

6 February 2024  
RENAUDIN Valérie

# Artificial intelligence for better guidance for visually impaired people



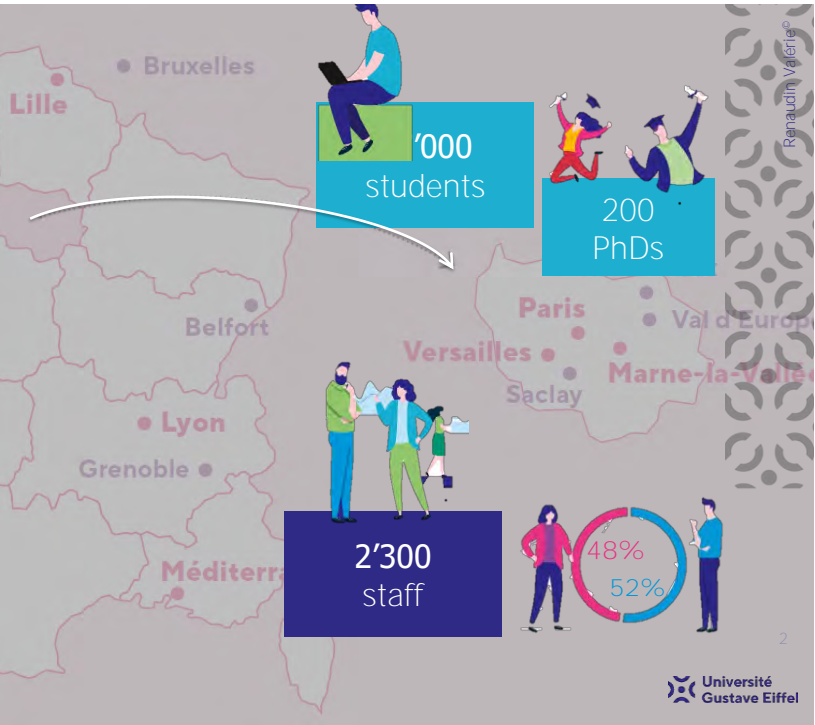
resource-efficient city



safe and resilient city



smart & connected city



Renaudin Valérie



**Université Gustave Eiffel**



**TEAM GEOLOC V**

17 persons 4 PhDs 2 Postdocs



Geoloc Laboratory Presentation  
youtube.com

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# NAVIGATION AIDS FOR THE VISUALLY IMPAIRED



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GUIDE DOG

First Guide Dog training center for the war-blind in Oldenburg, Germany, run by Dr. Gerhard Stalling.



WHITE CANE

Invented by British photographer James Biggs in 1921. Over time, the white cane has been instrumented with sensors, especially to detect distant obstacles.



ULTRA SOUND GLASSES

Electronic Travel Aids are introduced in 1940. The Sonic Glasses is invented by Dr. Leslie Kay in 1960. It detects obstacles with ultrasonic waves.



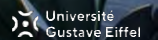
DIGITAL ASSISTIVE TECHNO.

Introduction of digital technology for assistive devices such as screen readers, Braille displays, GPS-based navigation apps, and object recognition systems supported by artificial intelligence.



AI-BASED NAVIGATION

Artificial Intelligence is used to enhance personal senses, improve navigation skills and is integrated into everyday clothing and tools





CAMERA BASED SOLUTIONS

IMAGE BASED MOBILITY AIDS

COMMON DESCRIPTION OF THE SURROUNDINGS ON REQUEST

**Be My Eyes**  
Connect visually impaired people with sighted volunteers via a live video call. Volunteers describe what the camera sees, helping them find their way in a new environment



**AIRA**  
Paid services where visually impaired people receive help from trained agents who are in a remote location  
The agents use the camera image from the user's smartphone or smart glasses to help in various situations



AI FOR THE INTERPRETATION AND DESCRIPTION OF THE SURROUNDING WORLD



**Seeing AI**  
Recognize and describe the world around the user.  
Functions: Reading text, recognizing products, describing scenes, even people and their emotions.

**Envision AI**  
Recognize and speak text, objects, and people.  
Functions: Reading documents, recognizing friends and describing scenes



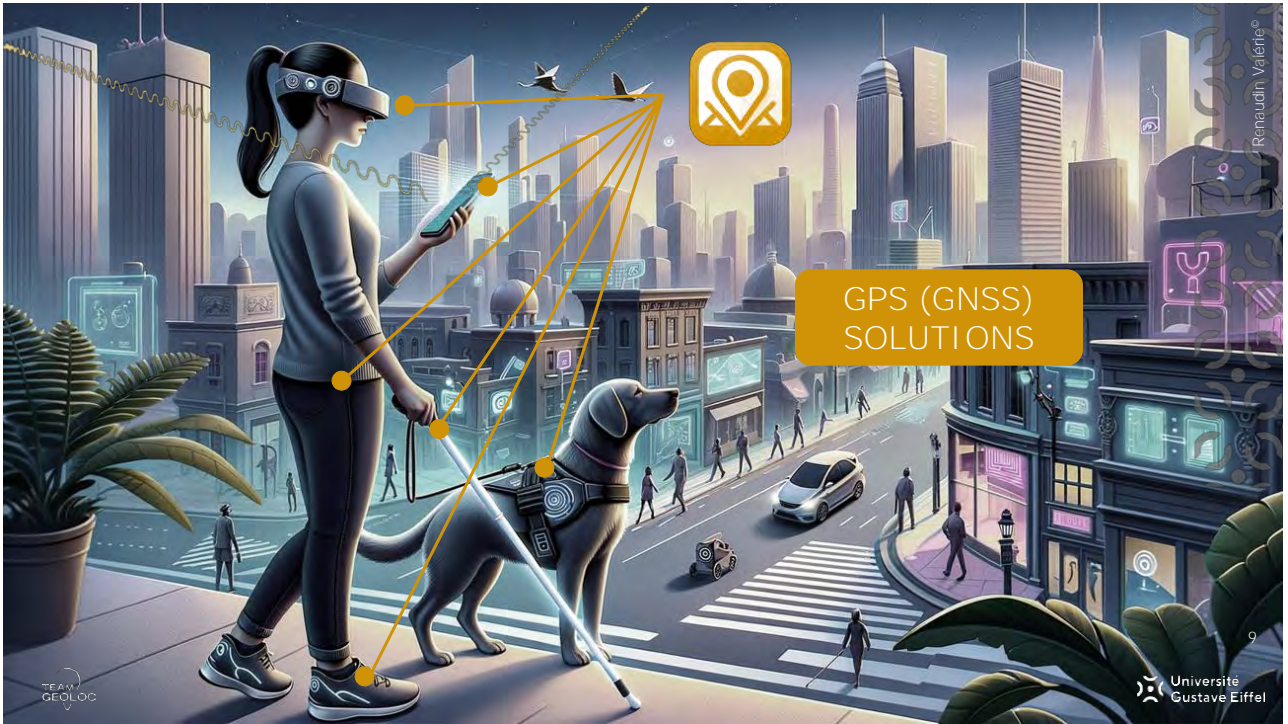
VISUAL LANDMARKS FOR POSITIONING



**GoodMaps**  
High-precision indoor maps created with LIDAR  
Recognition of visual markers to determine location and orientation  
Audio for guidance instructions and descriptions



**NaviLens**  
Recognition of high-contrast color codes QR codes  
Audio description and relative positioning to the visual marking



## GPS BASED MOBILITY AIDS

### GPS AND SURROUNDING DESCRIPTION

**Ariadne GPS**  
 Real-time position and street information.  
 Interactive talking map feature.  
 Street names and numbers are  
 Map navigation by finger  
 "Monitor" function for periodic position  
 updates.



**Seeing Eye GPS**  
 Accessible turn-by-turn GPS app for iPhone.  
 Tailored navigation features for blind users.  
 Verbal announcements at intersections, POIs  
 iOS only  
 Battery life impact due to GPS usage in the  
 background



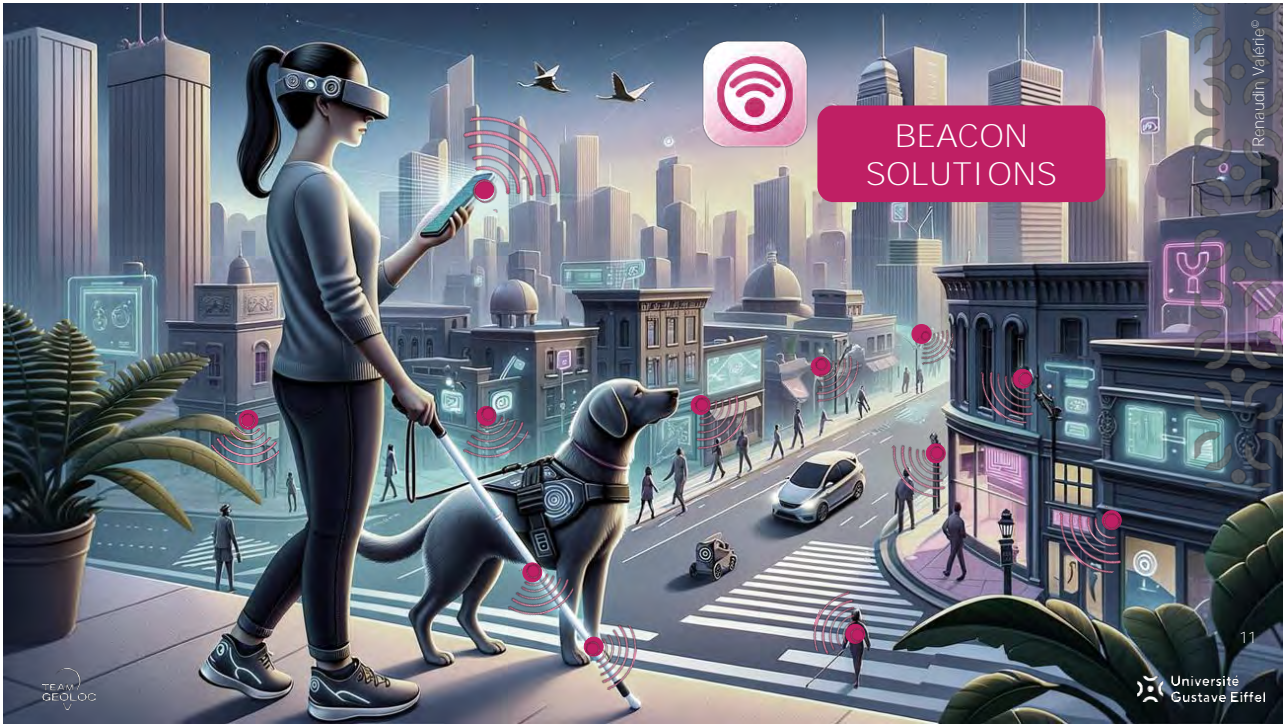
### GPS AND SENSOR FUSION

GoogleMaps



Apple Maps





## BEACON BASED MOBILITY AIDS

### NAVIGATION WITH BLE SIGNALS AND SENSOR FUSION

#### Evelity

Turn-by-turn navigation instructions  
Fusion of BLE signals and inertial signals  
Itineraries designed to account for furniture and indoor obstacles



#### Step Hear

Audio alerts passing by a Step-Hear device  
Signal via Bluetooth: location details, service information, and navigation instructions  
Cloud information  
Personal Wrist Activator with RFID technology



### OBSTACLES SENSING WITH INSTRUMENTED CANE

#### WeWalk

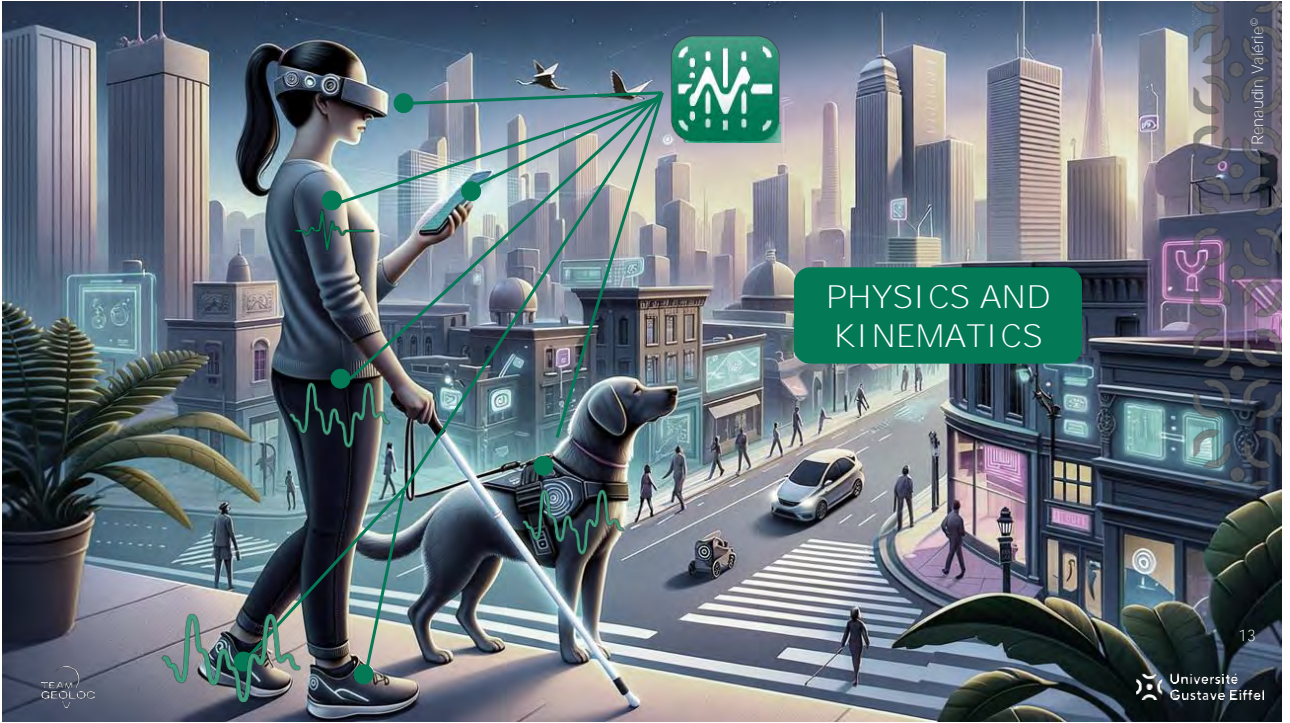
Smart Cane Integration  
Control cane features with a built-in touchpad via a custom app  
One-hand remains free and phone stays in pocket  
Detects obstacles, Navigation guidance  
Use of public transportation



#### UltraCane

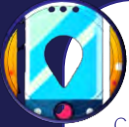
Dual Range, Ultrasonic with narrow beam  
Navigation guidance is not supported  
Obstacle detection





# ARTIFICIAL INTELLIGENCE TO ADDRESS NAVIGATION CHALLENGES FOR THE VISUALLY IMPAIRED

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## Today's Navigation Systems for the Visually Impaired

**Current Limitations**  
 Lack of dynamic interaction and adaptability to changes  
 No seamless indoor and outdoor operation  
 Inaccurate – unreliable positioning  
 Complex without addressing the specific needs of the visually impaired

**The needs of Visually Impaired**  
 Reliable and accurate positioning  
 Trustworthy system  
 Easy usage with a simple interface  
 Reduced complexity for user comfort



## Artificial Intelligence to Tailor the Solutions

**AI as a Promising Avenue**  
**Harnessing low cost sensors' data** from smart gadgets, future smart textiles such as clothing or shoes  
 Transform personal motion data into personalized guidance

**Methodology**  
 Complex methods considering human behavior for development  
 Unique adaptability to individual needs offering a tailored experience  
 Use engaged AI



Fu H et al. (2023), "Analysis of the Recent AI for Pedestrian Navigation With Wearable Inertial Sensors", IEEE Journal of Indoor and Seamless Positioning and Navigation.

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# ARTIFICIAL INTELLIGENCE TO OVERCOME TECHNOLOGY CHALLENGES

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## MACHINE LEARNING ALGOS

Predefined engineered features with explicit parameters based on expert knowledge  
 Select the most relevant features  
 Fitting statistical machine learning models to the data (SVM, RF)



## DEEP LEARNING ALGOS

Non-deterministic algorithms without explicit feature definition  
 Direct learning by navigating within the data space  
 Convolutional neural networks (CNNs) are the most prevalent deep learning architecture  
 Transfer learning for sparse-data problem



## TOMORROW

Deep learning algorithms scale with data  
 Moving from processed data to raw data  
 Seek to interpret the reasoning behind AI  
 Curating and labeling data: a push to unsupervised learning technique

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## TAILOR-MADE GUIDANCE SOLUTION WITH SMART GADGETS USING AI



Step detection, the orchestra conductor of AI learning algorithms



Accumulate data at the individual level, recognizing each person's particularities

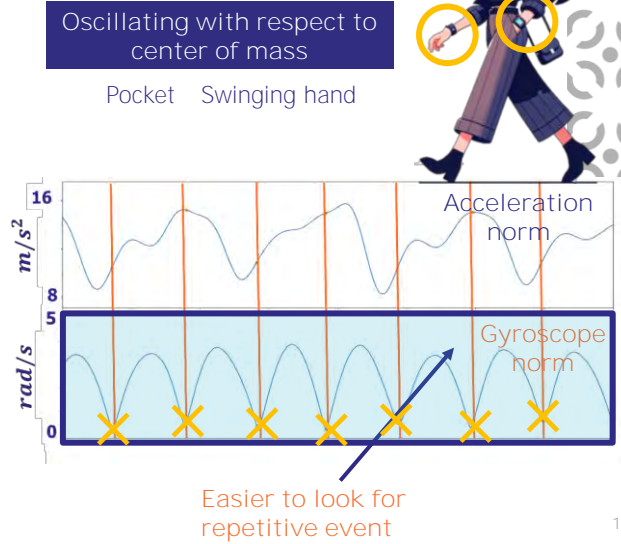
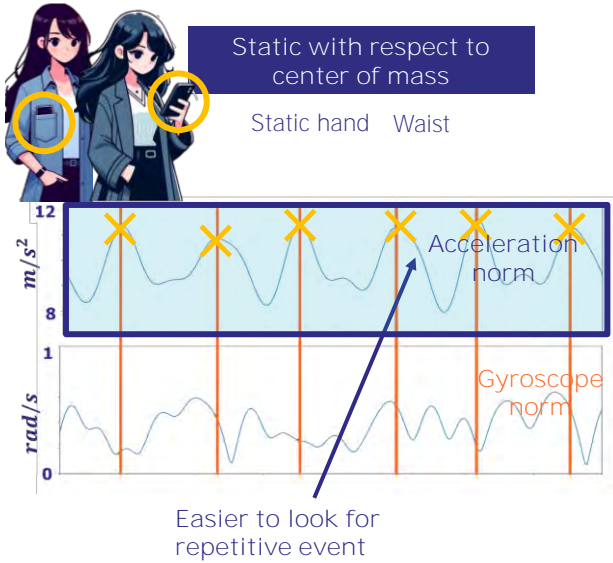


Guiding with the map data according to individual preferences

## DETECTING THE CORRECT STEPS WITH SMART GADGETS



# ROBUST STEP DETECTION FOR DIFFERENT SENSORS PLACEMENTS



# SMARTSTEP: AI-BASED PEDOMETER

**ModelGyro**

Detect steps on Gyroscope norm

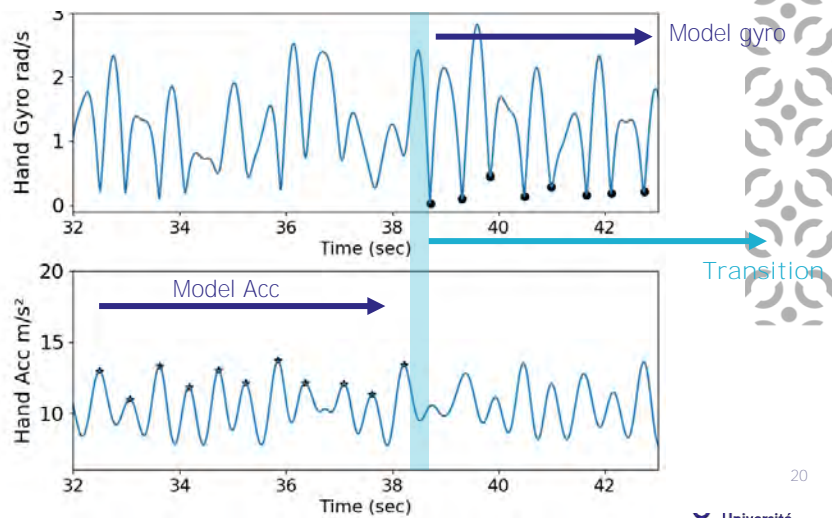


**ModelAcc**

Detect steps on Acceleration norm

**Transition**

When one fails to predict steps for 1 second



# IMPORTANCE OF ROBUST STEP DETECTION

**SMARTSTEP algorithm**  
*Machine learning applied to inertial signals from wearable devices*

10 features for each model

- Frequency related (2)
- Peak related (2)
- Statistic (6)

Model: LightGBM - Histogram Gradient Boosting Decision Trees

Tuning: Randomized Search CV



scenarios	simple	complex (in/out)
smartphone	-3,3%	+34%
Wrist band	-5%	+19%
Smartstep	-3%	+4%

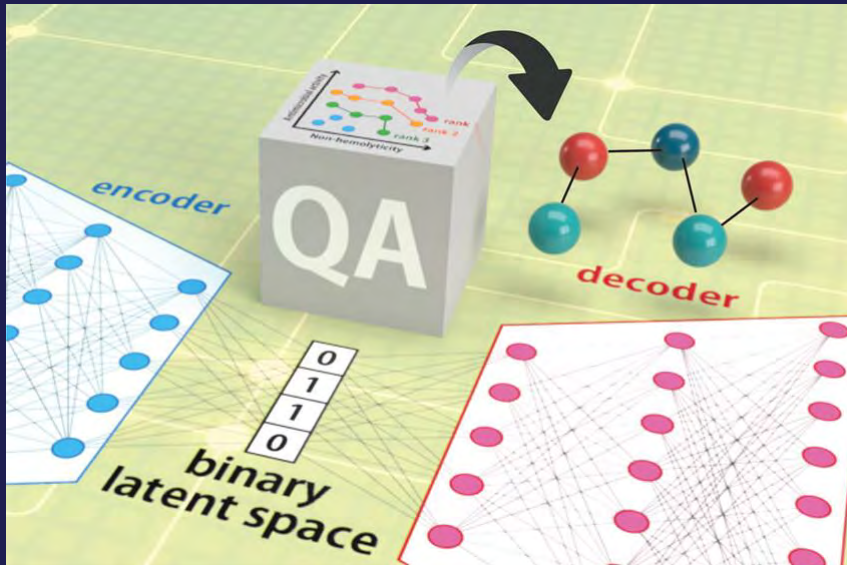
 *Al Abiad N, et al., "SMARTphone inertial sensors based STEP detection driven by human gait learning", International Conference on Indoor Positioning and Indoor Navigation (IPIN), Spain, November 2021.*



# MANAGING TRANSITION PHASES



# SMARTSTEP: DETECTING ABNORMAL MOVEMENTS

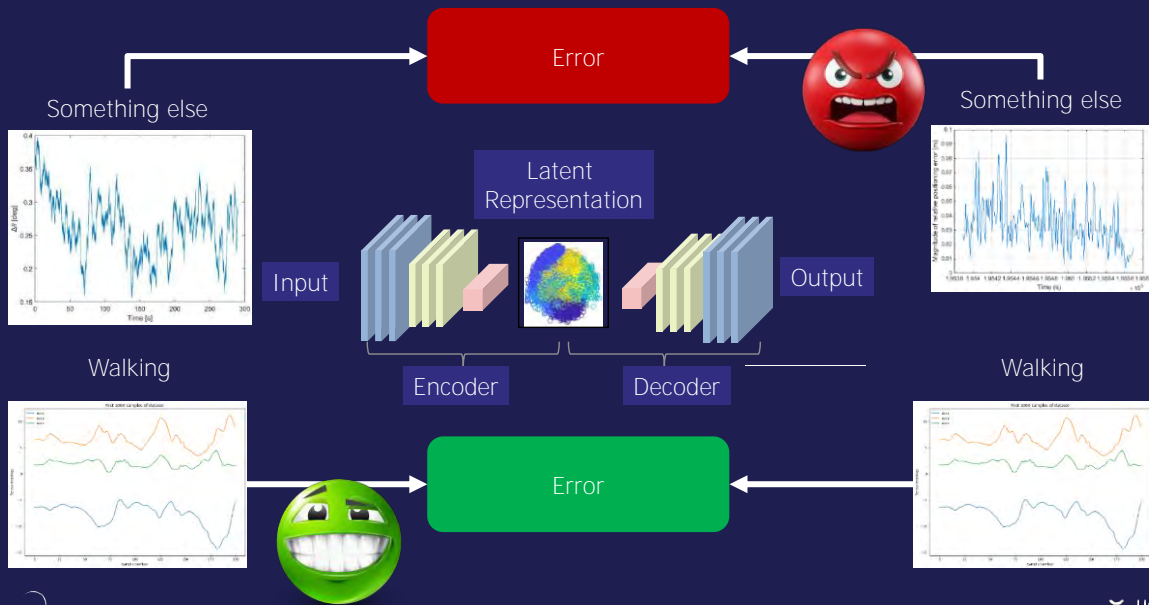


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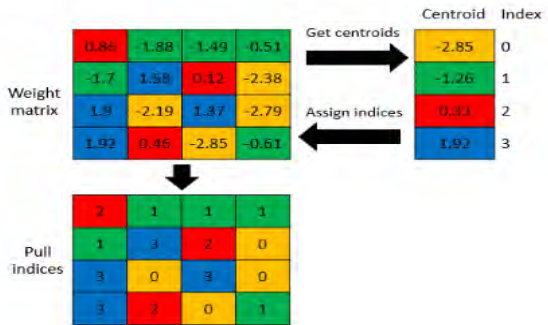
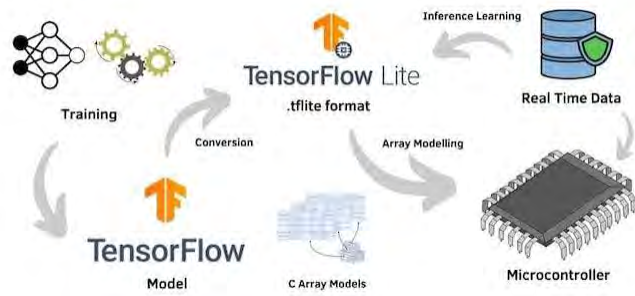
# RECOGNIZING THE ABNORMAL BY UNDERSTANDING THE NORMAL



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# CREATING INDIVIDUAL WALKING KINEMATIC PATTERN



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# HUMANS EXHIBIT DIFFERENT WALKING STYLES

Impacting factors are physiological, anatomical, and psychological factors

## Biomechanical Differences

Every person's body is structurally unique.



## Health and physical condition

Physical conditions such as injury or disease (e.g. arthritis)



## Adaptive changes

Adaptation to external factors such as carrying loads, using mobile devices or wearing certain clothing or shoes



## Neurological factors

Coordination of muscle movements (balance, rhythm and motor control)



## Psychological factors

Emotional and psychological states



## Habit and conditioning

Routing habits on certain journeys

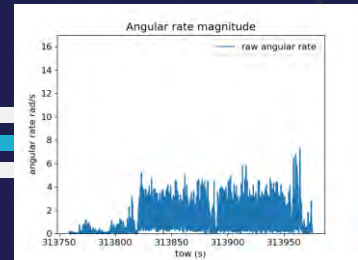
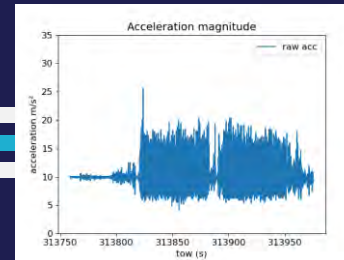
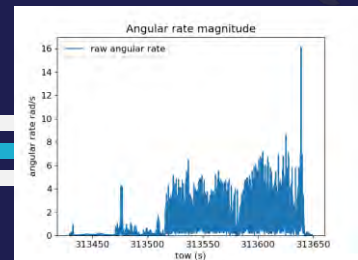
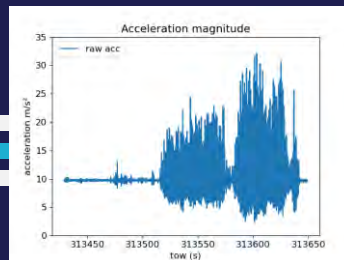


## Cultural influences

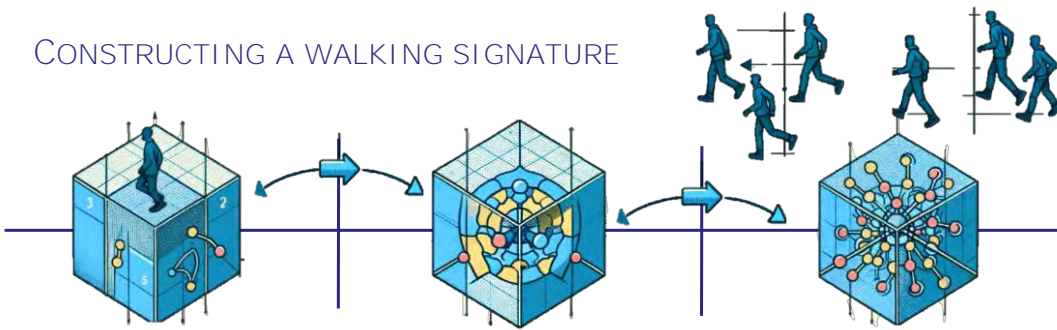
The shape of public places or the type of footwear



# IMPACT OF THE NAVIGATION AIDS ON THE WALKING GAIT

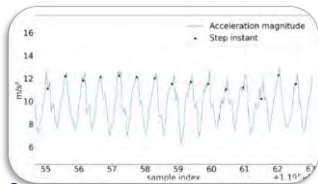


# CONSTRUCTING A WALKING SIGNATURE



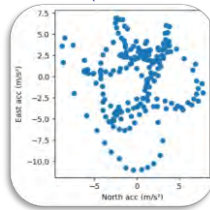
## Segmentation

Detecting step events  
Segmenting the inertial signal sequence into stride segments



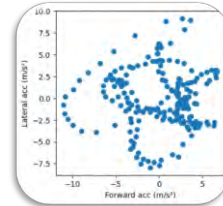
## Projection

Estimate the device attitude  
Project the acceleration sequence onto the map frame  
Low Pass filter (Butterworth 10Hz)



## Rotation

Express the horizontal acc. segment in a horizontal coordinate frame defined by the user's forward and lateral axes (PCA)

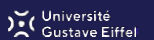


Fu H et al. (2023), "A Computer Vision Approach for Pedestrian Walking Direction Estimation with Wearable Inertial Sensors: PatternNet", IEEE/ION Position, Location and Navigation Symposium (PLANS) 29



Month	Value
Mai 2023	0.39+
June 2023	0.38+
July 2023	0.44+
June 2023	0.44+
Sep. 2023	0.44+
Oct. 2023	0.44+
Nov. 2023	0.44+
Dec. 2023	0.44+

Average step duration (s)



# STEADY WALKERS

Their paces are regular

Clear acceleration patterns without too much noise

Regular movements, stable and not too energetic

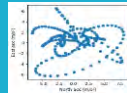


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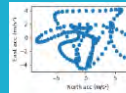


June 2023

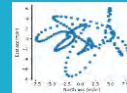


0.35+  
0.03

Dec. 2023

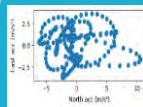


Dec. 2023

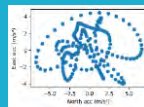


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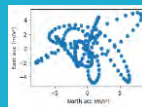
May 2023



June 2023



June 2023

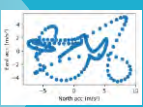


0.36+  
0.01

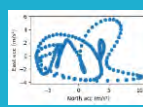


Average  
step  
duration  
(s)

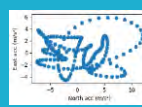
May 2023



Oct. 2023



Nov 2023



0.35+  
0.02



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## DYNAMIC WALKERS

Visually impaired individuals walk as fast as sighted people and even faster, especially those who walk with dogs

Their patterns exhibit bigger amplitudes and are less regular

These profiles are harder to learn → more data are needed

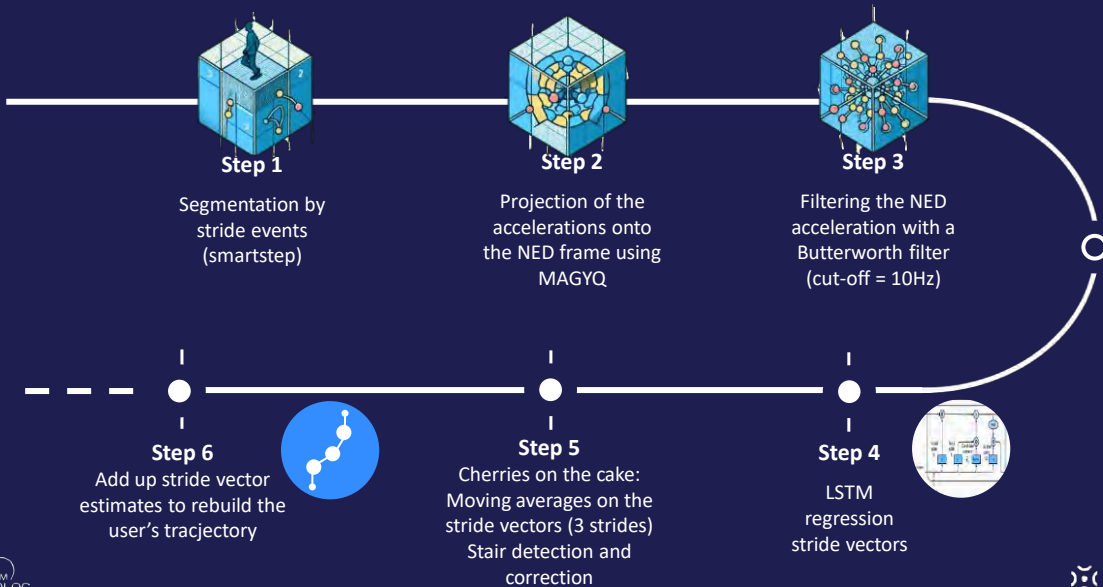


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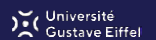


## A TAILOR-MADE PEDESTRIAN DEAD RECKONING MODEL



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# EVALUATING TAILOR-MADE POSITIONING ALGORITHMS

## Person 1 - Pants

Training set: 899 m

**Evaluation**

Walking distance = 2.2 km / Stride = 1790

*Tailor-made model*

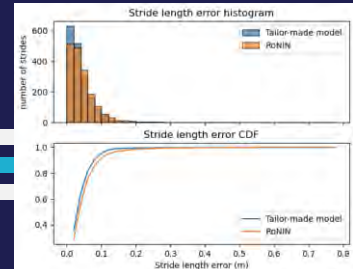
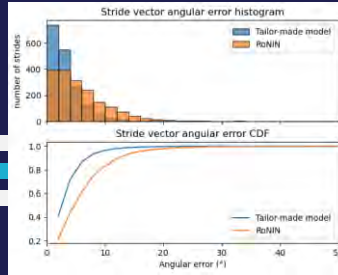
mean stride length error = 0.04 +-0.04 m

mean stride angular error = 3.24 +-2.96 °

*RoNIN*

mean stride length error = 0.05 +-0.05 m

mean stride angular error = 5.91 +-5.19 °



## Person 2 - Pants

Training set: 832 m

**Evaluation**

Walking distance = 2.6 km / Stride = 1877

*Tailor-made model*

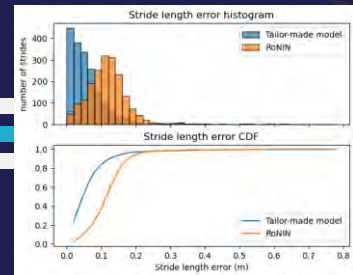
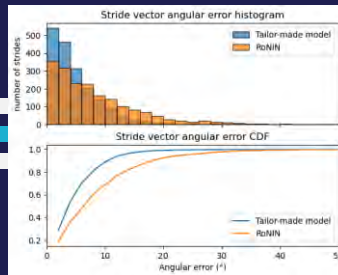
mean stride length error = 0.06 +-0.08 m

mean stride angular error = 5.43 +-10.42 °

*RoNIN*

mean stride length error = 0.12 +-0.07 m

mean stride angular error = 8.57 +-9.63 °



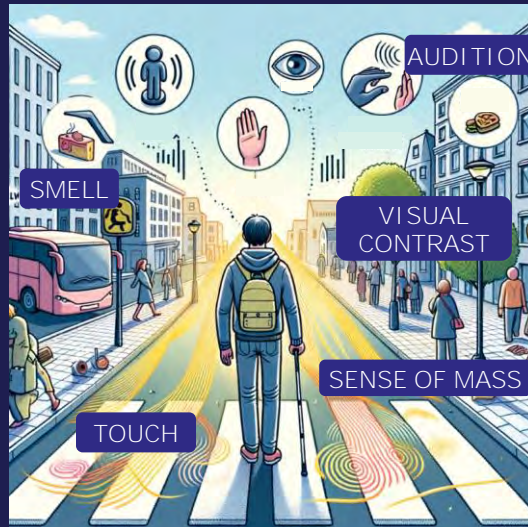
# LOST IN ITINERARY CHOICES AND MAP DATA



## SPATIAL LANDMARKS OF VISUALLY IMPAIRED



M. Wang et al. (2023)  
"Analysis of Spatial Landmarks for Seamless Urban Navigation of Visually Impaired People,"  
in *IEEE Journal of Indoor and Seamless Positioning and Navigation*



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## OVERVIEW OF URBAN DATABASES FOR NANTES: BD TOPO AND PCRS

### BD TOPO®

#### Comprehensive Topographic Database

Wide range of geographic information

**Includes elevation, land use, water bodies...**

Covers both urban and rural landscapes

Applications in GIS, cartography, environmental studies and land management

### PCRS

#### Simplified Street Layout Plan

Simplified representation of street layouts

Details on road networks, intersections, building footprints

Dedicated to urban planning, transportation analysis, and infrastructure development

Standardized format for planning and analysis

### Problem

#### Challenges in Integrating BD TOPO® and PCRS

Precision and incoherence issues

Difficulties in merging landmark information accurately



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# URBAN MAP ACCESSIBILITY TOOLS: MERGING MULTIPLE DATABASES

## Enhance general accessibility

### Municipality of Nantes Métropole

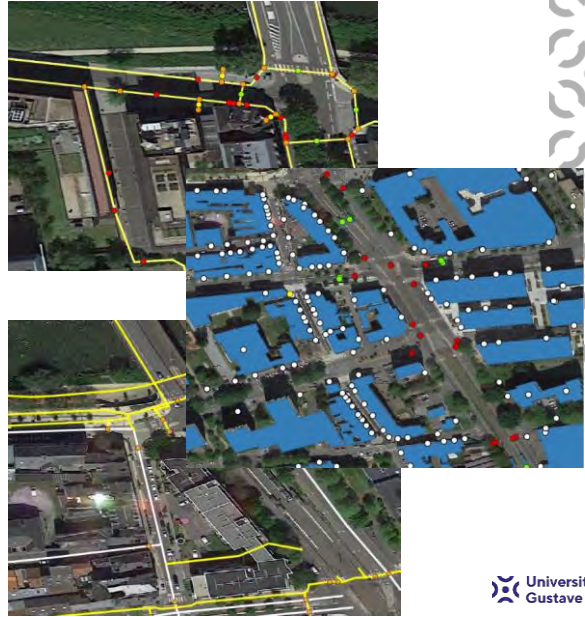
Provides detailed accurate urban databases.  
Key features: Stairs, bus stops, tactile bands (orange), crosswalks (green), other obstacles (red)

### OpenStreetMap (OSM)

A Collaborative Endeavor (2004)  
Free editable world map  
Doors and sidewalks (white), postboxes (yellow), bus stops and tram stations (green), walkways, traffic lights (red)  
API for quick data extraction  
Caution with misleading pedestrian walkways (yellow) and sidewalks (white)

### Challenge in Handling Urban Map Data

Existing maps are often vehicle-centric  
Need to merge data from different sources for comprehensive accessibility mapping



# NAVIGATIONAL AIDS FOR VISUALLY IMPAIRED USING OPEN MAP DATA

## Insights from Interviews with Visually Impaired

### People and Locomotion Experts

Key usable landmarks: Doors, corners, bus stops, crosswalks, traffic lights, tactile bands

### Mapping the Visually Impaired Routes

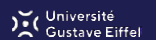
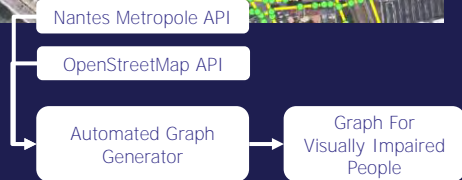
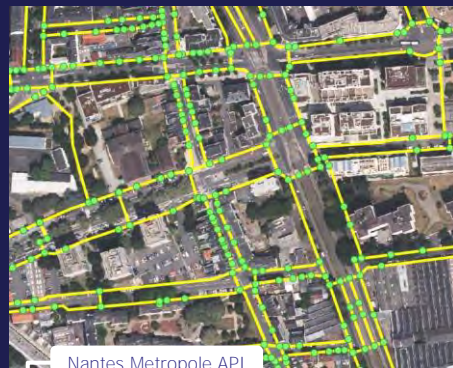
Process: Open map data is snapped and merged into specialized graphs

Graph features: Interconnected nodes based on landmarks usable by visually impaired individuals

### Final Graph Design

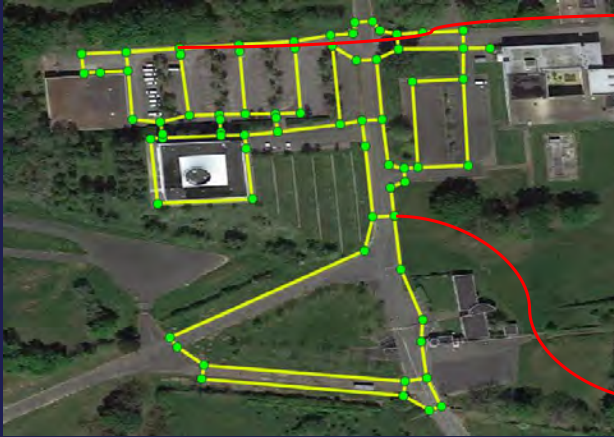
Purpose: Facilitate traversal and navigation for visually impaired users

Composition: interconnected nodes that can be traversed by visually impaired people with the help of the special landmarks they need



## BUILDING A TEST AREA WITH LANDMARKS IN THE CAMPUS

An experimental track for visually impaired people was constructed in terms of both the real landmarks and their graph correspondences



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## ENHANCED ITINERARY PLANNING FOR VISUALLY IMPAIRED PEOPLE (VIP) USING AI

### Inadequate Itineraries

Traditional shortest-path models address vehicles and pedestrians but fall short for the VIPs  
Itineraries should focus on safety and recognizable landmarks

### Personalization of the routes

Design individualized itinerary algorithms to incorporate VIP preferences  
Use AI to learn preferences from urban mobility patterns

### An example with 2 routes

**Red Path:** Shortest path but less secure  
**Green Path:** Longer routes, but safer and tailored to VIP preferences

### AI-Driven Innovation in Mobility

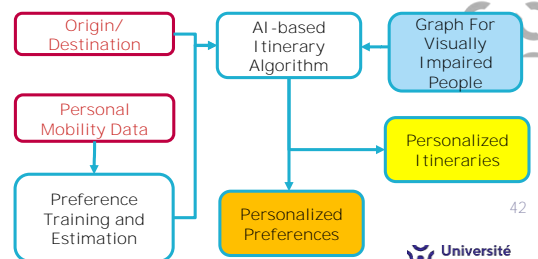
AI can leverage latent data to generate personalized mobility options, enhancing urban navigation for VIPs

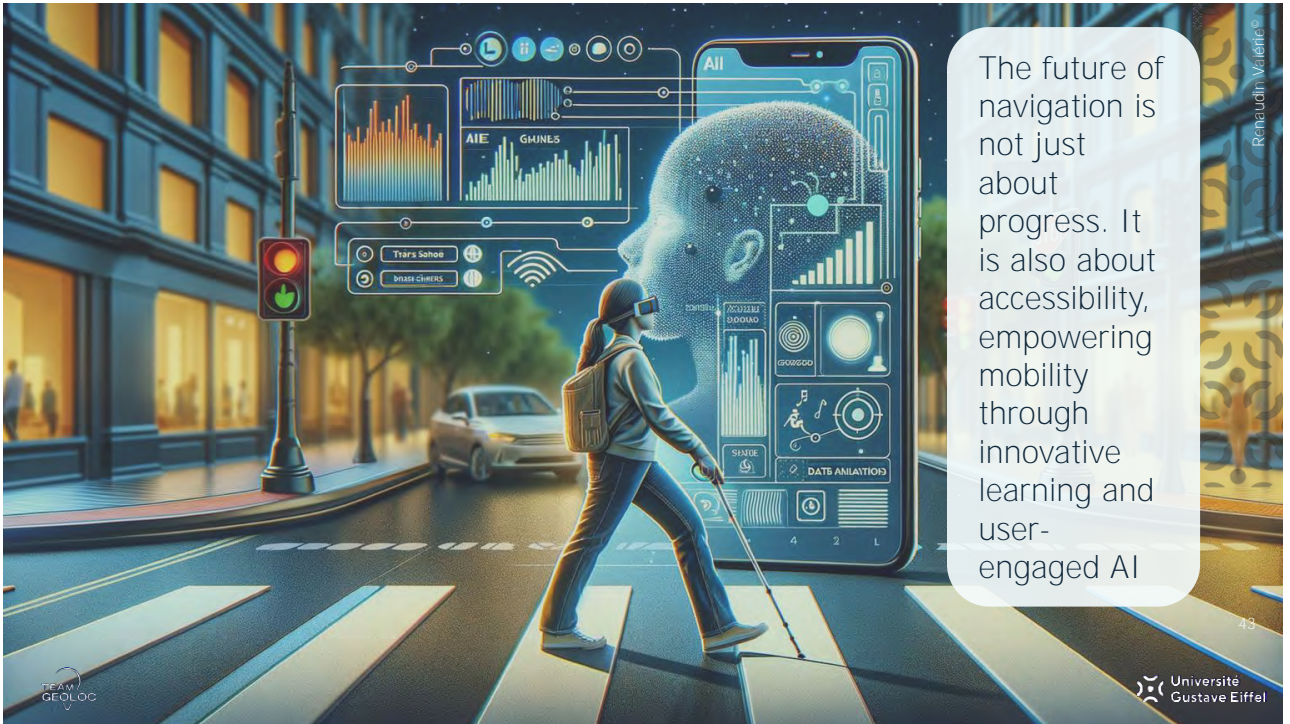


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**TEAM GEOLOC**

Université Gustave Eiffel

Valérie RENAUDIN  
 valerie.renaudin@univ-eiffel.fr  
 +33 (0)612 712 212  
<https://geoloc.univ-gustave-eiffel.fr/>