ENGD PROJECTS 2021

Automotive/Mechatronic Systems Design

TU/e

EINDHOVEN UNIVERSITY OF TECHNOLOGY

The EngD Automotive Systems Design, existing since 2011, is an accredited and challenging two-year doctorate-level engineering degree program. Since 2015 the subtrack Mechatronic Systems Design is part of this program. During these programs trainees focus on strengthening their technical and non-technical competencies related to the effective and efficient design and development of technologies and applications for modern high-tech automotive and mechatronic systems. In particular, there is a focus on the multidisciplinary design aspects of project-based research and engineering in high-tech automotive and mechatronic systems, reflected in the key contributions by four TU/e departments. For more information please visit tue.nl/asd.

Automotive/Mechatronic Systems Design - EngD Projects 2021

DR.IR. CAMILO RINDT
IR. RISKE MEIJER
ELLEN VAN HOOF-ROMPEN MSC

The 2019-2021 generation ASD/MSD trainees

The EngD-program Automotive/Mechatronic Systems Design is embedded in the department Mathematics and Computer Science, and supported by the departments Mechanical Engineering, Electrical Engineering, and Applied Physics. The program is also supported by the Eindhoven Artificial Intelligence Systems Institute. The program is driven by the rapid changes in the Dutch high-tech ecosystem with huge challenges in terms of multidisciplinary product and process design and engineering.

With great pleasure we present to you the results achieved by the twelve graduates of our program, of who there were five in the track of Automotive Systems Design, and seven in the track of Mechatronic Systems Design. These graduates started the program end of 2019.

The variation in disciplines is reflected in the 12 graduation projects that are presented in this booklet. The subjects of these projects are in the field of automated driving, alternative fuels for vehicles, charging of electric vehicles, artificial intelligence, system control, alternative energy source, and software architecture.

Most of these EngD-projects were funded and proposed by the high-tech industry, of which a few were co-funded. Some of the projects were part of a (co-)funded consortium project. One of the projects was performed internally.

The projects are diverse, complex and challenging. They require our trainees to deliver products and designs that meet high demands in a multidisciplinary setting. We are proud that our trainees live up to the high expectations from industry. We wish them all the best and a successful career.

In case you are also interested in an EngD-project within our program, please, contact **asd@tue.nl**, and we will organize an introduction meeting with you.

Camilo Rindt	Riske Meijer	Ellen van Hoof-Rompen
Scientific Director	Program Manager	Management Assistant


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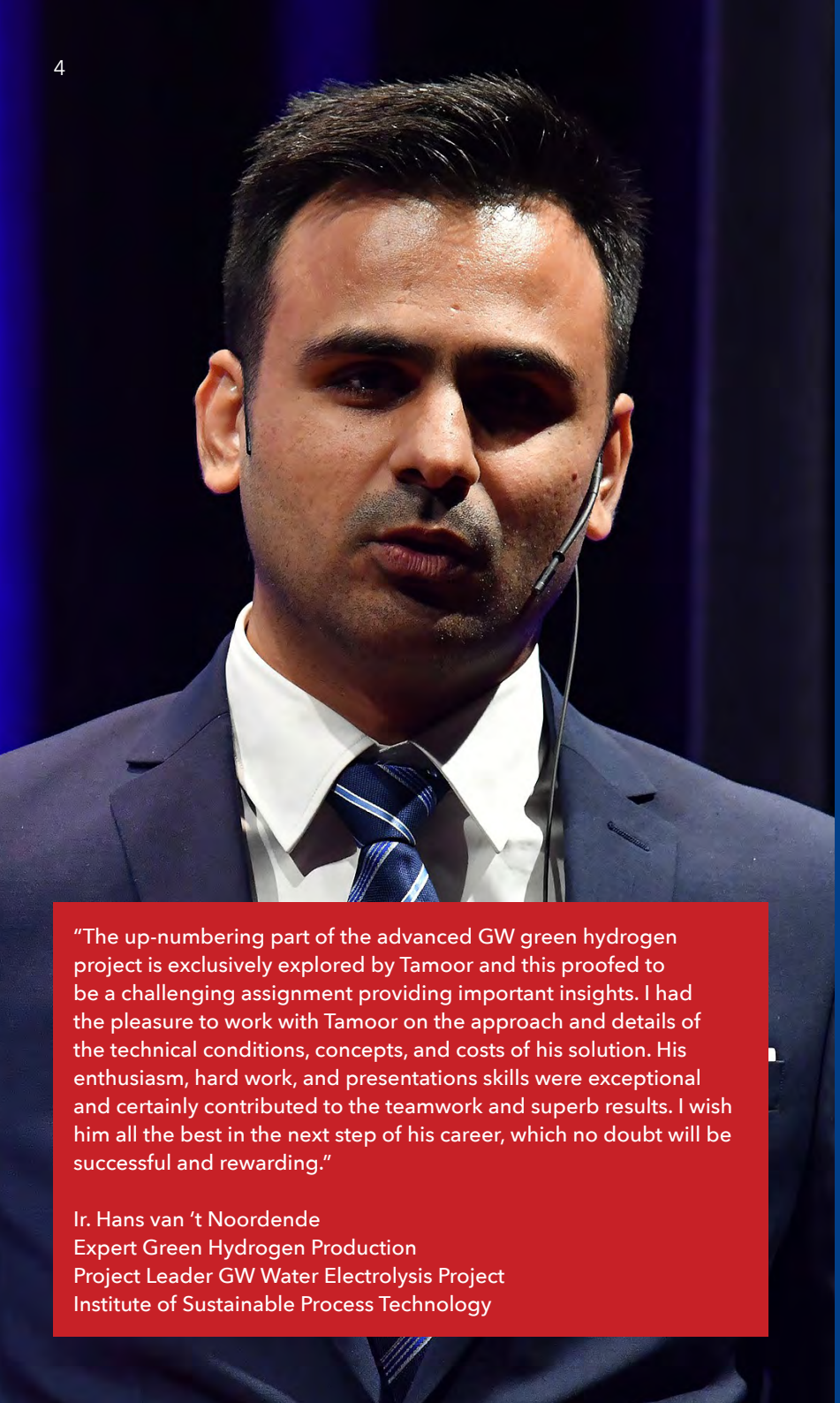


"The up-numbering part of the advanced GW green hydrogen project is exclusively explored by Tamoor and this proofed to be a challenging assignment providing important insights. I had the pleasure to work with Tamoor on the approach and details of the technical conditions, concepts, and costs of his solution. His enthusiasm, hard work, and presentations skills were exceptional and certainly contributed to the teamwork and superb results. I wish him all the best in the next step of his career, which no doubt will be successful and rewarding."

Ir. Hans van 't Noordende
Expert Green Hydrogen Production
Project Leader GW Water Electrolysis Project
Institute of Sustainable Process Technology

CHALLENGES

There were two main challenges. Assessing the technical feasibility parameters i.e., availability, reliability, and safety of electrolyzer plant these required extensive research and consultation with industry experts because of limited data available from the company. The second challenge was the validation of conceptual design which ideally happens via an experimental setup or a simulation but based on the research nature and limited time available, there was pressure to validate the design via industry experts.

RESULTS

Technical analysis models were developed to assess the technical feasibility of the conceptual design of electrolyzer stacks containers by following standard industry practices. The basis of these models was the V-Model methodology which translated system requirements into conceptual designs. The results were validated by multiple consultation sessions with industry experts and the design was approved to be technically feasible.

BENEFITS

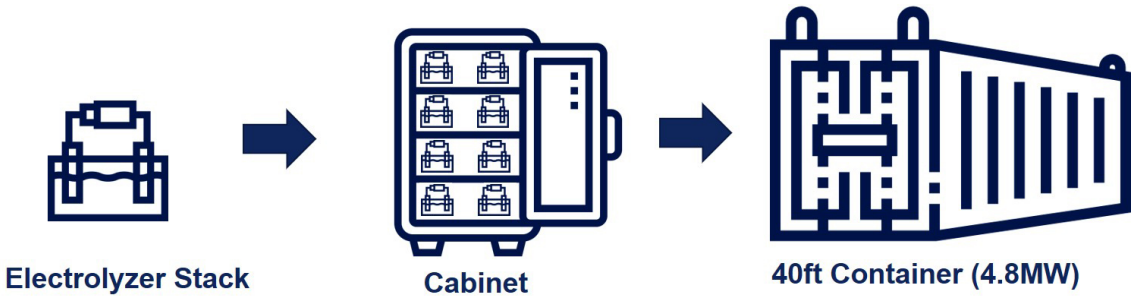
The proposed V-model methodology, technical feasibility and design models developed in the project will help design engineers to optimize the conceptual design for different physical and flow parameters and regulate the safety, availability, and reliability of the electrolyzer plants. By using the models, the engineers can readily get an idea about the technical feasibility of a setup in the early stages of design. This conforms to the first-time-right design and faster development timeframes.

TAMOOR ALI, MSc EngD

Conceptual Design of Gigawatt Scale Green Hydrogen Electrolyzer Plant for CAPEX Reduction

The importance of green hydrogen in decarbonizing the industrial sector is increasing to achieve the energy transition. However, the challenges of high upfront investment costs for green hydrogen production and in turn high cost of hydrogen gas at the output of green hydrogen electrolyzer lie ahead. To reduce investment costs, economies of scale modeling is adopted in the process industry. This means that the hydrogen production should go up to at least a gigawatt scale to be cost-effective. This is achieved by following the upscaling methodology where larger sized equipment helps to reduce cost by using fewer materials per capacity or volume with onsite mounting and erection or the up-numbering methodology where smaller sized but larger number of equipment benefit from mass manufacturing and pre-assembly in modules. However, up-numbering comes with the added complexity of architecture and the costs of interfaces.

The goal of this project was the development and technical feasibility analysis of a conceptual design of a containerized PEM Electrolyzer Stacks Module seeking to optimize CAPEX reduction through an up-numbering methodology for two stack sizes i.e., 10kW and 100kW. The results showed that the conceptual design was technically feasible to operate based on availability, reliability, and safety but was expensive in comparison to the upscaled versions.



CHALLENGES

There are multiple successive steps in the breaker preparation process until it is rolled on to the drum. Combined with the fact that sensors to measure position accuracy of edges where only available in limited parts of the process, it was a major challenge to determine the main source of error in edge alignment. Further, another challenge was to translate splice matching error on the drum to earlier steps, to evaluate the quality of the process.

RESULTS

In simulations, we observed that the designed controller helped in reducing the positioning error of the leading edge from 0.72 mm to 0.03 mm and for the trailing edge from 0.94 mm to 0.58 mm. Hence, the major takeaway of the project is to put efforts into improving the design of the PID controller to improve accuracy in positioning of breaker edges.

BENEFITS

The investigation performed in this project has assisted in pointing out various sources of error in the breaker preparation process. Moreover, improving control loop design showed the potential to reduce edge positioning error of the breaker, and thus setting up the base for future work.

"VMI develops and produces tire assembly machines. For one of these machines VMI wishes to further automate the system on the carcass side. The goal was to investigate if VMI can improve the tire quality by automating the process, by using output measurements from the system, and camera data as input to controllers. Pranjal investigated the system, and performed many tests. Finally, Pranjal showed the sources of errors in the system, and developed a model of a control loop that showed the splice matching error can greatly be reduced. With this work, Pranjal provided VMI with more insight into the system, and made valuable recommendations on how to improve its working by means of automation."

Ir. Riske Meijer
Program Manager ASD/MSD
Eindhoven University of Technology

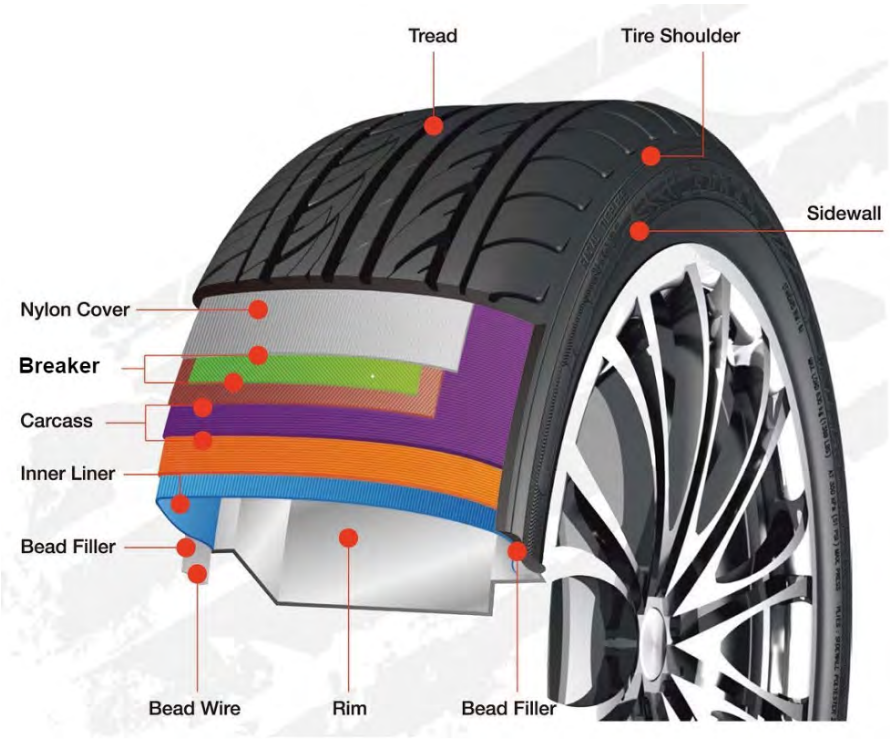
PRANJAL BISWAS, MSc EngD

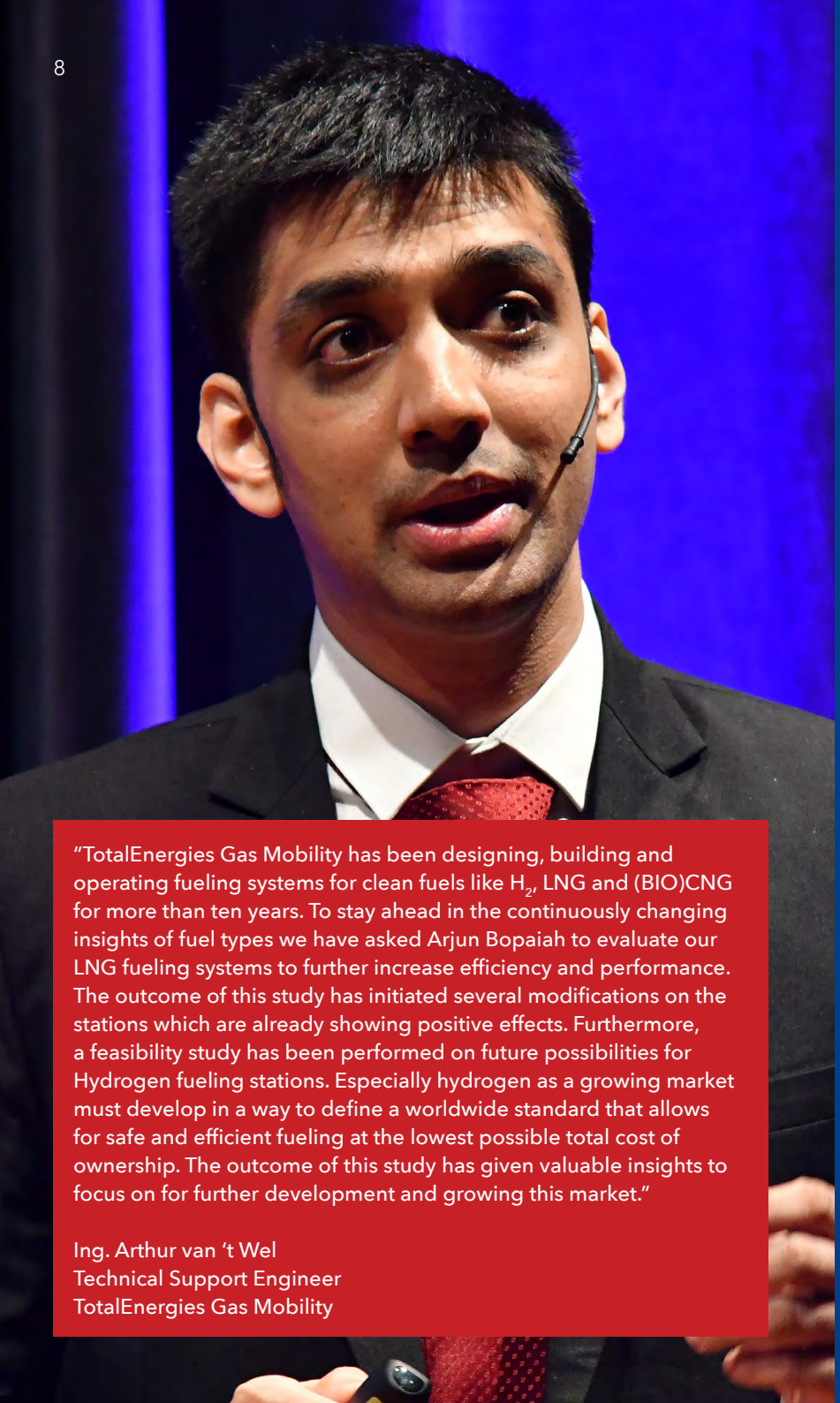
Self-Adjusting Breaker Servicer

To prevent car accidents, it is important to ensure good quality tires. In order to manufacture good quality tires we require specialized tools. One such tool, a Tire Assembly Machine (TAM) is produced by VMI. To produce good quality tires we need to ensure the quality of the processes involved in a TAM.

In this project we investigate one of the many processes of a TAM: namely the breaker preparation process. Here, a breaker (a type of tire material) moves forward across the conveyors and finally it is rolled on a drum. The rolled breaker is a semi-finished, but a crucial product of the whole process. We measure the quality of this product by a parameter called the splice matching error. It represents the quality of alignment of the leading and trailing edges of the breaker after the breaker has been rolled on the drum. This is where the main issue lies. In the TAM we observe considerable splice matching error which needs to be reduced to an absolute maximum value of 0.5 mm.

In this project we inspect various aspects of the TAM with respect to the preparation of the semi-finished breaker by performing multiple tests. We investigate the actuators, reference generation algorithm of the edges, the control loop, other sub-systems and help in improving the design of the control loop. To this end, the project mainly focused on reducing the splice matching error by performing extensive investigation and recommending design improvements.





"TotalEnergies Gas Mobility has been designing, building and operating fueling systems for clean fuels like H_2, LNG and (BIO)CNG for more than ten years. To stay ahead in the continuously changing insights of fuel types we have asked Arjun Bopaiah to evaluate our LNG fueling systems to further increase efficiency and performance. The outcome of this study has initiated several modifications on the stations which are already showing positive effects. Furthermore, a feasibility study has been performed on future possibilities for Hydrogen fueling stations. Especially hydrogen as a growing market must develop in a way to define a worldwide standard that allows for safe and efficient fueling at the lowest possible total cost of ownership. The outcome of this study has given valuable insights to focus on for further development and growing this market."

Ing. Arthur van 't Wel
Technical Support Engineer
TotalEnergies Gas Mobility

CHALLENGES

One of the greatest challenges in minimizing the energy and power consumption of an LNG and H_2 station is the accuracy and extent to which the dynamics of the fuels can be modelled during its storage and operational behavior at the station. Thus, considerable time and effort were put into modelling the true behavior of the fuels inside each component of the station and then validating it against the actual station data.

RESULTS

The developed LNG model showed good agreement with station data for particular scenarios of interest and the suggested operational changes could be realized for the current LNG station design to minimize the operation cost of the station. Finally, the feasibility study performed for different LH_2 filling station setups showed great promise in terms of reduced capital and operational cost of the H_2 station and is now under consideration for future station design.

BENEFITS

The reduced cost of operating and maintaining an LNG and H_2 filling station in years ahead will result in a reduction in the cost of LNG and H_2 fuels offered to the customers. This cost reduction shall enable more customers to switch from gasoline-powered fuels to alternate fuels which can be seen as an opportunistic business case for TotalEnergies for upscaling and expanding their future filling stations.

ARJUN BOPAIAH, MSc EngD

Materials for Compressed Fuels under Dynamic Loading Conditions

Alternate fuels like LNG and H_2 have shown great potential to replace gasoline-powered fuels in terms of transportation and more importantly in order to meet the emission regulations set by the EU for 2030. In order to accommodate the future demands for these fuels, there is a requirement of having higher and a widespread number of infrastructure for LNG and H_2 filling stations. Currently, the cost of building, maintaining, and operating an LNG and H_2 filling station infrastructure offered by TotalEnergies is quite expensive and this is resulting in an increased fuel cost offered to the customers. In order to have LNG and H_2 filling stations as a viable business case for future operations, TotalEnergies has a business goal in identifying ways in which the maintenance and operational cost of the filling station could be minimized.

In this project, energy, and power consumption models for LNG and H_2 filling stations are developed in order to provide an insight into the key areas where the current filling stations design could be improved wherein the introduction of different materials to the station adds to this improvement. The results obtained from the developed model could be used to either improve the current filling station design or extend the results for future filling station designs in order to minimize the operational and maintenance cost of running a filling station.

CHALLENGES

One of the major challenges was to design a framework that would be suitable for all versions of the communication protocols, especially because some of these protocols were being written while conducting this project. Making a design that would be generic and flexible was an iterative process because of this reason.

RESULTS

Simulations are executed on multiple abstraction levels. On the energy grid abstraction level, potential blackouts will be significantly reduced when introducing the smart, interconnected EV charger in a future neighborhood. On the software design level, the requirements defined in the use cases are verified successfully in the SysML simulation tool. Finally, on the implementation level, results show successful handling of the first protocol messages via the internet connection interface.

BENEFITS

With this system the EV owner saves money by storing their own generated energy at home by, e.g., solar panels for later usage, or to charge the EV when the price of energy is lower. The energy distributor benefits from this system as it has an extra energy source available. The charge point operators will also benefit from this system as it can introduce smart charging strategies for power optimization.

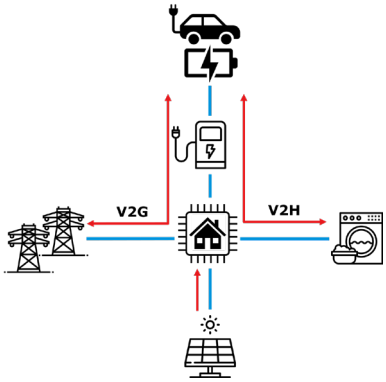
"The increasing EV fleet is becoming a burden for the electrical grid. Increasing the grid's capacity is a slow and costly effort, so alternatives such as smart energy management must be explored. An EV charger is an obvious choice to explore smart and bidirectional charging, as it has access to a significant energy buffer, i.e., the EV's battery, and is already equipped with digital communication interfaces. Koen's market research has provided Prodrive with insights into consumer behavior for EV charging. His software architecture has laid the foundation for the integration of smart charging in Prodrive's AC charger. A foundation from which the engineering team has continued with further development towards a commercially viable implementation. During his thesis, Koen has shown great passion for energy management in combination with a disciplined work style, resulting a great understanding of the market and a great collaboration with the project team. His excellent communication skills make him perfectly suited to further advance his career in the direction of sales activities. It has been a joy supervising Koen."

Ir. Juul Diks
System Architect
Prodrive Technologies

KOEN ELANDS, MSc EngD

Design of the Communication Controller Software for a Smart, Interconnected Electric Vehicle Charger

The increasing demand on the energy grid by electrification of our infrastructure will be a challenge in the near future. An energy grid of a future neighborhood has been simulated, which shows significant potential blackout moments if the charging strategy will remain uncontrolled. Uncontrolled charging is that Electric Vehicles (EVs) get charged at maximum power until the battery is full. Charging the EVs in a more efficient manner, or even use EV batteries as a buffer for the energy grid, will be a solution to optimize the energy usage and prevent potential blackouts. Two charging strategies are investigated in this project to reduce potential blackouts, i.e., smart charging and bidirectional charging. With smart charging, the charging power and timing is actively controlled. Incorporating also bidirectional charging, the EV battery can be discharged as well when this is required.



In this project, multiple aspects of smart and bidirectional charging are discussed, to show the feasibility, system functionality, and added value for the stakeholders involved with such charging infrastructure. An architectural design of the communication controller software component is proposed for the charger developed by Prodrive Technologies, using the model-based systems engineering approach. This controller complies with the latest protocols, such that it can communicate with a widespread range of EVs and charge point operators in a standardized manner to support smart and bidirectional charging.

Results show that if bidirectional chargers including the designed communication controller will be implemented in the future, the potential blackouts will be eliminated in the simulated neighborhood.

"A larger market of e-mobility requires a more flexible motor control system. In this project, Song demonstrated his solid background in mathematics and control engineering, and his outstanding competence in working independently as a system designer. What also impressed us was his structured way of working, his professional skills in communication, and his capability of cooperating with various parties in an industrial environment. We are happy to have Song in our team and proud of every milestone that he has achieved."

Dr. Yang Tang
Lead Senior Electrical Engineer
e-Traction

CHALLENGES

One of the major challenges is that e-Traction's customers have different levels of knowledge on their motors. They may not be able to provide abundant lookup tables for current-dependent motor parameters. Their provision can also be inaccurate. Parameter uncertainties of a certain percentage are expected. Under this circumstance, a robust current controller is required.

RESULTS

Two current control strategies and a current reference generation method are proposed. Through simulation on MATLAB/Simulink and the test on the Hardware-in-the-loop (HIL) setup, we find that our proposals are showing high practicability and have a high potential to improve the control performance.

BENEFITS

The proposed methods, which solves the optimization problems, are elaborated in an analytical manner and are validated under different conditions. A deeper understanding of control theories and control system design is achieved for the company. The company can further test the solutions on the real motors for multiple industrial applications.

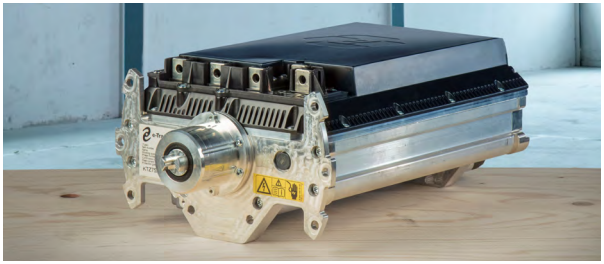
SONG GUO, MSc EngD

Optimal Current Control and Current Reference Generation for Various Permanent Magnet Synchronous Motors in Automotive Applications

With the continuous development of power technology and the increasing public awareness of zero emissions, electric cars have shown great potential to knock gasoline-powered vehicles off the throne. Attributed to high efficiency, low maintenance cost and low fuel consumption, permanent magnet synchronous motors (PMSMs) have gained substantial attention in the field of electric vehicle (EV) design and have been widely utilized in the EV industry.

e-Traction, located in Apeldoorn, the Netherlands, is dedicated to providing environmentally and economically competitive powertrain technology for e-mobility. Their product TheDrive has been adopted in many city buses and off-road vehicles across Europe. It consists of a self-developed PMSM and its control modules are developed and optimized for this machine. With TheDrive's outstanding capacities, e-Traction is ambitious to promote it as an independent product applicable to multiple industrial PMSM products. Under this circumstance, a controller adaptive to various PMSMs is required.

The project objective is to design a current controller and a current reference generator adaptive to various types of PMSMs with parameter variations. Meanwhile, the control performance in terms of response time is expected to be improved.



CHALLENGES

Defectivity performance is one of the priorities in the production of the semiconductor chip. A new specification for the defectivity performance demands a new measurement system to be added to the existing wafer load offset calibration process for ASML's lithography tools. The new measurement system not only has to satisfy the performance requirement but also should not add more complexity and risk to the current system. An example for that is the use of new hardware is not an option for the new measurement system. Next to that, the risk of damaging the current system should be avoided.

RESULTS

The achieved new measurement system ensures the production of the semiconductor chip by ASML's lithography tools becomes more cost-effective. The customers of ASML can gain more benefit by the less machine downtime and the less defectivity issue during chip production.

BENEFITS

The implemented system acts as a platform for testing high level path-planning and platooning control algorithms. The camera detections are suitable for fusion with other sensors, like radar measurements, thus improving the reliability and overall perception performance. In addition, specific car identification aids in the implementation of cooperative vehicle control.

"In this project, Yusuf performed the feasibility study of the new measurement system based on experiments and simulations. It has also been proven that this measurement system is feasible to use for the requested system requirements. On top of this feasibility study, Yusuf has also identified an optimal sequence for this measurement system and has described this is in a functional requirement specification report which can be used for initial software implementation. All of this was delivered in a timely manner with the required quality, as the supervisor of this project I want to show my gratitude to Yusuf for the collaboration."

Ir. Stijn Nouwen
Functional Architect NXT Waferstage
ASML, Development & Engineering Department

YUSUF SALMAN HARYADI, MSc EngD

New Measurement System for Wafer Load Offset Calibration Process

The demand for semiconductor chips is high and increasing every year. The use of chips has extended to many applications due to the technology advancement in areas such as automotive and Internet-of-Things. In 2020, the semiconductor industry grew about 6.5% due to the fact more people depend on electronic devices because of the needs of remote work. When the chip supply cannot respond to this growing demand, there is a negative impact on the customers who rely on this technology.

In order to satisfy the chip demand, chip manufacturers should aim for high-speed production as well as keeping production failure to minimum. One of the strategies is to equip high performance chip-making tools to ensure optimal production of the chips.

The motivation of this project is to reduce the defectivity issue during the production of semiconductor chip by improving the performance of the wafer load offset calibration process within ASML's lithography tools.

"Particle contamination control is a very important for high-tech industry. It is also being developed at VDL ETG as the competence program consisting of 3 main projects: particle generation, particle transport and particle removal. Ankita Kalra worked for the particle transport project, with a challenging goal to visualize the sub-micron particle trajectories in vacuum conditions and therefore enable further experimental studies and possible practical application. During project execution, Ankita has successfully applied the system engineering approach, starting with the project scope, stakeholders, goals, requirements and ending with the tool validation. She has also demonstrated quick learning skills and a well-structured work style. Her work resulted in a measurement tool consisting of hardware and software algorithm capable to trace the sub-micron particles in vacuum, in accordance to our initial requirements. It will help VDL ETG in development of contamination control expertise."

Dr. Dmitri Shestakov
Senior Functional Analyst
VDL Enabling Technologies Group

CHALLENGES

Light scattered by particles in sub-micron ranges is very low due to small particle sizes and therefore the detection and tracking of particles is challenging. A large particle density in the field of view makes it particularly challenging to differentiate one particle from the other. The size variance in particle diameter along with the clustering of small particles add to the complexities for particle visualization and tracing.

RESULTS

The visualization of particles in the range of 200 nm and 5 micro-meter was successfully performed. Velocity analysis was performed for the particles freely falling in the Knudsen Transition regime and various sources of errors were listed contributing to the error propagation in velocity variance. The velocity calibration of the imaging system provided an accuracy of under 2 percent - proving to be a precise technology.

BENEFITS

A comparison between the components of the imaging interface provided for the requirements for visualization of particles as a low-level light application. The Lagrangian particle algorithm was proven to be beneficial based on parameters including error estimation and accuracy in particle detection. The designed imaging system forms a benchmark for velocity estimation of non-spherical particles in the Knudsen transition regime at VDL-ETG.

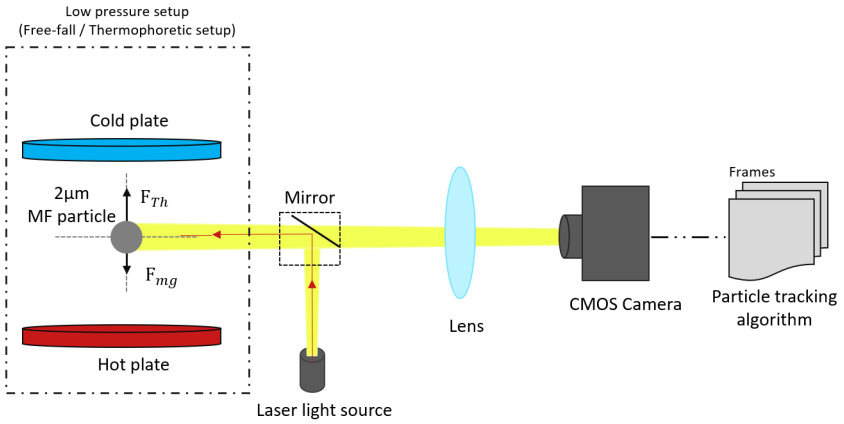
ANKITA KALRA, MSc EngD

Visualization of Sub-Micron Particles in Contamination Control

Moore's law observes that the number of transistors in dense integrated circuits double every two years. With the miniaturization of integrated circuits on wafers, contamination due to small dust and airborne particles tends to increase. There is, therefore, a significant need for the control and mitigation of these particles which requires an understanding of the behavior of particles under influence of several forces that become prominent as particle size decreases.

Accuracy on the velocity analysis of sub-micron, non-spherical particles under the influence of forces such as drag and gravity can help validate the constants in equations for particles in the Knudsen Transition regime. Verification of these constants is essential to validate the ongoing simulations that are being carried out by the ACCESS-Transport group at VDL-ETG through experiments.

An accurate way to perform the velocity analysis is to visualize the particles freely falling in low pressures to meet the Transition regime requirements using a CMOS camera, objective lens, and a laser light source. The acquired frames are then processed using the particle tracking algorithm to deduce information on particle position and velocity. The requirements for the particle tracking algorithm and the imaging interface are used in the design of the system. The estimated velocities are compared with the theoretical data to obtain and accuracy for the system as a whole. The objective of this design project was to estimate particle velocities as accurately as possible for particles in the range of 200 nm to 5 micro-meter.



CHALLENGES

Couple of challenges were posed whilew working on this project. First one is the software architecture designed for scaled TruckLab environment must be adapatable for the actual distribution centre as well as CAV vehicles in real world scenerios. Secondly, TruckLab-DTF is comprised of multiple entites running on different softwares with aim to achieve functional and buisness services each for end-users. End-users are developers, DC control room operators, testing engineers etc.

RESULTS

Physical Entities firmware architecture is loosly coupled allowing plug and play interfacing with 4AT100 based algorithms. The abstraction level of functionality of CAV vehicle for perception, planning, conectivity (V2X) and control can be achieved using services dimensions. Virtual Entity of the digital twin contains the vehicle physics module, motion tracking system for TruckLab environment. It is loosly coupled using the middleware and allows cyber physical simulations for accelerated development. Digital Database stores all the simulations perform to be used for services such as data analysis, big data and sensor fusion.

BENEFITS

Twin designed in this project is a modular framework which allows developers to focus on their specifc algotithm developmen in design and test phase of MBSE. In DC operations, it can be used is control room for motion capturing, replay modelling, fault detection, sensor calibrations. For the academic purposes, framework can be used for testing the controller design by students using the virtual entity of framework. Framework allows hybridization of data-driven and physics-driven models.

"The connected and autonomously driving truck requires a flexible generic project's framework, which will allow developers to accelerate their work focusing on sub-system under study and the students to approach new subjects in the future. Ayush was able to develop a Digital Twin framework for the TruckLab, which can integrate different modules developed by students and researchers from many AT specializations domains. Framework also take in accounts it's usage in operations of Distribution Centre. Also, he was able to integrate all the necessary tools needed, including Simulink, IBM Rhapsody, Unity Game Engine and ROS2, creating a software architecture which is flexible, scalable and extendible to be part of Systems of Systems.
Ayush' previous experience from the industry and his multidisciplinary education were important qualities necessary to tack the complexity of the project. For me it was a very pleasant period working with Ayush, and I wish him all the best in his career and personal life."

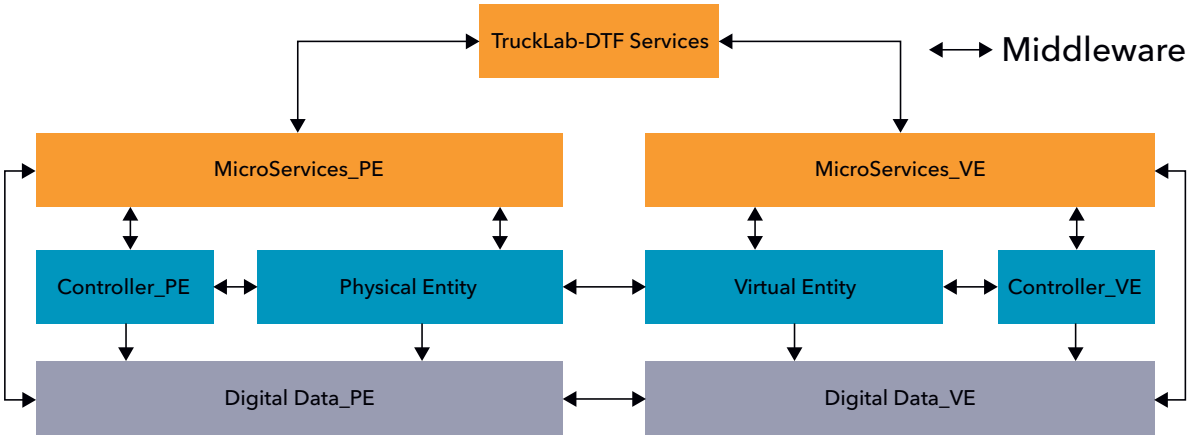
Dr. Ion Barosan
TU/e, Department of Mathematics and Computer Science

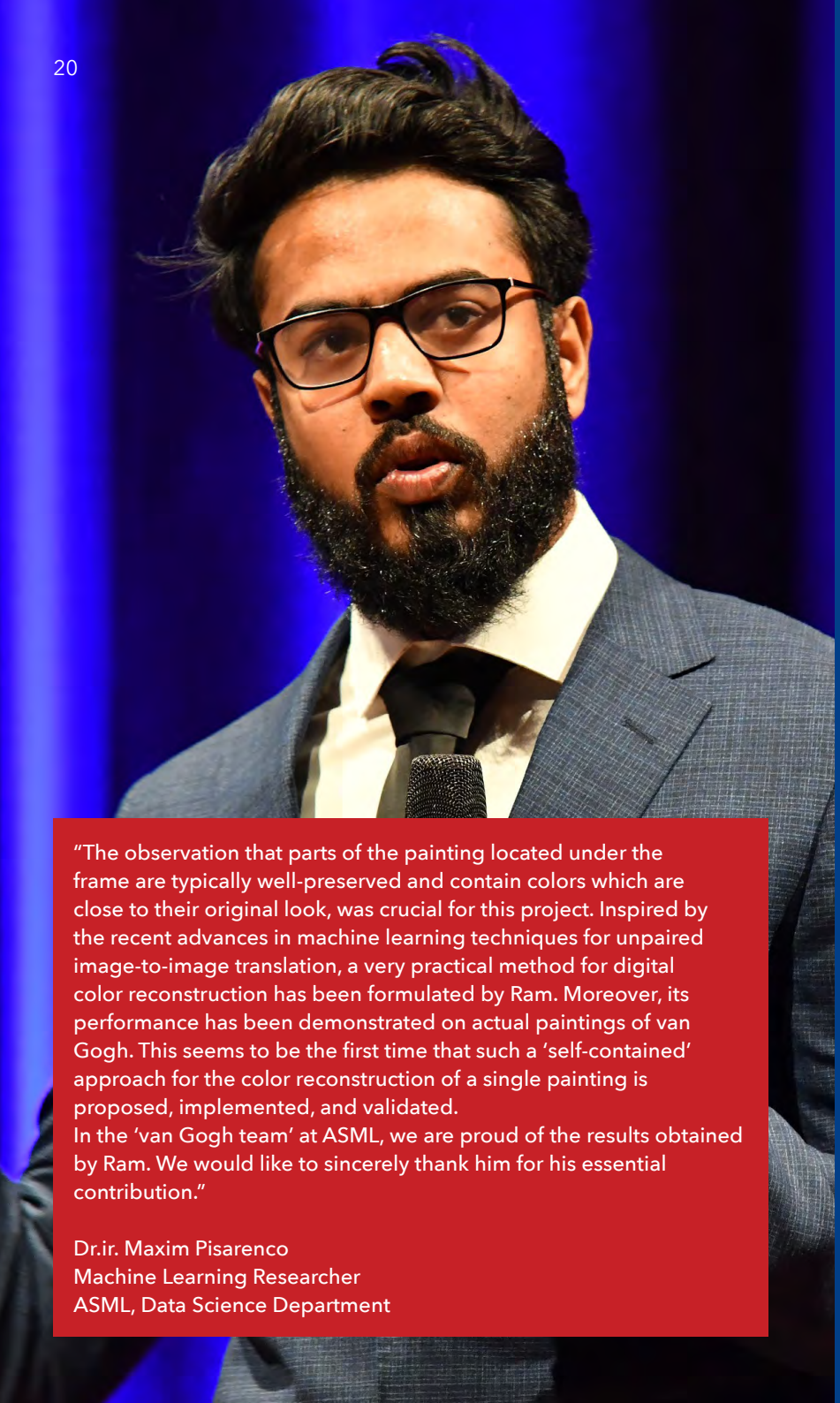
AYUSH MAHESHARI, MSc EngD

Development of Digital Twin Framework for TruckLab Environment

Logistics companies are now adopting connected and autonomous vehicles (CAV) in their supply chain pipeline in order to achieve fast and efficient freight transportation. Distribution centers (DC) being the relatively closed and controlled environment with no/minimal generic traffic, pre-existing knowledge of layout, and relatively low speed of articulated vehicles make an optimum environment to apply autonomy compared to public roads, which still face complex technical and legal challenges. To develop, implement and deploy autonomy in these centres, integrated softwares and hardware systems framework is required which supports product development lifecycle of CAV vehicle and usability by the end-customers.

In this project, software architecture of five-dimensional Digital Twin framework (TruckLab-DTF) has been developed and validated for the TruckLab environment. This project focuses upon designing the comprehensive and scalable framework, which shall assist designers, researchers and developers in accelerating their research and development on implementing "Autonomous docking of an articulated commercial vehicle at distribution centers and for the operations and monitoring of autonomous DC environment". Further project goal is to blend 4AT100 academic (Automotive Technology) course with TruckLab environment.





"The observation that parts of the painting located under the frame are typically well-preserved and contain colors which are close to their original look, was crucial for this project. Inspired by the recent advances in machine learning techniques for unpaired image-to-image translation, a very practical method for digital color reconstruction has been formulated by Ram. Moreover, its performance has been demonstrated on actual paintings of van Gogh. This seems to be the first time that such a 'self-contained' approach for the color reconstruction of a single painting is proposed, implemented, and validated.
In the 'van Gogh team' at ASML, we are proud of the results obtained by Ram. We would like to sincerely thank him for his essential contribution."

Dr.ir. Maxim Pisarenco
Machine Learning Researcher
ASML, Data Science Department

CHALLENGES

Fading of the original colors in the paintings of Vincent van Gogh is an immense challenge that the van Gogh museum is facing. Several factors are responsible for the undesired color change. These factors include natural aging, light-induced color change of paints, past reconstruction treatments and deposited surface dirt. The state-of-the-art generative adversarial networks used in this project generally suffer stability issues during training because of their unique training procedures.

RESULTS

In this project, the formulated proposals are implemented and validated. The results obtained prove that both paired and unpaired color transfer approaches are capable of reconstructing colors digitally. Stabilization techniques are explored to achieve stability in the training procedure. Uncertainty quantification of neural networks prediction is performed using the Monte Carlo dropout technique. In addition, visualization techniques are explored to depict the color fading and reconstructing process.

BENEFITS

The results demonstrate that color reconstruction achieved is in the right direction. This work also identifies potential future challenges as well as possibilities to improve the performance of neural networks. Moreover, the future directions suggested that the performance of networks can be further improved by incorporation of additional measurements such as XRF scans, and hyperspectral scans of the paintings into the training. This will enable the neural networks to better distinguish between different pigments and lead to better reconstructions.

TIRUMALA SAI RAM PARVATHANENI, MSc EngD

Virtual Unaging of van Gogh's Paintings

Paintings of Van Gogh have faded over the decades. Enormous amount of effort is being put from museum scientists and educational institutions to comprehend the fading process involved at pigment level of the artworks. This comprehension can help in slowing down the fading process before they lose their appearance completely.

ASML, Van Gogh Museum, University of Amsterdam and Dutch Cultural Heritage (RCE) formed a consortium in 2019 to speed up this research process. The ambition of this consortium is to keep paintings healthy. To achieve this objective, the project was divided into four work packages. The goal of this EngD project was to focus on the work package related to the data collected and generated from the artworks during previous research activities.

In this project, a problem statement of "Virtual Unaging" is defined. The goal is to virtually reconstruct the original colors of the faded Van Gogh's paintings. During this project, two proposals are formulated, implemented, and evaluated based on the type and amount of data available. These proposals are referred to as "Paired Color Transfer" and "Unpaired Color Transfer". Generative modelling has been adopted in this project. Two neural network architectures from the state-of-the-art approaches are selected for implementing the two proposals.

Field with irises current faded version

Field with irises color restored version

CHALLENGES

One of the main challenges was to select the correct Neural Architecture Search method to develop the proof of concept. Furthermore, understanding the fundamental principles of this novel domain to extract meaningful insights for NXP in a cost and resource-effective manner was a significant challenge.

RESULTS

A proof of concept has been implemented, showing the ability of this technology to design highly accurate and efficient models automatically. In addition, various challenges and adoption aspects for deploying this technology at scale have been identified. Furthermore, a demonstration set-up to showcase this technology at NXP has been developed successfully.

BENEFITS

The insights gathered throughout this project will guide further research and development and facilitate the eventual adoption of this technology at NXP. Furthermore, the system implementation can serve as a foundation for future work in this domain.

"Being such a new and highly complex field, what better option for NXP than to hire a capable research engineer to extend our team? Hiram personified this role with a lot of positivity and dedication. We asked him to do a full development cycle: select an applicable state-of-the-art method, adapt it towards NXP's ecosystem, develop a proof of concept system and keep an eye open for potential weaknesses and pitfalls. With his drive for structure, planning and satisfactory results, he managed to provide us with a strong, detailed evaluation and demonstration of this technology."

Dr.ir. Willem Sanberg
AI Research Engineer and Project Architect
NXP Semiconductors

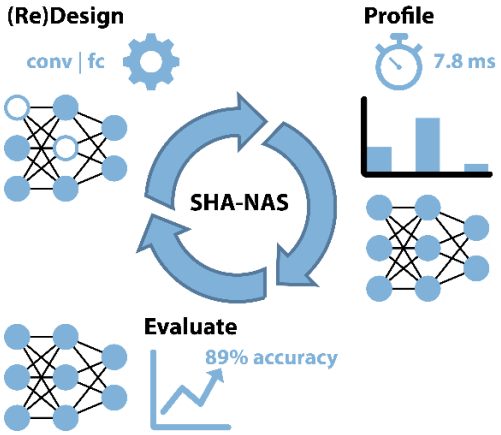
HIRAM RAYO TORRES RODRIGUEZ, MSc EngD

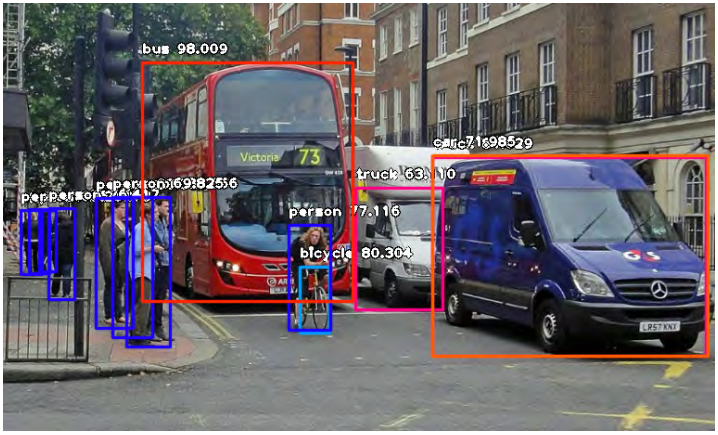
Software-and-Hardware-Aware Neural Architectural Search

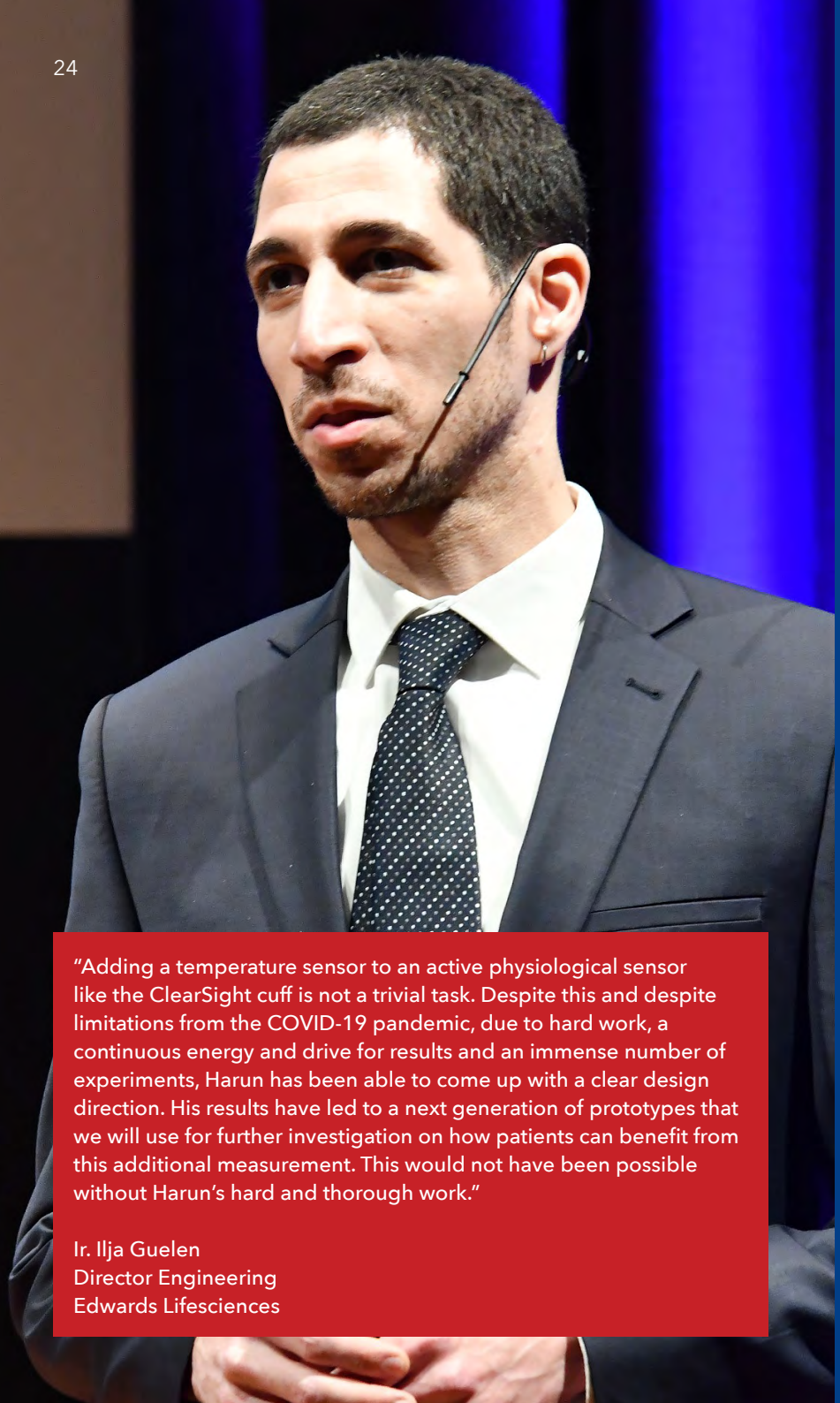
TOWARDS AUTOMATING THE DESIGN OF CONVOLUTIONAL NEURAL NETWORKS FOR EFFICIENT DEPLOYMENT OF EMBEDDED DEVICES

NXP Semiconductors designs and produces chips for a wide variety of markets and applications. For most of these applications, many customers envision the added value of Artificial Intelligence. More specifically, they are exploring how to integrate Neural Networks as part of many signal processing chains. For NXP, this means that they should facilitate that their embedded platforms can execute those Neural Networks efficiently. However, designing a Neural Network that is effective in performing its task and efficient when deployed on an embedded device is no easy task, even for an expert designer. Hence, researchers in the field of **Software-and-Hardware-aware Neural Architecture Search** target to automate this design process.

The main objective of this project is to develop a proof of concept to identify what this novel technology offers over traditional Neural Network design, its strengths, weaknesses, and the challenges of deploying it at scale for NXP. The project focuses on optimizing an object detection Convolutional Neural Network for high task performance and low inference latency for efficient deployment on NXP hardware.







"Adding a temperature sensor to an active physiological sensor like the ClearSight cuff is not a trivial task. Despite this and despite limitations from the COVID-19 pandemic, due to hard work, a continuous energy and drive for results and an immense number of experiments, Harun has been able to come up with a clear design direction. His results have led to a next generation of prototypes that we will use for further investigation on how patients can benefit from this additional measurement. This would not have been possible without Harun's hard and thorough work."

Ir. Ilja Guelen
Director Engineering
Edwards Lifesciences

CHALLENGES

Whether temperature signals are influenced from skin contact inside the cuff or if an active ClearSight operation disrupts temperature data, is unclear. Adding onto the uncertainty, is the complex physiological processes that cause variation in temperature measurements and coinciding electro-mechanical interactions within the finger cuff. While many unknowns existed, there was also an expectation to develop a marginally low cost yet reliable solution.

RESULTS

Working prototypes were successfully integrated with the monitoring platform and essentially acquired temperature data of the finger skin inside the cuff. A low-cost, simplistic hardware / software solution was developed such that the performance requirements were met. Extensive experimentation was conducted under various operational conditions to verify, validate, and investigate the overall system.

BENEFITS

Outcomes from experiments highlight feasible design alternatives that can be implemented onto a finger cuff. Prototypes built for the project showed potential to start future investigations on how temperature data can be leveraged to better qualify ClearSight measurement reliability. Ultimately, by utilizing a new temperature parameter, it may be possible to improve the performance and acceptance of non-invasive monitoring tools in healthcare.

HARUN SALMAN, MSc EngD

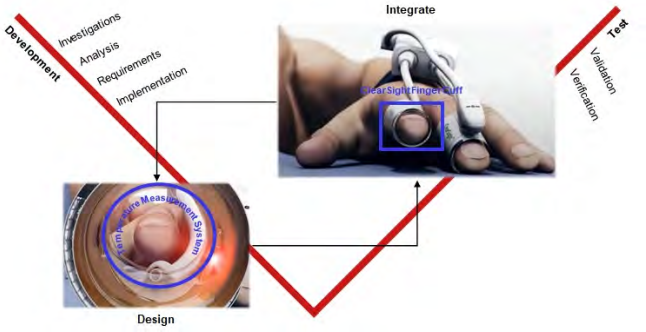
Temperature Measurement System and Finger Cuff Integration

DESIGNING, BUILDING, AND TESTING HARDWARE AND SOFTWARE ELEMENTS OF A TEMPERATURE SENSING SYSTEM THAT INTEGRATES INTO AN EXISTING NON-INVASIVE PATIENT MONITORING PLATFORM

In clinical platforms for cardiovascular health, non-invasive patient monitoring devices can serve as surrogate appliances to invasive options because they can offer easy-to-use, reliable operation at comparable performance.

The state of the art currently employs a finger cuff which wraps around a finger and measures arterial blood flow using modules that interact with each other according to ongoing changes in vascular physiology. Thermoregulation, which maintains constant core body temperature influences peripheral arteries by shrinking/expanding them to control heat dissipated from the blood to environment. Both physical processes of the body, impact a measurement conducted in the finger cuff.

Edwards Lifesciences aims to measure the temperature of the finger skin together with the ClearSight platform. Incorporation of temperature data could better qualify or potentially improve derived patient information. Furthermore, an independent parameter could bring value for predictive algorithms running in the device. This project exploits temperature measurement methods and tools that can be safely and reliably integrated into the platform. The goal is to obtain clear temperature signals from the finger cuff while ensuring the monitoring device maintains functionality.



CHALLENGES

To improve the development process and performance of the parallel transmit coils (pTX Coil), the main challenge was to identify bottlenecks and define the way to improve the complex development process. It was challenging not only because of the technical complexity of the pTX Coil, but also the requirement of utilizing an internet of things (IoT) framework, the Arrowhead Framework, which is powerful yet challenging to set up.

RESULTS

A prototype of the pTX Coil Optimizer has been successfully implemented and tested by the stakeholder. By adopting the Arrowhead Framework, service interactions across multiple users located in different local networks were enabled. Moreover, the simulation result analysis tool which automated the analysis process was implemented and integrated into the pTX Coil Optimizer.

BENEFITS

By using the pTX Coil Optimizer, the users of different development stages of the pTX Coil can have service interaction with each other via a secured protocol. Moreover, with part of the manual processes being automated, the efficiency of the pTX Coil development is significantly improved. On the other hand, implementation of the pTX Coil Optimizer also serves as a use case to justify the value of the Arrowhead Framework.

"Although MR-scanner technology and software platforms were clearly not in his comfort zone, Wan-Yi Tang accepted the challenge and devotedly worked on the pTX Coil optimizer for MRI scanners. He successfully created a prototype of this tool, making use of the Arrowhead Toolkit, which significantly can reduce development time and increase the reliability of the results.
Wan-Yi showed to be a very disciplinary and structured worker, always punctual and well prepared for any meeting and discussion, with agenda and slides to provide information about the status, plans and to raise questions. It was really a pleasure to guide him through this process as his mentor."

Ir. Peter van der Meulen
System Architect
Philips Healthcare

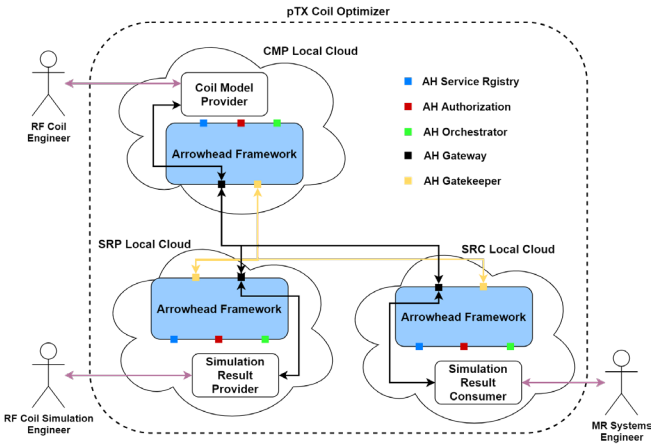
WAN-YI TANG, MSc EngD

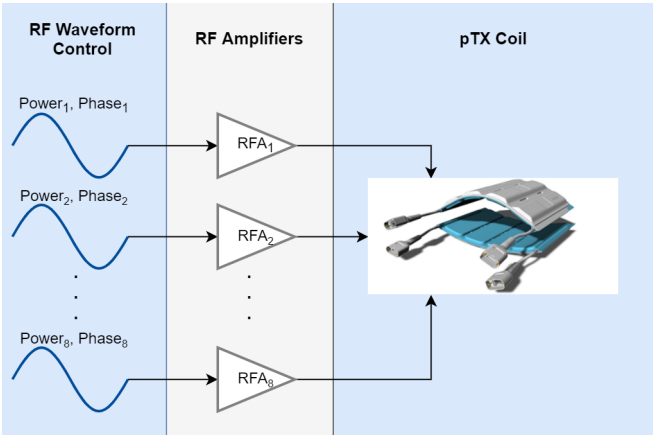
Philips MRI pTX Coil Optimizer

Magnetic resonance imaging (MRI) plays an important role in diagnosing by providing diagnostic images of the patient to doctors and radiologists. One of the directions to improve the performance of MRI is to apply a higher magnetic field, which may lead to higher spatial resolution and shorter scan time. However, besides the benefits, several challenges also arise when applying a higher magnetic field. For instance, the corresponding radio frequency (RF) field applied leads to the two challenges: intrinsic RF field inhomogeneity and heating.

To deal with the inhomogeneity issue, the parallel transmit coils (pTX Coil) is applied. With an appropriate control setting, the synthesized RF field from the individually controlled antennas of the pTX Coil may be homogeneous on the human body. However, deriving the optimal setting is a challenging process. With multiple sequential development stages that require the developers to manually apply complex models and algorithms to process the data, the development process of the pTX Coil is time-consuming and with limited solution space. To mitigate the problems, the idea of the pTX Coil Optimizer was proposed.

The pTX Coil Optimizer aims to improve the development process and performance of the pTX Coil by connecting the various development stages and automating parts of the development process. To realize the pTX Coil Optimizer, the Arrowhead Framework provided by the Arrowhead Tools project was applied.





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