7th International Workshop on Microsystems

Alexander Campus, International Hellenic University, 14 December 2022

Workshop Proceedings

Introduction

This workshop brings together research and development from a large spectrum of science and engineering fields related to the implementation of microsystems in the new era of distributed information technologies. As cloud computing services and smart portable systems are becoming ubiquitous and more advanced, new possibilities for interdisciplinary research emerge. The microsystems that comprise the so-called internet of things will encompass a wide range of technologies including new energy sources, energy and information electronics, sensor systems, smart and energy efficient control and computing, telecommunications and networking, and also nanotechnology and micro-electro-mechanical systems. Continuing six successful workshops between 2016 and 2021, the 7th International Workshop on Microsystems aims at bringing together related research and development advancements from the academic community and the industry. Scientific topics include but are not limited to::

- Energy microsystems
- Sensors and sensor electronics
- Embedded systems
- Integrated Circuits and Systems
- Industrial automation and control
- Microelectronics and nanoelectronics
- Micro-electro-mechanical systems
- Computing for microsystems

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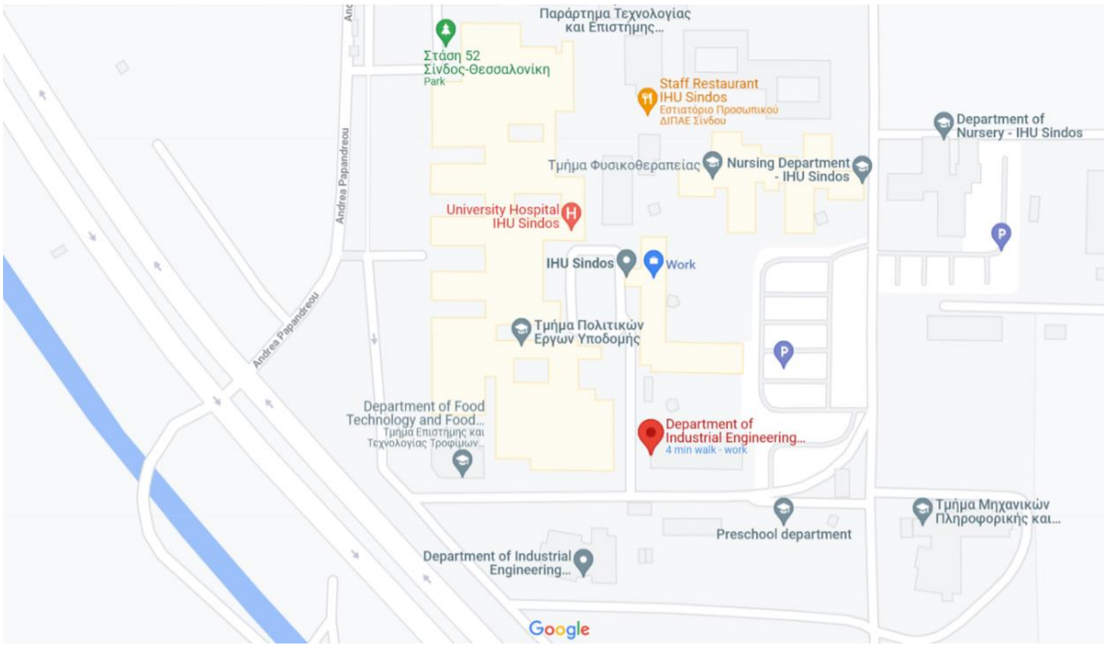
Venue

Lecture Theater, Automation and Informatics Building
Sindos Campus, ATEI Thessaloniki, Greece



Date

Wednesday, 14th of December, 2022

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Dr. Fotis Stergiopoulos, Industrial Eng. & Management, IHU, Greece
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Programme

08:45-09:00: Registration

Please check-in or register at the front desk.

09:00-09:05: Welcome and introduction

09:05-10:45: First Oral Session (Session Chair: Dimitrios Bechtsis, IHU)

09:05-10:00: Unmanned Aerial Vehicles: applications with embedded vision systems, *Antonios Gasteratos, Head of Department, Production and Management Engineering, Democritus University of Thrace,* 22WOM-01 (Invited)

10:00 Optimization of Electric Vehicle Routing Problem with Time Windows using Gurobi Solver. *I. Muraretu and C. Badica*, 22WOM-02

10:15: Autonomous Robotic Vehicle for Disinfecting Workplaces: Integration of the disinfection subsystem, *V. Sidiropoulos, E. Syrmos, G. Karamitsos and D. Bechtsis*, 22WOM-03

10:30: Artificial Intelligence in Automotive Industry – A Lightweight Perspective, *C. Badica, K. Kravari, Th. Kosmanis and I. D. Muraret*, 22WOM-04

10:45-11:15: Coffee Break and Poster Session

Nanotechnology 2022: A student perspective, *D. Lainas, N. Karaziotis, D. Paleochorinos et al*, 22WOM-05.

11:15-12:15: Second Oral Session (Session Chair: Fotis Stergiopoulos, IHU)

11:15: Utilizing potential operators on quantum walk evolution, G. D. Varsamis and I. G. Karafyllidis, 22WOM-06.

11:30: Hybrid Quantum Algorithms, I. Liliopoulos and I. G. Karafyllidis, 22WOM-07.

11:45: Conversion of a Climate Chamber to a Plant Growth Chamber, F. T. Stoupas, A. T. Hatzopoulos, V. D. Vassios and M. S. Papadopoulou, 22WOM-08

12:00 Design, Simulation and Construction of a TIG Welding Apparatus, *A. Vlachos, F. Stergiopoulos and D. Triantafyllidis*, 22WOM-09.

12:15-13:30: Third Oral Session: Vehicle Electrification

(Session Chair: Dr. Th. Kosmanis, IHU. Session Co-Chair: Dr. D. Tziourtzioumis, IHU)

12:15: E-DRIVETOUR: an interactive blended course on electric vehicle technology, *Th. I. Kosmanis and D. N. Tziourtzioumis*, 22WOM-10.

12:30: E-DRIVETOUR mobility intermediate projects: An Overview, *S. Karasakalidou, C. F. Draghici, A. Gkoudinakis, S. Rosu, A.-M. Soare and A. Tzanetou*, 22WOM-11.

12:45: Medium scale projects as a means for educating students on electric vehicle technology, *M. Michailidou, M. Ciudin, E. V. Enache, A. Samaras and X. Fejzo*, 22WOM-12.

13:00 Training on electric vehicle technology in an Erasmus Plus project from student point of view, *D.-A. Circiumariu, P. Adamidis, G. Emmanouil, M. Zomek, C.-I. Colpacci and I.-C. Vaduvescu*, 22WOM-13.

13:15: E-DRIVETOUR: A step towards the future of electric mobility, *A. Pavel, M. Barcikowski, G. Diamantis, A.-E. Georgiadou, K. Gkakidis, and S. Radu*, 22WOM-14.

13:30-13:45: Best Paper Award by Ioannidis Electronics. Concluding remarks.

WORKSHOP PAPERS

Unmanned Aerial Vehicles:
applications with emmbeded vision systems

Antonios Gasteratos
Dept. of Production and Management Engineering, Democritus University of Thrace

The use of Unmanned Aerial Vehicles (UAV) has gained momentum in everyday applications, including search and rescue, precision agriculture, surveillance, harsh environments exploration applications etc. This is owed to the fact that they offer high-end solutions, keeping the involved personnel safe at the same time. Over the last ten years, considerable effort and investments has taken place worldwide to provide suitable and satisfactory solutions to the scientific and technological problems involving UAV applications. At the same time, owed to the increased availability of computational power, cameras became the primary sensor unit for most of the robotic mechanisms. The main concern is the that until now, the enhanced computing power demanded for computer vision tasks, was not consistent with the increased mobility of targeted applications requirements. Yet, recent advancements in dedicated AI hardware platforms provide powerful solutions and allow complicated vision algorithms and networks to be fully deployed on a single board, suitable for embedded applications.

Optimization of Electric Vehicle Routing Problem with Time Windows using Gurobi Solver

Ionuț Murarețu, Costin Bădică

Department of Computers and Information Technology, University of Craiova

***Abstract*— The classic methods of delivering goods using internal combustion engines in urban areas are one of the important factors contributing to the pollution of these areas. Hence, the usage of electric vehicles in such delivery workflows could have a benefic impact on having greener cities.**

In this paper, we conducted some experiments on the Electric Vehicle Routing Problem using the Gurobi solver and a MIP model based on some classical VRP formulation on which we added some constraints related to the electric energy consumption of the vehicles.

***Index Terms*—electric vehicle, EVRP, MILP, Optimization, vehicle routing**

I. Introduction

In recent years, more and more logistic companies have introduced electric vehicles into their workflow as an alternative to internal combustion engines to combat carbon emissions. As a result, in the literature, more and more alternatives to the classic Vehicle Routing Problem have appeared that take into account the constraints of the times battery charging.

In this paper, we analyze the usage of the Gurobi Solver for the optimization of the MILP model for E-CVRP variation, having as objective functions the reduction of emissions by optimizing the number of vehicles used and the total distance traveled. In the next section, we present the problem formulation. The third section shows the experimental setup and some results of our experiments, and we conclude in section four with some discussion and future work objectives.

II. Problem Formulation

We formulate the Electrical Vehicle Routing Problem as an extension of the classical MIP formulation of the Vehicle Routing Problem with Time Windows, on which we added some constraints for the limitation of the driving range and electric power consumption. Our model is based on the one proposed in [3].

The VRPTW problem is usually modeled as a complete directed graph $G = (N, A)$ where $A = \{(i,j) \mid i,j \in N, i \neq j\}$ is the set of arcs and $N = R \cup C \cup \{0\} \cup \{n+m\}$ set of nodes, where $C = \{1, \dots, n\}$ is the set of customers, $R = \{n+1, \dots, n+m\}$ the set of recharging stations and $\{0\}$ and $\{n+1\}$ are the depot departure and depot arrival representation. Each arc has a defined positive value c_{ij} that represents the travel cost between customer i and customer j. For each customer $i \in C$ there is a demand q_i. We assume that all the vehicles are identical with the maximum battery capacity E and maximum load capacity Q.

As in the classical VRPTW variation, each customer must be visited by only a vehicle.

At each recharging station a vehicle is recharging its battery at a rate of r and needs to wait until it is fully recharged.

There are three auxiliary decision variables defined in our model: u_{ik} – the remaining capacity at location i of the vehicle k; τ_{ik} – time of arrival of vehicle k at location i; y_{ik} – the remaining battery on arrival at location i; $i \in N, k \in K$

Let x_{ijk} be a binary decision variable that is 1 if the arc (i,j) is traveled by the vehicle k, 0 otherwise ($i \in N \backslash \{n+m\}, j \in N\{0\}, k \in K$).

$$minimize \sum_{(i,j)\in A} \sum_{k\in K} c_{ij} x_{ijk} \quad (1)$$

s.t.

$$\sum_{j\in N\backslash\{0\}} \sum_{k\in K} x_{ijk} = 1, \forall i \in C \quad (2)$$

$$\sum_{j\in N\backslash\{0\}} x_{ijk} = 1, \forall i \in V, k \in K, i \neq j \quad (3)$$

$$\sum_{j\in N\backslash\{0\}} x_{ijk} - \sum_{i\in N\backslash\{n+m\}} x_{jik} = 0, \forall k \in K, i \neq j \quad (4)$$

$$\tau_{ik} + (t_{ij} + s_i) * x_{ijk} - M * (1 - x_{ij}) \leq \tau_j, \forall i \in C \cup \{0\}, j \in N\backslash\{0\}, k \in K, i \neq j \quad (5)$$

$$\tau_i + t_{ij} + r * (E - y_{ik}) - (M + r * B) * (1 - x_{ijk}) \leq \tau_j, \forall i \in R, j \in N\backslash\{0\}, k \in K \ i \neq j \quad (6)$$

$$0 \leq u_{jk} \leq u_{ik} - q_i x_{ijk} + Q(1 - x_{ijk}), \forall i \in N\backslash\{n + m\}, j \in N\backslash\{0\}, k \in K, i \neq j \quad (7)$$

$$0 \leq u_{0k} \leq Q, \forall k \in K \quad (8)$$

$$0 \leq y_{jk} \leq y_{ik} - bc_{ij} x_{ijk} + E(1 - x_{ijk}), \forall j \in N\backslash\{0\}, i \in C, i \neq j \quad (9)$$

$$0 \leq y_{ik} \leq E - rc_{ij} x_{ijk}, \forall i \in R\backslash\{0\}, j \in N\{0\}, k \in K, i \neq j \quad (10)$$

$$x_{ijk} \in \{0, 1\}, \forall i \in N\backslash\{n + m\}, j \in N\backslash\{0\}, k \in K, i \neq j \quad (11)$$

III. Experiments & Results

The experiments were conducted on Ubuntu 22.04 machine with an AMD Ryzen 7 1700X CPU with eight cores clocked at 3GHz with 24GB of RAM and 512GB SSD, with Gurobi ver. 9.

We conducted our experiments using the Solomon benchmark datasets. We present a snapshot of the data that we used in Table I.

TABLE I
Snapshot on testing instances

Customer	X	Y
1	20	30
2	50	40
…		

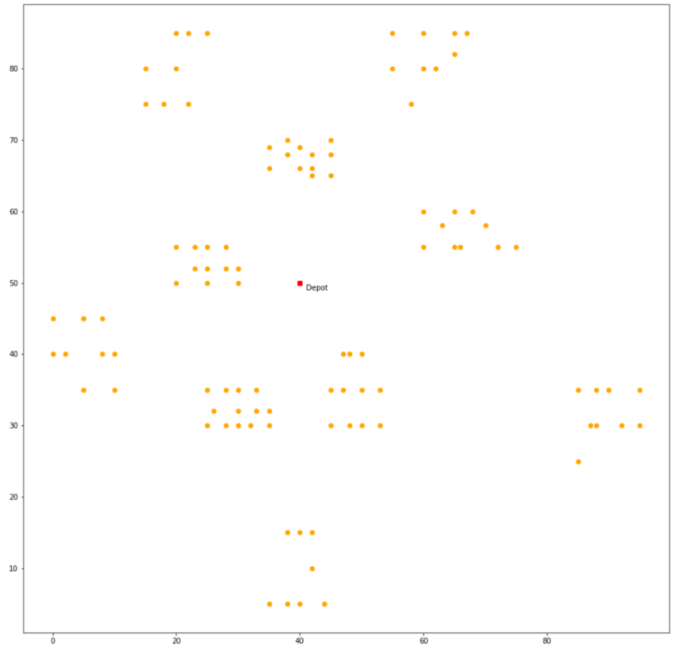

Fig. 1. C101 Solomon benchmark customers distribution.

IV. Discussions

In this paper, we solved the EVRP problem using the Gurobi solver and a MILP variation of the VRPTW formulation, on which we introduced some constraints related to the limited range and electric power consumption of the electric vehicles to optimize the distance traveled.

References

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[2] Kucukoglu, Ilker, Reginald Dewil, and Dirk Cattrysse. "The electric vehicle routing problem and its variations: A literature review." Computers & Industrial Engineering 161 (2021): 107650.
[3] Qin, Hu, et al. "A review on the electric vehicle routing problems: Variants and algorithms." Frontiers of Engineering Management 8.3 (2021): 370-389.
[4] M. Mavrovouniotis, C. Menelaou, S. Timotheou, G. Ellinas, C. Panayiotou and M. Polycarpou, "A Benchmark Test Suite for the Electric Capacitated Vehicle Routing Problem," 2020 IEEE Congress on Evolutionary Computation (CEC), 2020, pp. 1-8, doi: 10.1109/CEC48606.2020.9185753.

Autonomous Robotic Vehicle for Disinfecting Workplaces: Integrating the disinfection module

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Health in workplaces is a major concern, especially after the spread of the covid-19. The pandemic paved the way for a holistic change in workplace disinfection operations [1]. After the spread of the covid-19, humans are trying to get protection from contagious diseases in workplaces as they understand that they can contaminate by breathing particles and droplets of respiratory fluids. Thus, workplaces should identify new ways to reduce the spread of viruses. Currently, commercial robots are available but mainly rely on ultraviolet radiation [2], [3], which is inefficient in large areas such as industrial ones as it takes several minutes of exposure to destroy a virus [4]. On the other hand, disinfection with liquids is not sustainable in large workplaces due to the high amount of liquid needed for the operation. To this end, a more time and cost efficient way to disinfect workplaces is necessary. The proposed system tackles the aforementioned problems by integrating an autonomous robot with machine vision and data analysis to optimize the disinfection operation. The system consists of five (5) subsystems, namely the machine vision, the decision support system, the autonomous robot, the disinfection and the mobile application subsystem. For the machine vision subsystem, a depth camera is used, alongside machine learning algorithms and neural networks. The machine vision subsystem recognizes humans and saves their location. This information is then passed to the decision support system. The decision support system uses data analysis to determine the high-risk areas in the workplace, that need to be disinfected. Thus, the disinfection operation lasts less time, and the liquid used is minimized while the workplace is properly disinfected. To execute the disinfection procedure, the autonomous robot navigates itself to the location provided by the DSS. The robot utilizes navigation and obstacle avoidance algorithms to prevent accidents and equipment damage. Furthermore, the disinfection subsystem includes an electrostatic sprayer, a tablet apparatus and an auxiliary computing unit. Lastly, the mobile application provides an interface to control the autonomous robot. Through the application, users can configure multiple parameters and receive information about the system's operations. For the system integration the Robotic Operation System (ROS) was used. ROS provided a stable communication mean to exchange information between the subsystems. The DSS and the autonomous robot can trigger the disinfection mechanism. The trigger enables the electromagnetic sprayer and the tablet apparatus. The number of tablets used are also controlled via the trigger, based on the risk level. The proposed solution can be used in workplaces and public facilities which require disinfection operations. The novel architecture integrates state-of-the-art technologies and algorithms such as machine vision, data analysis and autonomous navigation in order to optimize the efficiency and cost-effectiveness of the process while ensuring the effectiveness of the disinfection.

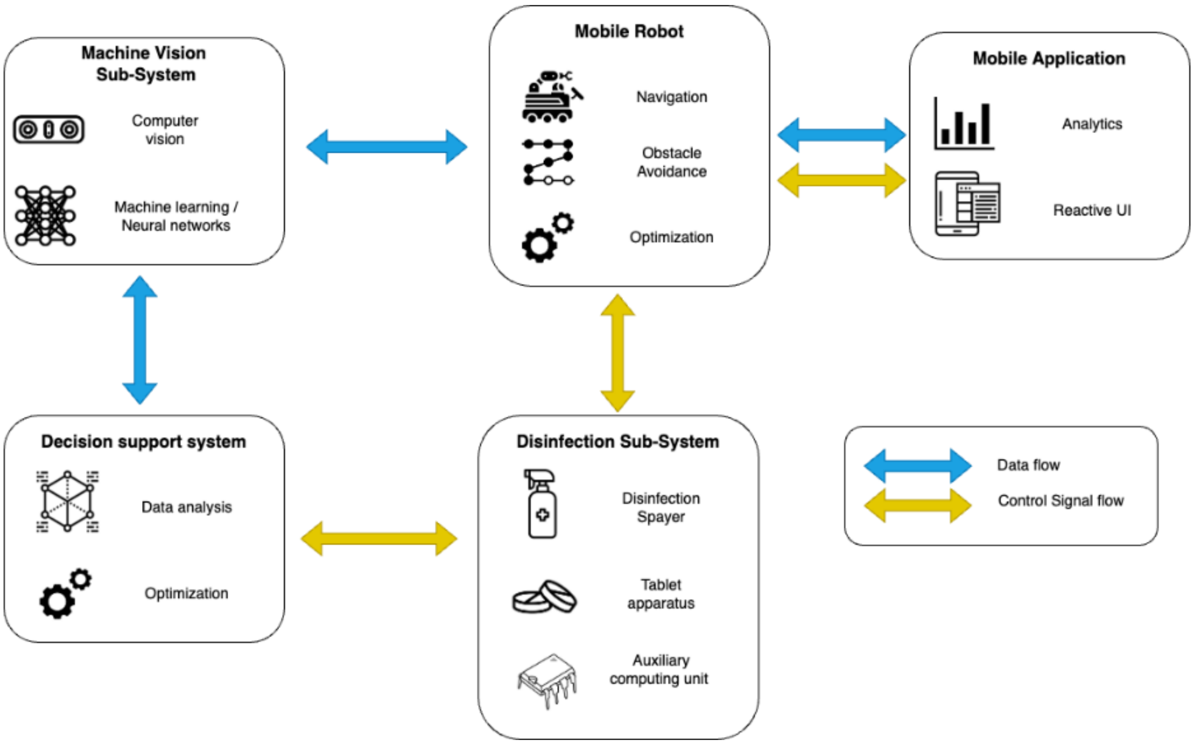

Fig 1. High level architecture

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[1] Centers for Disease Control and Prevention, Nov. 2021, “Cleaning Your Facility”, https://www.cdc.gov/coronavirus/2019-ncov/community/disinfecting-building-facility.html

[2] F. Astrid, Z. Beata, van den Nest Miriam, E. Julia, P. Elisabeth, and D. E. Magda, “The use of a UV-C disinfection robot in the routine cleaning process: a field study in an Academic hospital,” *Antimicrob Resist Infect Control*, vol. 10, no. 1, Dec. 2021, doi: 10.1186/s13756-021-00945-4.

[3] F. M. Fuchs *et al.*, “Characterization of a robot-assisted UV-C disinfection for the inactivation of surface-associated microorganisms and viruses,” *J Photochem Photobiol*, vol. 11, Sep. 2022, doi: 10.1016/j.jpap.2022.100123.

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Artificial Intelligence in Automotive Industry – A Lightweight Perspective

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***Abstract*—The aim of this paper is to briefly overview the sector of Automotive Industry (AY) with a focus on Artificial Intelligence (AI) technologies – Artificial Intelligence for Automotive Industry (AI4AY). We consider the business ecosystem and market of AI4AY as well as the most relevant AI methods for innovative applications in AY.**

***Index Terms*—artificial intelligence, machine learning, smart systems, automotive industry**

I. Introduction

Artificial intelligence (AI) is currently seen as one of the most disruptive factors of industry and society. AI has evolved from an exotic research trend to a key ingredient virtually spanning every aspect of computing. The synergy between new AI technologies with recent computing trends is a key enabler of innovation in business and industry. In the modern world, all industry sectors employ AI and advanced computing as tools to better meet their goals. AI itself is comprising a set of enabling technologies including AI agents, intelligent problem solving, machine learning (ML), knowledge representation and reasoning (KRR), natural language processing (NLP), and intelligent user interfaces, that can be used effectively to achieve business objectives.

In this paper we address the recent requirements, developments and challenges in the AY sector with a focus on the opportunities raised by the application of various AI technologies. We start with a brief overview of AI & AY ecosystems and markets, and then we concentrate on the most relevant AI methods and technologies that we consider relevant for the present and future of AY.

II. Background

A. Automotive Industry Ecosystem

The Automotive Industry (AY) is one of the world's largest industries by revenue, as well as the industry with the highest spending on research per firm. It comprises a diversity of companies and organizations engaged in the design, development, manufacturing, marketing, and selling of motor vehicles.

The AY ecosystem is very complex and dynamic, spanning many types of processes, organizations and services. At a very high level the AY ecosystem can be seen as comprising the following perspectives:

- *User & driving* perspective refers to the functions and services provided by the car together with the road infrastructure to the human driver. They include the following aspects: advanced driver-assistance systems (ADAS), provision of autonomic features for the safety and convenience of the driver, features for connected vehicles, as well as smart road and city infrastructure (from the driver perspective).
- *Manufacturing and Supply Chain* perspective contains customers, dealerships, original equipment manufacturers (OEM), as well as tier 1, 2, and 3 suppliers [16] and their smooth interactions.
- *Environment and Society* perspective addresses the smooth integration of automotive services into the surrounding world by focusing on the following issues: sustainability, pollution and waste management, infrastructure (from the environment sustainability perspective), smart services (e.g. ride sharing) and ethics.
- *Business* perspective addresses the business and economic aspects of the AY ecosystem by focusing on the following issues: customer relations management, customer preferences and customization, marketing and advertising.

B. Artificial Intelligence Ecosystem

During the last decade, AI reached a high level of maturity from scientific experimentation in research laboratories to powerful applications in business and industry. AI comprises a rather wide range of methods and techniques spanning various approaches in symbolic and sub-symbolic information processing that evolved and matured during a short history of more than 50 years. They can be succinctly grouped into three intertwined classes of approaches comprising representation, reasoning and learning methods.

Currently, AI technologies have penetrated virtually all areas of life and society. The recent technical performance of AI methods and technologies, as well as their impact in business and economy, present new and amazing achievements while also raising new scientific and practical challenges that require a careful investigation by the research community.

AI methods and technologies go hand-in-hand with computational methods and architectures. The aim of AI to build "intelligent computers" was set since the inception of AI as a well defined field during the '50s. So AI advances are inconceivable without the progress of modern computing systems including CPU, architectures, communications and networking. Modern AI is applied in conjunction with recent computing architectures: distributed, decentralized, secure, edge, fog, cloud computing leading to novel technologies like frugal AI and federated machine learning.

AI consists of a complex ecosystem that is difficult to define by a single all-encompassing definition. AI is very heterogeneous as it incorporates many ideas and results from other more established sciences including mathematics, statistics, logic, psychology, philosophy, biology, and economics. AI research can be synthesized as addressing 4 major challenges resulting from a two-axes classification of the AI target toward acting / thinking and respectively humanly / rationally, i.e.: acting humanly, thinking humanly, thinking rationally and acting rationally [17].

However, recent opinions driven by modern AI applications including AY have opted for a more pragmatic definition of the goal of modern AI towards building beneficial machines. According to this view, AI is concerned with not just understanding, but also with building intelligent entities that can compute how to act effectively and safely in a wide variety of novel situations. This aligns better with the recent AI achievements in the areas of autonomous systems including self-driving cars and social robots, and thus suits better our own purpose in AI4AY.

The core ingredients of an AI system are knowledge representation, reasoning and learning.

It is widely accepted that AI systems are able to achieve their functions if and only if they incorporate substantial amounts of general and domain-specific knowledge. Such knowledge is captured using a knowledge representation language and it can take either symbolic or numeric forms. Symbolic knowledge includes rules, ontologies and knowledge graphs, while numeric knowledge includes neural networks and concept embeddings. AI systems can be endowed with knowledge either by design or knowledge can be acquired gradually by adaptive processes or special "training" sessions using machine learning.

Reasoning encompasses AI processes involving the application of knowledge to solve specific problem instances. Reasoning can be based on symbolic processing, usually involving some form of logical inference or numeric processing (for example prediction or classification using neural networks).

Machine learning is the ability of an AI system to improve its competence and performance over time based on past problem solving experiences. It refers to expanding the system's range of behaviors by gaining new abilities to solve more problems, as well as to increasing the accuracy of solving old problems better and faster. Progress in machine learning exploited the tremendous achievements in hardware that enabled fast digesting of huge amounts of data for synthesizing deep neural network models that are able to solve difficult prediction and discovery problems.

III. AI4AY Market

The AI4AY market is expected to grow from about 1 billion USD in 2020 to more than 16 billions USD in 2026 at a growth rate of almost 40% of compound annual growth rate (CAGR). Following results of recent market research, AI4AY market segmentation is done according to components (hardware, software, services), technologies (machine learning, computer vision, natural language processing, context-aware computing), processes (signal / image / voice recognition, data mining), and applications (semi-autonomous driving, human-machine interface) [18].

According to the AI Index report that is updated yearly by a group of researchers from the Human-Centered AI Institute of Stanford University in US [1], there is a significant rate of adoption of AI in AY sector across all its envisioned functions: manufacturing, human resources, marketing & sales, product and/or service development, risk management, service operations, strategy and corporate finance, and supply-chain management. Moreover, as concerning the AI capabilities embedded in standard business processes in AY, the following are mentioned: computer vision and facial recognition, knowledge graphs, natural language processing (synthesis, speech, text), machine learning (deep, reinforcement and transfer learning), virtual agents, robotics, recommender systems, robotic process automation and simulations.

According to [3], current popular applications of AI4AY address the following areas: autonomous vehicles (Motional, Waymo, Zoox, AutoX), auto manufacturing (CCC Intelligent Solutions, Rethink Robotics), driver assistance (SapientX, CarVi, Nauto, Tesla), and autonomous delivery (Refraction AI, Starship Technologies, Kiwibot).

From the consumer point of view, the incorporation of AI features into automotive products can be conceptualized using the customer-value hierarchy of a product in marketing [20]: core, basic, expected, augmented and potential. Usually AI is perceived by customers as adding a high-value to the products and so AI features are best located at the level of the augmented product, with more advanced features included in the potential product. However, the increasing popularity of AI in all sectors will eventually lower some of the AI features to the level of the expected product.

Deployment of AI features utilizes information technology infrastructure, components and software services adapted to the needs and requirements of AY. Examples of such elements are embedded systems, automotive networks, smart sensors [21], specialized operating systems [2], computing architectures and platforms [22], as well as application software for requirements management, simulation and image processing.

IV. AI4AE Methods

We briefly overview some typical AI methods in support of AY. The landscape in rich and a full state-of-art review is outside our aim, as well as impossible to do in such limited space. Nevertheless, we strive to convey to the reader our message regarding the large diversity of available AI methods that currently enable useful applications in the AY sector, by going far beyond the most popular attraction of self-driving cars.

A. General State of the Art Surveys

A survey of AI application to vehicles by focusing mainly on the user & driving perspective is provided by [4]. The authors target the concept of "intelligent vehicle" seen as providing autonomy and connectivity functions. They highlight various types of machine learning including support vector machines (SVM), neural networks (NN) and reinforcement learning (RL). NN comprise basic artificial neural networks (ANN), as well as current deep NN architectures (recurrent NN and convolutional NN). NN together with advanced perception are seen as crucial for creating and understanding high-precision world models, while RL principles are fundamental for developing high-performance path planning and decision making strategies.

A broader view of AI and Data Science application in the AY sector is provided in [5]. The authors address the whole automotive value chain involving development, procurement, logistics, production, marketing, sales and after-sales, connected customer. The key observation is that devices, systems and processes in AY are quickly generating large amounts of heterogeneous data that require sophisticated processing for synthesizing knowledge and value via smart analytics functions: discovery, prediction, diagnosis and optimization. The following pillars of AI in AY are highlighted: machine learning (supervised and unsupervised), computer vision, inference and decision making, language and communication, agents and practical reasoning (directed toward action). Moreover, three challenges are envisioned from the synergy of vehicle intelligence and automotive Big Data: i) vehicles as autonomous, adaptive and social agents "acting" in smart cities seen as super-agents, ii) integrated automotive factory optimization and iii) transition from collective intelligence in companies to emerging autonomous companies.

A brief synthesis of AI applications in AY is presented in [6] by focusing on three aspects: smart cars, intelligent design and manufacturing, as well as after-sales and warranty management services. Smart car functions include control of vehicle parameters, driver-less parking, smart sensors, intelligent vision assistance, voice control, safety control, usage feedback to company, and on-board diagnostics. They involve the following AI techniques: fuzzy logic, ANN, smart sensors, intelligent user interfaces, NLP, SVM. Intelligent design and manufacturing include intelligent assembly line, vehicle production sequencing, intelligent production control, supply chain and inventory management and utilize KRR, constraint programming, genetic algorithms, fuzzy logic, and data mining. Finally, after-sales and warranty management services utilize KRR, Big Data analytics and data mining.

B. Knowledge Representation and Reasoning

Automotive engineers can use KRR for capturing expert knowledge useful for intelligent design, manufacturing planning and intelligent automated diagnosis in AY. In order to face the knowledge acquisition bottleneck that refers to the difficulty and ineffectiveness to manually extract non-trivial amounts of knowledge from human experts, other automated approaches can be used, for example ontology learning. A framework for ontology learning from unstructured repair text data for fault detection and isolation in automotive domain is presented in [11].

AY is considered one of the most complex manufacturing related industries in terms of product data management, involving extremely complex products comprising thousands of components and a huge number of possible configurations. Moreover, it is appreciated that traditional relational approaches do not meet these tight requirements, as product structures and configurations are dynamic and represented by dense directed acyclic graphs that are currently available in many formats and processed by many organisations from AY supply chain. One inevitable solution for the future data management in AY is the Automotive Knowledge Graph (AKG) [27]. A solution to extract an AKG from textual data using NLP techniques for application in automatic test case generation is presented in [25].

C. Intelligent Agents

Agents are abstractions used by AI researchers and engineers to model entities that can perceive their environment through sensors and can act upon their environment using actuators. Essential features of agents are autonomy, proactivity and sociability. Intelligent agents contain a "brain" able to process perceptions, beliefs and knowledge using practical reasoning directed toward synthesis of most appropriate actions for the benefit of the agent.

It worth noting that agents have many similarities with control systems. Agent perceptions are similar with inputs of control systems, while agent actions are similar with control system outputs. The agent - environment interaction loop consisting of sensing, processing and acting has similarities to the feedback control loop involving the control system and the controlled plant.

Smart cars can be modeled as autonomous intelligent agents [26]. This approach can bring benefits to smart transportation scenarios. For example, smart car agents can use their communication capabilities and coordination algorithms to form a platoon on a highway, thus improving traffic management and passengers safety, as well as reducing travel time, fuel consumption and emissions [23].

D. Machine Learning

ML is currently the most popular AI technology in all application domains, including AY. According to the type of ML task, we can distinguish between:

i) *Supervised learning:* given input features, target feature(s) and training examples containing values of input and target features, aims to predict values of target features of new examples given only their input features. If target features are discrete (categorical) we have a classification task, while if target features are continuous we have a regression task.
ii) *Unsupervised learning:* aims to discover structure (categories and regularities) in the data. An example is clustering.
iii) *Reinforcement learning:* aims to optimize longer-term agent behavior based on punishing and/or rewarding its performed actions.

Although NN have a long tradition in AI, it is only quite recently, during the last decade, when NN started to capture the attention of main stream AI research and applications. Current AI places NN research under the wider umbrella of deep learning (DL hereafter), which itself is considered a branch of ML. Basically, DL covers not only NN, but also the whole set of rich and deep hierarchical quantitative representations using linear and non-linear interconnections that are currently the focus of ML research and practice. Today DL has many practical applications in imagine recognition, computer vision, activity recognition, business intelligence, NLP, and text mining.

DL is applied to NLP in conjunction with word representations using vector space models, also known as word embeddings. The idea is to capture semantics by mapping each word to a numerical vector such that similar or related words are mapped to close vectors, according to a distance measure. The mapping is produced by ML applied to large natural language corpora. For example, an approach combining DL and word embeddings for automated requirements mapping in automotive system engineering is presented in [24].

Modern vehicles are capable of generating large amounts of data that can be efficiently processed by current ML algorithms. Predictive maintenance aims to predict the optimal maintenance actions of vehicles based on information about the system's health state and/or historical data [29]. Predictive maintenance is closely related to modelling a vehicle's normal behaviour and detecting deviations, so-called anomalies, which may point to present or evolving failures. A recent survey of use cases and challenges of applying ML for predictive maintenance including anomaly detection in automotive systems is proposed in [8].

A method based on data-driven ML approaches to assess change impacts in Engineering Change Management (ECM) processes in AY was proposed in [9]. ECM is based on gathering and storing a massive amount of well-documented data about Engineering Change Requests (ECR) expressed in semi-structured natural language. The analysis tasks were focused on two assessments: of change impact and of longer lead time. Change impact assessment was modeled as a multi-label classification problem, while longer lead time assessment was modeled as a binary classification problem. Authors have used NLP for data pre-processing, powerset labelling using a partitioned labelled space for multi-label classification, as well as ensemble learning algorithms for the classification processes enhanced with model-agnostic explanations for engineering decision making.

ML was also used for making predictions in environmental sustainability to estimate life cycle assessment based greenhouse gas emissions of natural versus glass fiber reinforced automotive parts that are used for car lightweighting [10]. Several ML algorithms for this problem were compared (linear regression, Bayesian regression, Poisson regression, NN, boosted decision tree, and decision forest).

E. Natural Language Processing

NLP is essential for capturing engineering requirements, as well as customer impressions and preferences in AY. NLP is very often used in conjunction with ML and text mining algorithms for automatic summarization, information extraction and decision making. Example AY applications of NLP in conjunction with ML are presented in [9] and [24] (see *Machine Learning* subsection). Moreover, natural language text is an important source for automatic construction of AKG [11], [25] (see *Knowledge Representation and Reasoning* subsection). An application of NLP and DL for automated vehicle diagnostics using free-text customer service reports is discussed in [19].

F. Computer Vision

Computer Vision (CV hereafter) is the subfield of AI interested in endowing intelligent agents with visual perception and inference capabilities, as typically found in animals and humans. There are at least three areas where CV can be applied in AY: autonomous vehicles, automotive manufacturing, automotive supply chains.

A recent and authoritative reference is [30]. It covers all the processes required for autonomous cars: localization, perception, prediction and routing, as well as decision, planning and control. CV is essential for localization and prediction tasks. Localization can be achieved by combining vision and radar sensors with accurate digital maps. CV is also fundamental for object detection, scene understanding, tracking and trajectory prediction that are core perception functions of autonomous cars [7].

An analysis of the benefits brought by the CV systems to automotive manufacturing within the framework of Industry 4.0 and Cyber-Physical Systems (CPS hereafter) is provided by [28]. The authors considered the four stages of automotive production (press, body, paint and final assembly shops) and identified opportunities for CV at each stage. Interesting conclusions revealed that most of the results were obtained in the assembly and body shops, while least of the results were obtained in the paint shop. Authors observed that CV is mainly employed in automation procedures, as well as for spotting out minor defects, while more advanced, self-adaptable and multi-integration features of smart automotive factories should be explored in the near future.

Regarding the automotive supply chain application, object recognition using DL for counting car components to support handling and packing processes in automotive supply chains is proposed in [12].

G. AI Search Algorithms

Intelligent optimization based on AI search methods involving evolutionary and meta-heuristic algorithms can be used for solving optimal design problems in AY. Usually these problems are NP-hard and their direct solving using searching or other mathematical programming approaches is unfeasible for realistic settings.

A comparative analysis of genetic and swarming algorithms for supply chain optimization in AY is proposed in [32]. A neuro-tabu search approach to manufacturing scheduling from a company producing subassemblies for the AY is discussed in [33].

AI optimization algorithms have proven their suitability for engineering optimization of car components, as well as of various devices and sub-systems involved in AY processes. A research literature survey of using meta-heuristic algorithms for car engine design is proposed in [34].

H. AI and Ethics

Standardisation of safe and ethical behaviors of automated vehicles (AV hereafter) is a challenging aspect raising many opportunities for interdisciplinary research. The ethics of AV safety involves: user expectations, perception and acceptance; AV safety choices; responsibility and liability. An interdisciplinary framework of research goals and tools for commonly accepted AV safe behaviour standards from the perspective of three relevant disciplines (ethics of technology, safety science, and standardisation) was recently proposed in [31].

The ethics of machine-to-machine cooperation in a world populated with autonomous devices including AV and social robots is addressed by [14]. The authors claim that autonomous machines should be cooperative by design for the benefit of their own functioning, as well as for the social benefit, similarly to human cooperation that drives favorable social and ethical behaviors.

V. Conclusions

This paper provides a brief overview of problems in Automotive Industry (AY) that can be approached with Artificial Intelligence (AI) methods. The AY sector is very rich and complex, providing many opportunities for researching with AI algorithms. On the other hand, the AI ecosystem is very heterogeneous and it offers a plenty of methods for approaching AY problems from different perspectives that are difficult to grasp by someone with less experience in the field. Several applications and opportunities for AI methods were presented including Knowledge Representation and Reasoning, Intelligent Agents, Machine Learning, Natural Language Processing, Computer Vision, AI Search Algorithms, AI & Ethics. Based on our brief overview, we can conclude that AI can successfully complement existing AY methods and products, leading to a higher performance of AY products and processes, and thus better meeting the requirements from industry, business, environment, and society.

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Nanotechnology 2022: A student perspective

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In this course we are willing to create a poster for the conference on December 2023 which will explain with every detail all the parameter and topics of nanotechnology. We wouldn't be able to create our project without the help of our colleagues because our information is based on their tasks. Our poster will include the most important information from each topic. For example nano-surgery[1] is the application of nano-mechanics in medicine and in surgery with the use of molecular tools and the molecular knowledge of the body. Also, molybdenum disulfide[2] is a dihalide transition metal consisting of a molybdenum atom between 2 sulfur atoms, is a hexagonal crystal with a multilayer structure which is found in 2 forms, bulk and monolayer. Another very important topic which we will touch is nano-medicine[3] which is separated in 5 categories cosmetology, nano-robotics, cancer, pharmacology and cell repair. As for MOSFET 7nm[4] is one of the latest process nodes in production today that provides shrink down transistors, offering improvement in silicon area utilization and power efficiency. Quantum Computers[5] are one of the most important topics because they use as measurement unit Oubit instead of Bit which is exponentially stronger in computing power. Graphene chemical sensors[6] and especially biosensors have developed rapidly in recent years and their contribution to Biomedicine is now very important. One more topic is Single-electron nano-electronics[7] which relies on the controlled transport of single electrons within solid-state devices. The operation of the devices is based on the tunnel effect, i.e. the transfer of an electron through a thin layer of dielectric. The last topic which we will analyze is nanotubes of carbon in order to make carbon nanotubes we need a periodic structure along the tube's axis and a finite structure in the perpendicular to the axis direction.

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Utilizing potential operators on quantum walk evolution

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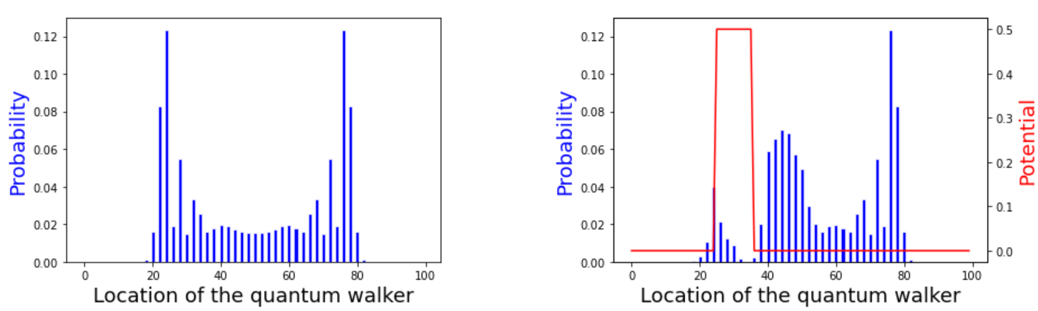
Quantum walks, introduced by Aharonov et al. in 1993 [1], are the quantized version of classical random walks. Despite the main principal between quantum and classical random walks being the same, due to quantum superposition and quantum interference the evolution pattern presents a dissimilar behavior. Quantum walks are proven to be a universal tool for quantum computation [2], equivalent to the dominant quantum gate model and can also be implemented as quantum circuits [3]. They are utilized in a vast spectrum of applications but in most cases, they evolve on free spaces, meaning that no external stimuli are present. The evolution is affected by the properties of the evolution space – lattice. Yet, a solution to the Schrödinger's equation, which describes the quantum walk evolution, comprises a kinetic and a potential energy. The kinetic energy is described by the definition of the coin and shift operators, that act on the evolution Hilbert space and depend on the lattice properties. To describe the potential energy we introduce two different operators that can be utilized for different application. The first one, called phase gate operator [4], is as the name suggests phase gate operators, that introduce the applied potential energy as a phase factor to the quantum walker located on the lattice site the potential is applied. By utilizing the phase gate potential operator, we showed that the lowest eigenstate of tight binding Hamiltonians can be computed [5]. The second operator, called quantum field potential operator, computes the differences between the applied potential on neighboring sites. After its action the quantum walker located at the affected site gets annihilated and new walkers are created on neighboring sites, with a phase factor corresponding to the potential differences. We utilized the quantum field potential operator, to introduce the applied potential as weights on a graph where we performed spatial search to compare the performance of quantum and classical random walks [6].



(a) (b)

Fig. 1. Probability distribution of a quantum walker evolution on (a) a free lattice and (b) a potential affected lattice. Initial location of the walker is lattice 50. Quantum walk evolves for 40 discrete time steps.

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Hybrid Quantum Algorithms

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Quantum Algorithms are a crucial part of quantum computing and have been developed very fast since the first steps of the second quantum revolution. They can be classified into two subcategories depending on whether they run solely on quantum computers, such as Schor's algorithm [1], Grover's algorithm [2] to name a few or they run partially on quantum and classical computers, hence the name "Hybrid Quantum Algorithms", such as QAOA [3] and VQE [4] algorithm. Hybrid quantum algorithms can be utilized in a wide spectrum of applications, ranging from chemistry and medical treatment development to robotics and autonomous driving. Most of the problems, hybrid quantum algorithms trying to tackle, are complex optimization problems, subject to linear and quadratic constraints. As Lukas [5] proposed, in order to be accurately solved, these problems must be mapped into an Ising Hamiltonian formation. An Ising Hamiltonian expresses the energy of an Ising model. This model allows physical systems to be encoded into optimization problems and it is widely used in statistical mechanics. So, the goal of these hybrid quantum algorithms is to determine the lowest energy state of this Ising Hamiltonian, known as the minimum eigenstate of the system, which is the optimal solution to the optimization problem mentioned before. Utilizing the VQE and QAOA algorithms we managed to obtain the optimal solutions for various instances of the knapsack and graph coloring problems. These problems are quite famous NP-Complete problems with applications in economy, telecommunications and many other fields. All our experiments were executed on IBM's quantum computers through the IBM's Qiskit framework [6], which is part of the IBM Quantum program [7].

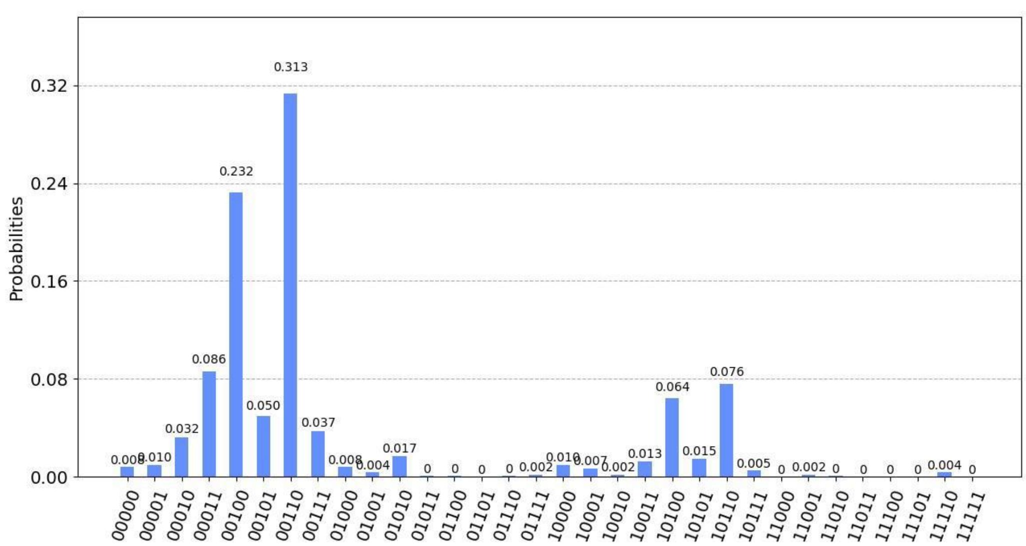

Fig. 1. Probability of finding the minimum eigenstate for a 5-qubit instance of the knapsack problem, with the use of the VQE algorithm. This algorithm was executed on the IBM's *ibm_quito* quantum computer.

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Conversion of a Climate Chamber to a Plant Growth Chamber

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***Abstract*—This paper presents the upgrade of a climate chamber to a plant growth chamber. Initially, the capabilities of a simple climate chamber are presented. Next, the needs of plant growth are analyzed and the conversion procedure is shown. The plants, in order to grow, have more needs than a controlled temperature and humidity. So, the upgraded chamber, except for the mandatory capabilities, must fulfill a series of optional add-ons to support the research on this scientific area. Depending on the economic budget, the researcher can select the most needed options [1-3]. This paper presents a medium budget conversion, including the initial necessary repairs of the devices and electric circuits. Also, presents the needs of the plants, the new modules and the way the researcher can use them [4-5].**

***Index Terms* — Climate chamber, controlled temperature, controlled humidity, plant chamber, controlled light intensity, plant growth chamber.**

I. Introduction

Climate chambers are devices that exist in the market for many decades. Their advantages are the controlled temperature and humidity. The middle and high budget chambers have good thermal insulation and this allows them to achieve a quite uniform temperature dispersion inside, with a low electric power cost, which is something very important the last years, especially in very warm or very cold regions. Controlled humidity is usually implemented with a water spray nozzle and a water pump. Finally, a fan is placed inside the chamber to help the heating or cooling and the uniform humidity dispersion inside the chamber. In the countryside, the plants have changing conditions regarding light intensity, humidity, carbon dioxide (CO_2) in the air and water with ingredients in the soil. A plant growth chamber must have a system to control temperature and humidity, like the climate chamber, and additionally must supply controlled light and CO_2. Finally, periodically or on demand, the researcher can provide the desired water quantity and ingredients in the soil. With a low budget available, after the needed repairs on the damaged equipment, the conversion of the chamber took place and the steps are presented.

Abbreviations and Acronyms

ADC	Analog to digital converter
CO_2	Carbon dioxide
LED	Light emitting diode
MCU	Microcontroller unit
PC	Personal computer
PTC	Positive temperature coefficient

II. Controled Climate Conditions

The plant growth chamber's interior, exterior and the main electric panel can be seen in figure 1.

Fig 1. The chamber's interior, exterior and the electric panel

A. *Temperature control system*

The plant growth chamber must have a temperature control system. In this chamber a temperature controller LAE Electronics MTC12 with a PTC thermistor sensor is installed. The sensor is positioned inside the chamber. The temperature controller is positioned on the main electric panel door and has two relay outputs (figure 2, Out1 and Out2) controlled by the comparison of the measured temperature with two threshold values stored in memory, so that different devices for heating or cooling can be used. The heating is done by a 2 kW resistor positioned above the fan and controlled by output 1. The cooling is offered by a cooling machine compressor, which is installed outside the chamber. The cooling compressor is powered through a separate power line by a user-handled switch on the electric panel door (figure 2, K1). The temperature controller relay output (figure 2, out 2) drives only the freon magnetic valve (figure 2, Y1) of the cooling fluid circuit. The chamber fan constantly circulates the air to achieve a uniform temperature dispersion. With the qualitative thick isolation inside the chamber walls, this temperature uniformity is done better than the required level and economically. The total temperature controlling system can be enabled manually (figure 2, K1) and the preferred temperature limits cannot be changed, unless the user does this locally. Finally, as needed, the electric power is controlled by power relays and safety is guaranteed by the appropriate electric automatic fuses. The electric circuit is shown in figure 2.

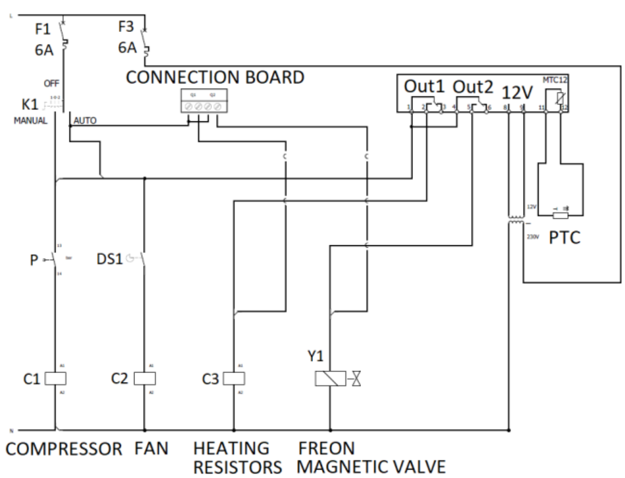

Fig 2. The automation circuit for cooling and heating.

B. *Humidity control system*

The air humidity is important for the study of plant growth and so is the measurement and the control. The researcher must have the capability to set the desired level of relative humidity, like in the dry atmosphere of summer or the moist atmosphere of autumn, or even a tropical region climate. The relative humidity control system consists of a sensor, a controller and a humidifier (figure 3) which adds humidity but cannot reduce it. The reduction is possible with a dehumidifier but the economic budget does not allow such a device.

The relative humidity sensor is capacitive and has a very fast response when there is an air flow. It communicates through 4-20mA current loop with the humidity controller and can measure in the range of 0-100% RH. The humidifier is a centrifugal device and has a small turbine that rotates very fast, elevates and breaks water drops into small droplets and then lifts them up in the chamber. With the help of the fan the droplets have a uniform spread on all the plants, regardless of their position in the chamber.

The relative humidity controller is the HC-231 [6] and has only one relay output. The user can set in the controller's memory the desired value and when the measured value is below this value, the relay enables a power relay in the main electric panel and the last gives power to the humidifier.

Fig 3. The humidity automation system.

C. *Lighting control system*

During the day, the light in nature has different intensities. The simple climate chambers usually have only fluorescent lights, which have a fixed intensity and spectrum. The plant growth chamber must be able to simulate the 24-hour light, which means low intensity for the morning and evening simulation, intense light for the noon and dark for the night [7]. For this work, three different fluorescent lamp circuits and one incandescent lamp circuit are installed. Therefore, different intensity can be configured with the selected number of light circuits that are enabled and the incandescent lamps can give a different spectrum. It is also possible to install LEDs with different wavelength emissions to investigate the effect of each wavelength on the plant growth rate [9].

Each lamp set can be enabled manually and separately by the user with the appropriate switch on the electric panel door. Also, there is the capability to select different time periods of operation for each circuit. Figure 4 shows the electric circuits and the arrangement of the lamps for the two lamp panels on both sides of the chamber. Finally, all the windows on the sides of the chamber were covered so no ambient light inserts in it.

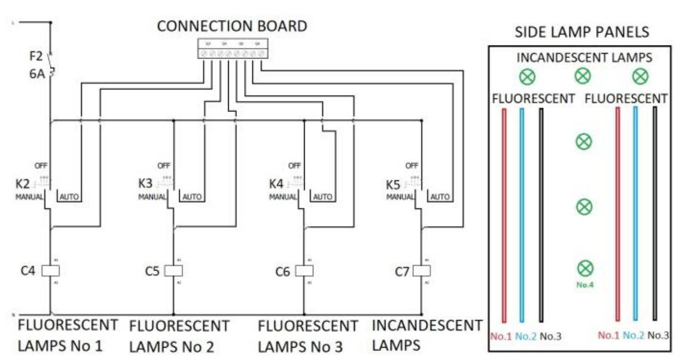

Fig 4. Lighting system with 4 different circuits and lamps

III. MONITORED CLIMATE PARAMETERS

The plant growth chamber cooling, as mentioned above needs to measure more parameters than temperature, humidity and light intensity [8]. Therefore, an electronic circuit was developed to measure CO_2 concentration and soil temperature. The circuit was based on a microcontroller ATmega328 which can communicate through an I2C bus and has an internal 10-bit resolution Analog to Digital Converter (ADC). These capabilities were used to measure the CO_2 concentration and the soil temperature.

A. *MCU board*

The MCU board can be seen in figure 5. The MCU is power supplied through a unit that can be configured to work with 5 VDC or with 7VDC and above, through a voltage regulator. The connectors of the CO_2 sensor and the thermometer are positioned above the MCU and can be transmitted to a PC through the UART to USB interface circuit, which is using the CH340G integrated circuit.

Fig 5. MCU board (left) and PT100 board (right)

The MCU board is not manufactured by a known PCB manufacturer. The board was handmade and although a tinning procedure was applied to protect the copper from corrosion and oxidation, still must avoid high temperature and humidity for a long time. Therefore, the board is installed outside the chamber.

The two sensors must be installed inside the chamber, which means that long cables will be used to connect them to the MCU board. To avoid the voltage drop and the electric noise across the cables, an intermediate node is used to reduce this undesired effect. A board with a 12bit ADC ADS1015 was placed inside the chamber and next to the sensors and the cable length was reduced to the minimum. The ADC can communicate with the PC using the I2C bus, with the quality of measurements preserved, due to the conversion to a digital format before transmission.

B. *Thermometer board*

The thermometer circuit board (figure 5 right) uses a PT100 sensor with a metallic inox enclosure and can be inserted in the soil of the plants or baptized in a hydroponic system and give an accurate temperature measurement of the plant's roots. The PT100 is a "resistor temperature dependent" sensor and is positioned in a 1/4 Wheatstone resistor bridge with linearity error below 2.5%. The voltage difference of the bridge goes to the input of an instrumentation amplifier AD623. To avoid any small voltage offsets, even the very small 25μV input offset voltage of the amplifier, two-point adjustment was used, on the output voltage shift and on the bridge output in balance. Finally, a comparison of the measurements was done against a commercial thermometer and the comparison showed that the measurement error was more than satisfied and there was no need for extra calibration or in-software correction.

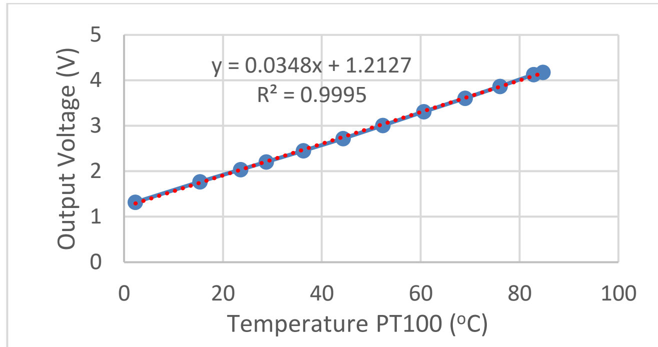

Fig 6. PT100 measurements (blue) vs commercial thermometer (red) over temperature range 0-80 Celsius

C. *Carbon dioxide sensor*

CO_2 is necessary for the plants, especially during the night. In this chamber CO_2 can be measured and regulated easily with a CO_2 bottle and an electronic valve. The used sensor is the MG-811 on a "GRAVITY-SEN0159" board and outputs an analog voltage proportional to the CO_2 concentration. The analog output of the circuit is connected to the ADC input of ADS1015. The measured value is transferred to the MCU and then is shown on the LCD Display with the temperature measurement and transmitted to user's PC [10].

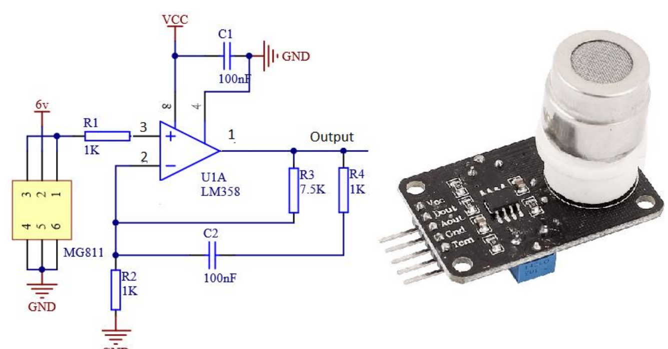

Fig 7. CO2 sensor (MG-811) and circuit for analog output

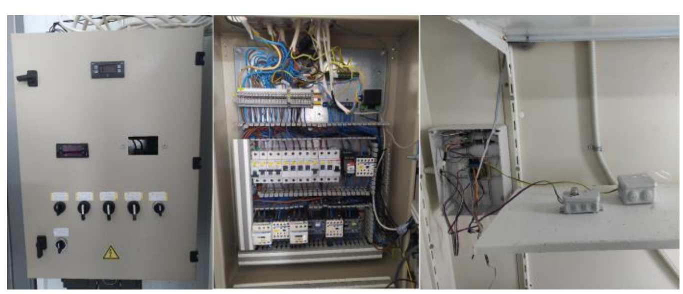

Fig 8. Main electric panel, control switches and connection board inside the chamber

IV. CONCLUSIONS AND FUTURE WORK

For research needs a climate chamber is converted to a plant growth chamber and the following power circuits are implemented:

i. Compressor circuit for cooling
ii. Fan circuit
iii. Heating resistance circuit
iv. Fluorescent lamp circuits No. 1 to 3
v. Incandescent lamp circuit No. 4
vi. Humidifier circuit

The researcher is able to control or measure air temperature, soil or liquid temperature, relative humidity, light with different intensity and spectrum and CO_2 concentration. The measurements are shown on the electric panel door, on LCD display and transmitted to PC for data-logging.

The next steps of this work could be a remote controlled soil ingredients analyzer and soil watering system. Also, very useful for the user could be a fully automated measuring and control system with data-logging based on an application on a PC and remote control of the power circuits.

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Design, Simulation and Construction of a TIG Welding Apparatus

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***Abstract* — This paper presents the design and construction of a metal welding device (TIG Welder) which consists of inverter power circuits as well as analog circuits which are necessary to control the process. It focuses on the calculations and simulations of the power electronics of the two-switch forward convert, using SPICE analysis software.**

***Keywords*— Power Electronics, SPICE, Analog Circuits, TIG Welder**

I. Introduction

Metal welding is a fabrication process where two or more pieces of metal are fused together using heat. The heat can be produced by an electric arc that melts the metals forming a joint after cooling down. Tungsten Inert Gas (TIG) welding is the process where an electric arc is generated between the base metal and a non-consumable electrode made of tungsten. While the metals are liquid, additional metal of the same alloy is needed to be purred into the weld pool to form a strong joint using a consumable filler rod. The weld pool is protected by an inert gas shield instead of slag that is used in stick welding. The gas that is mostly used is argon and sometimes helium.

To create such an arc, a welding machine is needed to provide the current and the voltage (typically 20 to 200A, 15 to 40V). Welding machines use mains input 110 or 230V AC (single or 3-phase) and convert it to AC or DC output. Older types of welding apparatus use a large iron core transformer to step down the voltage and a mechanical magnetic shunt to limit the current. The downsides are that these machines are really heavy, have limited control of the current, low duty cycle and low energy efficiency. The newer, inverter-based machines that rely on semiconductors to convert the mains power, have serious advantages over the older types of apparatus. The welding current waveform is precisely controlled in the time domain, having different shape waveforms according to the user settings. This paper focuses on the design and simulation procedure of the **power electronics** of an inverter welding machine

II. Abbreviations and Acronyms

N_s Number of turns of the secondary winding
N_p Number of turns of the primary winding
B_{sat} Magnetic Saturation Flux Density
A_e Effective area of the transformer core
A_L Inductance factor; $A_L = \frac{L}{N^2}$
D_{max} Max duty cycle of the converter
P_{Diss} Power dissipation
V_{CE} Voltage potential between collector and emitter
V_{GE} Voltage potential between gate and emitter
V_{ceSat} Saturation voltage between collector and emitter
$T_J max$ Maximum junction temperature

TABLE I: MACHINE SPECIFICATIONS

Input voltage	AC 230V single phase
Open circuit output voltage	50V
Welding current range	30 to 120A
Arc start method	High Frequency (HF) Start
Gas control	On/Off solenoid
TIG Functions	Pre and Post Flow control, Pulse Welding, “Cold welding”

III. Apparatus Operation

The proposed apparatus is specifically designed for the TIG welding process. In order to make the process more user friendly, a contactless arc start method is implemented.

Basic usage: Once the user presses and holds the button on the torch, the gas solenoid opens and the gas starts to flow for a specific time (“pre flow”). After that time period, the high current arc starts with the help of a high frequency high voltage arc and the welding begins. Once the user releases the button the arc extinguishes and the gas flows for an additional time called, “post flow”. The pre and post flow times are adjusted from two potentiometers on the front panel.

IV. Features

- Pulse welding: When this function is enabled, the welding current fluctuates between a high and a low level at a constant rate. Melting and fusion of the metals is achieved when the current is at its high level while the low level current maintains the arc with minimal heating. This allows for more controlled heat input to the work pieces and its beneficial when welding thin metals (0.5 to 1mm). The high and low current levels as well as the rate can be adjusted by the user on the front panel.
- “Cold welding”: This feature enables the user to utilize a single-shot high current low duration arc. When the button

on the torch is pressed, the operation is the same as the basic usage, while the arc extinguishes after a short period of time (100 to 1000ms), adjustable on the front panel. This function is used for autogenous welding on very thin metals (0.1 to 0.5mm). It is also used to weld copper, which has a very high heat conductivity, making it hard or impossible to weld it with the normal TIG welding process.

- HF Start: This feature starts the welding arc without having the tungsten electrode touch the work pieces and eliminates the risk of tungsten contamination. At the start of the process, a high frequency high voltage, low current arc is generated for roughly 150ms between the tungsten electrode and the metal. That arc ionizes the gas and the high-current welding arc starts. The distance between the tungsten electrode and the work pieces must be 1-5mm.

V. Electronic Circuits Calculations and Simulations

The simulation of the circuits is achieved using with the LTspice [5] software, which is freely available. The apparatus has three main circuits that are simulated, namely the input full bridge rectifier, the DC-DC converter and the analog control circuit. Each circuit is simulated separately. A general block diagram of the welding apparatus is displayed below.

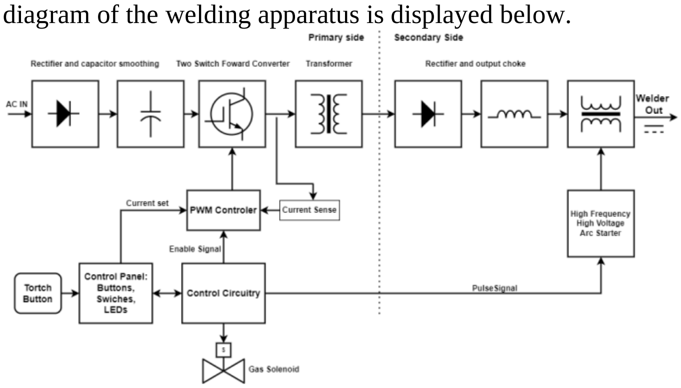

Fig1. Block diagram of the power and control circuits.

A. Input Full Bridge Rectifier

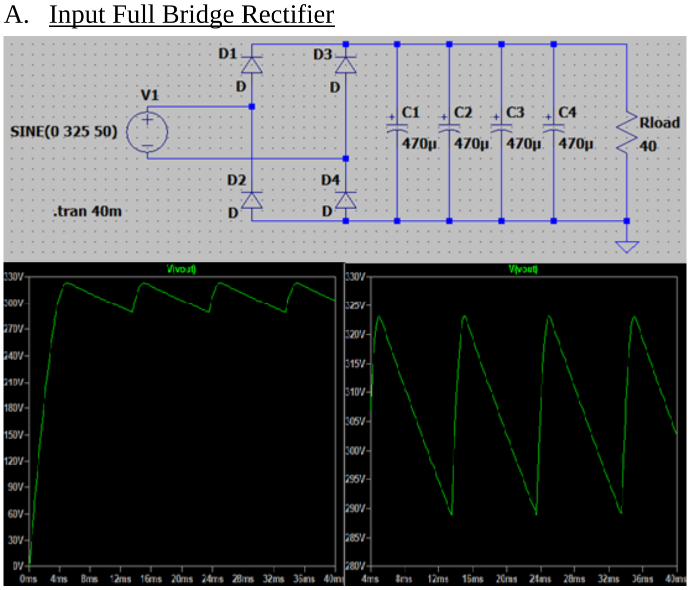

Fig2. Schematic and simulation result of the bridge rectifier in LTspice.

The mains input power is fed directly to a full bridge rectifier. The resistor R_{load} represents the inverter load. A capacitance close to $2000\mu F$ is selected, aiming for a voltage ripple less than $45V_{p-p}$ with average current of 8A, using the formula:

$$V_{ripple} = \frac{I_{load}}{2xfxC} \quad (1)$$

The simulation verifies this calculation. Four capacitors in parallel of $470\mu F/400V$ will meet the design requirements, instead of a single $2000\mu F$, minimizing the cost.

B. Forward Converter Power Stage

Transformer calculations: A two-switch forward converter [2] [4] is employed, stepping down the input DC voltage (325V) to a low DC voltage of 50V. The ratio of the transformer turns need to be calculated using the formula below:

$$\frac{N_s}{N_p} = \frac{V_{out}}{V_{supply}\ x\ D_{max}} = \frac{50}{325\ x\ 0.5} = 0.307 \quad (2)$$

Where D_{max} is the maximum duty cycle of the converter
The core of the transformer is a ferrite material, specifically a manganese-zinc alloy (MnZn), with code N27. The ferrite part number is *B66387G0000X127* with $B_{sat} = 320mT$, $A_e = 535mm^2$ and $A_L = 7200nH/N^2$ The minimum primary winding turns can be determined using the formula below, with a switching frequency of $60KHz$.

$$N_p > \frac{Vin_{max}\ x\ D_{max}\ x \frac{1}{fs}}{B_{sat} x\ A_e} \quad (3)$$

The minimum turns are calculated using (3) resulting in $N_p > 15.81$ or $N_p > 16$. In order to have a safety margin and not saturate the core of the transformer 20 primary turns are used. The secondary winding turns were calculated by using (2), resulting in 6 turns. The inductance values of the two windings of the transformer are calculated by using the formula below:

$$A_L = \frac{L}{N^2} \quad (4)$$

resulting in $L_P = 2.88mH, L_S = 0.2592mH$

Output rectifier diode selection: The voltage rectification of the secondary winding of the transformer is rectified by 2 diodes. Each diode conducts for half of the time on each period, so the maximum average diode current is the maximum output current divided by 2 which results in $60A$. The diode with part number (*VS-80EBU04*) ($I_F = 80A, V_R = 400Volt, V_F = 0.92V$) is selected for this task, as its package is easy mountable on the heatsink.

Output inductor calculation: The output filter inductor or choke minimizes the current ripples of the output of the converter [3]. The maximum required current is 120A. Due to the nature of the welding process, the current ripple can be up to 20 Ampere due to the fact that the average heat produced by the arc, is a product of the average current. On the other side, the larger the ripple, the more unstable the arc will be at low current values. Output current ripple selected at 10A. The output voltage during welding is about 15-25Volts.

The minimum inductance is calculated by using (5), resulting in $L_{chokeMIN} = 39.9\mu H, with$ the following parameters: $Vo = 25Volt, \Delta_I = 10A\ V_f = 0.93V, D_{min} = \frac{Vo}{V_{inmax}} = \frac{25}{325} = 0.076$

$$L_{choke} > \frac{\frac{1}{fs} \times (V_o + V_F) \times (1 - D_{min})}{\Delta_I} \quad (5)$$

A toroidal core is selected for this application with the part number *(T184-26)*. The material is iron powder, with inductance factor $A_L = 169nH/N^2$. Using two cores together doubles the inductance factor to $338nH/N^2$ and reduces the heat dissipation of each core. The minimum required turns are calculated by using (6), resulting in $N_{chokeMIN} = 11\ turns$. The selected inductor turns are 11.

$$N_{chokeMIN} > \sqrt{\frac{L_{chokeMIN}}{A_L}} \quad (6)$$

Transistor selection: The IGBT type transistor is selected over MOSFETs because of the lower cost for the same electrical switching specifications. They are designed for higher operating voltages, typically 600Volts and above and can withstand high current spikes resulting in higher reliability for this application. They are ideal for frequencies up to 80KHz, while MOSFETs are suitable for frequencies up to 200KHz. The IGBT with part number *(IGW30N60TFKSA1)* will be used in a TO-247 package with electrical characteristics: $I_C = 39A\ @\ T_C = 100C,\ V_{CE} = 600V,\ P_{Diss} = 187W,\ V_{ceSat} = 1.5V,\ T_J\ \max = 175C$.

Taking account all the above calculations, the converter circuit is drawn. The magnetizing current of the transformer is modeled by L4 and R5. The gates of the IGBTs are driven by a 1:1:1 transformer (L6, L7, L8) and the gate driver circuits. The output load is modeled by a resistor R_{arc}. A primary sensing circuit is also presented. The simulation parameter (D = 0.38) sets the duty cycle of the gate driving circuits to 38%, resulting of an average output current of 150A.

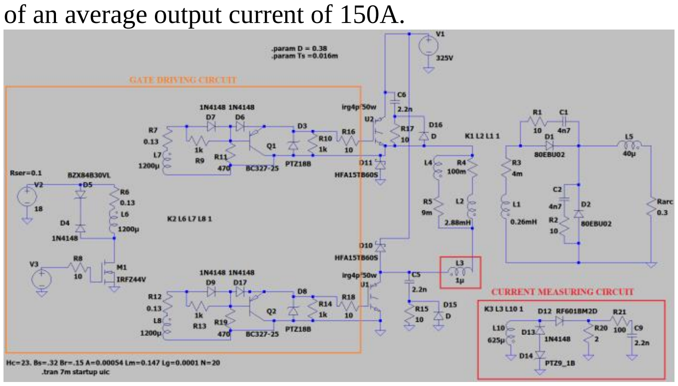

Fig3. Schematic of the forward converter in LTspice.

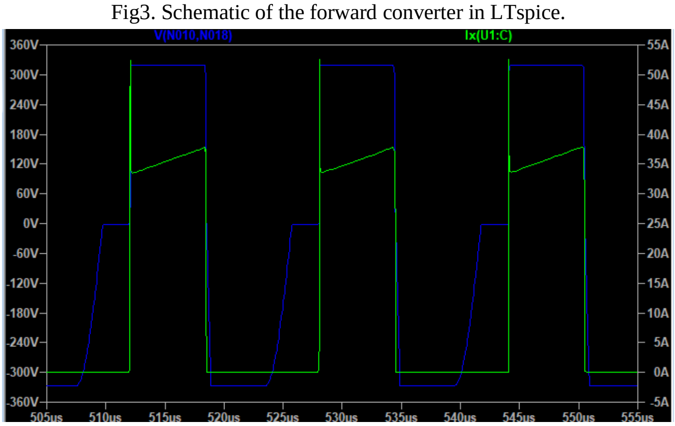

Fig4. IGBT current (green) and voltage (blue).

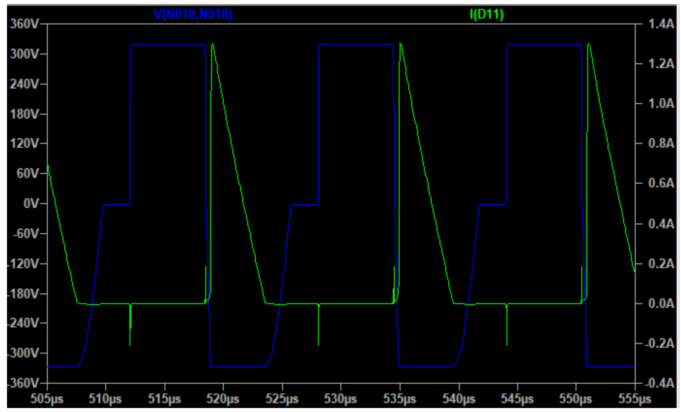

Fig5. Recovery diode current (green) and transformer voltage (blue)

Recovery diode selection: The recovery diodes must withstand the average recovery current as well as the peak currents [6]. The diode with part number *(MUR1560)* is chosen with characteristics: $I_F = 15A, V_{RRM} = 600V, V_F = 1.5V, t_{rr} = 60ns$.

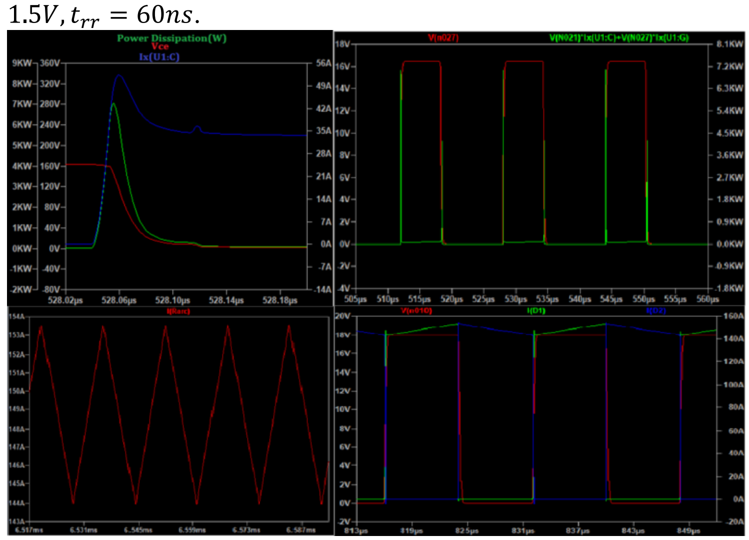

Fig6. IGBT waveforms: V_{CE}, I_C, P_{diss}(top left) | IGBT waveforms: V_{GE}, P_{diss} (top right) | Output current ripple (bottom left) | Current of D1, D2 and V_{GE} (red) waveform (bottom right)

Snubber networks: RC or RCD circuits are used in order to dampen oscillations and prevent over-voltages from destroying the semiconductors. They are essential in this kind of high-power circuit, as stray inductances that occur in the real application can induce high voltage spikes. Although the exact component values cannot be determined, the simulation helps to identify a reasonable compromise. Following that, experimenting with different values in the real application is required.

PWM Controller: The PWM controller circuit is not simulated as the model of the integrated circuit (IC) could not be found. The PWM controller IC is the *NCP1252*. A typical application schematic can be found in its datasheet which is modified to suit this application.

VI. CONTROL CIRCUIT, HF CIRCUIT AND FRONT PANEL

In order to have an interface with the user, a control panel is required. All the inputs are fed into a logic circuit (control circuit) consisting of logic gates, comparators and passive components that control the gas solenoid, control the high frequency high voltage circuit and set the desired current in the PWM controller. Analyzing these circuits is beyond this scope of this paper. The full working schematics of these circuits are presented below

VII. FINAL SCHEMATICS, PCBS AND CONSTRUCTION

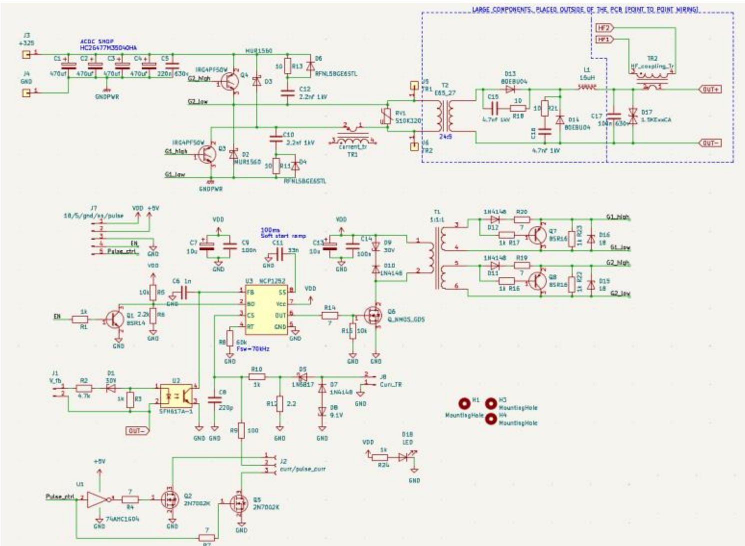

Fig7. Schematic of the two-switch forward converter with PWM controller.

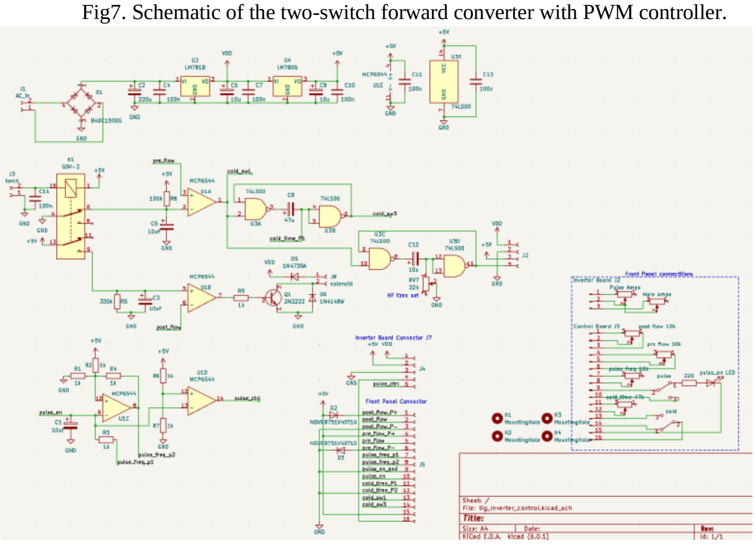

Fig8. Schematic of the control logic circuit.

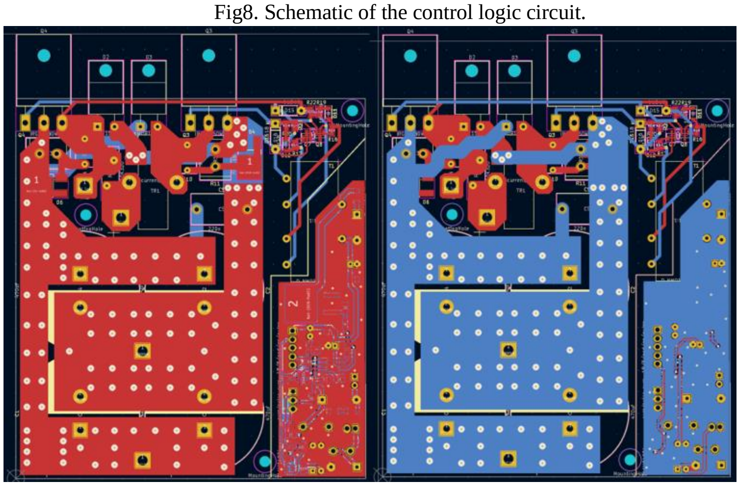

Fig9. PCB of the two-switch forward converter and PWM controller (top layer left and bottom)

Fig10. Finished product.

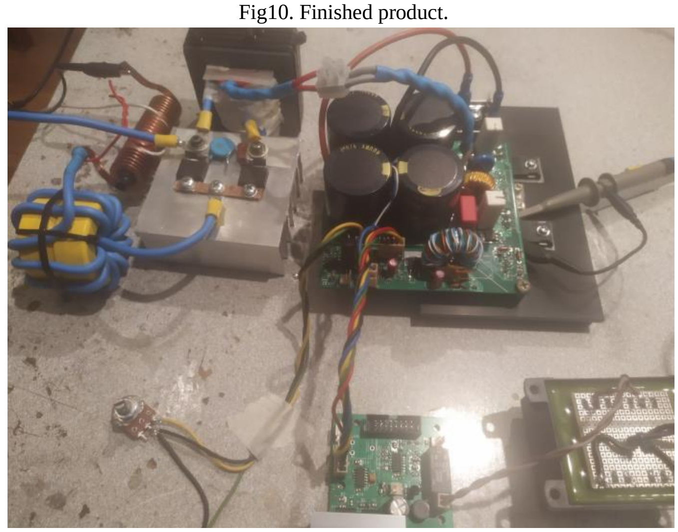

Fig11. Bench testing and acquiring measurements with the oscilloscope.

IX: CONCLUSIONS

A prototype welding apparatus has been designed and simulated. Following its construction, its operation has been tested with great success verifying the procedure followed.

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E-DRIVETOUR: an interactive blended course on electric vehicle technology

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***Abstract*—The educational procedure implemented in the frame of an Erasmus Plus Knowledge Alliances (KA2) program on electric vehicle technology is presented in this paper. In the project entitled "E-DRIVETOUR: Beyond the border of electric vehicles: an advanced interactive course" a blended learning approach has been proposed, which turned to be very efficient when followed shortly after COVID-19 pandemic. The attendants had the opportunity to participate in a multidisciplinary curriculum focusing on vehicle electrification through theoretical, online lectures, large scale laboratories requiring physical presence, advanced medium sized projects and industrial training. A form of project-based learning approach had been implemented.**

***Index Terms*— Electric vehicles, augmented reality, education, project-based learning**

I. INTRODUCTION

ELECTRIC cars, scooters, bikes and any other kind of vehicle is nowadays a reality and not something exotic or having only research interest as it seemed until several years ago [1]. Electric vehicles and related management procedures are widely spread all over Europe and constantly increase their market share. However, this penetration as well as the increase in supporting infrastructure does not uniformly appear inside the EU. In countries of the Southern and East Europe, and especially the Balkan Peninsula, electric vehicle market penetration is not considered important. As a result, the existing know how regarding vehicle electrification in a national (referring to the Balkans), not to mention regional or local level is practically very small. Infrastructure, like charging stations, in this area are rather too limited. This results in a general ignorance about vehicle electrification not only of the public but also of people working in the domain of vehicles.

The educational results from an educational program such as the E-DRIVETOUR [2], aiming at educating engineers, mechanics and vehicle related personnel with the difficulties mentioned above, synergies like the one obtained between Universities and companies of different countries has not only covered the gaps existing in a national level but also provided a full range education regarding electric vehicles. Theoretical and practical knowledge on vehicle electrification from Romanian and Polish Higher Educating Institutes has filled specific gaps in the International Hellenic University and vice versa. Private companies and research institutes specialized in the field of vehicle electrification, like the development of related technology or the production of specialized vehicles have provided the required practical knowledge on EV production, measurements, hybridization and troubleshooting as well as vehicle maintenance.

II. E-DRIVETOUR CURRICULUM

The curriculum, composed of 24 appropriately selected courses-topics, promises to cover the core and more advanced vehicle electrification issues combined with principles of entrepreneurship and automotive business administration and marketing. The multidisciplinary course developed includes also a small but important contribution from cultural courses (Fig. 1).

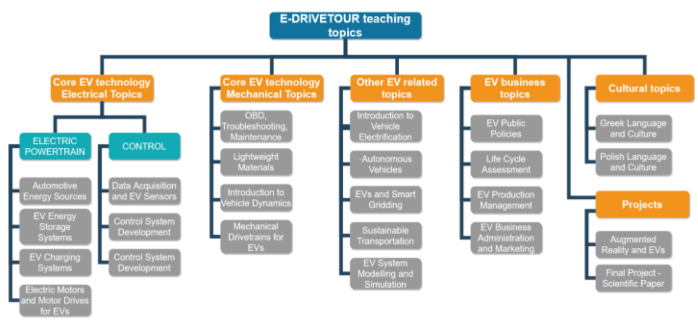

Fig. 1. Picture with defective transistor found inside the wheel motor.

The curriculum is a blend of traditional and innovative teaching methodologies involving in-class (if possible) and web based courses, traditional experimental laboratories with the ability to be implemented remotely in an effort to overcome practical problems in attendance, like the one caused by COVID-19 pandemic crisis. Simulation tools have been also a very important factor of the teaching methodology introducing the attendants, students, graduates or professionals, to modern technological advances and approaches. Two medium sized, project based courses have brought the attendants closer to the real world of electric vehicle technology combined with simple internet of things and augmented reality applications. Finally, the overall curriculum has been complemented by two weeks of industrial practice in the industrial partners of the project.

The course duration was 5 (teaching) + 3 (preparation and training) months, including a 14-day industrial experience, after the end of the teaching period. During the execution of the course, 3 mobility periods have been arranged. For the first 14-day period, all students have gathered along with educators in the premises of the International Hellenic University in Thessaloniki, Greece whereas in the second, similar one the gathering took place at the University of Technology and Humanities in Radom, Poland. All attendants have participated in the large-scale laboratories including two medium sized projects. In the third period, all attendants were spread to the industrial partners in order to perform their 14-day internship focused on electric vehicle technology. Thus, having completed all four periods of training (theoretical lectures and 3 mobility periods), the participants have gained significant theoretical knowledge on electric vehicle technology but most of all they have acquired significant practical experience, valuable for meeting the requirements of an emerging market.

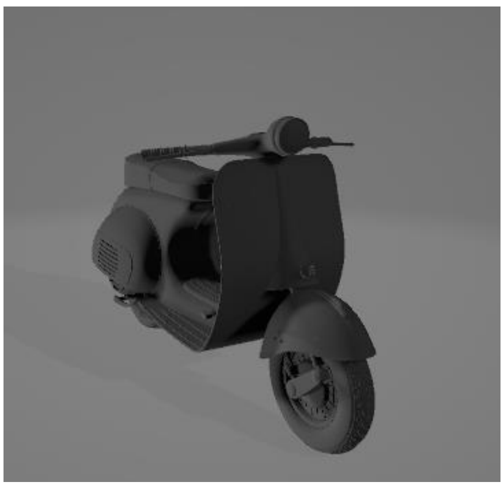

Fig. 2. Vespa 3D model on Tinker cad.

III. Medium sized projects

Divided into six groups of five or six members, the students had to participate in all laboratory sessions of the course as well as the two so-called intermediate projects. These two medium sized projects were the peak of students' laboratory experience.

In the first one, the students had to become familiar with a small scale electric vehicle, among the small EV fleet of the Laboratory of Energy Systems of IHU. They had to assembly the vehicle and make sure it operates. Following this, they had to design a 3D of the vehicle in TinkerCAD software [3] and exploit the OpenSpace3D software [4] in order to develop an augmented reality application that would allow them to present information of their vehicle in a modern and attractive way. Fig. 2 depicts the 3D mode of an electric scooter as it was designed by one of the student teams. The electric vehicles the student shad to work with were two tricycles, a delta and a tad-pole one, a kart, a bicycle and a scooter.

In the second one, the procedure was more or less the same. There was though a significant difference. The student groups had to work on a Toyota Prius hybrid electric vehicle [5]. At first, they had to investigate its structure and mainly its powertrain. Then, they had to acquire data from the powertrain during the vehicle's operation inside the lab on a dynamometer and on the road by means of appropriate data acquisition equipment. The data received as well as any other information obtained for the specific vehicle were combined with 3D models of the vehicle and an augmented reality application in a similar way as in the first project. Fig. 3 shows a view of the vehicle used.

Fig. 3. The Toyota Yaris Hybrid vehicle that was available to the students.

IV. Conclusion

Student training on electric vehicle technology through the cooperation of Universities and related companies is the subject of this paper. The multidisciplinary educational approach, emphasizing on its blended dimension (online and with physical presence, theoretical and laboratorial, project based and industrial training), is presented.

V. Acknowledgements

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E-DRIVETOUR mobility intermediate projects: An Overview

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***Abstract*— The purpose of this paper is to present the projects that group C of students carried out, during mobility periods in Thessaloniki and Radom, in the frame of the educational program ERASMUS PLUS KA2 EDRIVETOUR [1]. This paper describes the steps and the results for each project which was assigned to group C of students, according to certain instructions given at the beginning of each mobility period. The implemented methodology is based on existing and effective literature. The topic of the first intermediate project is related with the build and configuration of an electrical bike (scooter) on an existing 50cc bike chassis, advancing its user's interface with rain sensor and informative content. The topic of the second intermediate project is a brief but comprehensive presentation of the hybrid model of 2004 Toyota Prius.**

***Index Terms*—Electric Vehicles, Battery Electric Vehicles, Education, Training , Augmented Reality.**

I. Introduction

TLECTROMOBILITY has become important in our era more than ever. Since we rested our case for more than hundred years, environmental factors plus political awareness and determination, really urged scientific community, which and through industrial realization have managed in a short period of time, not only to plug us in to the electrical solution, but also to offer to the world relevant products with high tech advantages and benefits in terms of equality in comparison to what we have known so far.

This achievement was delivered by the practical and theoretical knowledge in certain fields, additionally with the extensive and non-stop research contributing to the safety and improvement of the final product.

At the same time the need to secure the acquired knowledge emerged, as well as to disseminate it, involving more human resources, especially through the distributive role of education.

Significant link to this direction constitutes the E-DRIVETOUR intensive training program. In the frame of this program, the participants had the chance to meet each other during mobility periods, after a long time of theoretical training (lectures), and to carry out various experiments in the laboratory. The intermediate projects, among them, were of crucial importance as they required theoretical, practical and collaboration skills. Herewith, are presented the intermediate projects that group C of students conducted.

II. Intermediate Project

The electrification of a bike meets various challenges. Decisions are to be taken, such as what we should do, but more likely what we can do under certain circumstances. Initially, we disassembled the bike to keep things in order and to evaluate the existing conditions. The 50cc bike is shown in Fig. 1.

Fig. 1. Yamaha JOG equipped with a 2-stroke single cylinder gasoline internal combustion engine of 50cc.

Concerning the parts we found, we labeled each one of them, and we took pictures in order to improve wire connections. As shown in Figs. 2 and 3, a controller and a motor were predated. Thereafter, we ordered the appropriate battery, taking into account the operation voltage of the motor and the approximate weight of the bike including one passenger. Using the indications disposed on each of the above devices, we found their characteristics via the web, which can be reviewed in the following tables.

TABLE I
MOTOR SPECIFICATIONS [2]

Permanent Magnet DC Motor MY 1020	
Power	1000 W
Input Voltage	48 V
Unload Speed	3700 rpm
Rated Speed	3000 rpm
Rated Current	≤ 35.6 / 26.7 A
Rated Torque	3.2 Nm

Units stands according to SI: W = Watt, V = Volt, A = ampere, rpm = revolutions per minute, Nm = Newton meter.

TABLE II
BATTERY SPECIFICATIONS [4]

DEEP DISCHARGE VRLA AGMGEL120055	
Connection	4s1p
Nominal Voltage	48 V
Energy	217,92 Wh
Weight	6,6 kg
Autonomy	≈2 km

Units stands according to SI: Wh = Watt for hours, V = Volt, kg = kilos, km = kilometers.

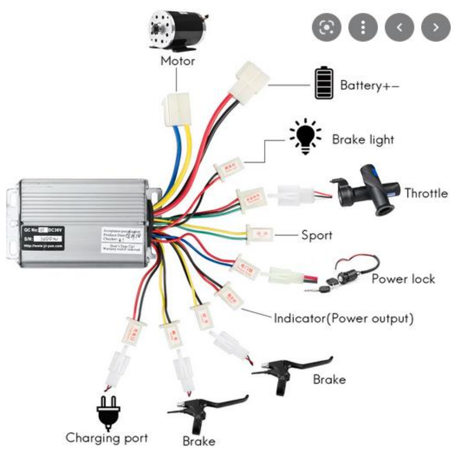

Fig. 2. OK 10E-4 suitable for 1000W motor. Operating Voltage 48 V [3].

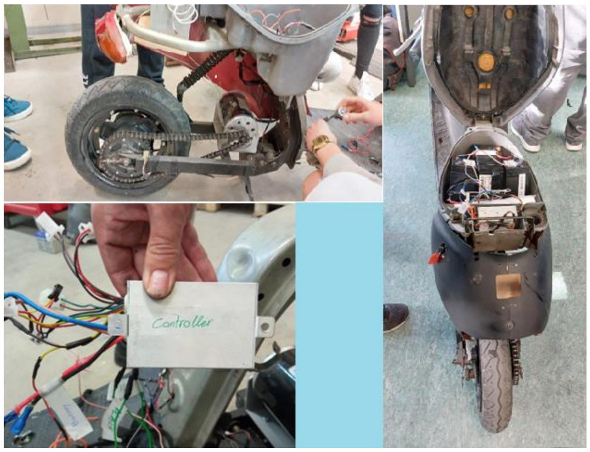
Fig. 3. Labeling existed parts.

A. TinkerCad

TinkerCad is an online, open-source application for 3D design, electronics and coding that really help you to bring project-based learning to the classroom [5]. In Fig. 4, the 3D model of a similar bike is presented.

Furthermore, in Fig. 5, the electronic circuit of the scooter is shown, including rain sensor and using Arduino board.

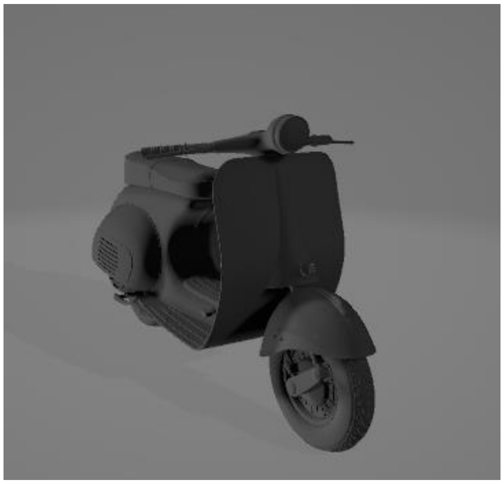
Fig. 4. Vespa 3D model on Tinker cad.

B. Rain sensor programming with Arduino Uno

The majority of the electric vehicles have rain sensor because it is often recommended the driving under normal or good weather conditions. Under those circumstances, we couldn't miss than to include one in our electrified scooter.

The code provided [7] investigates whether there is a droplet on the sensor board or not, and through a serial port, the output message is consequently "Rain Warning" or "Not raining" with almost 1 second frequency. (Fig. 6).

C. Open Space 3D

The word "application" may be one of the most common in use nowadays. The truth is that there is an application for almost everything we do or we use.

That led us to develop our application for the scooter that makes the experience fancy and friendly to the user, informing him at the same time, about the technology he is riding on.

Specifically, we developed a QR code in Open Space 3D (Fig. 7) that can be exported for mobiles, which is capable to read barcodes located in certain places on bike's chassis and to pop up different types of information, like technical data.

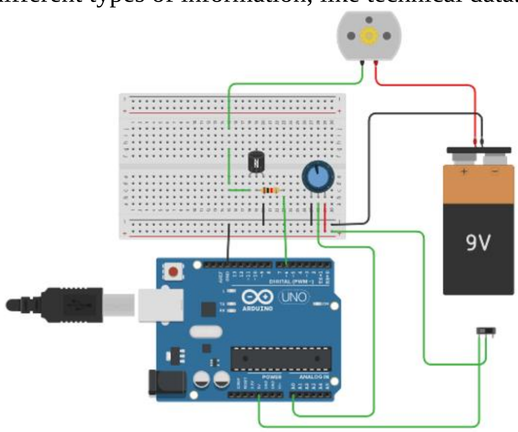

Fig. 5. Electronic circuit of the scooter.

A similar approach was attempted with the output message from the rain sensor (Fig. 8), as the aim was the notice to be readable as live data from the web. Unfortunately, our time was up to build in the complete application to the scooter's electronic circuit.

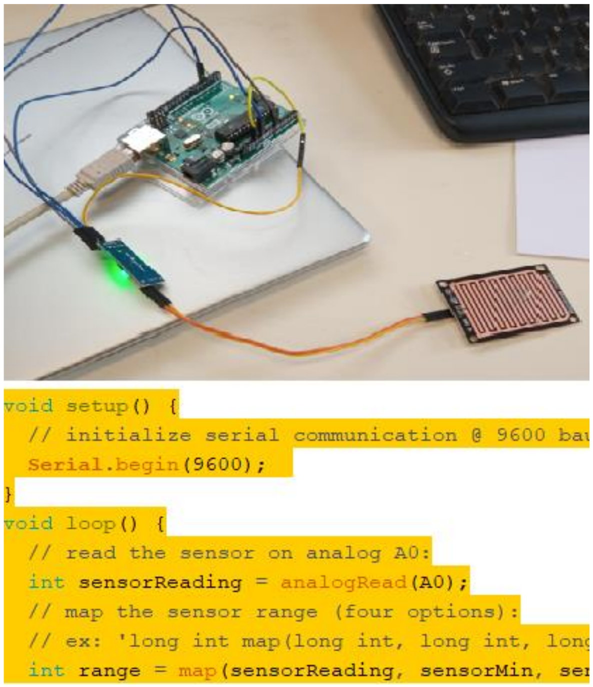

Fig. 6. Experimental setup and part of coding in Arduino IDE.

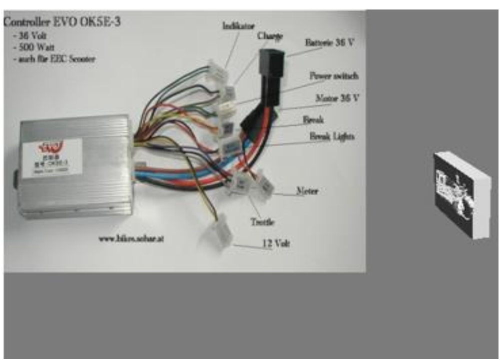

Fig. 7. Controller output with QR application

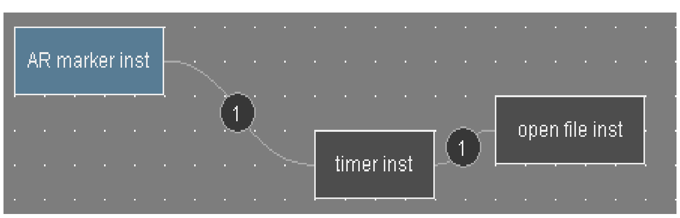

Fig. 8. Open space 3D environment for live data.

III. Intermediate Project II

Toyota Prius of 2004 belongs to the new generation of hybrid vehicles. Its vanguard lies to the fact that it seamlessly alternates the operation of a petrol engine and the electric drive system, with the aim of optimizing range and performance, achieving up to 80% electric motion.

The two motive power sources and other important system components (Fig. 9) are reviewed in the following sections [7].

A. Electric Motor

The battery powered motor is a synchronous 8-pole ac permanent magnet, capable of delivering a peak-power output of 50 kW with a high supply voltage up to 500 Volts. Considering the mass of the motor to be 45 kg, the specific power is estimated to 1.1 kW/kg. Also, it has a maximum torque of 400 Nm between 0-1500 rpm speed. Finally, it is designed as a high-efficiency, direct current brushless motor that uses alternative current.

B. Internal Combustion Engine

The internal combustion engine of Toyota Prius 2004 is based on the Atkinson Cycle, as all the hybrid electric applications. Therefore, the 1.5-litter gasoline is designed for high expansion ratio cycle, while the compression ratio is 13:1. The 4-stroke engine, as motive power source, can output 57 kW at 5000rpm speed, and a maximum torque of 115 Nm at 4200 rpm speed. The efficiency of the engine is also held out by its own coolant system, which preserves the level of the most efficient temperature.

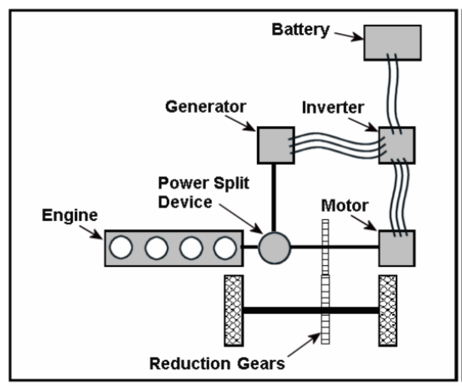

Fig. 9. Subassembly arrangement. [7]

C. Generator

The Generator is an eight-pole permanent magnet ac device, that functions as the engine starter, rotating at the high speed up to 10000 rpm. This high-speed rotation produces high power density, capable to charge the battery and to supplement motor's power requirements.

D. Power split device

The power split device is one of the major transmission components. Mechanically, is a planetary gear set, that adjusts the power allocation from the engine to the generator and the wheels, at the same time.

Briefly, the power from engine shaft arrives to the planetary carrier (Figs. 9, 10), which transmits the power to the outer ring gear and the centered sun gear, through the pinion gears. Then, the rotating shaft of the ring gear is directly linked to the motor to produce traction-drive force for the wheels, while the rotating shaft of the sun gear is directly linked to the generator which either charge the battery or supplements the motor. The overall efficiency is optimised under normal driving conditions in this way.

E. *Battery*

The battery of Toyota Prius 2004 is rechargeable, made of nickel-metal hydride, and features 28 modules in series, 7.2 Volts each. Therefore, the nominal voltage of the battery is 201,6 V, while the specified power is 21kW. It supplies electricity to the motor, contributing on the efficacy of the traction force, and receives charging power from the generator, so an external charging source is not acquired.

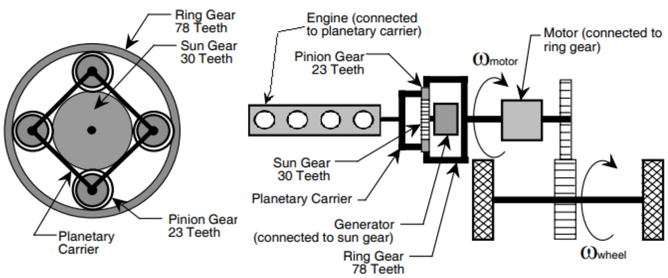

Fig. 10. Diagram of power split device. [7]

F. *Inverter*

The inverter is a closed power control unit (Fig. 11), that is consisted of a motor inverter, a generator inverter, a voltage-buck/boost converter, an air-conditioning compressor inverter, and a 12V dc-to-dc converter.

The unit converts the dc from the battery into a three-phase ac for driving the motor and includes a dc-to-dc converter that produces 12V for auxiliary equipment. Furthermore, features a high voltage, bi-directional, dc-to-dc converter that boosts the 200V battery up to a maximum of 500Vdc link, where the peak-power output of 50kW is achieved, or reduces the higher voltage dc link (that may vary from 200–500V) down to charge the 200V battery.

It has its own hybrid drive coolant system, separately from the engine-coolant system because the two systems operate at different temperatures.

G. *OpenSpace3D software*

A 3D rotating model simulation is outlined in Fig. 12 as developed in the OpenSpace3D software [8], [9].

Fig. 11. Inverter and converter unit. [7]

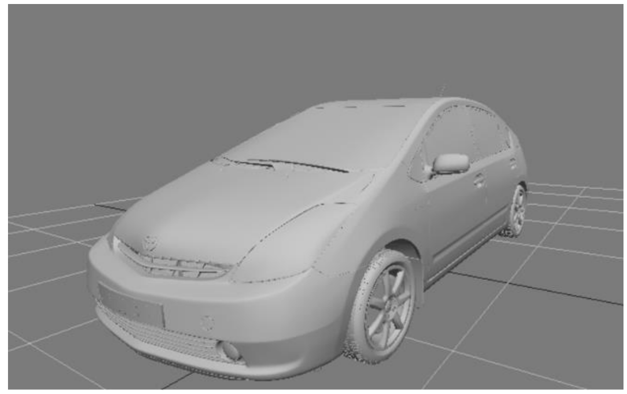

Fig. 12. OpenSpace 3D simulation of Toyota Prius 2004.

IV. Acknowledgements

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Medium scale projects as a means for educating students on electric vehicle technology

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***Abstract*—This paper describes the collective work of a student group during two medium scaled projects in the frame of the Erasmus Plus KA2 programme "Beyond the border of electric vehicles: an advanced interactive course" with the acronym EDRIVETOUR. The projects have been elaborated during its two mobility periods, the first at the premises of the International Hellenic University (IHU) in Thessaloniki, Greece and the second at the University of Technology and Humanities in Radom (UTHR), Poland. The EDRIVETOUR program focused on educating undergraduate engineering students from different fields of study such as mechanical or electrical engineering, in the matter of electromobility and modern technologies. During the mobility periods various procedures such as the development of augmented reality applications, collection of technical specifications and datasheets of electric vehicles, 3D modelling and the troubleshooting of a battery assisted Tad-pole tricycle and a Hybrid Toyota Yaris have been overseen.**

***Index Terms*—Electric Vehicles, Battery Electric Vehicles, Education, Training , Augmented Reality.**

I. Introduction

The EDRIVETOUR Erasmus Plus program's main focus was the education of undergraduate students on electric vehicle technology which would help them develop the necessary skills to be employed in the corresponding automotive industry. In the duration of the program the students were divided into five groups. This paper presents the activities of Group D. Throughout the three mobility periods of the program student groups were required to develop sensing cluster for automotive applications with microcontrollers, 3D models of electric vehicle parts, an augmented reality application, simulations as well as maintain and prepare their assigned vehicle for a racing contest. It should be noted that all the activities mentioned above were requirements needed to be met by the university students attending the Erasmus program for its completion and the eligibility for receiving the according certification.

II. Tad-Pole Trike Maintenance and AR Modelling

The first task to be elaborated by all student groups was the maintenance of a small-scale electric vehicle. In the case of Group D that was a tad-pole type electric tricycle.

Fig. 1. The Tad-pole trike as is currently stationed in EVAE laboratory at International Hellenic University at Sindos Campus.

A. Maintenance

Before any other procedure took place, it was of great importance to ensure that the vehicle provided by the hosting university (IHU) functioned properly with all the necessary mechanical and electrical parts working at their best condition. For that reason, simple maintenance has been performed under the supervision of the technician in charge. For the Tad-Pole trike a few modifications were made on the mechanical parts of the vehicle such as inspection of the proper function of the cassette, cleaning, and lubing of the chain of the vehicle and inspection of the brakes and their proper operation. On the electrical components of the vehicle the hub motors were checked through the freeware provided by their manufacturer (Miromax ltd.) [1] but unfortunately, several problems with the electronic components of the controller of the motor prevented the appropriate performance of the electrical assisted pedaling.

B. Modelling and AR Application

As the use of freeware and open-source software was promoted throughout the entire Erasmus program [2], Tinkercad software [3] was chosen as the appropriate design environment for the 3D modelling of the Tad-pole trike. The specific software was selected since an STL type file was essential in its use in the augmented reality application provided as the means to develop the AR code required for the project to be appropriately completed.

After gathering all the appropriate dimensions of the vehicle [4], the 3D design was elaborated and completed in Tinkercad. Completion of the 3D model in Tinkercad software has led to the better understanding of the mechanical and electrical parts of the vehicle's drivetrain, an extremely significant issue and aim of the project (Fig. 2). The development of the AR code in the OpenSpace3D software [5] has followed.

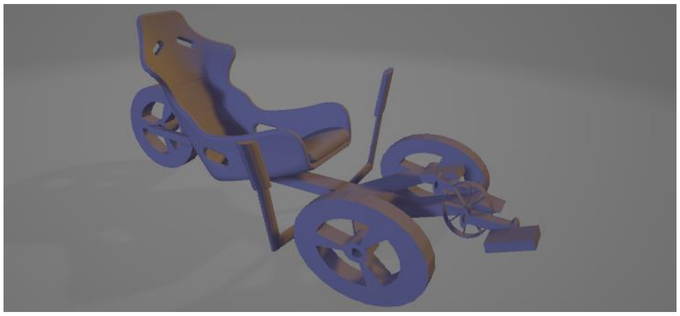

Fig. 2. The STL file of the Tad-Pole trike designed in Tinkercad software online in order to be used by the OpenSpace3D saftware.

The OpenSpace3D application has been developed for displaying the designed model in three dimensions alongside all the technical data and specifications relevant to any Tad-pole trike's information like powertrain characteristics, mechanical and electrical parts' specifications as well as maintenance details that had been previously collected by the student group. Following the initial version of the model, extra capabilities were added to the augmented reality application, such as the simulation of the throttle circuit of the vehicle using an Arduino Uno microcontroller as a potentiometer that simulated the throttle output and displayed its reading to OpenSpace3D's user interface [6]. At the same time, another circuit with an Adafruit LCD screen Arduino shield was used to appear the throttle data to the driver in real time allowing for better driving and steering of the vehicle (Figs. 3, 4).

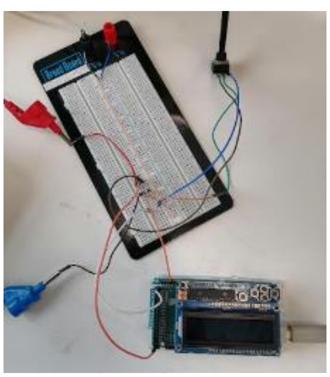

Fig. 3. Throttle circuit simulation with an Arduino Uno rev.3, an Adafruit LCD screen and a potentiometer capable of interfacing with OpenSpace3D.

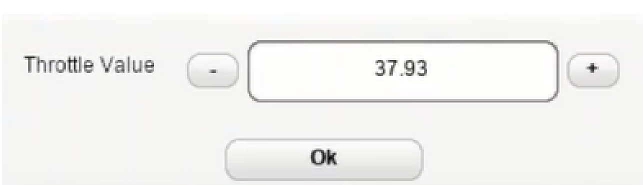

Fig. 4. Throttle value that shows in real time the resistance of the potentiometer as depicted in the user interface of our OpenSpace3D application.

III. TOYOTA YARIS HYBRID

Similarly, to the Tad-Pole trike case of the previous section, the student group had to troubleshoot a Toyota Yaris Hybrid. And in more details a Toyota Yaris Hybrid 1.5 HSD, P13, VNK, 55 kW model line of 2014-2020 with the 1NZFXE engine [7]. Given the cost and complexity of the hybrid vehicle, a supervising professor was present in a controlled laboratory environment. In a dedicated lab of the UTHR, the typical coding of automotive On Board Diagnostics (OBD) codes was used in order to troubleshoot the given vehicle (Fig. 5). It is important that real time driving conditions were simulated by means of chassis dynamometer and that all graphs depicting the state of charge status of the battery and the rotational speed of the electric motor were collected and recorded through the Bosch ESItronic 2.0 software and the Bosch KTS 570 diagnostic tool (Fig. 6).

Fig. 5. The Toyota Yaris Hybrid vehicle that was available to students of the EDRIVETOUR program at the University of Radom UTHR .

Fig. 6. Data collection process in which the hybrid vehicle is driven while a computer is connected to the vehicle with the Bosch KTS 570 diagnostic tool.

A. *The hybrid propulsion system*

Since the vehicle is hybrid, an internal combustion engine (ICE) also exists on board. Fig. 7 depicts the 3D model of the 1NZFXE propulsion system of the vehicle under test. It consists of the ICE together with the electric motors of the hybrid vehicle. The ICE is a first-generation gasoline engine with an economy narrow angle overhead camshaft, a hybrid Atkinson combustion cycle along with multi point electronic fuel injection capable of reaching a power output of 56 kW at 5,000 rpm and a torque output of 110 Nm at 4000 rpm with no power adder. The engine provides power to the vehicle as well as the generator that charges the battery pack of the hybrid vehicle and its usage is triggered by the vehicle computer.

It should be noted that this type of engine is actually used in the Toyota Prius, Prius C, Yaris, Corolla and Sienta models. It's production started at 1997 with displacement at 1.5 L and standard compression pressure being at 9.0 kg/m^2 with the total weight of the engine reaching 87kg and consuming 0.5 liters of 5W-30 oil per 1000km .

Fig. 7. The 1NZFXE combined engine 3D design showing the characteristic planetary gear of the power split device of the vehicle and in the front the two alternating current synchronous motors.

Another important feature of the vehicle's propulsion system is the two three-phase 45 kW AC motors that are used interchangeably mostly as a generator and motor, with the motor providing power to the front wheels while the generator powers the transaxle and battery pack of the hybrid. In that way kinetic energy throughout deceleration of the vehicle's front wheels is recovered and through regenerative braking charges the battery pack. Normally, the battery pack also charges through the planetary gear that is powered by the ICE of the vehicle, so charging is also achieved by accelerating the hybrid making the Toyota Yaris a quite energy efficient driving option.

The system main relay which is responsible for connecting and disconnecting the HV battery is another main important feature of the vehicle worth mentioning. With the activation of the positive side of the contact relay by the ECU the relay is powered on. Then the negative side of the contactless relay which is located inside the inverter closes the loop through a resistor resulting in the negative side of the contact relay also powering on. Thus, while this operation is taking place there is no chance of rush current producing dangerous sparks that could in turn lead to a fire hazard for the vehicle. However, that isn't the only use case of the system main relay since in the chance of a side or front collision the ECU after registering the impact signal from the circuit breaker sensor or the airbag assembly sensor triggers the system main relay to turn off thus preventing any further damage to the vehicle.

B. The Battery charging system

As was the case with the Tad-Pole Trike, the battery pack was also simulated in Tinkercad software as a 3D model and exported as an STL file for its usage in the OpenSpace3D software (Fig. 8). The battery pack of the hybrid vehicle consists of a 12V lead-acid battery, which is located under the right rear side seat and powers all the low voltage devices of the car and is grounded to the metal chassis of the vehicle following most car design principles. The other battery pack with total voltage of 144V is comprised of 20 Nickel Metal Hydride (NiMH) batteries connected in series with each one containing 7.2V and in total weighs 31 kg. It should be noted that this battery pack is charged only from one three-phase AC electric generator while it provides power back to the electric motor and generator, the inverter or converter as well as the A/C compressor of the hybrid.

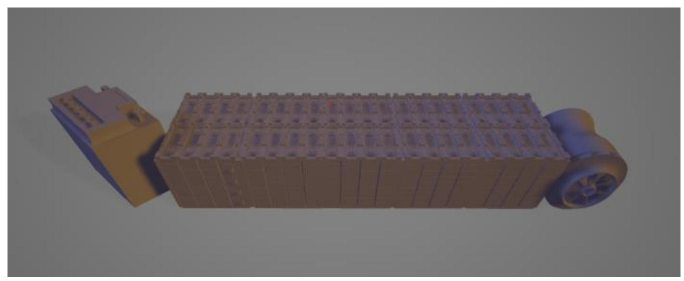

Fig. 8. 3D model (left to right) of the backup lead-acid 12v battery and the lithium-ion battery consisting of 48 cells reaching the nominal voltage of 177.6 V and capacity of 4.3 amp/h.

C. Measurements

The measurements performed on the hybrid Toyota Yaris are depicted in Figs. 9 and 10.

In Fig. 9, the kinetic energy transformed into electric energy to charge the battery during regenerative braking is examined. Through the OBD tool readings, a maximum regenerative braking torque of -191 Nm was observed. It is worth mentioning that after reaching this value of regenerative braking torque, the rest of the braking energy produced is absorbed by the brake pads of the vehicle as heat. Moreover, a general observation was that whenever the break was pressed severely the battery recharged about 1 to 2 percent of the overall state of charge.

In Fig 10 the measurements collected during only electric mode of the vehicle are presented. In this mode, only the electrical motor, powered by the battery, provides propulsion to the vehicle. During driving of the vehicle around the university campus a maximum motor speed 2851 rpm was recorded.

D. Data collection

All files and documents with measurements data created during all laboratory experiments of the project are available online in a Github repository [8].

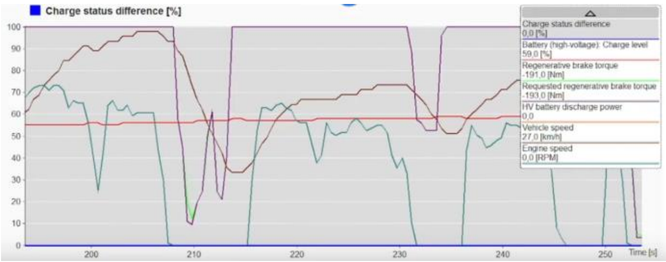

Fig. 9. Graph showing the Charge Status Difference of the vehicle during deceleration and the regenerative brake torque of the vehicle (green) reaching the -191 Nm.

Fig. 10. Figure from the Esitronic program showing the vehicle utilizing its electric drivetrain only and reaching -2851 rpm from its electric drive motor.

IV. ACKNOWLEDGEMENTS

All content presented in this paper has been created by the authors and funded by the European Union under the ERASMUS PLUS KA2 with GA 612522-EPP-1-2019-1-EL-EPPKA2-KA project entitled "Beyond the border of electric vehicles: an advanced interactive course" with acronym EDRIVETOUR.

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Training on electric vehicle technology in an Erasmus Plus project from student point of view

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***Abstract*— Electric vehicles have long since faced a lot of obstacles when trying to enter the mainstream market due to a variety of issues such as high price mainly due to expensive batteries, low mileage, high charging time and scarce charging stations. However, due to the advancements in technology, prices gradually decrease and while electric vehicles still have more to go until they become mainstream, hybrid vehicles have achieved that status. This paper presents project E-DRIVETOUR that aims to teach and pass the know-how in a multi-cultural setting having taken place in different locations.**

***Index Terms*—Electric Vehicles, Battery Electric Vehicles, Education, Training, Augmented Reality.**

I. Introduction

THE popularity of Hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) is on the rise in recent times due to a multitude of factors such as the rise of gas prices and the dangers of climate change becoming more and more accentuated. As such the need for skilled engineers is on the rise. Erasmus Plus KA2 project E-DRIVETOUR [1] aimed to introduce and implement new learning techniques and teaching methods through interactive laboratory equipment and an E-learning platform that enabled teaching from a distance and remote access to measuring equipment.

The project has been going on for 3 years and has 10 partners from 7 countries. It has been divided into multiple parts, the first being the online courses where the students were taught selected and up to date topics regarding the electric vehicle industry, ranging from embedded systems to mechanical aspects of the vehicles.

Approaching the end of the program, the students also participated in three "mobility periods" consisting of hands-on laboratories in different countries. The first two locations were pre-selected for every student, Greece being the first and Poland being the second. The third mobility period was more special as students could choose from a few companies located in different countries. The students would perform their practical training, akin to an internship, where they could put the theoretical knowledge they accumulated into practical skills. Each company specialized in a different field from transforming an existing classic ICE vehicle into electrical one to manufacturing of battery packs.

This approach provided the students access to experts in their respective fields as well as an opportunity to witness how development is obtained in an industrial environment. The companies available for the students to perform their practical training were located in Greece, Poland, Italy and Belgium. Besides the courses and mobility periods, appropriate exams taken at the end of the teaching program would allow the students to receive certification of the skills acquired from their successful participation in E-DRIVETOUR program.

The remaining of the document briefly presents the steps taken and the tasks undertaken by the students in the frame of the program.

II. Online Courses

The first part of the project consisted exclusively of online courses on different subjects in this field. This was a big advantage as the students could experience a variety of teaching styles not only from different educators but also from different countries.

The courses were interactive so the students could always ask a question where they needed to be explained again or expanded on a certain notion they felt necessary and professors had no problem doing so, on the contrary, participation and asking question being encouraged at every course. At the end of each course or sometimes at the end of a course chapter, the students were given quizzes or problems to solve. They were given a time period to work on it on their own and after that their answers were checked and the professors intervened where necessary to correct or to explain the answer. Besides these tests the students were also given homework projects or problems to solve. Thanks to this the information retention was high.

The courses were structured in a 3 hour format. This may seem like a lot of hour considering the students also had regular classes at their respective universities, but the interactive and open nature of the course combined with regular breaks didn't make it any different than a normal course at the university. The breaks were also important as studies have shown that taking short breaks helps one's brain learn new skills [2]. Another factor in helping of the retention of information was the schedule of the courses which included a repetitive session of the previous/s session material at the start of a course. Studies have shown that spaced out repeat sessions of the same material improve long term retention of the information [3].

III. Mobility Periods

A. *First Mobility Period*

The first mobility period was held in Thessaloniki, Greece and consisted of a more hands-on approach, mixing theoretical classes and practical examples. This is where students were split in teams to complete the tasks. They were also assigned a vehicle to study, from delta trikes to scooters and karts, all of them electric. The vehicle assignment was done randomly and team F ended up with the Delta trike depicted in Fig.1.

An interesting task given was the identification of system's components. This led to a block diagram of the delta trike which was the basis for identifying how the whole system works (Fig. 2).

Another interesting part of this mobility period was that the progress was presented by means of an AR (augmented reality) application, OpenSpace3D [4], [5]. It was scanning a QR code from a mobile phone and the application would show data about the vehicle's parts in real time. Besides this functionality, OpenSpace3D software can also be connected to a microcontroller such as Arduino to retrieve data from it.

Fig. 1. Delta trike

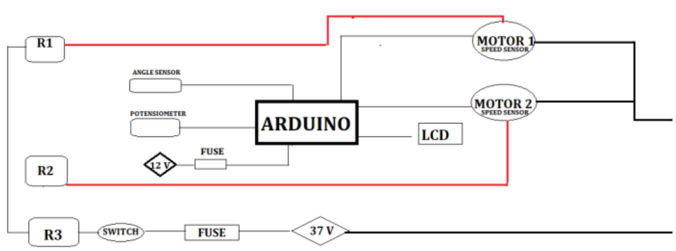

Fig. 2. Bloc diagram of the system

OpenSpace3D was used to read data from a simple rain detector in real time through an Arduino board. Finally, the AR software was utilized to present the electric, delta trike.

At the end of the mobility period, an "electric" race among students was organised. They were competed driving the electric vehicles they studied and had to complete a series of tasks. This experience was considered very important for the overall mobility period as it was an amusing way to teach the behavior of various small scale electric vehicles on the road.

B. *Second Mobility Period*

The second mobility period was held in Radom, Poland and was targeted more towards hybrid vehicles, in the case of group F the Toyota Yaris 2020 [6]. The main focus was on the understanding of the powertrain system. Therefore, a lot of research need to be made on the car and on the different data retrieved from the sensors. Car sensor data were taken through the OBD port. Artificial errors have been created in order for the students to see how the system would report it. Additionally, a solution to a diagnostic error should have been proposed. All these tasks had to be presented at the end of the mobility period by the student team including the AR application.

IV. Conclusions

An overview for the interactive E-DRIVETOUR course was presented in this paper and some major points of the project were highlighted. The didactic potential of such an approach was quite high as no other such educational approaches on electric vehicle technology are available. The combination of remote learning along with the mobility periods in different countries can really be eye opening and offers a great insight on how courses are taught in other countries.

Overall, this project can be considered an excellent experience involving a blend of educational approaches that certainly stimulated students interest.

V. Acknowledgements

All content presented in this paper has been created by the authors and funded by the European Union under the ERASMUS PLUS KA2 with GA 612522-EPP-1-2019-1-EL-EPPKA2-KA project entitled "Beyond the border of electric vehicles: an advanced interactive course" with acronym EDRIVETOUR. The information and views set out in this document are those of the authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

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E-DRIVETOUR: A step towards the future of electric mobility

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***Abstract*—This paper focuses on electric mobility as the fleet of electric vehicles is increasingly higher all around the world. Thermal engine vehicles will slowly be replaced by electric vehicles as they are friendlier to the environment because they emit fewer greenhouse gases and air pollutants than their predecessors, considering their production and electricity generation to keep them running. E-DRIVETOUR is an Erasmus+ KA2 programme that aims to increase awareness of electric vehicles by teaching and training students, future engineers, through online courses, laboratories and practical training on site. During the timeframe of the programme, students had to complete two projects, that will be presented in this paper.**

***Index Terms*— E-DRIVETOUR, electric mobility (e-mobility), electric vehicles, project based learning**

I. Introduction

THE E-DRIVETOUR Erasmus+ KA2 programme [1] aimed at introducing undergraduate students of three Universities to the electric vehicle technology [2]. It was consisted of theoretical lectures on appropriately selected topics on electric vehicle technology, laboratory courses taken place at the premises of the International Hellenic University and the University of Technology and Humanities in Radom, practical training and two medium scale projects. The projects were entitled as “Intermediate project 1” and “Intermediate project 2” and the students had to work on them in international groups. Their content and purpose are presented in the following sections of the paper.

II. Intermediate project 1

The purpose of the first project the students had to work on was the familiarization with the components and working principle of an electric, delta type tricycle (Fig. 1). The work should have been performed in steps in order to reach the point of actually assembling the initially partly disassembled trike.

The first step in completing the project was identifying all the components of the delta trike and perform some research on them. This was necessary step to determine the working principle of the delta trike.

After finding all the components and determining how the delta trike operates, the team had to try to make it functional as it was no longer operational.

The last part of the project was to create a 3D model of the delta trike and its components by means of the OpenSpace3D software [3], [4]. The 3D model would the basis of a smartphone application developed in order to allow 3D representation of the delta trike and its components and provide information such as technical datasheet or where the various components could be bought from by just scanning barcodes.

The main components of the delta trike were:

- Two in wheel brushless DC motors
- Arduino Mega2560
- Batteries
- Inclinometer
- Throttle potentiometer

After carefully examining all the components, the team started investigating the problems that caused the delta trike to malfunction by checking the functionality of the components. The first problem encountered was burned fuse and a relay that was not switching so the delta trike was not receiving power from the batteries. Replacing the damaged components made the delta trike power on but only one motor was working, so we started checking the wiring and every component related to the second motor that was not working.

The problem with the second motor was a defective transistor on the electric circuit of the motor (Fig. 2). The transistor was about to be replaced in order to make the electric tricycle fully functional.

Fig. 1. The electric, delta trike used for the intermediate project 1.

Fig. 2. Picture with defective transistor found inside the wheel motor.

At that point, the work of student team regarding the delta assembly was completed. The mobile phone application had also been developed.

III. Intermediate Project 2

The second project the student team had work on was a scale up of the first one since the same results should have been accomplished for a Toyota Prius hybrid electric vehicle [5].

As a hybrid electric vehicle is much more complex than an electric trike, the students had to focus on its main components:

- Internal combustion engine
- Electric motor
- Generator
- Inverter
- Battery pack
- Power split device

The components mentioned above are part of the powertrain of Toyota Prius (Fig. 3).

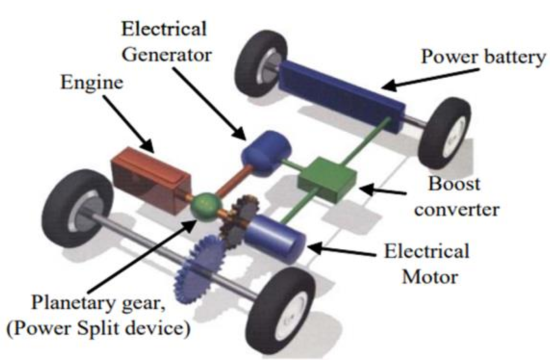

Fig. 3. Example of power train Toyota Prius hybrid

As in Intermediate Project 1, investigation on the main powertrain components was made, especially about their location on the vehicle and operation. OpenSpace 3D software was also used to present the corresponding 3D model of the vehicle and of all the components of the powertrain. Instead of barcodes or QR codes, push buttons were selected in order to display the 3D model with some technical information as well as an informational video. The initial screen of the application with the 3D model of the vehicle is depicted in Fig. 4.

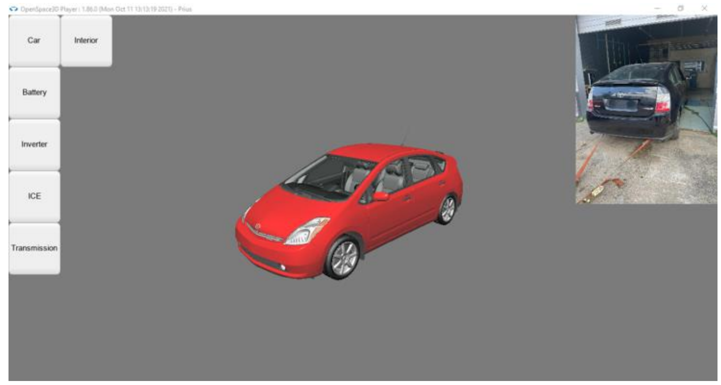

Fig. 4. Initial screen of the application developed in OpenSpace 3D software.

IV. Conclusion

The objective of the two intermediate projects has been achieved as the students have learned how an electric trike and a hybrid electric car work in general as well as about the operation of individual electric vehicle components. The experience gained out of these projects was not only theoretical but also technical as the students had the opportunity to work on real life electric vehicles, disassemble and measure various parts of the electric vehicles used. The onsite laboratories and online courses done prior to or during the time frame of the projects have significantly assisted the overall learning process.

V. Acknowledgements

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