Field report OMS 7

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Table of contents

Table of contents..I

List of illustrations..II

List of abbreviations..III

1 Background to the use.. - 1 -

2 Installation in the vehicle.. - 3 -

3 Use of the measurement data.. - 4 -

4 Summary.. - 6 -

List of illustrations

Figure 1 Structure and sequence of our state estimation .... - 1 -

Figure 2 Position of the OM7 ground speed sensor on the Stallardo '24 of the Esslingen racing team.. - 3 -

Figure 3 Position of the evaluation unit of the OMS 7 on the Stallardo '24 of the Esslingen racing stable.. - 4 -

Figure 4 Speed signal over one lap at Formula Student Netherlands. - 5 -

Figure 5 Distribution of the slip angles of all tires over one lap at Formula Student Netherlands.. - 5 -

Figure 6 Differential angle between front axle and rear axle at Formula Student Hungary .... - 6 -

List of abbreviations

IMUInertial Measurement Unit

GPSGlobal Positioning System

POIPoint - Of - Interest

1 Background to use

Formula Student is an international engineering competition in which student teams from all over the world compete against each other to develop the best racing car. Our team is developing a fully electric vehicle with all-wheel drive that is specially tailored to the requirements of Formula Student. The focus is on the combination of innovative technologies and outstanding vehicle dynamics.

With a fully electric all-wheel drive system, precise control of the drive force on each wheel is particularly complex. This is where our **State Estimation** comes into play, which monitors and estimates the state of the vehicle in real time, such as the vehicle position, speed, acceleration and the forces on the wheels. This data is essential in order to make optimum use of **torque vectoring**. By continuously recording the current state of the vehicle, we can ensure that each wheel receives exactly the right amount of torque to ensure maximum traction and stability. The calculation of the most important values within our State Estimation is shown in Figure 1 below.

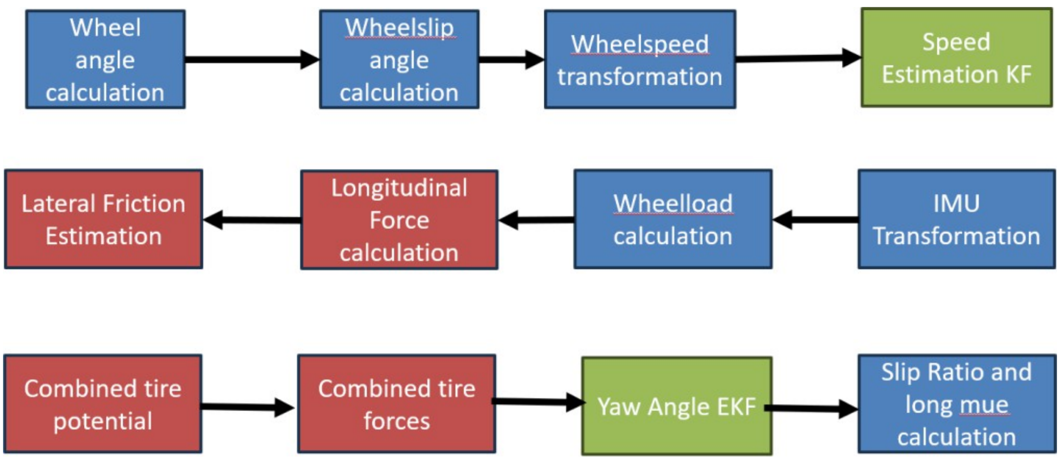

Figure 1 Structure and sequence of our state estimation

The most important aspect is **speed estimation**. In a four-wheel drive vehicle, especially in competition, it is crucial to know the actual speed of the vehicle precisely in order to control the dynamics. By using sensors and algorithms to measure and estimate speed, we not only record the overall speed, but also the differential speeds at the individual wheels. This information is crucial in order to avoid excessive slippage at the wheels and to keep the vehicle stable even when cornering. The speed estimation is fundamentally based on the sensor fusion of various sensors such as an Inertial Measurement Unit (IMU), a Global Positioning System (GPS), a three-hole probe and the wheel speed sensors. This sensor data is fused in a **Kalman filter** to estimate the speed. The aim is to estimate the speed of the vehicle as stably and realistically as possible and to use this primarily for our traction control.

In combination with our **torque vectoring system**, we can use **speed estimation** and **state estimation** to react quickly and precisely to any driving situation. For example, when cornering or during sudden load changes, we can distribute the torque specifically to the wheels that need it most to prevent the vehicle from swerving. In this way, we enable high driving stability and cornering speed, which offers a major advantage particularly in dynamic disciplines such as autocross and skid pad.

By integrating these technologies, we create a high-performance electric vehicle that not only impresses with its performance, but also with its ability to remain precise and stable in all conditions. The combination of state estimation, speed estimation and torque vectoring gives us the control needed to compete at the highest level.

Last year (2022/2023 season), we mainly used our INS system to estimate the speed. However, when measuring and calculating the speed of other sensors and validating with a ground speed sensor, we noticed that the estimation was sometimes up to 20 km/h incorrect. To prevent this, we wanted to fit a ground speed sensor to our vehicle not only for validation purposes, but also during our races and thus optimize the speed estimation. This sensor also enables us to determine the actual float angle of the vehicle.

For this purpose, **Sensoric Solution** kindly provided us with an **OMS 7**, which we were allowed to use both during the test phase and during our races (May 2024 - September 2024). Due to the fast measurement of the sensor, it was possible to record the values at a frequency of **1000 Hz.**

2 Installation in the vehicle

As the vehicle is a single-seater formula car, the packaging and positioning on the vehicle were particularly challenging. Things such as the minimum height of the sensor had to be adhered to, especially when positioning it; at the same time, the sensor should have as little influence on the aerodynamics as possible. For this reason, we decided to position the sensor at the height of the rear axle. This is shown in Figure 2.

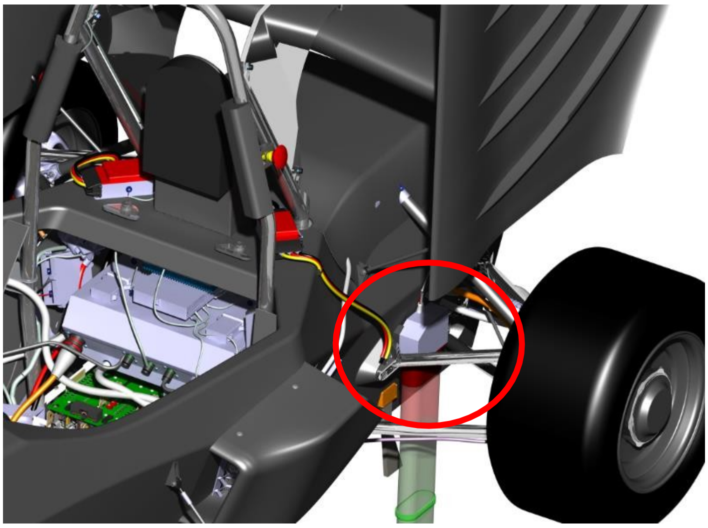

Figure 2 Position of the OM7 ground speed sensor on the Stallardo '24 of the Esslingen racing team

We positioned the evaluation unit in the vehicle (see Figure 3). Packaging was particularly challenging here, as the space between the inverter and the battery was very limited. We also had to decouple the unit as far as possible and protect it from shocks and vibrations.

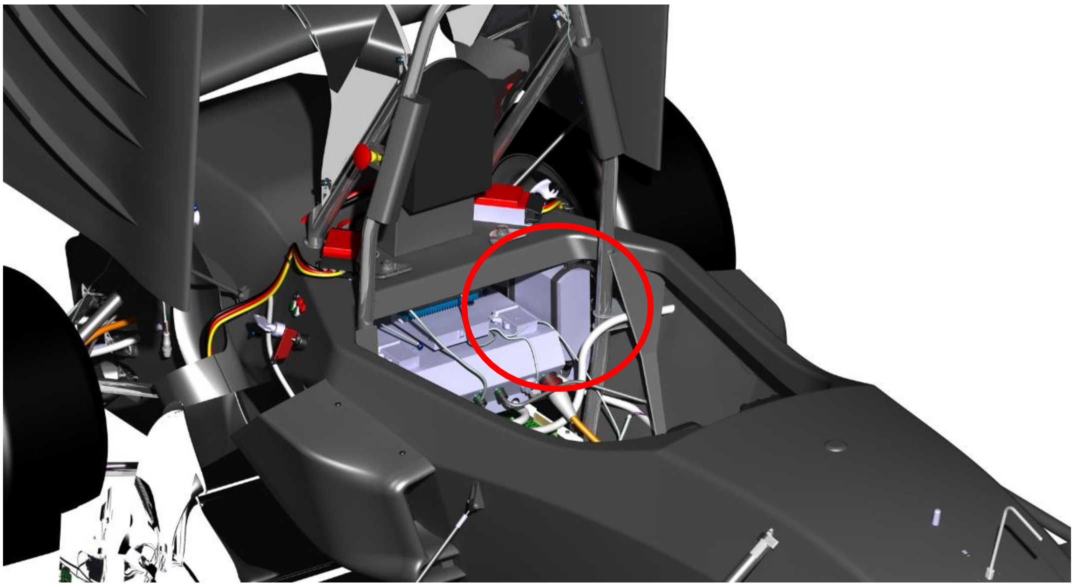

Figure 3 Position of the evaluation unit of the OMS 7 on the Stallardo '24 of the Esslingen racing stable

By positioning in CAD, we were also able to measure the position in relation to our **point of interest (POI)** so that this is already taken into account in the sensor data. This enabled us to apply the merged results from the ground speed sensor and its own IMU position-corrected to our center of gravity without having to perform the conversion ourselves. In addition, several presets can be saved so that it can be used on another vehicle with a different mounting position quickly and easily.

3 Use of the measurement data

We basically used the sensor for two aspects. Firstly, we were able to determine a highly precise measurement of the longitudinal and lateral speed of the vehicle and thus obtain ideal values for our slip control.

As can be seen in Figure 4, some deviations in speed between the measurement of the ground speed sensor and the INS system are recognizable. This speed difference of 5 km/h results in a speed difference of

$6\,0 \frac{U}{min}$ on the wheel, which has a major impact on the functionality of our slip control and has a negative effect on handling and lap times, especially during acceleration.

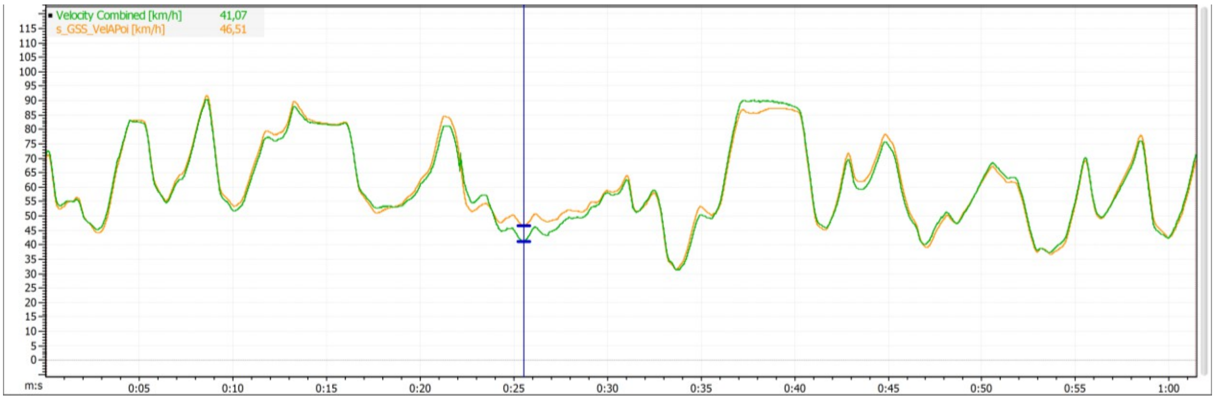

Figure 4 Speed signal over one lap at Formula Student Netherlands

We also used the speed of the vehicle for our torque vectoring, as this is also influenced by speed due to its complexity and dependencies.

We were also able to use the sensor to better assess the driving dynamics of our vehicle. The measurements from the ground speed sensor allow us to determine the slip angle of each individual wheel by conversion, which we used to optimize our vehicle. This allowed us to better understand the behavior of our tires. It can be seen that the slip angle on the front axle is often greater than on the rear axle. Furthermore, the slip angle is between 0 and 6 degrees most of the time, so the tire is mostly in the linear behavior range.

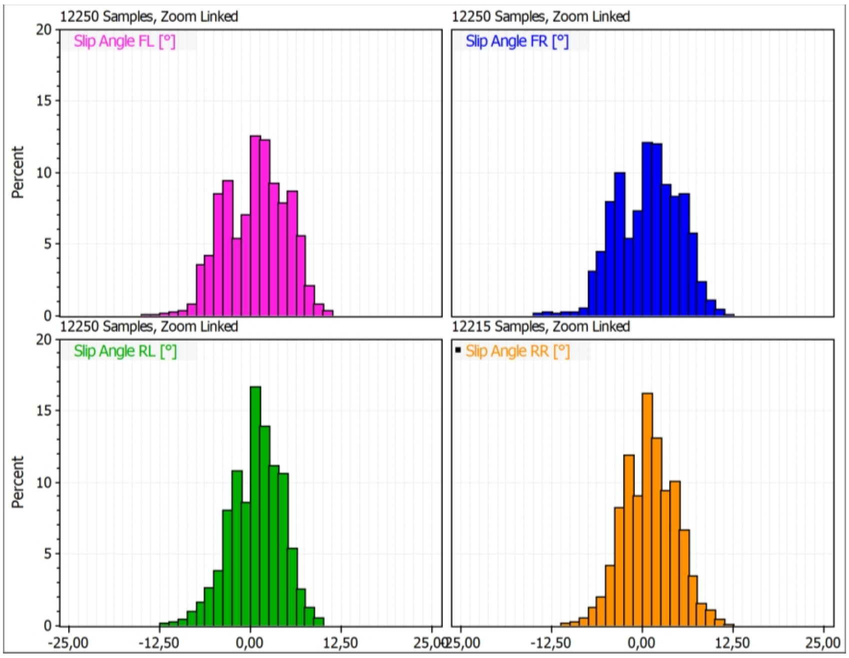

Figure 5 Distribution of the slip angles of all tires over one lap at Formula Student Netherlands

We can also use the slip angles to determine oversteer and understeer tendencies and then make adjustments to the setup to make the vehicle more drivable.

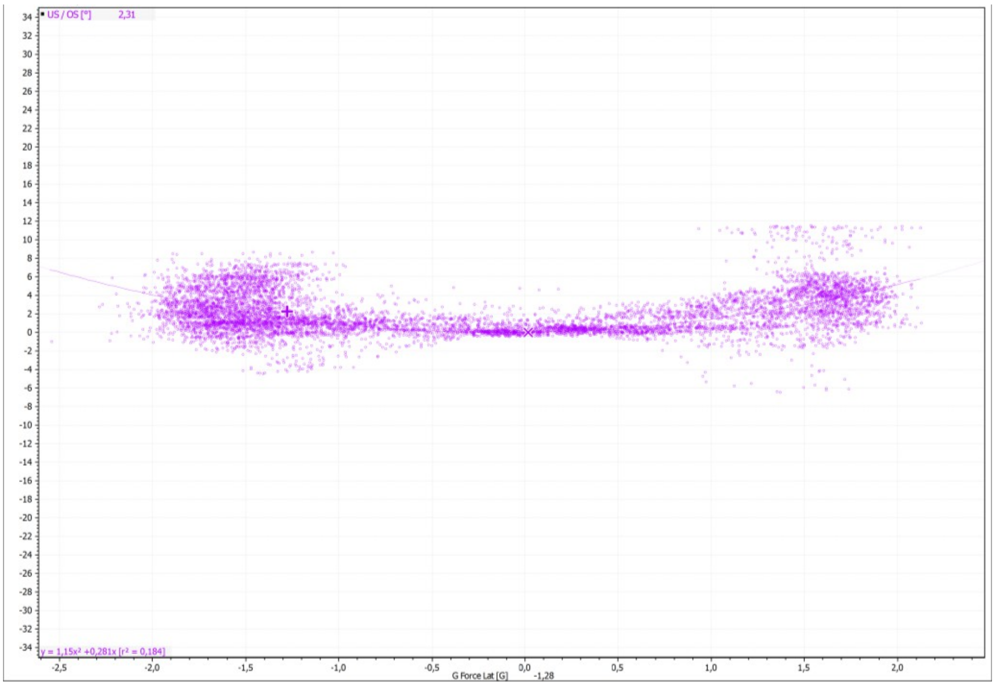

Figure 6 Differential angle between front axle and rear axle at Formula Student Hungary

Figure 6 clearly shows that the differential angle between the front and rear axles is mostly positive as lateral acceleration increases. From this we were able to deduce understeering behavior and adjust this for the next race.

4 Summary

By using the OMS 7 ground speed sensor provided by Sensoric Solutions, our team was able to achieve significant improvements in vehicle dynamics this year. The sensor enabled precise measurement of longitudinal and lateral speed with a frequency of up to 1000 Hz. This led to a significant reduction in speed deviations, which previously amounted to up to 20 km/h.

Thanks to the sensor, we were able to determine the speed differences at the wheels more precisely, which enabled optimized slip control and improved traction. The sensor also helped us to determine the vehicle's slip angle, which allowed us to better analyze and adjust the vehicle's behavior in curves. This resulted in increased driving stability and reduced lap times.

The ground speed sensor also provided important data for determining the slip angle, which helped us to fine-tune the tires. By analyzing this data, we were able to detect understeering at an early stage and make adjustments to the set-up.