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Sensor fusion: Inertial measurement units

An IMU embeds several sensors on the same physical device. Combined sensor data tailored for a certain application is available on a CAN interface. This unburdens the CAN network from additional traffic and allows a simpler network design.

(Source: Adobe Stock)

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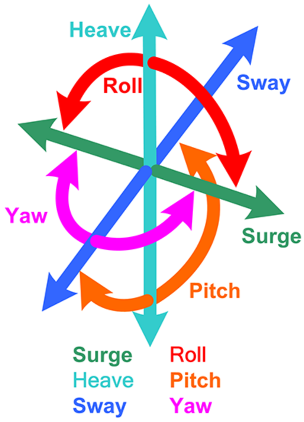
An inertial measurement unit (IMU) is an electronic de- vice that measures and reports a body's specific force, angular rate, and orientation. It works by detecting linear acceleration using accelerometers and rotational rate us- ing gyroscopes. Some IMUs also include a magnetometer, which is commonly used as a heading reference. Such IMU configurations contain one accelerometer, gyroscope, and magnetometer per axis for each of the three vehicle axes: pitch, roll, and yaw. As a rule, an IMU is equipped with a CAN interface. On the market devices with 9 DOF (degree of freedom) or 6 DOF (without magnetometers) are available. IMUs are essential components in robotics, diverse vehicles, manned and unmanned aircraft (e.g. drones), spacecraft, satellites, ships, submarines, etc.

Included in GPS (global positioning system) devices an IMU allows a GPS receiver to work when GPS signals are unavailable e.g. in tunnels, inside buildings or when electronic interference is present. The IMUs are often incorporated into inertial navigation systems (INS), which use the IMU data to calculate attitude, angular rates, linear velocity and position relative to a global reference frame. Thus, INS form the backbone for the navigation and control of many commercial and military vehicles. Simpler INS versions termed AHRS (attitude and heading reference systems) utilize IMUs to calculate vehicle attitude with heading relative to magnetic north. Here, the data collected from the IMU's sensors allows a computer to track a craft's position, using the so-called dead reckoning method.

In land vehicles, an IMU may be integrated into GPS- based automotive navigation systems or vehicle tracking systems. This gives the system a dead reckoning capability and the ability to gather data about the vehicle's current speed, turnrate, heading, inclination, and acceleration. In combination with the vehicle's wheel speed sensor output and the reverse gear signal the IMU data is used for traffic collision analysis.



Six degrees of freedom (Source: Honeywell)

IMUs serve as orientation sensors in smartphones and tablets. They are also used to measure motion in sport technology (e.g. fitness trackers), remote controls for gaming systems, and animation applications. The IMU is essential in the balancing technology used in the Segway personal transporters. Low-cost IMUs have enabled the proliferation of the consumer drone industry.

IMUs in unmanned aerial vehicles

In unmanned aerial vehicles typically the 9-DOF IMUs are used. An IMU measures the inertial quantities of a vehicle as accelerations and angular velocities. The measured values may be used for automatic feedback control loop or processed to estimate the attitude (roll, pitch, yaw or quaternion) of the vehicle. Accelerometers sense all applied accelerations also those due to vibrations or maneuvers. Thus, isolation and an accurate calibration are important. Gyroscopes measure the rotational velocity around their axis. This value may be used to estimate actual tilt angle and serves as a signal for feedback control loops e.g. for stabilization of RC helicopters.

Gyroscopes should be calibrated before each vehicle starting. A magnetometer measures the local magnetic field components, which may be compared with the world magnetic field model in order to estimate the attitude, and thus the heading respect to the local magnetic North. As the local magnetic field is easy to affect (e.g. by electric lines, sun activities, or other sensors) the local declination has to be considered while measuring.

More safety for autonomous vehicles

In an autonomous vehicle, CAN is used to pass IMU data to the main vehicle control and to share it with other vehicle sub-systems such as lidar, camera, radar, etc. The IMU application may also listen to other messages on the net- work. For example, the dynamic tilt algorithm supported by the IMU could be performance-enhanced by listening to messages such as odometer or vehicle speed to

Openimu300ri IMU for a wide range of applications (Source: Anceinna)

better compensate for the influence of linear acceleration on dynamic roll and pitch.

One of the CAN-enabled 9-DOF IMUs is the Open- imu300ri by Anceinna. The Mems-based (micro electro-mechanical system) device also provides an EIA-232 interface. The ARM Cortex M4 CPU (central processing unit) runs standardized and customized algorithms created with the company's free, open-source developer tool- chain. In the INS navigation application, GPS sensor data inputted via the EIA-232 interface is fused with the IMU data for the GPS/INS sensor fusion. The IMU supports 11-bit and 29-bit CAN-Identifiers. Consumer automobiles often use customer-defined messages with 11-bit CAN- identifiers, whereas heavy-equipment vehicles more commonly use the 29-bit CAN-identifiers and define messages according to the J1939 standard.

The IP67-rated IMU is designed for use on 12-V and 24-V vehicles. INS and GNSS (global navigation satellite system) developers not familiar with CAN may use a CAN analyzer to get started with the development. The company provides an open-source Python test application that allows to read and parse messages from IMU over CAN. A set of messages for accelerations, rates, and other data of an IMU may be defined. A DBC (data base CAN) file is then created to describe the chosen encoding of a CAN message.

The mentioned IMU application may be also used in a J1939 network. It provides the PGN (parameter group number) 61485 and PGN 61482 for acceleration and angular rate respectively. The company also supports a dynamic tilt algorithm, which computes the dynamic inclination (i.e. roll and pitch) by integrating the angular rate sensors to angle and then using the acceleration channels to establish a stable, absolute reference with respect to gravity as well as correct for the long-term drift of the integration process. The J1939 slope sensor 2 information message (PGN 61481) is used to encode dynamic roll and pitch.

The unit is dedicated for autonomous off-road, construction, agricultural, and automotive vehicle applications. It allows engineers to optimize an attitude, navigation or other algorithm for their vehicle or application and to run it in on the IMU. This minimizes communication on the CAN network and unburdens the processor, or allows to use a less expensive processor. The processed IMU data may be used for such applications as keeping a cab level, returning an arm to a specific position, keeping a bucket stable while traveling, locking out control for safety applications, supplementing GNSS data to keep a tractor on course, etc.

For construction and mobile machines

Honeywell's Tars-IMU (transportation attitude reference sys- tem) with 6 DOF is designed for heavy-duty and off-high- way transportation applications. The device reports key data required to automate and monitor movements of vehicle systems and components using a sensor fusion algorithm. Communication to the vehicle is carried through a CAN inter- face with J1939 connectivity. The CAN bit-rate of 250 kbit/s is used. A 120-Ohm termination resistor is not included with the IMU. With the IP67/IP69K-rated thermoplastic housing and an operating temperature range of -40 °C to +85 °C it is fitted for use in harsh environments. Two sensor models for 5-V and 9-V to 36-V power levels are available.

Construction vehicle OEMs (original equipment manufacturer) enable the equipment with intelligence and autonomy for certain functions to assist the operator. For example, to dig hundreds of post holes precisely placed in several rows a backhoe with an auger attachment was equipped with the Tars-IMU. In this project, the unit monitored vehicle and implement positions. In addition, it measured the alignment with the ground. An on-board system and graphical user interface (GUI) compared the information coming from the IMU and the site plan for the required holes. This allowed the operator to drive to a hole location, align the tool to specification, and dig the hole to required depth. According to the IMU supplier, construction industry moves toward fully-autonomous systems.

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