

# UniBS4All: A Mobile Application for Accessible Wayfinding and Navigation in an Urban University Campus

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## ABSTRACT

This paper presents the UniBS4All project, aimed at developing systems and practices for the creation of an accessible urban university campus. UniBS4All is also the name of a mobile application able to suggest personalized navigation paths towards and among the buildings of the University of Brescia. In particular, on the basis of the disabilities of the user (motor disability and/or visual impairment) and on the chosen path type (pedestrian, driving or with public transportation), the app proposes an accessible path, that is, a path able to avoid architectural barriers. The app is based on Google Maps API and exploits Google Directions API to compute the paths tailored to the users' characteristics and preferences.

## CCS CONCEPTS

• **Human-centered computing** → **Accessibility systems and tools**; *Empirical studies in accessibility*;

## KEYWORDS

Universal design, users with disabilities, architectural barrier, mobile navigator

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## 1 INTRODUCTION

Urban accessibility represents a challenge for most of towns all over the world [18]. The Italian Laws 41/1986 and 104/1992 require local administrators to catalog all architectural barriers in their

municipality and manage their removal appropriately. In particular, a plan for urban accessibility (Piano per l'Accessibilità Urbana - PAU) must be created by every municipality in the country in a paper-based format, or by using a digital tool, such as a spreadsheet or a geographic information system (GIS). This plan is actually an extension of the plan for the architectural barrier removal (Piano per l'Eliminazione delle Barriere Architettoniche - PEBA) [10]. The Italian law also regulates the definition of parking lots for disabled people. Furthermore, several towns often includes a limited traffic zone (Zona a Traffico Limitato - ZTL, in Italian), an area (usually downtown) where private cars cannot circulate, at least in some time slots; however, disabled people can be authorized to transit in these zones.

The University of Brescia can be regarded as an urban campus. Indeed, it encompasses a variety of buildings located in different areas of Brescia, a 200.000-inhabitants town in Northern Italy: several historical buildings, including also those ones hosting the administration offices, are located in the city center, whilst other modern buildings are located in the northern district of Brescia. University visitors and students thus need proper instructions to reach the desired destinations. In particular, people with mobility or visual impairments should be guided through the town on paths that avoid architectural barriers and that propose suitable public transportation, or, in case of private cars, they should be provided with information about reserved parking lots and how to cope with limited traffic zones.

Taking a Universal Design perspective [17], our interdisciplinary team has explored the problem of PAU development, combined with the need of supporting people interested in reaching the buildings of the University of Brescia. We are thus working on a project, called UniBS4All, aimed at developing a system able to suggest personalized navigation paths towards and among the buildings of the University of Brescia. The main result of this project consists of two native mobile applications, one for the Android operating system, the other for iOS, which, on the basis of the disabilities of the user (motor disability and/or visual impairment) and on the chosen means of transportation, are able to propose an accessible path. The apps are based on Google Maps API and exploits Google Directions API to compute the paths tailored to the users' characteristics and preferences. In addition, a system for database population has been developed, which can also be used by public administrators to develop a PAU.

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The paper is structured as follows: Section 2 discusses related work in the field of accessible wayfinding and navigation; Section 3 presents the research methodology; Section 4 describes the system architecture and the two versions of the mobile app UniBS4All; Section 5 illustrates the user study carried out with 20 participants (10 for each app); Section 6 delineates some conclusions.

## 2 RELATED WORK

The work reported in [5] presents a review of mobile apps for urban accessibility specifically targeted at users with mobility impairments. These apps mainly consider the accessibility of sidewalks and thus usually propose accessible pedestrian pathways. The authors of the survey underline how some proposals try to address different kinds of disabilities, but the focus is often more on the technical aspects of the application [3], such as the collection of GPS data measurements to build the trajectory followed by the user, rather than on actual users' requirements. Therefore, they propose MEP (Maps for Easy Paths) [4], a project aimed at developing a set of tools and mobile apps for gathering users' pedestrian routes and visualizing relevant information on accessibility maps.

The use of geo-crowdsourcing services is one of the main themes in literature to address the problem of collecting accessibility information. For instance, Path 2.0 [13] is one of the first proposals that allow users to passively contribute routes during their everyday movements. However, that work assumed that these routes can be useful also to other users with similar needs. PAM (Personalized Accessibility Map) [9], instead, is able to combine the general needs of wheelchair users with individual specific preferences to obtain personalized paths. IBM Sidewalks [16] is a mobile application that supports capturing pictures and uploading data about relevant aspects of sidewalks, such as steps, holes, etc. The system mPASS [12, 15] makes a step further by allowing the integration of three different sources of information: i) data gathered through smartphone sensors, ii) data produced by users who voluntarily review urban accessibility information, and iii) official reviews provided by authorities and organizations. As to our knowledge, the system is however still under development: some experimental data are discussed in [12] only by considering the emulation of mPASS operation in the city of Cesena (Italy).

One of the main challenges in data crowdsourcing is stimulating participation by end users to contribute their data. The proposal illustrated in [14] is to enrich applications for geo-crowdsourcing with gamification elements, which could make user experience more engaging and playful. Nevertheless geo-crowdsourcing data should be carefully analyzed by technicians expert in accessibility before entering them in the system, in order to guarantee a correct and uniform information. The concept and the perception of a barrier is very subjective, so it needs to be properly checked.

The problem of accessibility is being addressed by several universities and colleges all over the world. As observed in [9, 11], most universities worldwide make accessibility maps available for downloading, but these obviously contain static information, which cannot be used for real-time navigation. Some projects have however been carried out to develop suitable interactive tools for wayfinding and navigation. For instance, Way-finder [11] is a system targeted at students and visitors of the University College Cork (Ireland),

which supports blind and low-vision people in traditional orientation and mobility training. The already mentioned PAM application has been developed by collecting requirements from 20 USA campuses [8]; it supports trip planning by students of the University of Pittsburgh, by taking also into consideration the routes performed by the shuttle available in the campus, which are tracked by the system.

The above applications are usually tailored to specific places or universities, and thus also maps (such as the university pedestrian network with accessibility information) and navigation algorithms are often developed ad-hoc. In this way, their flexibility for easy adaptation to other contexts remain limited. Our idea was developing a more general system for urban accessibility that exploits well-known services and interaction features. For these reasons, UniBS4All has been designed and developed with the University of Brescia in mind, but, thanks to the use of Google Maps and Google Places APIs, the app could be easily applied to other universities or whole towns. Furthermore, we have chosen to develop native mobile applications, instead of a web application like PAM [9], in order to better exploit device features and make interaction more efficient and coherent with the related operating system.

The applications proposed in literature, including UniBS4All, are focused on outdoor navigation, namely navigation within a city or a campus, in case of universities. However, [6] has recently presented the design activity of AlmaWhere, a system, based on Bluetooth Low Energy (BLE or beacon) technology, that aims at supporting the students of the University of Bologna (Italy) in indoor wayfinding and navigation. This application is currently under development, but could be interesting to combine, in UniBS4All, the features of indoor localization through beacons with the exploitation of Google Maps APIs.

## 3 RESEARCH METHODOLOGY

The system proposed in this paper has been developed through an iterative activity carried out by an interdisciplinary team including software developers, architects and civil engineers, with expertise in web and mobile application development, GISs, and urban Universal Design, respectively. The development process started with some territorial reliefs of architectural barriers in the path from the Brescia train station to the Engineering Building of the University of Brescia. These reliefs were carried out by the team with the help of a person with mobility impairments and two blind persons, in order to better understand the mobility problems these people encounter everyday. After this preliminary phase, some scenarios and mock-ups of the mobile app have been created to foster discussions and brainstorming within the design team and to allow presenting the project to and gathering feedback from public administrators of the Brescia municipality.

Software developers then started developing interactive prototypes by taking always the different users' profiles at the center of the design activity; while the other team members were constantly involved in the evaluation of the different stages of the project.

Two important requirements emerged during the meetings: first, people with disabilities who travel by car are often interested in knowing where the parking lots reserved to them are located; second, they may travel also in ZTLs, but traffic authority requires that

non-resident people send information about car plate and permit within a couple of days after the entrance in a ZTL. The satisfaction of these requirements led to provide features for parking lots retrieval and selection as destinations, for signaling ZTLs in the generated paths to all people (both disabled and not disabled) and for sending automatic messages to the traffic authority on behalf of disabled people traveling in a ZTL.

Since the beginning, the idea was developing an app very similar to the well-known Google Maps app, in order to make its user experience easy to recognize and learn. For the same reason, but also for their powerfulness and reliability, the map services provided by Google were chosen as the basis of UniBS4All operation. The interdisciplinary and collaborative work carried out during design and development permitted to conceive the application according to a *Universal Design* perspective [17]: in other words, we did not actually developed an application that could be used by disabled people to find information about the type and location of architectural barriers, but UniBS4All aims to be an application where *each* user may fill in his/her profile and find the path that is most appropriate to him/her at that time. The app simply provides accessible paths, without showing where architectural barriers are. Another phenomenon was also observed, typical of the co-evolution of users and systems [1], and related to the use of Google Maps API: while, at the beginning of the project, we had the idea of developing an app just for the University of Brescia, we actually arrived at creating a more general app that, when its underlying database is properly populated, may help every citizen of Brescia or any other Italian town (or, in principle, any other town in the world) to find an accessible path.

## 4 UNIBS4ALL

The app UniBS4All provides the user with the most appropriate path according to his/her profile and the selected means of transportation (walking, private car, public transportation). Therefore, differently of other apps presented in literature [9, 12, 16], it does not provide pedestrian pathways only. This is possible thanks to the integration with Google Maps services.

The algorithm for accessible path retrieval is based on the concept of *alternative point*: this means that every architectural barrier identified in the town should be stored in the system along with a corresponding alternative point, namely a point to be included in the path instead of that one with the architectural barrier.

The overall system architecture (see Fig. 1) includes a MySQL database storing all the data related to the architectural barriers and their alternative points, a web application for public administrators to populate the database, and two native mobile applications running on Android and iOS operating systems respectively. The following sub-sections describe the main features of the mobile apps. For the sake of brevity, we only describe the visual interface of the Android version. The interface of the iOS version is slightly different to be coherent with the user experience provided by iOS apps. However, since visually impaired people involved in our project told us that they usually prefer the iOS device, we illustrate the voice-over features with reference to the iOS version of the app. Due to limited space, the description of the web application devoted to public administrators is not reported here.



Figure 1: The architecture of the system.

### 4.1 Mobile App User Interface

The app UniBS4All is structured in three main parts: a splash screen shown during the app activation, the core part of the app, and the navigator. The core part is in turn composed of three sections. The first section is the Toolbar including the typical menu icon in the left-hand side through which the user may access the Navigation Drawer for setting his/her profile and selecting the traveling modality. In the profile screen, the user may declare mobility and/or visual impairments (see Fig. 2a). Whenever the user selects some impairments, he/she may also fill in the form to provide the car plate and access permit, which will be used in case of traveling through a ZTL to send an email to the authority in charge. As to traveling modality selection, the user may choose among pedestrian path ("Percorso pedonale" in Italian, in Fig. 2b), private car ("Mezzo privato") and public transportation ("Mezzi pubblici").

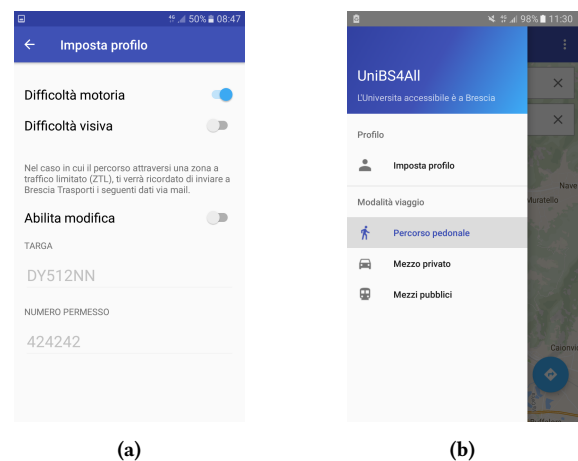


Figure 2: Profile setting (a) and transportation selection (b).

The second section of the core part is the map shown in the central part of the layout. This map (provided by Google Maps) is initially centered in the city of Brescia and shows icons that identify the University buildings (Fig. 3a) and the parking lots reserved to disabled people (Fig. 3b). All these points can be selected as destination points.

When the text boxes are filled in with the starting and destination points, an accessible path is looked for and shown in the third

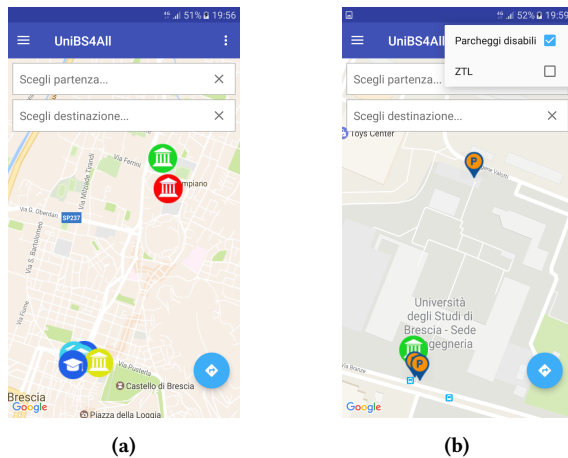


Figure 3: University buildings (a) and parking lots (b).

section, devoted to path visualization (Fig. 4a). Here, a light blue button (the navigation button) is shown in the bottom right-hand side of the application, as well as a text appears with the time and length of the path. When one clicks on the navigation button, the navigator screen is shown (Fig. 4b).

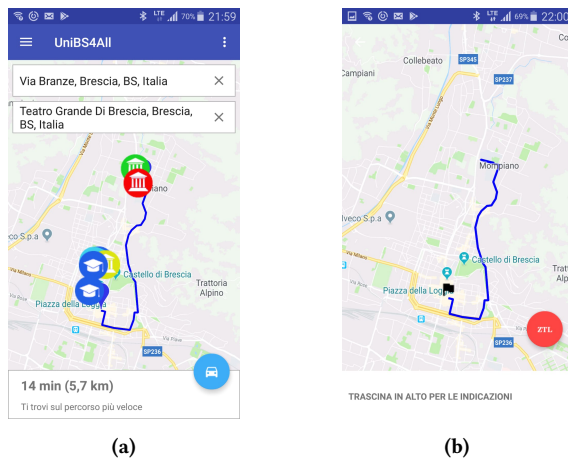


Figure 4: Path visualization (a) and navigator screen (b).

In the navigator screen, if the generated path for a private car requires to travel through a ZTL, this is notified through a red bottom in the bottom right-hand side (Fig. 4b). When this button is clicked, a pop-up with a warning is shown to the user that did not declare any impairments; otherwise, the app provides the user with the possibility of sending to the traffic authority an email with the data available in the user profile.

## 4.2 Navigator

A new navigator, as much similar as possible to the Google Maps navigator, has been developed for the sake of this project: the map with the path occupies the main part of the screen, and a collapsing toolbar includes the list of route directions. When the starting point

is set to "La mia posizione" ("My position"), the navigator can be activated: a voice will thus guide the user throughout the path towards the destination and textual indications will be shown in the top of the screen.

The algorithm for path generation exploits the Google Maps Directions API. When the user has not declared any impairments or the transportation modality is a private car, the path returned by the Directions service can be used as is, except for the visualization of ZTLs. Otherwise, if the user selects the pedestrian modality, the algorithm generates a path that avoids architectural barriers and transits through alternative points; this is obtained by first checking the path returned by the Directions service, and in case barriers are present on the path, an array of alternative points is passed as parameter to the same service to obtain another path that transits through the alternative points (this is iteratively repeated for all barriers). Finally, if the user selects the public transportation modality, since the path to generate is usually a combination of public transportation and walking segments (as currently occurs also in Google Maps), the algorithm must properly create the entire path by exploiting the method previously described for generating accessible walking segments.

The generated path is stored in a JSON file, which includes all routes directions, times and segment lengths. This file is used by the navigator to visualize the path and by the text-to-speech feature.

## 4.3 Interaction for visually impaired users

The iOS version of UniBS4All integrates Apple Voice Over and the AVFoundation Framework to make the app accessible to visually impaired people. Voice Over is actually a speech synthesizer that allows users to listen to object descriptions and interact with the app with suitable gestures (such as scrolling for listening or double-click for function activation), as well as to properly use the virtual keyboard. Each graphic element of UniBS4All has thus been associated with a customized label that can be read when the element is selected, whilst starting and destination points can be inserted through the Voice Over keyboard or through dictation.

In addition, specific sounds are produced by UniBS4All to notify the user of changes in the user interface; for instance, whenever the list of possible destinations is updated, this is notified to the user by a given sound. Finally, like in the Android version, text-to-speech is implemented to help the users follow the navigator indications.

## 5 USER STUDY

### 5.1 Methodology

A usability experiment of the two versions of the mobile application has been carried out. A total of 20 users participated in the experiment. Ten participants (4 females) used the Android version: their age ranged in 22-48 (M=29.4, SD=10); 5 participants declared mobility impairments, and one participant declared visual impairments. The other 10 participants (5 females) used the iOS version of UniBS4All: their age ranged in 17-52 (M=34.5, SD=12); 3 participants declared mobility impairments and 2 participants declared visual impairments.

The users were asked to perform six tasks concerning profile setting, visualization of parking lots on the map, destination selection on the map, access to ZTL information, path finding with

different transportation modalities, navigator usage. Finally, a more complex scenario to test the different features of the application was assigned. The smartphone of an experimenter was used in all the trials, but the users did not find any difficulty in using some other's device. No formal training was provided; only a brief explanation of the context and the goals of the project was given before starting the test.

For each task and scenario, the perceived difficulty and completion rate were collected. Qualitative data from direct observation and comments of participants were annotated as well. In addition, at the end of the experiment, we talked with the users to gather their feedback; in particular, we adopted a structured interview including the following questions:

- Q1:** Do you like the graphics of the app?
- Q2:** Do you think that the app is easy to use?
- Q3:** From the user interface point of view, do you think that it is similar to Google Maps?
- Q4:** Do you think that the app might be useful for disabled people?
- Q5:** What do you like most of the app?
- Q6:** What do you don't like of the app?
- Q7:** Do you have some suggestions to improve the app?

Finally, we submitted a SUS questionnaire [2] to obtain an estimation of the app usability.

## 5.2 Results

Participants indicated the perceived difficulty of each task and scenario on the qualitative scale {"very easy", "easy", "medium", "difficult", "very difficult"}.

As to the Android version of the app, most of participants found the first three tasks "very easy" or "easy"; Task 4, which required to find a pedestrian path from the current position to a given destination, to visualize directions and activate the navigator, was judged by most of the users as "easy" or "medium" to execute; similar results were found for Task 5, which concerned the finding of a driving path to a destination in a ZTL. Two participants judged as "difficult" Tasks 6, because it required to set the student administration building as destination, which was however not easy to identify without knowing its approximate position in advance; only one participant assessed the scenario as "difficult", while most of the other users considered it as "easy", thus demonstrating that the application is easy to learn. No participant assessed any task or scenario as "very difficult".

As far as the iOS version of UniBS4All, all tasks, out of Task 2, have been considered "very easy" or "easy". The two blind users found the difficulty of Task 2 as "medium", since they had problems in selecting a parking lot directly on the map (they could search it, but they did not know its name). One participant judged the difficulty of the scenario as "medium", whilst the others considered it as "very easy" or "easy".

Task and scenario completion rates for both apps are reported in Table 1. As one may observe, only Tasks 4 and 6 were not completed by all users of the Android version. Whilst, for the iOS version, the two blind users were not able to complete Task 2 due to the issue mentioned above. All the encountered problems were however useful to gather suggestions for improving the app. Interestingly

**Table 1: Task and scenario completion rates**

| Device  | T1   | T2   | T3   | T4   | T5   | T6   | S1   |
|---------|------|------|------|------|------|------|------|
| Android | 100% | 100% | 100% | 90%  | 100% | 80%  | 100% |
| iOS     | 100% | 80%  | 100% | 100% | 100% | 100% | 100% |

enough, all participants completed the scenario, even though it was much more articulated than the previous tasks.

From the observations and comments gathered during the experiment we found that some users did not initially understand that the icons of parking lots can be selected and used as destinations; also the use of the ZTL button for opening the precompiled email to be sent to the traffic authority was not so intuitive; furthermore, in the tasks requiring to find a path from the current position to a given destination, some inefficiencies emerged in case the GPS is not active. Finally, we derived several indications for improvement: the users suggested to make icons more explicative (including descriptions if possible); another suggestion is concerned with the visualization of route directions that, according to the users, should be provided just after the path computation, and not only in the navigator section; similarly, they proposed to visualize the position of ZTLs, if any, as soon as possible, thus anticipating the time of path acceptance or rejection before the navigator activation.

The semi-structured interview provided encouraging results: all participants gave positive answers to questions Q1-Q4. As to Q5, the users appreciated the limited number of screens that help remembering the actions to perform, and they also declared their appreciation for the purposes of the application; in particular, the two blind users that used the iOS version appreciated the Voice Over features by considering it effective and coherent with the usual interaction with iOS devices. The answer to question Q6 was focused on the ZTL management, because the meaning of the red button was not clear (this problem has been already solved by including, in the Android version, a new option in the Navigation Drawer to access a legend screen and, in the iOS one, the typical tutorial available in many iOS apps). As to Q7, the visually impaired participants suggested to use a different sound for list updates, to avoid confusion with that of Siri functionalities. Some participants suggested to provide a search chronology, while some others proposed to give the possibility of inserting permit information just before sending the email, thus avoiding to fill them in advance in the user profile.

Table 2 presents the SUS scores assigned by the users to the UniBS4All app. Not only the mean value for both versions is pretty high (88.25 for Android and 90 for iOS respectively), but also the individual scores are all greater than 70, the threshold usually adopted for declaring that a system is easy to use [2].

## 6 DISCUSSION AND CONCLUSIONS

In this paper we have presented UniBS4All, an app for accessible path finding and navigation, currently applied and tested at the University of Brescia. With respect to other literature approaches, we followed a Universal Design perspective, in that our app is not focused on visualizing and notifying architectural barriers and accessible routes, but on supporting every user, with or without

**Table 2: Results of the SUS**

| User Android | SUS Score | User iOS | SUS Score |
|--------------|-----------|----------|-----------|
| UA-1         | 82.5      | UI-1     | 85        |
| UA-2         | 92.5      | UI-2     | 82.5      |
| UA-3         | 72.5      | UI-3     | 92.5      |
| UA-4         | 97.5      | UI-4     | 90        |
| UA-5         | 90        | UI-5     | 100       |
| UA-5         | 95        | UI-6     | 87.5      |
| UA-7         | 92.5      | UI-7     | 100       |
| UA-8         | 87.5      | UI-8     | 90        |
| UA-9         | 90        | UI-9     | 85        |
| UA-10        | 82.5      | UI-10    | 87.5      |
| Mean         | 88.25     | Mean     | 90        |
| SD           | 7.36      | SD       | 6         |

impairments, or possibly with a temporarily impairment (e.g. a parent driving a stroller, a person carrying a heavy object, etc.), to find the path that best suites his/her needs and preferences.

The app is based on Google Maps APIs and thus exploits its Directions service and available data. In particular, data about Points of Interests (POIs) and sidewalks are thus kept automatically up-to-date, and public administrators should provide only architectural barriers and alternative points, possibly during the preparation of a PAU. This paper also presents a usability test carried out with 20 users, including low vision and blind people, who judged positively the voice-over functionalities.

However, there are a set of limitations that should be overcome in the future. First of all, inspired by literature work [3, 12], we are implementing a crowdsourcing feature: the users will be able to signal the presence of barriers, by providing their location, but these notifications will be validated by public administrators in charge of the PAU who have the authority and competence to update the database used by UniBS4All. In the current version, the user profile is static, whilst it might be useful to implement an algorithm to learn the profile on the basis of user's behavior, as proposed in PAM [9]. Furthermore, we respect to PAM, UniBS4All does not personalize paths for hearing impaired people; this is another aspect to be considered in the future.

As to future work, we would like to explore the use of Google Maps APIs for both outdoor and indoor navigation. In the latter case, markers should be created to map all the relevant places inside buildings, such as class rooms, offices, stairs, elevators and so on, as well as architectural barriers and their alternative points must be added to our database. The algorithm implemented in UniBS4All can then generate accessible paths just as in the case of outdoor navigation. However, proper mechanisms for user localization must be adopted in alternative to GPS signal; the idea of using beacons, as proposed in the AlmaWhere project [6], appears as an interesting approach to address this problem. We are also planning to widen the project by integrating these navigation features into another system we developed for enhancing interaction with artworks in museums and cultural sites [7].

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