<u>The missing element of an autopilot.</u>

"Level 5: the human driver is not required to perform any operations apart from starting the system and indicating the destination. The automated system is able to arrive at any destination unless it is prohibited by law"

According to SAE classification

'The only crucial thing is, an autopilot must save, and not kill'

A real automotive industry revolution is currently under way: the self-driving car development race is constantly joined by more and more manufacturers. ‘Driverless’ cars supervised by a human driver ready to take over the control have already traveled millions of motorway kilometers worldwide. Unfortunately, the experience has also included a number of fatal accidents involving self-driving cars.

This article describes the most common autopilot type already, or at least in the nearest future, capable of claiming Level 4 or 5 under SAE classification, which is intended for installation on a mass production vehicle and consisting of:

- Vision devices, such as video cameras, lidars, radars and other suchlike sensors.
- Centralized hardware and software component set represented by a high-speed computing system containing features of a learning neural network.

This component set is interfaced to the vehicle’s motion components through standard asynchronous communication channels.

The autopilot operates as follows:

The data from cameras, radars, lidars and other sensors (vision devices) are processed and synchronized. This information together with the information received from the motor car’s sensors and systems is used to generate the motion vector. To maintain the latter, the autopilot generates commands for the car’s actuating mechanisms (steering wheel, accelerator, brakes, clutch, etc.). There is a continuous monitoring over the car position assigned by the autopilot and the actual one (there is no need to describe what is widely known).

And that is precisely where we encounter the principal problem, namely:

- The motor car controlled by the autopilot is made of mass produced electromechanical motion control systems.

- These systems are interfaced with the autopilot through asynchronous communication channels. The channels’ asynchronous nature results in accumulation of data referring to to different time points. As a result, the generated vector is ‘fuzzy’, which is also true about the motion vector transmitted by the Autopilot in reference to the synchronization grid where it was formed.

- The upper limit for the frequency of the motor car interaction with its ambience is around 100 Hz (upwards of 60-80 km/h). This implies that ensuring of 1 per cent control precision requires the duration of the control vector generation not to exceed 1 ms (Kotelnikov 's - Shannon Theorem).
  When the amount of information is large the vector generation in the existing (asynchronous) systems takes longer than that specified above.

- Asynchronous communication between the motion control systems disrupts the time grid of the vehicle’s assemblies and systems. This, according to Control Theory, renders unstable the control systems. This is the primary cause for the vehicle skidding during quick change of commands. The vehicle controllability decreases dramatically.

Conditions like that make it complicated to control the car, as the vehicle is deviating from the generated motion vector, which under certain circumstances can bring about unfavorable results.

The autopilot worked perfectly but was let down by the asynchronous communication between the motion control system components.

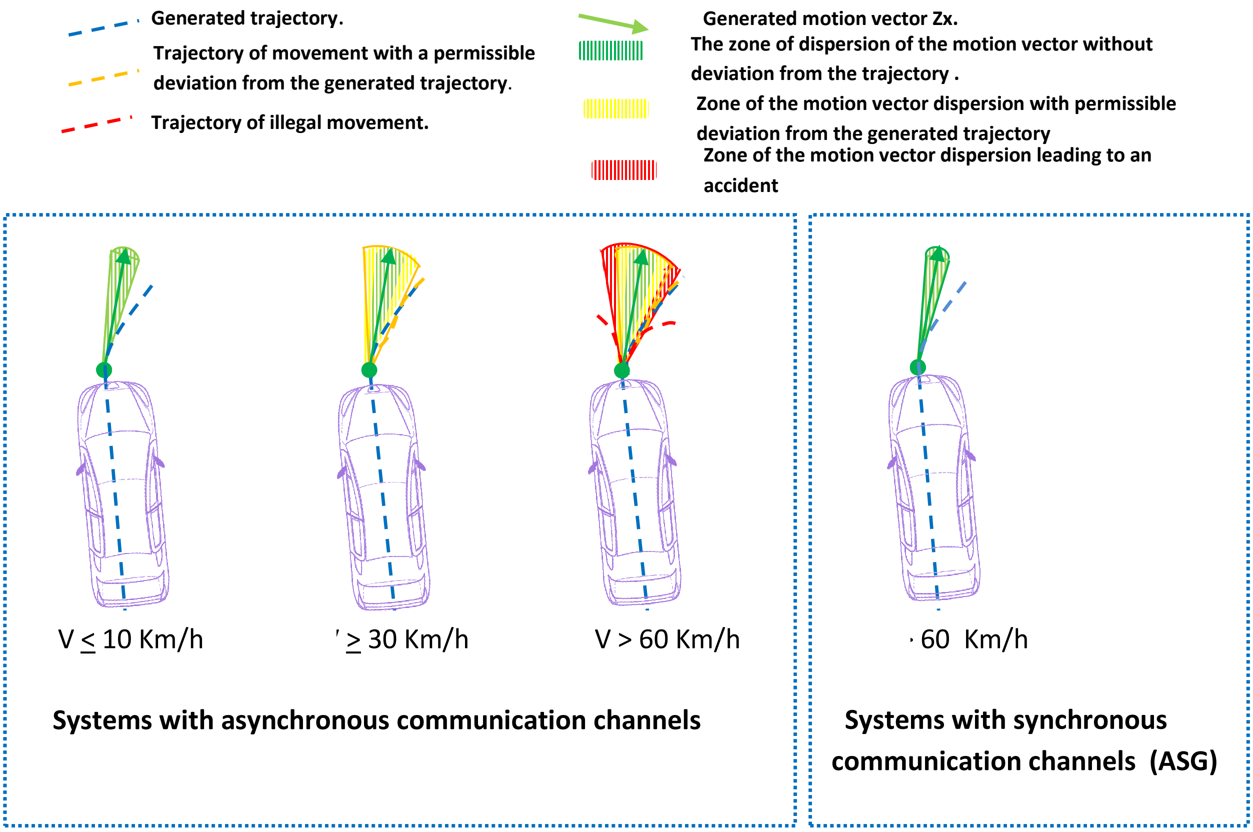


Fig. 1.

The faster the car goes, the more dispersed its motion vector Zm becomes as compared to the generated motion vector Zx at each point of the car's trajectory.

The Zm vector's dispersion zones are shown in Fig.1. In the same place, the deviations of the trajectory of movement are shown, provided that the deviations of the vector within the boundaries of the zone are equally probable.

The ratio of the width of the zone of the motion vectors' distortion that does not cause deviation from the given trajectory (shown with the green section of the dispersion zone) - Δ Zmg to the full width of the dispersion zones for vectors Δ Zm is shown in Fig. 2.

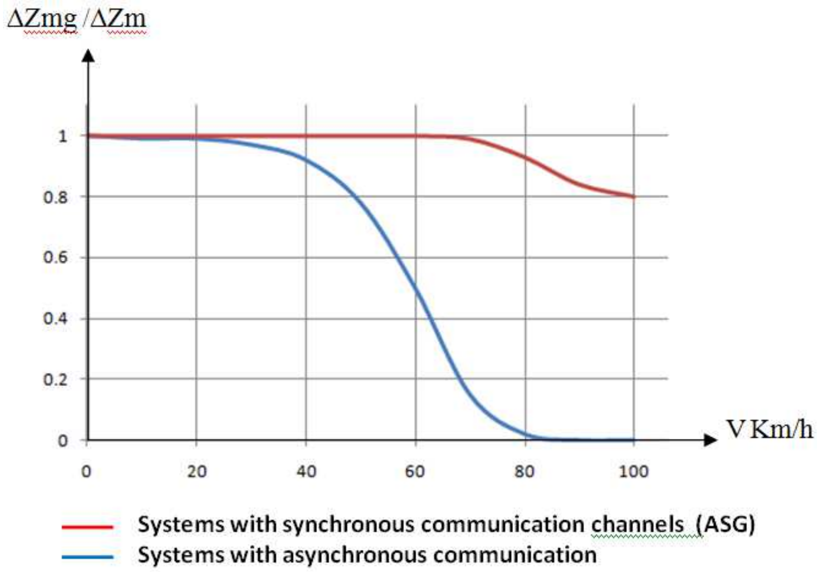


Fig.2.

All this can be avoided if the control system governing the motor car motion management units and subsystems operates in the same time grid with the Autopilot. A still better option would be for the motion control system itself to process the motion vector generated by the autopilot and manage the vehicle's motion.

Thus, in a Level 4-5 autopilot the control platform managing the motion control units and subsystems must make an integral part of such autopilot and operate in the same time grid with it.

The autopilot's computer must act as the motion control system supervisor and consider the car as a single entity, generating its motion vector as a whole instead of giving separate commands (steering wheel turning, acceleration, activation of brakes or clutch, etc.)

While automotive electronics has been growing exponentially over the last 30 years, new functions are constantly being added to those already existing and implemented using the asynchronous communication protocols which fail to comply with today's requirements.

Conflicts between the inner electronic systems make one of the major problems with today's cars, mentioned by numerous automotive engineers and journals.

But even the newest Ethernet-based vehicle control platforms cannot totally eliminate the consequences brought about by the delays at the network junctions, which negatively affect the vehicle motion control system stability. The works to rectify such delays are performed as early as the implementation stage.

Despite the automotive industry being prone to conservatism both market and evolution demand a major upgrade of the vehicle control architecture.

It is imperative to drastically change its lower level architecture arrangement principles.

This is the only way to ensure motor car motion control stability.

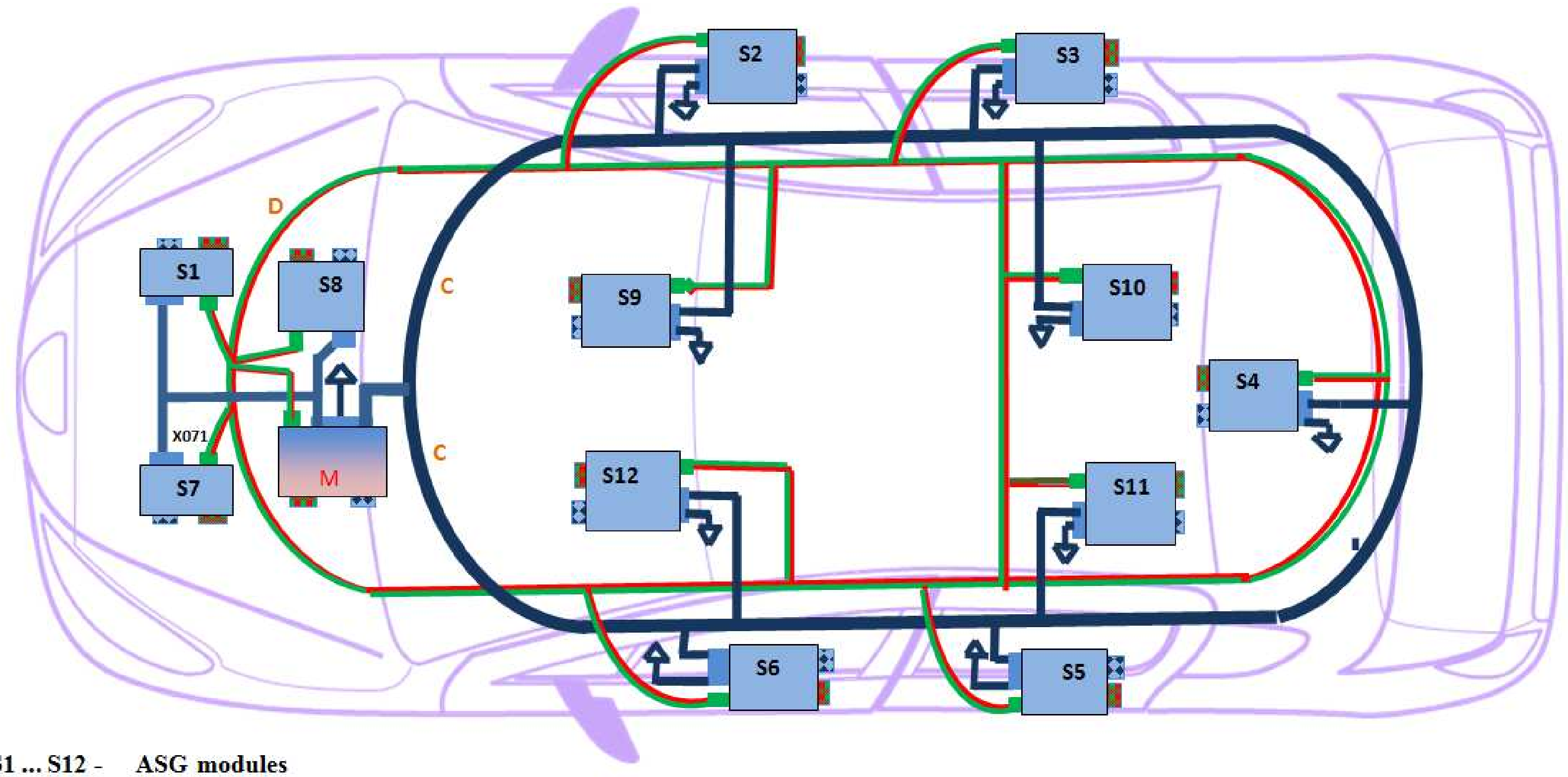
We consider the ASG (Automotive Smart Grid)* control platform which is currently being developed by Industrial Group FINPROM-RESOURCE (FPR) to be the most promising baseline for solution of the mentioned issues. ASG is the missing component for making the Level 4-5 autopilot really safe.

ASG integrates nodes and control systems of vehicles into a single synchronized organism capable of making decisions in real time under the guidance of an autopilot.

Besides, it is cheaper than the systems installed on the currently built motor cars and exceeds their efficiency by several times. Synchronized operation of the units and distributed computing network enable building of a distributed control system to manage the motor car units and neural networking integration to the lower level**.** When installed on a vehicle, our platform can replace the existing control systems thus removing kilometers of harnesses and decrease the cost of their installation.

Hardware and Software architectures are shown in the figures below.

Hardware architecture of the ASG control platform



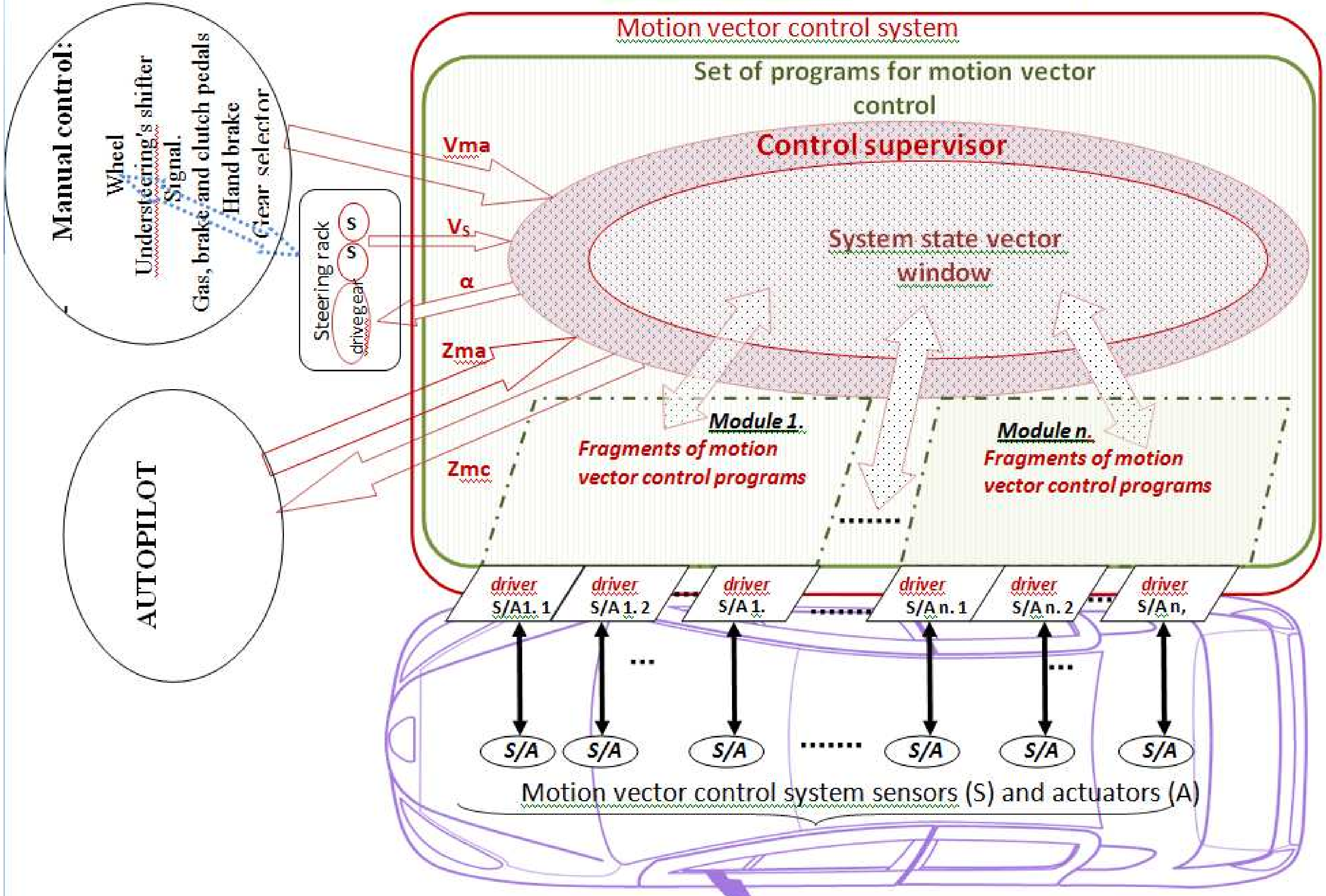
S1 ... S12 - ASG modules

M - Module "MASTER" ASG

(red/green line) - PLC bus - (twisted pair)

(dark blue line) - Single wire bus + Ucc {Ucc = 12 ou 24 ou 48 volt}

Software architecture of the ASG control platform



The frame rate of the motion state vector window is 1 kHz (1 ms).

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* ASG (Automotive Smart Grid) is a digital control platform that integrates distributed nodes and systems into a distributed real-time control system. The units of the ASG platform are interfaced by a two-wire circular PLC communication channel (Power Line Communication). The computing capacity of the ASG platform modules are represented by a distributed synchronous computing network (Real-Time) with motion control functions.