# Crowd Orchestration - An EPS@ISEP 2021 Project

No Author Given

No Institute Given

**Abstract.** In the second semester of the 2020/2021 academic year, 5 students from different areas of study and from different countries, namely: Portugal, Romania, Poland and France, teamed up and decided to create a solution to solve the problem of Crowd Orchestration. This project is called European Project Semester (EPS) and was developed at the Instituto Superior de Engenharia do Porto (ISEP). The disorganisation of events/festivals is a reality that affects the quality of life of many people and, in this sense, the team wants to contribute with a product that solves all the problems of disorganisation of events around the world. To solve this, we created a product called "ScanGo" that has several features, such as: alerting the number of people in real time in a certain area, indicating activities that are happening at the event, indicating the easiest way to go from a stage to the other, etc. Nowadays, the pandemic has become an obstacle to the fun and work of many people. People's desire is to return to normal life as soon as possible, as during this last year, festivals or any type of events that required the existence of a large audience were interrupted. In this way, it can be said that COVID19 has had and will continue to have a great impact on our lives. In short, the team wants to contribute with a product that solves all the disorganisation problems of events around the world.

**Keywords:** computational geometry, graph theory, Hamilton cycles

## 1 Introduction

The European Project Semester is a programme for international students who have completed at least two years of study. Designed by Arvid Andersen in 1995, especially for engineering students, EPS combines problem based learning with project related courses [13]. Adopted by a network of 19 European universities, including the School of Engineering (ISEP) of the Polytechnic of Porto, the goal of this semester programme is to promote teamwork, motivating students to work together in the design, and development of an innovative product, while improving communication skills and getting familiar with different cultures, and work methods.

In the 21st century, large events have become very popular. There are many outdoors and indoors festivals organised. In this events, organisation is sometimes really poor - people often do not know where the concerts take place and

where they can find the place they are interested in, because of the large area the festival takes place in. Moreover, people have often to wait in long queues to go to the toilet or to buy something in a restaurant or bar due to the high number of people in the given zone. Also since 2020 we are facing the problem of pandemics, everyone wants to avoid crowds of people and have control over the number of people in a place.

Controlling crowds during festivals is a very difficult task, even if a large number of staff are involved. For this reason, we decided to create a product that is missing on the market, which will help minimise these problems. ScanGo aims to help in organising events, showing festival participants the right path, thus avoiding overcrowding and to make attending the festivals more pleasurable and less complicated.

The team has ideated a system whereby a festival attendee will get real-time information about different concerts, crowd density and incentives about alternative activities and his/her smartphone using our device.

Within this context, five students from four different countries Portugal, France, Romania and Poland, and with diverse study backgrounds mechanical engineering, biotechnology, industrial design engineering, business and technology, packaging engineering got together to embrace the challenge of devising an innovative product: ScanGo. Our main mission is to make team work our main strength in order to create a positive work environment and achieve all established goals.

There are many restrictions when creating the project, among them we have to use inexpensive materials, because our budget is maximum 100 euros. Our task is to follow ethical, sustainable and environmental requirements. We want our device to be easy to use.

This paper starts by outlining the aims of the project and the functionalities of the device. It will describe ScanGo in detail, including its design, development, testing and finally a summary of the project, and our personal achievements.

## 2 Background

This section goes over related products and systems, ethics, sustainability aspects and marketing. The aim was to point out the most crucial requirements in the mentioned fields and design the product according to the rules of sustainable development and ethics.

### 2.1 Related Works

Related products are the devices and systems that already exist on the market and are implemented in crowded spaces and on big events in order to enhance participants' experience. The research identified four different types of products orchestrating the crowd: air plane boarding system, Orange Belgium system, counting camera, digital displays.

The airplane boarding system has different advantages to orchestrate the crowd effectively: (*i*) boarding information is projected on the ground; and (*ii*) passport checking queue is projected by the person who checks the passports, using colourful blocks, to depict and maintain the proper social distance. As a result, social distance is respected, personal space is preserved and people find easily the way [15].

Orange Belgium System is able to provide a real-time data stream of the location of all mobile phones connected to its network within a given area. It shows the density of people within small squares across the specified zone, and allows the city to monitor the crowd in the real-time. This idea can be implemented in every crowded place to control the number of people [10].

Canon has developed a crowd counting technology that counts the number of people in an area instantaneously, which can be employed at a wide variety of locations where congestion is expected to occur. It monitors threshold capacities (for example, to track how many people are in a designated area) and thanks to that security control is reached [5].

The integration of digital displays and mobile apps is used in crowd-intelligent way finding. These components help guests to make smart decisions when moving through the space [6].

### 2.2 Sustainability

Sustainability is a very important and complex concept that our team must take into account, since the product, as far as possible, must be sustainable, in order to improve the quality of life of its users without harming the environment. In this sense, eco-efficiency is a concept used by companies to have a sustainable development and to take into account environmental aspects, however, they also take into account the needs of human beings. The main objective is not to use so many natural resources and to use only what is necessary, and also to promote the recycling of materials and give them more years of life.

The United Nations (UN) organisation aims to achieve 17 Sustainable Development Goals by 2030, namely: eradicate poverty; eradicate hunger; quality health; quality education; gender equality; clean water and sanitation; renewable and affordable energies; decent work and economic growth; innovation and infrastructure industry; reduce inequalities; sustainable cities and communities; sustainable production and consumption; climatic action; protect marine life; protect terrestrial life; peace, justice and effective institutions and partnerships for the implementation of objectives [8].

To respect and achieve these established goals, the team stipulated some decisions in favour of that. Regarding the environmental aspect, it is important to mention that we will take into account that global warming is a very serious problem and that many companies compromise the health of our planet with their work. Therefore, we will follow the Craddle to Cradlle, ISO 14062 and ISO 14001 certifications and the product will rely on a 5 V solar panel for power. Thus, ScanGo aims to make the most of the solar energy available through existing technologies. On the other hand, the materials we are going to use are

Aluminium and Polypropylene. While Aluminium is non-toxic to users or the environment (does not have negative quality either in the air, on the ground or water and does not burn in the event of a fire), polypropylene is recyclable [2].

Socially, it is important to reiterate that we want to treat our employees in a polite and respectful manner and benefit those who manage to achieve the goals set by our company. We will probably offer maternity arrangements, parental benefits, etc. Finally, it is important to say that we will respect human rights.

Finally, as our ScanGo product will work directly with mobile phones and other electronic devices, we think it is important to create a list of environmental objectives to be met.

### 2.3 Ethics

Our team developed the product in accordance with ethical values and current European Union (EU) directives. Ethical and deontological issues are of great importance to society as a whole. They are major key factors in any company, so we want our product to provide a good reputation for the company and be in line with the words "ethics" and "deontology", which means being honest with both the customers and the competition. By using ethical marketing, our product brand will provide the public with understandable information about the product and will not mislead them. Recognition of reliability and dependability is a priority. Taking into account environmental ethics, our equipment should be designed in an environmentally friendly way. It is important to find a balance between social, economic and environmental aspects. The promotion of the product should focus on the well-being of the user. Before naming our device ScanGo and the logo, we made sure that we were not infringing the company's intellectual property. All sources used in this work were referenced. General ethical and deontological issues were carefully considered throughout the project, as they are key factors in any global business

Regarding our project, we will comply with the following EU Directives: (*i*) Machinery legislation; (*ii*) Electromagnetic Compatibility Directive (EMC); (*iii*) Low Voltage Directive (LVD); (*iv*) Radio Equipment Directive (RED); and (*v*) Restriction of Hazardous Substances (ROHS).

### 2.4 Marketing

It is essential to create a marketing plan to clearly determine our target and objectives. The festival market has been growing steadily for several years and will continue to do so in the coming years, so it is interesting to exploit[17]. Moreover, ScanGo scanner uses the Near Field Communication (NFC) module, which differentiates us from the competition, which mainly uses Quick Response (QR) codes.

The analysis of the Political, Economic, Social, Technological, Environmental and Legal (PESTEL) [4] factors highlights several points: increasing the safety of festival-goers by orchestrating the crowd and avoiding overcrowding, facilitating and speeding up usage, participating in the cultural economy, improving the

festival-goers' experience, using new modules such as NFC, reducing our environmental impact by offering rental and reusing packaging, and finally, adapting to government restrictions.

The Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis showed that the product targets a broad spectrum of users, is a new brand with a new offering that needs to establish itself in the market, wants to expand in Europe, and needs to make sure that it stays different from the competition.

We have economic objectives (to contribute to the economy of the festivals and the country by bringing in foreign festival-goers for tourism and consumption), ecological objectives (to offer a rental service, which encourages the use of the scanners at different festivals and the reuse of packaging for transport) and customer objectives (to improve the user experience and encourage loyalty).

Our brand ScanGo wants to offer a rental and installation service of scanners using the NFC module to festival organisers. The latter are connected to our application, which offers a map updated in real time. Our promotion will be done through social networks (about 1000 €) and we will create a website (between 500 € and 1000 €) in order to list a video presentation of our scanner and its qualities, a leaflet with our objectives and a manual to explain the operation.

## 3 Proposed Solution

Based on the studies discussed in the previous chapters, our solution is represented by our scanning device that was created keeping in mind the main objective: providing people with the maximum possible security at different festivals or related events by avoiding overcrowding and disorganisation. In this sense, with the proposed product people will obtain information that will allow them to go to the area / venue of the festival and even suggestions for alternative activities that may be taking place.

### 3.1 Concept

Our concept helps organising events in a way that overcrowding is avoided as much as possible, which is very desirable nowadays due to the pandemic. Using our scanner, festival goer's experience is optimised by being provided the quickest and safest way to your their desired destination. Specifically at festivals, people often end up missing concerts or other activities due to this lack of organisation. On the other hand, they also get lost from their friends due to the great confusion that exists in the space or wait a long time to go to the bathroom or buy something in a restaurant, bar, etc.

### 3.2 Design

To achieve the solution, we have created a scanner keeping in mind the human body proportions for an easy and convenient interaction. While placing two of them back to back, the modern body of the scanner will create a pentagonal

shape. It is composed of three rectangular pieces hollow on the inside. Using this form, the internal components are protected from external factors such as weather, people with bad intentions trying to steal, etc. The prototype, figure 1b, we created to test our product was made in wood, it order to don't spend a lot of money on materials and also because the wood can be reused in the future for other jobs, but for the official scanner we are going to use aluminium, since is a material with good resistance. The scanner dimensions provide easy to access for every user, with the total height of 130 cm. The inclination angle of 30° provides a good water flow in case of rain.

**Name** : The name ScanGo inspires the speed of use, the phone will direct the user as soon as it is scanned. The name consists of simple words to make it easy to remember. It is inspired by the names of big brands, which have named their company having the same idea in mind.

**Logo** : The logo created, Figure 1a, represents a crowd of people heading in different directions. In order to make it as attractive as possible and to attract the user's attention, it is necessary that the created logo is simple and easy to identify. To easily differentiate it from the competitors, colour plays an important role, so the final logo is multicoloured, incorporating all shades of the colour spectrum. This symbolises the multiculturalism of the people in the audience.

**Slogan** : The slogan must be short, clear and original. The thinking behind it is to promote the product in just a few words. The chosen motto: "Find your own path!" is simple and reminds users of the basic goal of the product: to guide the festival audience in real time.


(a) Logo (b) 3D model

**Fig. 1.** ScanGo

### 3.3 Components

The internal components consist of a NFC module, an ESP32 microcontroller, a Light-Emmitting Diode (LED) diode, a solar panel and a 18650 battery. How it works is that the user presents his smartphone to our scanner which has an NFC module integrated. ESP32 system connects with a remote database thanks to the integrated Wireless Fidelity (Wi-Fi) module. ESP32 is responsible for counting festival participants' smartphones scanned in the given area. The user will be redirected to the ScanGo application which gives the user a map of the festival which is updated in real-time, providing information such as the crowd density, possible paths to take to reach different stages, incentives for alternative activities and concerts taking place.

**Microcontroller** : On average, a typical microcontroller can have from 6 to 60 pins on it, to which you are expected to attach communications connections, power connections and input and output connections. Every microcontroller's pins can be configured differently, and most times one pin will have more than only one function. This process of combining functions to one pin is called pin multiplexing. We have created a pin diagram illustrated in Figure 2. to display the connections between the ESP32 microcontroller and the NFC Module.

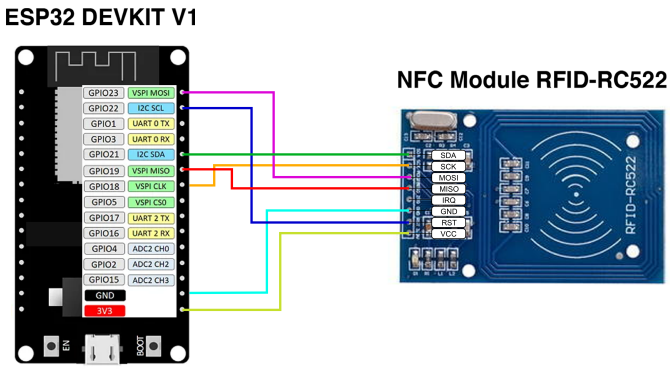



**Fig. 2.** Pin diagram [18]

**NFC module** : NFC is a wireless form of data exchange, that allows devices to communicate by being in the proximity. Just like Wi-Fi or Bluetooth, NFC is a wireless technology that sends information using radio waves. We chose to use NFC in our product since most of today's smartphones have it integrated straight from the factory and it has advantages such as [16]:

- versatility since it is does more than just wireless payments;
- convenient since it substitutes the use of a wallet by effortless fast scanning;
- instant linking between the devices;
- already implemented;
- enhanced safety [14].

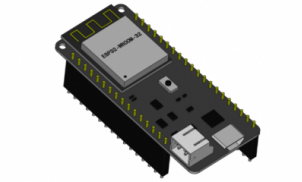
**ESP32 and battery 18650** : The ESP32 development kit is cheaper than Arduino Uno, which means that we get a more powerful board for a lower price. We can treat the ESP32 as a supercharged Arduino Uno: faster, better in many respects [19]. The ESP32 is a powerful 32-bit micro-controller with integrated Wi-Fi and Bluetooth. Due to the low cost combined with great power and the opportunity to connect the ESP32 to many other electronic devices, the micro-controller is well suited for IoT(Internet of Things) projects [7]. Our choice is TTGO ESP32 (Figure 3a) with battery 18650 support and OLED(Organic Light Emitting Diodes) display. The device has a built-in battery charger for battery 18650 and micro USB(Universal Serial Bus) port that can be connected to the solar panel responsible for charging our device. The chosen battery is battery rechargeable XTAR 18650, 3000 mA h Li-ion presented in Figure 3c.

**Solar panel** : The solar panel charges the device in the case of outdoor festivals. The selected panel was a portable mono-crystalline silicon solar panel in a PET(Polyester Terephthalate) package, with an integrated voltage regulator output of 5 V and a USB plug. The connection between the solar panel and the ESP32 microcontroller uses then a micro USB cable. Figure 3b showcases a close-up of the two components attached.

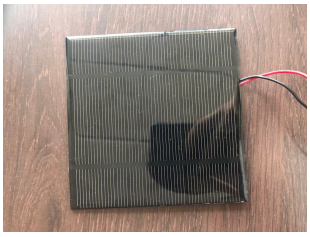

(a) TTGO ESP32 [18] (b) ESP32 and solar panel connection[18] (c) Battery [18]

**Fig. 3.** Selected power system components

However, the components used in the prototype were an LOLIN32 micro-controller, a 120 mm x 120 mm solar panel, 5 V regulator and a 103450 battery of 3.7 V and 1800 mA h. The microcontroller and battery are displayed in Figures 4c and 4a. This solar panel does include an USB plug.



(a) LOLIN32 component



(b) Solar panel

(c) Battery 103450

**Fig. 4.** Prototype power system components

### 3.4 Structure

**Printing materials** :

The team decided to 3D-print some of the parts of the device. Two of the most popular 3D printing materials were considered: PLA(Polilaktyd) and ABS(Acrylonitrile Butadiene Styrene). Both can be extruded using basic 3D printers and are among the most affordable filaments available today. ABS, while weaker and less rigid than PLA, is a tougher filament. ABS is a bit more durable, but it does require more effort to print than PLA because it's more heat resistant and prone to warping. It is a user-friendly thermoplastic with a higher strength and stiffness than ABS. With a low melting temperature and minimal warping, PLA is one of the easiest materials to 3D print successfully, that is why we would like to use this filament in small elements 3D printing [12].

**Ground anchors** :ScanGo scanner will consist of two parts. To place stably our bottom part on the ground we took into consideration two possible choices. First of them was a ground screw that replaces the need to dig traditional foundations and lay concrete. It is shown in Figure 5b. Using ground screws avoids any unnecessary surface sealing of the soil. The soil ecosystem is not disturbed, and it remains intact. With ground screws, you can plan exactly where you want your foundations to go so that you can avoid damaging these cables running under your foundation [11]. Despite all of the advantages that ground screw has, its cost is relatively high, and special construction machinery is needed, that

is why we considered another choice: angle brackets/corner which are a small piece of metal that have been angled to form an L shape to provide a secure join between two pieces of material as you can see in Figure 5a.

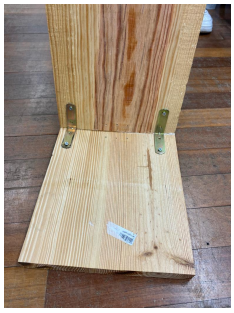
(a) Angle Bracket (b) Ground Screw

**Fig. 5.** Ground anchors [18]

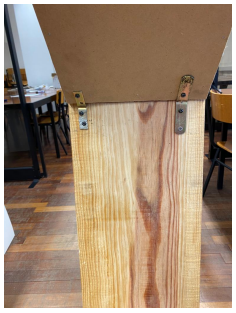
To ensure the scanner does not fall the best choice is to place weights on the base. This way the centre of gravity is lowered, making it harder to fall over. For our prototype we thought of a pack of water bottles with the necessary quantity to block the base of our scanner.

**Connectors** : The base and the pillar are connected by brackets which are fastened to the inner part of the pillar with screws. It is shown Figures 6a and 6b. On the other side two metal parts were also attached with screws, as shown Figure 6e. This gave us the outline of our prototype. We then created our box, which is the upper part of our prototype. We used wood to create the box, we attached plywood to the bottom of the box using glue and screws. It was connected to the pillar with hinges, which were attached with screws on the inside of the pillar, as shown Figures 6c and 6d. We attached plywood to the top of the box using rubber and screws, thanks to this attachment we can open and close our box.It is shown on the figure 6f and 6g.

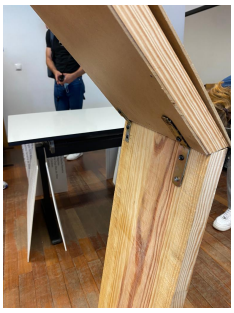
(a) Internal connection between pillar and base



(b) Internal connection between pillar and base



(c) Internal connection between pillar and upper part of prototype



(d) Internal connection between pillar and upper part of prototype

(e) External connection between pillar and base

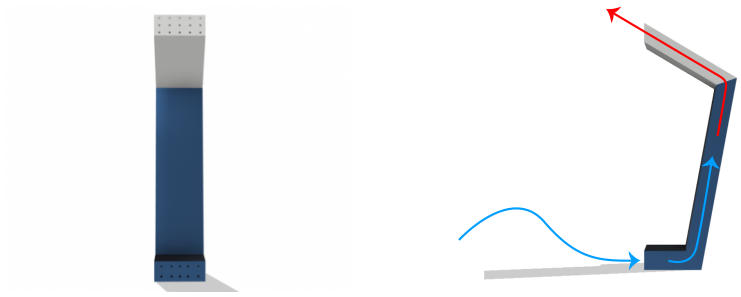
(f) Rubber

(g) Upper part of the box

**Fig. 6.** Connectors [18]

**Solar chimney** : In order to take full advantage of the shape of our device, we will drill holes in the bottom and top of it, Figure 7a, to create a solar chimney effect. The scanner is tall and empty on the inside, so the warm air will travel through the bottom holes and will exit to the top, cooling our internal components. Once the hot air rises up, it draws in more air from the bottom.

This will be used to drive passive ventilation. How the airflow is produced can be visible in Figure 7b [3]:

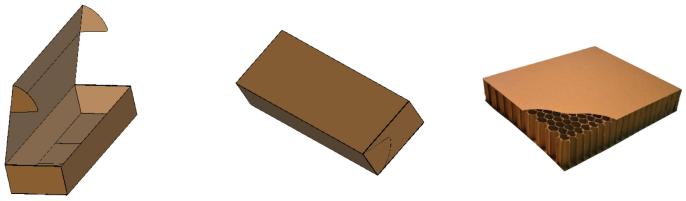


(a) Holes drilled (b) Airflow

**Fig. 7.** Solar chimney [18]

### 3.5 Packaging

We want to offer a service to festival organisers by renting out our scanners and installing and uninstalling them as well as transporting them from one festival to another. For this we need a packaging that is resistant because it will be handled several times for installation and transport. That's why we chose to place an easy-to-handle opening/closing on the top of the packaging, which doesn't require tape or tearing the cardboard. The "ears" on either side of the lid will fit into the slots and stabilise the whole thing. In addition, we have reinforced the strength on the underside to prevent damage. This packaging is made of corrugated cardboard, for a better resistance to shocks. Inside we will find wedges made of honeycomb cardboard, which replaces the traditional expanded polystyrene which is not recycled and is often found in nature. This cardboard can be used for a variety of shapes, which will allow us to adapt to our scanner and protect it as well as possible.



(a) Assemble packaging (b) Closed packaging (c) Honeycomb cardboard

**Fig. 8.** Packaging [18]

### 3.6 Functionalities

- The first function of our scanner is to connect with the users' phones thanks to the NFC module.
- The second function will be the ability, after connection, to open ScanGo application on the user's phone that will give access to a map of the festival.
- The third function will be to provide real-time information to the festival-goer about the different concerts and activities by indicating them on the map via the application. Moreover it will give the current number of people in the chosen area.
- This saves time for festival goers and reduces the risk of overcrowding for the organisers.
- We offer a multi-day scanner rental service with transport, installation and start-up of the scanners. This saves organisers time and money as they can adapt the number of scanners they wish to hire each year.

### 3.7 Tests

**DEVICE TESTS** Our first step was to configure the ESP32 and it was performed and based on installing the ESP32 Board in Arduino IDE. Figure presents the steps of ESP32 configuration:

**Fig. 9.** Configuration steps of ESP32[18]

After finding the board in the Arduino IDE that we wanted to install we started running the program.

The next step was to check that the LED was working, we used components such as:

- Lolin32 microcontroller;
- diode LED;
- resistor 100 Ω
- jumpers;
- breadboard.

This is how we connected the links between the Pins:

1. Pin 33 → resistor;
2. Resistor → (-) diode LED;
3. Pin GND → (+) diode LED.

We used the Arduino program "Blink" To make the LED blink. We had to make modifications to the code because the WEMOS LOLIN32 did not have a built-in LED. After the modification, the LED lights up all the time the device is running, I will turn off when the device is not charging.

Next step was to investigate NFC module work. Firstly the following connections between ESP32 and NFC modules were created as presented on the following Figure 10.

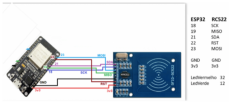


**Fig. 10.** Connections between ESP32 and NFC module[18]

In our prototype we used battery 103450 provided by the teachers. The battery is connected to the LOLIN32 through the built-in charge port. LOLIN32 connects with the solar panel through the wires with the usage of voltage stabiliser. The 5 V solar panel regulator presented in the figure 11 was used to provide proper voltage. The circuit is turned on using the power switch placed on the back side of the scanner. The final circuit diagram is presented in the figure 12:

For our needs we also needed a program responsible for NFC communication. First we needed to initialise the MFRC522 in order to make it work. Then we also initialised Wi-Fi connection using the network name and password. Turning on the diode LED was implemented in the same way as in the previously explained blink program. Next the program is waiting for the smartphone with NFC turned on to appear nearby. When the smartphone is scanned, the program sends the HyperText Transfer Protocol (HTTP) request to the server in order to update

**Fig. 11.** KIS-3R33S 5V solar panel regulator[18]

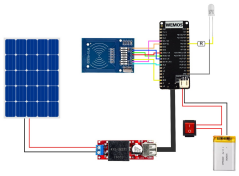


**Fig. 12.** Circuit diagram[18]

the data in the database. When it is updated, we get the response with 200 status code. The crucial thing is that we need to give the HTTP address of the server that we want to connect to. Figure 13 shows final program responsible for sending the data to the database

**Fig. 13.** Final program responsible for sending the data to the database[18]

We have also prepared a diagram showing the role of the HTTP request and the database connection. Figure 14 shows this diagram. The server program seen here, consists of a controller that redirects information to the repository, and then the repository is responsible for the database operation.

To be sure that the program performed correctly, after scanning on the screen we obtain 200 HTTP status code that means “OK” and assures us that the

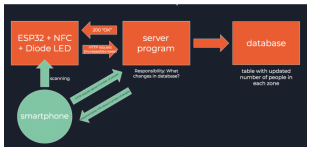



**Fig. 14.** Diagram depicting the role of HTTP request and connection with database[18]

number of people in the database was changed correctly. Our database is in the form of table as presented below on the Figure 15

SELECT * FROM ZONE_STATISTICS;

| ID | ZONE_NUMBER | PEOPLE_NUMBER |
|---|---|---|
| 1 | 1 | 51 |
| 2 | 2 | 0 |
| 3 | 3 | 0 |
| 4 | 4 | 0 |

(4 rows, 2 ms)

**Fig. 15.** Database table[18]

Our server application was developed using IntelliJ IDEA. This is the environment which allows us to develop applications using the Java programming language. We wrote the code using Spring framework. Our program code is responsible for finding the row according to the zone number in the table from the database. In case of an increasing number of people in the zone, the number of people is increased by 1. When the number of people decreases, the only condition that needs to be taken into consideration is that the number of people needs to be different from 0 (cannot be negative) and is decreased by 1. Our team faced some obstacles while working on the functionalities of our device. We could scan the NFC static tag from the phone and get its data. We tried to scan the Radio-Frequency IDentification (RFID) RC522 module on ESP32 and there was no possibility to obtain the data on the phone, since RC522 works just as a reader (it reads the input from the phone but the phone does not recognise it in the reverse direction). That's why we came up with an idea of double scanning. First scanning performed between smartphone and NFC module attached to ESP32, is responsible for informing ESP32 that someone enters the new zone. Second one performed between the NFC tag (containing the zone number) and the smartphone is responsible for receiving the data of how many people are in the zone that the user is located in.

**Mobile Application Tests** : To obtain the zone number from the static tag, we needed to write data on it first. It was done thanks to the application called NFC Tools, that can be found in the Google Play store. NFC Tools can read and

write your NFC tags. By passing your device near an NFC chip, you can read the data it contains and interact with the content. In figure 16. are represented the steps of writing the data (the number of the zone) on the static tag.

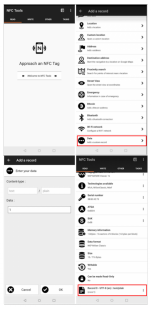


**Fig. 16.** Writing the data on the NFC tag in NFC Tools[18]

First in the "WRITE" section we needed to add the record in the form of data which is the number of the zone. Then we hold the tag close to the device to let it write the data. To check if writing the data works, we need to go to the "READ" section and scan our tag.

We had to download Android Studio to write code, in order to create our mobile app. That is part of the system together with our ScanGo scanner. Firstly, we prepared the design of the application icon. Next design was the application interface. Figure 17 below presents home screen of the application:


**Fig. 17.** Application interface design[18]

The home screen depicts the number of people in the current zone. Whenever the user scans the NFC tag with their smartphone, the current zone number and number of people in the given area is displayed. Besides this data, the festival participant can pick one from the activities on the home screen. After picking the activity the user is redirected to the map presenting the crowd density, points on the map of the festival and paths to take by the user. Schematic design presented in Figure 18


**Fig. 18.** Redirection to the festival map[18]

Before generating an interface of an android application the team needed to focus on the best method of creating the map that can be implemented in our system, universal and used in every place in the world where the festival takes place. In order to orchestrate the crowd during festival events we needed to create our own map with the specific paths and zones of the festival. Initially we made a general map of the festival in Canva, attached in the figure 19a.

We assumed that our festival was 60 ha and that scanners were placed on the borders of the zones every 50 m, we also placed a scanner at each entrance, to sum up the number of scanners we would need 50. Initially we assumed that the scanners would not be back to back. For example, we assumed that zone 1 has 3 ha, zone 2 has 7 ha, etc. The total came out to be about 60 ha. Taking zone 1 as an example, since it has 3 ha, we assumed that it has more or less dimensions of 150 m x 200 m. So there are 3 scanners on one boundary (150 m) and 4 scanners on the other boundary (which has 200 m). Unfortunately this option was very vague and did not work. So we started looking for a more accurate program into which we could plot our map and use for the application. Our found program was OpenGeofiction which is a collaborative platform for creating fictional maps. [9]. The program allowed us to create our area, mark and sign both zones and points/services. We made some sample paths, for example from the scanner to the toilet. In case of 50 scanners we need 25 spots for double back-to-back scanners. Figure 19b shows a map in this program.

Finally, we used the layer on real area in Google Maps created on our own. With this application we could get the exact dimension of the area, it was: 55.5

ha. Comparing with the previous methods, this one turned out to be the most accurate and beneficial. It gave us the possibility to choose a real area located on the map. Our choice was the Parque da Cidade in Porto. This idea makes our application universal for every place in the world. By getting more accurate dimensions, we spaced the scanners every 150m, but still stayed with 50 back-to-back scanners (25 spots). Figure 19c. illustrates the map using Google Maps.


(a) Festival Map in Canva [18]

(b) Festival Map in OpenGeofiction[18]

(c) Layer of festival map in Google Maps [18]

**Fig. 19.** Festival Maps

After choosing the proper map, we could start creating an application interface in Android Studio. Thanks to the very intuitive interface in this program we were able to create our application interface using drag and drop feature. Later we made our screen interactive. OnCreate method is performed when the application home screen starts. Firstly, the set ContentView method is called in order to assign the layout we prepared previously. The next step is to check if the user has NFC enabled. If not, there is a prompt displayed with the information "NFC disabled. Please turn it on.". Later we tried to find a way to inform the application that the NFC tag was scanned. Then thanks to this intent we were able to recognize that the NFC tag was scanned, which allowed us to obtain the zone number previously saved on the NFC tag. Then the phone used the zone number from the NFC tag to send the HTTP request to receive the data about the zone (number, crowd density) from the database. Our buttons were not interactive yet. To make them clickable, we needed to assign them a click event. In our case after clicking each button the user is redirected to the map with specific activities. According to various chosen activities the user is redirected to the new screen with the map. At the beginning we declared the arrays containing zone numbers with the specific activities. Then we used the data (origin zone, destination) obtained from the previous screen to assign specific zone numbers according to the chosen activities. Based on that there is a HTTP request sent to the server application in order to obtain the zone number that is less crowded and display the path leading to specific activity in this zone

**Strength Tests** : In order to test the resistance of our prototype, through the Fusion 360 software, where the prototype was developed, we did a Safety Factor Test and a Stress Test. The force we applied was 600 N, which is the average

force a person applies when pushing an object. As we can see in the following images, our product resists to the applied forces [1].

(a) Safety Factor (b) Stress Tests

**Fig. 20.** Strength Tests [18]

## 4 Discussion

ScanGo allows you to organise events using your Scanner and your application as explained and referred to in the previous chapters. After performing the tests referred to in chapter 3.7, we draw several conclusions about what can be improved in future work. For example, the LED Diode could eventually be used not only to inform if the device is working but also to inform the user that his Scanning is complete or not and for that he could find a way to make the LED Diode blink, change colour, etc. Another thing that could be improved is the relationship between the Scanner and the Application, since in our case the application has to be opened and subsequently scanned for the user to receive the information on the numbers of people in a given zone, etc. What could be improved was to implement a system that would make the application open automatically after scanning and instantly receive the necessary information. In the future, we also want to expand the application to iOS and not just Androids. Also we should focus in the fact that the application only can be installed either by connecting the phone and running Android Studio or by sending to the user directly the installation file. This is not efficient in terms of reaching a largar number of users, that´s why the application should be uploaded to the Google Pay Store. On the other hand, in the future, we have to improve the stability of our scanner, since it is necessary to put weights on the bottom to keep it upright. The upper part, where the electrical system is located, also needs to be improved, as we have to find a way to close the lid easily. As stated before, our original product will consist of aluminium and polypropylene on top. To prevent the top from having too much damage due to UV rays and heat, it is important that the polypropylene used has stabilisers that allow and contribute to a better resistance to them. Finally, obviously, a larger budget would have allowed us to choose better quality materials, which would allow for a better and more efficient product.

# 5 Conclusion

The initial goals were all achieved and even surpassed, once we built the prototype of our wooden product and created the application for Android SmartPhones. After several tests, our ScanGo product worked the way we expected. Teamwork and communication were the key to the success of this project, as we meet all deadlines and distribute existing tasks according to the skills of each team member. This experience also contributed to increase the culture, as we worked these months with people from other countries and above all to make new friends.

## 5.1 Project Outcomes

The team created the ScanGo product, consisting of the device, system control, application and packaging. Apart from what was mentioned, throughout the semester, we also had to work on other aspects, creating a report on all the activities we did, we also created a poster, a leaflet, a flyer, a user manual with instructions for use and with the safety rules and also made several presentations on the various topics that we covered with all teachers.

## 5.2 Personal Outcomes

**Cristian**: "I was sceptic before applying for this project mainly because of the global pandemic and the instable situation I thought we were going to face here. I have faced my fears and doubts and it was the best decision I could possibly make. Here I learned many new skills, improved my English level from interacting with international students and gained a lot of knowledge in working as a team."
**Bruno** "At first I was not sure to be part of this European project. I think it was a good experience for the simple fact that it forced me to leave my comfort zone, as I approached areas that don't have much to do with engineering and that will be an asset at work and for the future. On the other hand, I grew up as a person because I was forced to work in groups on a daily basis. Overall, it was worth it."
**Maja**: "I really wanted to take part in European Project Semester since it is the interdisciplinary project that enables the students to gain new skills and meet international students from different fields of study. This experience met my expectations. The project helped me to get out of my comfort zone as I needed to learn about programming, materials and marketing that are not in my field of study. I had an opportunity to discover and explore the fields that I was never thinking about. EPS broadened my mind to many aspects and I am glad that I had an opportunity to develop both myself and my competencies."
**Ewa**: "European Project Semester was a positive experience for me. The activities accompanying the project allowed me to gain new, additional knowledge that was outside my area of specialisation. Thanks to working in a group with people from other nationalities I have improved my English and

communication skills, for example communicating different ideas. The project was very well organised with deadlines for tasks. I believe that the skills I gained in the project will be useful to me in the future. I am glad that I had the opportunity to participate in the project."
**Bleuenn**: "At first I was afraid to spend my whole Erasmus online because of the pandemic, but it quickly got better and I was able to interact with students from different countries, improve my English and complete a project from start to finish. Moreover, I was able to discover new facets of teamwork and develop new skills in many different areas. It is for these reasons that European Project Semester has been an enriching experience for me and I am glad I was able to participate"

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