Navi Campus: Quantitative methodology for evaluating the user interface of a navigation app using eye tracker and smartphone

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- Research and Innovation Leader at the Capgemini Engineering.
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- Lecturer at ECAM (Engineering School) in the field of IoT.
- Catheter Tracking and data fusion for reducing the X-ray exposition in an interventional Radiology procedure (2020).
- Conception of a touchless human machine interaction system for operating rooms using deep learning (2017).
- Navi Campus : an enhanced GPS navigation app for University Campuses,» 12th ITS European Congress (2017).

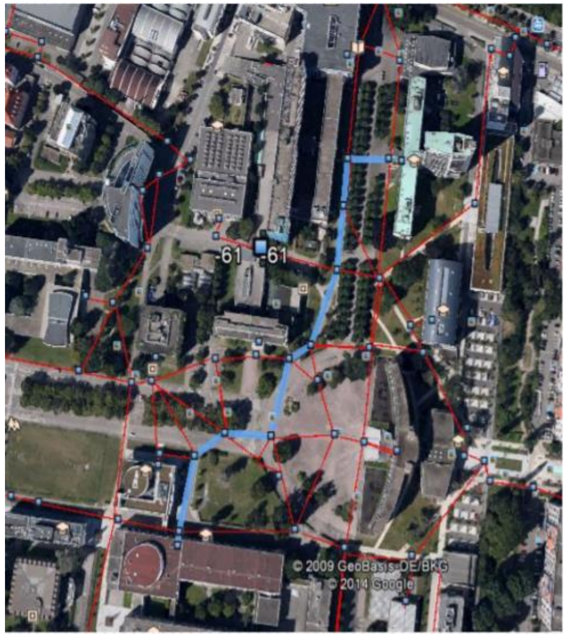
The app

Navi Campus: navigation mobile app for the Strasbourg Campus

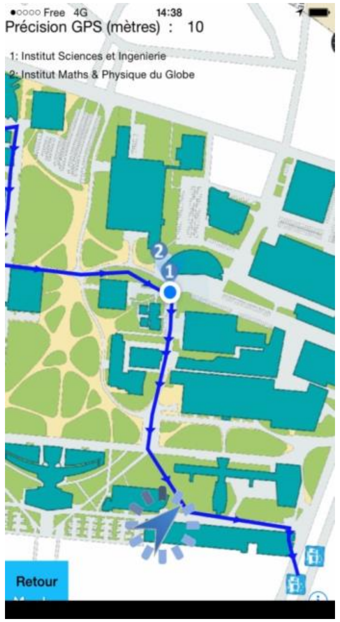
Classic navigation apps (like Google) are not precise enough to locate buildings' entry. These apps are not updated regularly enough to consider civil work on the campus in the itineraries provided to the users. Moreover, the itineraries provided can be inaccessible to people with visual/mobility impairment.

The user select the destination in the app

Dijkstra algorithm draw the best path



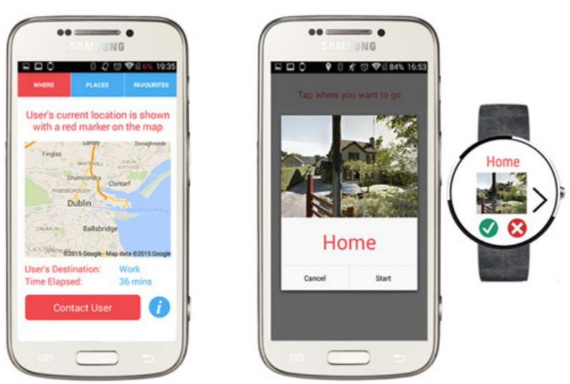
The user is guided with a map where the person can see his/her current location and orientation



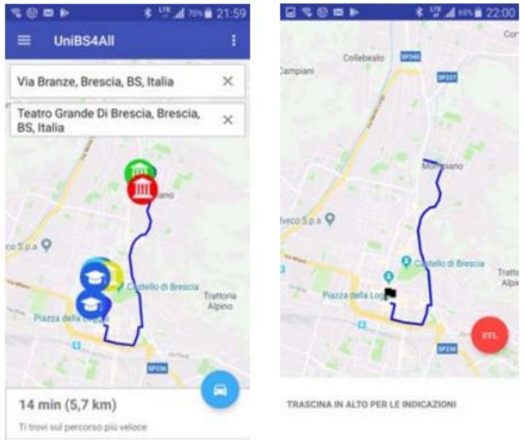
Quantitative study to evaluate the performances of the app

State of the art

Qualitative studies



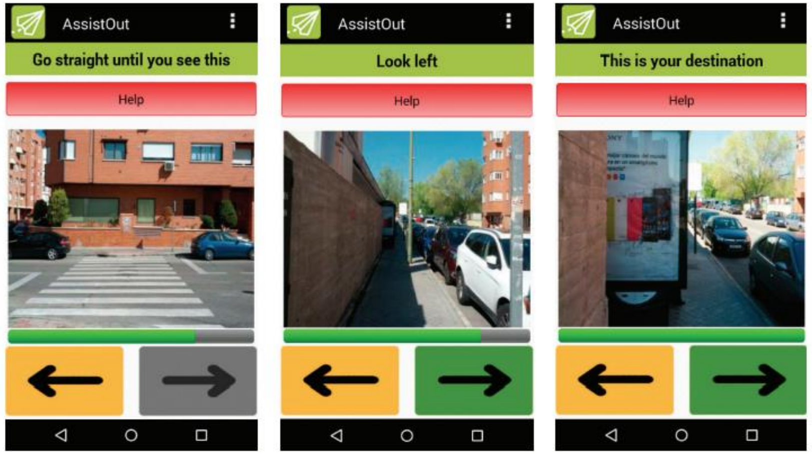
WaytoB



UniBS4All

Survey to collect the felling of the users. 5 levels of answers : from unsatisfied to very satisfied

Quantitative studies



AssitOut

Compare AssistOut vs Google Maps

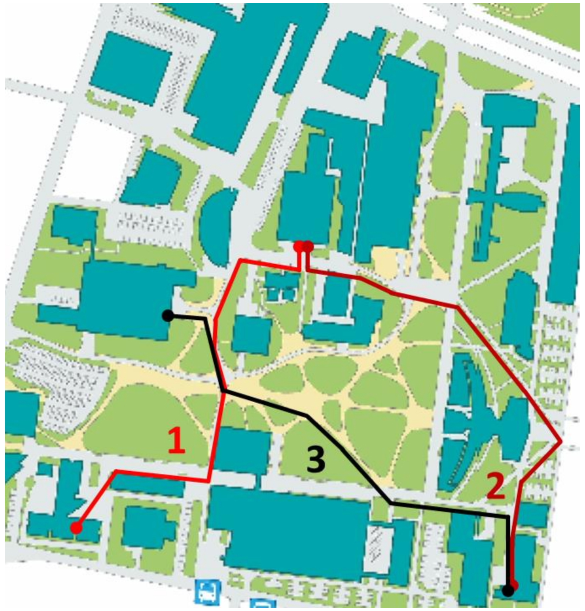
- Time taken to walk to the destination.
- Does the user reached the final destination ?
- Does the user understand he/she reached the destination?
- Does the user need help to find his way after getting lost ?
- Does the user make wrong decisions ?

The experiment

3 itineraries are defined across the campus, 3 subjects are asked to follow them in the same order, using the Navi Campus app. They are wearing smart glasses with several sensors. The phone used for the app is also collecting motion data.

	Subject A	Subject B	Subject C
Know the campus	NO	YES	YES
Know the application	NO	NO	YES

Summary of the users' knowledge



The 3 itineraries defined across the campus

Phone (T=20ms)

- Accelerometer
- Gyroscope
- Magnetometer
- GPS (T=1s)

Smart glasses eye Tracker Tobii (T=10ms)

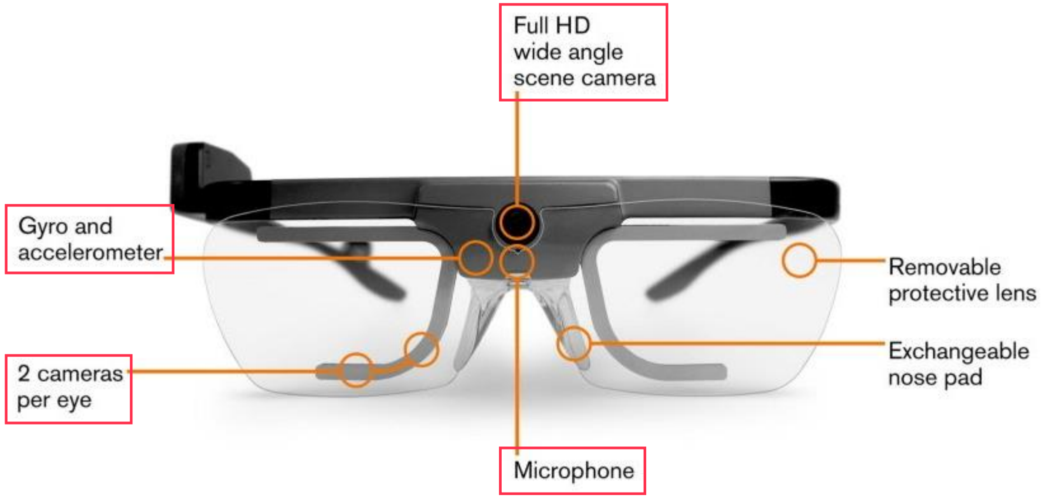


Illustration of the smart glasses used. [5]

Method

Phone

- Accelerometer
- Gyroscope
- Magnetometer
- GPS

Smart glasses Tobii

- Accelerometer
- Gyroscope
- Camera
- Eye tracker

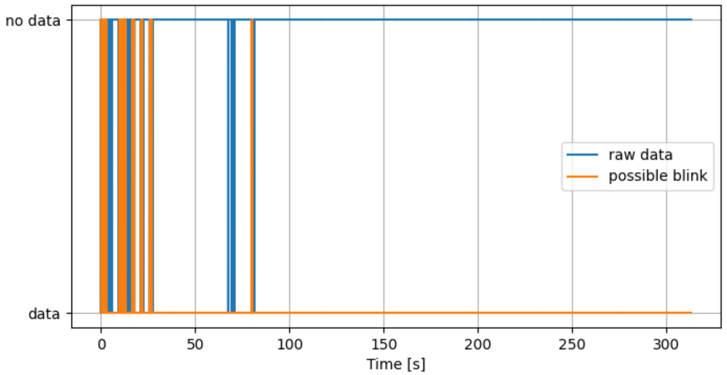
Step frequency analysis
Steps detection to calculate the walking frequency.

Speed analysis

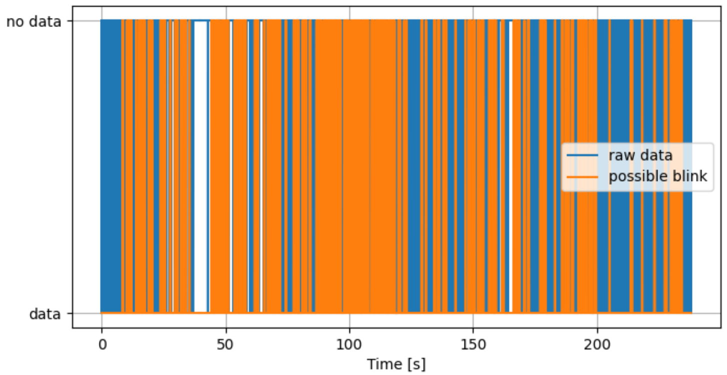
$$speed = \frac{distance}{time}$$

Use of the app
Pairing the head motion and the phone detection in the camera’s filed

Gaze analysis
In some paths, sensors couldn’t record gaze data due to high brightness. Therefore, this analysis will not be conducted.



Itinerary 1, Subject A



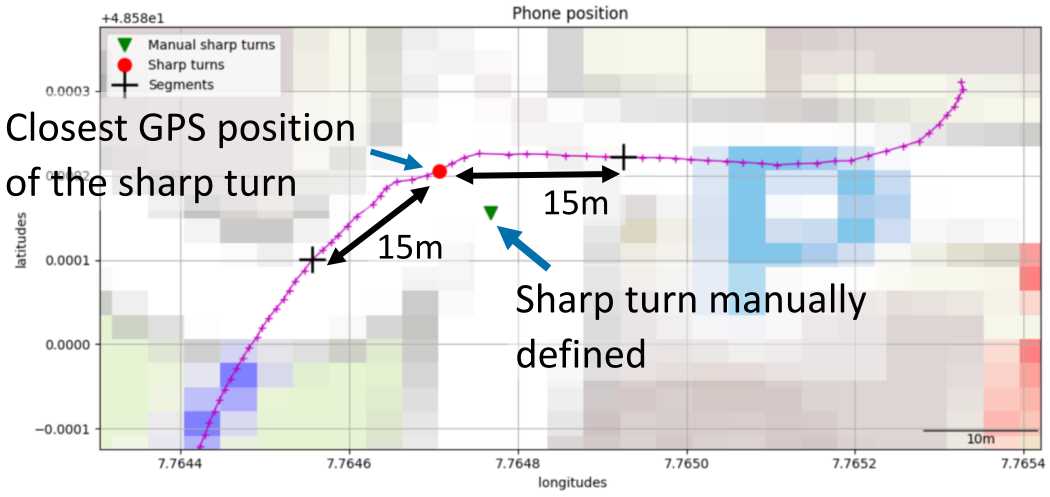
Itinerary 1, Subject C

Method

Segmentation

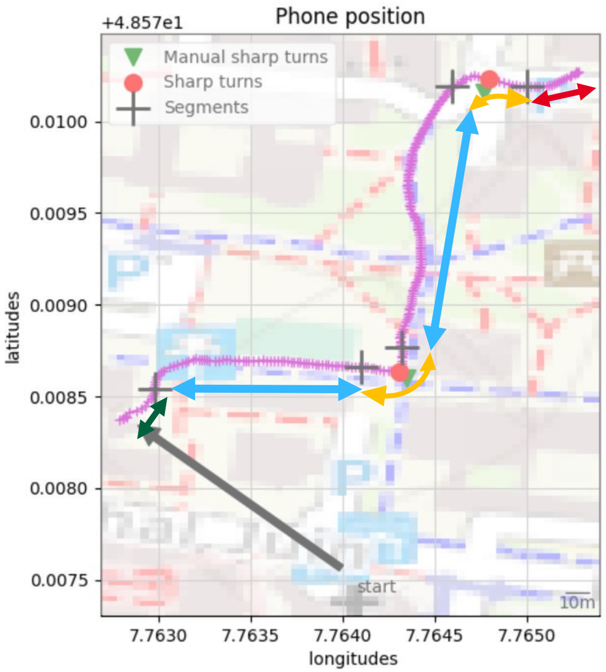
Automatic segmentation: detection of sharp turns for each user path with an algorithm

⇨ not robust enough to user trajectory variation and GPS noise

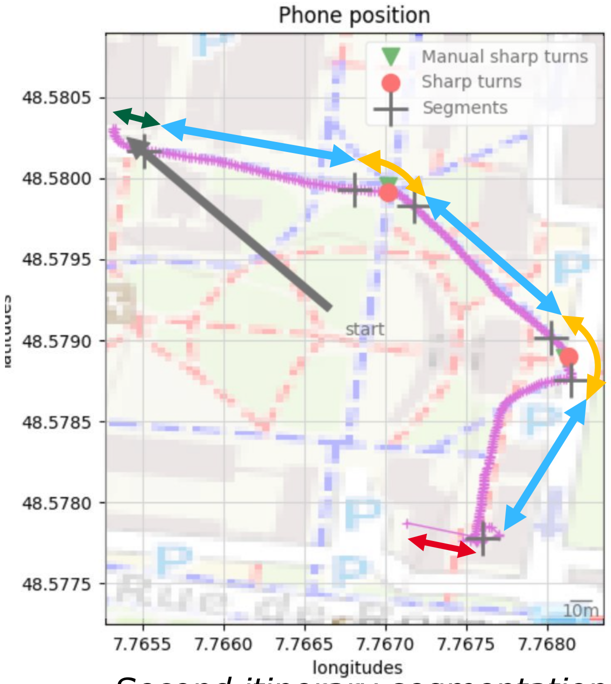


Semi-automatic path segmentation

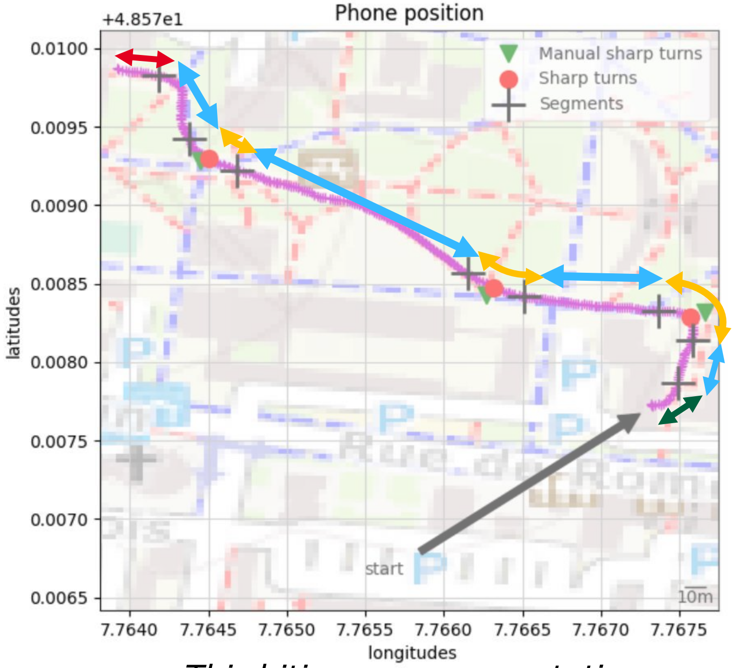
Semi-automatic segmentation : turns manually defined and interpolated on user trajectory



First itinerary segmentation



Second itinerary segmentation



Third itinerary segmentation

: Start
: End
: Curve
: Straight line

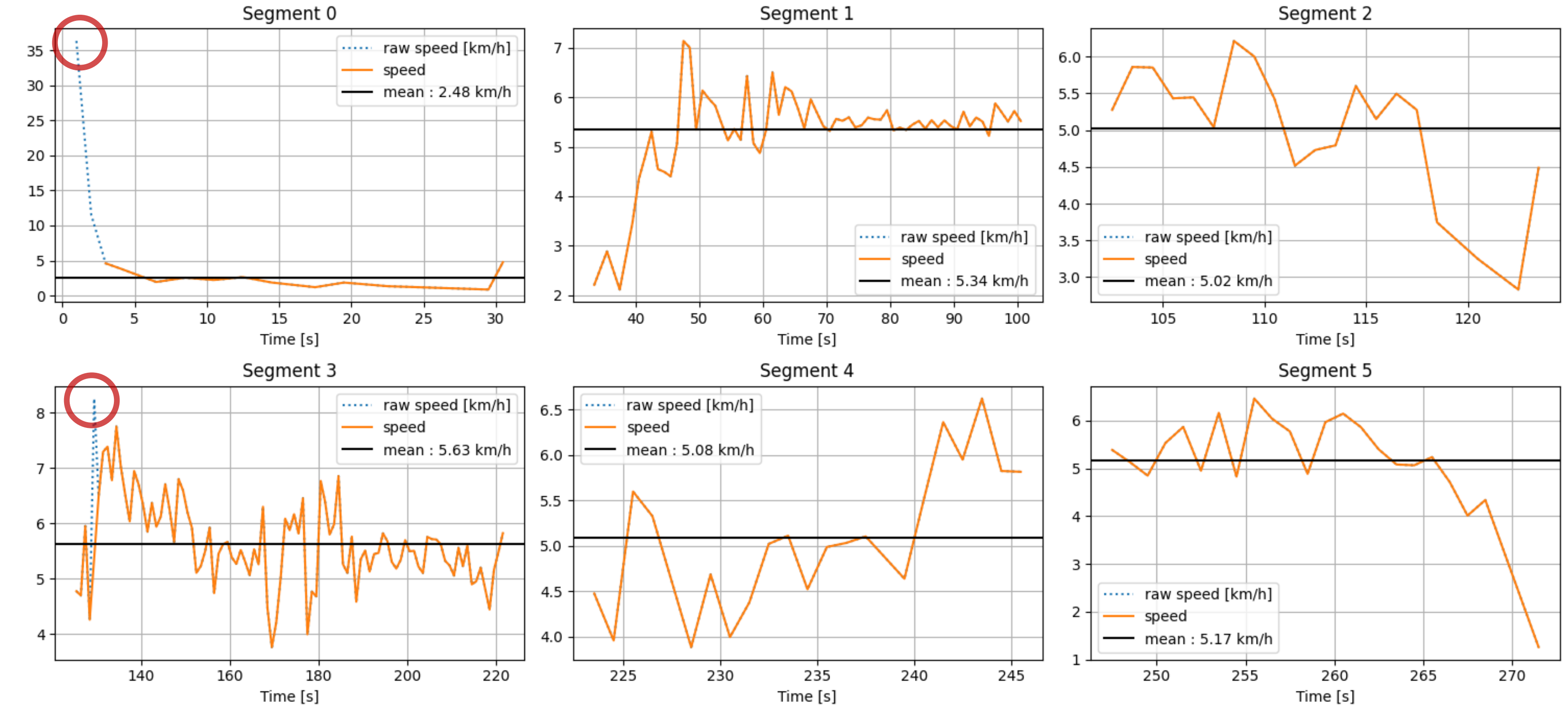
Method

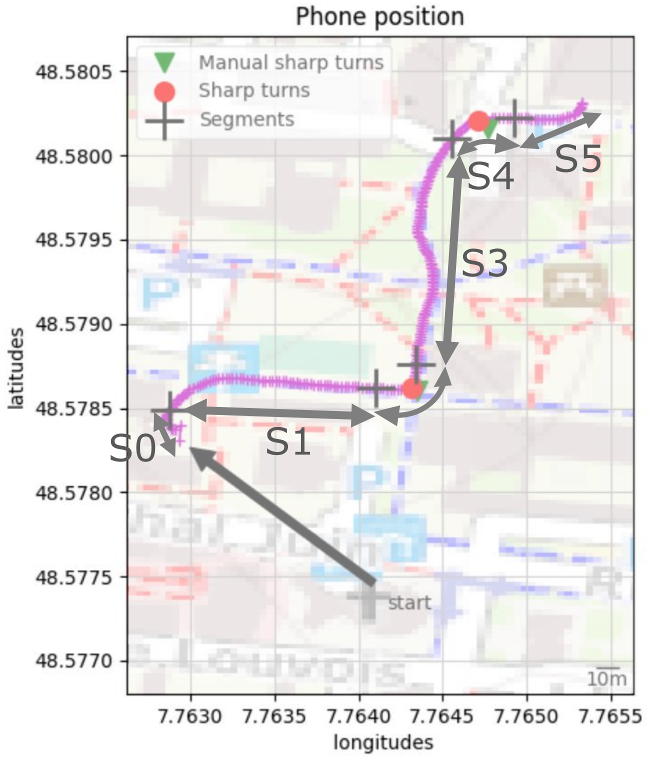
Speed

Hypothesis : If a user who doesn't know the campus is as fast as a user who knows, the app is considered efficient.

User's speed is calculated from GPS positions : $speed = \frac{distance\ between\ consecutive\ GPS\ positions\ [6]}{elapsed\ time}$

As GPS positions can be noised, a filter delete all points with speed higher than 8km/h



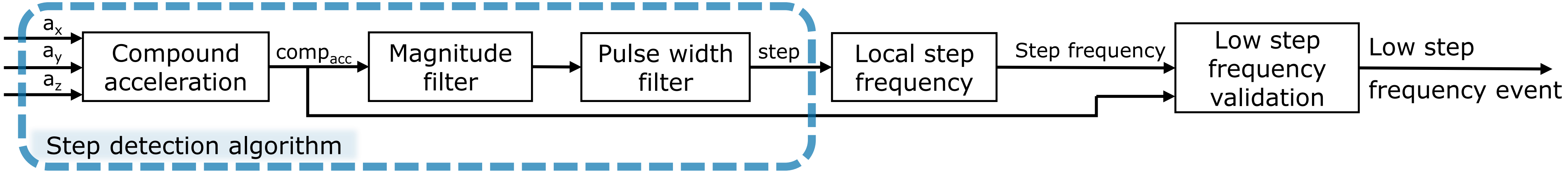


Speed of the subject B on the first itinerary, for each segment

Method

Step frequency

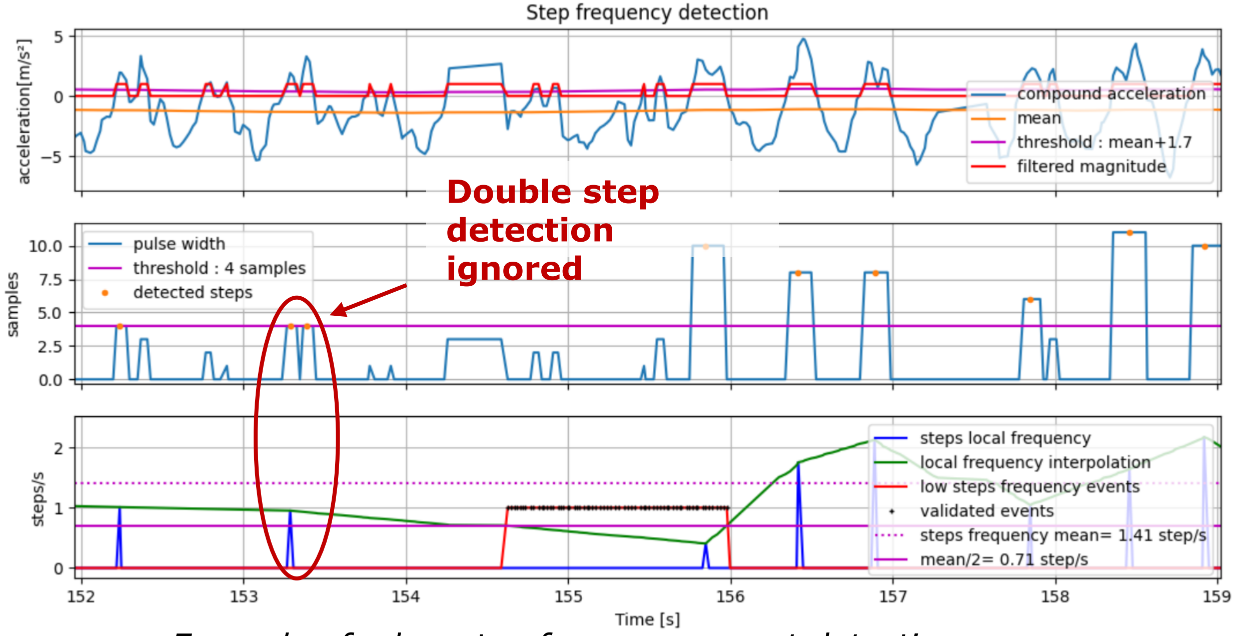
Hypothesis : If the user's step frequency is lower than his regular frequency, the user is doubting about the path to follow.



Algorithm to detect the low step frequency zones

To detect the user's steps, the phone's accelerometer is used rather than the glasses' accelerometer. Indeed, the subjects regularly move theirs head to look at the phone or their environment, which disturb the detection.

On the other side, the subjects naturally hold the phone in the horizontal position, which reduce perturbation, but also absorb step shock.

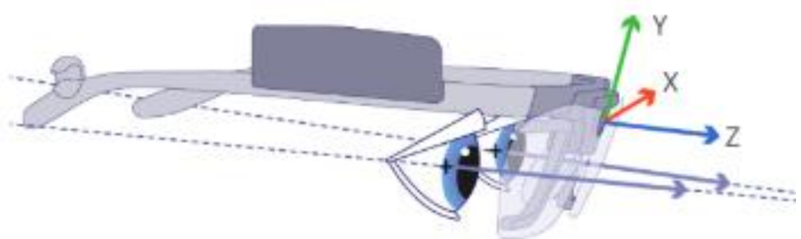


Example of a low step frequency event detection

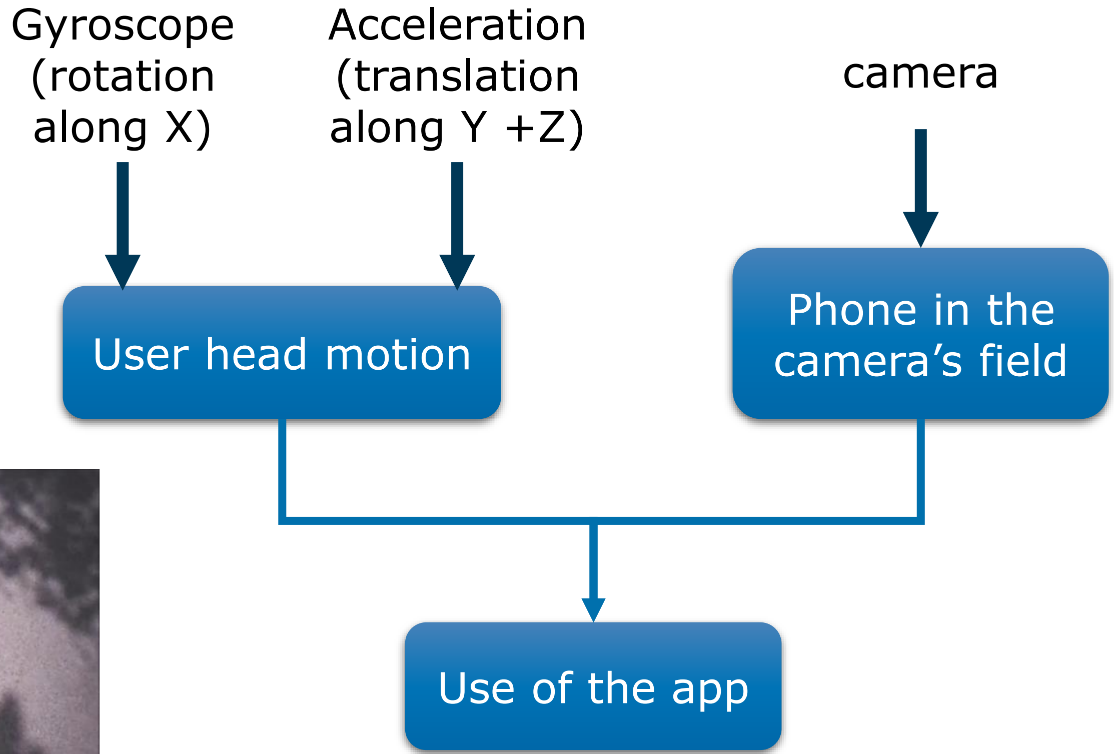
Method

Use of the app

Hypothesis : If a subject looks very often at the app to know where he has to go, that could mean that the navigation information is not clear enough and the user has to look several times to understand which direction to take and what action to do.



Parametric schematic of the glasses [7]



Use of the app detection diagram

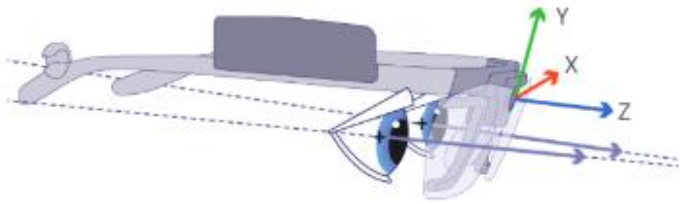
Frame of the glasses' camera while not using the phone

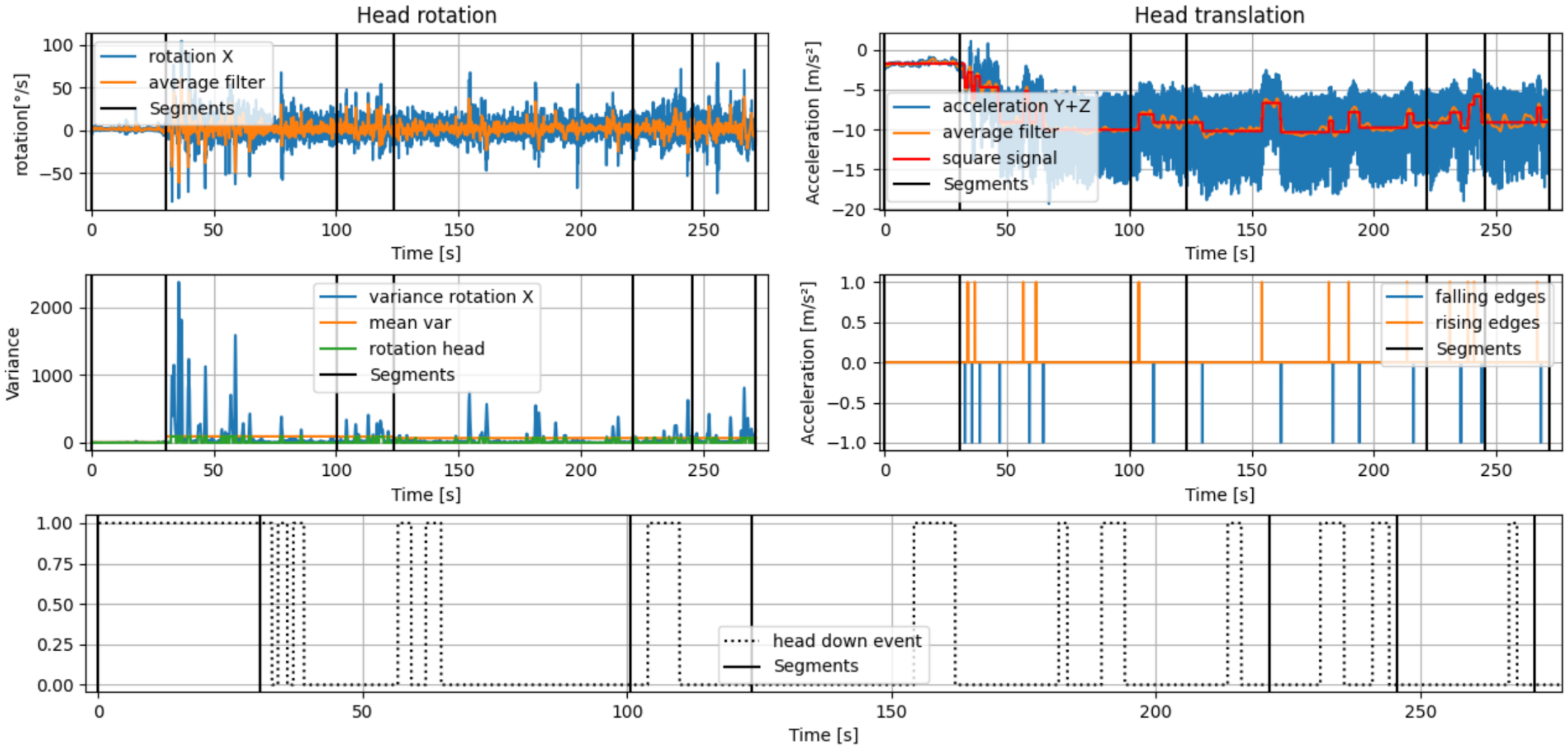
Frame of the glasses' camera while using the phone

Method

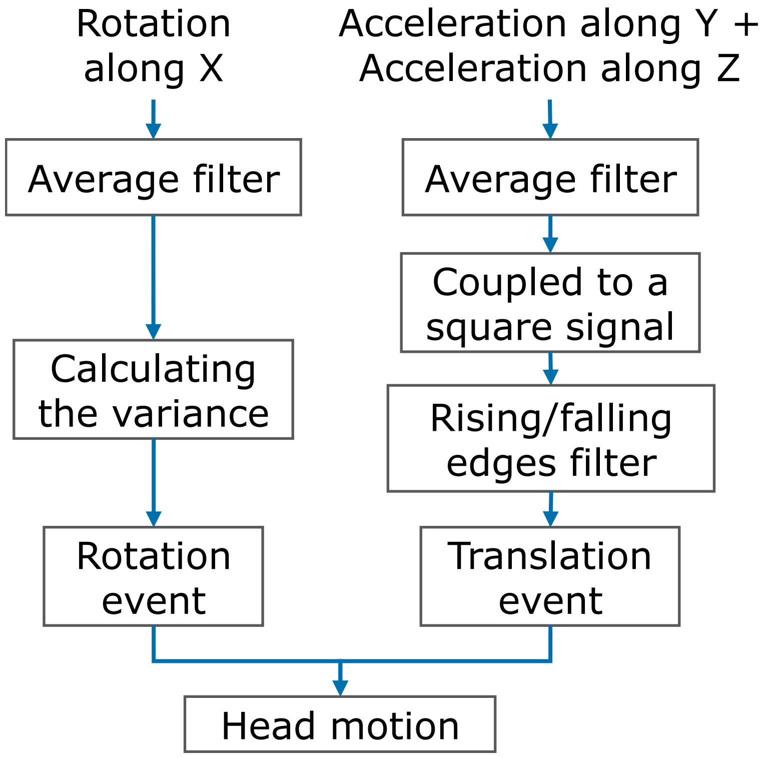
Use of the app – Head motion

When the user puts his head down (to look at the app) the glasses' gyroscope senses a rotation along the X axis and the glasses' accelerometer senses an acceleration (translation) along the Y and Z axes.





Example head motion detection



Head motion detection algorithm

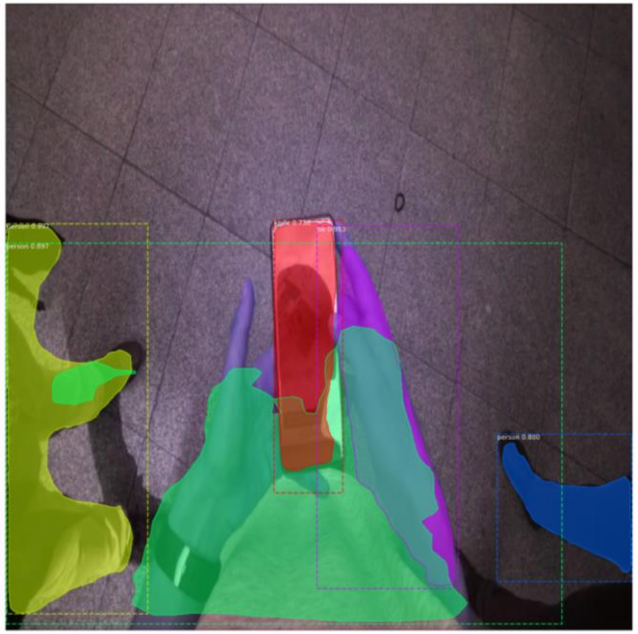
Method

Use of the app – Phone detection

To be sure whether or not the user is looking down at the phone, the glasses' camera frames are recovered to detect the phone in the user's field of view. To do so, a mask RCNN in transfer learning mode on COCO [7] is used to classified all objects in each frame. As the outside brightness is high, the phone is often miss detected and classified as other objects. A super class phone is defined, which contains the classes *cell phone*, *tie*, *knife*, *snowboard*, *skateboard*.

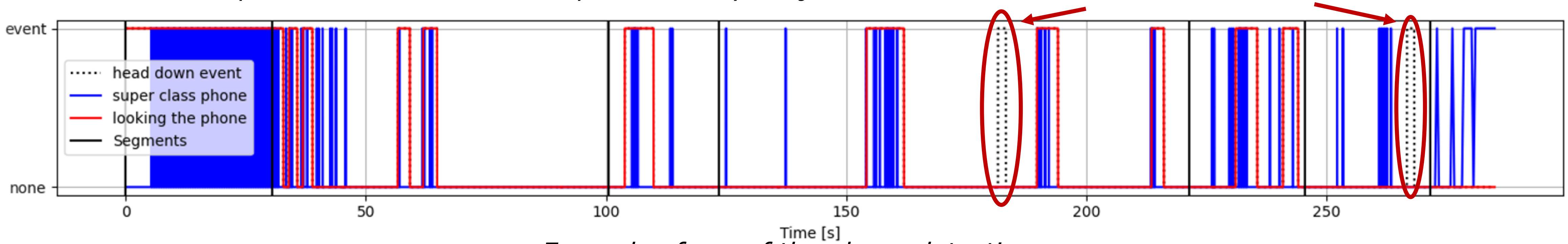
Percentage appearance	Class detected				
	Cell phone	Tie	Knife	Snowboard	Skateboard
Subject A	43,98 %	25,00 %	23,49 %	3,92 %	3,61 %
Subject B	55,63 %	17,34 %	0,45 %	18,47 %	8,11 %
Subject C	75,82 %	0,00 %	3,30 %	8,79 %	12,09 %

Table of the phone classification for all path of every subject



Example of phone classified as "knife"

User head motion without looking at the phone

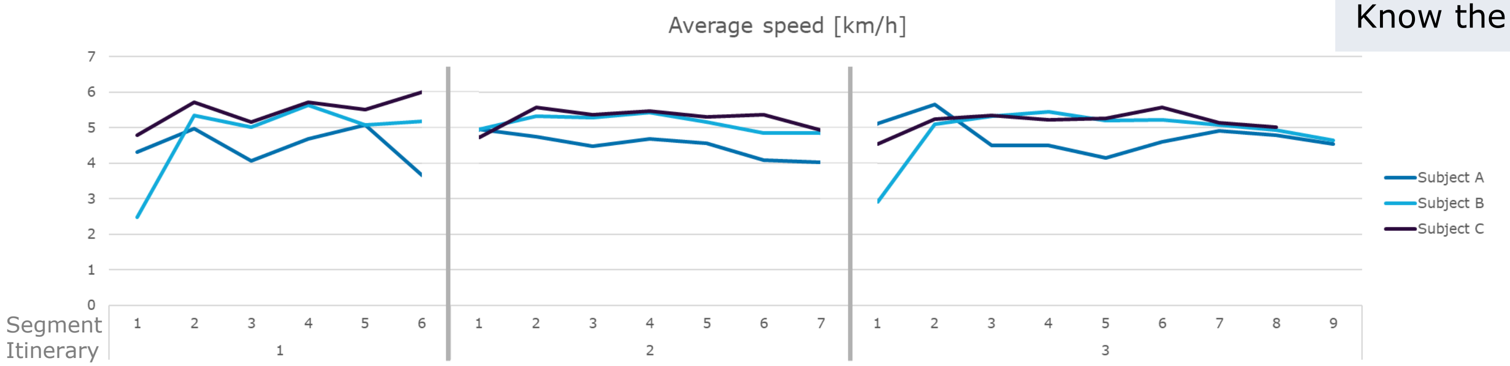


Example of use of the phone detection

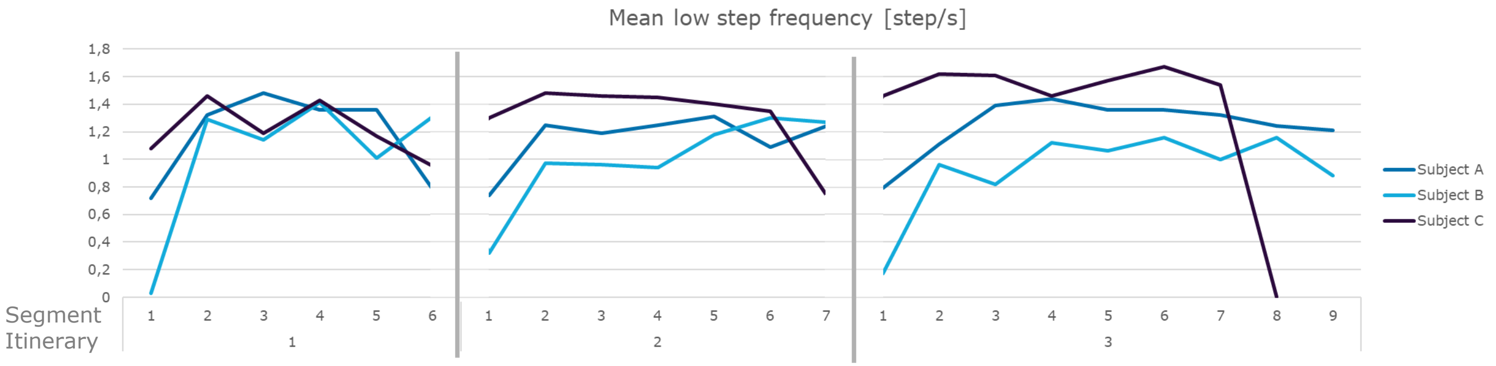
Results

Quantitative study validation

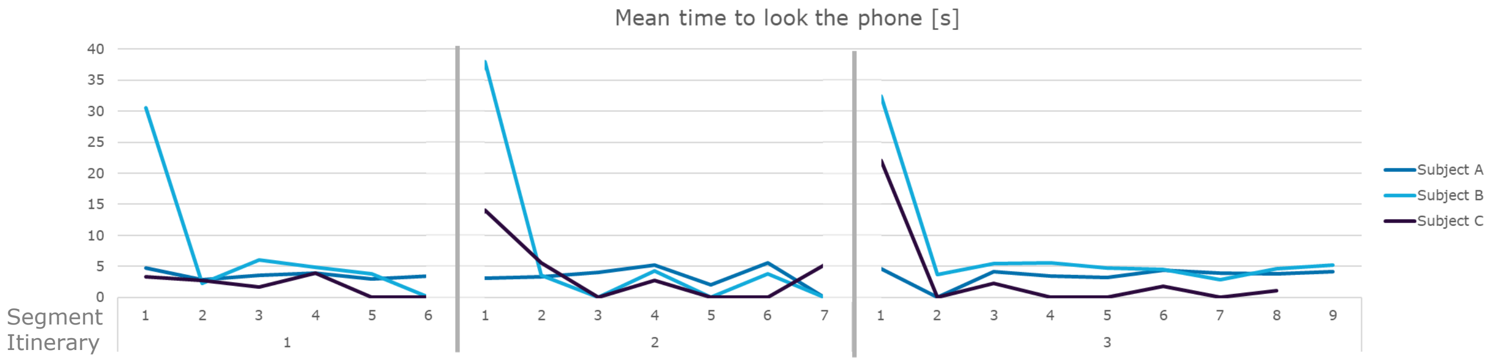
	Subject A	Subject B	Subject C
Know the campus	NO	YES	YES
Know the application	NO	NO	YES



Speed analysis :
Average speed around 5km/h => coherent with the average speed of a pedestrian



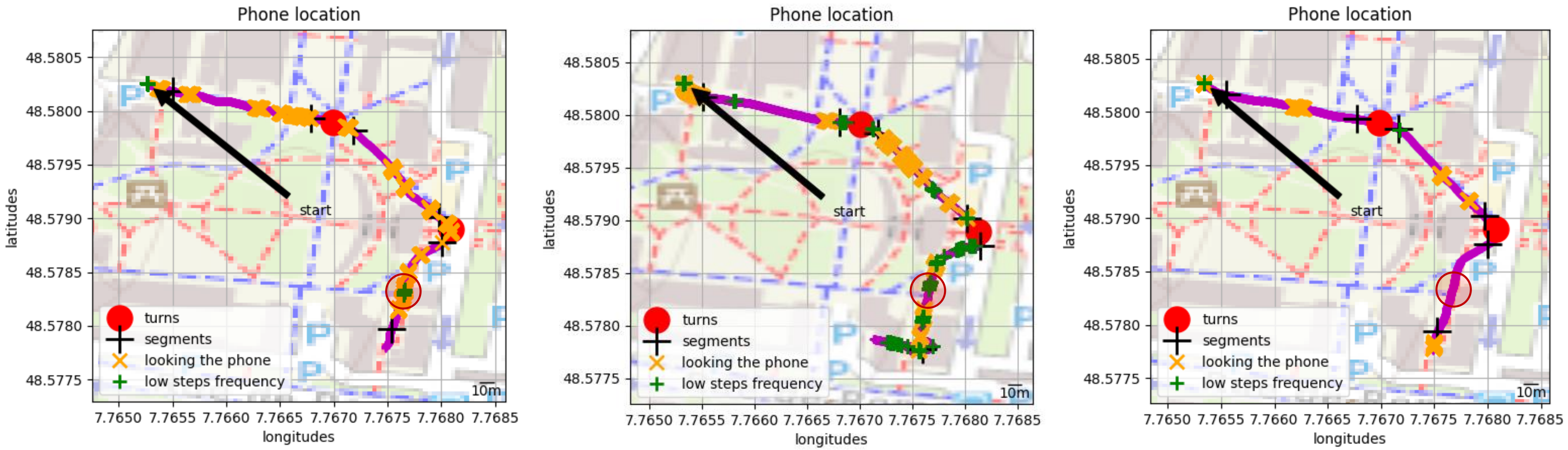
Step frequency analysis :
Average step frequency very different from a subject to another. A lot of low step frequency zones detected => subjects doubt a lot



Use of the phone analysis :
Triple sources (gyroscope, accelerometer, camera) =>robust to perturbations

Results

Evaluation of the performances of the app



: pop-up trigger area

- On the 2nd itinerary, the destination announcement appears in front of the entry of another building. Using the frequency step analysis, subjects A and B who do not know the app are walking at lower step frequency. This pop-up introduces doubt for the users.

- The glasses' microphone recorded subjects impressions as they were walking : the Dijkstra algorithm could be improved, one of the users who knows the campus has mentioned that he could have used another path.

Conclusion

- Most of the available data were used to analyse the users' behaviour. Unfortunately the eye tracker data were not exploitable.
- The speed analysis and the use of the phone analysis are robust to several users' behaviour. Indeed, despite the GPS noise, the subjects speed is coherent. Moreover, as 3 sources (glasses' gyroscope, glasses' accelerometer and glasses' camera) are use in addition to the use of the phone analysis, this study seems to be robust for perturbation.
- The user who knows the app and the campus was generally the fastest in all the paths.
- More tests are necessary in order to validate our approach.
- This first study has highlighted some development ideas to improve the app.

Perspectives

Quantitative study :

- the step frequency analysis can be improved by coupled it with the user speed to calculate the step length of the subject in order to be more precise. Sensors could also be added to measure the steps’ shock in the users knees in order to have two different sources of information
- The phone detection in the camera’s field should also be improved to be more robust to outdoor brightness

Experiment :

- A questionary should be submitted to the subjects before the experiment to adapt the analysis to their usual behaviour. For example, if a subject looks often at the app to have information about the path to follow, that’s because either the app is not efficient and he has to look several times to understand the information or the user could have problems to focus and to remember the information.
- The experiment should also be done at the end of the day or on cloudy days as the outdoor brightness disturbed the eye tracker and the phone detection. In that way, the eye tracker data can be use to study where on the interface is the user looking for navigation information.

References

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[7] T. AB, User's manual Tobii Pro Lab, Version 1.130, 12/2019.

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