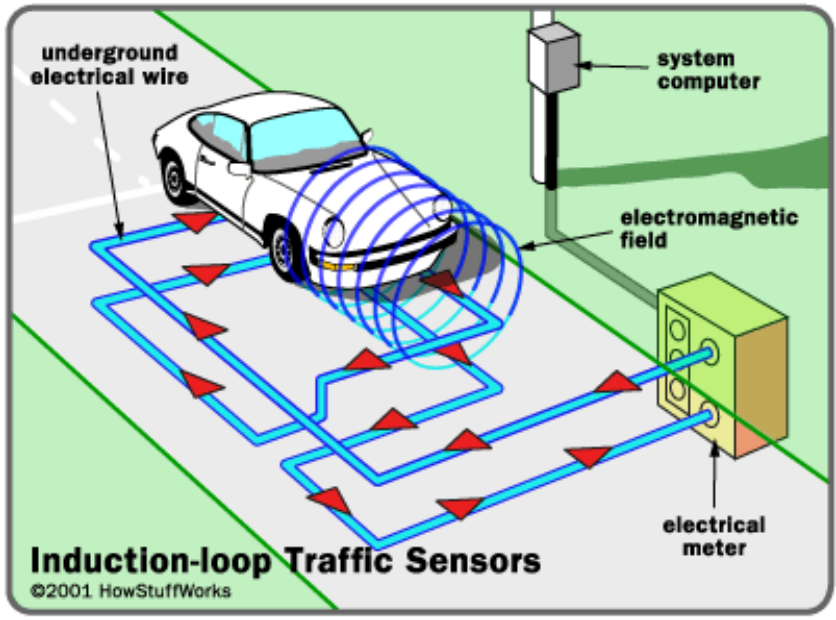
Traffic Monitoring Systems

Technology and sensors

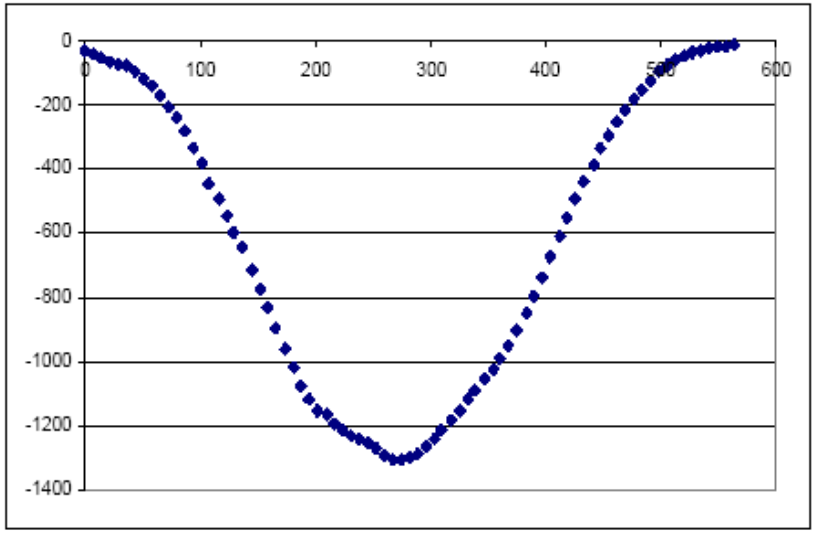
Technology

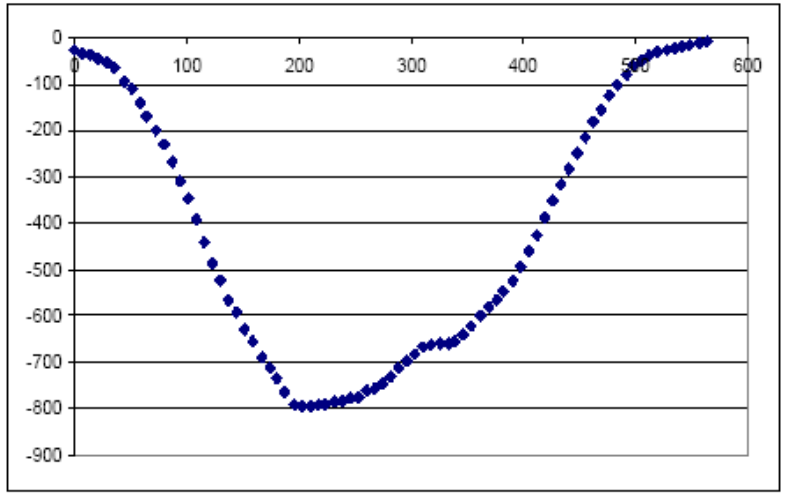
- Inductive loops
- Cameras
- Lidar/Ladar and laser
- Radar
- GPS
- etc

Inductive loops



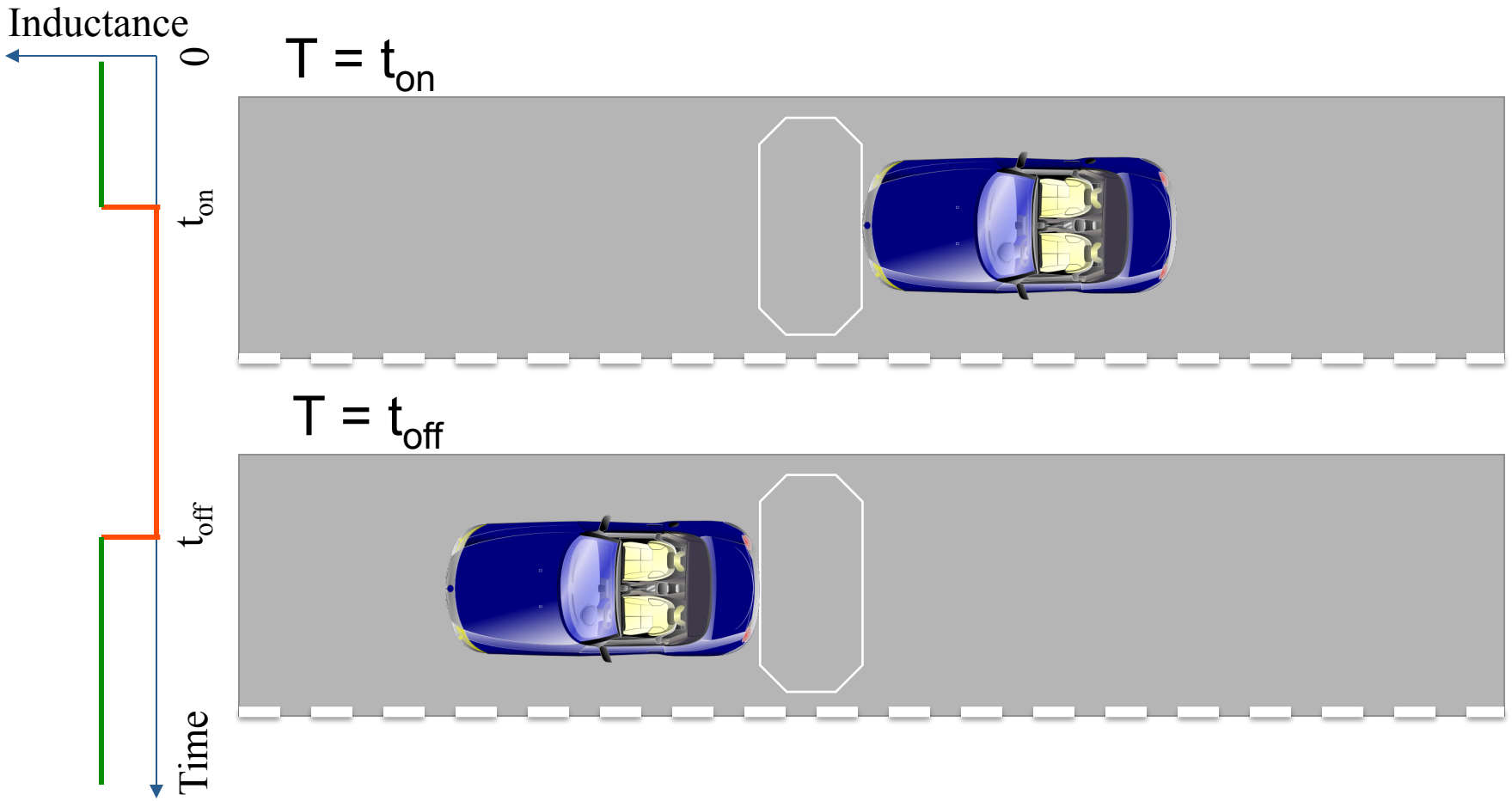
Inductive loops signals



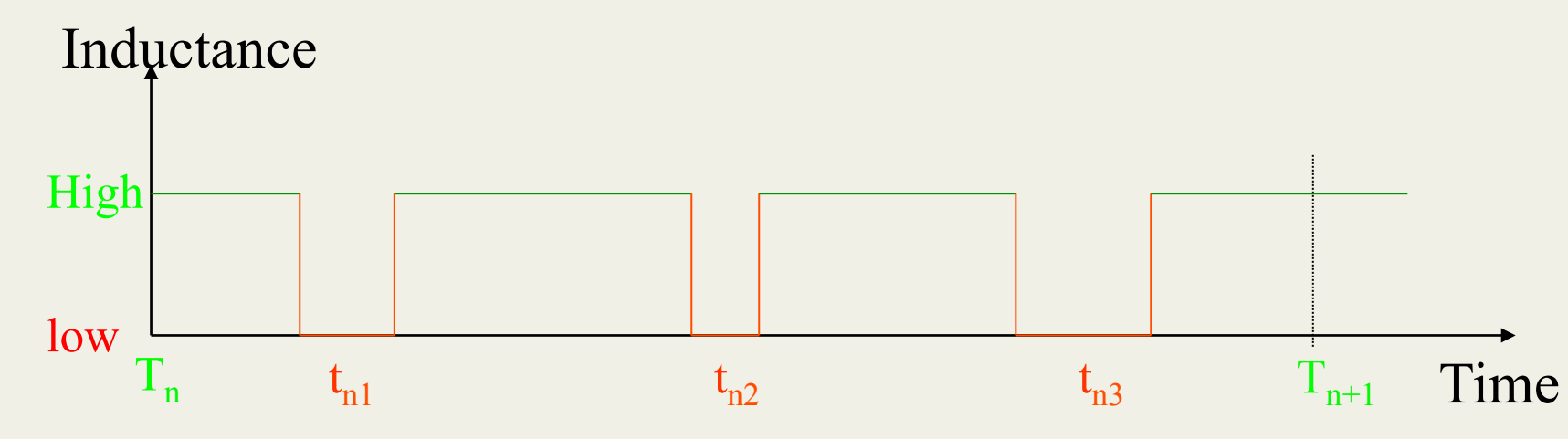


Inductive loop sensor

The inductance signal decreases when a car pass through the loop



Inductive loop sensor



- Loops can measure:
  - Occupancy (percentage of time loop is occipied per interval)
  - Volume (vehicle per interval)

Inductive loop sensor

- How can we get speed from loops:

$$s = \frac{EVL}{t_o}$$

s = speed (m/sec)

EVL = effective vehicle length (m)

t_o = occupancy time (s)

EVL ~ (vehicle length + detector length)

Inductive loop sensor

- Estimating speed

$$s = \frac{N}{T \times O \times g} \times 3600 \ \frac{\text{sec}}{hr}$$

s = speed (km/hr)

N = number of vehicles in the observation interval

T = observation interval (s)

O = percentage of time the loop is occupied by vehicles during the observation interval (occupancy)

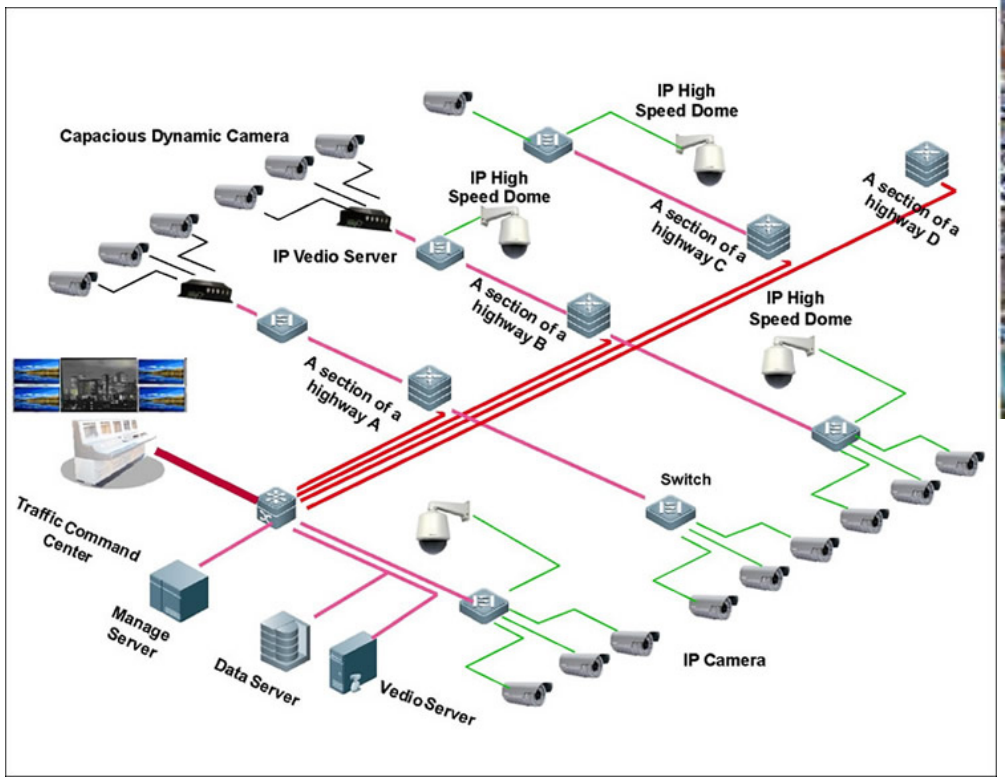
g = speed estimation parameter

$$g = \frac{1000 \ m/km}{EVL \times 100}$$ ← 100 converts percent to decimal

Inductive loop sensor

- Is this speed estimation a TMS or SMS?

Video surveillance



Video surveillance

- Detection and tracking of moving objects
- Interpret movement of the moving objects and their patterns behaviors.
- This will allow us:
  - Minimize the user interaction, the cost and the time.
  - Reduce traffic jams, accidents, and identifying suspicious vehicles or events.

Video surveillance for traffic monitoring system

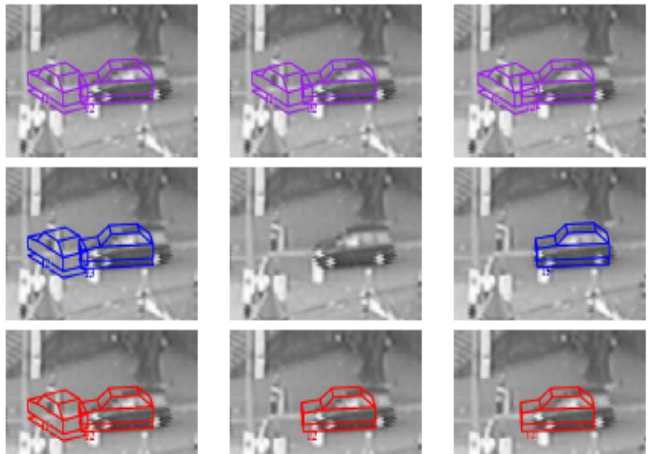
- Should be capable of:
  - Adaptive to changes that occurs in real world
  - Operating independently of human operators
  - Easy to set up
  - Making decisions
  - Working in real time

Vehicle detection

- Model based detection
- Region based detection
- Active contour based detection
- Feature based detection

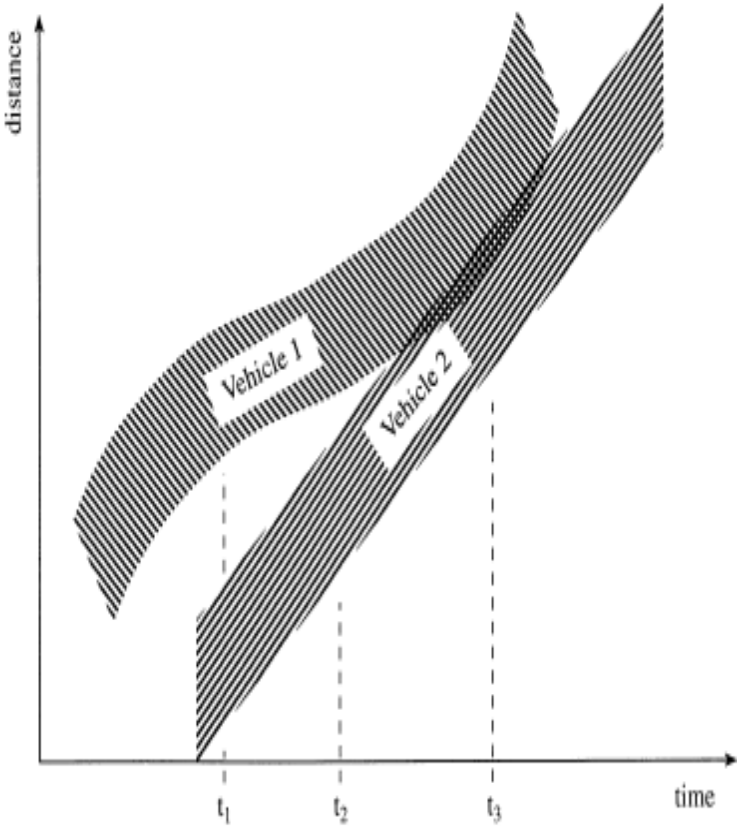
Vehicle detection

- Model based tracking
  - Recovering trajectories and models for small number of vehicle with high accuracy
  - Weakness:
    - Not good with geometric details
    - Not realistic (you can not know all kind of vehicles models)



Vehicle detection

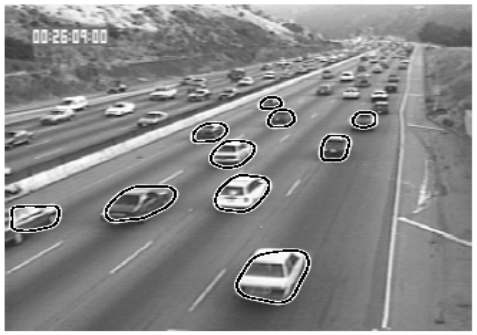
- Region based tracking
  - Detect each vehicle blob using cross correlation function.
  - Vehicle detection is based on background subtraction.
  - Weakness:
    - Hard to detect vehicle in traffic jams due to occlusion phenomena.

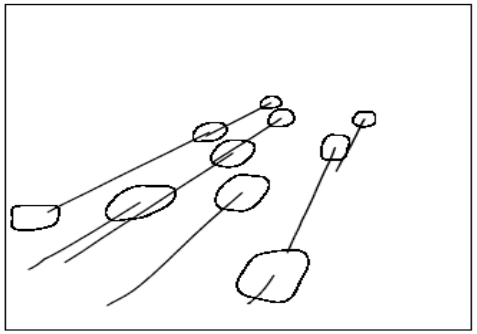


Potential segmentation problem

Vehicle detection

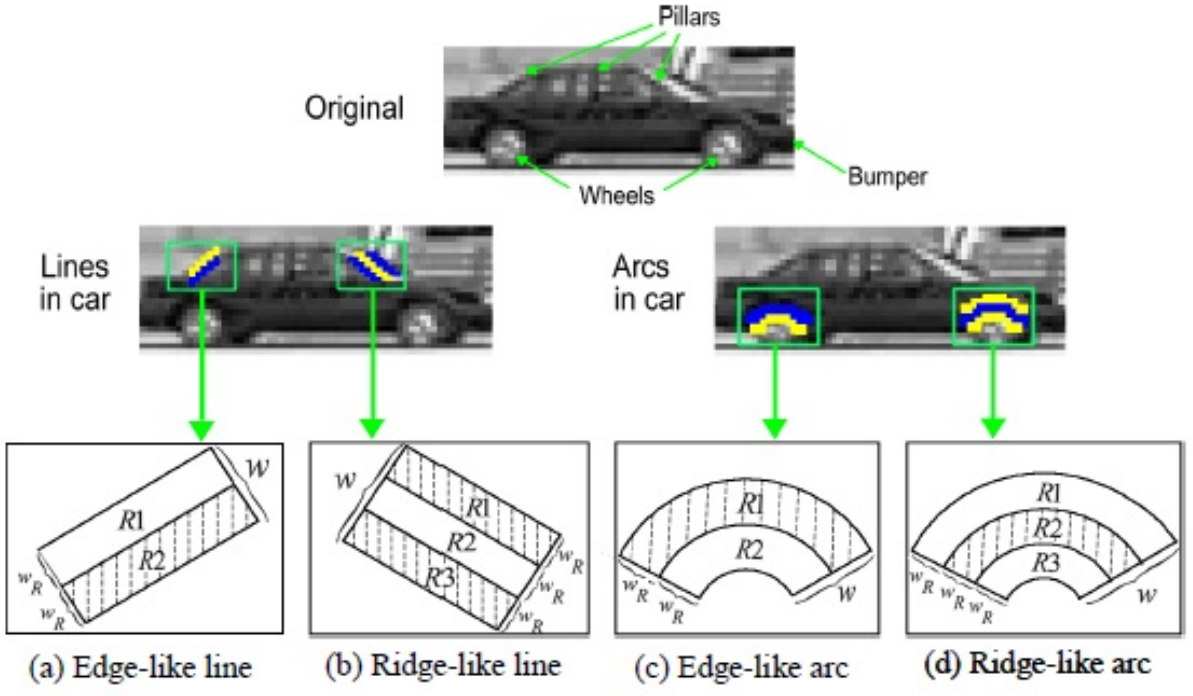
- Snakes/ active contour detection
  - Tracking is based on active contour models or snakes
  - Reduce computational complexity compared to region based detection
  - Representing objects in bounding contour
  - Weakness:
    - Can not detect vehicle that are occluded





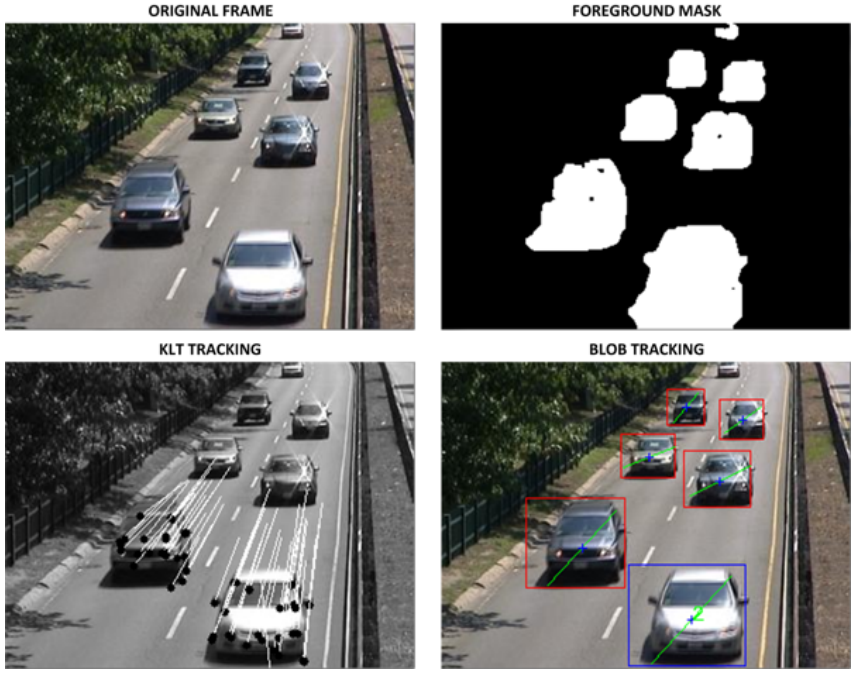
Vehicle detection

- Feature based detection
  - Track specific sub-feature present on the vehicle
  - Performance depends on the motion constraints



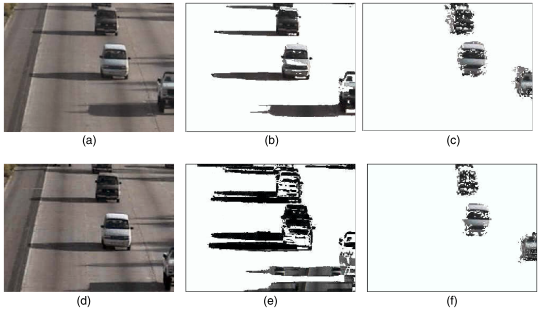
Vehicle tracking

- Background subtraction
  - Image comparison (reference background image)
  - Sensitive to background change
  - Suitable for static environment



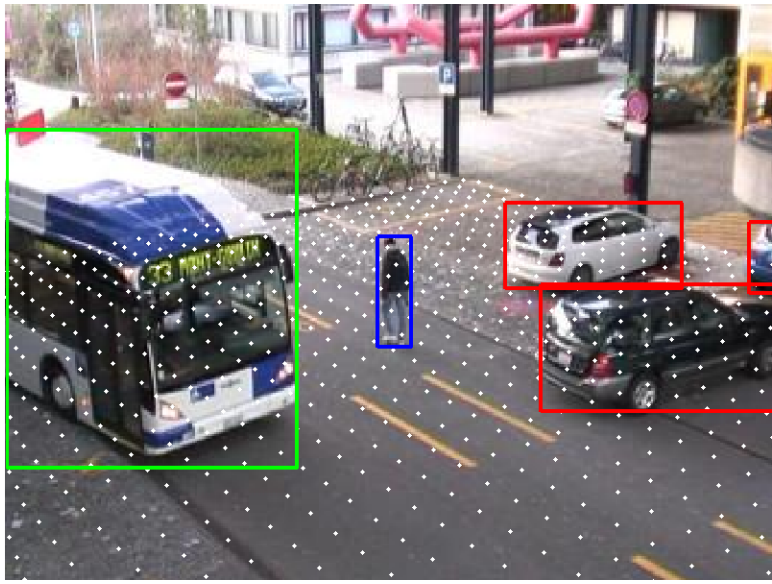
Vehicle tracking

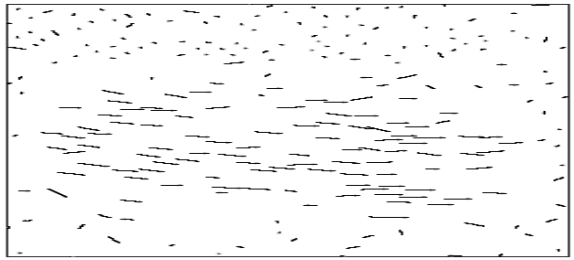
- Temporal differencing
  - Checking intensity evolution in the images (moving object has the tendency to change intensity faster than static ones)
  - Use chronological frames to detect the changes
  - Weakness:
    - Extracting all the relevant features
    - Number of frames used in the analysis can affect the performance



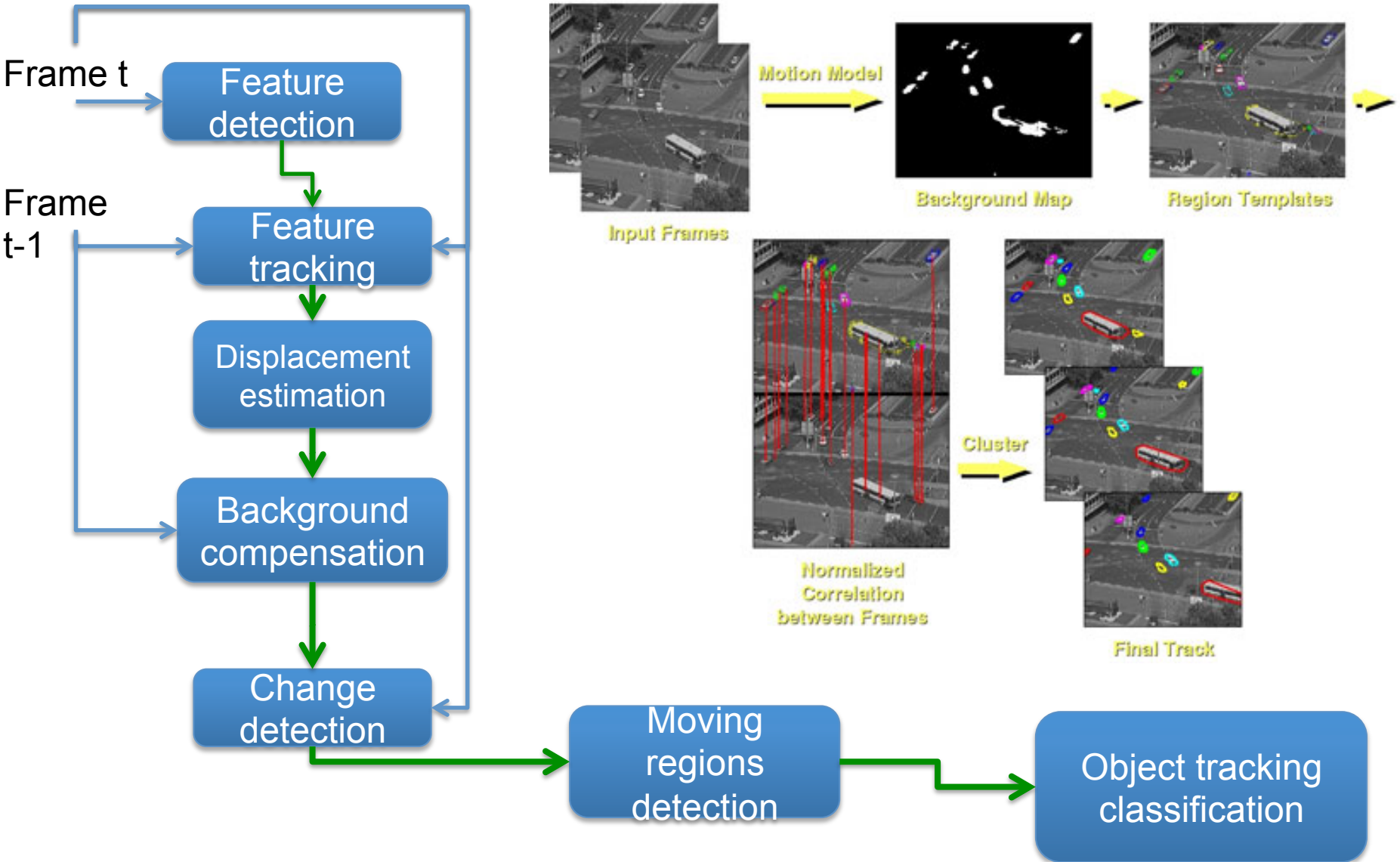
Vehicle tracking

- Optical flow
  - Characteristics Identification using flow vectors of moving objects
  - Weakness:
    - Can be very slow to run in real time.





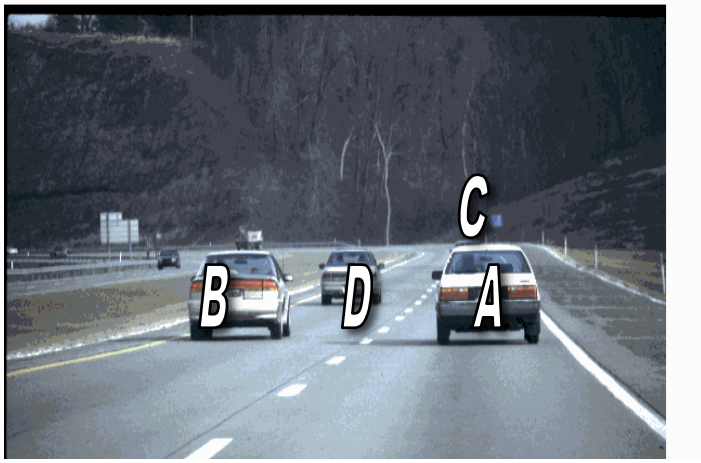
Vehicle tracking procedure

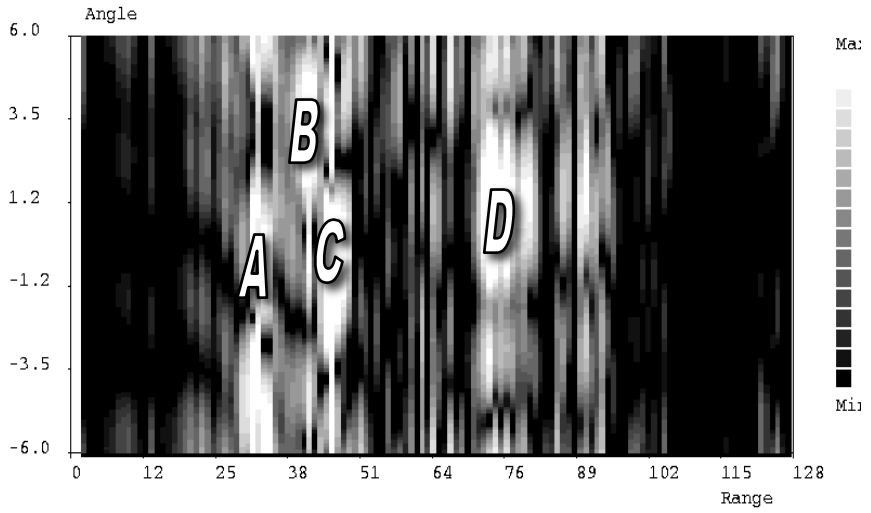


Radar

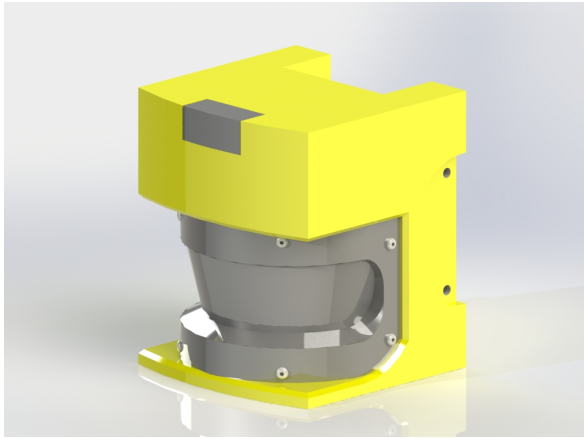
Radar

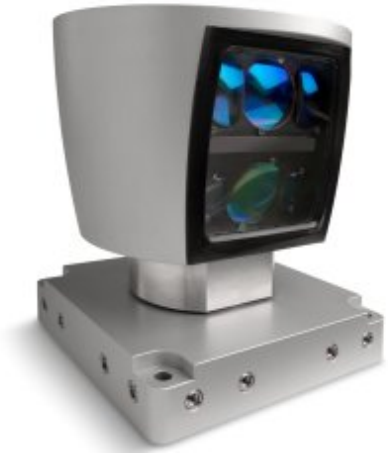
- The radar data has a horizontal range
- Bearing angles (vertical: up is left and down is right)
- Brightness indicated strength of the return

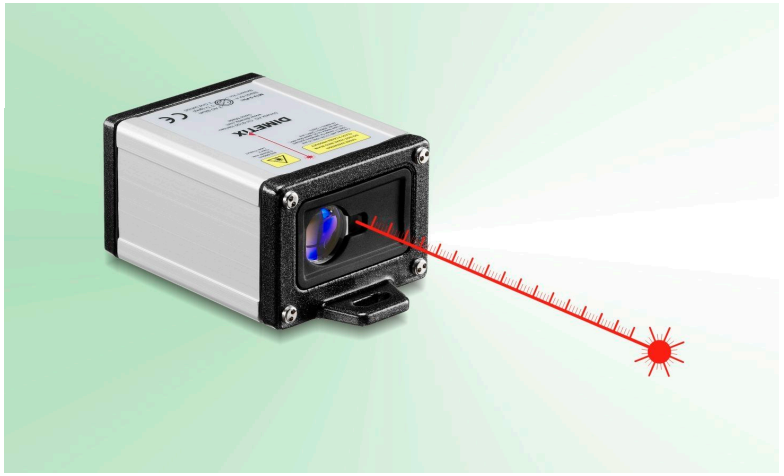




Ladar, lidar and laser







Ladar, lidar and laser

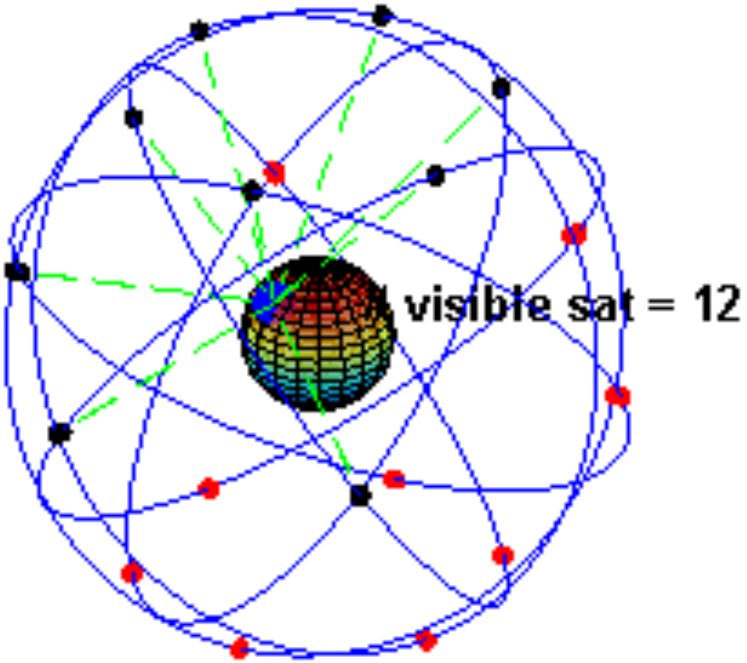
- They all use travel time of laser beam to measure distance.
- The laser beam can be scanned to create a “range image” using mirrors.
- Lasers can be focus to very small spots
- Ladar is near visible light therefore can be blocked by fog, snow, heavy rain, etc

Ladar, lidar and laser

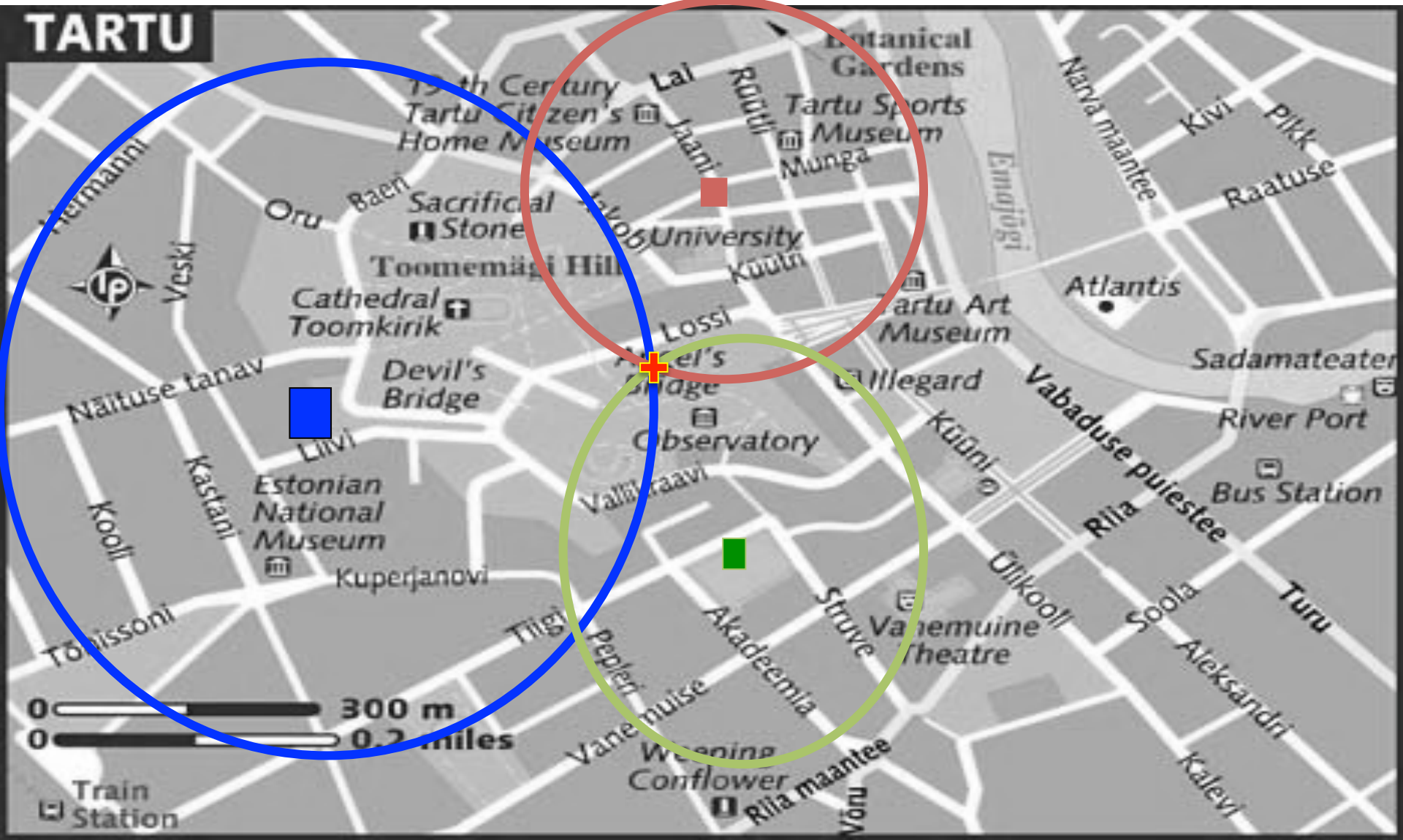
GPS

GPS

- About 31 satellites with very high orbits
- Several ones are replaced every year

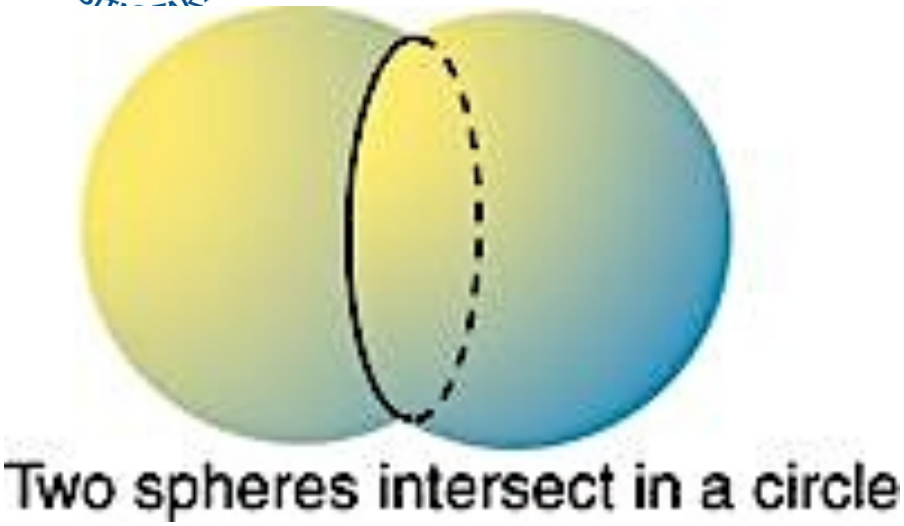


GPS


TARTU
Botanical Gardens
Tartu Sports Museum
Munga
Lai
Jaani
Ruutli
Narva maantee
Kivi
Pikk
Raatuse
Emajõgi
Hermanni
Oru
Baeri
Sacrificial Stone
Jakobi
University
Küüni
Toomemägi Hill
Veski
Cathedral Toomkirik
Lossi
Tartu Art Museum
Atlantis
Devil's Bridge
Observatory
Illegard
Sadamateater
River Port
Näituse tanav
Liivi
Kastani
Kooli
Estonian National Museum
Kuperjanovi
Vabaduse puiestee
Bus Station
Rüa
Ülikooli
Soola
Turu
Aleksandri
Tõnissoni
Tiigi
Pepleri
Akadeemia
Struve
Vanemuise Theatre
Vanemuise
Weeping Cornflower
Rüa maantee
Võru
Kalevi
Train Station
0
300 m
0
0.2 miles

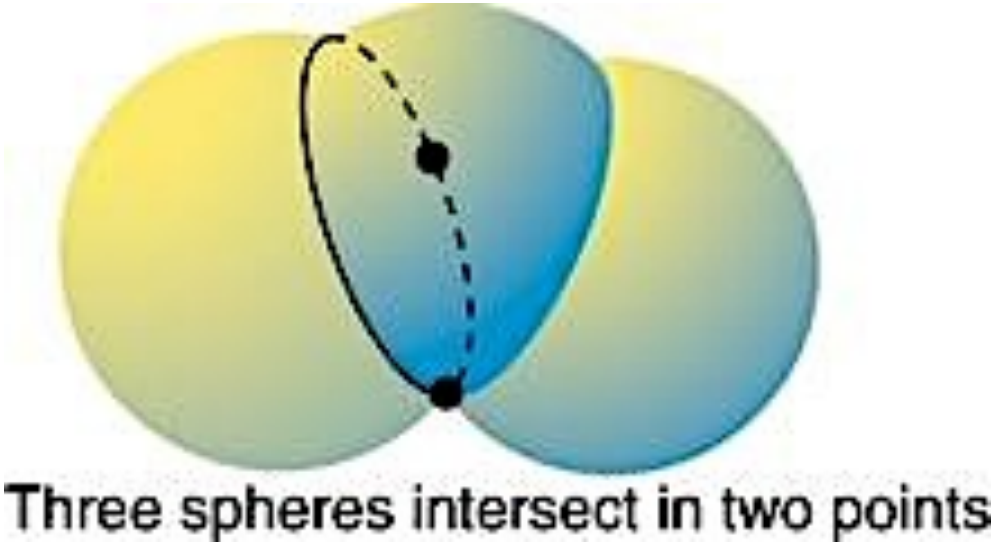
GPS

Intersecting Spheres



Two spheres intersect in a circle

But only 1 point is on the Earth

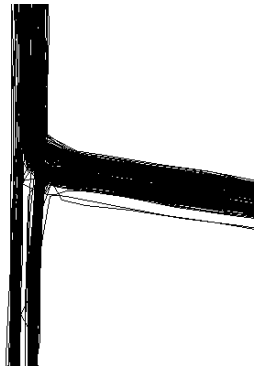


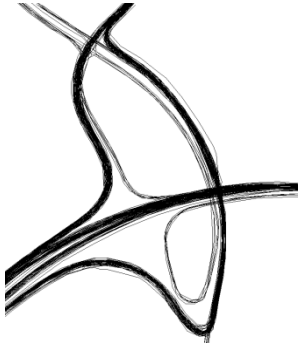
Three spheres intersect in two points

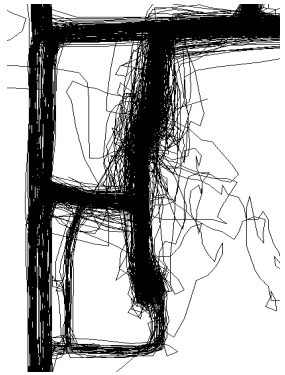
GPS

Satellite

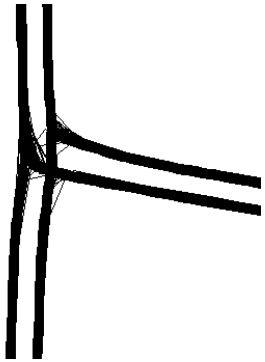
Original GPS data

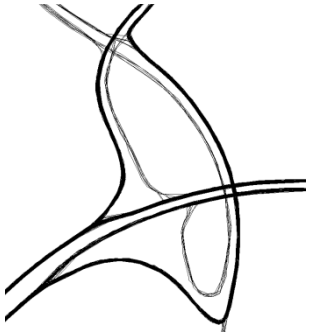


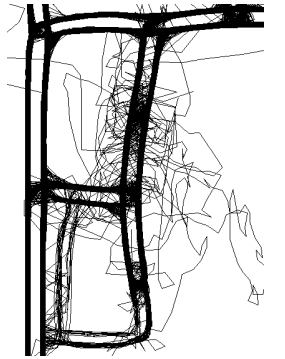




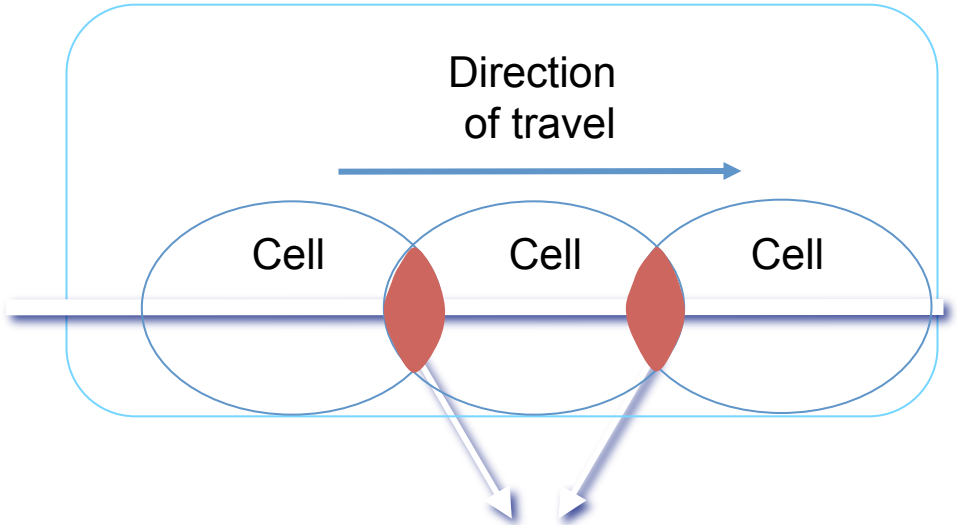
Clarified GPS data







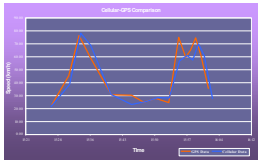
Cellular data

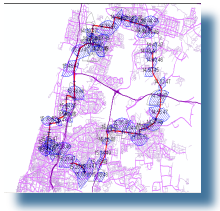


Overlaid on
Navigation quality
GIS

Flow pattern
Analyzed
against GPS
drive data
And
adjustments
made to
pattern model

Iterative process

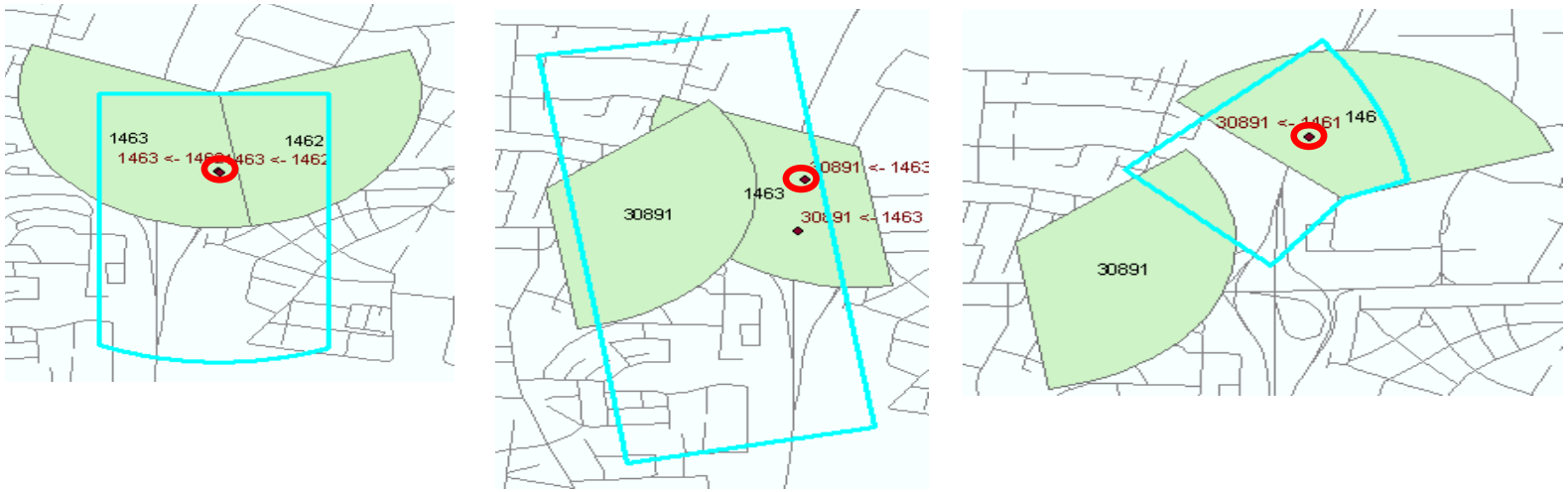




Creates
sample
observer to
observe flow
patterns

Cellular data

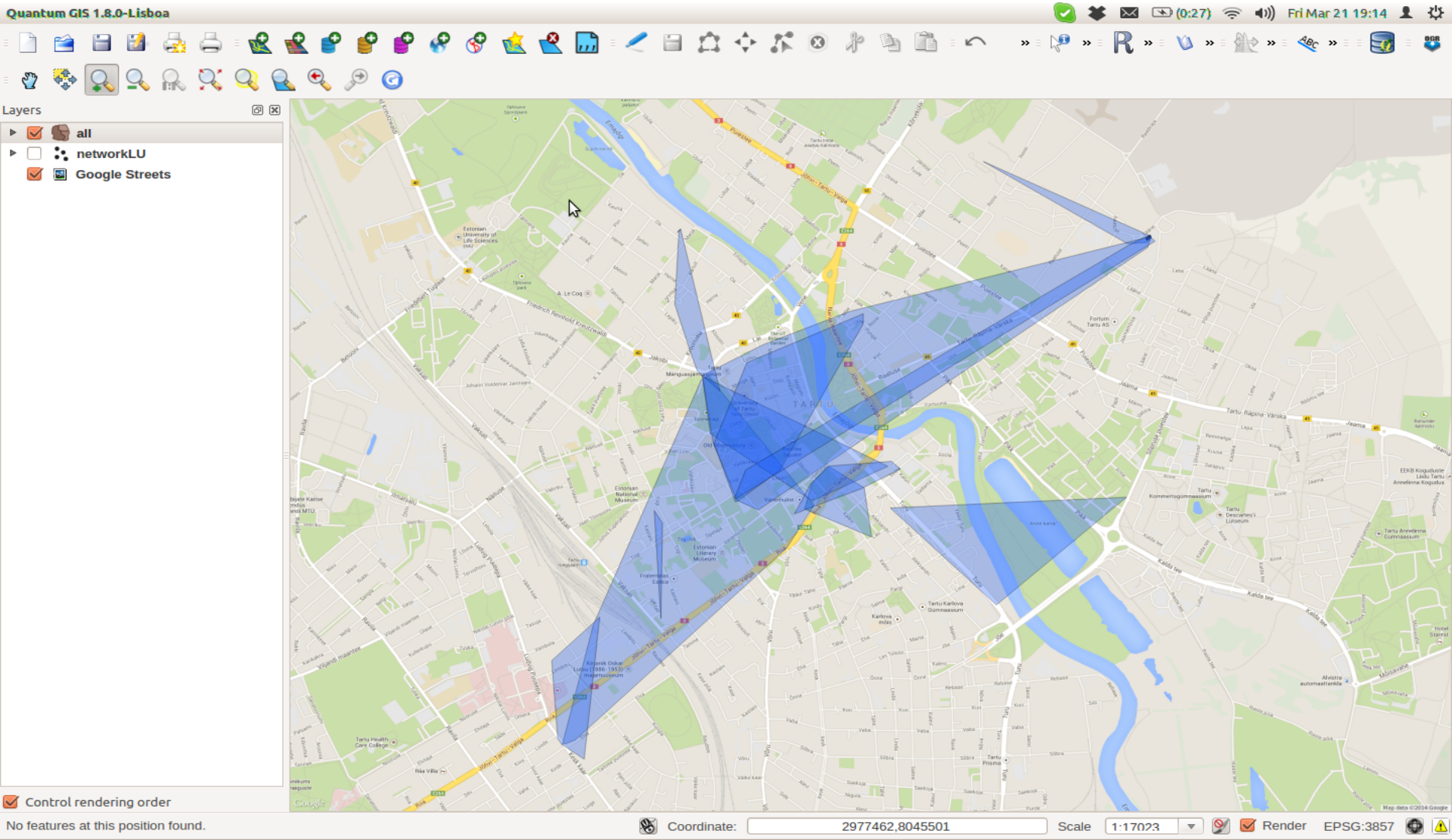
Handover event



GPS data

Location area derived
from location module

Cellular data



Cellular data

Cellular data