of the previous process of assigning values to each of the pixels that conform the MDT, on which one can calculate these optimal routes.

Design of the Integrated System

Here was developed the system design. We worked in an integrated way with phase; developing technological solutions, ended with the elaboration of the Web and the App.

The web platform design was defined on the base of the user's basic requirements, according to the pre-stablished types and the destination chosen point. The origin point can be anyone in each case. In order to achieve this, we need to draw the paths that correspond to the routes, from any point (no previously defined) in the studied scope, following the rules given by the calculation of optimal routes. It was used *the Netlogo language* (Figure 9), developed at the Northwestern University, which is specialized in Agent Based Models. The result of this could be executed on the web in a Java applet, but because the security issues, the decreasing use of the plug-in, and the slow to execute, we decided to rewrite the program by using the latest web multiplatform technologies (Javascript and HTML5), which ae capable to run in newest navigators on several OS, as in mobile devices.

The final result to view the routes on the web platform (desk) was developed in Processing 3.o language (developed at Massachussets Institute of Technology). This language uses the Java Virtual Machine, and makes it easy to create the applications in real time. Once the functionality of the NetLogo prototype is implemented, the code is compiled in Javascript and the result is shown as an canvas element of HTML5, where graphics ae drawn and interaction is possible, with the mouse o the touch screen, according to the device (Figure 10). With this procedure, once the user and the destination point are defined, when clicking on any random origin point, it generates immediately the optimal route for every case.

**Figure 9. NetLogo Aplication (Java)   Figure 10. HTML5 View**
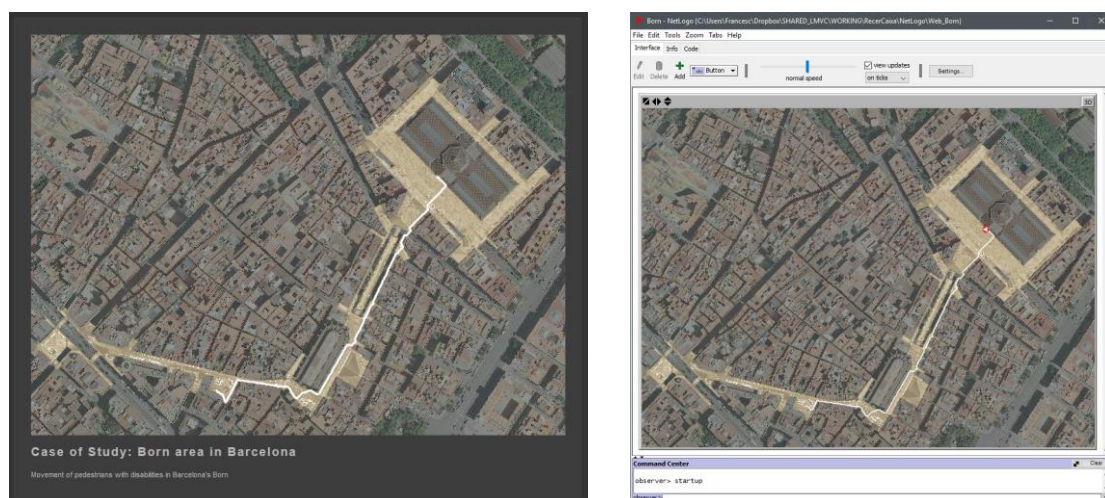
Source: CPSV's own elaboration in the framework of the PATRAC Project. (MICINN 2007 - 2009)

Regarding the app, we decided to work on the base of the plugin Maps Online (http://u3d.as/5YJ), developed by Unity Technologies, that allows to add interactive maps (such as Google Maps and Google Earth) to the applications that can be designed for the Android system and which have been used as a base to the GPS localization for mobile devices. Applied criteria for its development have been the same to the platform web, taking in account the three kinds of users and destinations. Anyway, it is important to notice that from the web

project, one can download executable file, but it has been given the option to use the mobile device GPS or not.

Figure 7. Pedestrian, Sta. Maria. Figure 8. Disabled, Fossar. Figure 9. Wheelchair, Born
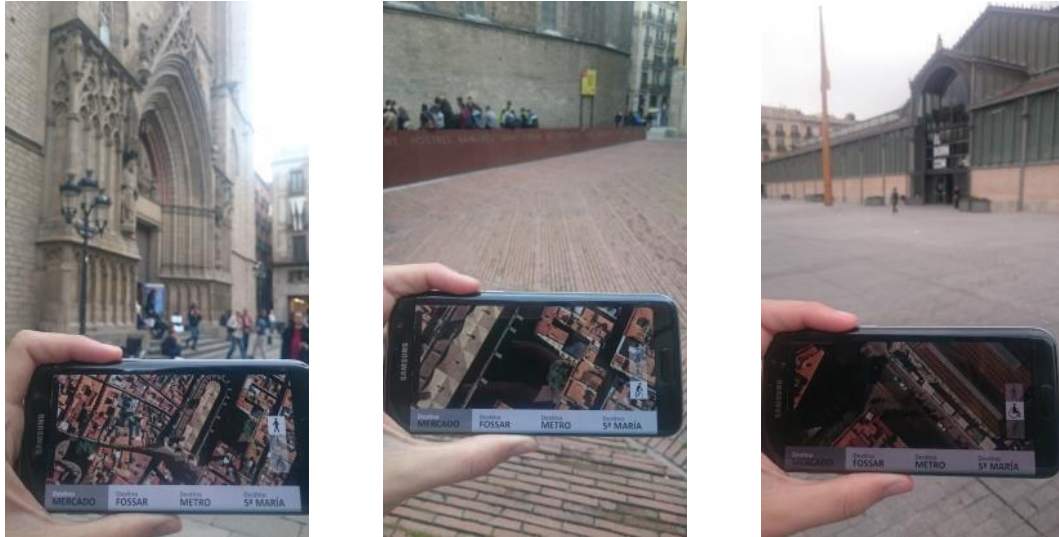
Source: Photography of the authors in the framework of the PATRAC Project. (MICINN 2007 - 2009)

Pilot proves, spread and exploitation has been developed

Regarding the tasks about validation, once the web tool and the App were developed, tests were done *in situ* in order to evaluate the effectiveness of that one. Other validation tests of the tool was made with Professor Del Moral's participation, the last week of the project during her visit to Barcelona to verify the implemented calculation process and to test the app in situ.

Results and futures proposals

The major new of the project, from a scientific perspective, is the integration of methodologies to analyse the reality, with the goal to achieve improvements in the information accessibility and added information about urban space and, ultimately, the calculation of optimal routes for the best displacement in the studied environments.

In order to calculate this, it has been necessary a previous development of a whole methodology for the evaluation of the accessibility to the spaces and the generation of added data, which comes from cloudpoints to generate the 3D models and which, later, has required the identification and classification in groups of the diverse being elements (soils, furnishing, trees, etc.) with the goal to be able to load them with information, assigning to each pixel specific values (0, 1, etc.), according to access difficulty for each one of the three kind of selected users. Finally, once loaded all the information, the formula is developed to calculate the routes. The new part of this methodology compared to other developed and use previously by CPSV is that it does not require a previous draw of specified routes, in a vector way, but the

results are effectively the optimal calculated routes based on the whole added information by each pixel of the model.

The main achieved contribution by the project is the development of a tool of evaluation for the accessibility degree and calculation the optimal routes for users with functional diversity (based on the three predefined groups) and its incorporation to a whole system at disposal on mobile devices and contents and services that can be downloaded in situ remotely via web.

We've got a first product that allows improving certain aspects regarding information and support for the whole access to the public space and the obtaining of routes for three specific kinds of users. Probably the most remarkable aspects under the perspective of the achieved progress during the development is the possibility to calculate the accessibility evaluation from any point of the work area, and not only from predefined routes –as it was been done in previous CPSV projects. So, the applications become a real utility for the users from both areas, not only from restricted specific points but from the whole scope and from any location in each of them.

This evaluation and calculation tool and its implementation through the Web and App, both available on line, are useful to ease the access and understanding for every people who visit both worked cases. There is the possibility to expand easily, and as a result of the project it has been developed the methodology that will allow export the calculation criteria almost automatically to the possible future areas that one would want to develop.

Anyway, we can deduct from these three kind of users previously explained that people with visual disabilities have not taken into account, but criteria for their incorporation have been considered, and methods to incorporate information in these cases have been worked. In this way are remarkable the works developed by Narzt and Wasserburger (2013) explaining experiences of how to incorporate information obtained from visual disabled people, by recording their experiences and reactions to problems in real environments, and by playing these responses on sound devices.

With this consideration, it is evident that there is an open branch for future development, based on the addition of the use of sound information to the calculation tools, which allow other ways to perceive and enjoy the space by visual disabled people.

It is obvious that there is still a way to advance from the perspective of improving the aspects of localization in situ on mobile devices for this kind of products, to be really massive and commonly used and with a level of accuracy higher than the one they currently have and for these kinds of Apps can be part of a kind of service, available for the people in the Smart Cities frame. In this sense is possible work in new future proposals.

Acknowledgements

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