Using Stationary Vehicles to Enhance Cooperative Positioning in Vehicular Ad-hoc Networks

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- TS: vehicles + infrastructure + human component.
- Problems: traffic congestion, COx emissions, routing.
- Trivial solutions: build additional capacity, incorporate new physical infrastructure.

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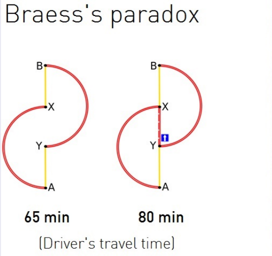

Transportation systems

- Modern tools: wireless communication systems, information technologies.
  - **Intelligent Transportation Systems (ITSs):** flexibility, adaptation, scalability, better-informed decisions.

Some examples of ITSs

- Advanced Traveler Information: Real-Time Traffic Information.
- Advanced Public Transportation: Electronic Fare Payment.
- Fully integrated systems (V2V + V2I + integration): Positioning Systems for location-based services.

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Positioning systems

- Non-cooperative systems: no interaction between vehicles. Mainly based on
  - Global Navigation Satellite Systems (GNSSs), and Augmented GNSSs (A-GNSSs).
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Relevance of anchor nodes in CP algorithms

- Anchor: a node which knows its absolute location with high accuracy.
- CP algorithms using anchors: High accuracy for relative and absolute localisation of blind (unlocalised) nodes.

Road-side unit (RSU) as anchors

- Pros:
  - Only require to be localised once.
  - Located close to roads.
- Cons:
  - Costs for deploying RSUs are, in general, high.
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Types of stationary vehicles

- Powered-on stationary vehicles: e.g. cars stopped in a queue.
- Powered-off stationary vehicles: e.g. parked cars.

Some uses of stationary vehicles as prioritised nodes

- Mitigation of inter-vehicle signal attenuation.
- Content downloading and distribution[a].

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Pros/cons of using stationary vehicles for positioning purposes

- Pros:
  - On-board system remaining active: stationary cars can stay as active nodes.
  - Stationary cars turning into anchors: they can act like RSUs and have high priority for the CP process.
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Some statistics

- Duration of the stop: a car is stopped up to 50% of the travelling time and parked up to 95% of its life time (on average).
- Zones to be covered: stopped cars at intersections and parked cars have wide geographical distribution.
- Battery consumption: a typical on-board system using the 10% of the battery capacity can be continuously used up to 2 days.

Some potential benefits

- Coverage: at intersection and in between intersections.
- Time of availability: full time (on average).
- Localisation accuracy: lane-level (expected).

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Localisation capabilities

- A-GNSS positioning
  - for scenarios without time restrictions (e.g. powered-off blind stationary nodes).
- CP
  - for scenarios with access to information from nearby vehicles (blind stationary/moving vehicles).
- GNSS positioning
  - for scenarios where nearby vehicles are not available but enough number of satellites,
- INS positioning
  - for scenarios where neither nearby vehicles nor satellites are available.

Localisation process

- Blind stationary vehicles:
  - If at least 3 anchor nodes are available inside the communication zone, use a CP algorithm.
  - Use A-GNSS positioning as back-up method.
  - After successful localisation, they become anchors.
- Blind moving vehicles:
  - Use a CP algorithm if at least 1 neighbor node is available inside the communication zone.
  - Otherwise, use GNSSs/INSs.
  - After successful localisation becomes at most a pseudo-anchor (moving car with access to 3 anchors).

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Node selection strategy

- At most three vehicles are going to be considered in the CP process of any vehicle of interest.
- Node selection is according to three different priority levels:
  - first priority for anchor nodes,
  - second priority for pseudo-anchor nodes (blind vehicles with access to enough information from anchor nodes),
  - third priority for the remaining vehicles.

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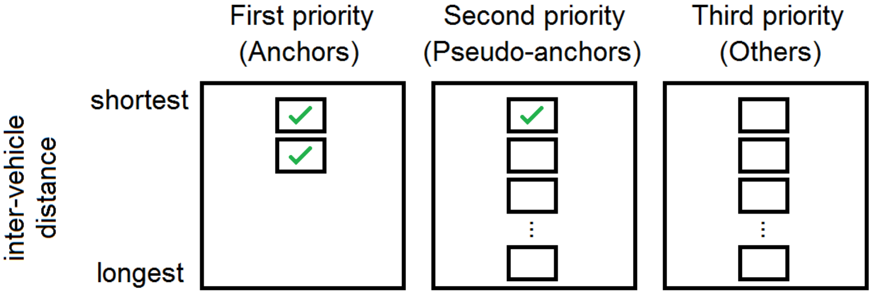

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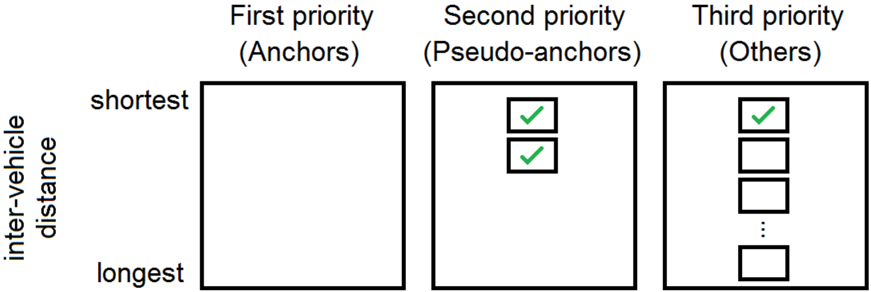
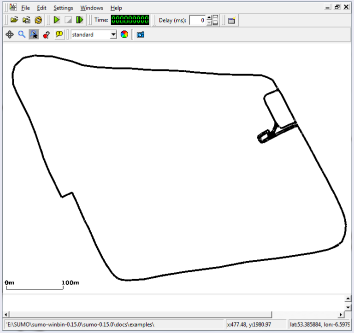


SUMO side

The road: A street circuit around the North Campus, National University of Ireland - Maynooth.



Parameters

- Simulated vehicles: 20 cars (5 of them parked).
- Attributes of vehicles: 5 cars of each type A,B,C,D.

Type	A	B	C	D
Accel	2.15	5.5	4.54	50
Decel	1.22	5.0	4.51	30
Length	1.75	6.1	4.45	40
Max.S.	2.45	6.1	4.48	50

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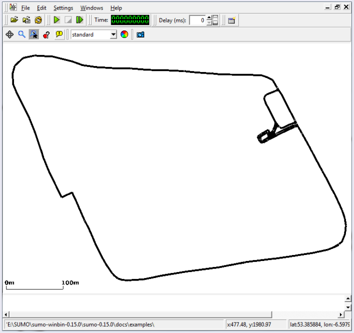

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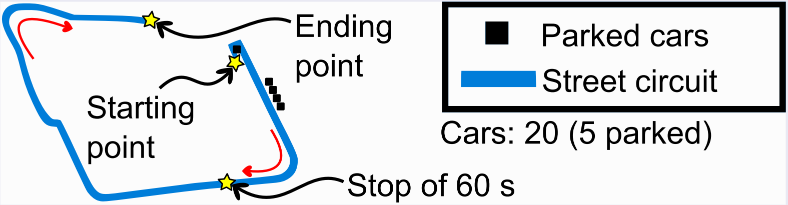
Algorithm side

- CP Algorithm:
  - Extended Kalman Filter (EKF) with distributed architecture[a].
  - Data fusion: inter-vehicle distance measurement + vehicle kinematics (velocity).
- Parameters:
  - GPS noise covariance: 100.
  - Covariance of mobility variations: 2.
  - Covariance of inter-vehicle measurement noise: 0.05.
  - Covariance for velocity measurements: 0.5.

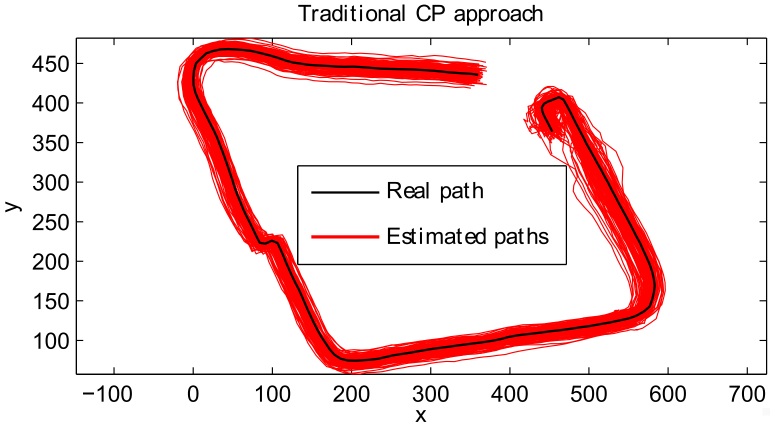
[a] R. Parker and S. Valaee, "Cooperative vehicle position estimation", in IEEE ICC '07.

Type of test

- Scenario:
  - 5 parked cars.
  - 15 cars going from the starting point to the ending point, with a stop of 60 seconds at a given intersection.
  - Communication zone: 100 m.
  - Number of repetitions: 100.



Simulation results



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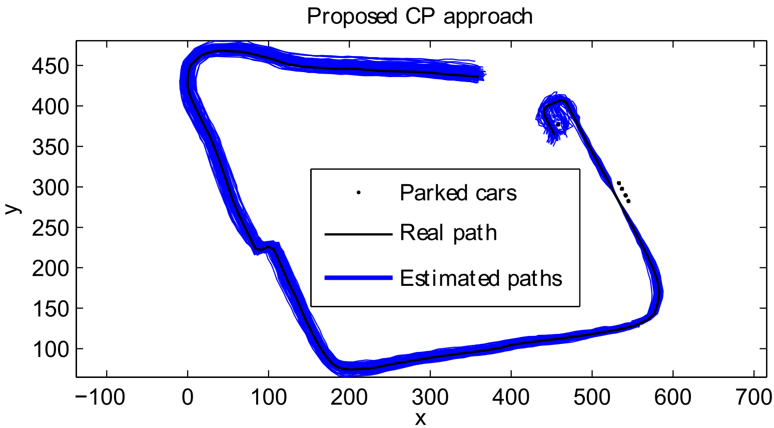
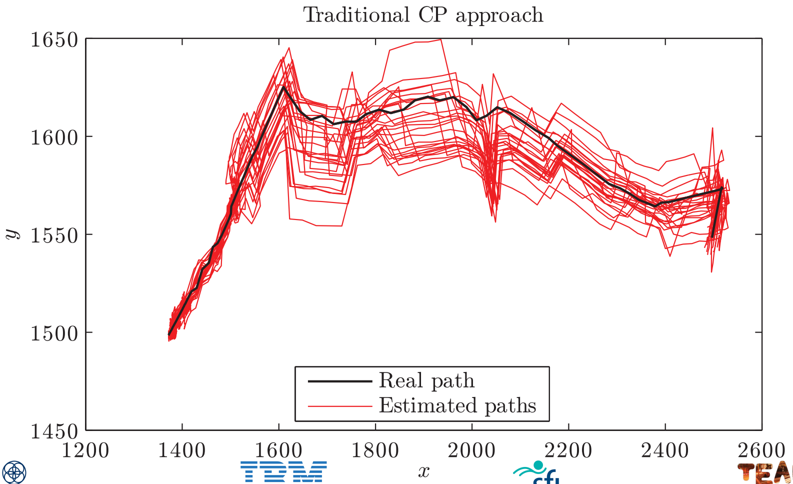


Quantitative analysis

RMS localisation error (meters)				
Traditional CP approach		Proposed CP approach		
Mean	σ	Mean	σ	Average improvement
9.04	5.09	4.06	2.97	55.09%

Some results from the current work



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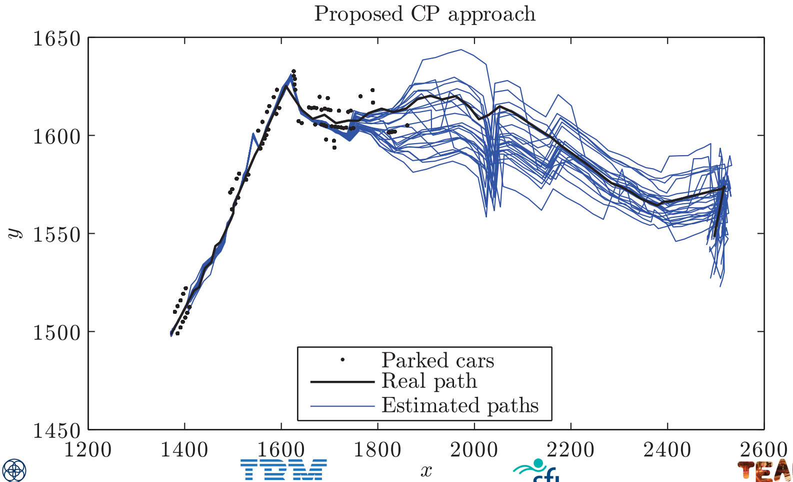

Quantitative analysis

Communication zone: 15 meters.

Repetitions: 25.

RMS localisation error (meters)				
Traditional CP approach		Proposed CP approach		
Mean	σ	Mean	σ	Average improvement
8.46	6.97	3.14	6.27	62.85%

Preliminary conclusions

- Direct:
  - Accuracy for localisation was greatly improved (about 55%) with respect to a traditional approach.
  - Zones covered by stationary vehicles showed to have wide geographical distribution.
- Indirect:
  - Potentially any CP algorithm can be benefited from the proposed CP approach.

Current and future work

- General paper [3] is being prepared: battery-consumption issues, large-scale tests, more detailed analyses.

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For Further Reading

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