Using sensor-data collected by a *meet rollator* for deriving outdoor accessibility information concerning mobility impaired people

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P5 Presentation

TU Delft

Using sensor-data collected by a *meet rollator* for deriving outdoor accessibility information concerning mobility impaired people

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Introduction & methodology

- Research
- Meet Rollator
- Review

My research & results

- Workflow
- Implementation
- Validating and put semantics to
- Storing
- Conclusions and recommendations
- Meet Rollator 2.0

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Storing	**Conclusions and recommendations**	**Meet Rollator 2.0**	

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Research

Motivation

Wheelchairs, rollators and mobility scooters

Sensing rollator called ***meet rollator*** gathers data about the accessibility of the outdoor environment with 3 sensors:

1. Handheld Global Positioning System (GPS) → Handheld GPS
2. Real-Time Kinematic (RTK) Global Positioning System (GPS) → RTK GPS
3. Camera

Description of the problem

<u>Not</u> all pedestrian paths are accessible for every pedestrian

<u>No</u> geo-database exist in the Netherlands that provides insight in the accessibility of pavements

A *meet rollator* gathers data which is **supplementary, new and different**

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Research questions

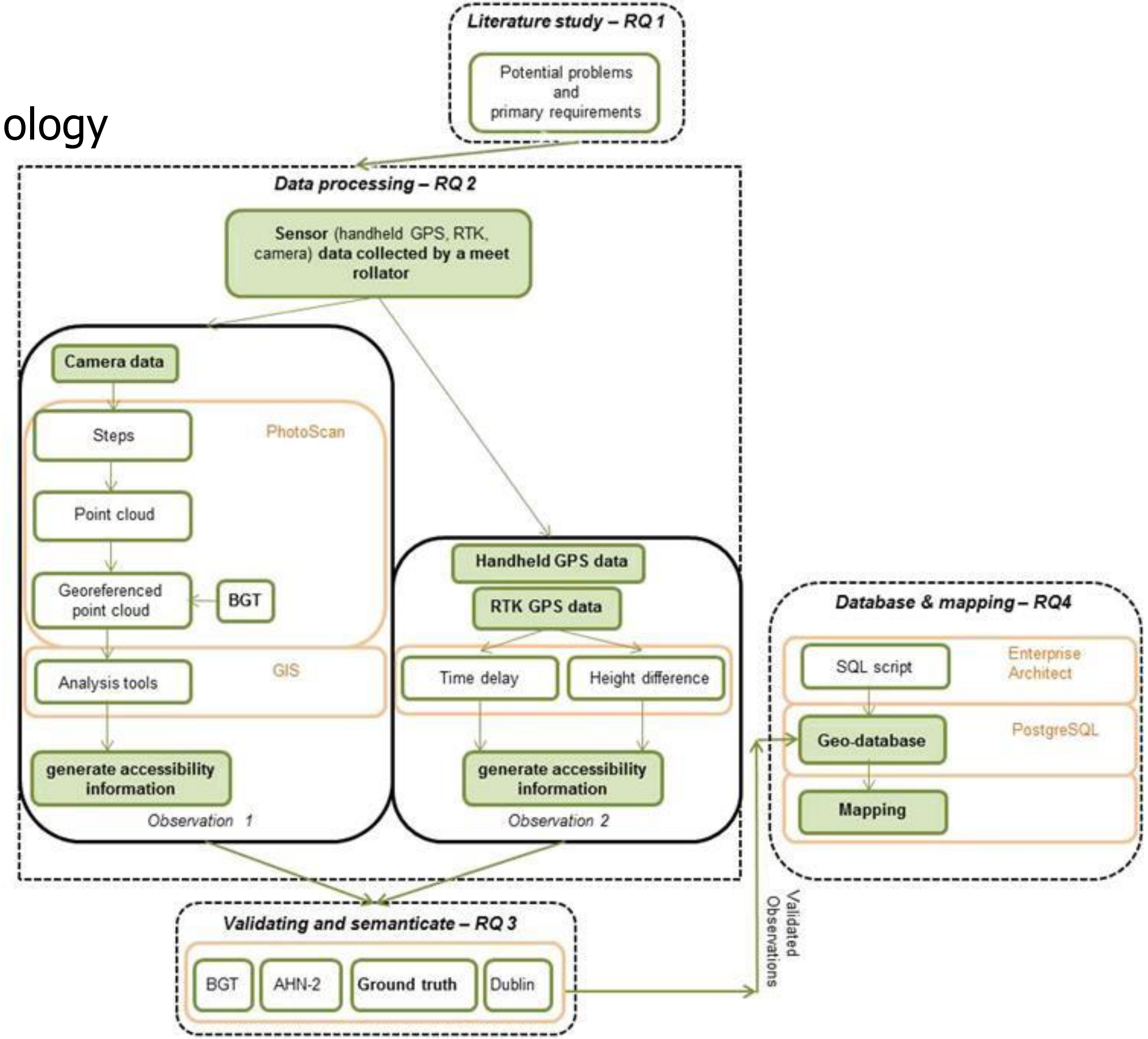
Main research question:

Does the current setting of the *meet rollator* provide insight into the accessibility of pedestrian routes for mobility impaired people? If not, how can the current setting be improved?

Sub research questions:

1. What are potential problems presented by the public space and primary requirements for people with mobility impairments regarding the accessibility?
2. Which measure-method could be developed to generate accessibility information, by making use of the sensor (handheld Global Positioning System (GPS), Real-Time Kinematic (RTK) GPS and camera) data collected by a *meet rollator*, software package PhotoScan, Geographic Information System (GIS) analysis tools and the core-registration Large-scale Topography of the Netherlands (BGT)?
3. How can the ground truth and results of the UMG algorithm be used to validate the generated accessibility information? And do the AHN-2 and BGT+ provide more insight in and put semantics to the generated accessibility information?
4. In what way can the results best be stored in a geo-database in PostgreSQL?

Methodology



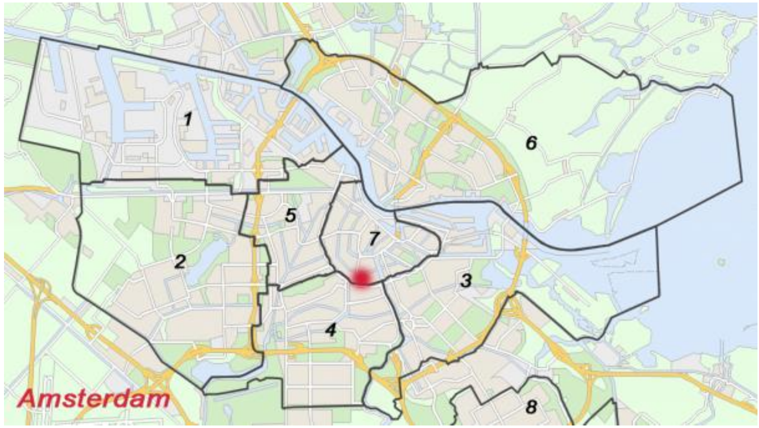
Research area

A part of **Amsterdam** in the province North-Holland

2 Districts: South and Centre (numbers 4 and 7)

South: 17 square kilometers, 132.000 residents

Centre: 8 square kilometers, 81.000 residents



The *meet rollator* was used in this research area

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Meet Rollator

Project

Started in 2013

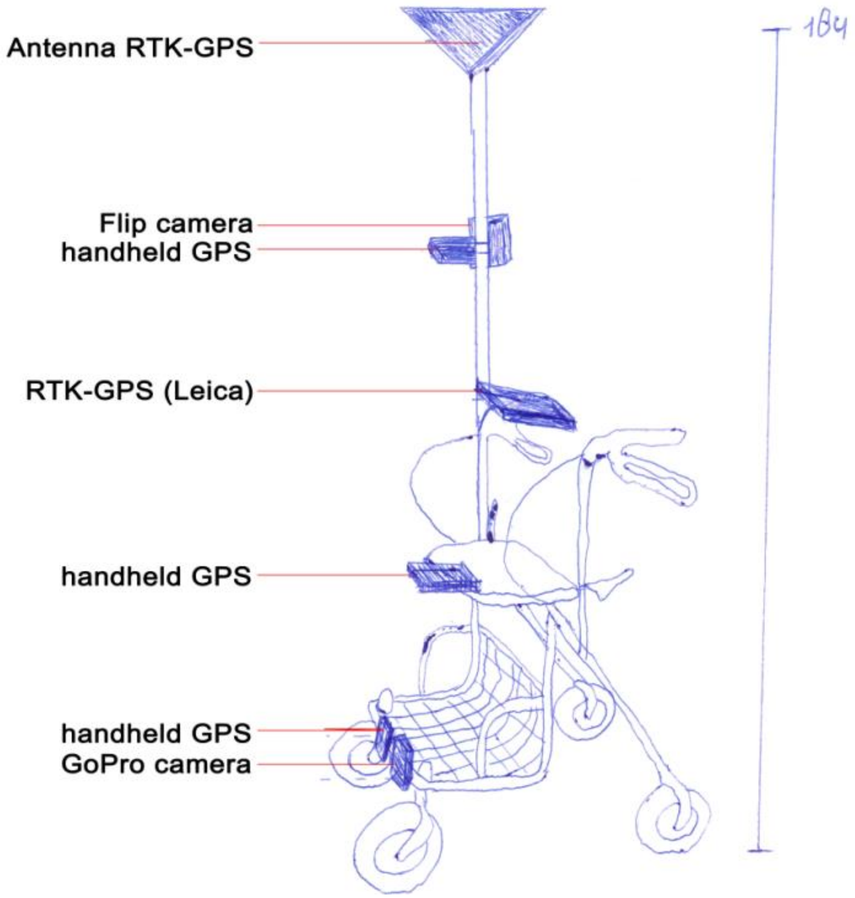
Data collection

Meet rollator gathers data with 3 sensors

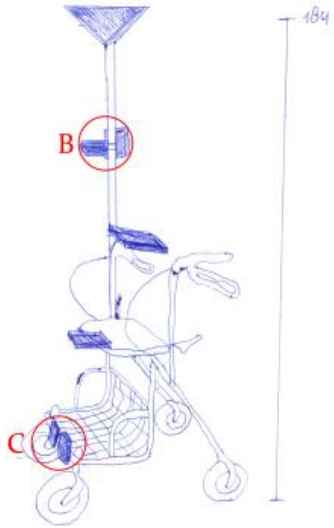
- Handheld GPS (3x)
- RTK GPS
- Camera (2x)

Two measurements were performed on:

- 16-12-2014 (December)
- 22-01-2015 (January)

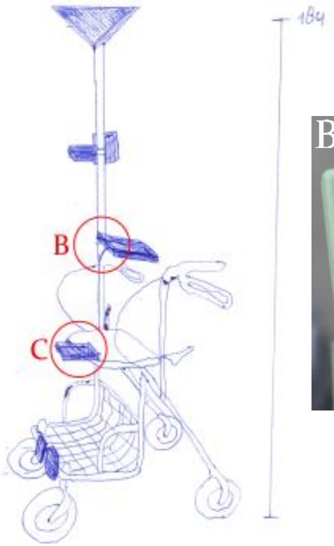


Purpose: to discover whether a handheld GPS receiver is as useful as RTK GPS for position determination



Handhelds GPS &
Flip Camera

Handhelds GPS &
GoPro Camera



RTK GPS

Handhelds GPS

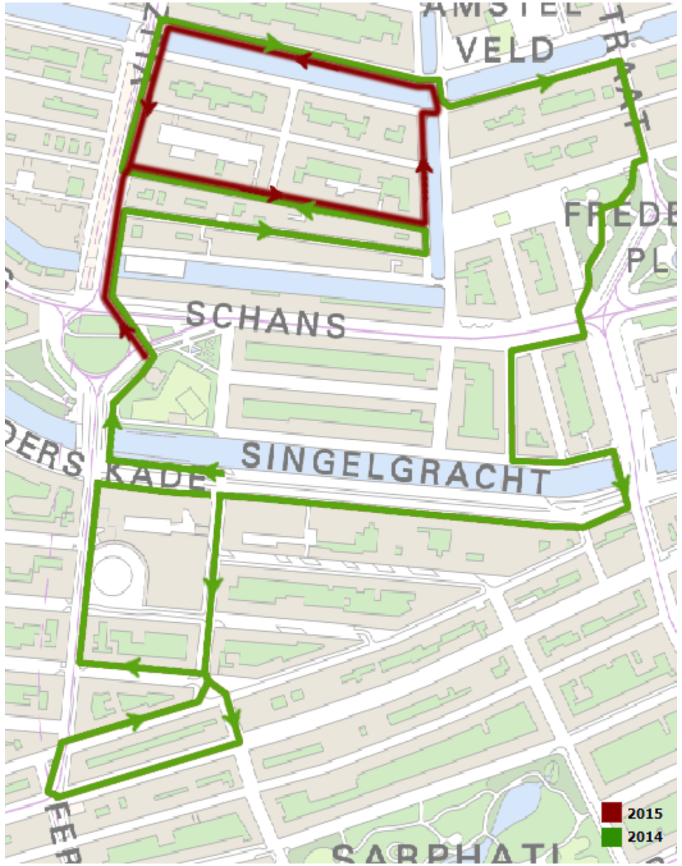
Sensor-data

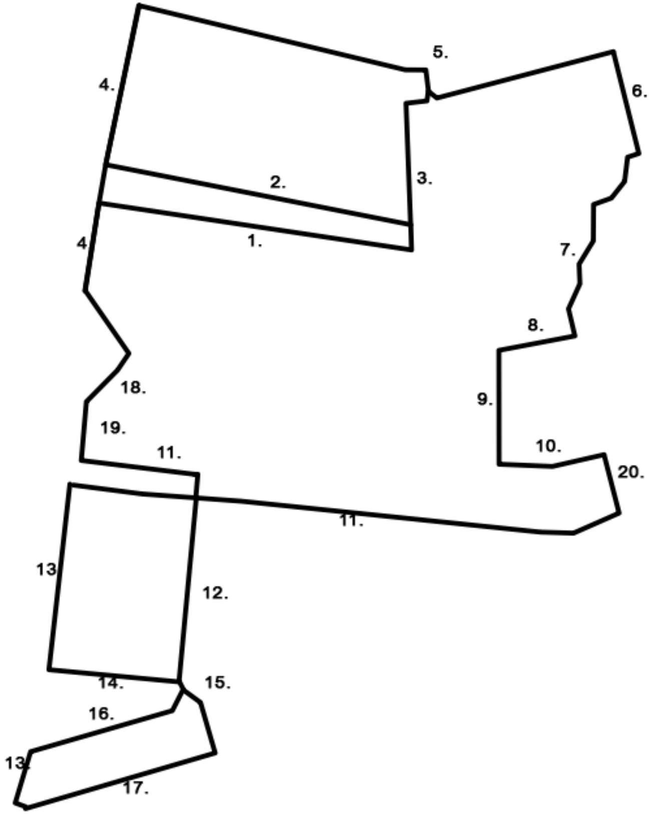
- Handheld GPS → *.GPX file (also KLM files and Text document)
- RTK GPS → Excel/CSV-document with x, y, z-coordinates
- Camera → Video

2015 (January): distance 2.0 km

2014 (December): distance 6.3 km

** http://www.ams-institute.org/solution/roving-rollators-2/ *(1:34 min)*





1. Fokke Simonszstraat
2. Nieuwe Looiersstraat
3. Reguliersgracht*
4. Vijzelgracht
5. Prinsengracht
6. Utrechtsestraat
7. Frederiksplein
8. Weteringschans
9. Pieter Pauwstraat
10. Nicolaas Witsenkade
11. Stadhouderskade
12. Eerste van der Helststraat
13. Ferdinand Bolstraat
14. Daniël Stalpertstraat
15. Gerard Douplein
16. Gerard Doustraat
17. Albert Cuypstraat
18. H.M.V. Randwijkplantsoen
19. Weteringlaan
20. Westeinde

For this study the meet rollator **sensor-data** is used obtained in December 2014 and January 2015

I did not set up the setting of the *meet rollator*, this was done completely by somebody else

For my thesis I used the data derived from the 3 available sensors

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Review

GPS

For positioning

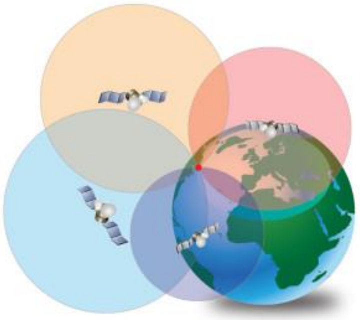
3 parameters of position

(latitude, longitude, height)

Time

Position is calculated by using trilateration

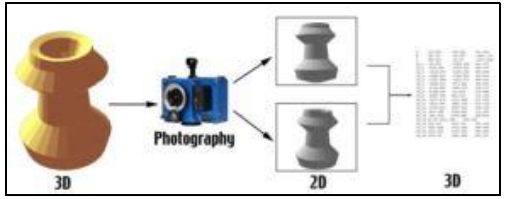
intersection of sphere surfaces



Photogrammetry

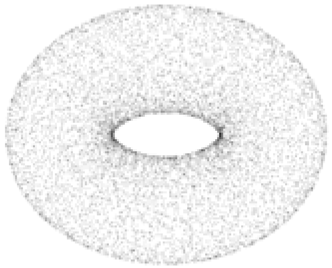
Is the field dealing with information extraction from images

A camera is the device that makes the transformation from the real 3D world into flat 2D images



It is possible to generate a point cloud (i.e. a group of 3D points) from a set of 2D images

by using an application that allows 3D reconstruction



Point clouds can be used for many purposes

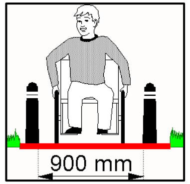
- Creating a digital elevation model (DEM) of a terrain
- Generating a 3D model of an urban environment

Requirements regarding accessibility

17 years ago 1st version of Manual-book of Accessibility - guidelines for outdoor spaces

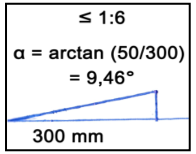
Three geometrical **demands** for movement:

1. **Suitable free passage** – at least 0.9 meter wide



2. **Minimum angle of inclination** – not steeper than the ratio 1:6 (height:length)

	Angle of inclination
Ratio (height : length)	≤ 1:6
Max. length until (grid size)	0.3m
Max. angle of inclination (rise)	9.46°
Max. height until (rise)	0.05m



3. **Minimum threshold** – a maximum height of 0.05 meter

This means that a pedestrian path forms an obstacle if it is narrower than 0.9 meter, steeper than 9.46° or/and if the height difference on the path is higher than 0.05 meter

It has to be noticed that one has to be critical with norms

** https://www.youtube.com/watch?v=aUhoetRYTBE (0:04 min & 1:25 min)

Content

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Storing	Conclusions and recommendations	Meet Rollator 2.0

Introduction & methodology (Research, Meet Rollator, Review)

My research & results (Workflow, Implementation, Validating and put semantics to, Storing, Conclusions and recommendations, Meet Rollator 2.0)

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Workflow

Available *meet rollator* sensors

	According knowledge:	*Precision:*
• Handheld GPS	✗	*Few meter to decameter*
• RTK GPS	✓	*Sub-centimeter (used for high-accuracy GPS surveying)*
• Camera	✓	

Two workflows were made for generating accessibility information according to the sensors

Workflow RTK GPS data

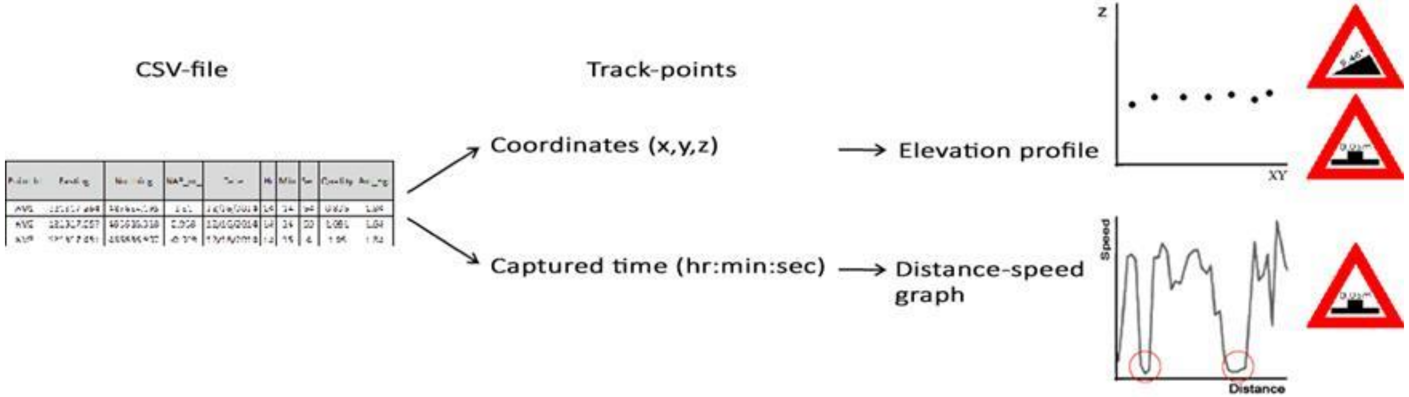
HYPOTHESIS

RTK GPS data collected by a *meet rollator* & GIS analysis tools can be used to develop a methodology that generates and determines accessibility information

2 Geometrical demands for movement:

- Angle of inclination
- Threshold

HOW TO PROVE IT



WORKFLOW

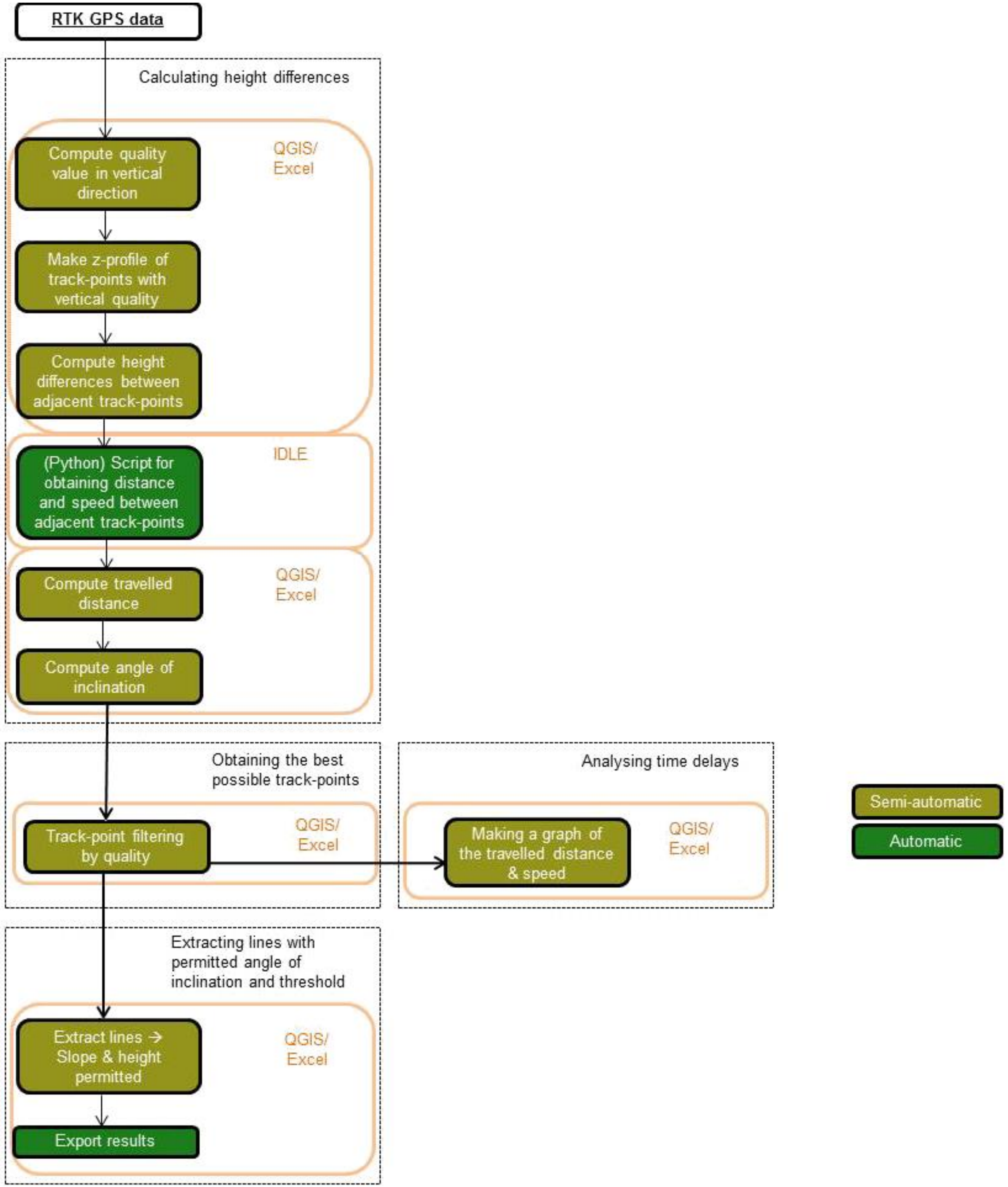
Four parts

(1) Computing 7 parameters

(2) Filtering → Quality

(3) Filtering → Threshold

(4) Analysing time delays



Workflow Camera data

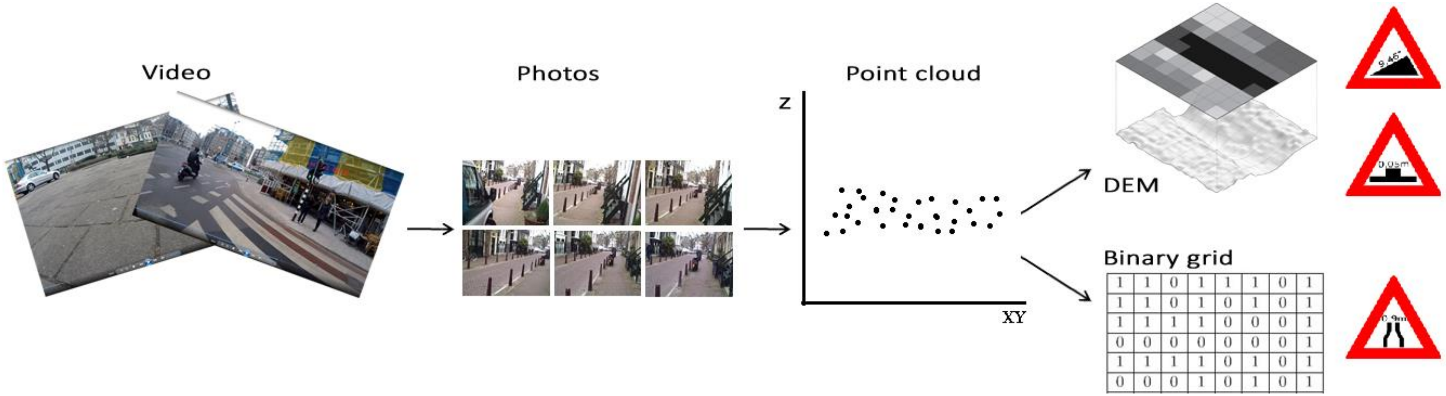
HYPOTHESIS

Video camera data collected by a *meet rollator*, the software Agisoft Photoscan Professional, GIS analysis tools and the BGT can be used to develop a methodology that generates and determines accessibility information

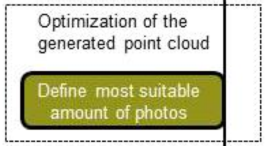
3 Geometrical demands for movement:

- Free passage
- Angle of inclination
- Threshold

HOW TO PROVE IT



WORKFLOW



Five parts

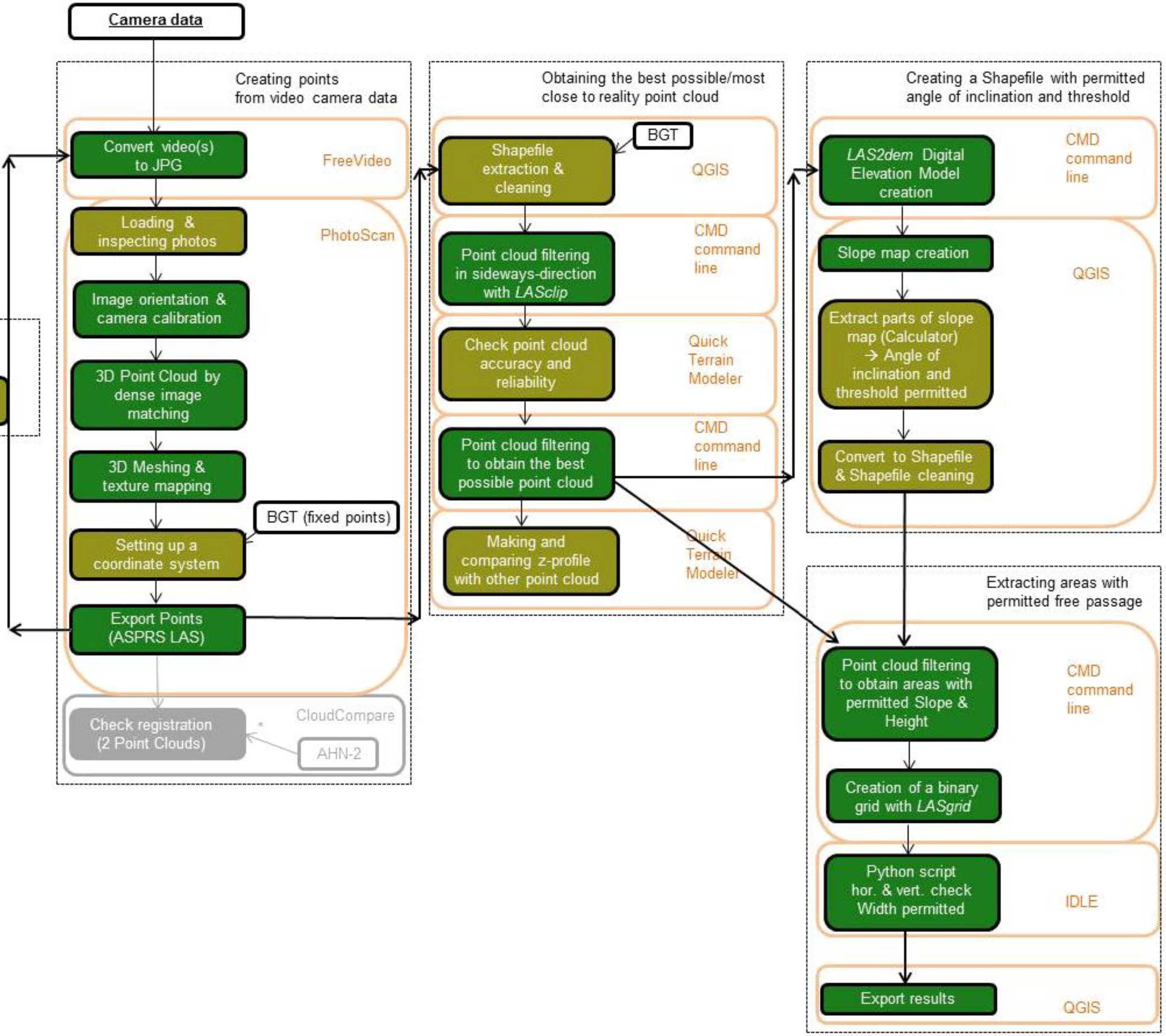
(1) Creation of point cloud

(2) Filtering → AOI

(3) DEM and Slope map construction

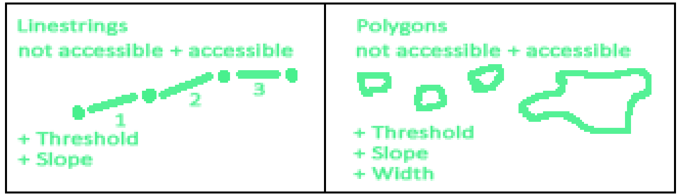
(4) Filtering (2),(3) and binary grid

(5) Images, camera used, image resolution



Workflow conclusions

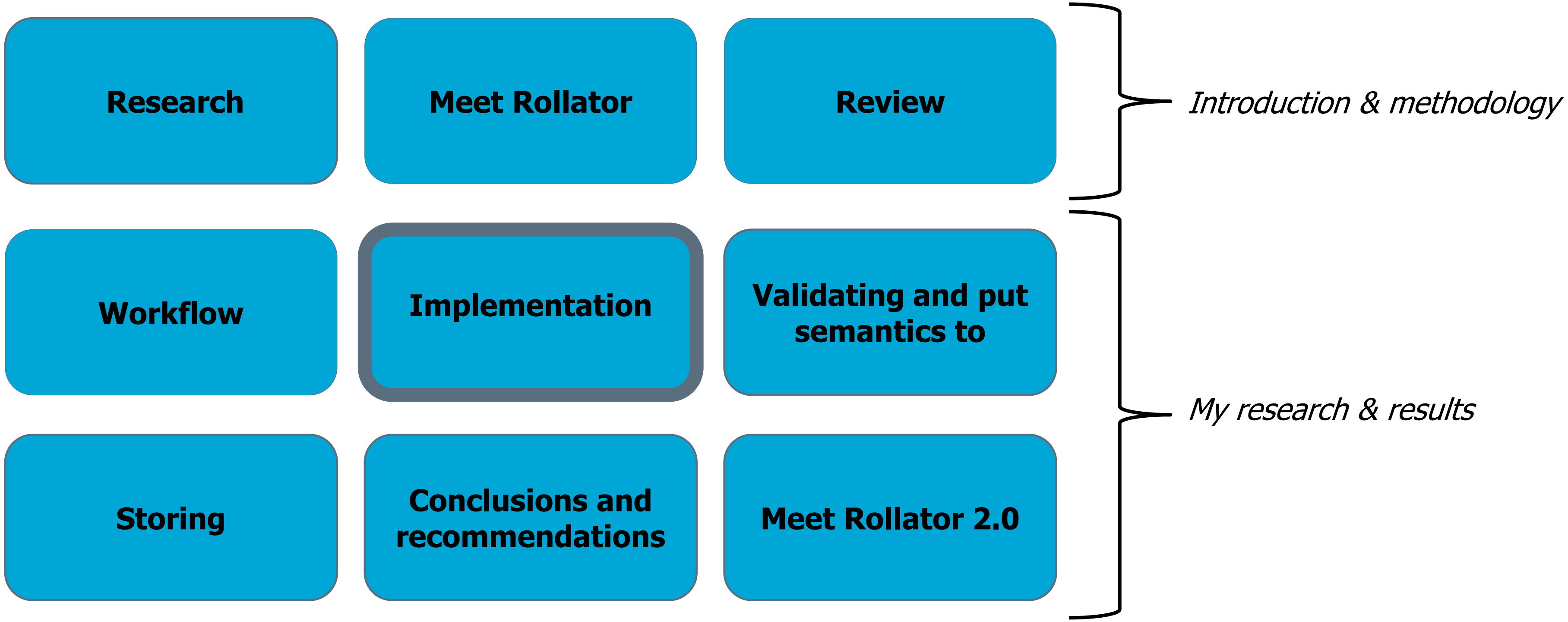
- Both workflows are useful
- A municipality will not be happy with workflows that consist of different types of software
- Both workflows differ in the representation
    - The RTK GPS data processing is a kind of point-measurements. In a certain street mobility impaired people can or cannot pass. The generated accessibility information of RTK GPS data will consist of linestrings
    - Camera data is modelled following a raster-based approach. This was done to limit complexity of the methodology. The derived accessibility information of camera data will consist of polygons



The workflow by making use of RTK GPS data is recommended to a municipality

- It takes less time to process RTK GPS data and fewer programs are needed

Content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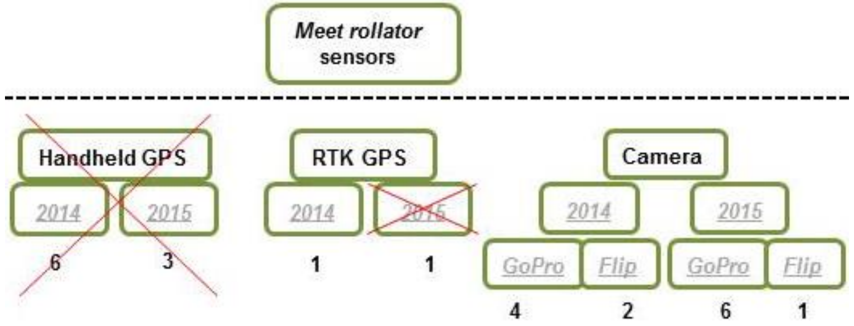
Implementing the workflow

Used data

- RTK GPS data – measured with a Leica device in 2014
- Camera data – measured with a Flip camera in 2015

Focus street:

Collected sensor-data:



Implementing workflow RTK GPS data

Input - CSV file of RTK GPS data 2014:

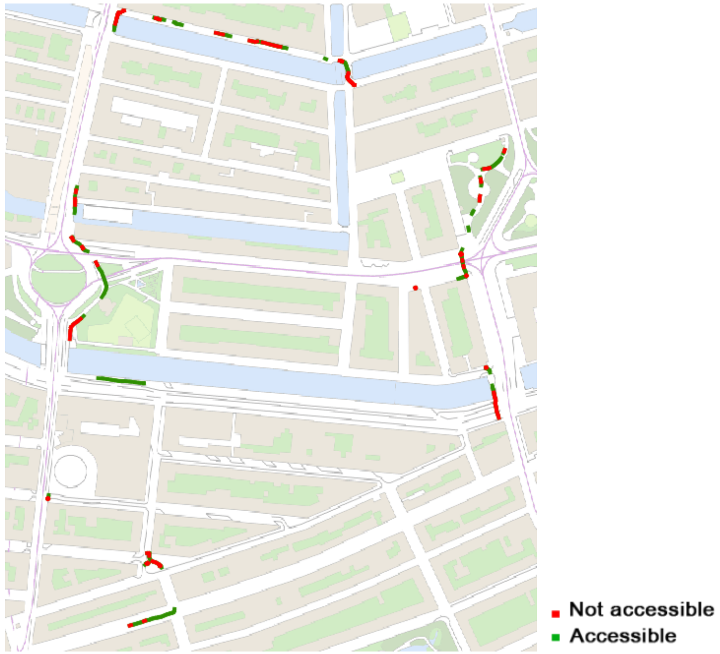
Point Id	Easting	Northing	NAP_m_	Date	Hr	Min	Sec	Quality	Ant_Hgt
AM1	121317.264	485684.195	2.81	12/16/2014	14	14	54	0.825	1.84
AM2	121317.657	485685.318	0.958	12/16/2014	14	14	59	1.081	1.84
AM3	121317.451	485685.907	-0.019	12/16/2014	14	15	4	1.05	1.84

Point-measurement

Output - Derived outdoor accessibility information:

province	municip_name	district	neighbourhood	accessible	line_id	good_quality
North-Holland	Amsterdam	Zuid	Oude Pijp	YES	8	YES
North-Holland	Amsterdam	Zuid	Oude Pijp	YES	9	YES
North-Holland	Amsterdam	Zuid	Oude Pijp	YES	10	YES

geom	point_id_one	point_id_two	data_year	obtained_year
LINESTRING (121300.098 485691.008,121300.076 485691.002)	AM8	AM9	2014	2015
LINESTRING (121300.076 485691.002,121299.903 485691.021)	AM9	AM10	2014	2015
LINESTRING (121299.903 485691.021,121294.435 485691.591)	AM10	AM11	2014	2015



Precision was for several places not good enough !

Implementing workflow Camera data

Input - Videos of Camera data 2015:



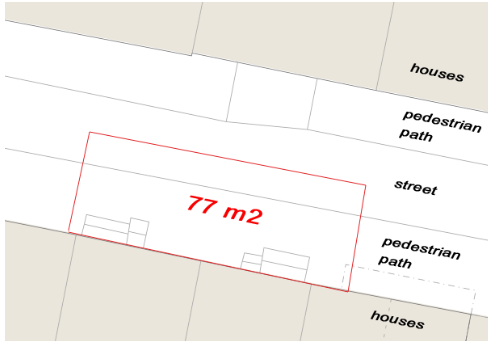
17 photos

Output - Derived outdoor accessibility information:

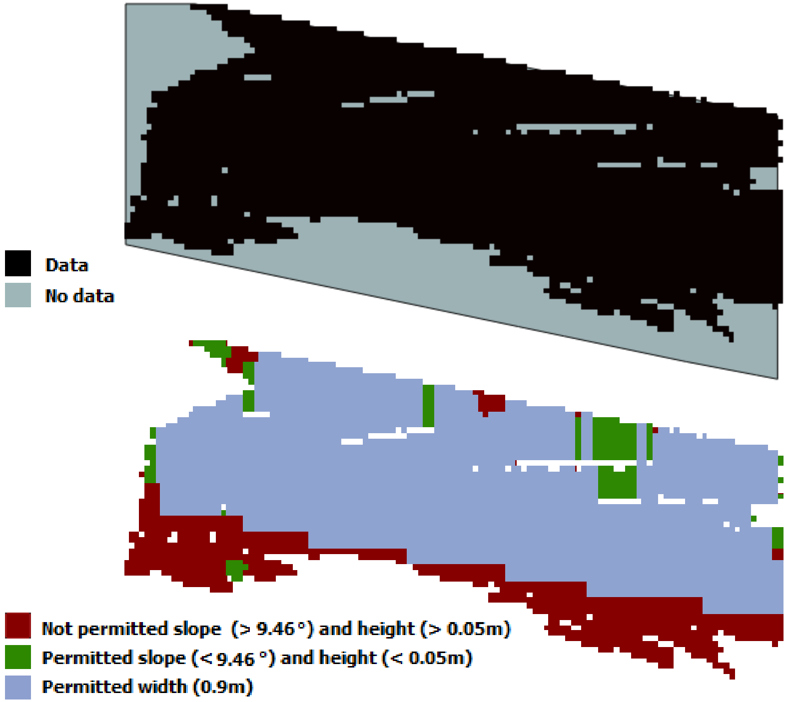
province	municip_name	district	neighbourhood	street	accessible
North-Holland	Amsterdam	Centre	De Weteringschans	Nieuwe Looiersstraat	Yes
North-Holland	Amsterdam	Centre	De Weteringschans	Nieuwe Looiersstraat	No

geovlak	data_year	obtained_year
POLYGON (((121501.802 485949.410475, 121501.802 …)))	2015	2015
POLYGON (((121498.416 485945.507241, 121498.416 …)))	2015	2015





Raster-based-measurement



Evaluate fit for purpose

According implementing workflow:

- Handheld GPS ✕
- RTK GPS ✕
- Camera ✕

Through data processing, more insight is gained into sensor data and about the usefulness of the different sensors

This research has shown that the used sensors did <u>not</u> provide the needed precision for deriving outdoor accessibility information concerning mobility impaired people

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Validating and put semantics to the accessibility information

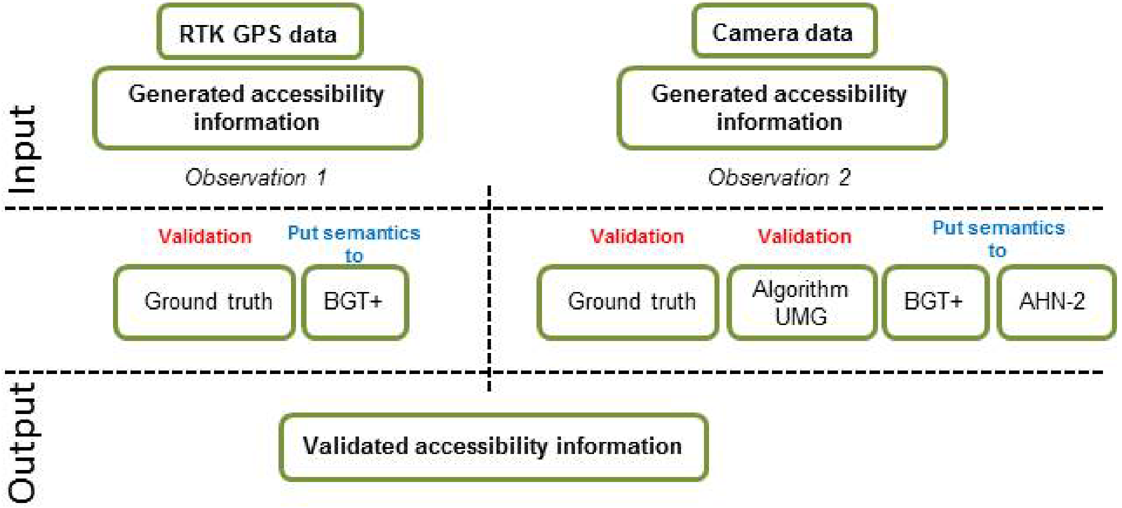
Used data

Ground truth = the absolute truth

BGT+ = the Dutch key registry for large scale topography (BGT – Dutch: Basisregistratie Grootschalige Topografie)

AHN-2 = the second part of the Height model of the Netherlands (Dutch: Actueel Hoogtebestand Nederland)

Algorithm of Urban Modelling Group (Dublin)



BGT+

AHN-2

Observations of RTK GPS data

Validate and put semantics to the generated accessibility information obtained by RTK GPS data by using:

- Ground truth
- BGT+

GROUND TRUTH

Validation

Direct visit

The generated accessibility information consists of 330 locations that cover an area of approximately 594m2

		Results after implementing workflow			After Survey	
		Total lines	Accessible	Not accessible	Accessible	Not accessible
1.	Albert Cuypstraat	31	29	2	31	0
2.	Ferdinant Bolstraat	13	6	7	13	0
3.	Frederiksplein	57	31	26	53	4
4.	Gerard Douplein	33	20	13	32	1
5.	H.M.V. Randwijkplantsoen	14	7	7	13	1
6.	Prinsengracht	78	51	27	62	16
7.	Stadhouderskade	13	13	0	13	0
8.	Vijzelgracht	42	24	18	35	7
9.	Westeinde	28	12	16	28	0
10.	Weteringschans	21	13	8	20	1
	Total	330	206	124	**300**	**30**

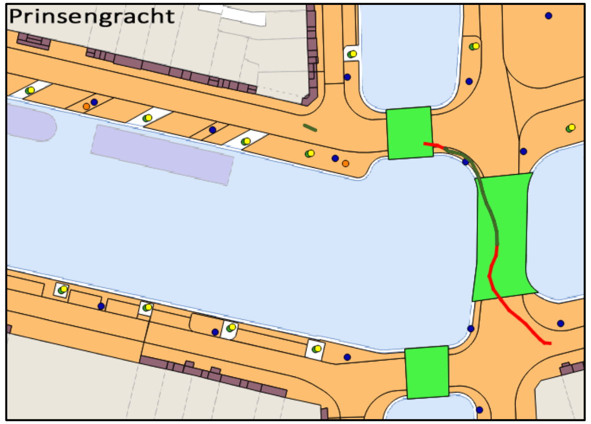
A rollator needs to be lifted to bridge the height difference caused by different pavement material

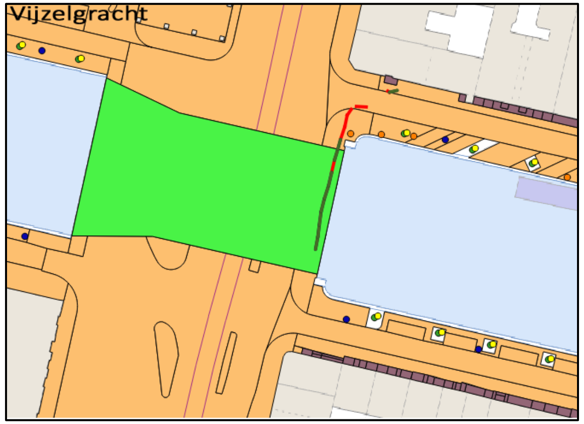
BGT+

Put semantics to the generated accessibility information

Overlaid in a GIS environment

For example to know whether a threshold is caused by a railway or curbstone





The generated accessibility information obtained with the use of RTK GPS data is often correspond with the BGT+

Observations of Camera data

Validate and put semantics to the generated accessibility information obtained by RTK GPS data by using:

- Ground truth
- BGT+
- AHN-2
- Algorithm of Urban Modelling Group (Dublin)

GROUND TRUTH

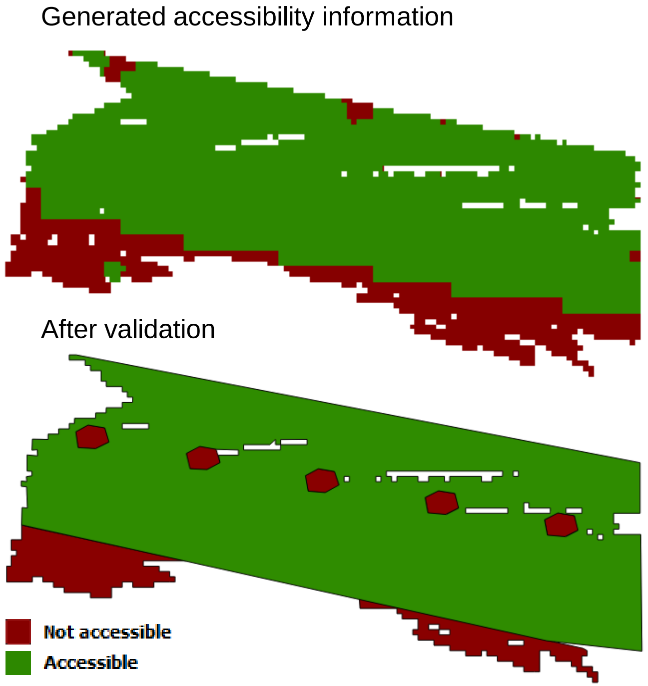
Validation

Direct visit

The generated accessibility information consist of one location (approximately 77 m^2) in the focus street called 'Nieuwe Looiersstraat'

The obstacles detected during the survey

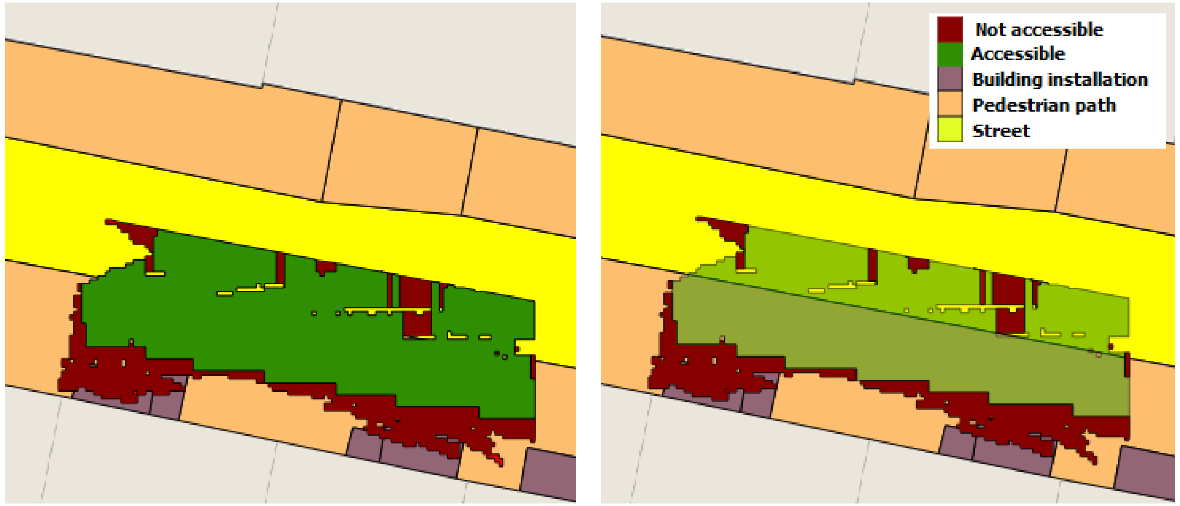
-> row of poles



BGT+

Put semantics to the generated accessibility information

Overlaid in a GIS environment

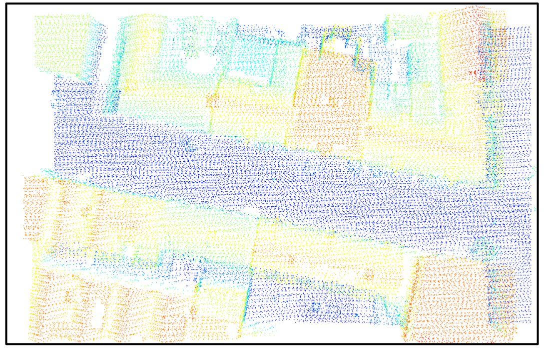


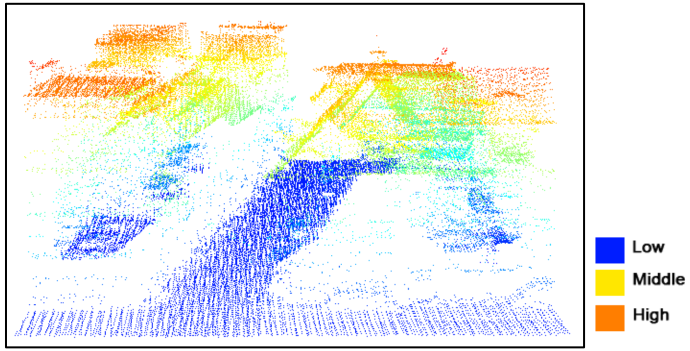
At some places the generated accessibility information is in line with the BGT+, especially where building installations (in the BGT+) are located

AHN-2

Put semantics to the derived observations

Overlaid -> visual comparison





This data is not completely coverage, even not close enough to be able to determine profile information

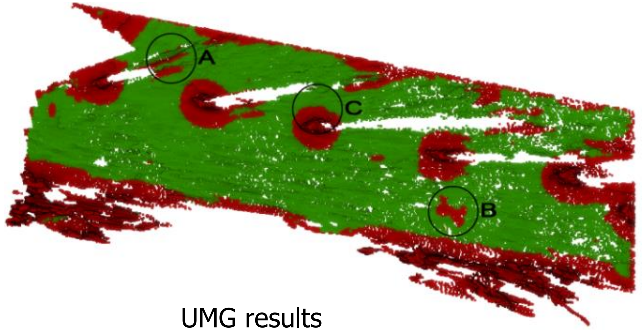
So the AHN-2 can<u>not</u> be used for achieving more insight in and put semantics to the derived observations

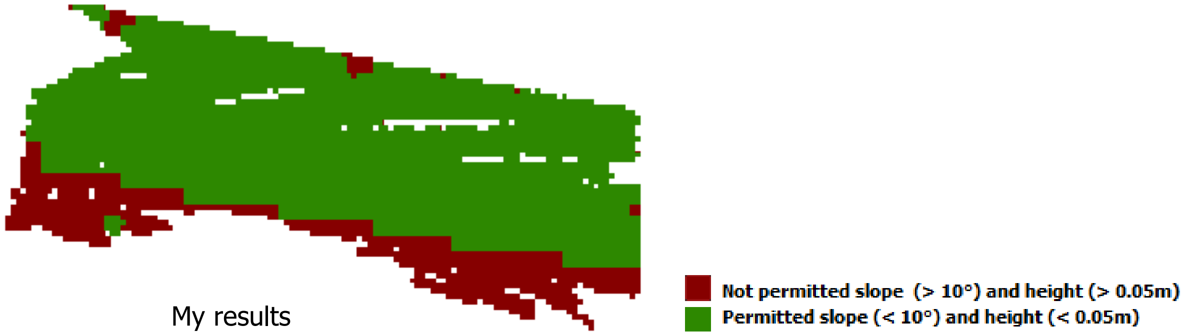
ALGORITHM OF URBAN MODELLING GROUP (DUBLIN)

Validation

Applied their algorithm on the same point cloud data

Slope and height

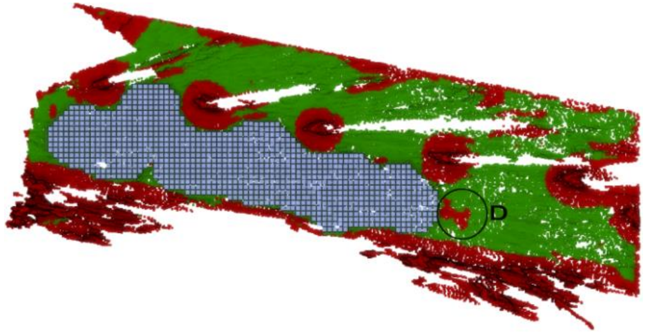


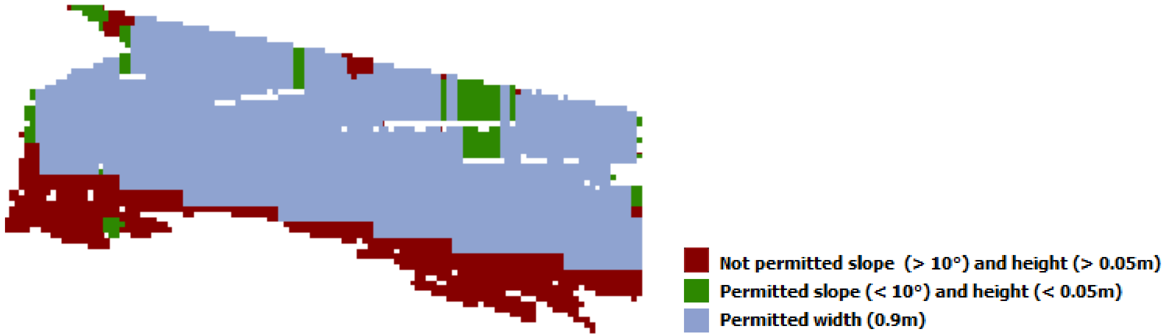


UMG results

My results

The overall result





The road roughness (see letter A) including those caused by data imperfection (see letter B) showed up clearly

Regions around the street poles are excluded from the accessible path (see letter C)

The bottle necks are terminating the growing in the UMG result (see letter D). The growing does not go through the bottle neck

COMPARISON OF THE UMG RESULTS AND MY RESULTS

- Another way of computing height and slope changes is used (point/raster-based-measurement)
- The result of the UMG are able to pick up the surface changes better
- Also by using a smaller grid size for processing, the results of the approach of this thesis are still less precise than the UMG results
- However the results of this thesis are <u>good</u> enough for the generation of outdoor accessibility information

Conclusion

	RTK GPS observations:	*Camera observations:*	
AHN-2		✗	*Put semantics to*
BGT+	✓	✓	*Put semantics to*
Ground truth	✓	✓	*Validation*
Algorithm of Urban Modelling Group (Dublin)		✓	*Validation*

The AHN-2 and BGT+ can be used for putting semantics to the observations

The ground truth and results of the algorithm made by the Urban Modelling Group can be used for the validation of the observations

The AHN-2 is not suitable for providing more insight in and put semantics to the observations

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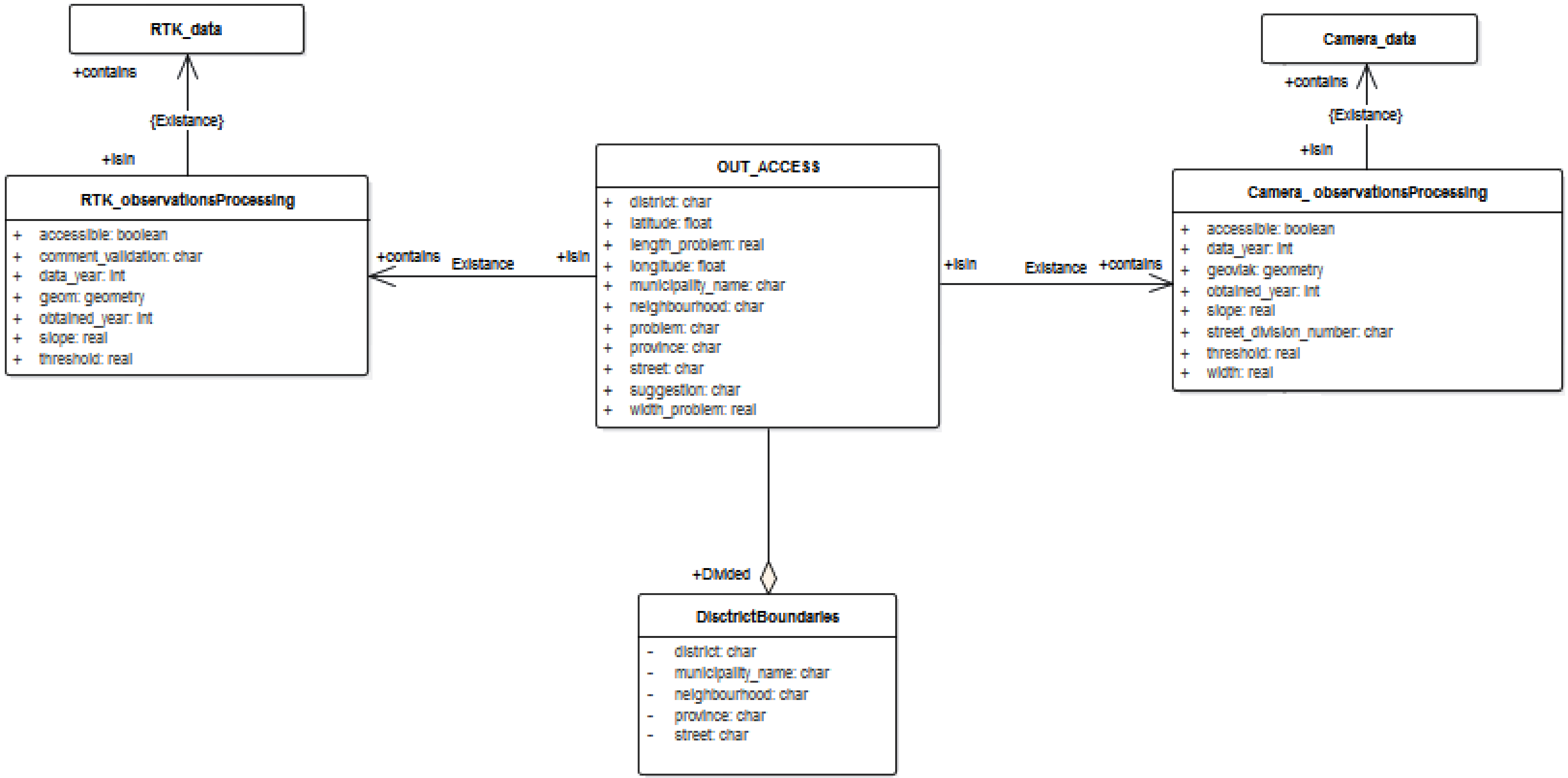
Storing the validated accessibility information

Geo-database

A database is a digitally stored archive

UML class diagram

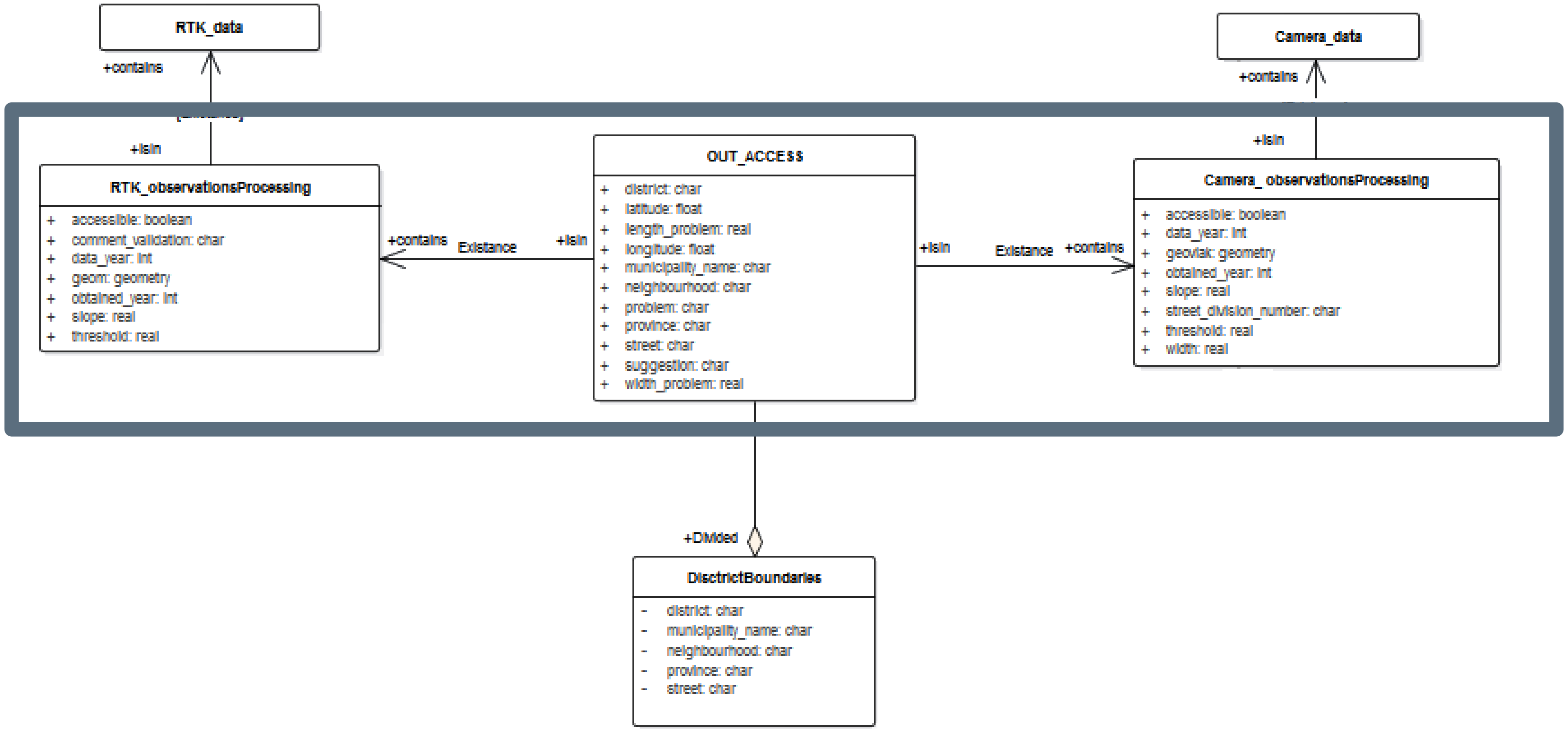


Storing the validated accessibility information

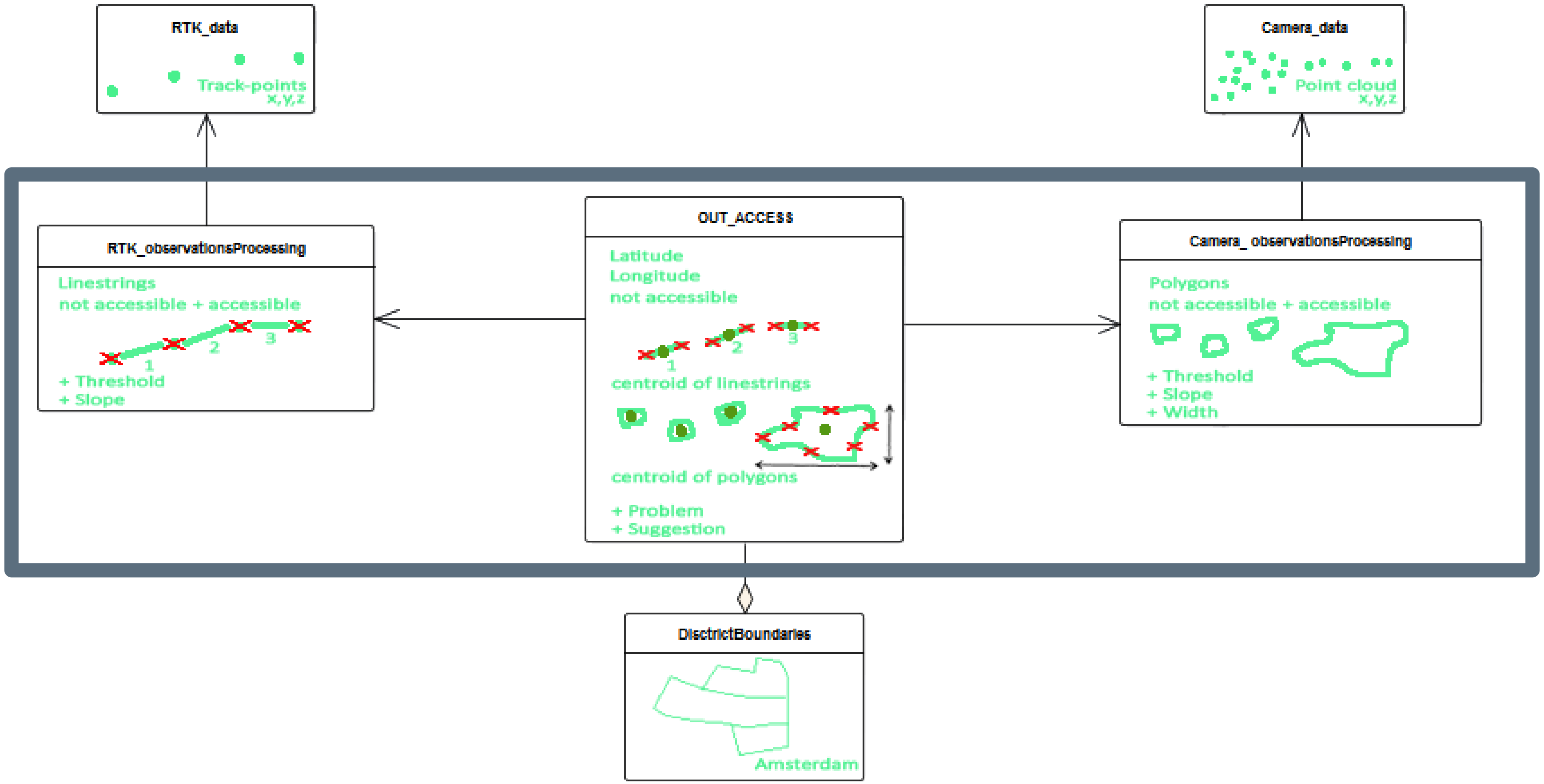
Geo-database

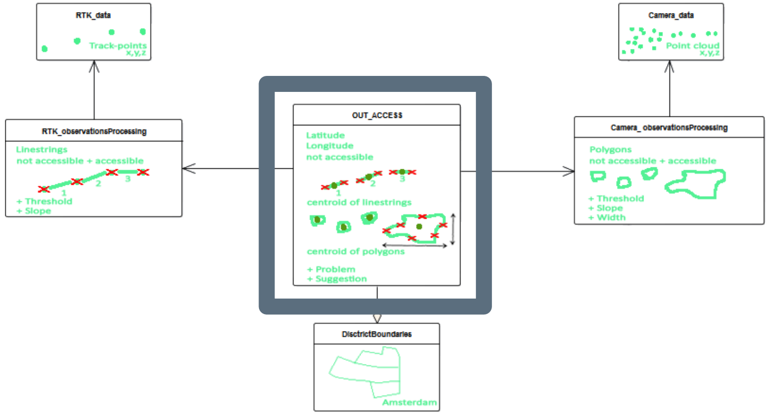
A database is a digitally stored archive

UML class diagram



UML class diagram conceptual





Database: OUT_ACCESS

- an overview of all improvements that are necessary
- positions where problems occur and the suggestions for improvement

province character(100)	municip_name character(100)	district character(100)	neighbourhood character(100)	street character(100)
North-Holland	Amsterdam	Centre	De Weteringschans	H.M.V. Randwijkplantsoen
North-Holland	Amsterdam	Centre	De Weteringschans	Vijzelgracht
North-Holland	Amsterdam	Centre	Grachtengordel-Zuid	Vijzelgracht

latitude real	longitude real	problem character(100)
121241	485842	Threshold is not accessible (crossing road)
121223	485863	Threshold is not accessible (crossing road)
121265	486150	Threshold is not accessible because paving stones lie slanting

length_problem real	width_problem real	suggestion character(100)
0.3	0.5	Apply a ramp with the right angle
0.3	0.5	Apply a ramp with the right angle
0.5	0.2	New pavement or resurfacing

This table could be of importance for a municipality

It can be used as Spatial Decision Support Systems (SDSS) by road managers since it provide them with new information about the outdoor accessibility

Application of the geo-database

Querying the database

Link the data to other applications in order to make it more usable

According to a Teamleader of Process Unit at the Municipality of Amsterdam

This geo-database can be very useful for the management of the public space, specifically for the management of pavements/surfacing

If it appears that a public area is not sufficiently accessible, this information may be included in the deliberations of where a municipality commits their efforts

So this information is very useful for road managers

With this database the municipality can improve the mobility in the outdoor environment

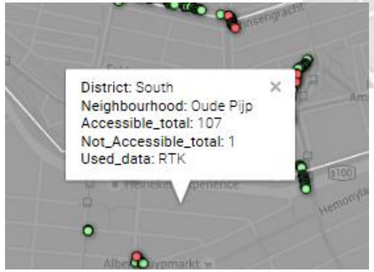
Map

With QGIS no interactive map can be made & a map cannot be made publicly available

Google Fusion Table map application

Neighbourhood: Oude Pijp, De Weteringschans, Grachtengordel-Zuid

To provide insight in the accessibility of pedestrian routes for mobility impaired people



C:\Users\Rosann Aarsen\Desktop\Graduation project\+P4 presentatie\Map\Map\Map_gray.html

Content

Research	Meet Rollator	Review	*Introduction & methodology*
Workflow	Implementation	Validating and put semantics to	*My research & results*
Storing	**Conclusions and recommendations**	Meet Rollator 2.0	

Conclusions

Answering the sub research questions:

1. **What are potential problems presented by the public space and primary requirements for people with mobility impairments regarding the accessibility?**

A pedestrian path forms an obstacle if it is narrower than 0.9 meter, steeper than 9.46° or if the height difference on the path is higher than 0.05 meter

For this thesis is focused on the three most important parameters for mobility impaired people, namely:

- *Suitable free passage*
- *Minimum angle of inclination*
- *Minimum threshold*

2. **Which measure-method could be developed to generate accessibility information, by making use of the sensor (handheld Global Positioning System (GPS), Real-Time Kinematic (RTK) GPS and camera) data collected by a *meet rollator*, software package PhotoScan, Geographic Information System (GIS) analysis tools and the core-registration Large-scale Topography of the Netherlands (BGT)?**

For this thesis two measure-methods were made according to the available sensors

1. RTK GPS workflow: Software package PhotoScan, GIS analysis tools and the BGT (+ Quick Terrain Modeler, IDLE and Freevideo)
2. Camera workflow: QGIS (+ IDLE)

3. How can the ground truth and results of the UMG algorithm be used to validate the generated accessibility information? And do the AHN-2 and BGT+ provide more insight in and put semantics to the generated accessibility information?

Additional data will provide more insight in and put semantics to the derived outdoor accessibility information

Ground truth is the best way to check whether the observations are complete, accurate and precise

The algorithm made by the UMG is suitable for validating the observations obtained by using camera data

Only the BGT+ provide more insight in and put semantics to the observations (not the AHN-2)

4. In what way can the results best be stored in a geo-database in PostgreSQL?

The derived accessibility information obtained via Camera data can best be stored by using polygons, to represent complex areas

The derived accessibility information obtained via RTK GPS data can best be stored by using linestrings

Answering the main research question:

Does the current setting of the *meet rollator* provide insight into the accessibility of pedestrian routes for mobility impaired people? If not, how can the current setting be improved?

Yes, the current setting of the *meet rollator* provides insight into the accessibility of pedestrian routes for mobility impaired people

However, this research has shown that the used sensors did not provide the needed precision !

A part of the used sensors does not provide any insight into the outdoor accessibility information

The current setting of the *meet rollator* can be improved

Recommendations

- A suggestion to improve the workflow by making use of Camera data, is to use more coordinates for georeferencing

- For comparing the measurements instead of the derived observations
  a surveyor's level (Dutch: Waterpasinstrument) can be used, which measures for a given test-path an accurate altitude profile
  In this way the real truth could be compared with the RTK GPS data, and with the camera data

- It is advisable to further investigate the usefulness of other sensors to decide which sensors produce more precise measurements

It should be noticed that it is not easy to measure the needed information !

Content

Research	**Meet Rollator**	**Review**
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Introduction & methodology

My research & results

TUDelft

Meet Rollator 2.0 *@ Designed by Rosann*

They (from the University of Wageningen) have used the current setting of the *meet rollator*

However you can do it better this way !

By taking the same measurement platform

Sensor: 3D laser scanning system → handheld laser mapping system: **ZEB1**

- allows fast data capturing
- result of a ZEB1 measurement is point cloud data which is directly available for further processing

Sensor: For the position determination **RTK GPS**

Another option: Directly measure the needed information instead of calculating it

By using a sensor that derives the needed information directly without sensor data processing

A little cart with (two) wheels that measures an angle of inclination and threshold directly

- To know the location of a sidewalk you have to use something with wheels that will run against a higher-situated pavement

In combination with: Accelerometer (a device that measures proper acceleration)

- it directly measures a stop when it drives against a curb

Thank you