THE WORLD'S ONLY PUBLICATION DEDICATED TO ADVANCED AUTOMOTIVE SAFETY TECHNOLOGIES

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Mind readers

How MIT is measuring the cognitive component of driver workload and distraction

Emotionally charged

Tjark Kreuzinger reveals why Toyota is in the mood to do more with facial recognition

Natural defence

From bees to bats, how safety experts are looking to the animal kingdom for collision avoidance inspiration

Traction men

Could the tyre industry's pursuit of efficiency and market share take safety to a whole new level?

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Looking at ways in which vision-based data acquisition and processing is revolutionising ADAS

Dr Pim van der Jagt

The leader of Ford's Aachen Research Centre on the promise of V2X technologies

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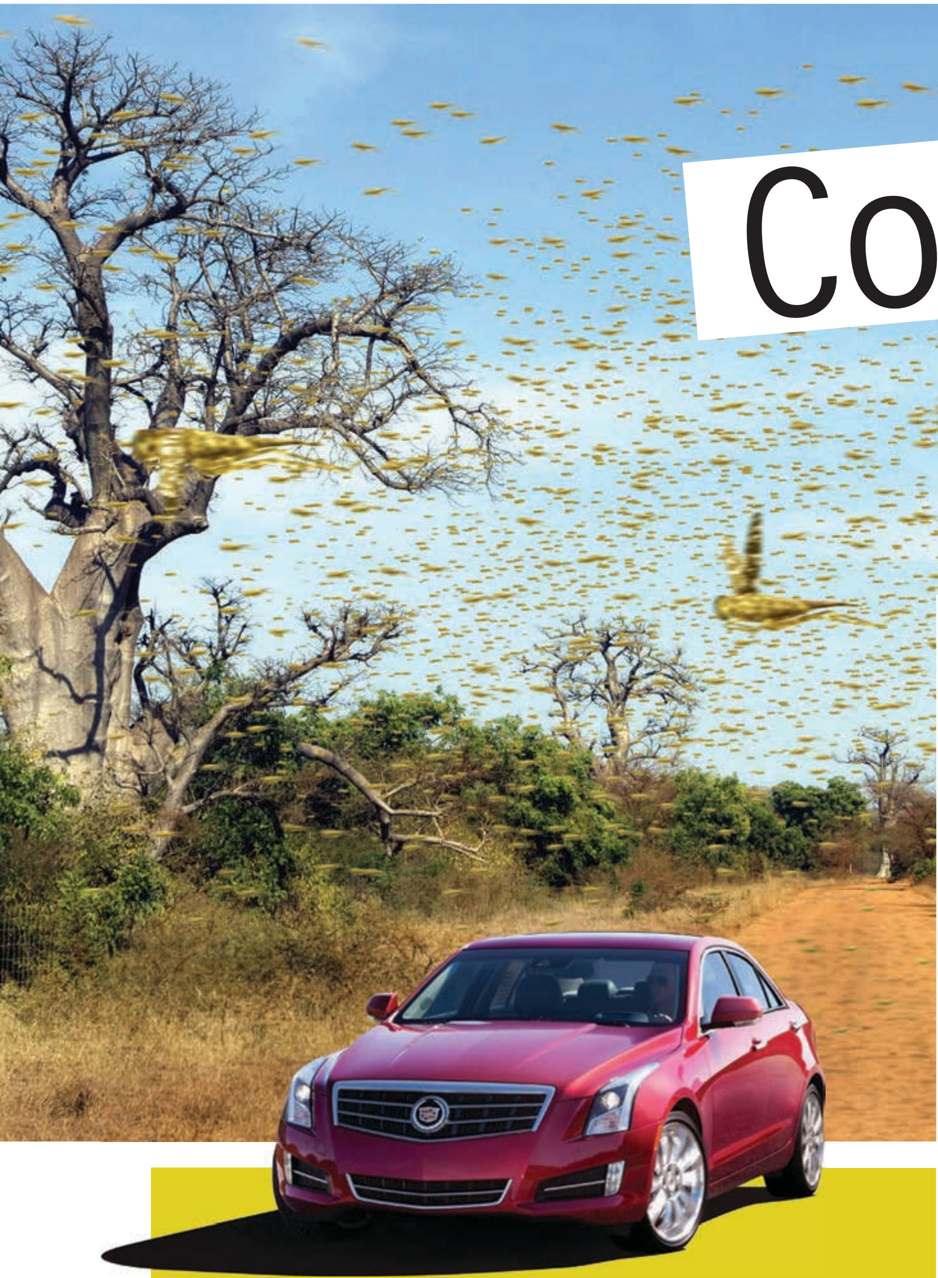

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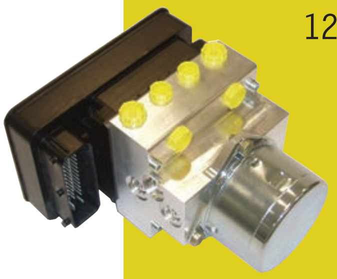

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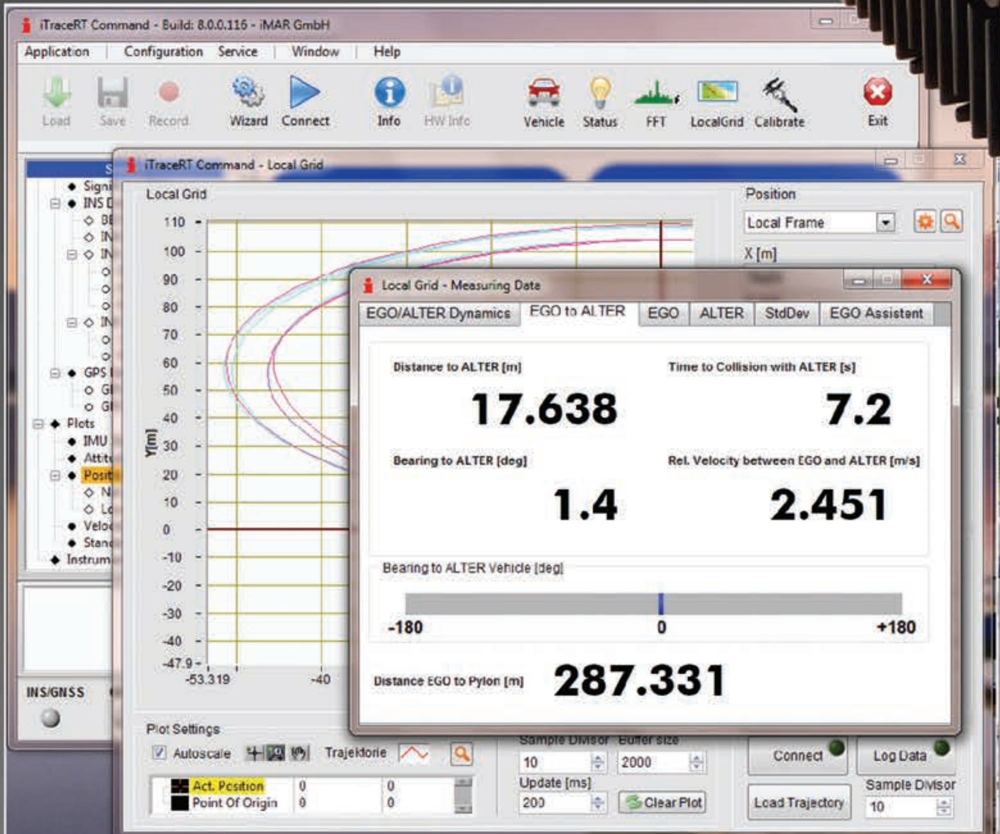
Leading in Inertial Measurement and Control

iTraceRT-MVT... *[Multi Vehicle Tracking]*

...the ADAS Vehicle Motion Verification Tool

Measure & Trust - high accuracy for real world measurements
Open data interface to data acquisition systems
Steering and driving robot interface
Deeply coupled INS/GNSS
Position accuracy 2 cm
Velocity accuracy 1 cm/s
Attitude accuracy 0.01 deg



Real-world measurements

As vehicle safety advances in the future and becomes increasingly connected, testing will need to be conducted away from proving grounds, calling for an equally advanced verification toolset

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IMAGES COURTESY OF iMAR NAVIGATION

ADAS functionality is available in quite a number of cars already and in the future this will be a fast-growing segment – and not only for top-of-the-range models. Such functions were once more or less advertised as 'comfort features', but the aim now is clearly about enhancing safety. Looking into the future, cars will either be interacting directly with the driver, or actively taking part in controlling the car in dynamic environments featuring other traffic participants such as cars, bicycles or pedestrians.

This raises new test requirements, however, because all of these functions need to be verified and certified before they can go into production. Most of the testing conducted in the past centred around vehicle dynamics, performed on proving grounds under pretty much open-sky conditions using standalone GPS or GPS-aided inertial measurement units (IMUs) to reference the measured data. Under real-world conditions, though – where GPS isn't available all of the time, such as in urban or rural areas – there were no reliable tools available for absolute positioning or performing ADAS verification.

Testing requirements for current and future ADAS systems will differ, in that the reference systems being used for verification and testing should provide accurate data under real-world conditions – i.e. in areas where there are GPS signal blockages and multipath created by nearby obstacles such as buildings, trees or bridges.

(Figure 1, above) **Advantage of deeply coupled architecture**
(Figure 2, right) **Behaviour in urban canyons (9m distortion with loosely coupled solution against deeply coupled solution)**

This problem can be fixed partially by utilising all GNSS signals, including GPS, GLONASS and in the near future Compass or even Galileo to enhance the satellite coverage. But in those areas where no reliable position information can be attained, an IMU in combination with the IMU/GNSS data fusion ('filter') will need to be employed to overcome blockage and multipath problems.

Two things must be considered with regard to the IMU and the IMU/GNSS integration: the first is the grade or performance of the IMU being able to fill those gaps where insufficient GNSS signals are available, running on 'free wheeling' inertial only; the second being the type of filter used for IMU/GNSS integration.

Commonly used systems are based on a so-called 'loosely coupled' approach, which is cheap and easy to implement and can use any kind of GNSS receiver. The more sophisticated and reliable method is the 'deeply coupled' approach.

As the implemented data fusion has a severe effect on system performance, it makes sense to investigate both solutions in a little more detail.

Why deeply coupled?

The loosely coupled solution is also known as 'cascaded filters' because it contains multiple filters. There's usually one inside the GNSS receiver, the 'GNSS filter', and one within the INS, the 'Navigation Filter'. It mostly uses a 'car model' and a 'single-track model' filter to smooth the output data as well as to extract the slip angle. The Navigation Filter uses the preprocessed data of the GNSS filter, so there's just 'one way' for the GNSS data flow and thus no bidirectional communication between the IMU and the GNSS.

The disadvantage of such a simple approach together with a vehicle model is that the result of such measuring tool is affected (smoothed) by model assumptions, while a strict demand on every ADAS verification task is to guarantee independency between the used measurement tool and the device under test. Furthermore, due to the missing link from the IMS to the GNSS, degradation in performance in relation to the deeply coupled solution has to be accepted.

In contrast, the deeply coupled solution processes all IMU and GNSS information together in one common filter, in doing so generating an integrated solution. All calculations are based on real-time raw measurement data from the IMU and GNSS receiver. The bidirectional link between IMU and GNSS allows for a powerful aiding of the tracking loops of the GNSS receiver by IMU data and – in parallel – to estimate the error model of the inertial sensors (gyros and accelerometers) by GNSS data.

The major advantage of this approach is that it is able to produce more valid GNSS solutions than the loosely coupled equivalent. For example, you can navigate with fewer than five satellites, you can reduce the number and length of GNSS outages, combined with a two to three times faster recovery after loss of lock, and you can resolve the carrier phase ambiguity (RTK Solution) faster – typically only 12 seconds compared with 30 seconds – by being able to use the IMU information to validate individual satellite locks.

Figure 1 shows a typical example driving through a cutting in the landscape, which results in a loss of GNSS lock. Both systems, iMAR's iTraceRT-F400 (green) and a 'loosely coupled' (red) system, are operated in the same car from the same antenna signal (with a splitter) so they're tested in a comparable environment, in this case by a well-known German car manufacturer. The red line goes off track and needs a while to recover, while the green line remains on track.

The deeply coupled solution also copes with the effects of multipath, not merely present in urban areas but also on motorways, for instance when you approach and pass beneath a bridge. In such a scenario, you will experience a heading error with a loosely coupled system just before you reach the bridge, and recovery won't be established until you obtain a valid fix after coming out on the other side, by which time the results can be significantly distorted. You are likely to have seen 'bridges' on proving grounds, which are used to let obstacles such as pedestrian dummies cross the path of the vehicle. The deeply coupled system, however, can cope with such a scenario.

The only good thing with multipath is that the portion created by the environment is going to be depressed by the speed of the vehicle, although as soon as you come to a standstill, it will adversely affect your navigation again.

(Figure 3) Antenna setup on two test vehicles (GNSS, radio modem, WLAN for inter-vehicle communication)

(Figure 4) Small space setup with iTraceRT-400, GSM, radio modem and WLAN, as well as a smart battery to bridge vehicle's power breakdown during engine startup

As can be seen in Figure 2, the vehicle stopping at a traffic sign with a building on the right side, you see the 'loosely coupled' solution going off track again (same colour scheme as before), whereas the iTraceRT solution stays on track well.

Inertial sensor performance

Based on this experience, iMAR offers deeply coupled solutions for these applications. They also include a high-accuracy IMU with 1°/h FOG gyro and 2m*g* accelerometer raw data performance. This allows for a much faster converging of the filter with the advantage for the user being great time savings during ADAS testing, and high data reliability even in areas where only poor or even non-existent GNSS solutions are achievable.

These iTraceRT-F400 systems are widely used for automotive testing in general – for ADAS testing and verification as well as for autonomous driving, using integrated interfaces for steering and driving robots.

The fact that the iTraceRT offers true measurement results and is unaffected by any kind of dynamic model – and with very small latency of <5ms at a data rate up to 400Hz – enables the testing technology to be used in a wide range of measurement and control applications on cars, bikes, ships and even aircraft.

Multi vehicle tracking

In real-world environments, multi vehicle tracking (MVT) is the core technology to verify ADAS functions away from established proving grounds. In addition to the INS/GNSS iTraceRT-F400 measurement system itself, iMAR Navigation provides complete multi-vehicle installations including software and communication equipment for car-to-car (WLAN 5.8GHz Link) and correction data networks (GSM, radio modem) for multi vehicle tracking. These have some useful applications for ADAS already embedded. The software provides an open interface for standard or customer-defined test procedures to be implemented by the customer or iMAR upon request. The aim of these procedures is to guide the test driver through the test, as well as to monitor the correct execution, and then present the results at the end. The open interface therefore also supports the data integration into third-party data-acquisition systems.

Easy setup

Aside from high reliability and superior performance, compact dimensions, low weight and easy setup in the car are demanding requirements for future ADAS verification test systems. Figure 3 shows an antenna setup, which is easy to mount with magnetic feet. Figure 4 shows the setup inside the car, withstanding also dynamical forces and vibration up to 1*g* and more without adverse impacts. Figure 5, meanwhile, shows the setup of the GNSS reference data station in case the user doesn't want to use GSM-based RTK data.

Not only for ADAS...

iMAR Navigation's ADAS testing range also includes iTraceRT-R300, based on an RLG (ring laser gyro) technology used to create highly precise maps, and the iTraceRT-M100, based on MEMS gyro technology for cost-effective fleet testing or the control of pedestrian dummies, bicycles and other small targets. These, too, are based on the same technology as the iTraceRT-F400. ❮

(Figure 5) For autonomous users – using your own GNSS reference station

The table provides a rough performance overview using iTraceRT-F400

Measurement value	Accuracy	Range
Absolute vehicle position	0.02m	Worldwide
Relative position between vehicles	0.03 m 0.02m	Worldwide Within Car-2-Car (WLAN)
Velocity	0.01m/sec	Up to 150m/sec
Heading	0.05°	No limitation
Roll and pitch	0.01°	No limitation