NoBis: A Crowd Monitoring Service Against COVID-19

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Abstract. This paper presents *NoBis*, a new service for monitoring the crowding of indoor spaces in the COVID-19 era. The name links the concept of "We" to the desire of not having an "Encore" of the first lockdown experienced worldwide in March 2020. *NoBis* is a REST-based web application which provides tools for allowing "Referents" to manage places to be monitored and, at the same time, for allowing end users to consult in real time the crowding state related to monitored places. The entire platform is based on the use of QR codes which users scan each time they enter (Check-in operation) and exit (Check-out operation) from a monitored place. *NoBis* is implemented in JavaScript both for the front end, with the help of libraries such as JQuery, and the back-end, through the use of Node.js. This choice allowed for a more agile and "lightweight" development, in accordance with the time constraints required by the project. During the month of September 2020 a preliminary testing phase took place at the Department of Information Engineering of the University of Padova. *NoBis* represents a valuable tool to monitor crowding in libraries and similar enclosed places accessible to the public.

1 Introduction

SARS-CoV-2 (COVID-19) represents the most recent and largest pandemic of the last Century, and has caused in the first nine months of 2020 more than one million deaths globally. After China, Italy was – unexpectedly – the EU country most affected by its spread, with Italian people experiencing very hard times and facing ever seen challenges. It was clear from the beginning that social distancing was a useful option to counter the spread of the pandemic. Subsequent studies related to COVID-19 [1, 2] have

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confirmed the effectiveness of maintaining social distancing, which is therefore necessary in the absence of pharmacological alternatives. In this scenario, ICT and digital technologies gained much traction as they provide an invaluable support to society, especially for containing the number of new infections. An example is the "Immuni" application [3], an ICT solution proposed by the Italian Government, which implements the exposure notification system developed by Apple [4] and Google, based on the generation, sharing, and rotation of random keys and identifiers via the Bluetooth technology. This system allows for tracking, anonymously, the contacts of individuals, and for identifying, in case of COVID-19 positive subjects, networks of infected individuals in a simple and fast way. Along these lines, in this paper we introduce *NoBis*, a crowd monitoring service, complementing existing systems, e.g., Immuni, by allowing citizens to monitor in real time the crowd level of public and private places and adapt their mobility accordingly. *NoBis* is based on the technology of the QR code, a two-dimensional matrix barcode, which is displayed near the entrance and the exit of places to be monitored. When framing the QR codes with a smartphone camera, the users perform check-in/check-out operations at/from these venues, thus making it possible for *NoBis* to monitor how many visitors are at a certain location. Users can also access such information through a public website in order to avoid moving to excessively crowded areas and to reduce the opportunities for gathering and, therefore, for further the spreading of COVID-19.

NoBis is a free of charge and and easy-to-use system, which requires neither external hardware nor dedicated apps, while only the scanning of a QR code with the built-in smartphone camera. Moreover, *NoBis* does not pose any privacy issue, since it does not store any personal data.

The paper is organized as follow: Section 2 presents some services similar to *NoBis*; Section 3 introduces the architecture of *NoBis*, while Section 4 describes the current prototype; Section 5 conducts a preliminary evaluation of *NoBis*, and Section 6; finally, Section 7 draws some conclusions and outlooks for future work.

2 Related Work and Background

NoBis differs from already existing systems for crowd monitoring and exposure notification, as the ones listed in Table 1 (see [5] for an extended comparison), for simplicity of installation and use, and for privacy management.

Table 1: Example of technological solutions against COVID-19.

App Name	Hardware	App needed	Technology	Use cases
Immuni	No	Yes	Bluetooth	Exposure notification
Affluences	Yes	No	Mixed	Crowd monitoring
Google Maps	No	Yes	GPS	Crowd monitoring
NoBis	No	No	QR Codes	Crowd monitoring

Like most European countries, Italy has developed a Bluetooth-based application for contact tracing called *Immuni*, a tracking system that safeguards the privacy of its users. In these regards, *NoBis* does not aim at replacing Immuni by implementing contact tracing functionalities but offers a complementary service where users can limit

Schema Unipd NoBis Project 1-1.png

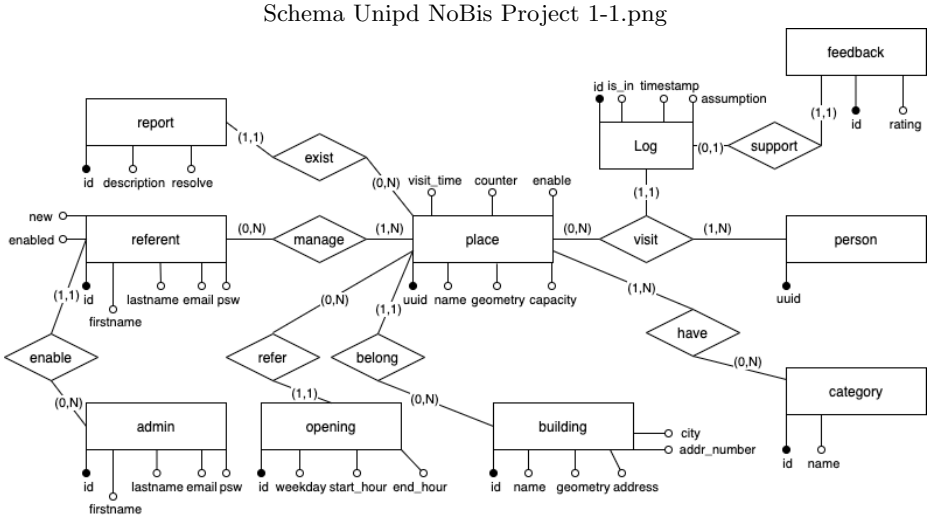


Fig. 1: NoBis entity-relationship schema.

and adapt their mobility decisions depending on the crowd level of the different areas. Among others, two services to estimate the affluence of public places are worth mentioning: "Google Maps" and "Affluences". The first one takes into account the location information that Google Maps users provide to the system over time. Affluences, on the other hand, which is mostly used in libraries, museums, stores and swimming pools, provides an estimate of people and uses multiple technologies. In particular, Affluences' predictive algorithm estimates the crowd level by taking into account both the information made available from the sensors deployed at the place of interest, as well as the access history, calendar, and number of visits to the application by users. Unlike Affluences, *NoBis* does not require expensive sensing technologies but it simply needs to post two printable posters on the main entrance and exit of a location, to display the corresponding QR codes, thereby providing a cost-free solution.

3 Design and Architecture

3.1 Conceptual Design

Figure 1 shows the Entity-Relationship scheme of the *NoBis* application. Its main elements are:

- `Place`s and `Building`s which represent the monitored areas where a `Building`, e.g. a University department, can be divided into several `Place`s, e.g. a library or a computer room, to be monitored. We can also attach additional information to each `Place`, such as a `Category` or `Opening` hours.
- End Users who scan the QR code at the entrance/exit of a `Place`, and that can visit the *NoBis* website to check the current crowd level of the `Place`s traced by the system. An End User is represented as a `Person`: an anonymous token generated when an End User checks-in at a `Place`, in order to keep track of how many people

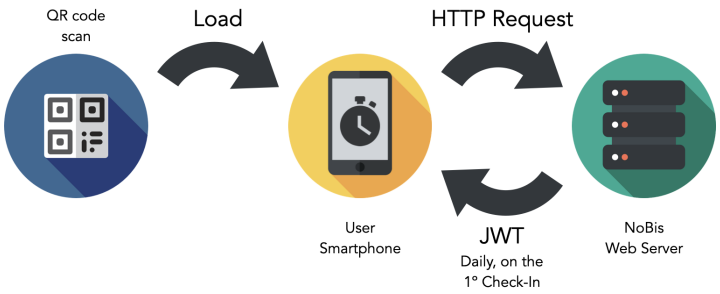


Fig. 2: Check-in/out operations workflow.

are there, still ensuring their privacy. A `Person` is associated with a `Log` entry, where also `Feedback` information can be reported to let the End Users assess the crowding state of a `Place`.

– `Referent`s can create new `Building`s and `Place`s to be monitored, and download the corresponding QR codes to deploy. Also, the `Referent` can inspect the actual number of `Person`s who checked-in at the `Place`s he/she has created, as well as any problems that the `User`s might have eventually, anonymously, `Report`ed. The `Referent` status must be directly enabled by an `Admin`.

3.2 Workflow

Check-in and Check-out Operations As shown in Figure 2, the user, after scanning the QR code, is redirected to the page of the check-in/check-out operation, which automatically starts a five second timer. When the timer expires, the operation is recorded within the system by calling a specific API. This time interval allows the user to cancel the current operation if it was started by mistake. If the users are aware that they want to continue with the current operation, they do not have to wait for the timer to expire but can put their smartphone on standby so that the process will be completed in the background. In this way, we provided a process to make the numerous operations that may take place during day less time consuming, still offering a possibility to cancel the useless ones. For security reasons it is not possible to programmatically close browser tabs, so at the end of the Check-in and Check-out processes the web page may remain open [6]. After reopening the browser, the web page is reloaded and, if the user does not stop it, this will result in a new Check-in or Check-out operation and a consequent inconsistency in *NoBis* database. To get around this issue, we save in the device storage the UUID (Universally unique identifier) of the location of the current operation and timestamp and only when checking out from the location, that information is deleted. Therefore, if the users try to do multiple check-in operations in a place where they have already registered in the previous eight hours, the page shows that the operation may be repeated and does not activate the timer, asking the users for an explicit confirmation to perform the operation. The situation is similar if users do not close the check-out page.

JSON Web Token Usage To ensure privacy, we associate each user with an anonymous UUID with a daily validity, stored inside a JSON Web Token (JWT) and

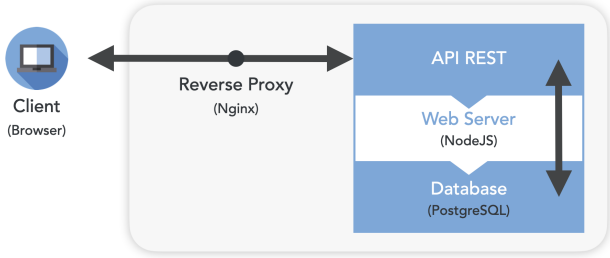


Fig. 3: Software architecture and technological stack.

sent to the user device during the first check-in/out of the day, as shown in Figure 2. In this way it was possible to understand if a user has forgotten to perform a check-in or check-out and ensure a greater consistency of the logs. Additionally, the UUID permits all actions that the device performs in the system to be identified without using or storing any personal/sensitive data about the User and/or his/her device.

3.3 Architecture

Figure 3 shows the architecture of *NoBis*. Nginx [7] operates as a reverse proxy to the client, in order to balance the load, moves CPU-bound operation away from node.JS and protects the *NoBis* web server and database behind a firewall. The *NoBis* web server is implemented using Node.JS [8] with the help of the Express.js framework [9], that allowed us to build robust and light-weight REST (Representational State Transfer) API. Finally the data layer is implemented using the PostgreSQL relational database management system and the PostGIS extension to manage the spatial information related to monitored places.

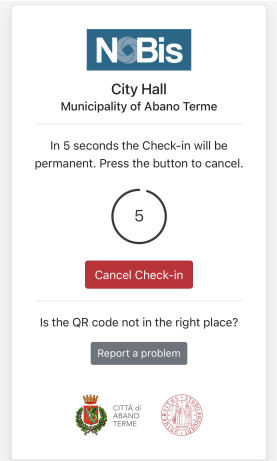
4 Prototype

The current prototype of *NoBis* is available at `nobis.dei.unipd.it`. Its user Interface has been designed to be as simple and immediate as possible: all the relevant information (related to the level of crowding level of target places) are available in one single page.

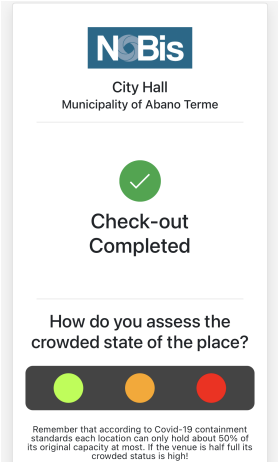
Figure 5 shows the check-in/check-out process by scanning QR Codes. As illustrated in Figure 4c, after the check-out is completed the user can express feedback regarding the state of crowding that he/she perceived: this represents a method of mitigating any possible discrepancy between the data visualized by *NoBis* and the real crowding of a place.

The User's Dashboard is divided into two sections, as illustrated in Figure 6. On the left-hand side there is a map where it is possible to observe and interact with the places listed on the right-hand side of the Dashboard. Each place, in addition to its name, specifies the building in which it is located, its type, and finally the crowdedness level calculated based on the Check-in and Check-out logs. A place is reported as highly crowded if *NoBis* detects a number of people at that place exceeding 80% the available covid-limited capacity, as specified in the capacity attribute of the place entity. Instead,

Check-in (left) check-out (right) operations.



Check-in interface.



Check-out interface.

Fig. 5: The check-in and check-out operations.

if the crowding is between 40% and 80%, the occupation level is defined as moderate. Inside the User's Dashboard it is possible to search by name, or move the map, to display new locations. Place search via map is enabled only if the map is zoomed in after a certain threshold, in order to avoid the user devices to handle a possibly huge number of monitored places. This choice has been made necessary for performance reasons as, in less performing clients, the quality of experience could be very bad due to the loading of a high number of places automatically.

Finally, the administrators can access the admin panel where they can enable or disable the various registered Referents. On the other hand Referents, once they have logged into the main page i.e., the Dashboard (Fig. 7), can create and manage places, buildings and any problems reported by the users. The Referent's Dashboard contains all the data related to the locations managed by the Referent itself, including the current number of people within each location. A Referent can also enable or disable a location, download the QR codes for Check-in and Check-out operations, add the opening hours of the various places, and finally modify each place. By design, a building can include several places: the Referent is not allowed to modify the main building,

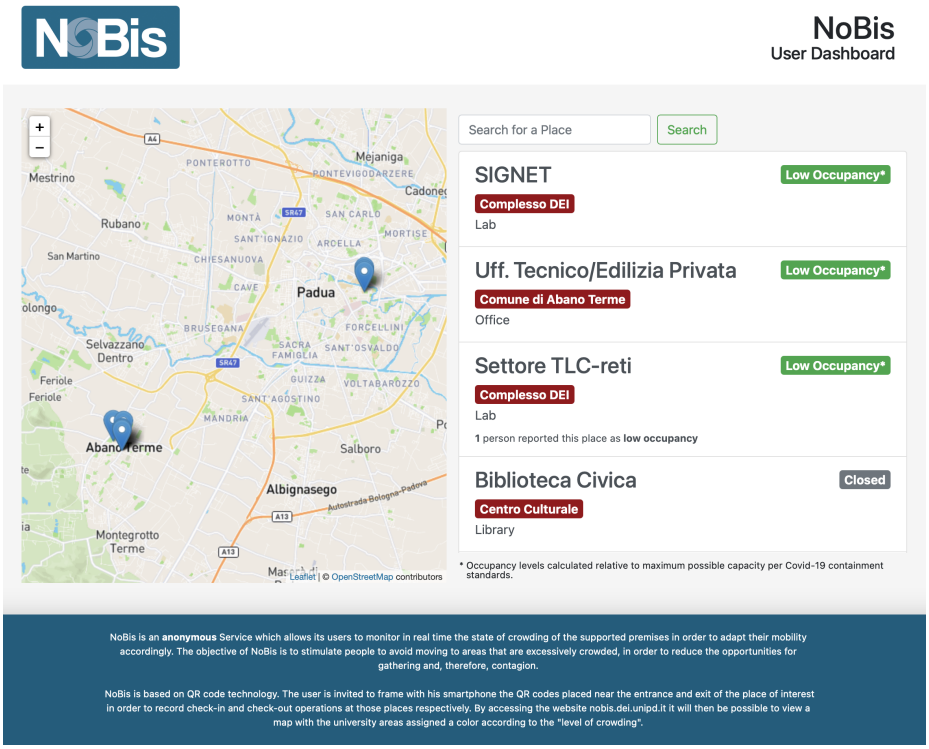


Fig. 6: NoBis User's dashboard.

but the places only. Instead, the cancellation of a building is allowed and involves the elimination of all the places connected to it.

A video overview of *NoBis* functionalities can be found here [10].

5 Evaluation

5.1 User Testing

NoBis has been deployed, tried, and tested at the Department of Information Engineering of the University of Padova between September 10 and October 21, 2020. This phase included the monitoring of the crowdedness level of three specific places, i.e., two laboratories and the building that contains one of them. It was chosen to include this building, as well, to have the possibility to involve a larger number of users, while keeping the number of places/buildings to manage limited. During the six weeks of testing, 475 Check-in/out operations were carried out, with an average of 8 unique users per day.

During this testing phase, we have been able to collect real-time statistics about check-in/check-out operations, that are analyzed, in the form of aggregated anonymized information, to ensure the smooth and proper functioning of the system. We have examined the following metrics:

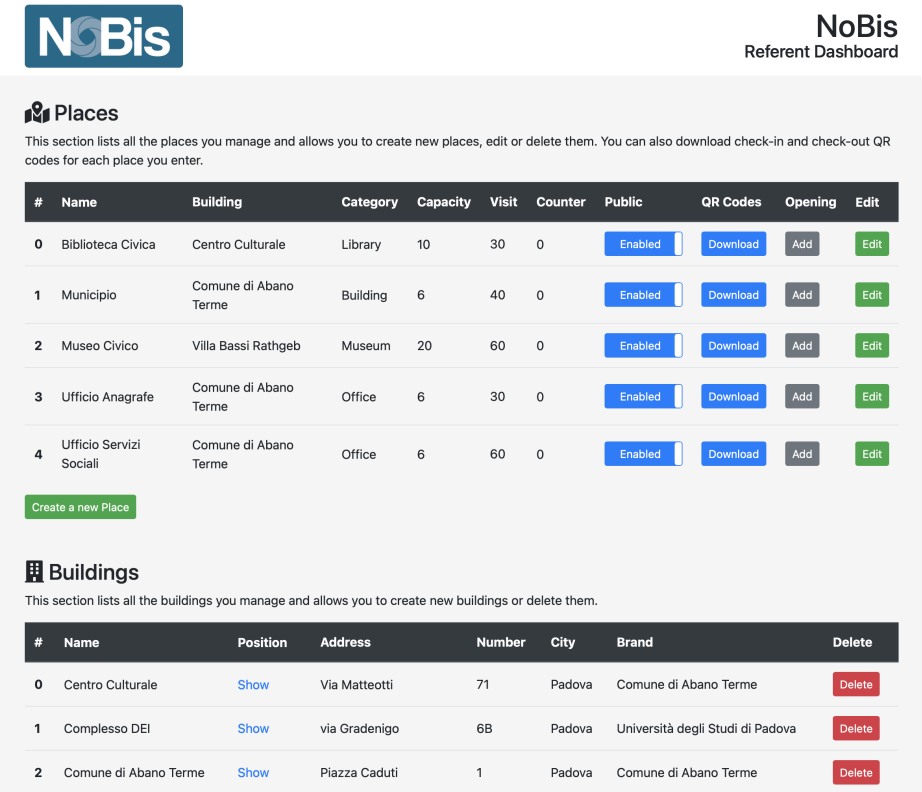


Fig. 7: NoBis Referent's dashboard.

– The check-in/check-out conversion ratio, which evaluates the percentage of checking-in users who also check-out. It should be noticed that, while it is important that each user checks-in by his/her own at each access to a location, check-outs will be automatically triggered in any case if the visitor forgets the check-out and completes his/her next check-in, or if the system resets (i.e., at midnight, every day).
– The check-in/check-out accuracy ratio, which compares the real number of visitors in a certain location (manually tracked by our Department's Administrative Office) with the number of visitors estimated by *NoBis*. This metric demonstrates the reliability of the information we make available to the public through *NoBis*.

The results of our preliminary testing phase at our University Department have already proven *NoBis* to be effective: both the conversion and the accuracy ratios are above 75% in most locations. Moreover, our analysis shows that in the first three weeks of testing, about 20% of the total logs could be ascribed to assumptions of the system had to make as a result of users' forgetfulness. In the second half of the testing period, instead, the assumptions are less than 10% of the total, an indication that *NoBis* users have become accustomed to the service and less system interventions were needed to ensure the consistency of Check-in and Check-out logs.

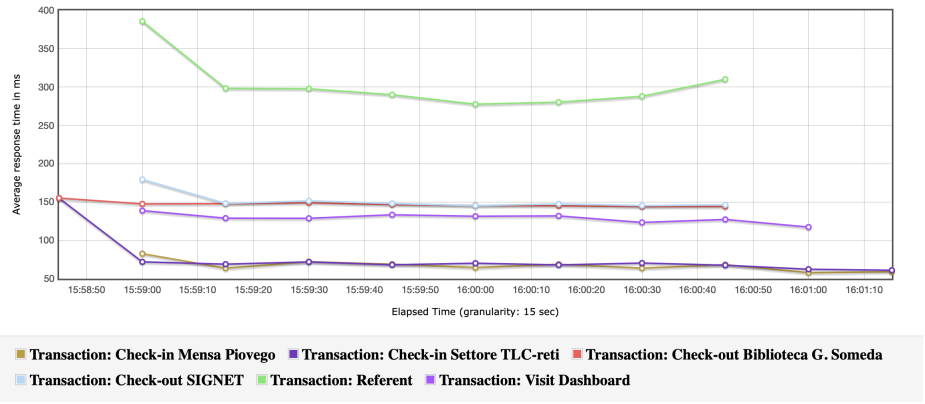


Fig. 8: Response times of aggregated HTTP requests.

5.2 Load Analysis

NoBis has been developed with the aim of providing a high performance service with low response times, even under high loads. We used Apache JMeter [11] to test the system with about 1400 concurrent and simulated users, which perform the following operations: check-out from a location; check the crowdedness state of the places in the User Dashboard, with three movements across the map to discover new places; and, check-in at the next place. We introduced some randomness to produce results more similar to reality, for example transactions are separated in time by a value that is produced by a Gaussian timer with 15 seconds of mean and 5 seconds of standard deviation; in addition, a simulated user is assumed to forget to Check-in or Check-out with a probability of 80%. For a greater homogeneity of the tested cases, it was decided to create, within the test, two flows of users with an identical structure, but different locations, and to assign to each of them 700 threads (users). In addition to the two groups represented by the end users, it was decided to introduce a further Thread Group of 50 Referents related to the operations concerning the management of the places. This test allowed us to evaluate the behavior of the system in the presence of the following (critical) cases:

- Concurrent Check-out from the same place;
- Concurrent Check-out from different places, an event that may arise due to the introduction of the two parallel flows of users;
- Concurrent Check-out and Check-in, an event that may arise due to the phase shift introduced by activation of users in a two-minute interval;
- Concurrent Check-in in the same place;
- Concurrent Check-in in different places, again due to the introduction of two separate streams;
- Concurrent assumptions by the system to correct forgotten check-in/out operations from users;
- Concurrent use of private and public REST APIs;
- Mix of Check-in/out operations and access to the User and Contact Dashboard.

The test obtained very good results. In Figure. 8, it is shown that the response times are relatively low and constant throughout the duration of the test. Moreover,

the test has shown a good throughput with almost 90 transactions (groups of HTTP requests) per second without stressing the available hardware resources. This allows us to conclude that *NoBis* is scalable to loads of a small/medium community, such as a University or a municipality. More details can be found in [12, 13].

6 NoBis Impact

In countries with declining numbers of cases of COVID-19, lockdown measures are gradually being lifted. In this scenario, new rules are being developed so people can move in a comfortable and safe way. To begin with, social distancing is the most critical pre-requisite to keep everyone safe, and the key to achieve this in limited public space lies in the ability to have a real-time overview of how crowded hotspots are so that appropriate steps can be taken when an area gets too busy. This is indeed the main purpose of *NoBis*, which targets the following objectives.

- **Safer environment for local communities**. *NoBis* is a system that uses QR codes to determine and control the number of people that access to enclosed public spaces. Once complete, this information is displayed on-line to inform the public about crowds and potential risks, enabling people to make conscious and smart choices about their mobility (e.g., by avoiding visits to the most crowded areas and diverting their mobility towards less busy places). This strategic policy ensures better confidence in mitigating the risk of formation of large clusters, thereby providing the social community a safer environment in the fight against COVID-19 spreading. Moreover, the QR-based nature of *NoBis* allows users to safely complete their check-in/check-out operations with no contact with physical devices like touch screens or buttons, thereby limiting the potential spread of the virus compared to other applications in which visitors have to use their hands to tap the screen.
- **Cost-free**. Unlike other crowd monitoring solutions that use expensive NFC-based and/or wearable technologies, *NoBis* simply requires the installation of printable posters to display QR codes. Indeed, *NoBis* imposes as a cost-free solution, accessible to everyone, with no need for external hardware to be purchased and/or installed.
- **Ready-to-use**. *NoBis* does not require the download of any specific application to properly work, while it simply requires the use of the visitor's smartphone to scan QR codes: nearly all recent Apple's and Android's phones have built-in QR code scanning capabilities right in the camera app itself.
- **Accessibility**. *NoBis* design is lean and clear, and visitors do not need to create an account to use its functionalities, hence imposing as an accessible, ready-to-use, easy-to-deploy solution also for elderly adopters, which represent the most fragile and sensitive category of people that will benefit most from *NoBis*' services.
- **Complimentary**. In recent months, many countries have developed contact tracing apps that allow to receive an alert when a person has been in close contact with somebody that, later on, will turn out to be positive to the COVID-19. In these regards, *NoBis* is born as a complimentary, and not alternative, service to those applications, and allows users to preventively limit and adapt their mobility decisions as a function of the crowd level of the different areas.
- **Privacy-compliant**. *NoBis* does not use GPS, WiFi, or Bluetooth tracking, and lets its users control when to share data. Moreover, *NoBis* does not use the check-in data for advertising or marketing purposes, thereby promoting privacy and data

protection. Moreover, the *NoBis* dashboard does not show precisely how many people are in an area but an "index of crowdedness" associated with those areas, hence providing a totally anonymous service.

7 Conclusions and future perspectives: beyond COVID-19

NoBis is a service that allows its users to know in advance the crowdedness state of the places they are planning to visit, and to make more aware trips based on the information that *NoBis* is able to provide. The testing phase of *NoBis*, that took place in the laboratories and buildings of the Department of Information Engineering of the University of Padova, allowed first of all to carry out real tests and correct any errors in the code of the platform. Secondly, but equally important, it was possible to collect the opinions of the first users and better understand the difficulties of use and possible barriers of diffusion that a tool like *NoBis* can present. This testing phase has actually intercepted curiosity and enthusiasm thanks to its nature of strictly voluntary access, which allows to create, in some cases, a sense of community (hence the name "NoBis"). An important aspect of the trial period of the platform has been related to the privacy of the user and the laws and regulations that seek to protect it: the design and development of *NoBis* has always had in mind the privacy of its users. Moreover, during the month of October 2020 a dialogue with the Municipality of Abano Terme (Padova, Italy) has allowed to realize, in the following months, a second testing phase in specific places related to a municipal reality. This recent agreement with the Municipality of Abano Terme demonstrates the relevance that *NoBis* has attracted. As it is clear, the future of *NoBis* is undoubtedly closely linked to the need to avoid, during pandemics, crowded places and to provide people with useful tools so that possible gatherings do not take place. Beyond that, the *NoBis team* is working to structure a sustainable business model, like cultural events, museums and exhibitions, that will allow *NoBis* to remain active in the future when the emergency period dictated by the spread of SARS-CoV-2 virus will be over.

8 Acknowledgments

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