WHEELFLOW

Mobile and Social Sensing Systems Project

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WHAT WE ARE GOING TO PRESENT

01 WHAT IS WHEELFLOW?

02 ARCHITECTURE

03 DATA COLLECTION

04 DATA ANALYSIS

05 ANDROID APPLICATION

06 LANDMARK SCORES

LET'S START!

01

WHAT IS WHEELFLOW?

THE ISSUE

For wheelchair users, accessibility is a crucial problem

They need to know about inaccessible locations before planning their trips

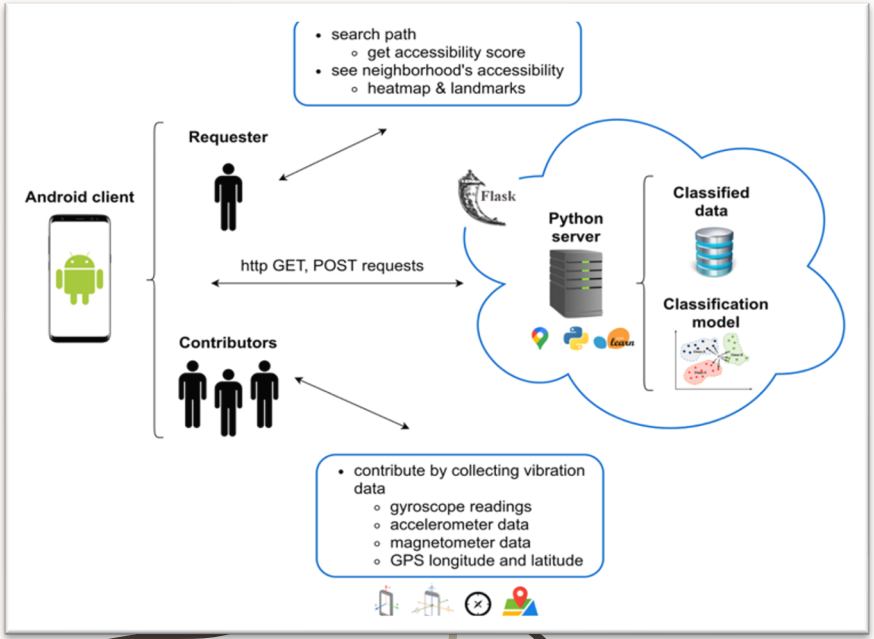
WheelFlow focuses on collecting and sharing geolocalized accessibility information about routes

02

THE ARCHITECTURE

HOW IT WORKS

WheelFlow is a crowd-sourced Android application where users can search for a path from a source to a destination and receive some accessibility information about the path.



DATABASE STRUCTURE

ID	LATITUDE	LONGITUDE	SCORE	THRESHOLD
1	44.085	10.0377	-4	7
2	43.7222	10.389	5	10
3	43.717	10.397	-3	12

EXAMPLE OF A REQUEST

Post: Send to /locations/update

{ “data”:[{"timestamp": "2022/05/04-11:36:58.558",
"latitude": 43.716141,
"longitude": 10.3965,
"ACC_X": 1.6759412,
"ACC_Y": 1.2737153,
"ACC_Z": 7.7667904,
"GYR_X": 0.45448375,
"GYR_Y": 0.41172317,
"GYR_Z": 0.35430184,
"MAG_X": 13.6875,
"MAG_Y": -0.3125,
"MAG_Z": -47.625},
...}

Get: Request to /locations/inaccessible/scores

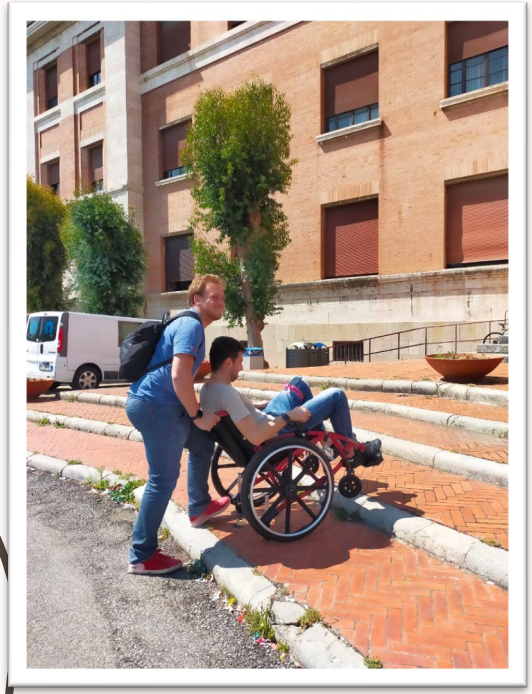
[{"latitude": 44.0495,
"longitude": 10.0588,
"score": -4,
"bound": 7}]

03

DATA COLLECTION

RECORD APPLICATION

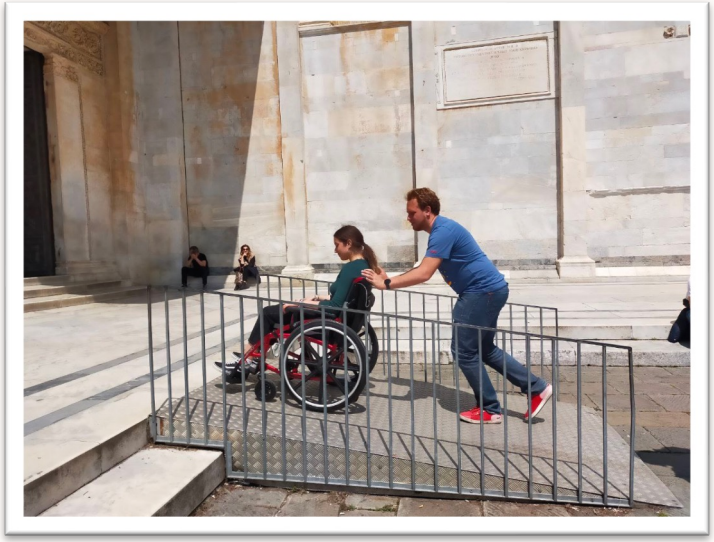
HOW IT IS PERFORMED



Collect data though a traditional wheelchair mostly in an assistant – propelled way

- GPS
- Timestamp
- Accelerometer (x,y,z axis)
- Gyroscope (x,y,z axis)
- Magnetometer (x,y,z axis)
- Label

Total of 2 milions records!



04

DATA ANALYSIS

PREPROCESSING PIPELINE

SENSOR DATA TRASFORMATION

WINDOW CREATION

FEATURE EXTRACTION

FEATURE NORMALIZATION AND SELECTION

REBALANCING

DATA TRANSFORMATION

RAW DATA FROM SMARTPHONE

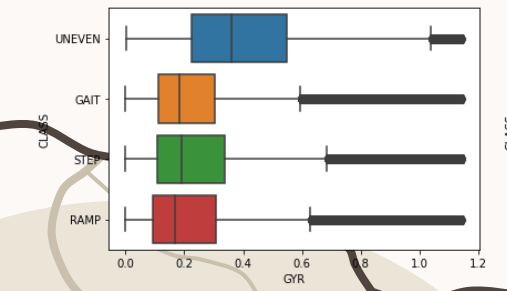
3 FEATURES FOR EACH SENSOR	ONE FOR EACH AXIS OF THE SENSORS

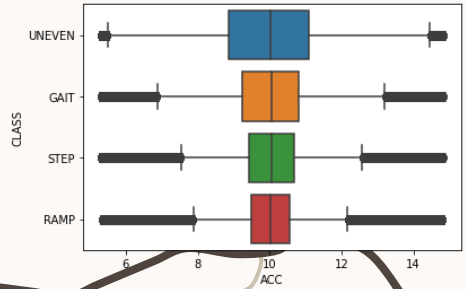
SENSOR DATA AGGREGATION

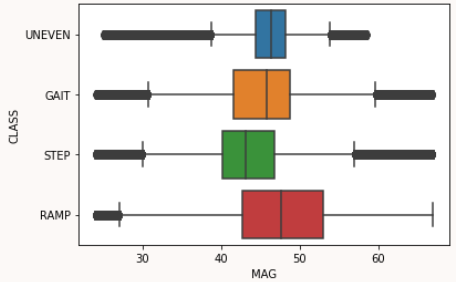
1 FEATURE FOR EACH SENSOR	EACH FEATURE IS THE NORM OF A SENSOR'S COORDINATES → OUTLIERS REMOVED HERE

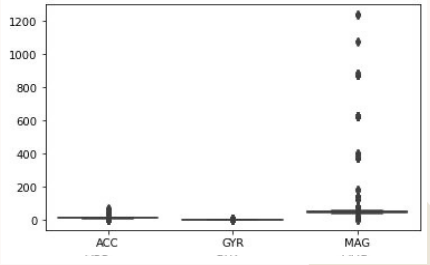
DOMAIN TRANSFORMATION

3 FEATURES FOR EACH SENSOR	2 FEATURES GENERATED BY DISCRETE WAVELET TRANSFORMATION, 1 FOR THE TIME DOMAIN

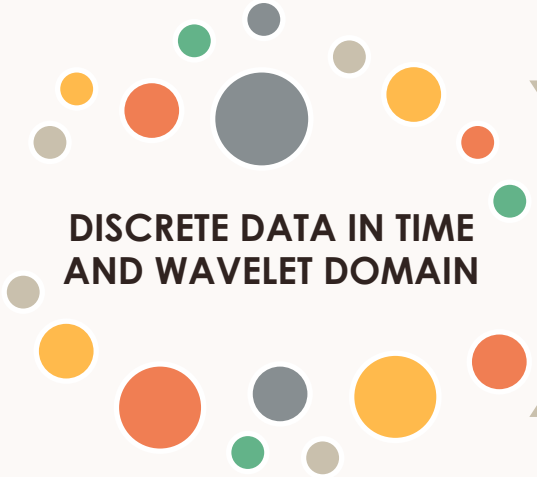








DATA SEGMENTATION



DISCRETE DATA IN TIME AND WAVELET DOMAIN

DATA SEGMENTED IN MACRO WINDOWS

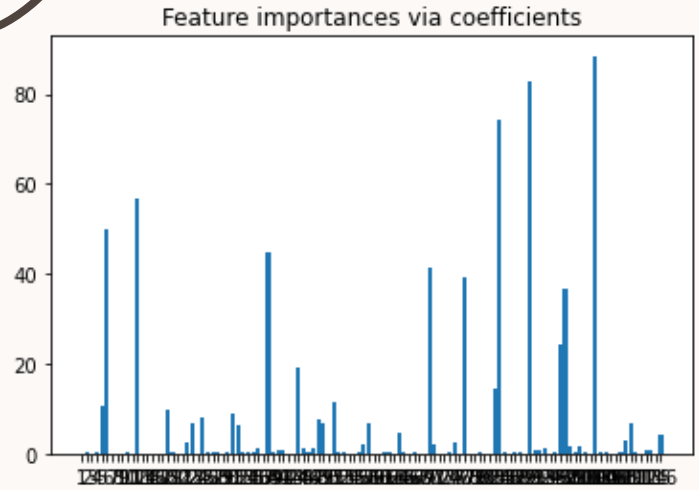
One macro window for each recording

DATA AGGREGATED IN SMALLER WINDOWS

Window size in range 0.5 - 1s, with or without overlapping

FEATURE EXTRACTED FROM THE AGGREGATION OF THE DATA IN THE FINAL WINDOWS

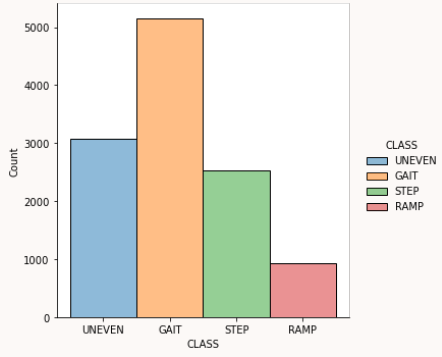
FEATURE SELECTION



FEATURE SELECTED DATA — 5 – 20 FEATURES

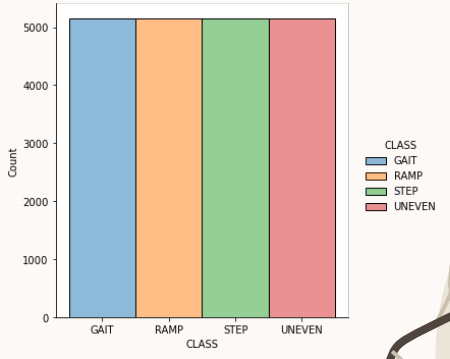
RAW WINDOW DATA — 117 FEATURES

REBALANCING



OVERSAMPLING WITH SMOTE

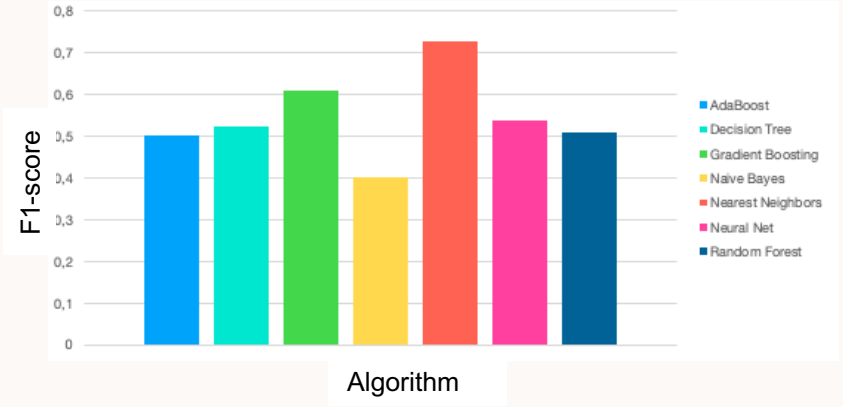
UNDERSAMPLING WITH ENN



EXPERIMENTAL RESULTS

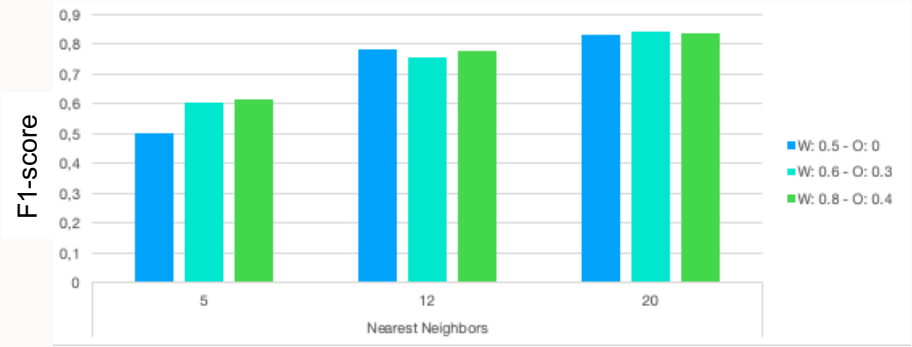
BEST SET-UP

- Window size: 0.6, with Overlap 0.3
- Number of features: 20
- Algorithm: K-Nearest Neighbors



RESULTS

- Accuracy: 0.8511
- F1-score: 0.843



05

ANDROID APPLICATION

WHAT CAN USERS DO?

EXPLORE

Get an overview of the accessibility barriers of the neighborhood in the form of landmarks in a map

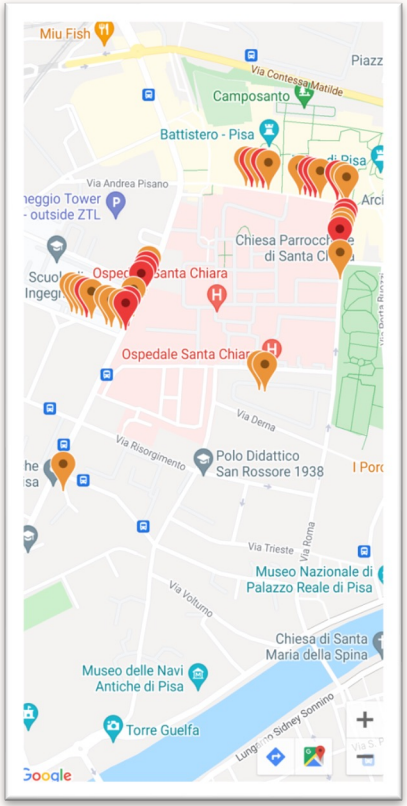
CONTRIBUTE

Contribute to the collection of vibration data while on the move using smartphone's sensors and GPS

SEARCH A ROUTE

Search a path from a source to a destination and discover which is the route accessibility

EXPLORE ACTIVITY

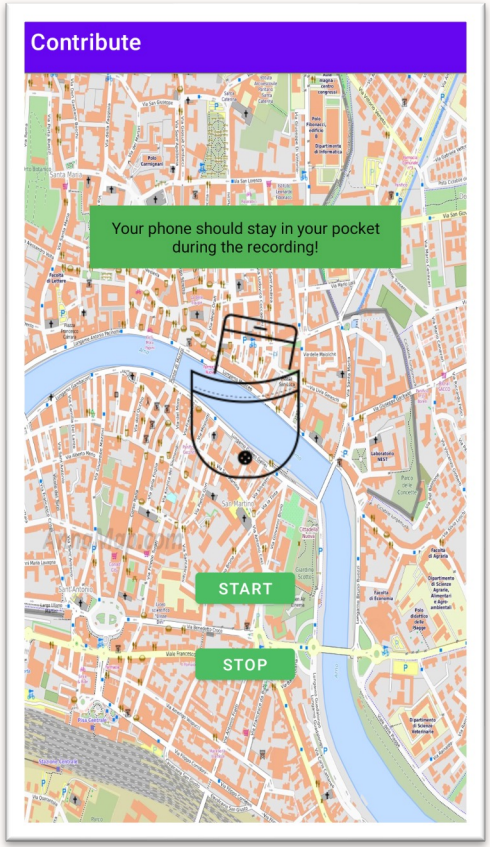


Accessibility barriers of the area are shown using **landmarks** with different colors based on **macro-area inaccessibility scores**:

highly inaccessible area: score ≥ 0.7

inaccessible area: score < 0.7

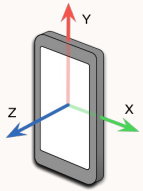
CONTRIBUTION & CROWD-SOURCING



Users can contribute by using *WheelFlow* while they are on the move.

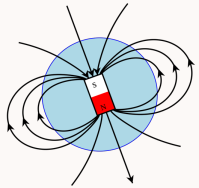
For better results, contributors should put their phone in trousers' pocket during the contribution.

The application exploits:



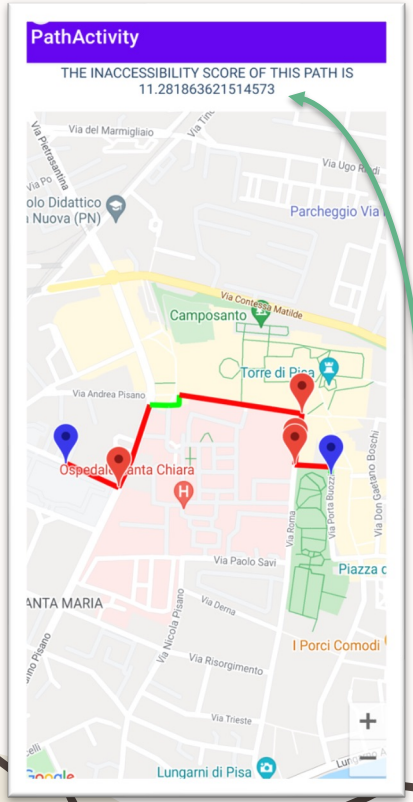
accelerometer


gyroscope


magnetometer


GPS

SEARCH ACTIVITY - ROUTE



Path's accessibility is shown using different colors based on the **sub-route inaccessibility score**:

highly inaccessible sub-route: score ≥ 3

inaccessible sub-route: 1 < score < 3

accessible sub-route: score < 1

source and destination points

sub-route score = accessibility barriers/km

route score = weighted average of sub-route scores

06

LANDMARK SCORES

ROUTING

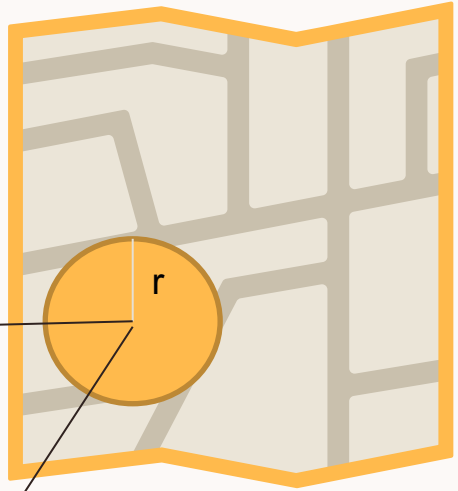
How to evaluate a route from a source to a destination for a wheelchair user?

The Google Maps API does not provide information about accessibility for wheelchair users.

INACCESSIBILITY SCORE

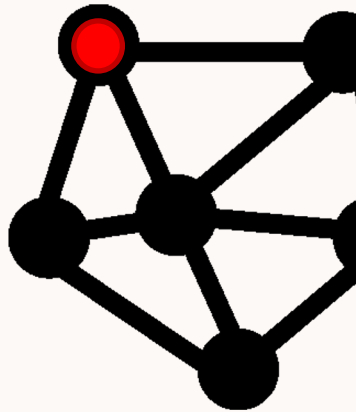
Relying on the results of the classifier, we've determined an inaccessibility score for each location.

Close measurements may regard the same achitectural barrier. We've decided to compress all accessibility information in a certain radius of coordinates in a **macro-zone.**



CHALLENGES

We have multiple potential **unreliable sources of information**.
We need to deal with different factors:
- possible human errors or noises
- unreliability of the classification

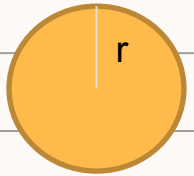


We also have to deal with **outdated** measurements which accounts for temporary or permanent changes.

Solution: not rely on a single classification result but exploit crowdsensing.

MACROZONE'S WINDOW

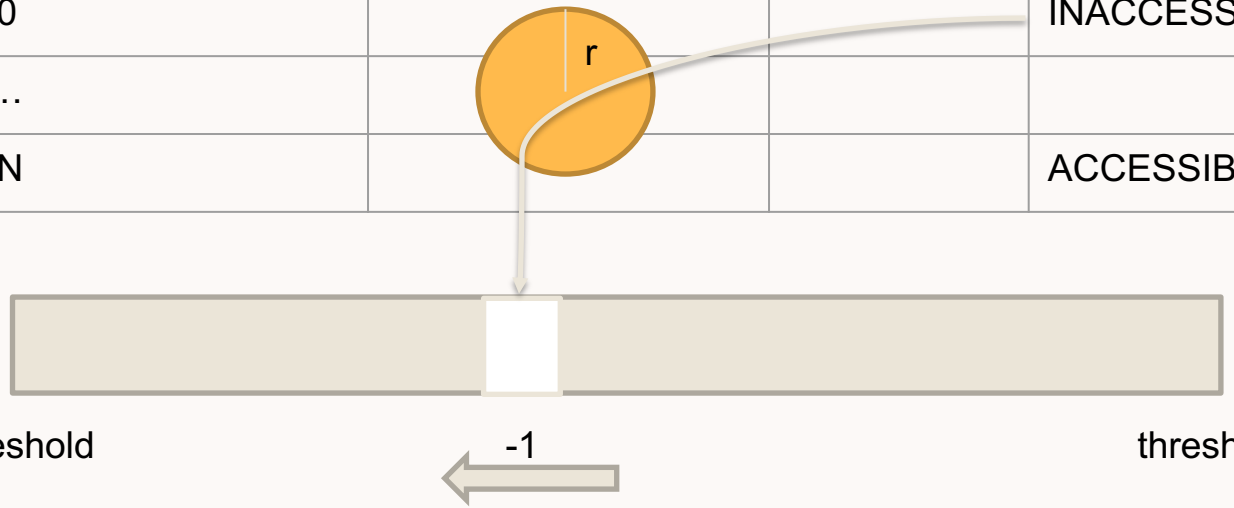
TIMESTAMP	LOCATION	.....	CLASS
t0			INACCESSIBLE
…			
tN			ACCESSIBLE



-threshold 0 threshold

MACROZONE'S WINDOW

TIMESTAMP	LOCATION	……	CLASS
t0			INACCESSIBLE
…			
tN			ACCESSIBLE



MACROZONE'S WINDOW

TIMESTAMP	LOCATION	……	CLASS
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…			
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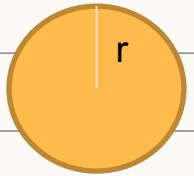
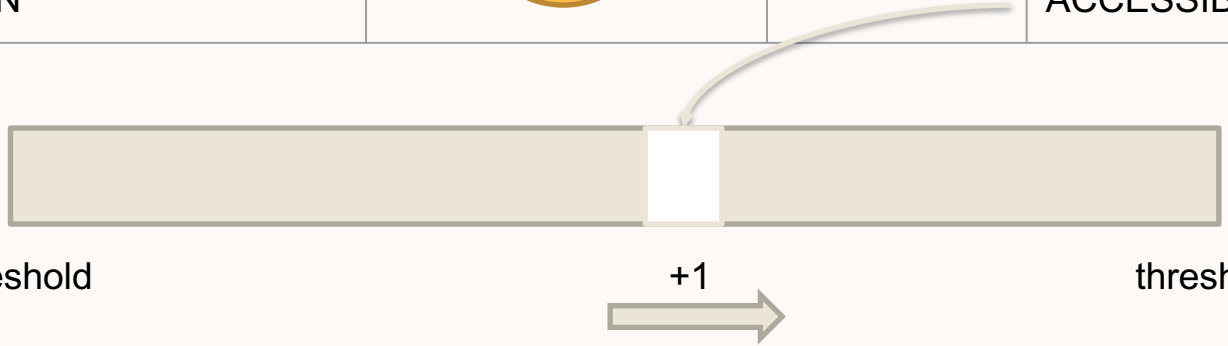




ALGORITHM

Algorithm 1 Accessibility Score

threshold = function(location$_i$)
score[location$_i$] = 0
for sample *close to* location$_i$ **do**
    if entry.class == ACCESSIBLE **then**
        score[location$_i$] = min($score[location_i]$+1, $threshold$)
    else
        score[location$_i$] = max($-threshold$, $score[location_i]$-1)
    end if
end for

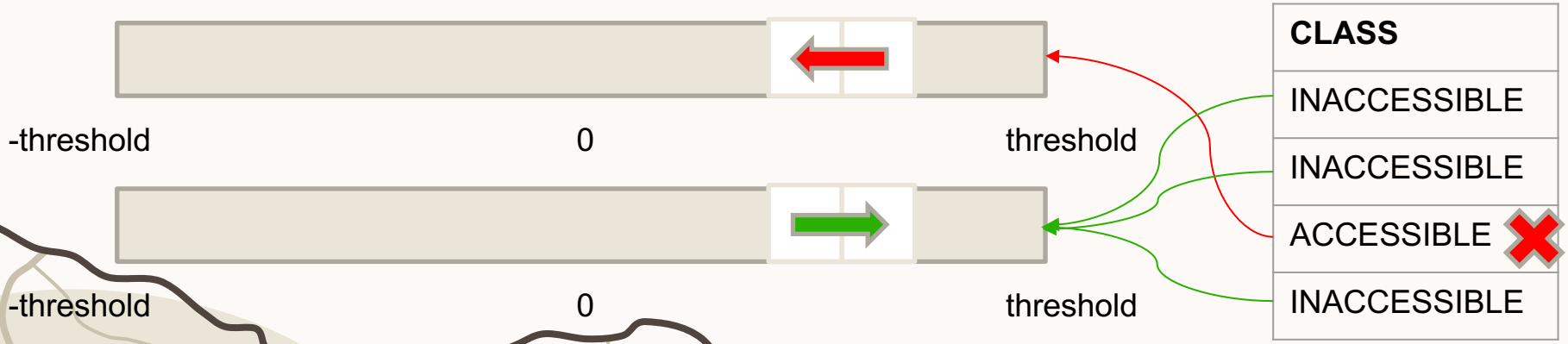
CHALLENGES

This solution allowed us to deal with:

- permanent and temporary changes to the location

-threshold 0 threshold

- non reliability of the classification or possible human errors or noise



THRESHOLD

How to choose the threshold?

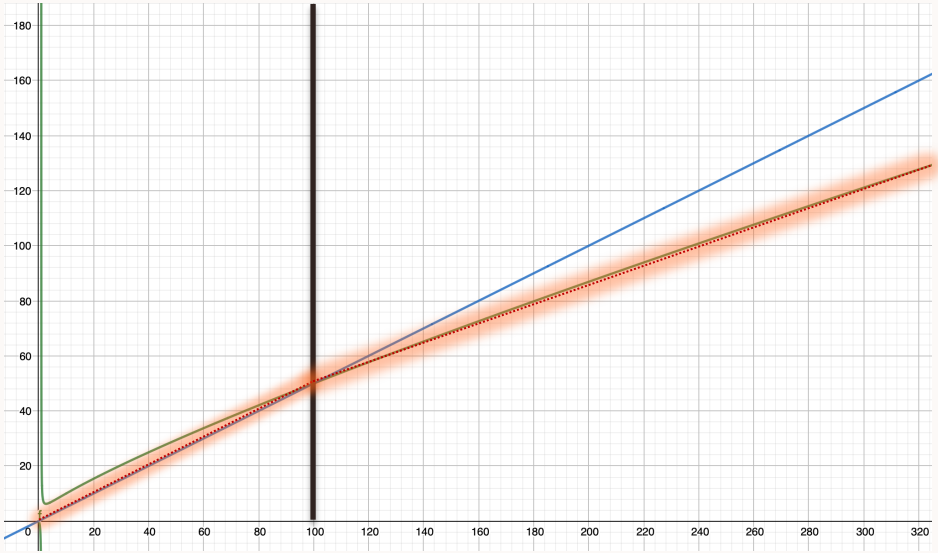
- very small values -> continuous changes
- very large values -> difficulty in changing the accessibility

THRESHOLD CALCULATION

Dynamic adaptive threshold proportional to the traffic in the macrozone.

$$threshold = function(|samples\ in\ the\ macrozone|)$$

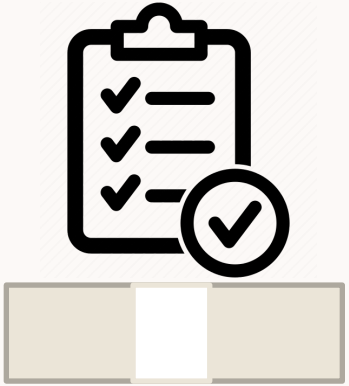
$$function(x) = \begin{cases} \dfrac{x}{2} & x \leq 100 \\ \dfrac{x}{log_{10}(x)} & x > 100 \end{cases}$$



CONCLUSIONS

Using our application, local municipalities can discover in real-time about possible local architectural barriers and handling their reparation in a quick manner.

FURTHER IMPROVEMENTS



$|score|$ close to 0

Unreliable results

More heterogeneous dataset

Weight the reliability of sources of information