



ARte

Augmented Reality to educate

Internet of Things course 2019/20
MSc in Engineering in Computer Science
Sapienza University of Rome

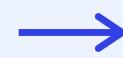
Ivan Fardin
Claudiu Ivan
Francesco Ottaviani

Design Advisor
Andrea Nardone

The problem

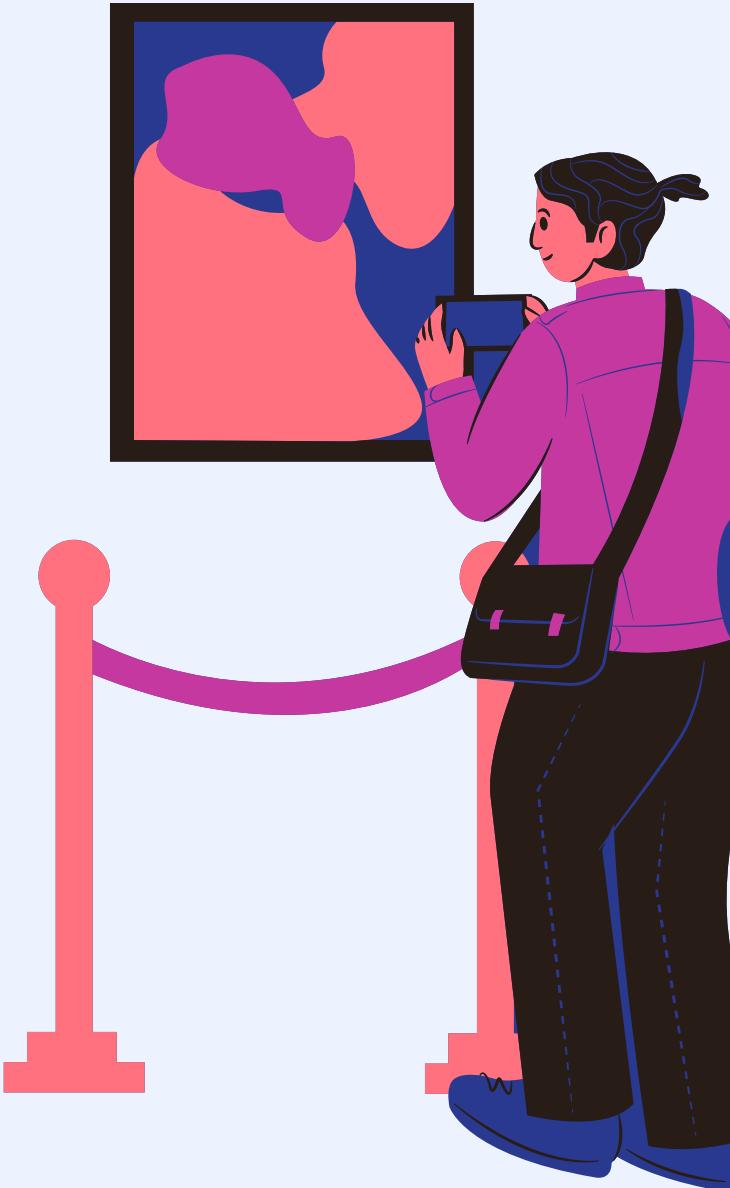
The world is continuously evolving and the way to visit a museum is not an exception. Just looking at artworks is no longer enough, visitors want to interact with them, maintaining social distance (COVID-19 era).





Interaction

New approach in visiting museums



Museum's analytics

Absence of useful stats for the museum's managers



Social distancing

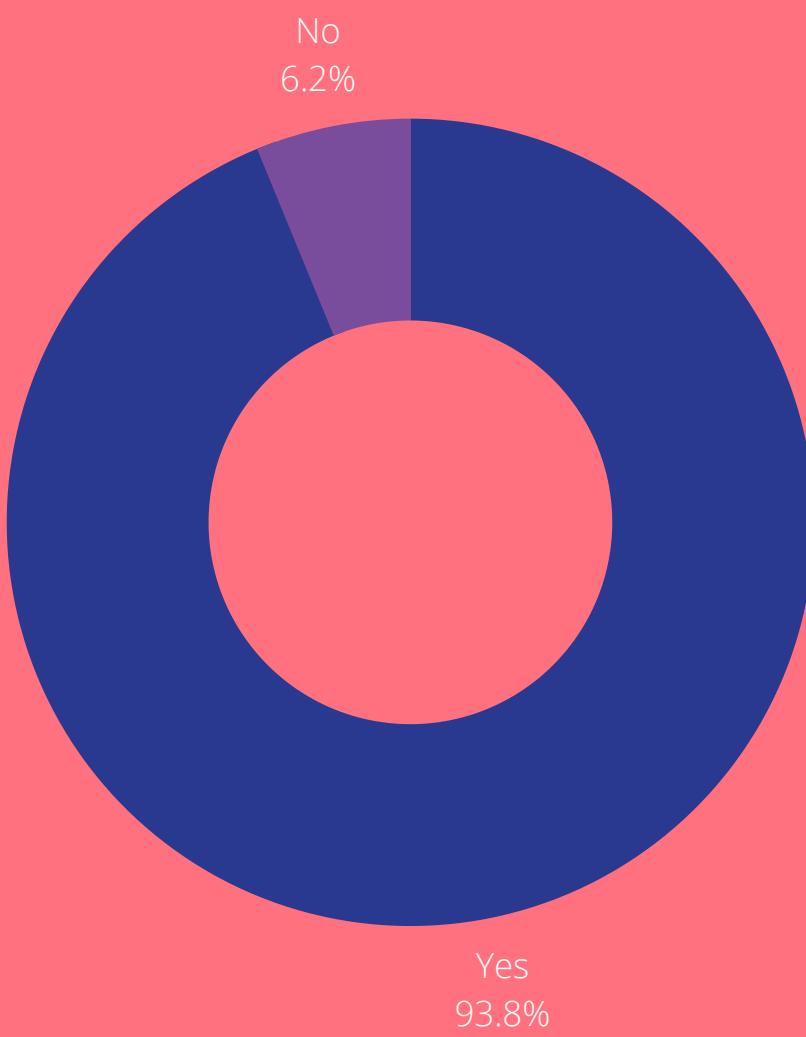
A big problem in COVID-19 era

What is people searching for?

Don't you like visiting museums? Why?

- "There is not enough involvement"
- "Museums are too static, they fail to interest me"
- "They annoy me"

Would you like to have different kinds of interaction with the artworks?





Our solution

ARte: Augmented Reality to educate
with a focus on entertainment powered by IoT

Augmented Reality



Enhance interaction and entertainment



Sensors



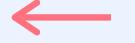
Collect data about visitors' flow and interests

LED and map

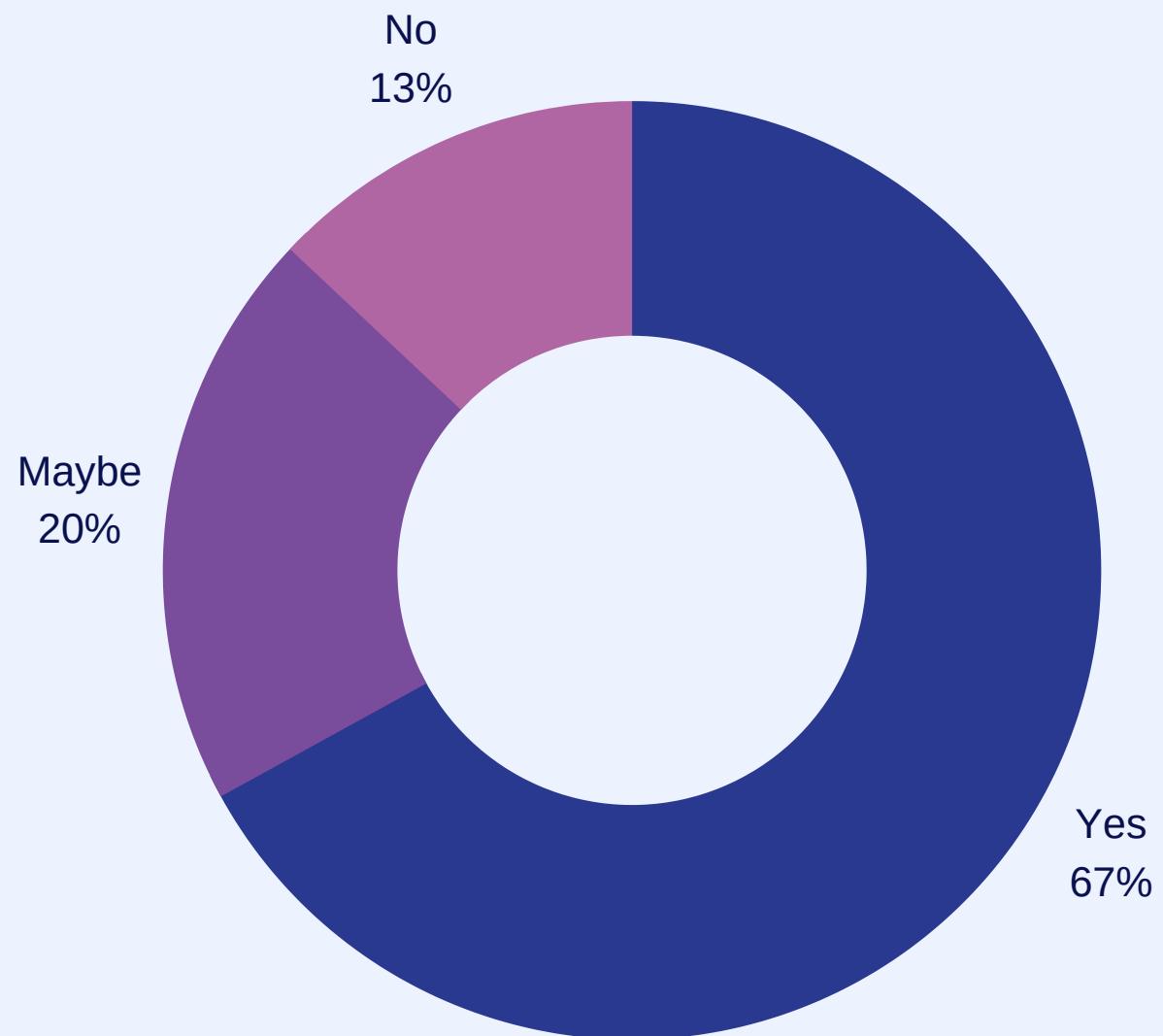


Help maintaining social distancing

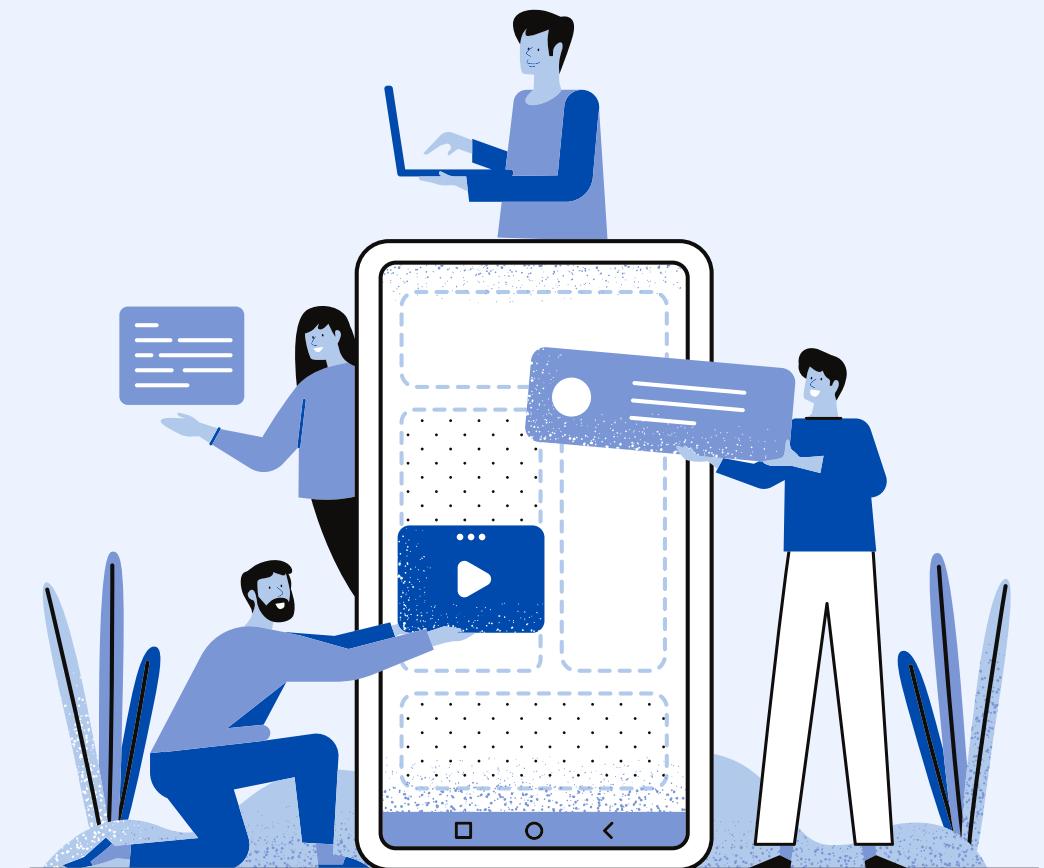
Internet of things and Augmented Reality



Would you use an app to improve your experience in visiting a museum?



ARte: a web application for smartphones that combines IoT and AR to achieve a new way to entertain and educate



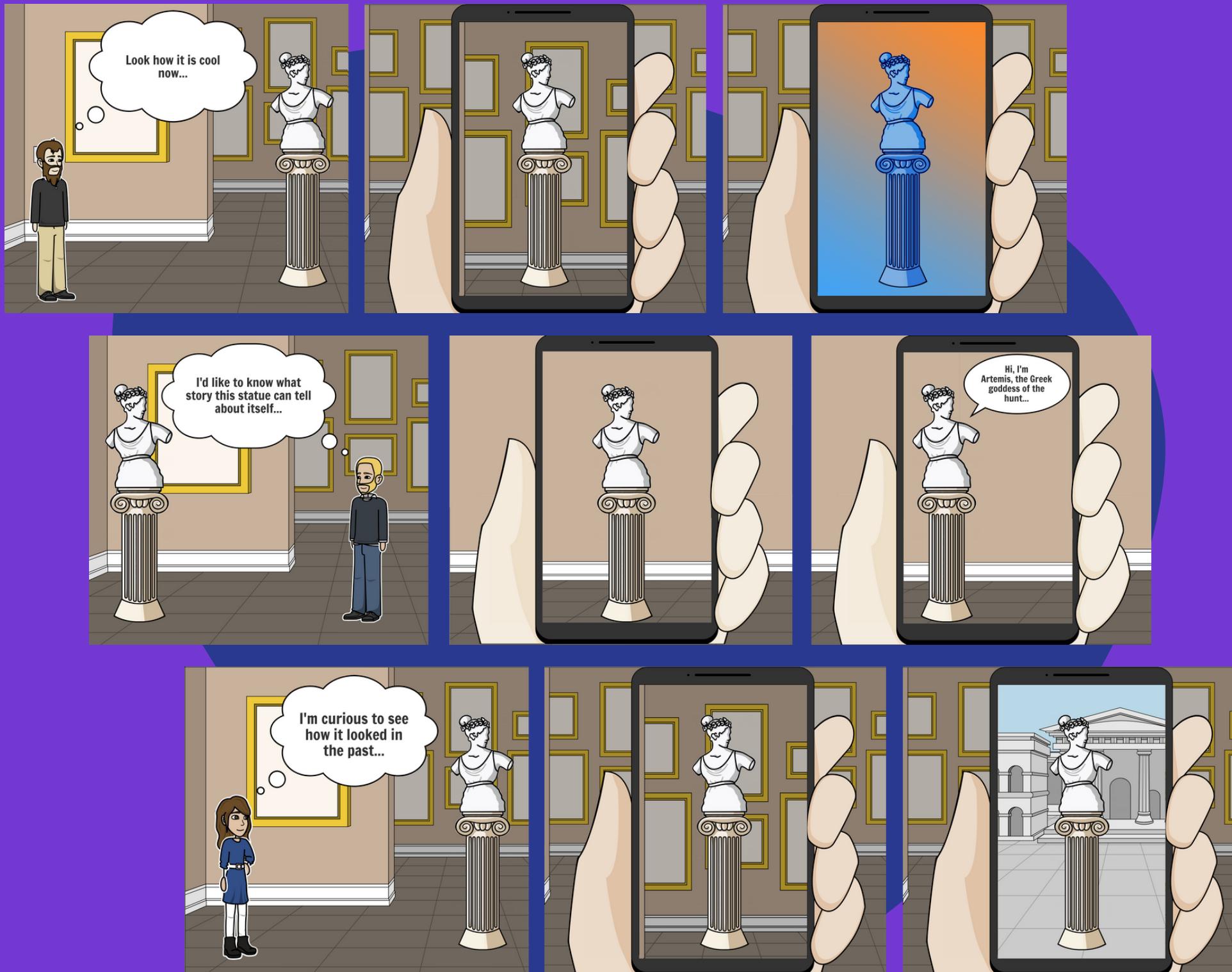


ARte

Augmented Reality to educate



Features



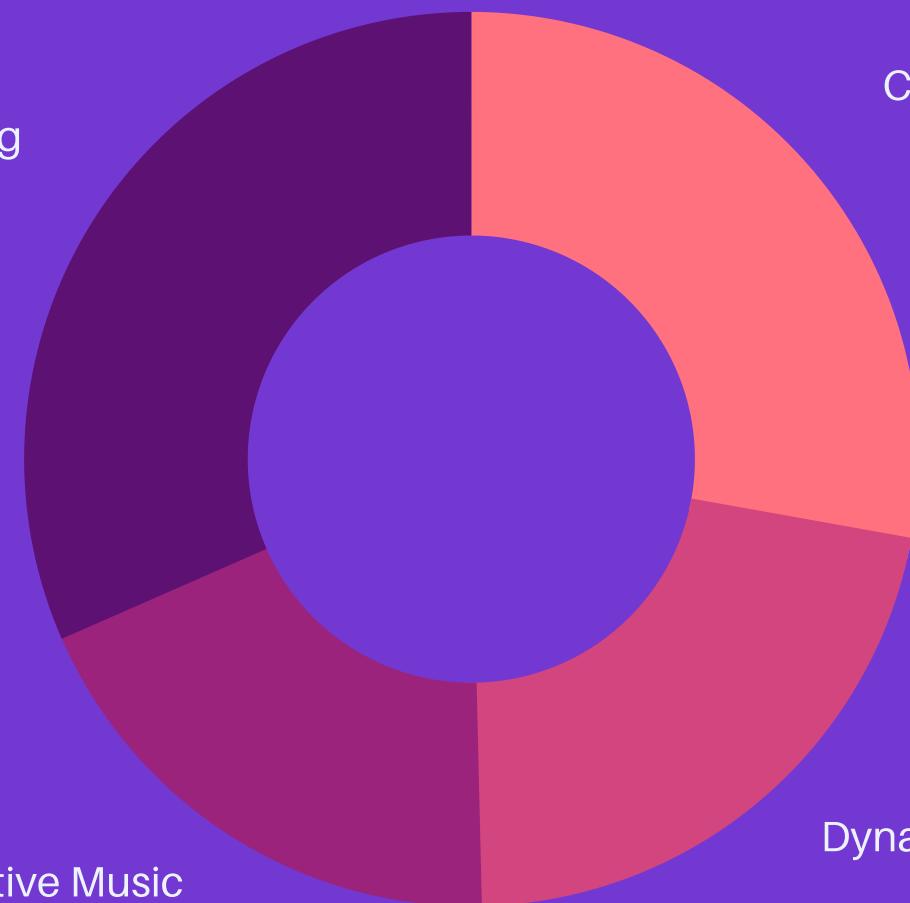
Most liked features

Storytelling
31.6%

Contextualization
27.8%

Interactive Music
18.8%

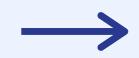
Dynamic Artwork Reimagination
21.8%





Existing approaches

What is going on around the world?



Museum guides

Museums often offer guided tours through museum guides or audio guides



Investments in technology

Several museums around the world have invested in technology, such as the *National Museum of Singapore*, *The Art Gallery of Ontario (Toronto)*, and *The Smithsonian Institution, Washington DC*



Competitors

○ ReBlink

The Art Gallery of Ontario, Toronto

Visitors, using their phones or tablets, can see the subjects come alive and be transported to our 21st-century reality



○ Skin and Bone

The Smithsonian Institution, Washington D.C.

Visitors, using their Apple devices, can bring the exposed skeletons to life via 3D models that reproduce their original appearance



Competitive Advantages



○ Interactive features

Real-time data processing based on visitors' flow measured by STM32 boards

○ No useless download

Cross-platform web app available via browser with no storage waste

○ Real-time museum's map

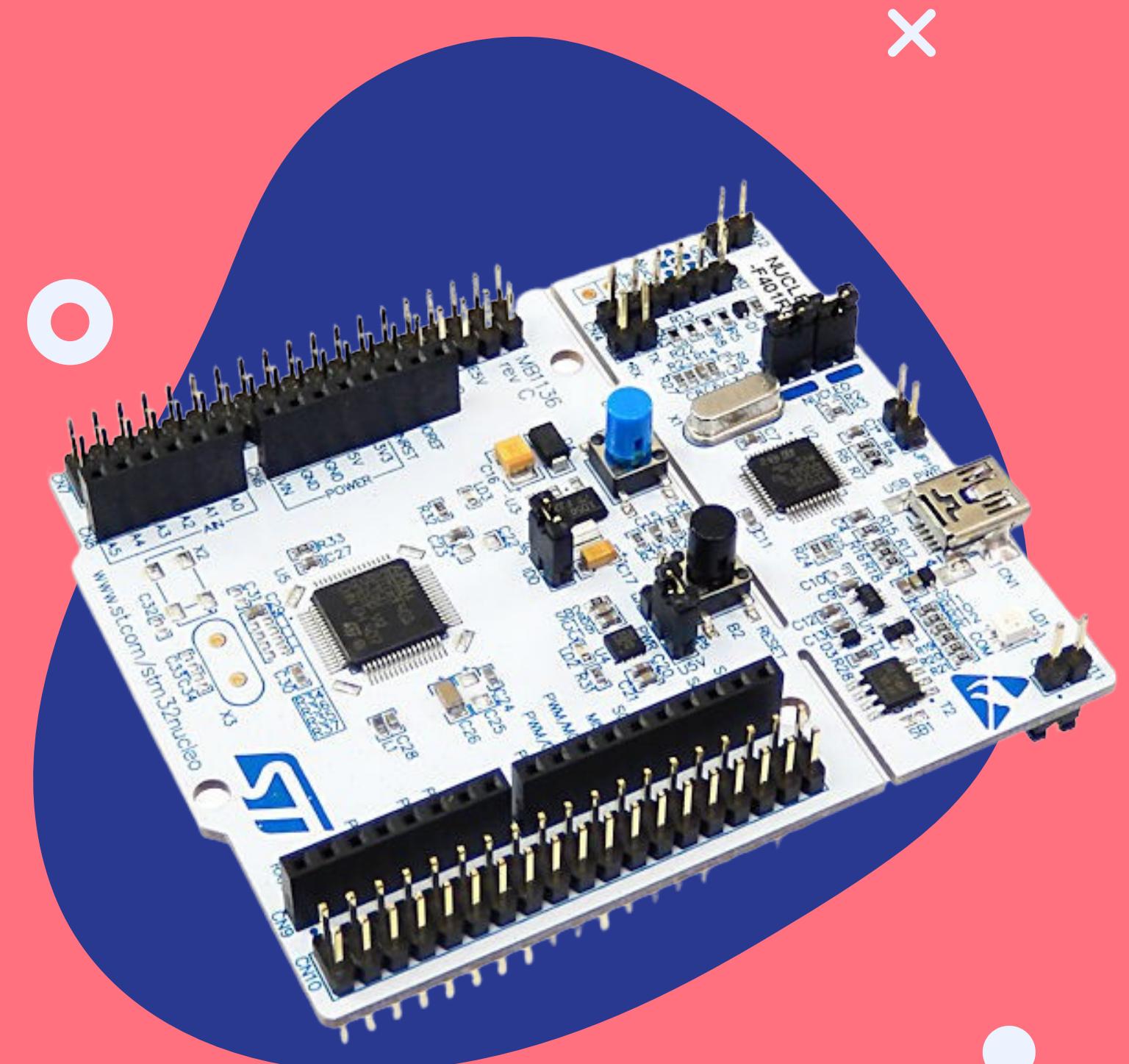
Keep social distances (COVID-19 era) to avoid crowded situations

○ Data collection

Provide useful data to museum managers

Hardware and software

The main hardware components of our system and the network diagram



STM32 Nucleo board



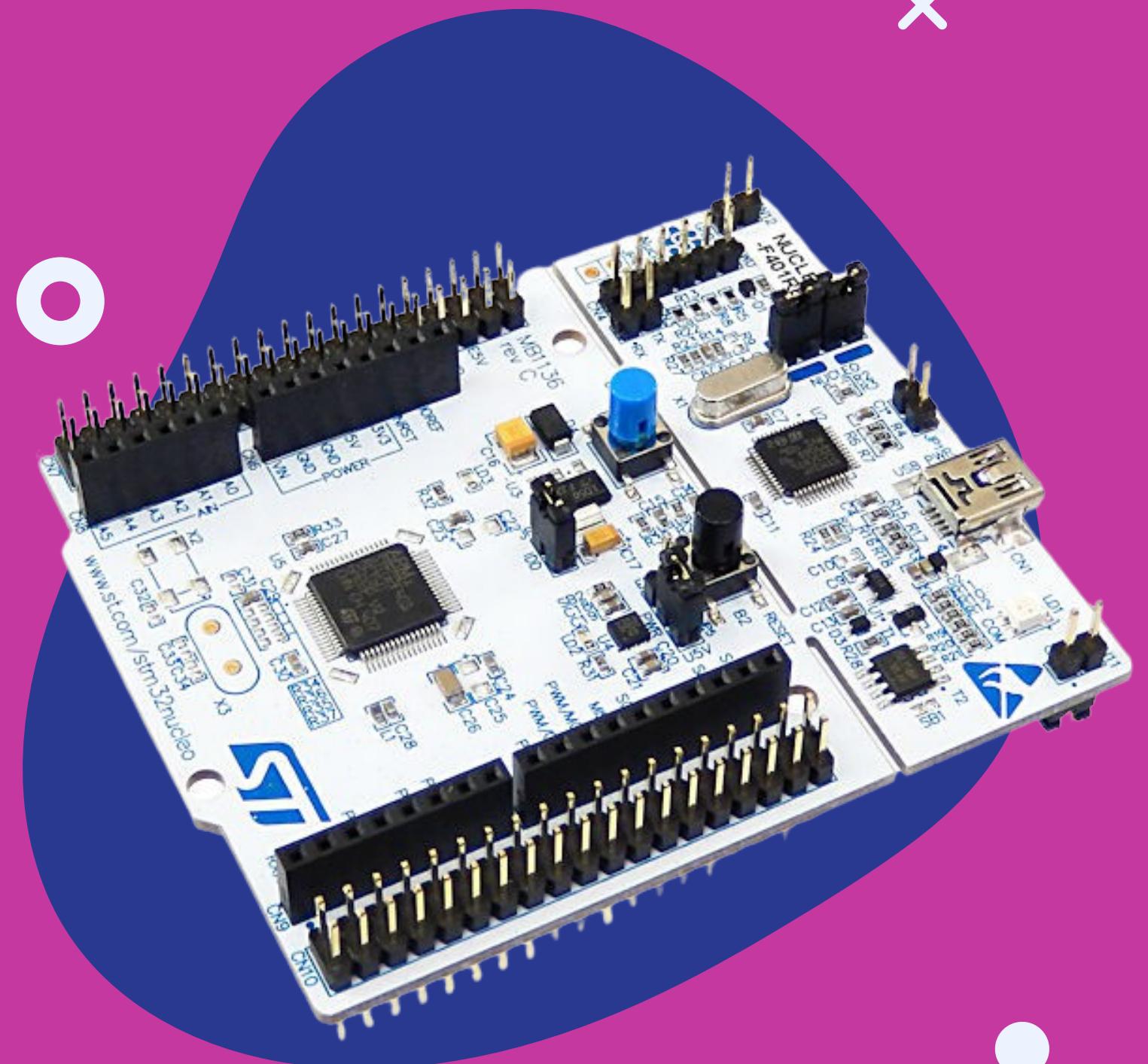
People counting

VL53L0X ranging and gesture detection sensor
to detect when people enter certain areas.



Motion detection

Passive infrared (PIR) sensor for human
movement detection.



X-NUCLEO-53L0A1 expansion board

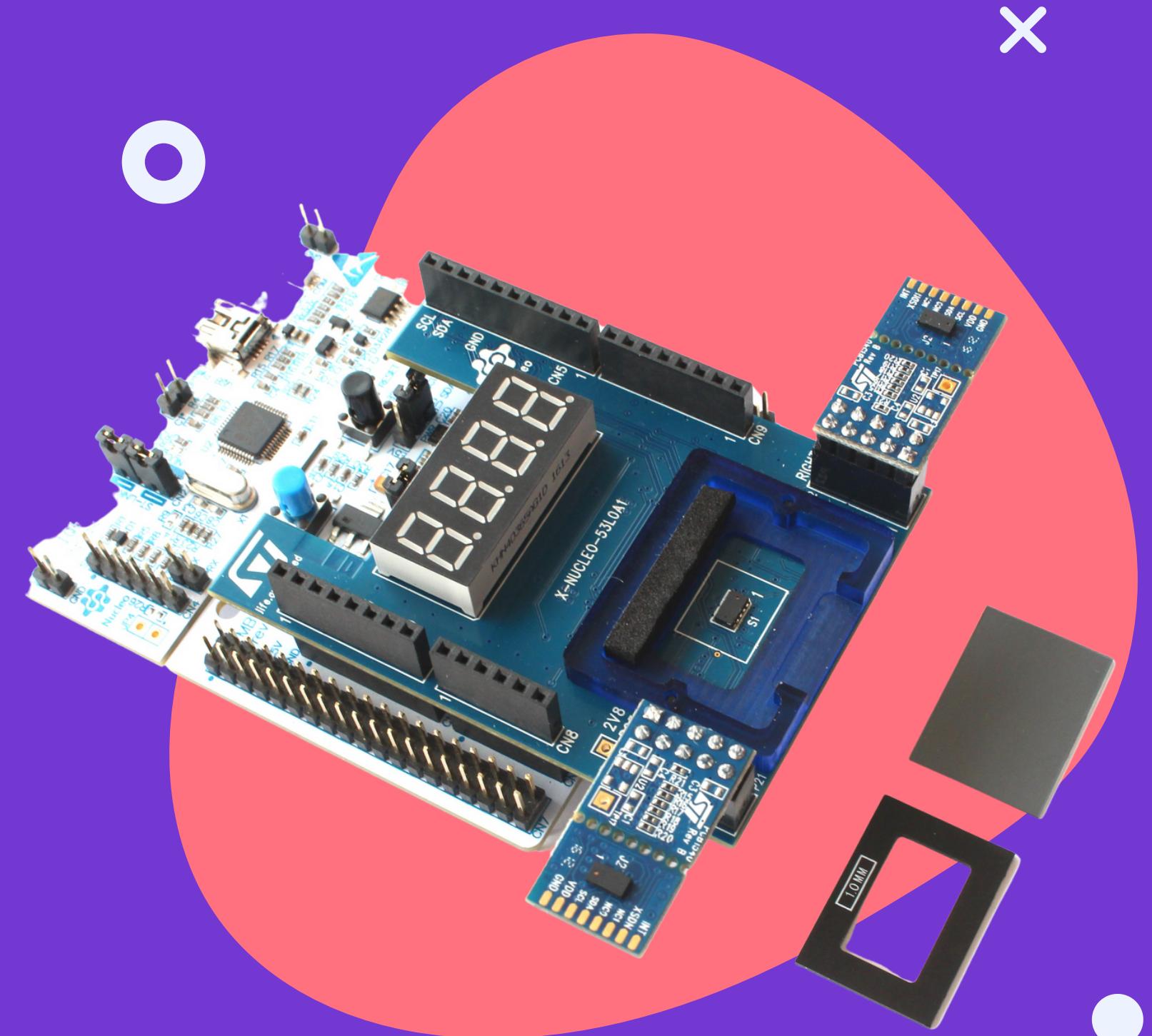


People counting

VL53L0X ranging and gesture detection sensor to detect when people enter certain areas.

Every board stores a local counter and sends real-time data for web app and dashboard consulting.

Every board communicates via PIN with a close installed LED, that lights up in different colors according to the number of visitors in the room.



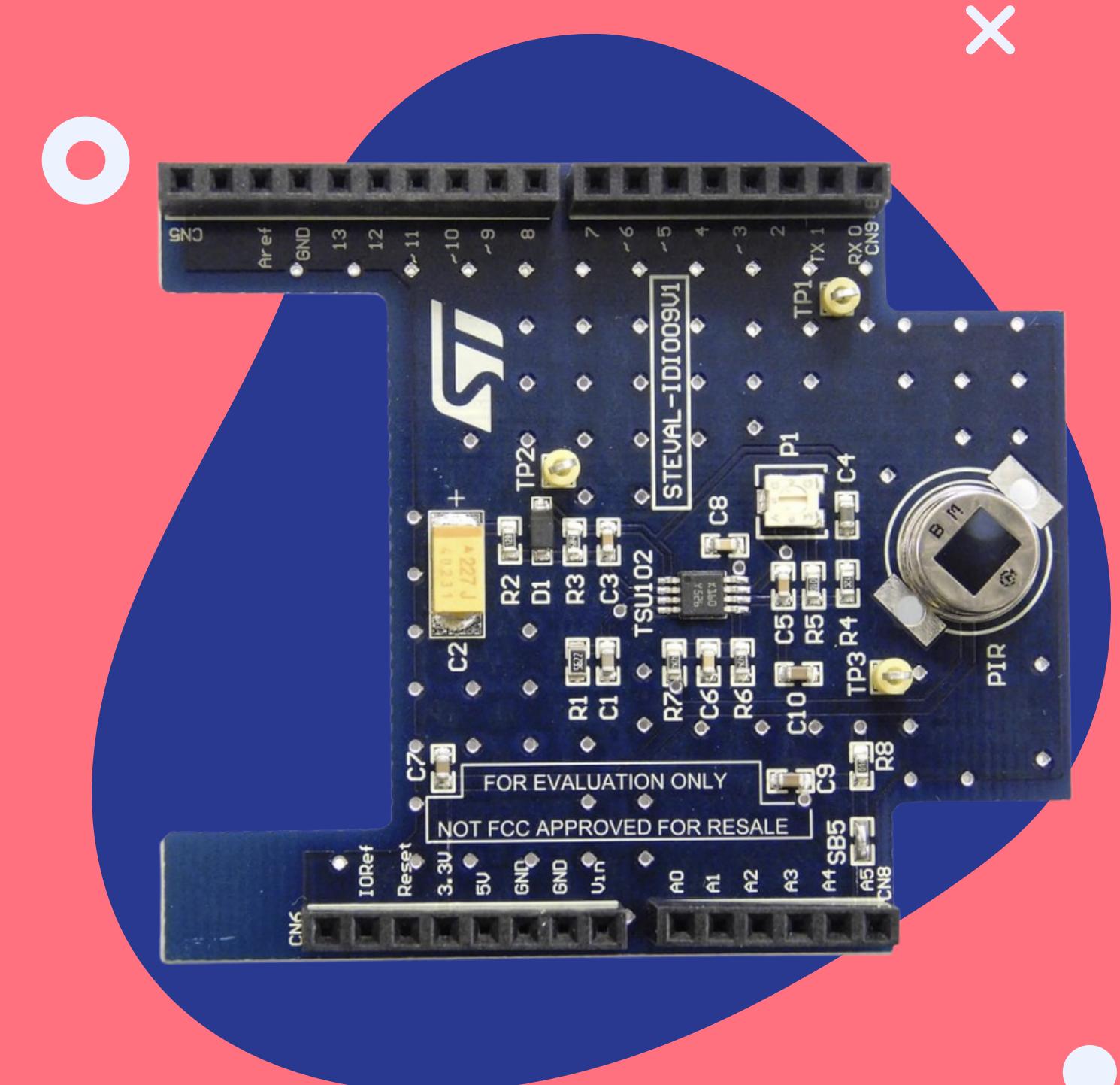
STEVAL-IDI009V1 evaluation board



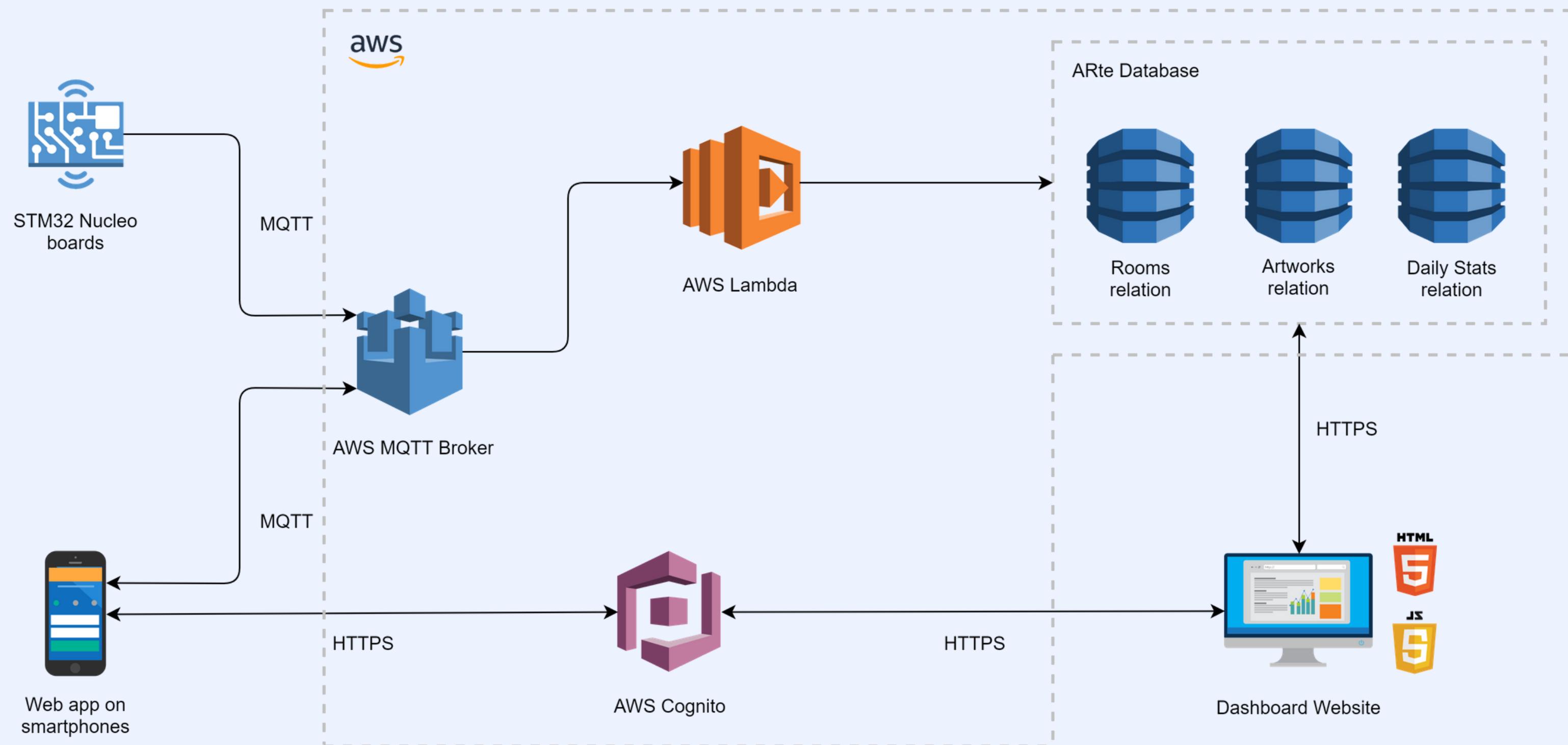
Motion detection

Passive infrared (PIR) sensor for human movement detection.

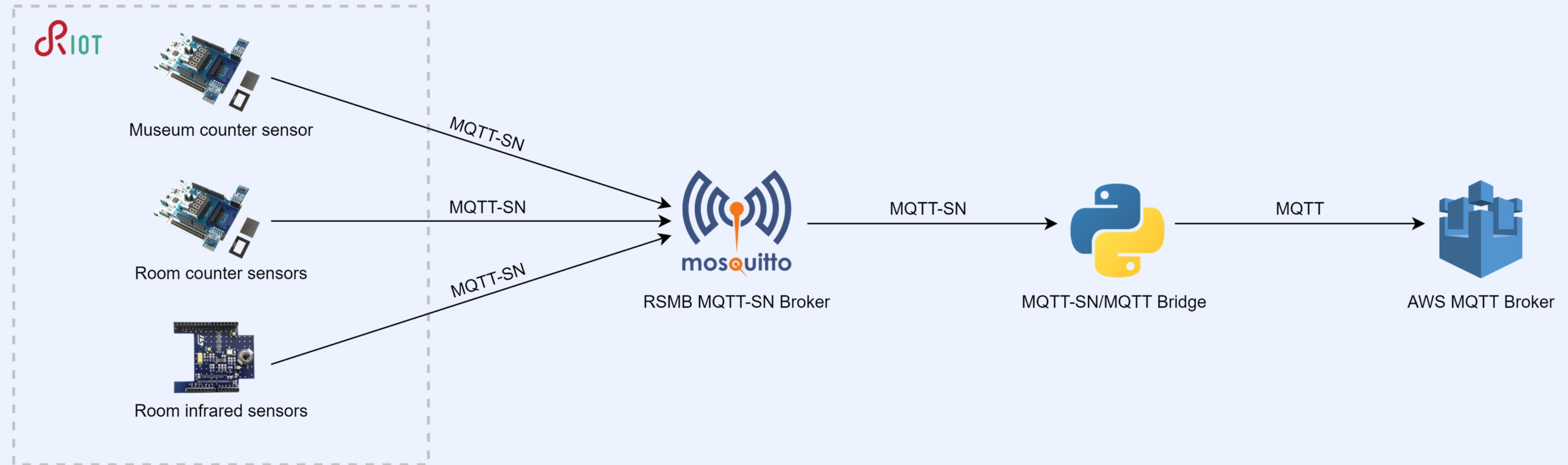
Every board obtains and sends continuous and variable data (inside the museum) suitable to be combined and, therefore, able to produce variable results after a proper elaboration.



ARte architecture



Boards and RIOT-OS



AR Web App

→ **Four interactive features**

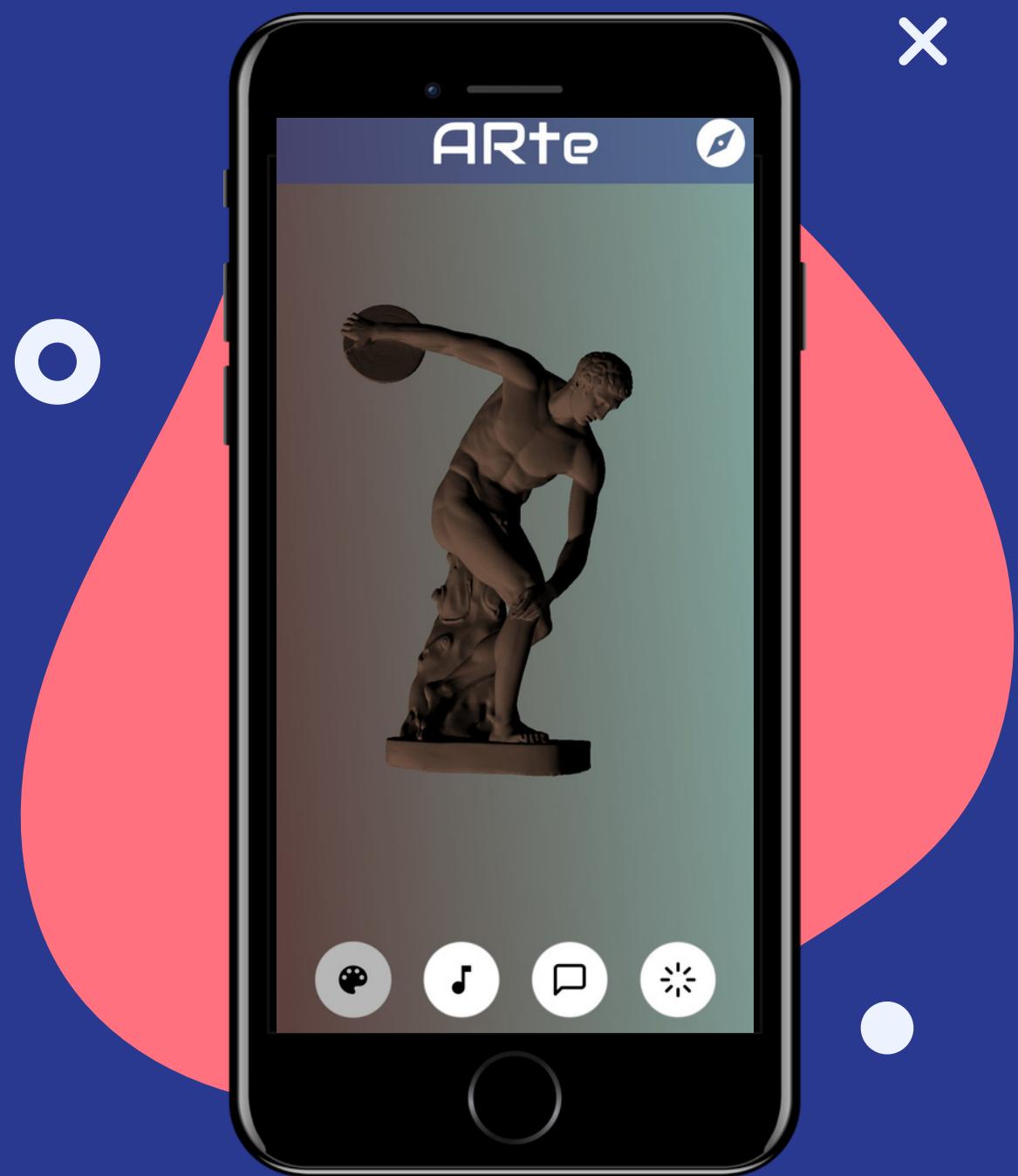
Web app interacts with STEVAL-IDI009V1 and X-NUCLEO-53L0A1 expansion boards in order to provide interactive entertainment.

→ **Crowding map**

Connect to the MQTT broker to obtain real-time data about rooms' crowding.

→ **Mobile sensors**

Smartphone's camera to support interaction via augmented reality.



Dashboard

→ **Museum stats**

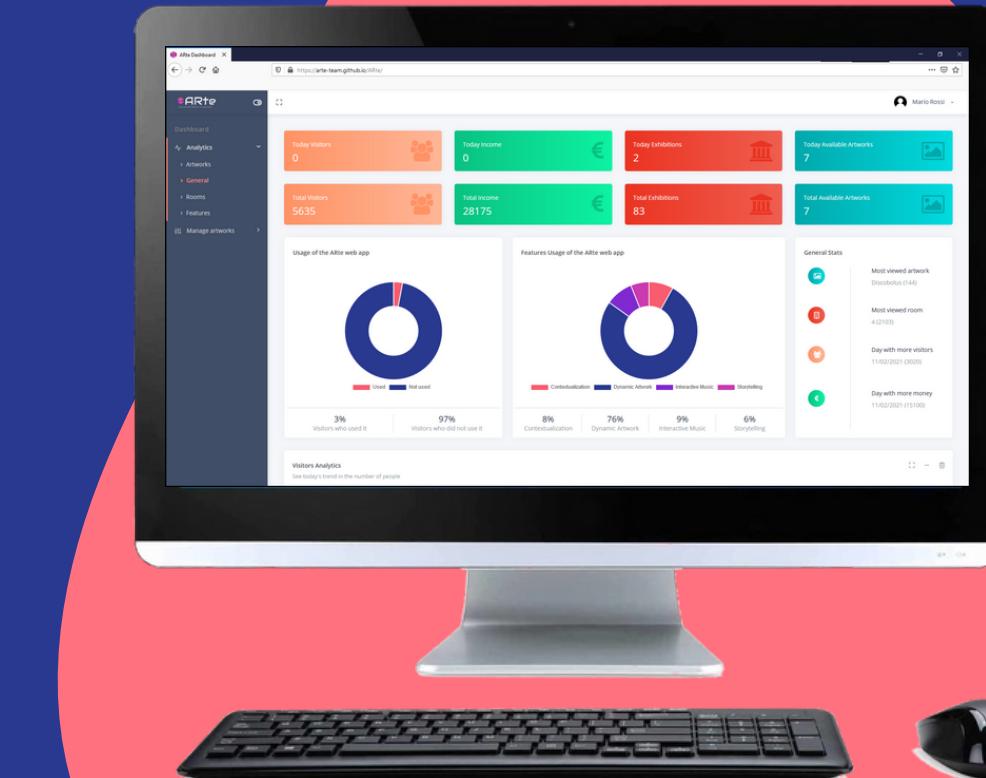
Real-time and periodic statistics about the museum progresses.

→ **Crowding map**

Connect to the backend to obtain real-time data about rooms' crowding.

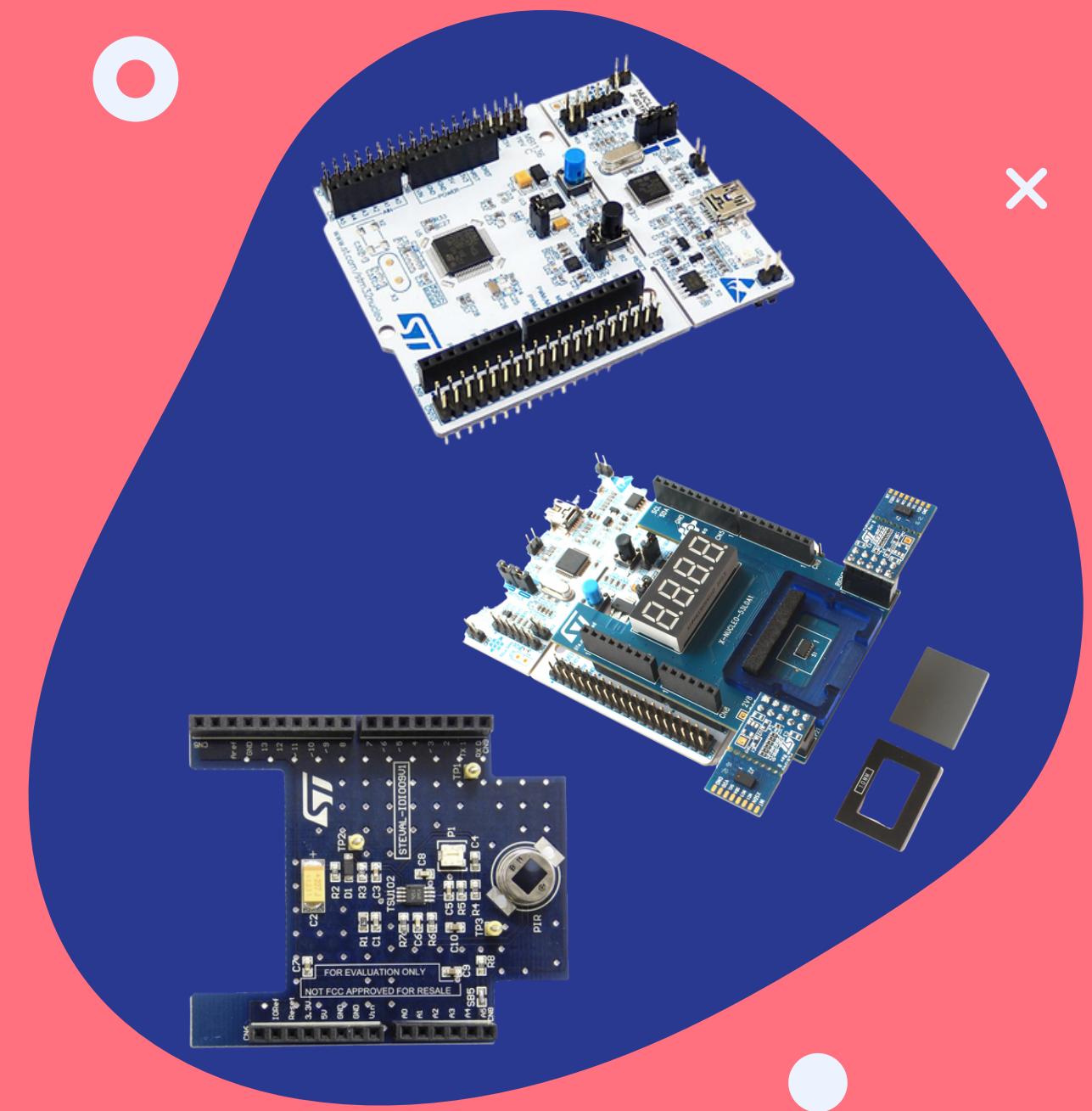
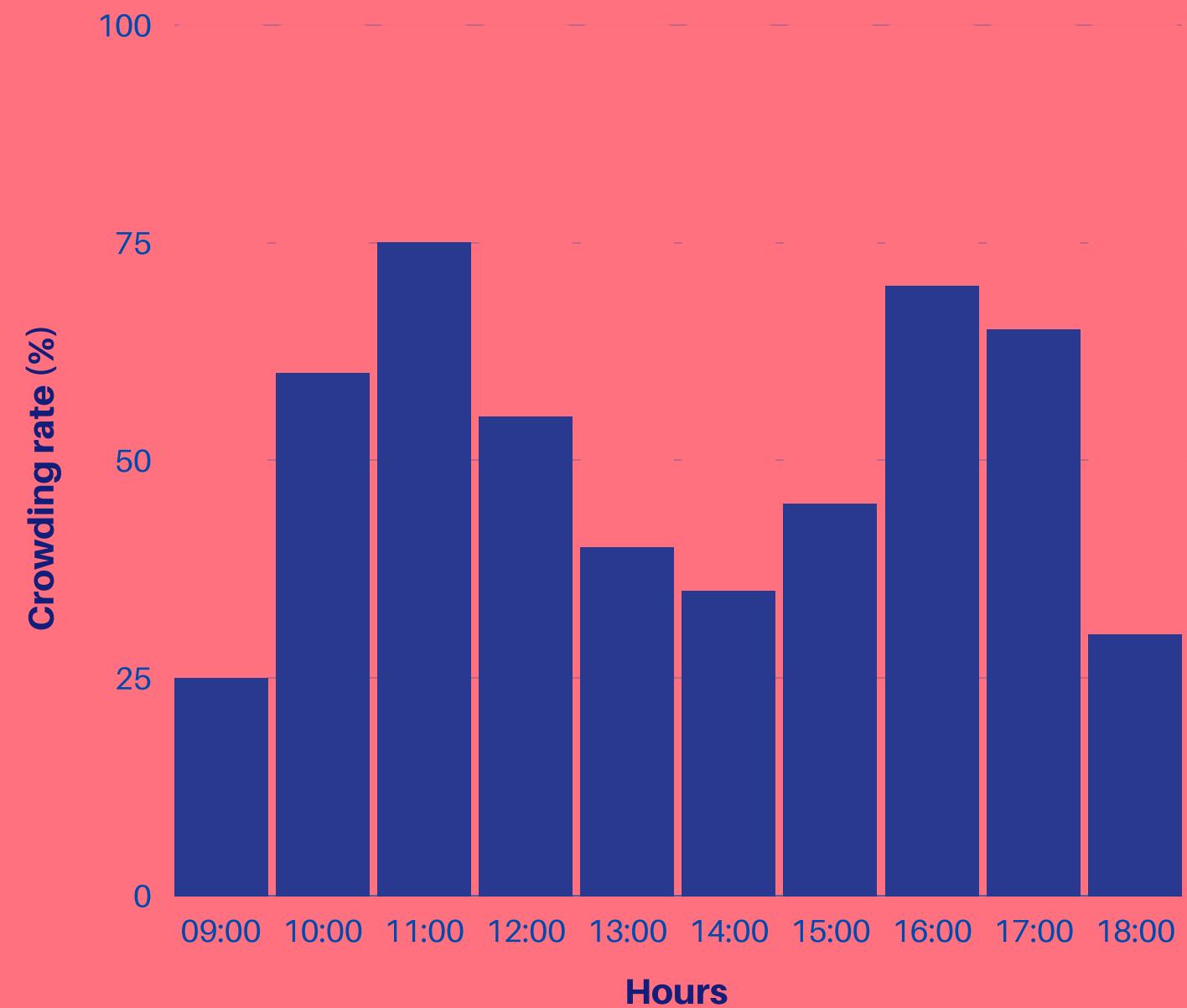
→ **Visitors interests**

Discover the most liked artworks and rooms.



Sensors emulation

- Realistic emulation using RIOT-OS



LEDs and web app map

Social distancing is fundamental in COVID-19 era



Map

Real-time privacy preserving rooms list about rooms accessibility based on crowding



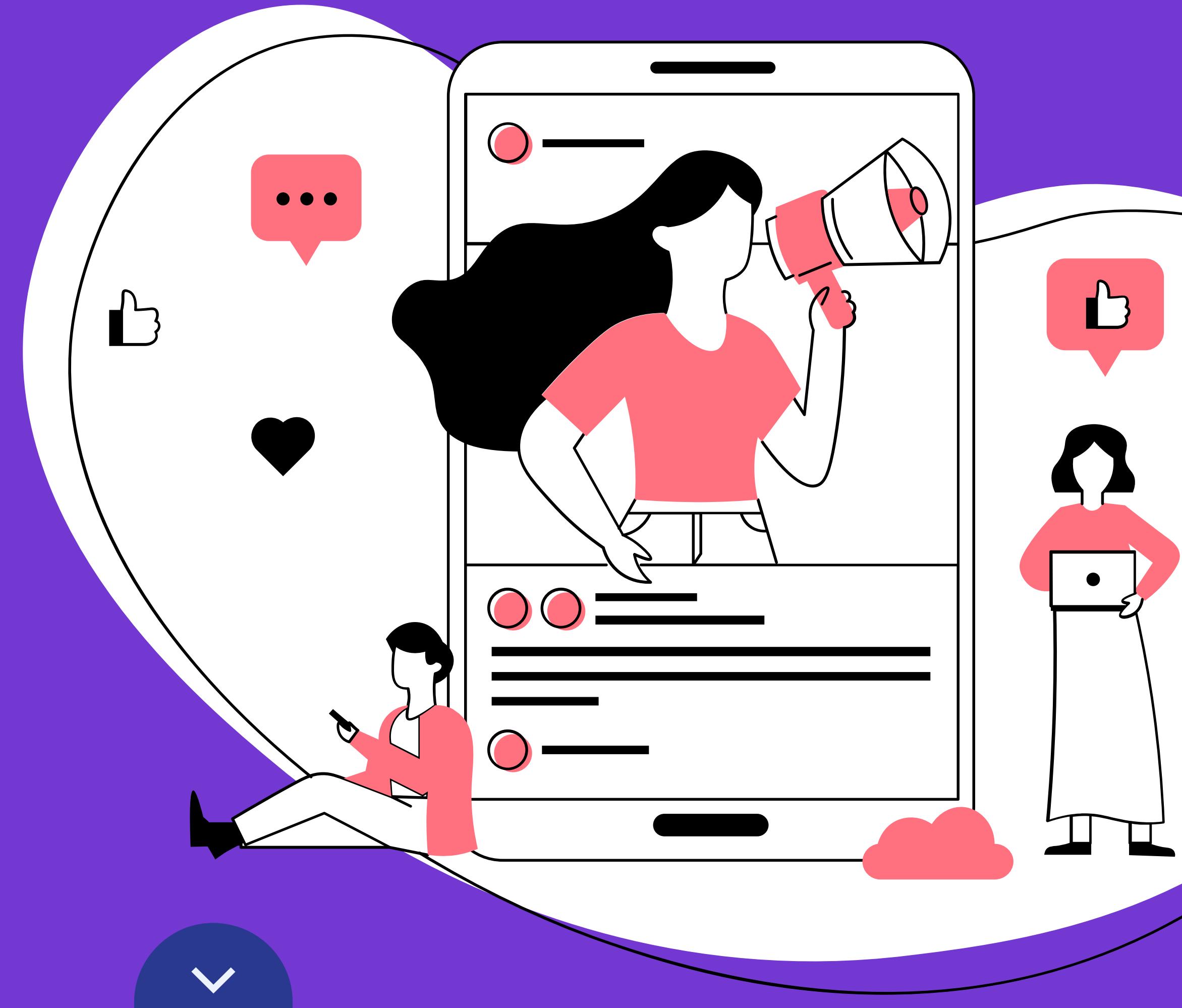
LED

Placed at room entrance acts as a semaphore by lighting up in different colors according to room crowding



Evaluation

The evaluation study:
performance achieved for each
metric considered



What was evaluated?



Accessibility



Compliance



Cost



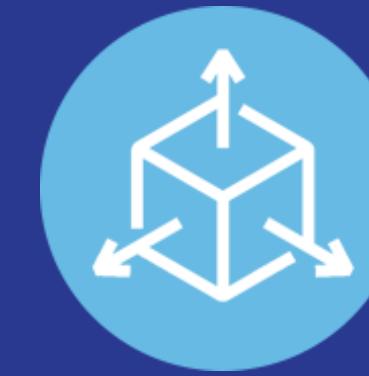
Latency



Performance



Privacy



Scalability



Security



UX

Accessibility and compliance with standards



W3C validation

All the web code is perfectly compliant with the W3C standard definition



Web Accessibility validation

User accessibility is granted for both the web app and the dashboard

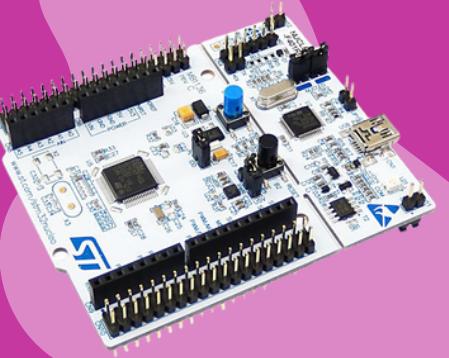


A11y validation

Color contrast accessibility is granted for both the web app and the dashboard

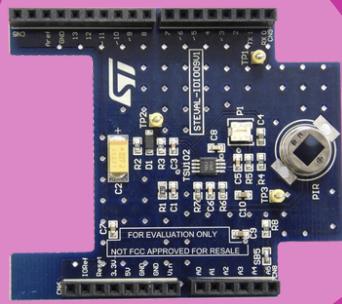


Cost



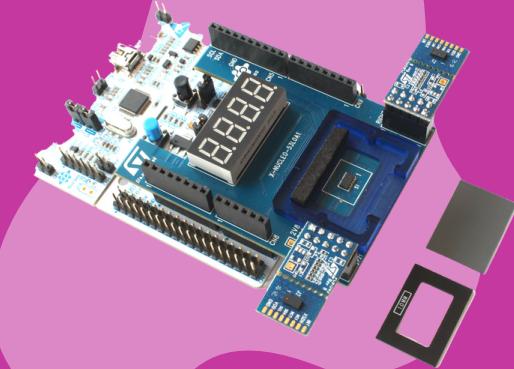
STM32 Nucleo Board

14,00 €



**STEVAL-IDI009V1
evaluation board**

32,00 €



**X-NUCLEO-53L0A1
expansion board**

39,00 €



AWS educate

Free

- Prices for multiple components may decrease
- Affordable expense for museums

Costs updated at 13/02/2021

Latency and Performances



Pingdom test

Speed test by Pingdom returned a score of 80 out of 100



Pagespeed

This tool was not used in the evaluation because we understood it was not suitable for web pages like the web app. The tool cannot grant access to the smartphone's camera, so the evaluation cannot be correct.

Privacy



No sensitive data

The web app does not store any sensitive data, but only feature's related data



Anonymous data

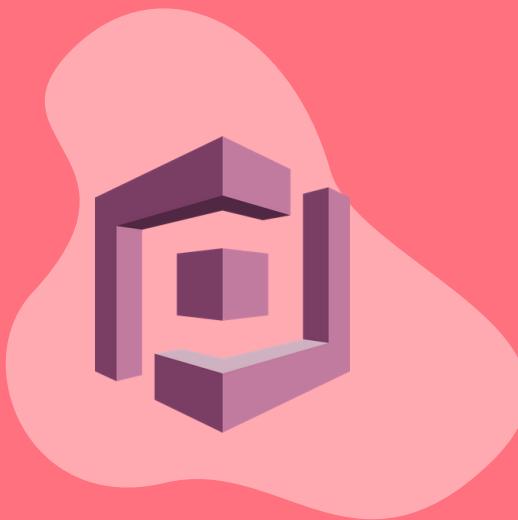
All data sent and stored are completely anonymous



Privacy policy

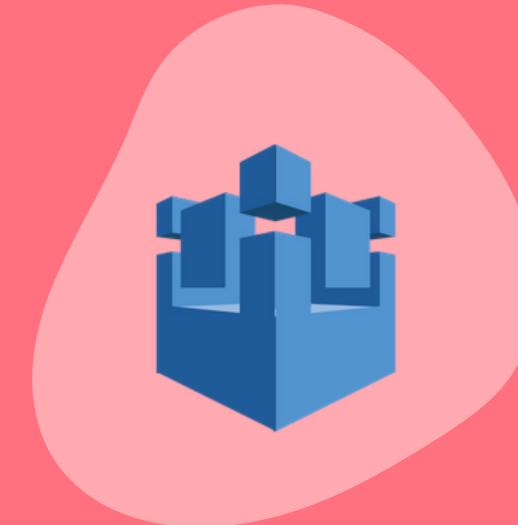
The web app declares an explicit and clear privacy policy

Scalability



AWS Cognito

Scales to millions of users



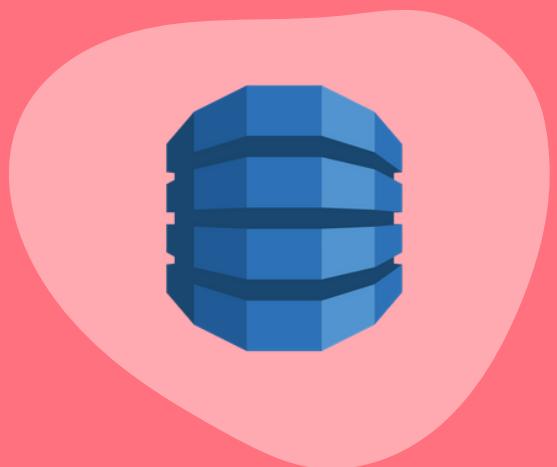
AWS MQTT Broker

500,000
Concurrent connections



AWS Lambda

1,000
Concurrent executions



AWS DynamoDB

Throughput:
40,000 read request units and
40,000 write request units

Security



AWS IoT keys and certs

Secure connections between the MQTT broker and the boards via RSA keys



TLS everywhere

CIA for data in transit between the AR web app \ dashboard and the server



Server-side access control

Deny attackers to perform functionalities or access to resources for which they are not entitled via Cognito authentication and IAM roles



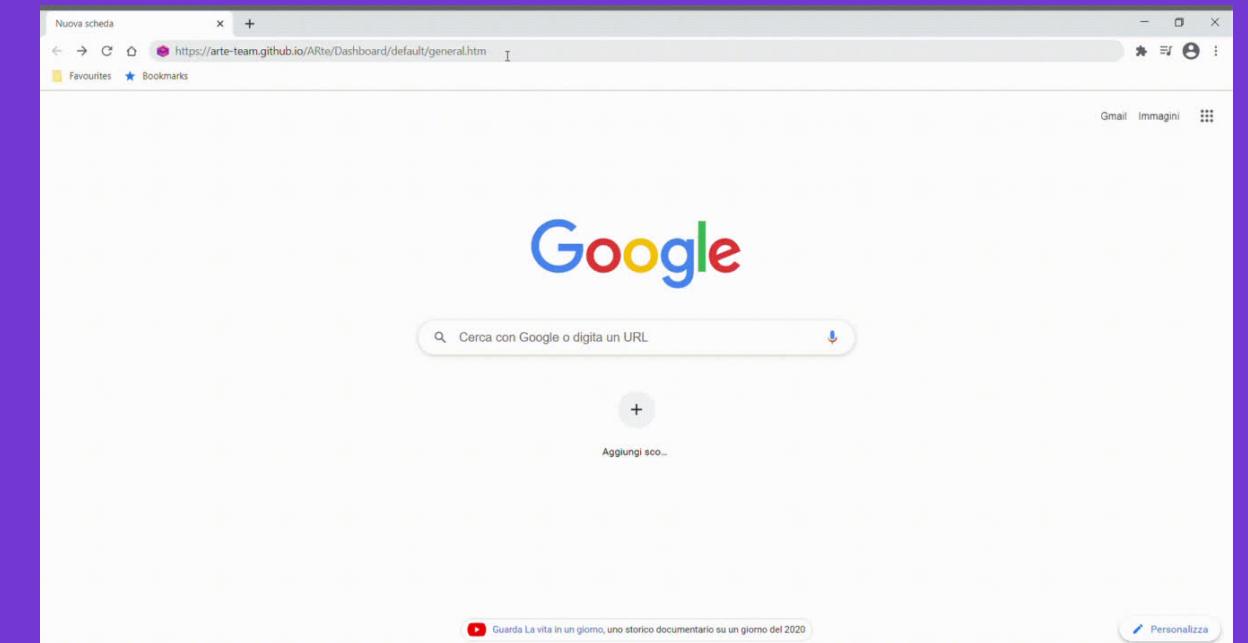
Server-side input validation

Protection against Injection and XSS attacks

SSL Report: arte-team.github.io

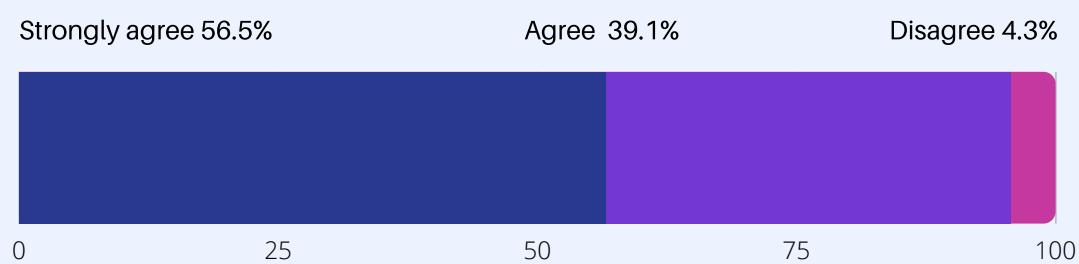
Assessed on: Tue, 09 Feb 2021 22:20:59 UTC | HIDDEN | [Clear cache](#)

	Server	Test time	Grade
1	185.199.108.153 cdn-185-199-108-153.github.com Ready	Tue, 09 Feb 2021 22:14:58 UTC Duration: 89.792 sec	A
2	185.199.109.153 cdn-185-199-109-153.github.com Ready	Tue, 09 Feb 2021 22:16:28 UTC Duration: 89.942 sec	A
3	185.199.110.153 cdn-185-199-110-153.github.com Ready	Tue, 09 Feb 2021 22:17:58 UTC Duration: 90.315 sec	A
4	185.199.111.153 cdn-185-199-111-153.github.com Ready	Tue, 09 Feb 2021 22:19:28 UTC Duration: 91.24 sec	A

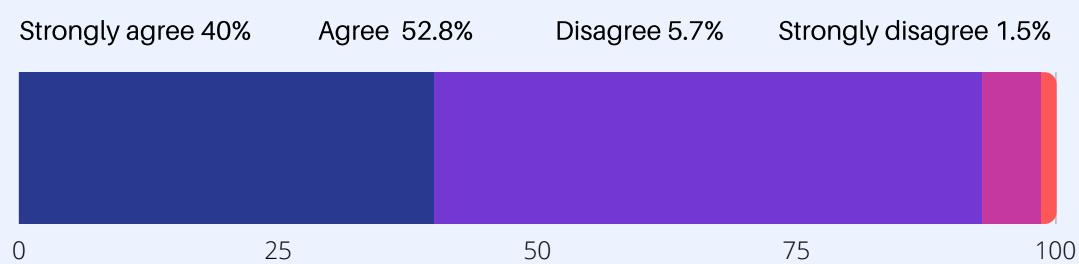


User experience

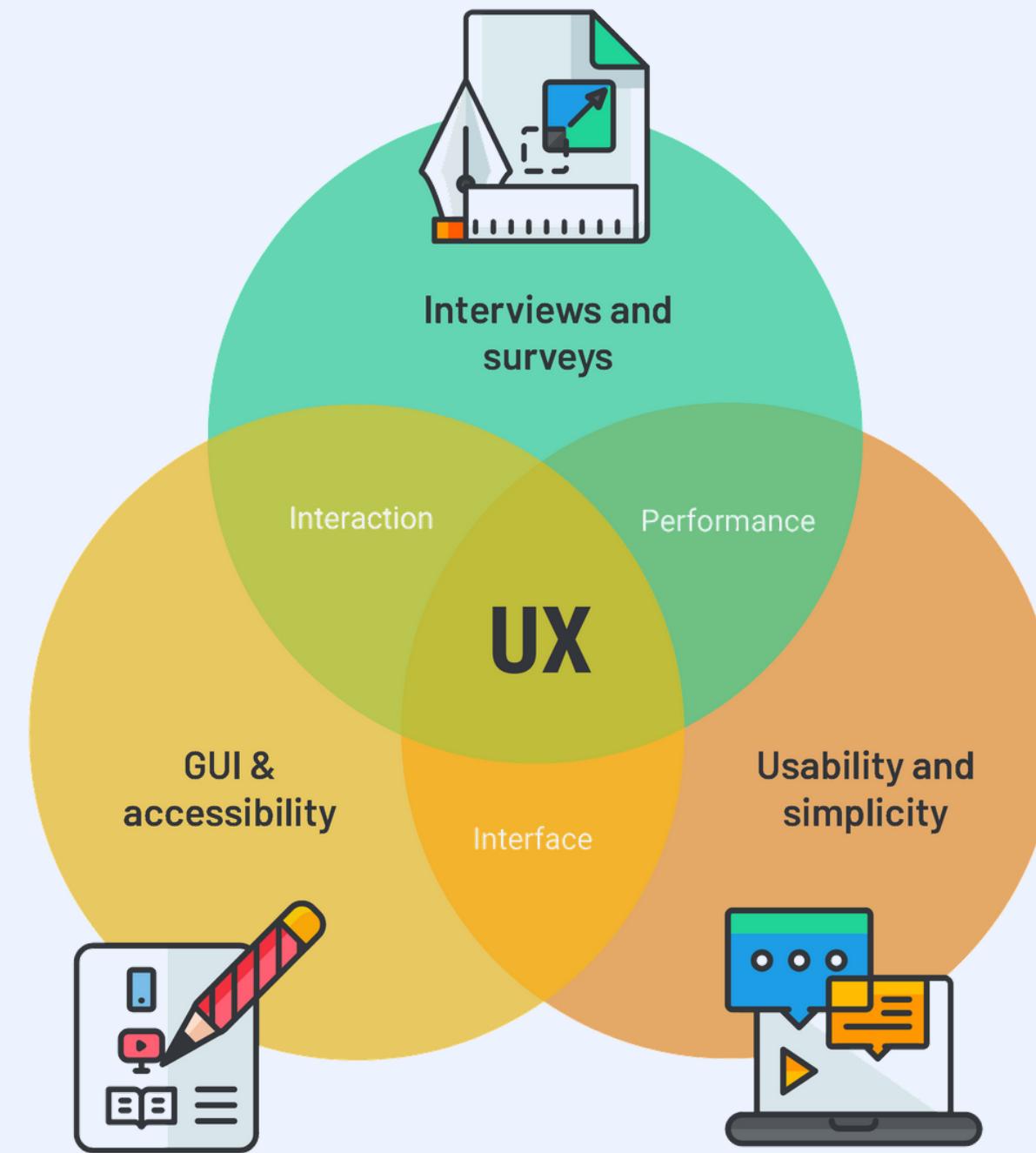
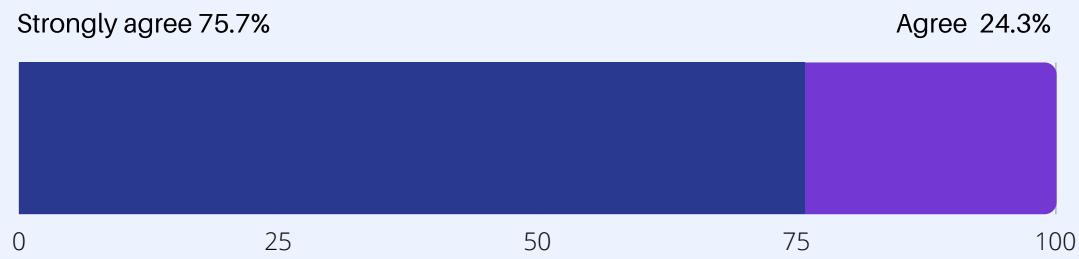
Do you think the app can enhance your museum's visit?



Do you think the icons are explanatory of the features they represent?



Do you think the app is overall simple to use?



What we did not implement and why

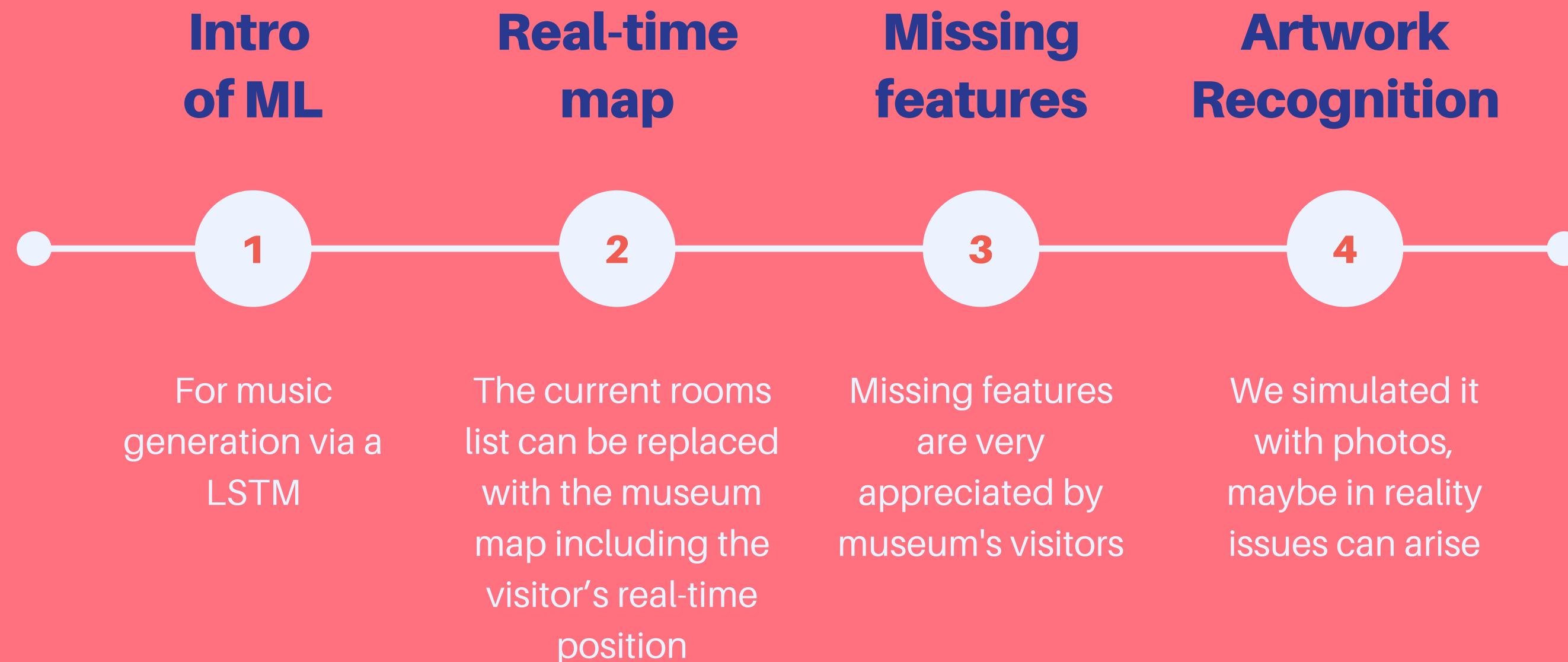
✗ Animation

We tried to focus on features with IoT implications.

✗ Rebuilding of missing components

We tried to focus on features with IoT implications. Moreover this is really difficult task.

Future Roadmap



The Team



Ivan Fardin



Claudiu Ivan



Francesco Ottaviani



ARte

Augmented Reality to educate

Thank you