Unique Challenges

with Autonomous Vehicle Systems Design and Integration

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Stories about autonomous vehicles are regular fare in the tech news cycle and usually include forecasts about the eventual ascendancy of self-driving cars. It is projected that by 2035, 25% of all cars will have partial or full autonomy [1]. In the short few years since the Google concept car, auto manufacturers new and old have announced their plans [2] for commercializing autonomous vehicles starting as early as 2021. That's disruption! So what will it take to deliver on this future? Without a doubt, artificial intelligence with robust machine algorithms to comprehend road and traffic conditions and make appropriate decisions is the most critical. However, it will take a lot more than artificial intelligence to build commercially-viable autonomous vehicles.

To deliver, the automotive supply chain will reshape very drastically in the coming years, where necessary component-level technology (sensors/fusion box/new electronics) will be driven by the new entrants (technology/electronics startups or large organizations) but the responsibility of vehicle integration will continue to be with auto OEMs. This fast evolving supply chain coupled with a paradigm shift in desired vehicle functionalities, pose unique challenges to autonomous vehicle engineering. In this article, I highlight the key challenges and Mentor's solutions to address them.

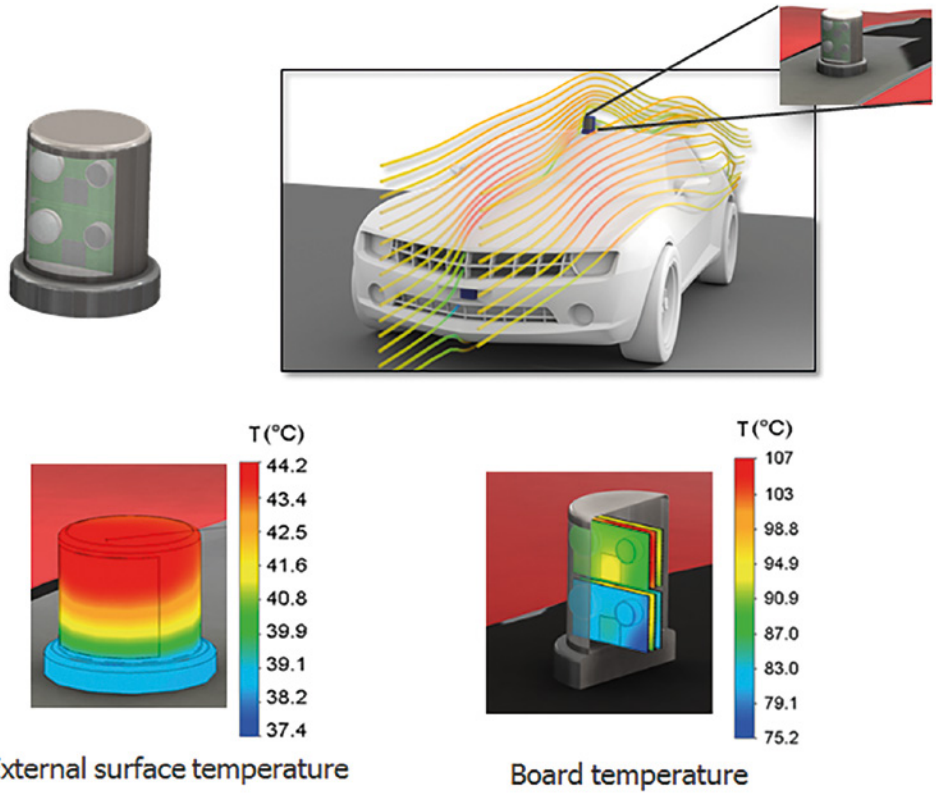

Figure 1. FloTHERM XT CAD-embedded thermal simulation of a rotating lidar mounted on a vehicle. Vehicle is moving at 10m/s and the ambient temperature is 25ºC.

Sensor Design Exploration

Design goals for lidars, radars and cameras, three of the most critical sensors for autonomous vehicles, are largely centered on size and cost reduction without sacrificing high resolution and the high range necessary to support various levels of vehicle autonomy. Additionally, these sensors when integrated in vehicles, must function reliably in an automotive environment and in all-weather conditions. Desired small form factors and functionality consolidation for signal processing in the sensors may cause significant heat build-up that may be detrimental to performance and/or reliability of sensors. This may deter sensor size (and cost) reduction efforts. Thermally-conscious designs for sensor electronics as well as for their enclosures, while taking into account their vehicle integration locations, is critical to achieve the desired size (and cost) reduction while achieving high resolution and range goals are met. Mentor's EDA-centric, CAD-embedded softwares are ideally positioned to address these challenges from the early design stages. Figure 1 exhibits thermal simulation of autonomous vehicle lidar, accounting for its vehicle integration location using FloTHERM XT. In this Engineering Edge, there is also an article on IR camera thermal management design exploration based on the Masters' thesis of Hugo Falk from KTH Industrial Engineering and Management Institute. Reliable estimation of thermal behavior for lidars (solid-state lidars and/or mechanical rotating lidars) allow hardware engineers to achieve the desired size (and therefore cost) reduction without jeopardizing sensor life, due to undesired hotspots, in the automotive environment. Lidar integration in headlights, pursued by many companies, may pose additional challenges to lidar thermal footprint, as well as may impact lidar performance with headlight fogging or icing. FloEFD™, with its design-centric headlight design simulation capabilities, is helping companies to account for such vehicle integration issues. Additionally, heat build-up in sensors, especially in cameras, can negatively impact output quality, posing challenges to building reliable a 360º view around the vehicle. Sensor thermal simulation, therefore, taking its vehicle integration location and real world driving scenarios, impacts autonomous vehicle virtual testing, verification and validation.

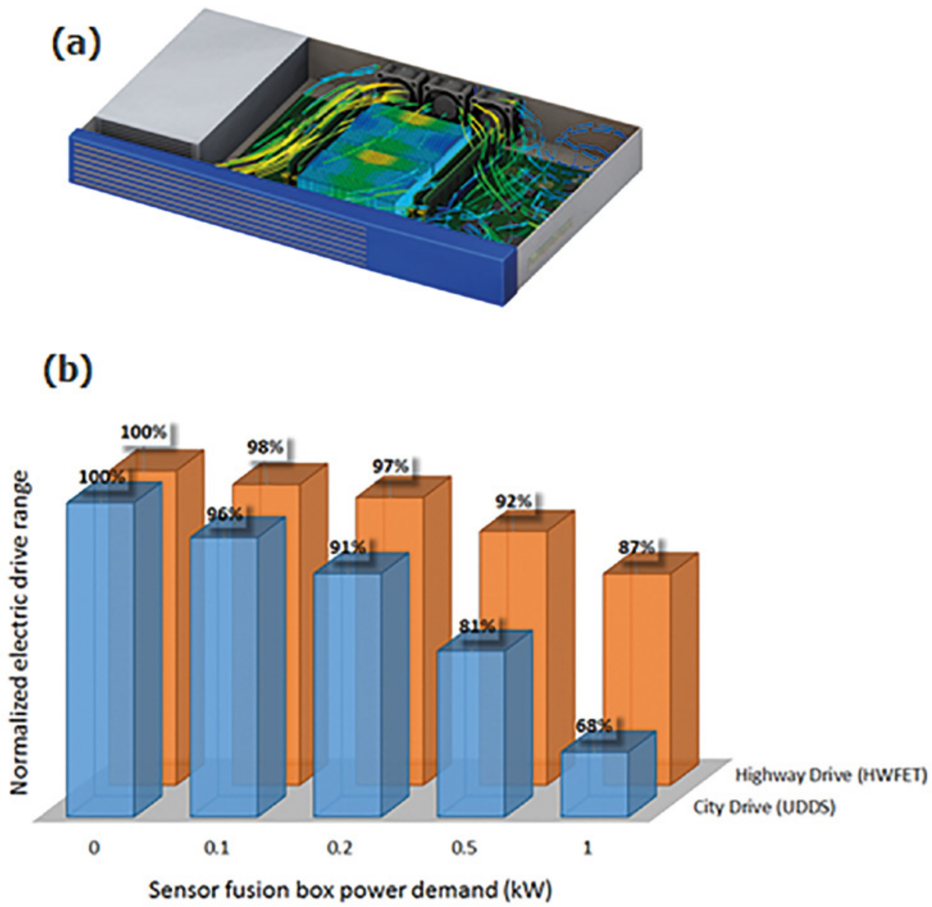

Figure 2. (a) CAD-embedded electronics cooling simulation of sensor fusion box using FloTHERM XT (b) FloMASTER autonomous vehicle system simulation to evaluate sensor fusion box power demand on electric drive range. Sensor fusion box is powered by the high voltage battery via DC-DC converter, in this example

Sensor Fusion Box Reliability and Power Consumption

Most of today's autonomous test vehicles have a trunk full of computers to ensure data from multiple vision and non-vision sensors can be efficiently fused together to create an accurate 360° view around a vehicle. However, for a commercial ready vehicle, desired processing efficiency must accompany size reduction for the fusion box for easy integration in a vehicle. This poses a significant challenge to sensor fusion electronics board design, as well as box enclosure design to ensure robust active cooling design considerations are taken into account. Our electronic cooling software FloTHERM™, a de facto standard for electronic cooling for the last 30 years, and its seamless integration with T3ster®, is ideally suited to address shrinking geometry related design challenges for sensor fusion box. With an electric powertrain, sensor fusion box will likely be powered by high voltage battery, through a DC-DC converter, and that can impact electric drive range. This makes power consumption of the sensor fusion box a key criterion for vehicle integration. However, there is no publicly mentioned target for sensor fusion box maximum power consumption. FloMASTER™ system simulation can evaluate the impact of the sensor fusion box power demand impact on battery drive range and can empower suppliers and auto OEMs alike to develop and integrate a sensor fusion box that can deliver the required intelligence without impacting on vehicle performance/range. For instance, Figure 2 shows a 250W (NVIDIA PX2) or higher power consumption sensor fusion box can reduce electric drive range by 10% or more, especially in city drive. This analysis further highlights the advantage of Mentor's DRS360 sensor fusion platform, which consumes no more than 100W- for commercially-viable autonomous vehicles.

Vehicle Integration and E-Powertrain Implications

Electric powertrain is indispensable for autonomous vehicles as it offers a) higher fuel efficiency and reduced CO_2 emissions, b) an easier platform to support drive-by-wire

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systems needed for vehicle autonomy, and c) as battery prices keep dropping sharply, an attractive proposition of lower cost of ownership and maintenance, especially for fleet owners in a ride-sharing ecosystem. However, integrating vehicle autonomy with electrification will not be simple additive manufacturing. Vehicle autonomy poses additional challenges as well as unique opportunities to optimize electric powertrain size and energy management. For instance, the tremendous increase of vehicle electronics can impact electric drive range, especially in city drive. Whereas, autonomous vehicles are expected to be driven in a pre-determined way, especially Level 4 and Level 5 autonomous vehicles, that eliminate the need to account for 90th percentile driver (with highly aggressive driving pattern) and its impact on electric powertrain sizing and operation. Additionally, in a ride-sharing city-centric usage of autonomous vehicle, power demand to support cabin comfort is expected to challenge the available drive range and may warrant a complete redesign of cabin comfort. For these and many other aspects of autonomous electric vehicle, Mentor's frontloading e-powertrain simulation capabilities in FloMASTER and FloEFD allow users to define, design and evaluate electric powertrain architectures in the early phase of design. To learn more about Mentor's e-powertrain component to system simulation and reliability characterization offering, refer to our very recent white paper [3].

Vehicle Safety and In-Cabin Experience

With the increase in vehicle autonomy, safety-critical functions of steering and braking will depend on electronic control units (ECU). One of the biggest challenges for ECU design engineers is to manage power (and hence thermal) load on electronics, especially in harsh automotive operation. It has been demonstrated that thermal problems with ECUs invariably lead to electronic failures, which for autonomous vehicles will have severe safety implications. Mentor's Mechanical Analysis Division has been empowering major suppliers all over the world in developing reliable ECUs [4]. Additionally, as vehicles evolve towards Level 5 autonomy, passengers' expectations from in-cabin experience are expected to go through a paradigm shift. Infotainment systems are very likely to evolve towards thin large screens that may be integrated in the vehicle interior in ways that haven't been done to date. To meet these challenges, ECU and infotainment systems design engineers are exploring electronics consolidation. This can pose unique electronics cooling challenges for such systems. Mentor's T3Ster products are one-of-a-kind tools for non-destructive reliability characterization of PCB/semiconductors that allow suppliers to accurately quantify their product's life in real world drive cycle conditions. This coupled with FloTHERM XT/FloEFD electronic cooling software, benefit users to significantly compress time to design and develop ECUs for the drive-by-wire units and new infotainment systems.

As mentioned before, autonomous vehicles warrant technology integration from two vastly different verticals: electronics/technology and automotive. Historically, the two industries have very different product lifecycle requirements and product development trajectories. Simulations are, therefore, expected to play a critical role to connect these two industry verticals from component level design exploration to vehicle integration to vehicle-level verification and validation. Mentor's Mechanical Analysis Division frontloading, design-centric software, as shown through some of the examples in this article, are well-suited to address the challenges for autonomous vehicle engineering. Various customer stories in this edition of Engineering Edge and in the previous ones showcase the improvement in design efficiency our softwares are bringing to the customers in automotive and electronics industries all over the world. Extrapolating these benefits to autonomous vehicle engineering promises to bring a significant reduction in time and cost for design and vehicle integration for autonomous vehicle hardware.

References:

[1] https://www.bcg.com/expertise/industries/automotive/autonomous-vehicle-adoption-study.aspx

[2] http://www.businessinsider.com/companies-making-driverless-cars-by-2020-2017-1/

[3] "E-Vehicle Thermal Management Powertrain Simulation", a Mentor White Paper (Link)

[4] "ECU Thermal Reliability Becomes Mission Critical", a Mentor White Paper (Link)

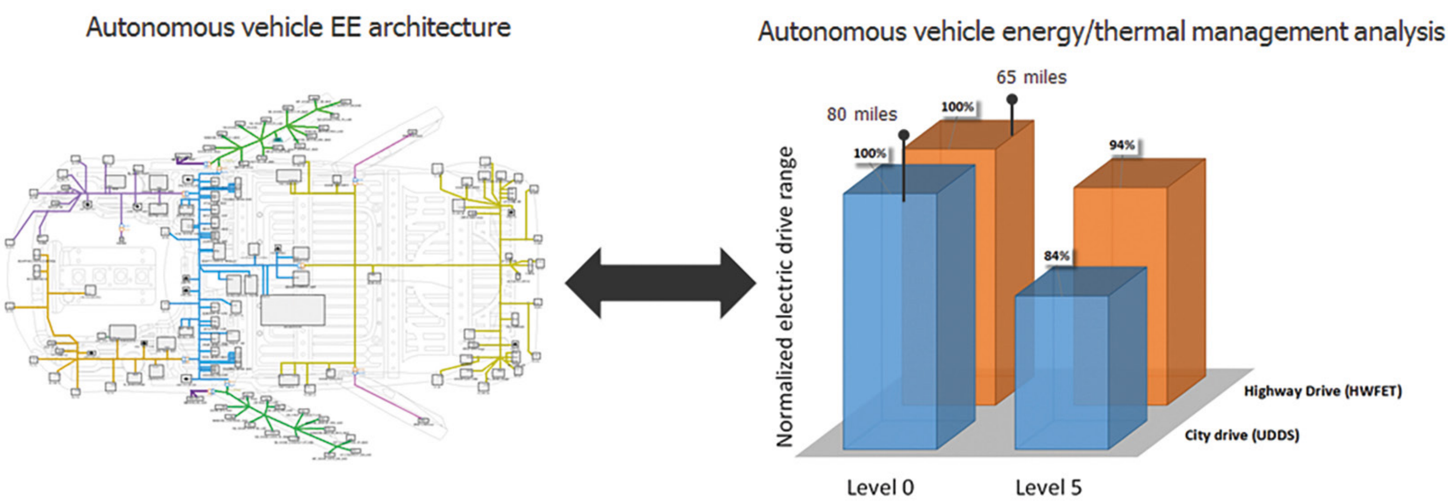

Figure 3. Impact of Level 5 autonomous vehicle system integration on electric drive range. In this example, Level 5 autonomous electric vehicle (80 miles electric range with 80kW front motor drive unit) is simulated where vehicle EE architecture (simulated using Mentor's Captial software) includes 30 sensors, DRS360 centralized sensor fusion and ECUs for steering and braking. Electric drive range is simulated at 25°C ambient conditions using FloMASTER based e-powertrain simulation framework.