NAVENTIK POSITIONING SOLUTIONS FOR VEHICLE AUTONOMY

NAVENTIK PATHFINDER
Product Summary

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PATHFINDER is NAVENTIK's technology for demanding and safety-critical localization tasks.

PATHFINDER GNSS

developed by NAVENTIK

PATHFINDER FUSION

developed by NAVENTIK

Our Basic Principle

Accurate and robust vehicle localization for use cases beyond human navigation requires a combination of GNSS with further sensors. PATHFINDER is the scalable platform to provide a deep integration of our high integrity GNSS algorithms with your sensor stack to achieve a new level of localization performance - accurate, precise, robust, highly available and functional safety compliant at lowest cost.

NAVENTIK PATHFINDER
Features

Quality GNSS Software Receiver
Due to the seamless embedding into the cluster computing architectures of ADAS, our flexible software based GNSS sensor can now substitute expensive legacy hardware components (e.g. GNSS/INS solutions) to achieve mass market readiness and high performance levels – ready for safety critical applications!

High Accuracy and Integrity
PATHFINDER reliably estimates the vehicle system state including the accurate position, velocity and heading as well as their associated integrity values (measures of trust). Combined with next generation correction services these data dimensions are the basis for a safety critical GNSS integration into ADAS and AV use cases that require lane-level positioning.

Sensor Fusion
The deeply coupled combination of GNSS and motion data leads to an extremely robust and high-performance GNSS/INS positioning. Furthermore it is possible to extend fusion of GNSS with additional vehicle onboard sensors e.g. odometers or vision based navigation systems, tailored to specialized use cases.

Safety Compliance
PATHFINDER is designed according the highest quality standards of the automotive industry.
We are working towards ISO26262 and ASIL B compliance for our PATHFINDER localization solution for safety critical vehicle applications.

Advanced Multipath Mitigation Models
Multipath and non-line-of-sight (NLOS) effects strongly degrade GNSS positioning performance.
PATHFINDER uses advanced probabilistic multipath mitigation algorithms to detect the type of pseudorange measurement to adjust the protection level of the state estimate.

In-Field Software Upgrades
Keep PATHFINDER up to date within the product lifecycle. Current and future GNSS features such as new constellations or argumentation services are provided by a simple update process.

Wide Support of ADAS Platforms and Middlewares
PATHFINDER is written in C++ and highly portable. For easy integration into prototyping and evaluation frameworks, PATHFINDER supports common middlewares and is tested on various ADAS platforms.

Low Cost Serial Production
The use of PATHFINDER drastically lowers the cost factor compared to a conventional hardware GNSS solution. The integration of PATHFINDER into your vehicle systems reduces the hardware overhead and enables a simplified and centralized architecture.

Post Processing
PATHFINDER's powerful and highly configurable post-processing engine maximizes the performance of the localization solution using all available GNSS and INS data.

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Technology

PATHFINDER GNSS is NAVENTIK's unique Software Defined GNSS sensor that fully substitutes your existing hardware receiver by a flexible and scalable ECU embedded software. PATHFINDER GNSS is Real-Time Kinematic (RTK) capable and delivers a highly accurate positioning including integrity data. The real-time confidence estimation is the key for a seamless and safety-compliant integration based on a deeply coupled sensor fusion.

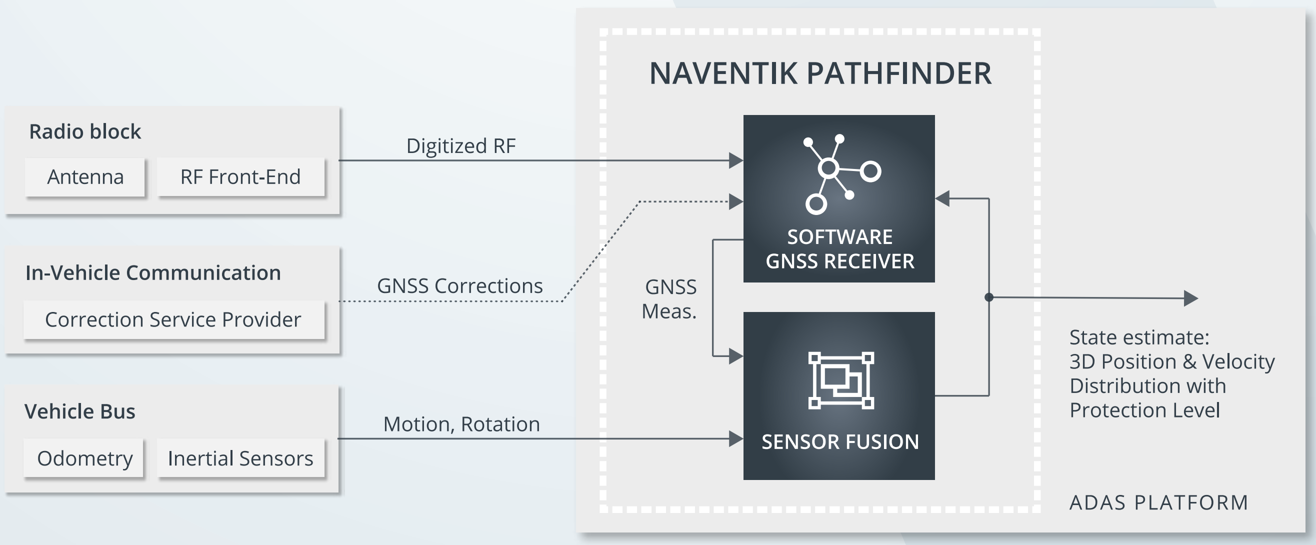
PATHFINDER FUSION uses the synergies of GNSS positioning and motion data from additional vehicle sensors. Starting from INS (Inertial Navigation System) integration, we provide algorithms that combine odometry or vision based motion data with measurements from any GNSS receiver under consideration of the vehicle model. PATHFINDER FUSION creates the most robust and accurate navigation solution using all available information.

PATHFINDER GNSS

PATHFINDER FUSION

The Combined Power of PATHFINDER GNSS & FUSION

The PATHFINDER GNSS software receiver utilization in a deeply coupled mode enables extremely robust and uninterrupted high-performance GNSS/INS positioning. In contrast to conventional tightly- or loosely-coupled GNSS/INS systems, deeply coupled systems do not just combine autonomously generated GNSS and INS solutions. Inertial measurement unit (IMU) based speed and direction information is used to aid and stabilize the satellite tracking of the GNSS receiver in challenging environments or after a loss of the satellite signal. Likewise, e.g. the "Delta-Phases" of the GNSS receiver, which are already available when receiving only two satellites, can be used to compensate the drift of the IMU.



PATHFINDER GNSS+FUSION architecture example

NAVENTIK PATHFINDER
Safety

PATHFINDER is designed and built for safety critical applications

Exact vehicle positioning is a major challenge for V2X, ADAS and AVs. Future safety-critical driving functions also require functional safety (FuSi) down to the sensor layer. PATHFINDER enables both - a more robust localization even in urban environments and the implementation of FuSi concepts through transparency of the signal pre-processing within the receiver framework.

PATHFINDER is compliant with ISO 26262 (ASIL B, Safety Element out of Context) and developed according highly controlled coding standards (AutoSAR C++14).

Safety Lifecycle. In order to implement a security concept for GNSS position data, the entire processing chain from the GNSS ground segment via satellites in space to the final position in a digital environmental model must be covered. This includes the explicit modeling and mitigation of all known sources of error. Some of the influences are related to signal propagation disturbances, others to errors inherent in the system. Most of them can be monitored by external service providers and integrity information must be evaluated in real time in the receiver.

Multipath/NLOS and Receicer Noise. In addition to global GNSS errors, which will be provided with integrity measures by next generation GNSS services, the most critical remaining sources of error are associated with local environmental conditions such as multipath or non-line-of-sight (NLOS). The GNSS receiver must be qualified to evaluate this additional error budget.
We have redesigned the entire signal processing from scratch, including explicit error models for multipath/NLOS and system models for signal tracking for handling these uncertainties. PATHFINDER generates the corresponding error budget as probability density when the system is exposed to signal interference. Our software receiver notifies you when multipath occurs, how much influence it has and what this means for the accuracy and integrity of the vehicle state estimation.

> *In short, PATHFINDER integrates all safety-relevant aspects of vehicle localization. All steps of signal processing are carefully reviewed so as not to lose or falsify any information relevant for the estimating a valid error budget. The PATHFINDER modules will be interfaced by an API tailored to your needs and requirements. As we aim to implement on your ECU or ADAS processor, we carefully develop according to automotive standards and comply with ISO 26262.*

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Specifications

Sensor characteristics

GNSS Constellations & Frequencies	GPS L1/L1C, L2/L2C, L5 Galileo E1, Galileo E5a/E5b
SBAS	WAAS, EGNOS, MSAS, GAGAN according DO-229E_SBAS_VTU592S7
Number of Channels	platform specific [1] e.g. 32 channels @ 3% GPU NIVIDA PX2
Multipath Mitigation	Several advanced algorithms
Signal Tracking	Shared State Vector
GNSS Front-End	Reference multiband HW with high precision clock
Interfaces	SW interface, platform specific[1] HW interfaces
Sensor Fusion	All kind of odometry, motion and rotation data
Corrections	RTCM 3.x over NTRIP
Navigation Output	GPX, GeoJSON, KML, NMEA 0183, RTCM 3.x, RINEX

Performance [2]

GNSS only (Standalone mode)	1.2 m (RMSE)
SBAS	0.8 m (RMSE)
DGPS	0.4 m (RMSE)
GNSS/INS (deeply coupled)	Improved continuity, availability and precision [3]
RTK	0.02 m (RMSE)
RTK convergence time	< 10 s
Post processing (deeply coupled)	0.01 m (RMSE)
Time to first fix (TTFF) [4]	COLD < 40 s Reacquisition < 1 s HOT (aided start) < 9 s
Data rates	25 Hz, up to 100 Hz using sensor fusion
Confidence estimate	maximum NEES [5] 10
Initialization Reliability	> 99%
Solution latency	< 40 ms

[1] Highly scalable depending on available resources of the processing platform

[2] Positioning performance depends on atmospheric conditions signal multipath, satellite geometry as well as available corrections and their quality. A minimum of 5 satellites is assumed. All accuracies apply to Horizontal Position accuracies.

[3] Accuracy similar to GNSS standalone mode, but increased robustness (bridging GNSS signal losses) and localization performance in high dynamic scenarios.

[4] TTFF times apply in open sky and strong signals conditions. Hot Start is the time taken by the receiver to achieve a standard position fix after a brief outage between 30 and 50 seconds. For example, the time taken to fix a position for a car that is exiting a long tunnel. Cold Start is the time taken by the receiver to achieve a standard position fix after a prolonged outage. For example, the time taken to achieve a position fix for a car that has been parked overnight in a garage and once it sees the sky view for the first time. Re-acquisition is defined as the time taken to re-acquire position lock after brief moment of outage between between 1 and 5 seconds. For example, a car traveling under a freeway/highway overpass.

[5] Normalized Error Estimation Squared

NAVENTIK PATHFINDER
Frequently asked questions

1) How many position candidates and confidence pairs come from PATHFINDER?

That currently depends on the receiver mode (code only, D-GPS, RTK) and is ultimately depending on both the environment and receiver configuration. For example, under open-sky reception conditions a single candidate is usually enough to approximate the probability density of the position estimation well enough. Only under multipath and/or non-line-of-sight conditions ambiguities arise, which may be further increased by the ambiguity problem RTK has to resolve anyhow. In this case, 2-5 candidates are usually a fair enough representation.

2) How do you handle multi-path & NLOS situations?

Our GNSS receiver employs probabilistic models within the signal tracking itself to assess and mitigate the presence of multi-path and non-line-of-sight conditions. This leads to a reliable confidence estimation for the receiver measurements and increases its resistance to localization biases caused by such effects (especially during short-term signal disturbance).

3) As I understand the PATHFINDER SW receiver uses IMU data internally, so it can output position candidates even though fewer than four satellites are in sight, right? And a low-cost IMU can meet the PATHFINDER requirements? What's the IMU model in your reference board?

PATHFINDER itself does not require an IMU to function, although such additional input can highly increase its performance depending on the chosen data fusion scheme.
If PATHFINDER is to be integrated into a larger data-fusion based localization engine that already uses such an inertial sensor, then IMU data shall only be used to tune its signal tracking dynamics. This would still improve its tracking performance without violating the data-fusion systems presumptions (fusing a sensor twice is usually not a sound approach, especially if the caused correlations are ignored).
If this is not the case, then PATHFINDER can deeply integrate IMU sensor data on its own to fully exploit its usefulness. It is designed to work with arbitrary IMU models if the noise/drift parameters of that IMU can be adequately determined. We usually do not supply an IMU on our own, PATHFINDER is software, although we can point out models we used so far.
As a last note: As most modern GNSS receivers, PATHFINDER can update its position estimation using a single satellite in sight as well. The four satellites requirement is true for trivial single positioning algorithms only, that need to solve the position and clock bias estimation at each update step. Using more sophisticated assumptions on the receiver dynamics softens this requirement. However, this is only suitable to bridge short term signal interruptions like at an underpass. Understandably, precision will suffer over time (but slower with an IMU) and confidence estimation will disclose this.

4) If there is short detection of satellite, is PATHFINDER still working?

This depends on the time scale we are talking about. GNSS based localization requires continuous signal tracking for various reasons, although after meeting the initial requirements shorter visibilities may allow updates. For example, to establish a single satellites transmission time (the fundamental basis for the ranging) a navigation message with this information must be decoded first. For GPS those repeat every 6 seconds. If the orbit description of the satellite is unknown or got unusable duo to its limited validity, it needs to be retrieved next. This can be done using internet services (often phrased assisted GPS) to speed this up. If not, multiple navigation frames need to be received to gather this information from the satellite itself, which can take 30s.
However, once that's achieved, a satellite can likely be reused again after several hundred milliseconds after its reacquisition.

5) In case of cold booting, for example the system totally turns down in urban canyon, and totally lost GPS signal – How quick will PATHFINDER be "alive" again?

As described at the previous question, this depends on the information the receiver can still rely upon. If it leaves a GNSS denied area, it will regain position estimates within few seconds, typically between 5s and 15s. That's usually called the warm or normal time-to-first-fix (TTFF).
There is also a "cold TTFF" describing the time to the first position if the receiver has no valid information at all. In this case it needs to find available satellites and retrieve the required information from them. In traditional, unassisted operation, this tends to take around 40s to 60s.

6) What if the long tunnel case (if there is no GPS signal) and the IMU will perform the operation. In most cases, this would be not enough due to the drift. How can the NAVENTIK Technology cover this kind of a worst case scenario?

We at NAVENTIK focus on GNSS based localization. By principle, long term operation in a GNSS denied environment leaves the scope of our technology. The IMU based dead reckoning is the only, optional, method we directly support. Depending on its performance, this allows bridging signal gaps from several seconds up to few minutes, with ever increasing covariance estimations.
PATHFINDER is precisely designed for integration into a large-scale positioning data fusion system, maximizing the use of GNSS. ADASs need precise and reliable positioning during a broad range of conditions, something no single sensor can achieve. Optical systems like camera and lidar can have too few or too much light to properly function, map and feature based approaches fail in unmapped areas or if the surrounding lacks notable features and GNSS fails under poor radio reception conditions. To solve this, many different sensors and a lot of know-how must be combined to function under all conditions sufficiently, with NAVENTIK covering the GNSS part and integration support.

7) Is there an indicator of the current integrity of the localization?

Confidence is expressed using average Normalized Estimation Error Squared (A-NEES). PATHFINDER confidence estimate maximum in deeply coupled mode is A-NEES < 10.