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PUSHING THE LIMITS OF LOW-COST PPP WITH REAL-TIME IONOSPHERIC CORRECTIONS

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OUTLINE

- Motivation
- *magicFAST* Real-Time Infrastructure
- Experimentation Results
- Conclusions

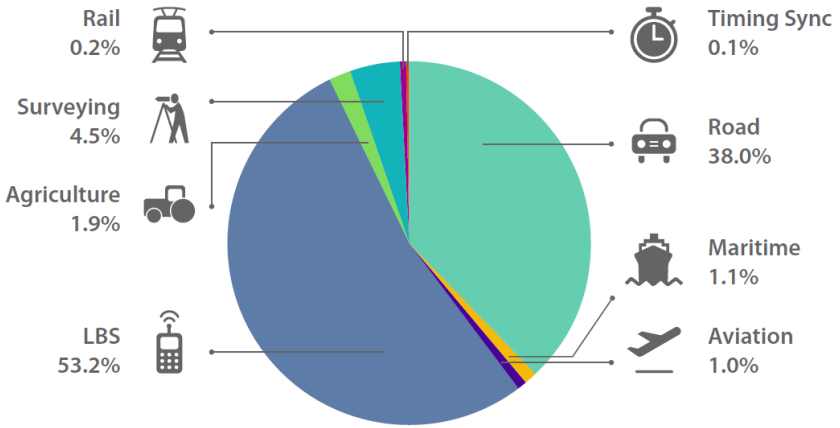
MOTIVATION

- Precise Point Positioning (PPP) has traditionally played an important role in surveying, farming, offshore applications…

- Jump to mass-market applications limited by:
  - Need of a professional-grade receiver
  - Multi-frequency measurements
  - Market motivation

- Recent Low-Cost Receivers:
  - Improved measurement quality
  - Still single frequency
  - Mass-market oriented

Cumulative core revene 2013-2023



Extracted from GSA Market Report 2015

MOTIVATION

Market shows a niche opportunity for Low-Cost PPP
Especially in the automobile sector for In-Vehicle Systems

- GMV has developed the algorithms and infrastructure to provide real-time PPP with single-frequency low-cost receivers
- Focused on the achievement of two goals:
  - *High Accuracy*: Provide a positioning solution with an error of few centimeters in steady state
  - *Fast Convergence*: Reach High Accuracy within a short time after the PPP algorithm is started

Initial Objective

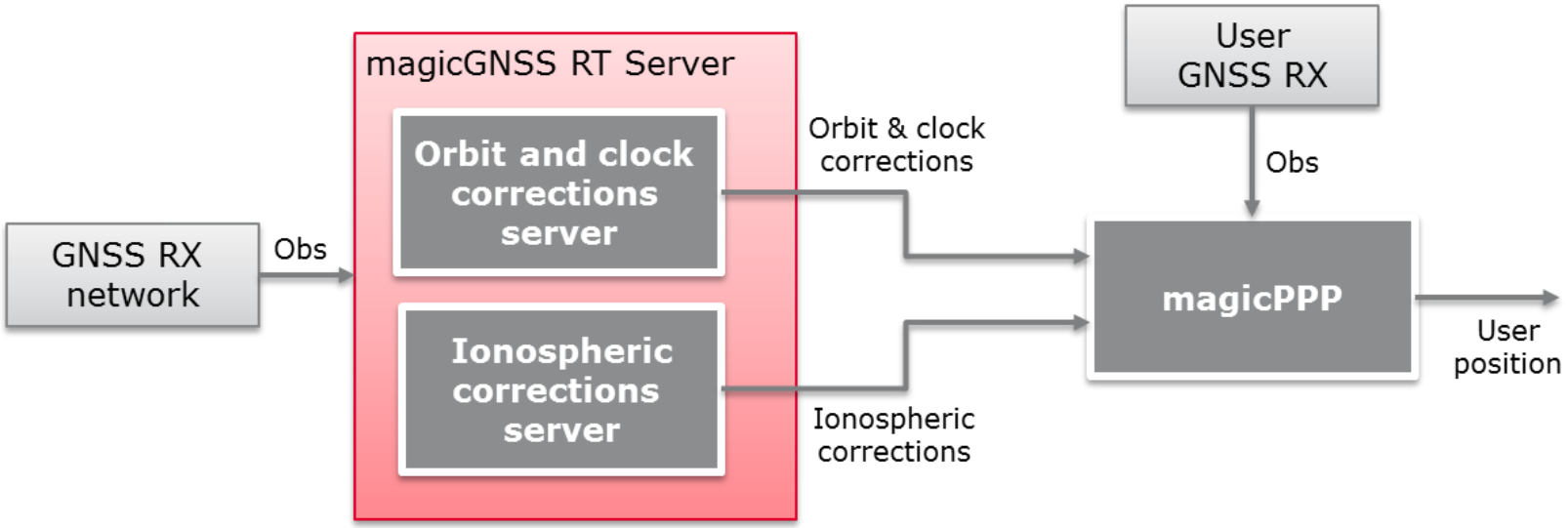
Convergence Time	Positioning Accuracy
5 min	40 cm
10 min	30 cm

MAGICFAST REAL-TIME INFRASTRUCTURE

magicFAST

GMV's service of Low-Cost PPP based on Single Frequency techniques using Ionospheric Corrections

- Update of *magicPPP* to cope with peculiarities of processing measurements from low-cost receivers
- Development of *magicFAST* server to predict ionosphere delays



MAGICFAST REAL-TIME INFRASTRUCTURE

magicPPP

Iono-Free

$$l_p = \rho + c(b_{Rx} - b_{sat}) + Tr + HW_p + \varepsilon_p$$
$$l_\phi = \rho + c(b_{Rx} - b_{sat}) + Tr + HW_\phi + N\lambda + \varepsilon_\phi$$

Single Freq

$$l_{1p} = \rho + c(b_{Rx} - b_{sat}) + Tr + I + HW_p + \varepsilon_{1p}$$
$$l_{1\phi} = \rho + c(b_{Rx} - b_{sat}) + Tr - I + HW_\phi + N_1\lambda + \varepsilon_{1\phi}$$

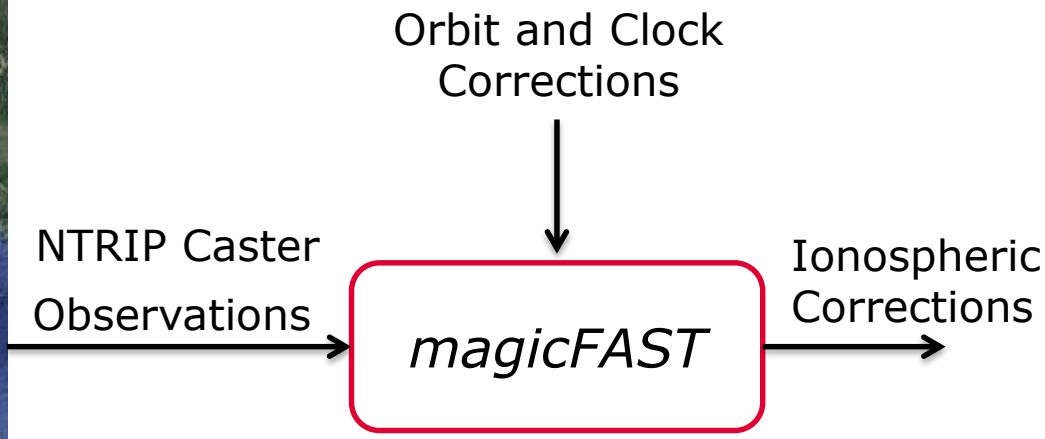
In addition:

- Update of multipath rejection models for low-cost receivers and patch antennae
- Fine-tuning of PPP algorithm
  - Measurement and process noise
  - Preprocessing and validation of measurements
  - …

MAGICFAST REAL-TIME INFRASTRUCTURE

magicFAST Server

- Regional Network
- Low Station Density: 115000 km^2/station
- Independent Server



EXPERIMENTATION RESULTS

Experimentation Set-Up

- Static open-sky benchmark scenario using choke ring antenna
  - Known calibrated position of antenna
- Kinematic tests using patch antenna
  - Trimble R10 professional-grade rover receiver used for reference trajectory generation using RTK technique

EXPERIMENTATION RESULTS

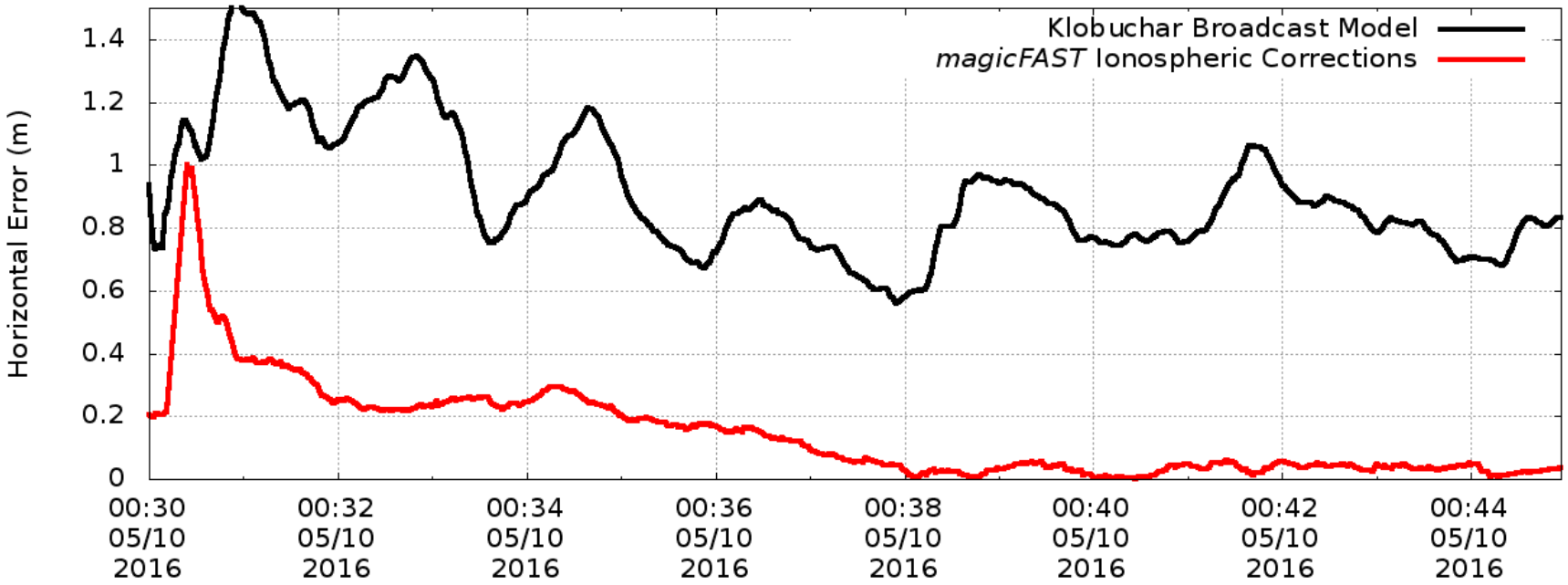
Experimentation Set-Up

- Experimentation campaign carried out in Tres Cantos (Madrid)
- *magicFAST* server configured with a low-density network

- Data obtained from the European Permanent Network (EPN) provided by the EUREF NTRIP Caster hosted by ROB
- Limited to 6 stations at a maximum distance of 600 km to the user
- Closest station to user located in Leon, at a distance of 290 km

EXPERIMENTATION RESULTS

Static Open Sky Benchmark Scenario



- Horizontal positioning error below 50cm after 1 minute
- After 10 minutes, positioning error is bound by 10 cm
- Bear in mind that this scenario uses a choke ring antenna

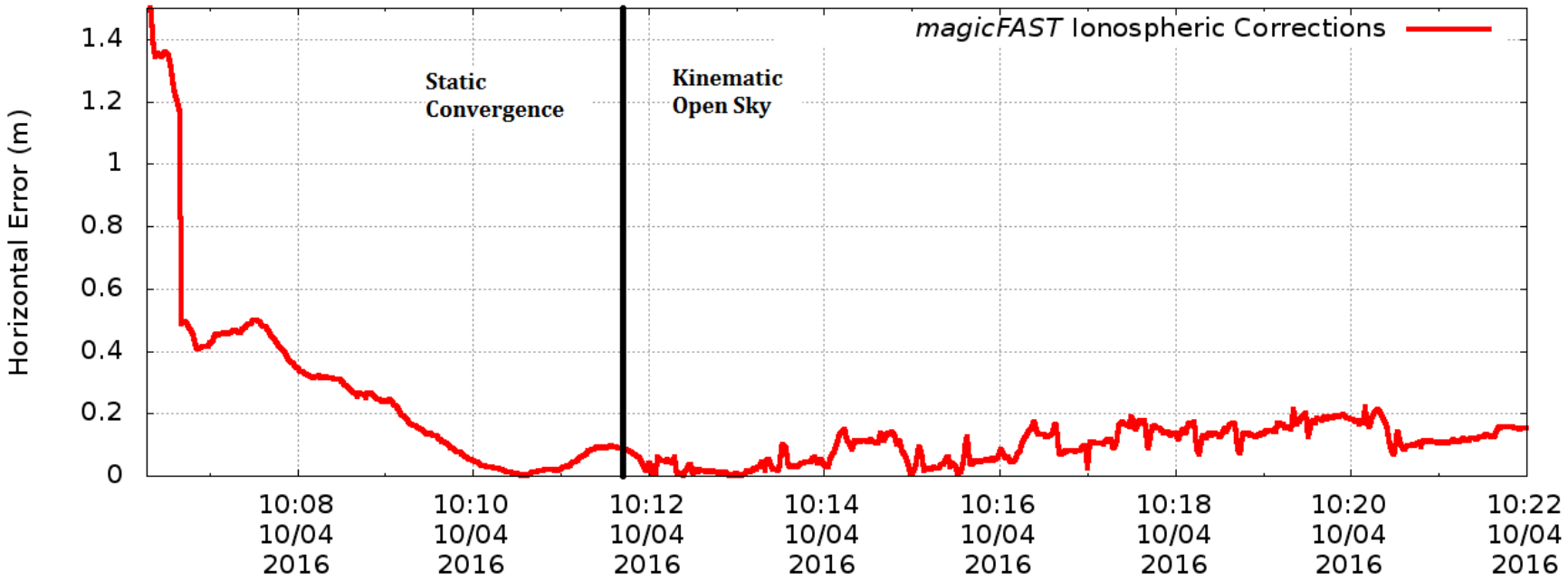
EXPERIMENTATION RESULTS

Kinematic Open Sky

- Outskirts of Tres Cantos in a residential area with isolated buildings
- Activity related to the building sector, presence of trucks
- Testing car parked during the first 5 minutes of the test
- Patch Antenna

EXPERIMENTATION RESULTS

Kinematic Open Sky



- Positioning error is below 20 cm after 5 minutes
- Increased multipath inherent to patch antenna
- Peaks related to reference trajectory misalignment in bends

EXPERIMENTATION RESULTS

Kinematic Sub-Urban

1. *Weak Sub-urban*: Tall buildings (8 stories) with low densitiy, i.e. one building every 4-5 unconstructed lands
2. *Sub-urban*: Industrial area with factories at both sides of the street. Low foliage density
3. *Strong sub-urban*: Building occultation 20-35 deg of elevation. Typically dense folliage up to 60-70 deg

EXPERIMENTATION RESULTS

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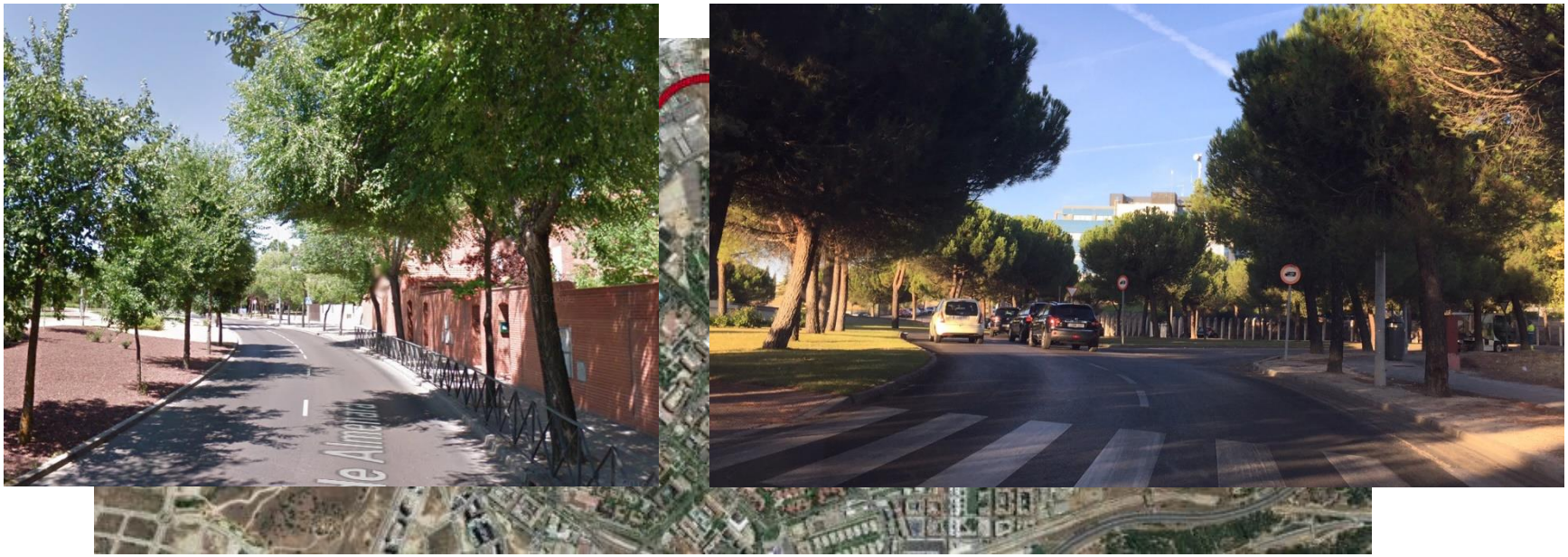
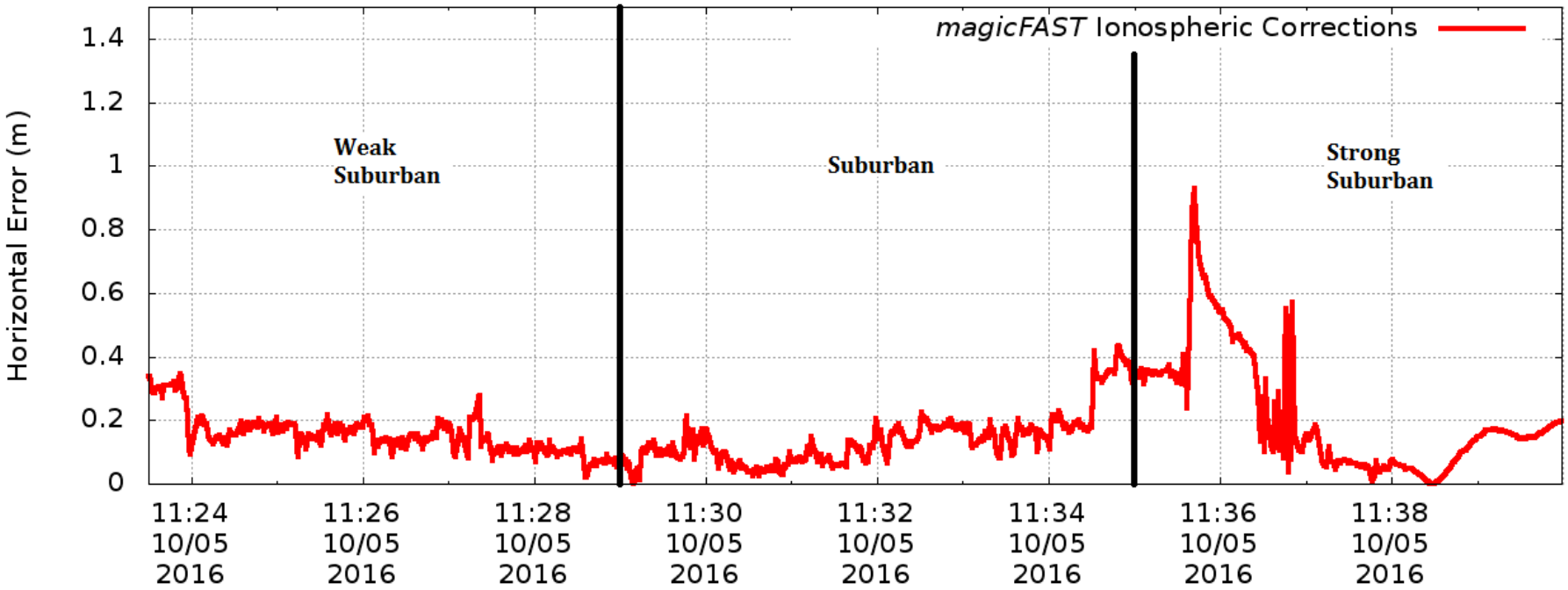


EXPERIMENTATION RESULTS

Kinematic Sub-Urban

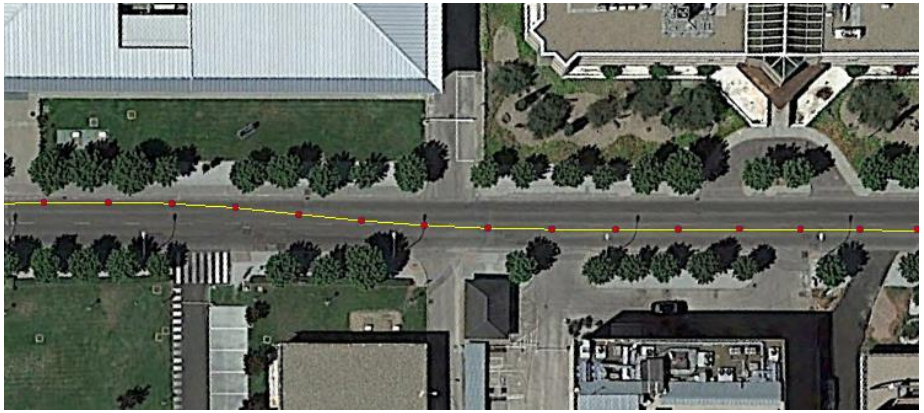


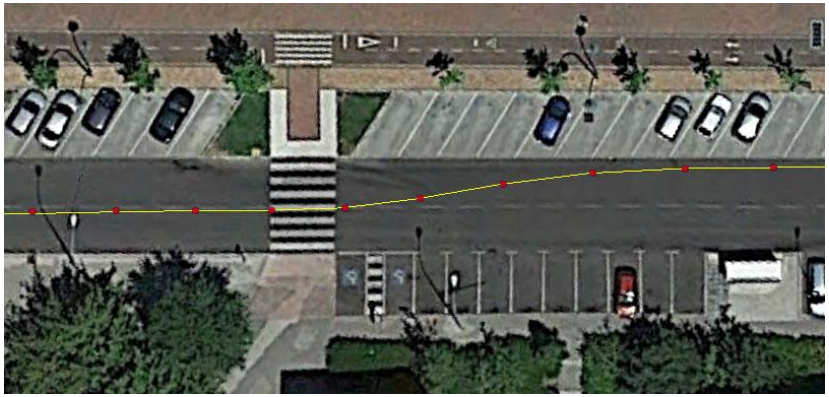
- No major issues in weak sub-urban environment
- Error increases in sub-urban environment due to increased multipath and foliage density
- Error peaks in strong sub-urban caused by dense foliage covering in zenith
- Fast reconvergence is achieved when signal quality increases thanks to ionospheric delay estimates

EXPERIMENTATION RESULTS

Lane Change Detection

- Lane-detection tests performed informally
- Urban Environment:
  - 4-story buildings at both sides of the street
  - Medium-density foliage





EXPERIMENTATION RESULTS

Conclusions

- ***magicFAST*** has been introduced as new GMV's real-time service able to achieve Fast Convergence and High Accuracy with low-cost user receivers
- The total cost of user hardware employed (Receiver and Antenna) is below 100€
- Conclusions of the experimentation campaign:
  - *magicFAST* is capable of providing 20cm of positioning accuracy after 5 minutes of PPP convergence
  - Level of accuracy maintained in open-sky and sub-urban environments
  - PPP robustness in challenging scenarios (high multipath and dense foliage) is increased by rapid re-convergence using *magicFAST* ionospheric corrections
- Continuous improvement is being carried out both on server and client sides

Thank you

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