Institut für Kartographie und Geoinformatik | Leibniz Universität Hannover

Interpretation of Moving Point Trajectories

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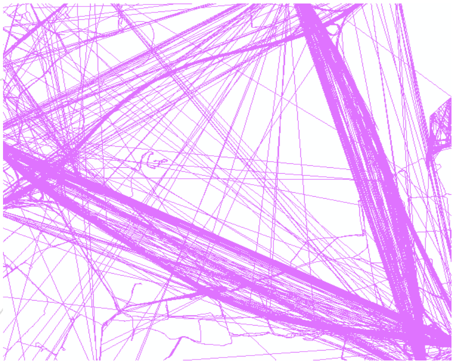
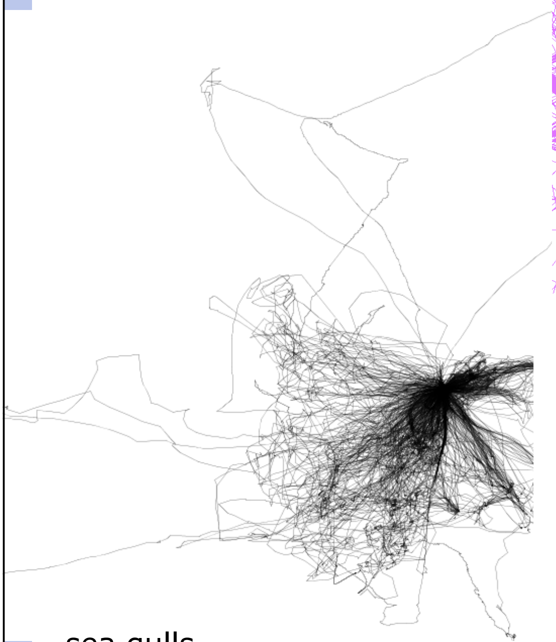
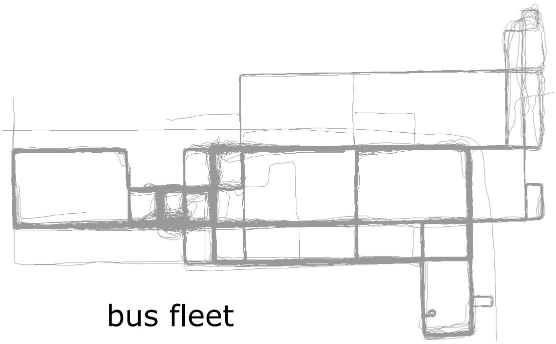
Moving point data

Trajectories



OSM data



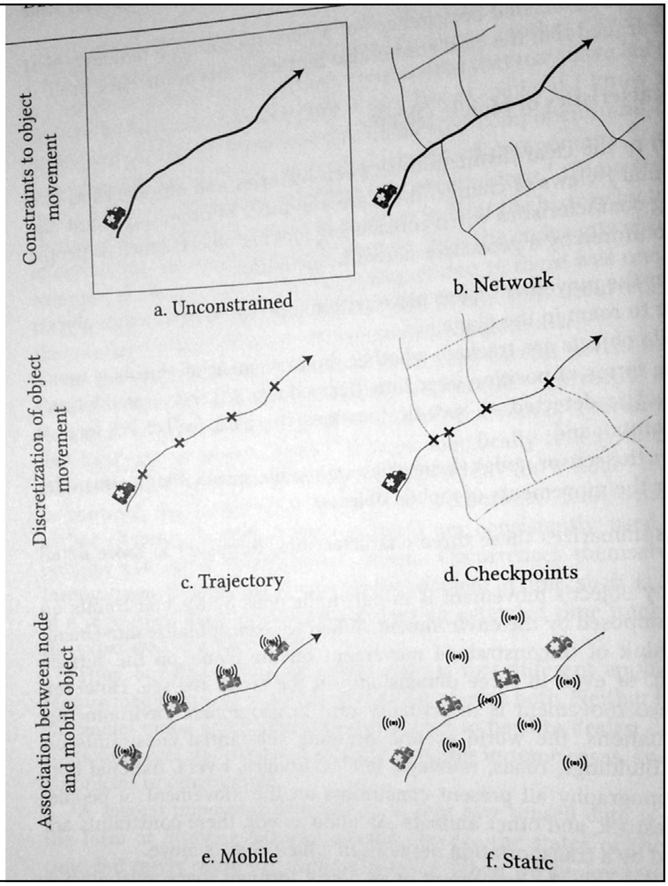


sea gulls

bus fleet

Characteristics of moving objects

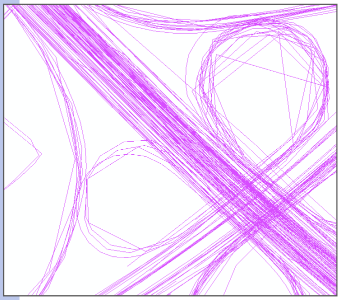
a. unrestricted movement of object
b. restricted movement on network
c. discrete measurement points
d. measurements at certain locations (anchors)
e. mobile sensors
f. static sensors observe moving nodes

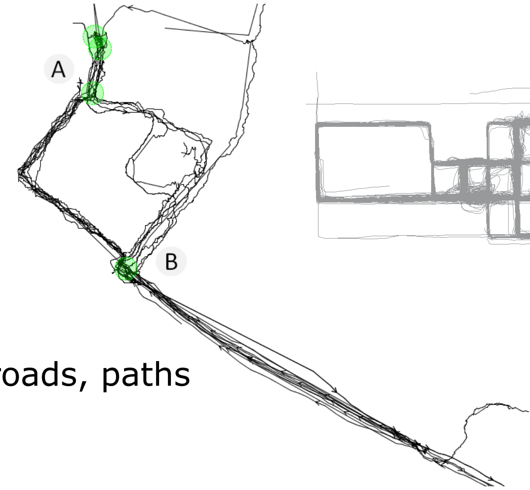


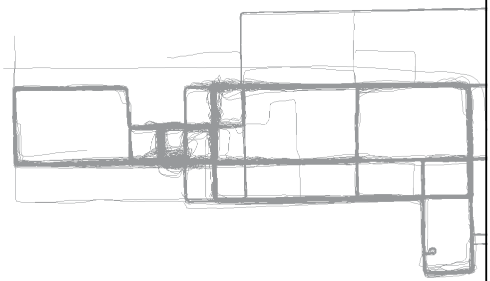
Duckham, 2012

Constrained Movement

- .. by road network
  - e.g. Road junction in OSM
  - pedestrian trajectories at LUH
  - Bus fleet



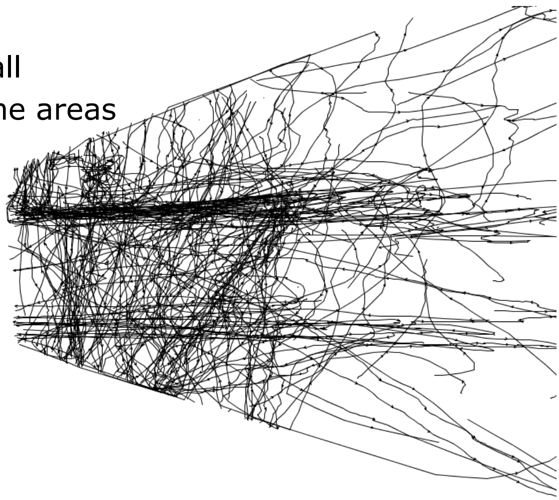




- „Digitization" of roads, paths

Constrained Movement

- By environment:
  - e.g. in a railway station hall: restrictions by kiosks, stairs, elevators, other people
- Example:
  - Trajectories in university hall
  - temporarily blocking of some areas



Constrained Movement

- By behaviour / habits
- Example:
  - GPS-trajectories of sea gulls
  - analysis of animal behaviour: foraging, breeding, …

Moving Point Data

- Sensor registers movement; inferences possible:
  - individual movement behaviour
  - collective movement behaviour
  - constraints in movement (e.g. paths)
- Sensors observe (changing) environment
  - e.g. measure temperature, rainfall, distance to objects, …
  - dense sampling of environmental phenomena (many measurements – possibly of lower quality)
  - inferences possible:
    - environmental maps – of different resolution, thematic depth, …
    - interpolation of continuous phenomena
- Analysis
  - central and/or decentral processing
  - pattern detection, clustering, …

Types of analyses

- moving sensors:
  - a) reflect unterlying movement constraint
  - b) reflect behaviour
- (moving) sensors observe environment:
  - a) incremental data acquisition
  - b) collaborative data acquisition

Interpretation of trajectories

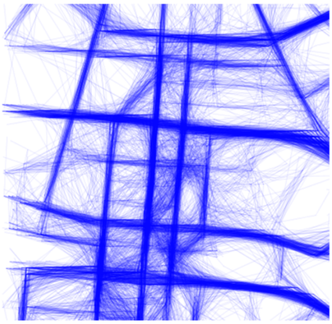
- determination of underlying infrastructure (e.g. road, path)
- determination of rules constraining the movement (e.g. traffic rules)
- determination of movement behavior of individuals or groups
- determination of unusual behavior of individuals or groups
- identification of underlying phenomenon (e.g. part of hill which is sliding)

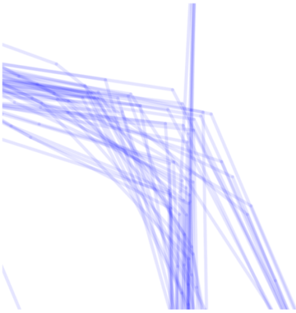
Extraction of road structure

Colin Kuntzsch

Data sets … and challenges

- Data sets acquired by cars / buses
- different coverage of roads
- different accuracy of trajectory locations
  - especially at junctions
  - dependent on sampling rate and position accuracy





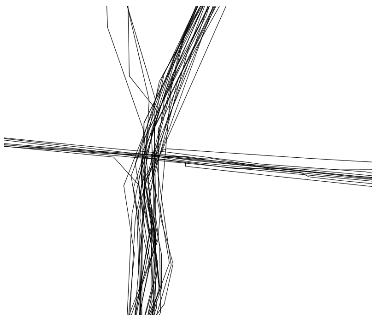
mapconstruction.org

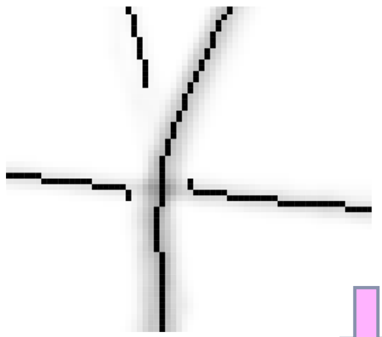
Challenge

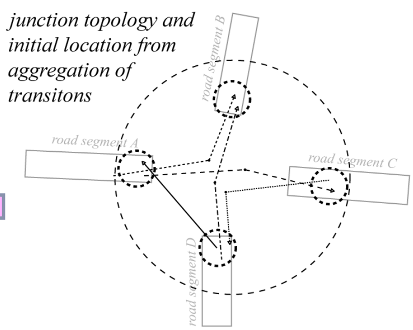
- Recover individual roads – even if coverage is different
- Recover junctions

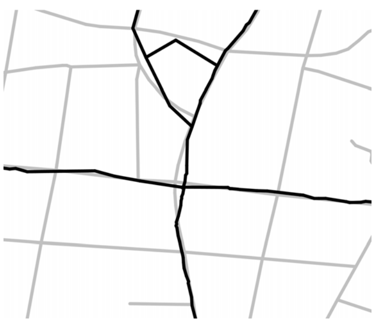
- Approach:
  - Identify road network using density based approach (KDE) – especially road segments
  - Reconstruct correct location and type of junctions, as well as direction of roads using model based approach

Approach



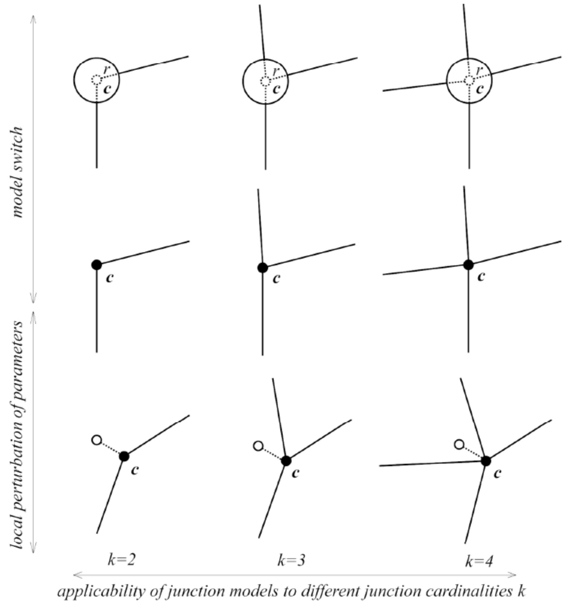




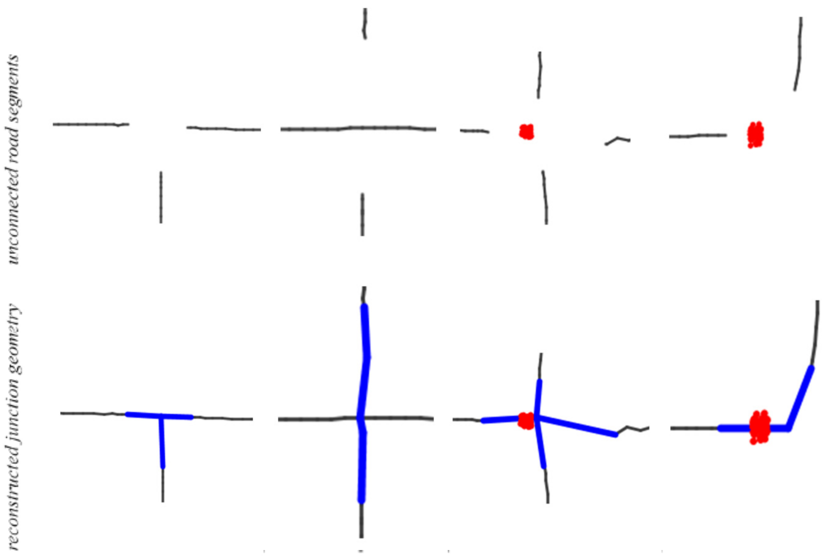


Junction Model

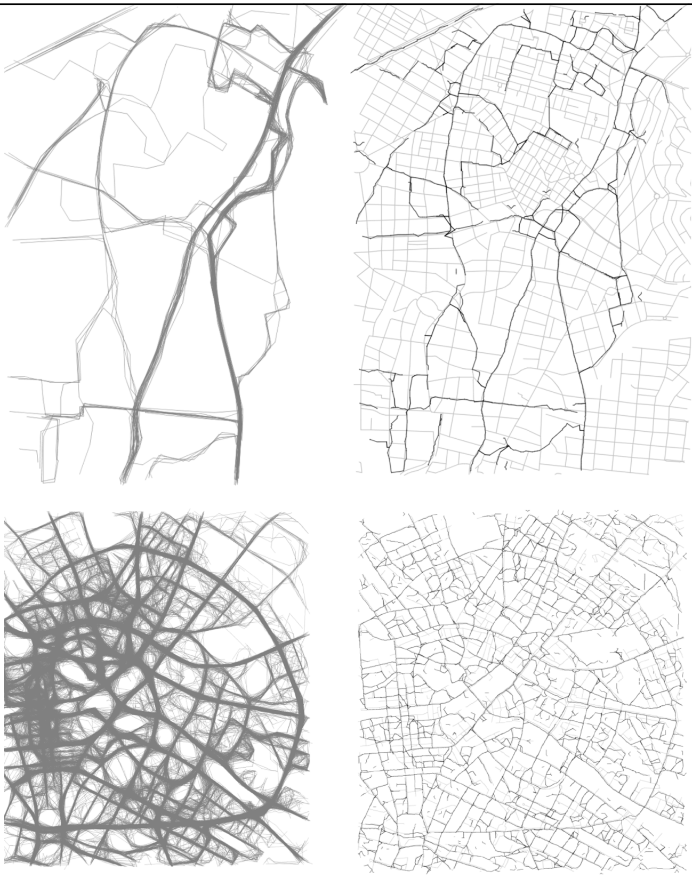
- Explore different possibilities of junction types (cardinality) and junction positions



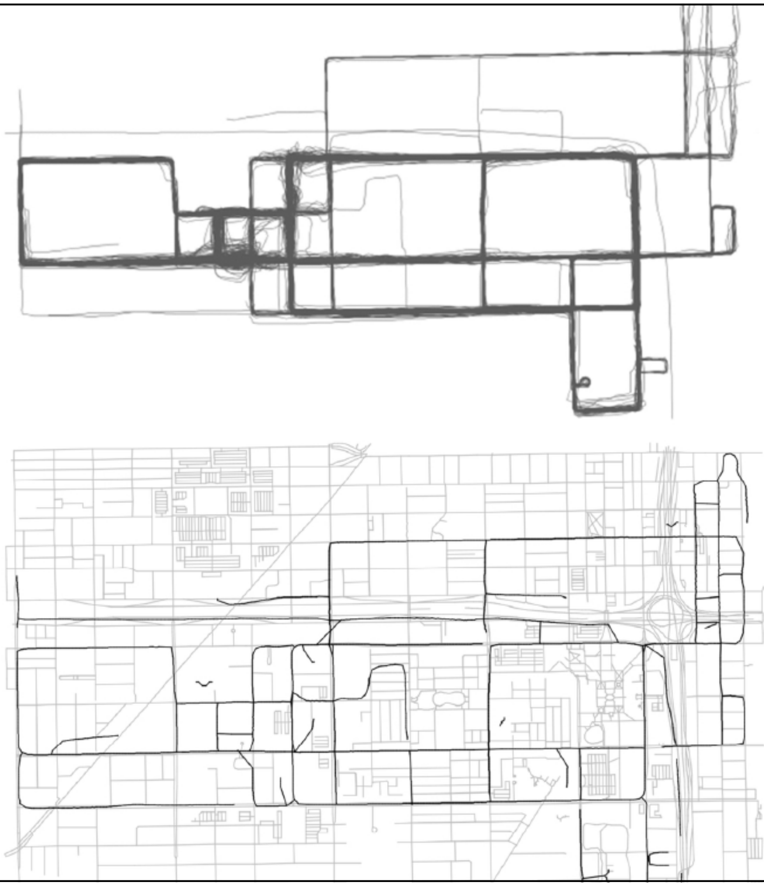
Result of junction reconstruction



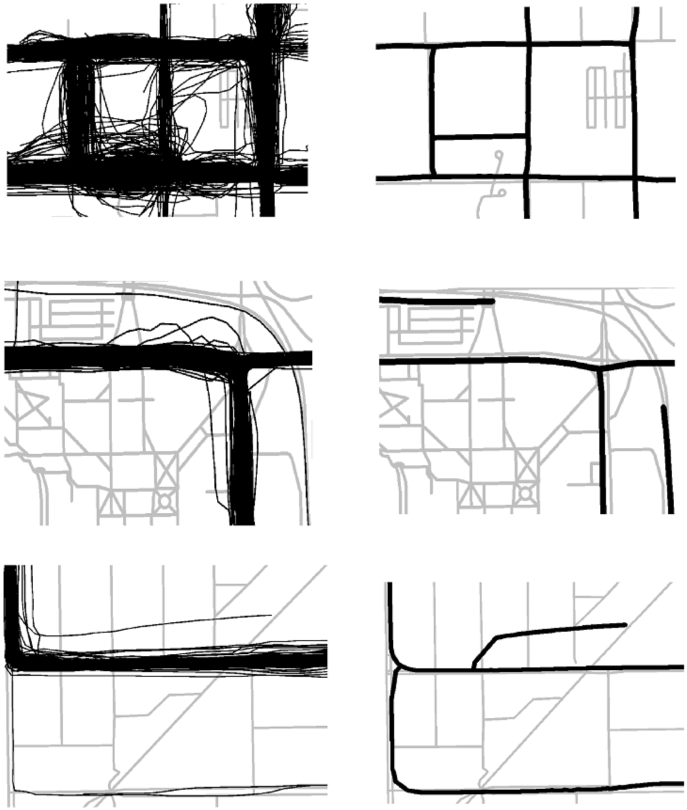
Results



Results



Results



a)

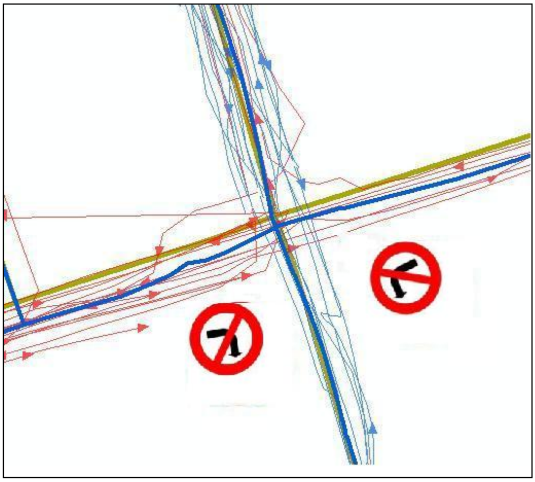
b)

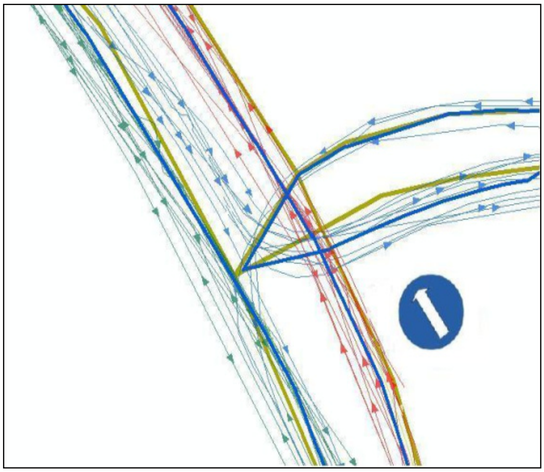
c)

Extraction of traffic regulations

Stefania Zourlidou

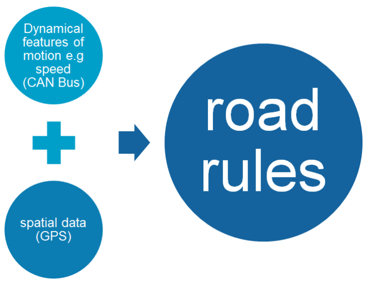
Derivation of traffic regulations





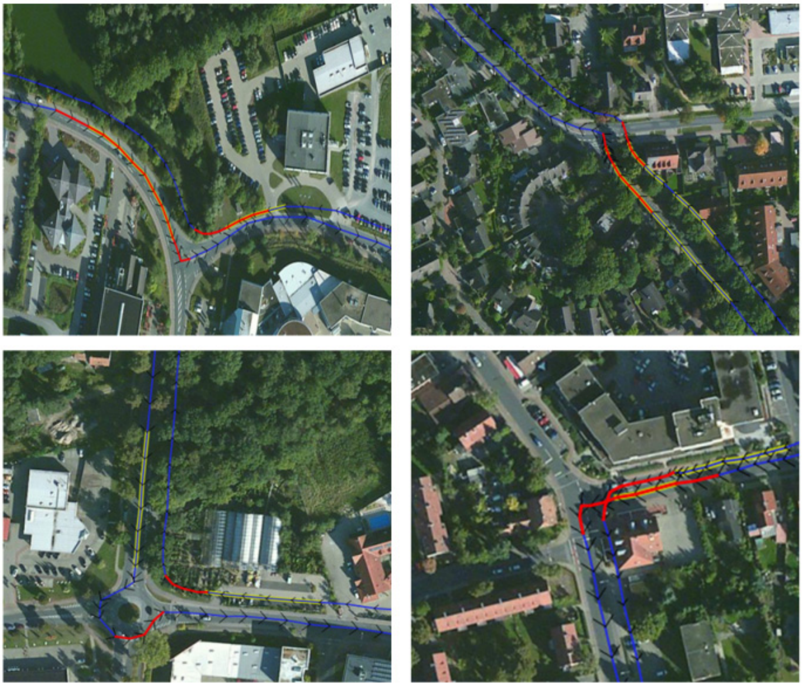
Data source

- In car CAN bus all kinds of information is recorded and stored
  - Position
  - velocity
  - brake
  - blinker
  - motor characteristics
  - energy consumption
  - …



- Idea: exploit information to extract
  - traffic rules
  - traffic behaviour of drivers

Traffic rules / behaviour from trajectories

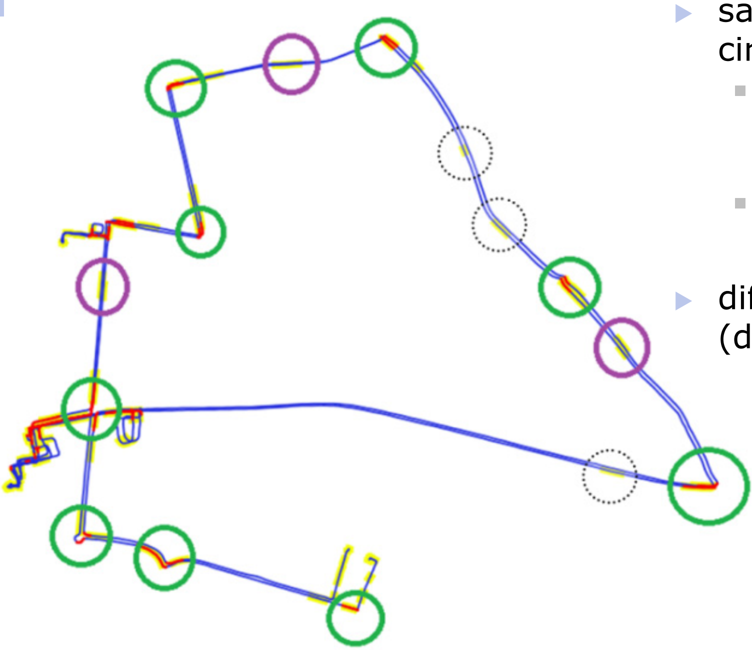


- blue: trajectory
- yellow: break
- red: blinker
- assumption: different drivers show similar behaviour in similar situation / location
- extract rules: speed restrictions, stop, yield, red light, …

Two step approach

- *Clustering of the trajectories:*
  - find clusters of similar trajectories, that is, trajectories that show the same maneuver pattern
  - find clusters of similar pattern at same location
- *Analysis of the extracted clusters:* given a standard 4-way intersection of two roads:
  - If only a right turn maneuver pattern has been identified (cluster of right turns), a compulsory *right turn* rule is valid.
  - If only a left turn maneuver pattern has been identified, a compulsory *left turn* rule is valid.
  - ….
  - If a stop maneuver pattern is detected, a compulsory stop rule is valid

Small Example: two trajectories



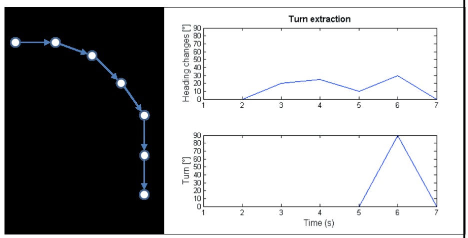
- same behaviour (solid circles)
  - green: sequence of blinker (red) and break (yellow) -> turn
  - violet: break
- different behaviour (dotted circles)

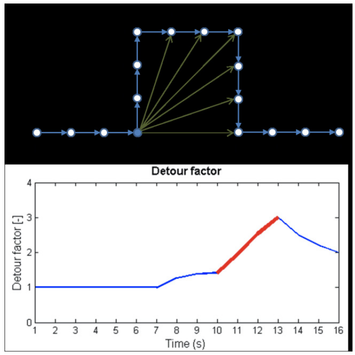
Interpretation of (atypical) behaviour

Lijuan Zhang, Hai Huang

Determination of atypical behaviour

- Idea: driver shows a specific behaviour when he/she got lost
- -> offer help!
- Components of behaviour:
  - dense sequence of turns
  - detour
  - route repetition
- for each of these components probabilities for typical behaviour are determined
- fusion of probabilities in Hidden Markov Model



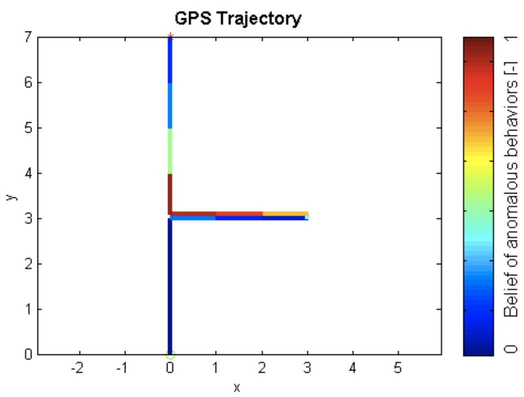


[Huang & Zhang]

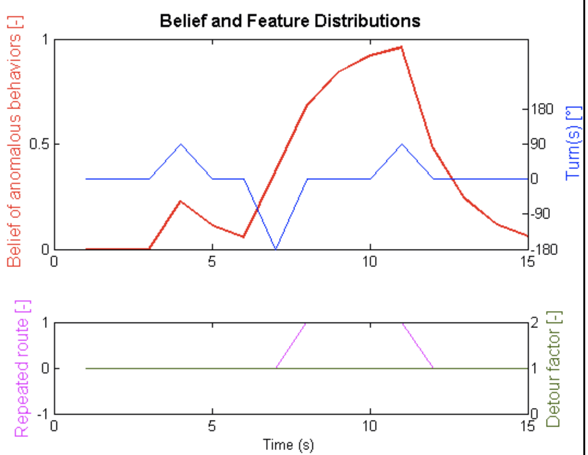
Determination of atypical behaviour

- Example: route from bottom to top

Goal

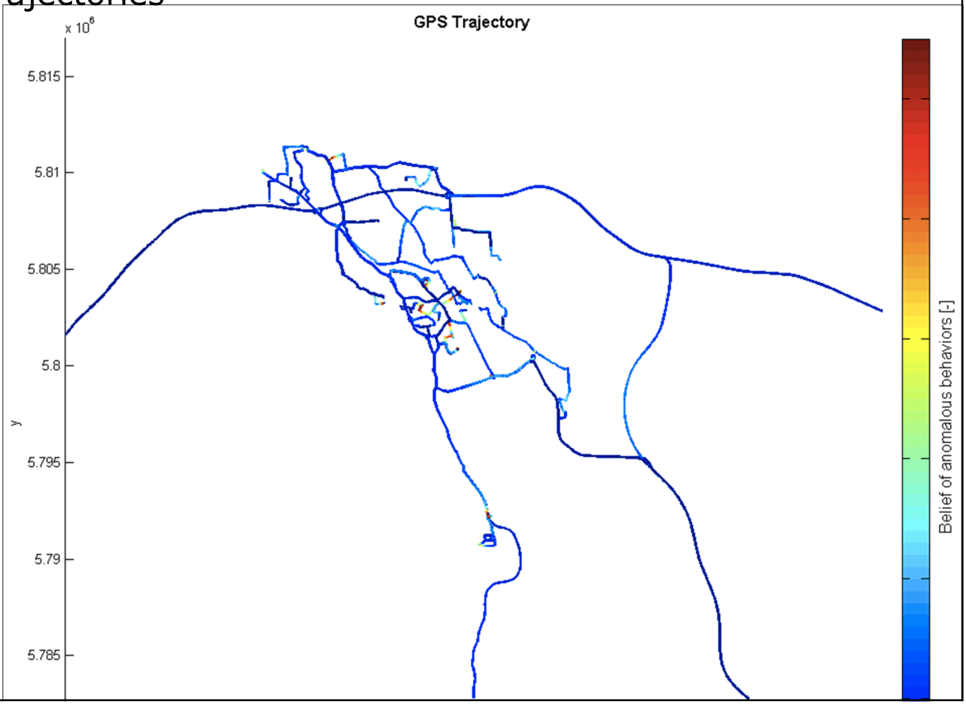


Start



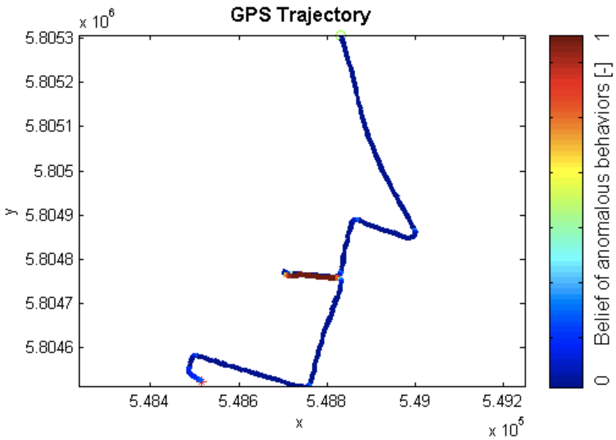
Determination of atypical behaviour

- 100 trajectories

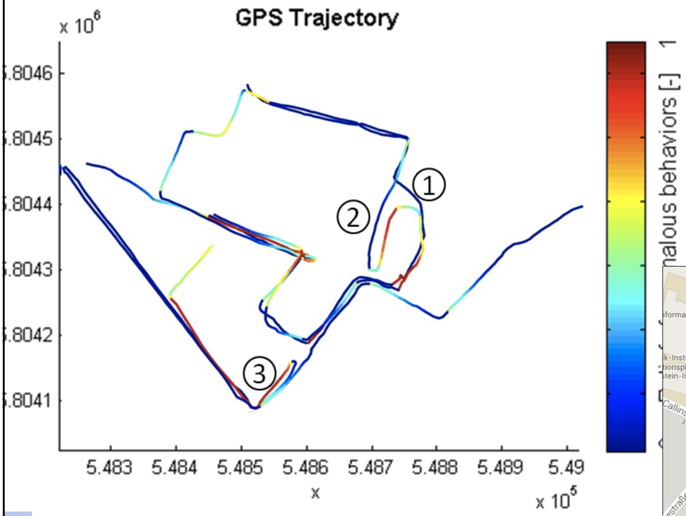


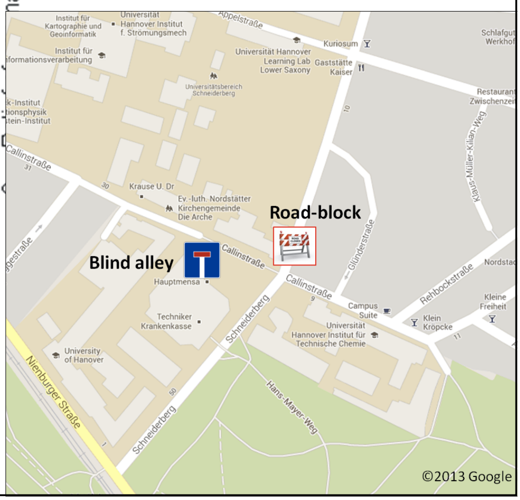
Examples

- Details



Indication of atypical traffic situation



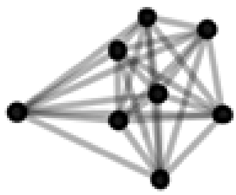


Detection of Group Patterns – in soccer

Udo Feuerhake

Team Movement Patterns

Team Movement Patterns



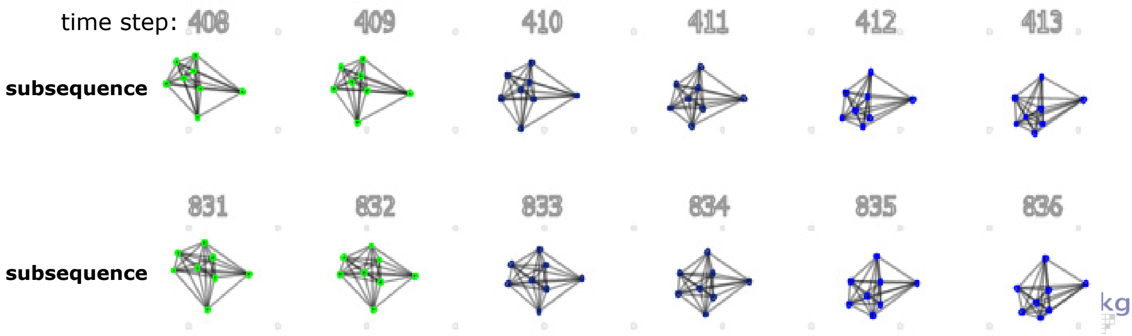
- Approach is based on
  - fixed number of players
  - constellations (vector of relative player positions – scale, rotation, translation independent)
- Sequence of constellations is recorded during the observation time (e.g. at 1Hz)

- Clustering of constellations based on similarities

- -> Cluster Sequences (e.g. red, red, red, green, green, green, …)

Team Movement Patterns

- Use of **sequence mining** algorithm to extract patterns from the sequence of clusters (clustered constellations): same sequence of constellations, e.g.:
  - D,F,A,A,B,C,D,E,F,A,A,B,A,B,C,C, ..
- Example pattern (occurred twice during the observation time):
  - Transition of constellations green, green, blue, blue, light blue, light blue
  - "three middle players move from top to down"



Team Movement Patterns

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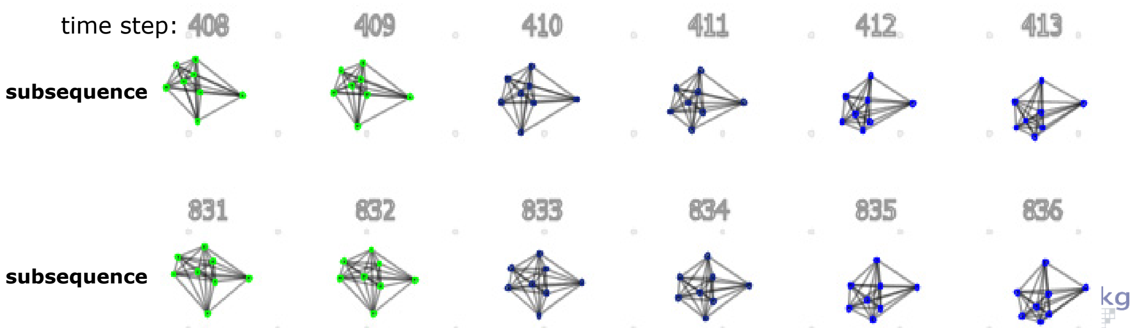
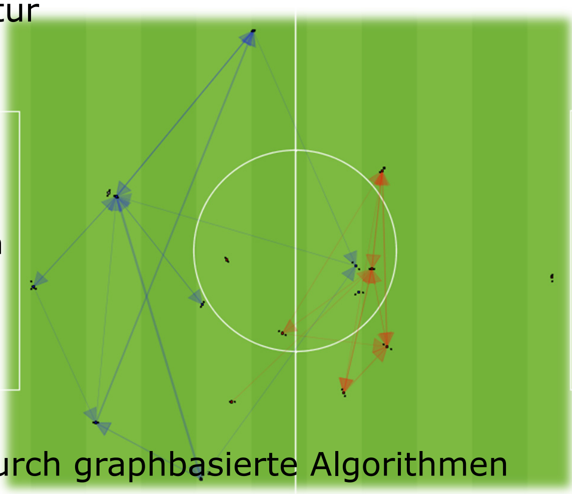


Weitere Analysen: "Passgraph"

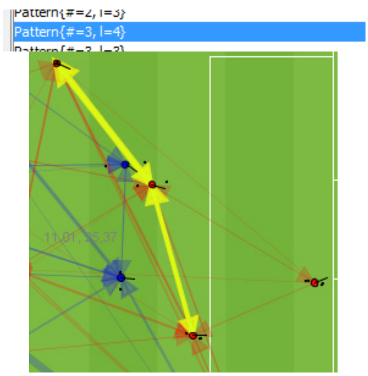
- Erzeugung einer Graphstruktur
  - Knoten ↔ Spieler
  - Kanten ↔ Pässe
  - Kantengewicht ↔ Anzahl der Pässe zwischen Paaren von Spielern



- Visuelle Analyse
- Automatische Auswertung durch graphbasierte Algorithmen
  - z.B. häufige Passsequenzen
  - …

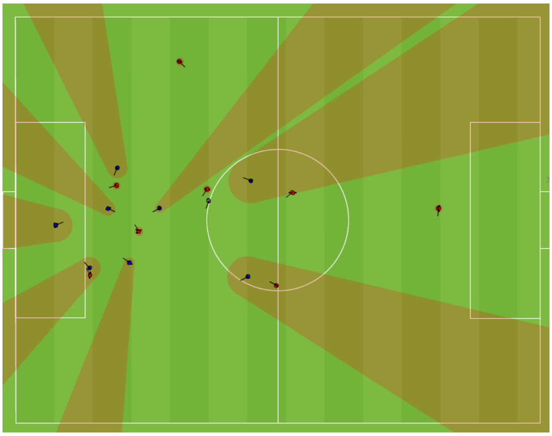
Passmuster

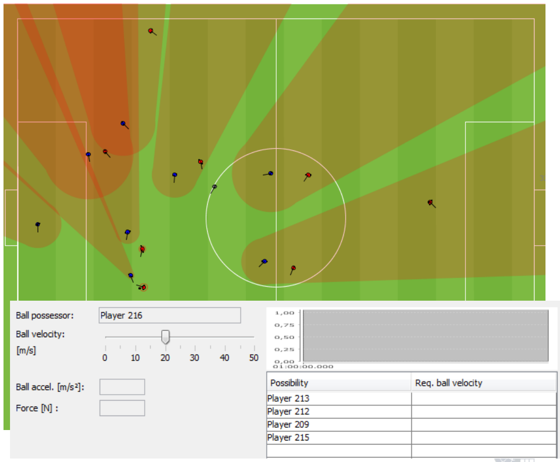
- Muster aus der Pass-Historie
- Sequenz Mining Ansatz: Spieler A spielt zu B, der zu C und zurück zu A, ..



Mögliche Pass-Empfänger

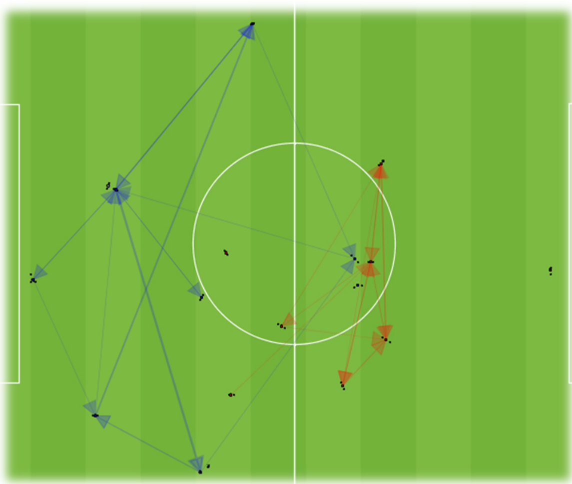
- Bestimmung der überdeckten Flächen
  - Abhängig vom Bewegungsmodell der Spieler und des Balls
  - Manuelle Variation der Passgeschwindigkeit möglich
- Interessant: Bestimmung der optimalen Passgeschwindigkeit!





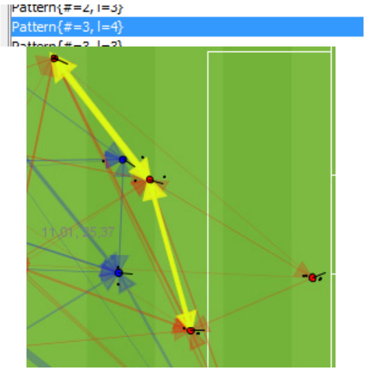
Advanced Analyses: Pass Graph

- Generation of a graph structure ↔
  - Nodes ↔ players
  - Edges ↔ passes
  - Edge weight ↔ frequency of passes between pair of players
- Visual analysis is possible
- Analysis via graph based algorithms
  - Frequent pass sequences
  - …



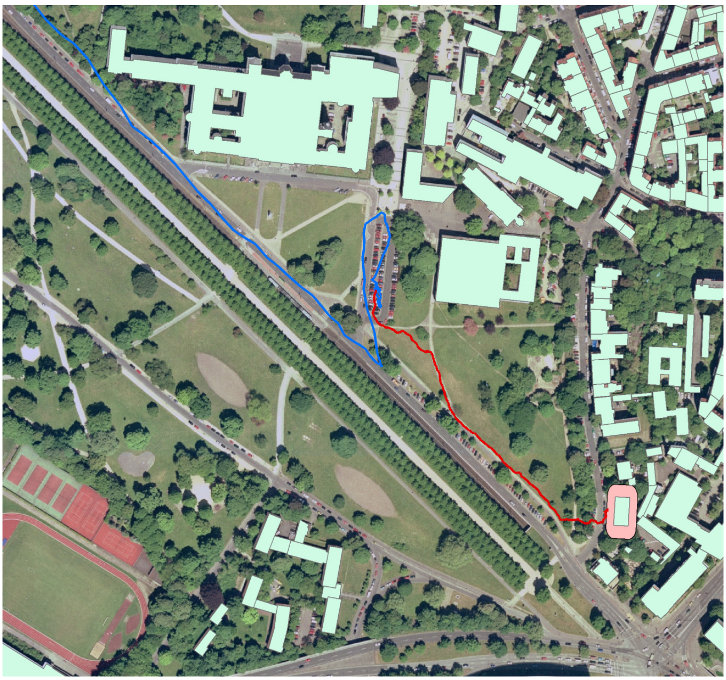
Advanced Analyses: Pass Patterns

- Patterns are extracted from pass history
- Mining approach similar to the ‚team movement pattern‘ approach



Analysis of typical transitions between modes

- E.g. car -> walk: identify parking spaces associated with entrances



Interpretation of movement behaviour

- Moving point data are being acquired by different sensors (e.g. cameras, GPS, Mobile phones, …) and for different purposes and applications (e.g. animal behaviour analysis, surveillance, …)

- Two projects dealing with interpretation of movement behaviour
  - Determination of group patterns
  - Determination of typical behaviour and movement prediction

Summary

Summary

- More and more trajectory data are available
- Trajectory data contain rich information concerning **behaviour** and **underlying structure**

- Relevant applications:
  - Analysis of animal behaviour
  - Analysis of typical/atypical behaviour
  - Capture of up-to-date environmental information (e.g. traffic jams, usage of infrastructure, …)

- Challenges
  - large data sets / streaming data
  - integration of different data sets
  - generic analysis methods
  - decentralized processing
  - data ownership and privacy