EDITOR-IN-CHIEF'S WORD

Dear readers,

With the completion of the present HATZ Administration's mandate, this second issue for 2022 also marks the end of the Editorial Council's mandate for our long-running bulletin Engineering Power.

Since 2016, the Editorial Council, which includes Prof. Vladimir Andročec, Ph.D, Prof. Zdravko Terze, Ph.D., Prof. Slavko Krajcar, Ph.D., and Prof. Vladimir Mrša, Ph.D., has been offering an overview of our members' scientific-professional achievements to the content of Engineering Power as a guest editor of a specific number, ensuring that as many of our members as possible are active in the Academy's activity and on this level.

The guest editor of this issue is our distinguished member, Prof. Emer. Nedjeljko Perić, Ph.D., who is known as a promoter of cooperation between science and business. He demonstrated the achievements of five companies focused on the development of new technologies, which are on the rise globally and are visible in our country.

Editor-in-Chief
Vladimir Andročec

EDITOR'S WORD

Dear readers,

The Croatian Academy of Engineering is always pleased to report on collaborations between academic institutions and the innovative industry sector.

To this end, in this edition of HATZ bulletin Engineering Power, we focus on Croatian start-up ecosystem and present four successful companies whose business activities are inextricably linked to technological advancements in their respective niches.

Professor Emeritus Nedjeljko Perić, Innovation Centre Nikola Tesla and University of Zagreb Faculty of Electrical Engineering and Computing, and Full Member of the Academy, participates as a guest editor.

I am confident that you will enjoy reading the presented contributions.

Editor
Zdravko Terze

FOREWORD

Five papers on the evolution of Croatia's start-up ecosystem have been chosen for publication in this edition of Engineering Power. Although the establishment and development of start-ups in Croatia do not have a long history, there is a significant tendency in their development. It is expected that the new wave of digitization of the Croatian industry would accelerate the development of new business models such as start-ups.

The first paper presents a young drone solution company - AIR-RMLD, which is specialized in Drone Flying and Drone Development. Its primary focus is airborne industrial gas-pipeline inspection but has developed into a drone solution company that develops or operates practically anything that flies without a pilot.

The second paper describes the FIVE company, a digital design, development, and growth marketing agency. Their primary goal is to solve essential business problems and produce results through end-to-end product design from fuzzy ideas through launch and iteration. They enable data-driven decisions that benefit clients - global companies in finance, media, publishing, NGOs, pharmaceuticals, and other global marketplaces. FIVE has been a member of the international Endava software group since 2021.

The third paper presents H2O Robotics, a SME company established in 2017. Corporate R&D focuses on marine technologies, autonomous vehicles, and applications. To promote its own innovations, the company was very successful on EU Horizon calls for proposals, and *APad – a smaller, lighter, smarter autonomous marine surface vehicle* was funded in 2017. The project intended to turn an autonomous drone/robot into a commercially attractive, sustainable, and innovative product that would be highly competitive in global markets.

The title of the fourth paper is *Crossing the Innovation Valley of Death through the Venture Builder Model*. A Venture Builder concept could be one feasible way to bridge the valley of death. This model is a novel approach that is essentially a start-up that builds deep-tech start-ups using its own ideas while focusing on resource sharing among its partners. Venture Builders leverage their extensive network consisting of different partners, experts, and seasoned entrepreneurs to share their capital, skills, and market expertise with the participating ventures, resulting in a perfect innovation ecosystem. When it comes to the commercialization of innovations and the development of deep-tech ventures, collaboration between academia and industry is essential from the get-go.

The fifth paper describes Romb Technologies, an academic spin-off company focusing on commercializing autonomous navigation technologies in the logistics sector. Romb Technologies offers a complete software suite for automated material handling, from map-building and localization to layout planning and path following. As a newly founded company with strong academic ties, Romb Technologies invests a significant portion of its resources in R&D, developing rich visual perception modules, powered by deep learning, which will endow the vehicles with a semantic understanding of their environment and open up new use-cases for AGVs.

Guest-Editor
Nedjeljko Perić, Innovation Centre Nikola Tesla, and University of Zagreb, Faculty of Electrical Engineering and Computing

CONTENT

Milan Domazet

AIR-RMLD

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AIR-RMLD is a DRONE SOLUTION Company that specializes in Drone Flying and Drone Development. AIR-RMLD was founded in 2018 by three partners, each specializing in their own field of expertise. Their main speciality is aerial industrial gas-pipeline inspection, therefore the name AIR-RMLD – aerial remote methane leak detection, but they have developed into a drone solution company that develops or controls almost anything that flies without a pilot. With various partners, the company works mostly in Croatia and the Balkan region, but also in Germany, Israel, Kazakhstan, and Saudi Arabia. Because the primary focus of the company is gas pipeline inspection, the company's growth is measured in inspected kilometres of gas pipelines, and the yearly growth. For the time being, AIR-RMLD has successfully inspected over 800km of gas pipelines and discovered dozens of potential leaks. The company has broadened its offering and developed into numerous different fields of expertise in Aerial Industrial inspection.

History

AIR-RMLD was founded by its three core members, Davor Sladović, Ivan Vidaković and Milan Domazet. Davor Sladović with his long experience (20 years) in engineering and GAS pipelines worked and collaborated on several projects with Milan Domazet, who has over 10 years of experience as an automation engineer, project manager, hardware and software developer, and has successfully completed dozens of engineering automation projects. Davor had the notion of outfitting a drone with a methane gas sensor one day, while Milan was working on his own drone project at the time.

They agreed that they should try to make a "Proof-of-concept" and invited Ivan Vidaković to join them on the team. It was 2018, and Ivan Vidaković was a pioneer in UAV flying and development, but already had almost 10 years of experience in drone flying, especially in the film industry. In three months, they developed POC and tested it in a real-world setting. The sensor weighed 5kg that day, and the drone had a wing span of over two meters.

Because of great results of POC and testing, they presented their results to PLINACRO (Croatia national gas distributor) and the feedback was great, but they said it should be commercialised.

AIR-RMLD was founded in a matter of months, in May 2018, by its three core Team Members.

Gas Pipelines

After a successful presentation and POC, it was time to fully dedicate themselves to the AIR-RMLD project. Milan and Ivan, started working full time at AIR-RMLD with Davor's full support. They redefined the Drones, found new lighter and better Laser Methane sensor and AIR- RMLD was ready for commercialization.

By the end of 2018 it was fully tested and presented to several gas distributors, local and national, and agreed for several projects in spring 2019. In May 2019 the project and the company were presented at the annual meeting of the GAS industry in Opatija (HSUP) and received great feedback. By the end of 2019, AIR-RMLD inspected 100 km of Gas Pipelines for 5 five local Croatian distributors and 30 km for national Gas Distributor (PLINACRO) and was awarded the contract for spring 2020 for the most difficult terrain in Croatia, the Velebit Mountains. It was the first mountain drone to inspect gas pipelines.

The gas pipeline business is growing annually and is also expanding into foreign markets, such as Slovenia and Hungary, and at the end of 2021 into the German market, with the Leipzig distribution part. Gas pipeline inspection remains the main component of AIR-RMLD's business and the heart of the company's development.

AIR-RMLD offers a unique service, with planning software, mission drone execution parameters and its own in-house developed data visualisation software called ARMLD-GIS, which is already being used in several other projects.
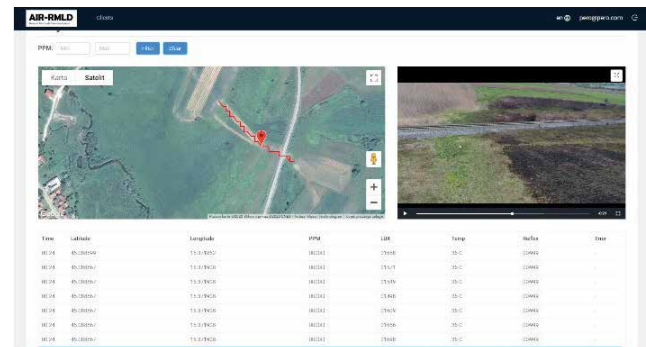
Postal drone delivery

We began negotiations with Croatian Post and its drone delivery project in autumn 2019 as part of our corporate objective to transition from a service and product firm to a DRONE SERVICE COMPANY. The project was on a very tight timeframe, with very few deliverables, however it was planned and delivered in 8 weeks.

The requirements were an autonomous drone delivery to an island on the Croatian coast that has a post office. The decision was made for the Zadar post office (Gaženice) and the Preko post office (Ugljan Island). The flight is 8 km long and was completely autonomous from take-off to landing.

On the other hand, it was a problem to get all the permits in such a short time, but this was also managed and the project was pursued fully and legally. This project is now on hold, but there are exciting plans to connect many Croatian islands to the mainland via continuous drone supply lines.

Powerline inspection

Other industrial inspections, particularly in difficult-to-reach locations, and important infrastructure were added to the company's expansion. The ELECTRIC POWERLINES are a better description of these criteria. A company's development should not involve only one

possible aspect (such as inspection), but should include other added value products that customers should appreciate. Thus, we included AI (artificial intelligence to our projects).

Project was: *Improving transmission line maintenance using drones and artificial intelligence and the AI part was done with our partner company that fully developed dataset needed for this project.*

AI was used for detection for asset management, with a dataset developed specifically for this purpose. The idea is to have a predictive asset management cycle with automatic detection of rust, missing parts, insulators and vegetation around the power lines and poles.

The project was a huge success, and there are currently efforts to include this method and parameters into normal asset management.

Project 02 – reforestation

Since the European Union adopted carbon footprint legislation and raised awareness of the carbon pollution and ecological aspects, many companies have started to collaborate with ecological parameters. Both technical and biological firms began to investigate many areas of possible decreased carbon pollution. BIOTA biologists and its spinoff PROJECT 02 have thoroughly tested and manufactured "seed bombs" that can be simply launched in difficult to reach regions and produce a huge number of these balls quickly.

The next important step was figuring out how to scale this up and reforest difficult-to-reach areas, such as those affected by wildfires. PROJECT 02, in collaboration with AIR-RMLD, created a drone equipped with a "seed launcher" that can effortlessly fly to different parts of the land and deploy seeds. According to calculations, 1 hectare (10 000 square meters) requires the deployment of 5000 seed bombs. One drone can reforest 2 hectares every day, and the future idea is to create a fleet of drones, Swarm, to quickly and easily forest a location.

PROJECT 02 successfully forested more than 90 000 square meters in 2021 and 2022, and the objective for the next year is to treble that amount.

Conslusion

AIR-RMLD is on a mission to become a full-service DRONE SOLUTIONS provider capable of delivering both projects and services, no matter how difficult or unusual the project.

Luka Abrus

FIVE, an Endava company

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1. FIVE, an Endava company

FIVE is a digital design, development, and growth marketing agency that started as a small development studio back in 2007. Their primary goal is to solve essential business problems and provide outcomes through end-to-end product design from fuzzy idea through launch and iteration. They enable data-driven decisions that help clients - global companies in finance, media, publishing, non-governmental organisations, pharmaceuticals and other industries in global markets, but especially in the US market - get to market faster and more confidently. They have created and continue to create award- winning digital products that are used daily by more than 50 million people.

As of March, the 4th, 2021 FIVE has become part of the international Endava software group, company thirty times the size of FIVE that has established itself as a leader in the application of technological solutions in the financial segment. Endava had roughly 7,500 people in 33 offices throughout the world at the time of the acquisition, and the staff count has now topped 11,000 today. These two companies share similar business and cultural values, and their joining of forces enables FIVE and its employees to work on even bigger projects with even bigger global clients and an additional opportunity to accelerate growth across all business segments.

History overview

FIVE was founded by Viktor Marohnić, who was joined in the following years by his partners Luka Abrus and Sven Marušić FIVE had over 250 experts split among offices in New York, Zagreb, Split, Osijek, and Rijeka in 2021, and they now have over 300 employees across all locations in 2022.

Viktor Marohnić, who is currently at the helm of his passion project 57 hours, founded the FIVE New York office around 2010 and began to develop the agency's business in the U.S.

During the last decade, FIVE has developed into one of New York's most respected digital agencies, which was confirmed in 2020 by being included in the list of the three best mobile development agencies, according to Clutch, the leading ratings and reviews platform for IT, Marketing and Business service providers. FIVE's position as a top New York agency was strengthened by a breakthrough in the rigorous New York digital design scene.

Continuous growth

Aside from its fast-growing Zagreb team, FIVE has continued to expand its teams in other locations. In July 2021 they opened the doors to their new office facility in Osijek where more and more young talent buckles down and finds a place to develop and grow their skills, primarily in software testing, application development, DevOps, and customer support. This was also one of the first realized projects since the merger with Endava. FIVE has been in Osijek since 2008, and since the opening of its new office space in the Eurodom business complex FIVE has achieved 27% growth in staff. A new wave of expansion is expected in Split in 2022 as part of the announced opening of a new office.

In 2020, despite the global economic crisis due to the COVID-19 pandemic, FIVE experienced an upward trend in business, which is best illustrated by the level of newly acquired clients and retaining the old clients who rely entirely on their development teams.

During that period, they had become a partner to some of the world's industry-leading companies, including the world's leading fixed income management company, the fifth-largest pharma company in the world, and a global leader in security software. Their list of clients today, compared to a year ago, has changed significantly, and

they have managed to reduce business risk by distributing revenue to a greater number of strong clients.

In the first nine months of 2021, FIVE recorded growth rates higher than 45%. During the current year only, FIVE hired more than 100 new experts in Croatia

and the United States. They ended 2020 with a service revenue of more than 100 M kn.

FIVE plans to hire an additional 200 people in Croatia aloe, bringing the total number of professionals to 500 by mid-2023.

Expanding to new markets

The integration with Endava brought new business opportunities that enabled FIVE employees to work on large-scale projects in the fields of digital payments, banking, trade, and insurance.

Their first joint venture in the field of financial technologies was realized at the end of 2021. It was the opening of the FinTech Hub, which aims to bring together more than 100 software development experts and, in cooperation with Endava's teams, to deliver innovative solutions for the fintech sector.

In addition to its long-term clients, FIVE has started working with several new Endava clients in recent months, including Fortune 500 companies, the fourth largest bank in Europe, and the second-largest private television company in Germany.

Today, Endava has 33 offices worldwide with over 11,000 employees in Europe, Australia and North and South America. In the last 20 years, this international company has established itself as a leader in the application of technological solutions in the financial segment.

A scientific approach to product design

For more than 15 years and hundreds of product and feature launches behind them, FIVE has always worked hard to stay lean and on the cutting edge, offering clients services ranging from research and strategy, to design, technology, and growth marketing. Their approach is based on continuous questioning of the genuine value

they deliver to their clients, as well as on ongoing improvement and innovation.

With expertise from launching startups and experience working with product teams inside industry-leading businesses, over the years, FIVE developed an iterative process to bring new products to the market that have proven successful for larger companies, as well as start-ups with limited access to funding and resources.

Product discovery

Product discovery is the first phase of product development.

It is an agile methodology based on testing, learning, iterating until product/market fit is achieved. It is done prior to any design and development in order to establish "what to build and why."

Steps in the discovery process:
- Determine the target user
- Detect the size of the market opportunity
- Define the MVP
- Determine the cost of manufacturing the product
- Determine how much it will cost to gain users

The team conducting a product discovery process is multidisciplinary and involves experts from different departments in the company (Product Manager, Product Designer, Project Manager, Growth Specialist and a Tech Lead).

Design

FIVE has one of the largest product design teams in Croatia with nearly 50 experienced UX/UI designers that take client's ideas and turn them into screens and user flow that solve users' problems in a way that is delightful and that meets business goals.

Every day they:
- Conduct the relevant market and user research
- Define the information architecture, optimal flows, features and functionality for each digital instant
- Fine tune our concepts through user testing and feedback
- Think about how everything maps to client's goals, measure and iterate the process

- Assist the sales team with pitches and concepts
- Support the tech team during the development phase

Design validation and testing are critical steps in the FIVE designers' process. They ensure that they are creating (and, eventually, producing) the correct product to solve the correct problem. There are two mandatory user test moments: at the end of the UX phase and at the end of the UI phase. Regardless, they conduct multiple tests throughout the design process and focus on usability testing. They validate essential user flows before creating comprehensive UX and UI.

The design is ready to be handed over to development once it has been completed and signed off on by all stakeholders, has successfully passed through comprehensive user testing with wonderful reviews, and has received feedback from the lead developers throughout the design phase.

Development

Being a developer in FIVE entails more than executing tasks and „pumping out" code. Their decisions are influenced by how they will affect the product as a whole.

There are two common denominators in all the processes they own through different teams that they rigorously adhere to in their work:

- Nothing gets pushed without code review by other team members to ensure the highest quality
- Nothing gets published without being carefully inspected by the QA team to prevent mistakes and defects in the final application

The main purpose of code reviews is to ensure constant, high-level quality across the codebase, allowing any developer to work on any area of the code. They established a mantra years ago:

„You shouldn't be able to recognize who developed which feature. All code should be written according to the coding standards of your organization. So when project planning, plan enough time for code reviews to

make sure your senior developers are not bottlenecked by taking several days to do code reviews later. The process does take a bit of time, but it should always be streamlined, seamless, and never blocked by other tasks."

Success story – Rosetta Stone mobile application

Throughout the years, the FIVE team has been a part of all the major inflection points for the Rosetta Stone product including the shift to a subscription-based model, introduction of learning plans, integration of coaching into e-learning and 50+ A/B tests to improve monetization, engagement and retention.

Product metrics speak for themselves as they have managed to increase revenue by 6x, MAU/DAU by 3x, maintain crash-free user rates at ~99.8%, and increase the average rating by 4.8 points.

Growth marketing

FIVE firmly believes that Growth strategy is a an integral part of any serious product, because products without growth are simply a solution that no one uses or knows about. Product traction is provided through growth.

This is why they work hard to include growth into every stage of product development, from the business strategy to design and development. FIVE's growth marketing team is committed to assisting its clients by attracting and maintaining new, valuable users. All of their activities can be classified as one of these three key aspects of their work:

- Acquisition - bringing new users to the product.
- Engagement - retaining and activating existing users.
- Data - assisting us to make better choices by monitoring all activities (from Acquisition and Engagement sides) along with other product indicators.

Antonio Vasilijevic[1], Nikola Miskovic[1,2], Vladimir Djapic[1]

H2O Robotics

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H2O Robotics is an SME company established 2017. The company is located in Zagreb, Croatia. Corporate R&D focuses on marine technology, autonomous vehicles and applications. The first commercial product was Autonomous Surface Vehicle (ASV) H2Omni-X (Figure 1). Overall, the company's mission after its establishment was to turn H2Omni-X into a market-ready product capable of launching a sustainable business in the ASV industry. According to the authoritative Gartner Inc. research (Gartner Inc.'s Hype Cycle of Emerging Technologies 2018 report), autonomous mobile robots were a technology on top among emerging technologies in 2018, exactly close to deep learning and IoT platforms. Motivated by this fact, H2O robotics believed to have solid arguments to apply for the FET (future and technology in emerging) commercialization call of the European Horizon 2020 program. In promoting its own innovation the company was very successful on EU Horizon calls for proposals. In 2017, the project "APad - smaller, lighter, smarter autonomous marine surface vehicle" was funded. The project aimed to turn an autonomous drone/robot into a commercially attractive, sustainable and an innovative product that is highly competitive in global markets. As part of the aPad project, a business plan was developed that includes market research, intellectual property management and a financial plan. The technology has advanced to the product-for-the-market level (TRL9) and the product was demonstrated at several fairs to potential end-users, customers and investors, but also to general public and civil society. The aPad project also assisted us in establishing the manufacturing process and supply chain. As a result, the product matured to the commercial level and was awarded the gold medal for innovation at the international fair for ideas and innovation IENA 2017 Nuremberg, Germany. The H2Omni-X was now a vehicle capable of autonomously doing various tasks such as dynamic positioning, path following, go-to-point, and so on, and it was equipped with the wireless link for data transfer to shore/boat-based users or generally to the cloud. It was also capable of carrying significant payloads, e.g. optical and acoustic marine sensors and devices. Therefore, ASV was offered on the market in a variety of options for different applications. In that venture to launch the first products to the market, another H2020 project Pladyfleet also played a significant role. The ASV was delivered to distinguished customers such as: DFKI - The German Research Center for Artificial Intelligence, University of Athens, University of Zagreb etc. Soon after, the wonderful effort was recognized. Since 2015, the European Commission has given the annual

Fig. 1. ASV H2Omni-X

Fig. 2. The annual Innovation Radar Prize to the best EU-funded innovators

Innovation Radar Prize to the top EU-funded inventors. The H2Omni-X was in the final among the four best innovations of the Innovation Radar Award 2018 in the category Excellent Science (Figure 2).

However, because every new technology and product has a limited lifespan, the focus of H2O Robotics business strategy was on the timely creation of new innovative products and applications. The Company has a pipeline of innovative ideas, potential applications and new products including lightweight and low-cost Internet of Underwater Things concept which was presented to potential investors as well as offered to different EU and national calls for proposals. Having substantial experience in preparing project proposals, H2O robotics was successful and was granted the national project "Lightweight portable autonomous buoy for diving support". Market research done within H2O robotics indicated support for diving operations as one of the applications with high market interest and potential. H2O robotics' original product autonomous surface vehicle (ASV) served as the link between the undersea and surface/terrestrial worlds in the proposed diving support system (Figure 3).

It tracks and locates the diver and allows for easy communication between the diver and the surface. The system also includes a device for underwater acoustic localization and communication (USBL - Ultra-Short BaseLine system) with a probe on the robot and a small transponder mounted on the diver and waterproof portable device e.g. tablet for interaction with the diver and subsea navigation. During the 2 years of the project implementation, ideas matured and three new items were produced:

- H2Orbit - lightweight version of the ASV,
- H2Observe - a portable and affordable acoustic system for underwater localisation and communication and
- H2Orologio - a system that turns diving watch/computer into interactive device for divers.

In the meantime, the company was again successful in two other European calls for proposals. Both new projects complemented very well the existing project and H2O robotics business strategy. Project Teuta supported an innovation associate who assisted in the preparation, promotion, and introduction of new goods on the market. Project Tectonics is academia-industry staff exchange project that gives us an insight into new and relevant developments within Europe. The project is currently ongoing, and we anticipate seeing results in the next months.
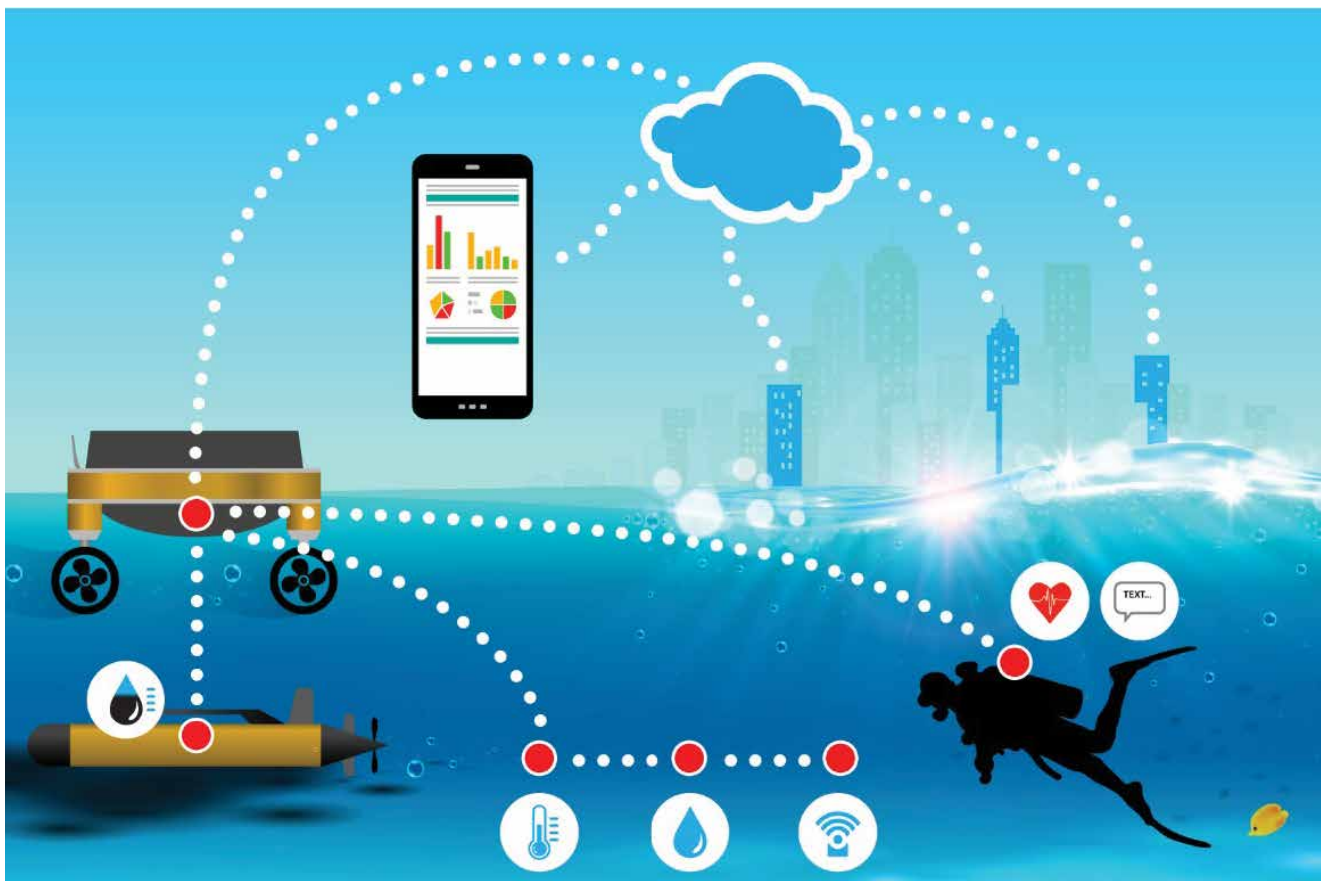

Fig. 3. The diving support system

Matija Srbić[1,2], Deni Nurkić[3]

Crossing the Innovation Valley of Death through the Venture Builder Model

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Abstract

On the path to a successful deep-tech venture, many innovations fall into what is generally known as the valley of death. There are many reasons why innovative projects (and associated deep-tech ventures) fail to cross the valley of death, but some of the most common ones are; lack of commercialization and business development experience and the inability to attract investors. One possible solution to bridge this valley could come in the form of a Venture Builder model. This model (also called Venture Studio) is a novel approach that is essentially a start-up that builds start-ups using its own ideas (or innovations) while focusing on resource sharing among partners that constitute it. Venture Builders leverage their extensive network consisting of different partners, experts and seasoned entrepreneurs who share their capital, skills, and market expertise with the participating ventures, creating a perfect innovation ecosystem. When it comes to commercializing innovations and developing deep-tech ventures, collaboration between academia and industry is essential from the get-go. Hence, this paper focuses on the model proposed and instituted by the University of Zagreb Faculty of Electrical Engineering and Computing and the Innovation Centre Nikola Tesla. It will provide a detailed description of different phases of venture building as well as all of the activities, programs and partners required for the successful implementation of the venture builder model for the establishment and development of deep-tech ventures.

1. Introduction

Start-up ecosystems are the bedrock of innovation [1] especially when the accompanying field of work is deep-tech, i.e. technology that is based on tangible engineering innovation or scientific advances and discoveries. There is a universal need in the European Union (EU) for a transformation of the researchers' mind-sets and the higher education institutions' (HEI) approach to research commercialization. This need has been widely recognized, as seen by the EU agenda for higher education which has specified „Ensuring higher education institutions contribute to innovation" as one of its four priorities [2]. Furthermore, the EU made innovation a top priority through the Lisbon Agenda and the Europe Horizon 2020 initiative. It set a goal of investing 3% of the EU's GDP in R&D, while implementing a range of innovation policies to close the technological gap between EU and U.S. and to become "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion" [3]. However, in 2017, R&D expenditure in the EU was only 2.07% of GDP, while in Croatia it was an even more worrying 0.86%. Compared to the US, HEIs in the EU often do not contribute as much as they could to innovation in the wider economy, particularly in their regions, i.e. they do not usually behave as entrepreneurial actors. This is a considerable issue since innovations are the most important driver of economic growth.

In addition, too few startups and spin-off companies in the EU are founded by PhD holders. In a 2018 report, only 12.57% of EU startups were founded by founders with doctoral or equivalent degrees [4]. As a result, the EU is in a serious deficit of successful startups and spin-off companies coming from the universities [5]. This is especially true for the national context of Croatia which lags behind the rest of the EU.

Even when researchers overcome all the initial challenges and manage to start a spin-off, their lack of commercialization and business development experience, coupled with the inability to attract investors, often leaves them stranded in the so called "valley of death" – the phase between basic research and successful innovation in which both the research and the commercialization resources are insufficient (Figure 1).

One possible solution to bridge the valley of death could be a Venture Builder model which brings together
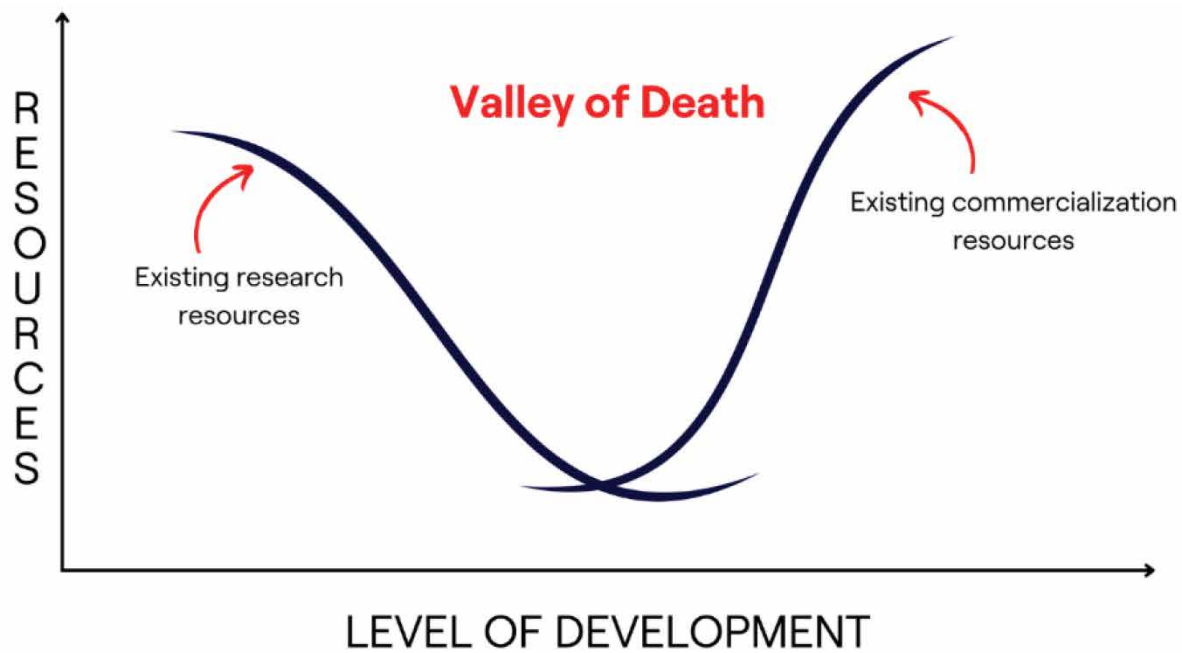
Fig. 1. Valley of death and available resources

interested industry partners, serial entrepreneurs and specialised venture capital (VC) funds to act as a proverbial ''bridge'' over the ''valley'' by sharing their resources and knowledge in the joint mission of research commercialization. This model is described in more detail in the next section.

Crossing the valley

To help get skills, knowledge, and ideas "out of the lab," researchers must collaborate with people who have varied experience and expertise, such as product designers and business developers, making the deep-tech startup development an interdisciplinary collaborative process. Having an interdisciplinary team without significant experience in creating successful businesses usually leads to a trial-and-error approach which can negatively affect startups' success and make them stuck in the valley of death. This is why it is important to have exceptional mentors that are well versed in the specific technology, industry and the process of rapid startup development and growth. For later stages, startups need strong and experienced partners with market access who can assist with client acquisition, brand building, and product creation and maintenance. Even though these processes are sequential, it is really important to involve all the above-mentioned stakeholders from the beginning so that they can help build a solid foundation and avoid major mistakes in the later stages of development.

All this can be done via a Venture Builder (VB); a novel approach which is essentially a start-up that builds start-ups using its own ideas while focusing on resource sharing between the partners that constitute it [6]. VBs leverage their extensive networks and ecosystems consisting of experienced entrepreneurs who share their capital, skills and market expertise with the participating ventures. The goal is to combine large amounts of resources, both physical and non-physical, in the most efficient manner possible, i.e. the resources must be instantly available and free flowing to create an internal culture of trust, deal flow and attentiveness. This way the venture gains a significant competitive advantage. A typical venture development process includes the following steps:

1. **Identifying business ideas** – ideas can originate from the VB team or from dedicated events,

2. **Idea validation** – VB team selects several ideas which are tested for customer demand, market size, investor interest, technical feasibility, and business model,

3. **Business creation** – best ideas are chosen by the VB teams, and they begin working with the founding team on business development, sales, branding, legal issues, and fundraising,

4. **Spin-out** – VB teams hire an experienced management team to run the company.

Compared with other similar market actors such as incubators, accelerators, etc., VBs are far more involved in the daily management of their ventures, and the relationships with their ventures are long term.

Furthermore, with this assistance, the enterprise may concentrate completely on building technology, verifying and polishing the business model, and testing its minimum viable product (MVP), reducing time-to-market for the products and increasing their chances of success. In essence, VBs industrialize and demystify the process of venture building. By doing so, VBs effectively change the labour market by speeding up and optimizing typical practices.

For the past two years, the University of Zagreb Faculty of Electrical Engineering and Computing (UniZG-FER) and the Innovation Centre Nikola Tesla (ICENT) have been working on advancing the Croatian deep-tech ecosystem with a new Venture Builder as its focal point.

Venture Builder at FER and ICENT

FER is one of Croatia's leading research institutions, with over 250 current national and European R&D projects. FER is divided into 12 departments that focus on education, research, and development in subjects such as robotics, energy, artificial intelligence, communications, electrical engineering, electronics, biomedical engineering and others. The current research and educational staff consist of more than 200 professors and 371 teaching and research assistants and around 3450 students at the undergraduate and graduate level as well as 399 PhD students. Also, FER has established valuable international cooperation with many research institutions around the world, either directly or through inter-university cooperation. To support their students, researchers and professors in the startup creation process, in 2016 FER started its own student startup incubator programme called SPOCK. FER is also currently implementing an Erasmus+ project called "Crossing the Gap: Start-up education and support for PhD students, researchers and scientists" (COGSTEPS) with the goal of connecting the academic community and startup ecosystems.

Through its two digital innovations hubs (DIHs), CybersecRDI and CROBOHUB, ICENT serves as a one-stop shop, assisting Croatian businesses in digitalizing their operations and improving cybersecurity by efficiently orchestrating various stakeholders in the robotic and cybersecurity innovation ecosystem. In 2018, ICENT started the "Imagine, Create, Innovate" program which brings together students from Croatian universities to learn about the prototype development process through several stages of education.

FER and ICENT are now working together to integrate all the above-mentioned activities and programmes into a single progressive and comprehensive programme that will enable collaboration between the research community, corporates and successful start-ups with the aim of research commercialisation and deep tech start-up development. To be able to develop a program with a clear plan and vision, the first step is to identify the key stakeholders, their needs and strengths, and
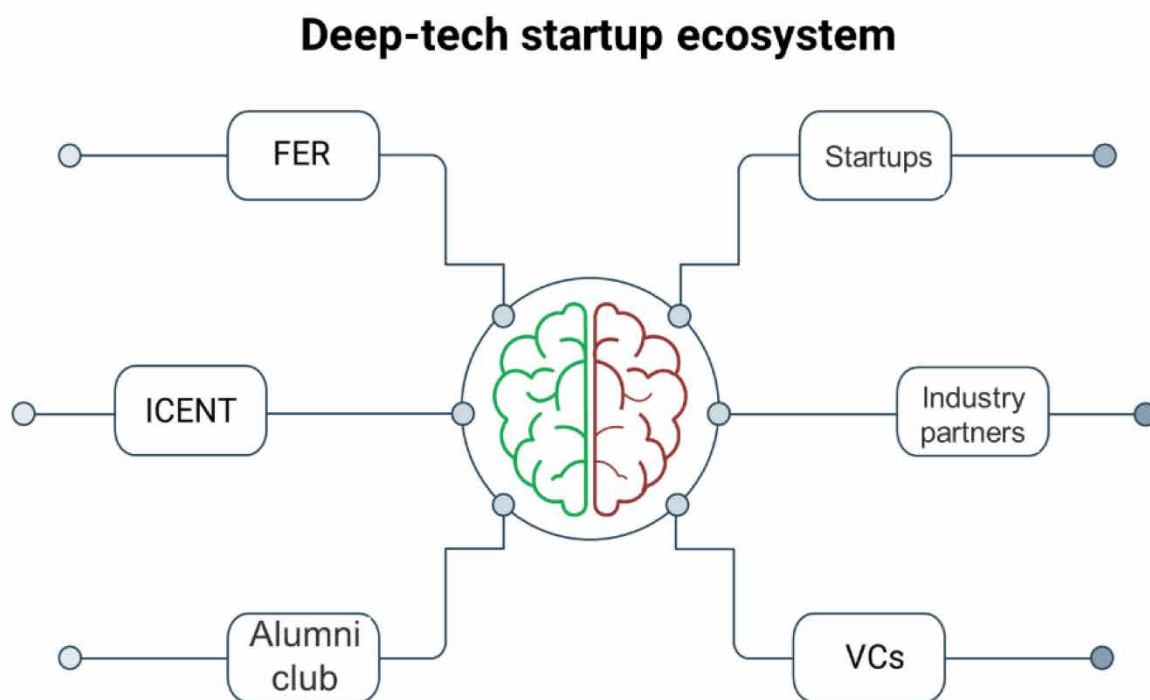

Fig. 2. Stakeholders of Croatian deep-tech ecosystem

their incentives for entering the deep-tech ecosystem (Figure 2).

An ideal scenario would be as follows: (i) FER engages best researchers and scientists to work on solving one of the recognized problems, (ii) ICENT provides its experience and support in prototyping and MVP creation, (iii) FER's alumni club provides experienced upper level management with strong R&D backgrounds who are interested in leading the startup development in early stage, (iv) successful Croatian startups provide experts with knowledge and experience in relevant fields such as market research, customer development, fundraising and storytelling, (v) industry partners provide support in branding and sales while providing access to a targeted market, (vi) VCs specialised for deep-tech provide critical early-stage funding.

All these actors will work together as part of the VB program, which is divided into four phases:

1. Partner selection and talent scouting,
2. Matchmaking and ideation,
3. Idea validation and startup education,
4. Business development and fundraising.

The VB program begins with a phase of **Partner selection and talent scouting** The first goal of this 2-month long phase is to identify and select the best industry partners interested in working with deep-tech startups who are developing an idea in their fields of interest (e. g. Energy, Finance, Smart City, Mobility, Robotics, Food, Health, Safety, Telecommunications, Internet of Things, Agriculture). The selected partners are subsequently educated on the deep-tech startup development process and what to expect from this collaboration. The second goal is to develop a comprehensive application process methodology in order to attract the greatest Croatian talents. This includes defining the application method and questions, profiling the applicants based on their background and experience, testing their entrepreneurship mindset and defining the selection criteria.

In the second phase, **Matchmaking and ideation**, the selected participants are brought to an in-person 3-day long event in Zagreb. On the first day of the event participants will be introduced to the whole VB program, have a "Startup introduction" lecture and get to know each other through speed-dating-like activities. On the second day, industry partners will pitch their challenges and participants will pitch their ideas. Participants will also be guided through a structured brainstorming session to spark idea creation and initial idea formation. On the last day of the event, previously formed teams will go through the Design Thinking process. After the event, teams will be encouraged to continue working on their ideas through weekly meetings and other activities in a dedicated working space where they will be able to meet with other participants and improve their ideas.

Then, a special committee will select the best teams who will go to the third phase of the VB program – **Idea**
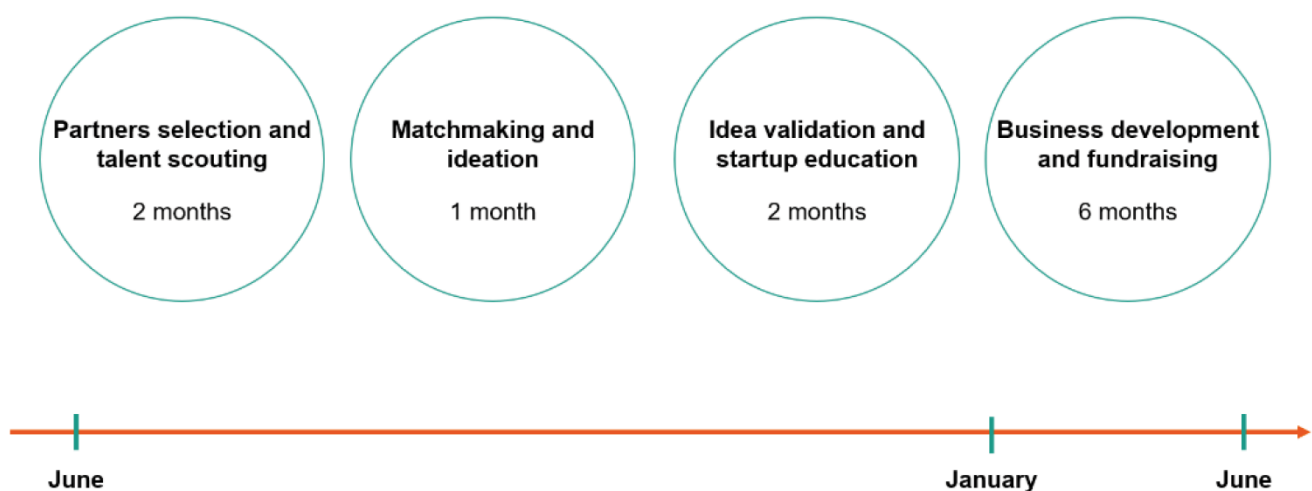
Venture Builder program

Fig. 3. Phases of VB program at FER and ICENT

validation and startup education. At this point, each team is assigned a specialized industry partner who will support them in conducting market research via client access, interviews, and data analysis. Simultaneously, teams will participate in a 10-week long startup education which will cover all important topics for early-stage startup development such as Market Research, Business Model Canvas, Customer Development, Prototyping, Pitch & Storytelling, Fundraising and IP management. At the end of this phase, each team will present their project to relevant stakeholders from industry, startup community, academia and the general public at a demo day. The best teams will continue working with the VB team in the **Business development and fundraising** phase at the end of the third phase. This phase is tailored-made for the selected teams and the VB team will continue working with each of them individually. These teams will have access to shared resources and experts who will help them prepare for the specific challenges they will face. This final phase focuses on client acquisition, product development, and fundraising.

Each year, at least one deep-tech startup is expected to successfully shift from the innovation stage to a well-defined commercial project. When they complete the VB program, they will be on their way to become a successful business.

Conclusion

The sustainable development goals [7] are staples of contemporary development plans for Croatia, the EU, and the rest of the world. Innovations are crucial to reach these goals till the optimistic 2030 deadline. Deep-tech innovations must continue to be the primary drivers of progress within the innovation landscape, as they have always been. This means that, at this point in time, the implementation of innovative methods that enable fast tracking of deep-tech ventures is definitively crucial. Hence, VB programs, which take deep-tech solutions from the research stage to full commercial viability, are the "perfect match" for this development level of the world's economy and industry. The University of Zagreb Faculty of Electrical Engineering and Computing and the Innovation Centre Nikola Tesla are well-positioned to serve as the pillars of these processes in Croatia and the wider region. The Venture Builder model is a powerful tool to have on hand.

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Romb Technologies – autonomous navigation in logistics sector

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1. Introduction

Romb Technologies is an academic spin-off company that commercializes autonomous navigation technologies in the logistics sector. Based on over 40 years of combined R&D experience in robotics and autonomous navigation, the company, founded in November 2018. as a spin-off of the Laboratory for Robotics and Intelligent Control Systems at the Faculty for Electrical Engineering and Computing at the University of Zagreb and incubated at the Zagreb Innovation Centre (ZICER), develops software for accurate and efficient automated material handling activities.

Romb Technologies offers a complete software suite for automated material handling, from map-building and localization to layout planning and path following. Localization algorithms are based exclusively on on-board sensing and do not require any additional infrastructure in the environment. The technology, when combined with patent-pending interactive map building methodology, reduces AGV deployment time from weeks to days. Developed a path-following method, based on model-predictive control (MPC), which works with all industrial kinematic configurations, ensures maximum vehicle utilization by optimizing velocity while maintaining high positioning accuracy. This is complemented with an intuitive layout-planning tool which optimizes vehicle paths and visualizes the interaction of the safety subsystem with the environment.

As a newly founded company with strong academic ties, Romb Technologies invests a significant portion of its resources in R&D, developing rich visual perception modules, powered by deep learning, which will endow the vehicles with semantic understanding of their environment and open up new use-cases for AGVs.

Automated Guided Vehicles

The automated warehouses are the facilities that can be equipped with both stationary and mobile robotic parts (e.g. palletization work cells and unmanned forklifts, respectively). The complexity of control increases as a number of involved robotic devices increases. Other goals to consider include overall system safety, effective adaptation to system faults, collision avoidance, and accommodation to dynamic changes within the manufacturing process itself, in addition to traditional goals such as maximum production throughput, efficient utilization of all robotic subsystems, and savings based on the elimination of human work in the process. AVG integration into automated materials handling systems requires the use of effective on-line supervisory control mechanisms capable of resolving conflict and deadlock issues in the system layout. This usually means that routing and scheduling algorithms used on-line for AGV's traffic and mission control must be executed in a very short time interval, which leads to the solving of an NP-hard computational problem.

Technologies

AGV delivery missions are often divided into the following parts: i) point-to-point motion, and ii) docking. During the point-to-point phase, the vehicle should take the shortest path from its current location to the docking station. During the docking phase, the vehicle must precisely match its orientation in order to position its forks accurately for pallet pickup.

The basic purpose of the point-to-point motion controller is to safely navigate the vehicle along the shortest obstacle- free path from an initial location towards a desired destination in the vehicle working space. Therefore, the initial step is to select and implement an acceptable path planning algorithm. Unlike most practical AGV systems in which the vehicles follow paths along predetermined path network, Romb Technologies implements a free-ranging motion that allows for motion planning and execution throughout the whole obstacle free environment. The free-ranging motion scheme is more appropriate sincerity allows for the easy definition of arbitrary motion sequences within any section of the dynamic working environment. Path feasibility is an important factor that had to be considered during the design of the path planning algorithm. due to the non-holonomic vehicle constraints. Taking into account the intended free-range properties as well as the path
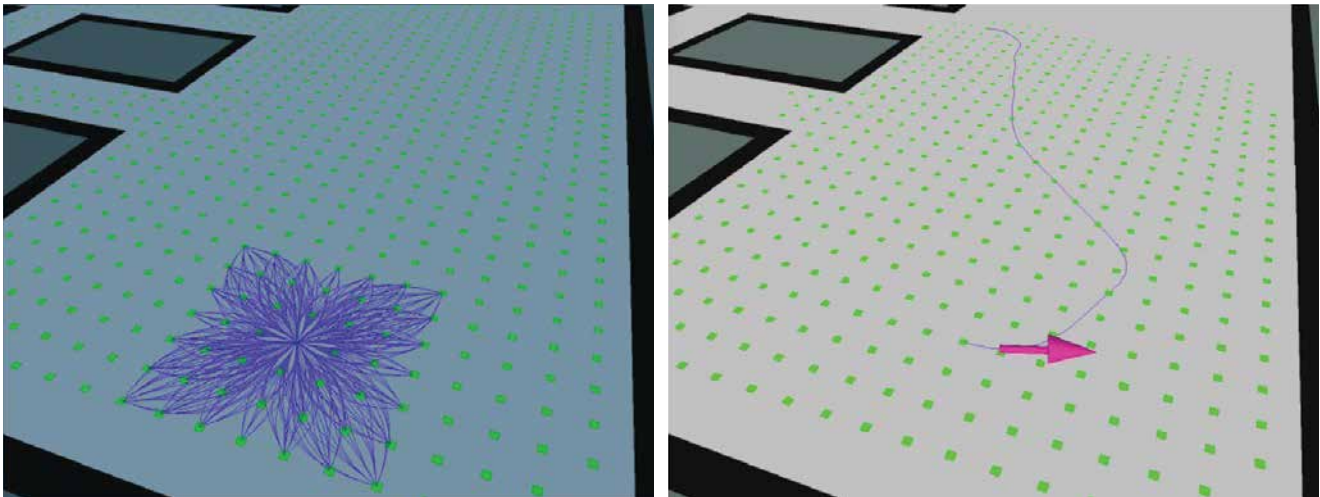
Figure A. The AGV state lattice and the final path

feasibility criteria, we implemented a sampled vehicle state space which encodes feasible motions by design, reducing the overall route planning problem to finding an appropriate sequence of motion primitives (latices), which represents the resulting vehicle path connecting the initial and desired vehicle states (Figure A).

Although there are various commercial systems that use autonomous ground vehicles (AGVs) t, significant improvements can be accomplished in terms of their level of autonomy and deployment cost. The current state of the art for vehicle localisation, in particular, necessitates extra infrastructure, typically in the form of reflective markers or electromagnetic guides, in order to accurately determine vehicle posture. This strategy has various drawbacks, including a high installation cost (up to 30% of system commissioning) and the need for many man-hours of work by experienced staff. Moreover, they are sensitive to environmental changes which may obstruct the field of view of the vehicle; in tough industrial conditions they might become damaged or soiled.

The capacity of AGVs to self-localize without the usage of extra infrastructure (markers, guides) is the essential technology that considerably improves their performance and adaptability, allowing them to be widely used. Wheel encoders, contact switches, sonar arrays, 2D and 3D laser scanners, mono, stereo, and RGBD cameras are among the most typical sensors used for this purpose. Romb Technologies developed real- time natural localization (using laser scanner – Figures 1 and 2) based on the robust AMCL (Adaptive Monte Carlo Localization) algorithm, which fuses odometry data with laser range readings providing a location of the AGV with a known covariance. The initial estimate for the scan matching ICP algorithm is based on this finding. Finally, the obtained result, which typically has a very good orientation estimate, is used as the initial estimate in a discrete Fourier transform method, which returns the final result of sub-centimetre localization accuracy in real-time, using only natural features in the environment.
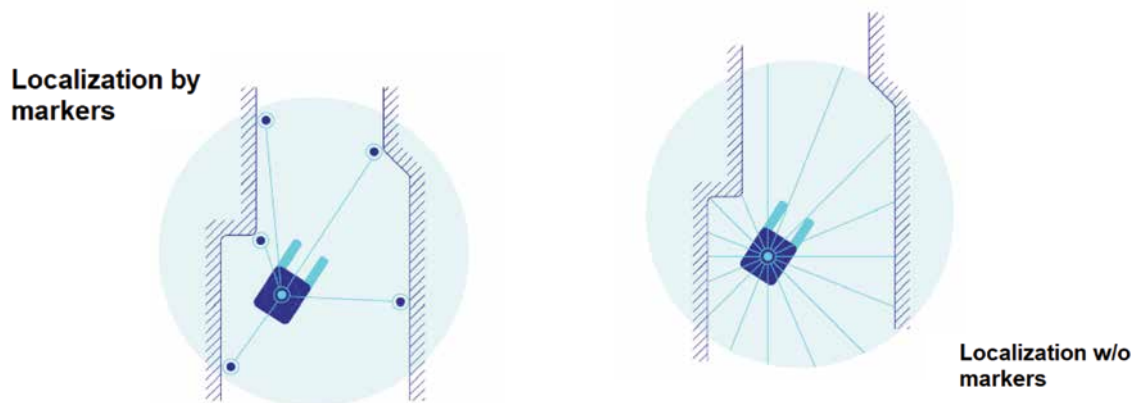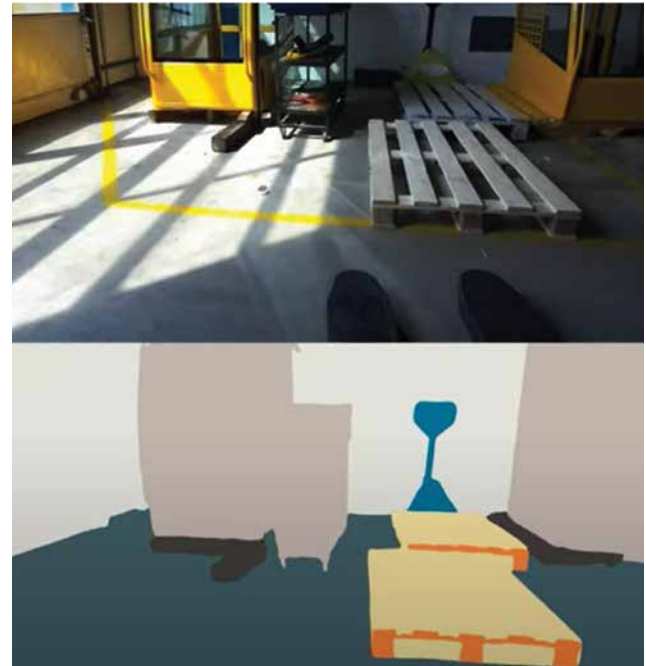

Figure 1. Standard localization with markers and natural localization without artificial markers positioned in the environment

Figure 2. Natural localization (artistic depiction of laser scan). A laser on the top of the AGV measures distances from the objects surrounding the AGV, thus providing data for an algorithm that an artificial grid of occupied and free spaces around the vehicle

Figure 3. Visual perception for a pallet pickup

A further step toward improving environmental awareness is based on deep learning and AI models for real time object classification (Figure 3). This novel technology leverages deep learning and machine vision to provide human-like environment awareness to AGVs. It enables adaptive pallet pickup based on a rich visual perception of the environment, thus providing the pick-up of incorrectly positioned pallets enabling vehicles to better support human workers by operating in unstructured and unpredictable conditions. As a result, the method can be implemented without the use of mechanical pallet guides.

Accurate and effective path-following based on Model Predictive Control (MPC) with an optimum speed profile requires precise localization of an AGV and perception of the environment (Figure 4). This method, patented by Romb Technologies, provides better AGV utilization by allowing up to 20% faster movement on curved segments with sub-centimeter positioning accuracy. Furthermore, it allows for arbitrary vehicle kinematics with numerous actuated wheels.

Figure 4. An AGV passing next to an obstacle by using MPC-based path following

Activities of the Croatian Academy of Engineering (HATZ) in 2022
Auspices, Organization/Coorganization of Conferences

Auspices

- 14th Scientific and Professional Symposium Textile Science and Economy (TZG Symposium, University of Zagreb Faculty of Textile Technology, January 26, 2022, Zagreb;

- Professional meeting "Buildings 3+, Security, comfort, quality", University of Zagreb, Faculty of Architecture, February 17 to 18, 2022, Zagreb, live lectures with live video streaming;

- 14th meeting of young chemical engineers, Faculty of Chemical Engineering and Croatian Society of Chemical Engineers and Technologists, February 24 to 25, 2022, Zagreb;

- Invitation to the lecture „Model Based Human Shape and Pose", University of Zagreb Faculty of Electrical Engineering and Computing, Department of Systems and Cybernetics of HATZ, March 28, 2022, Zagreb;

- Lecture „Underwater Surveying R&D at the Underwater Robotics Research Lab at VICOROB – Girona", University of Zagreb Faculty of Electrical Engineering and Computing, Department of Systems and Cybernetics of HATZ, May 10, 2022, Zagreb;

- International professional meeting „7th International Conference on Road and Rail Infrastructure – CETRA 2022", University of Zagreb, Faculty of Civil Engineering, May 11 to 13, 2022, Pula;

- Conference "Adria Space Conference - Artificial Intelligence in Space", Adriatic Aerospace Association, May 12 to 13, 2022, Zagreb;

- 9th International conference "WATER FOR ALL", J.J. Strossmayer University of Osijek, Faculty of Food Technology, May 19 to 20, 2002, Osijek;

- 2nd International Student GREEN Conference, June 2 to 3, 2022, Osijek;

- Conference "Brijuni Conference - DEEP space communication, navigation and propulsion", August 29 to 31, 2022, Brijuni;

- International conference 19th Ružička Days "Today Science – Tomorrow Industry", J.J. Strossmayer University of Osijek, Faculty of Food Technology, September 21 to 23, 2022, Vukovar;

- International Conference on Smart Systems and Technologies 2022 (SST 2022)", Faculty of Electrical Engineering, Computer Science and Information Technology of J.J. Strossmayer University Osijek, October 19 to 21, 2022, Osijek;

- International Scientific Conference "Solution in Chemistry", Croatian Chemical Society, November 8 to 11, 2022, Sv. Martin na Muri;

- 9th International Ergonomics Conference - ERGONOMICS 2022, Croatian Ergonomics Society, December 7 to 10, 2002, Zagreb

- 28th Croatian Assembly of Chemists and Chemical Engineers, March 28 to 31, 2023, Rovinj

Organization/organization of conferences

- International scientific conference „Printing & Design 2022.", University of Zagreb Faculty of Graphic Arts), Zagreb University of Applied Sciences, (North University, Varaždin – Koprivnica, Croatian Academy of Engineering, May 12, 2022, Zagreb;

- 7th Croatian Congress of Microbiology with International Participation, Croatian Microbiology Society and Croatian Academy of Engineering, May 24 to 27, 2022., Sv. Martin na Muri;

- 3rd International Conference "Food Industry By-Products", Faculty of Food Technology Osijek, HATZ, August 29, 2022, Osijek;

- International Conferences „Conference on Sustainable Development of Energy, Water and Environment Systems – SDEWES", May 22 to 26, 2022, July 24 – 28, 2022, November 6 to 10, 2022;

- 10th International Congress of Food Technologists, Biotechnologists and Nutritionists, University of Zagreb Faculty of Food Technology and Biotechnology and HATZ, November 30 to December 2, 2022, Zagreb;

On June 6, 2022, the 44th Regular Annual Assembly of the Croatian Academy of Engineering was held at the University of Zagreb Faculty of Electrical Engineering and Computing (Unska 3, Zagreb). The assembly was attended by members of the Academy and distinguished guests from science and economy.

Diplomas were presented on this occasion to the Academy's new full members and emeritus members, as

well as the winners of the Academy Awards for 2021, who had already been confirmed by the Academy's Presidency and Assembly.

The full new members' status was achieved by

Department of Bioprocess Engineering
- Prof. Blaženka Kos, PhD

Department of Electrical Engineering and Electronics
- Prof. Adrijan Barić, PhD
- Prof. Viktor Sučić, PhD
- Prof. Slavko Vujević, PhD
- Prof. Drago Žagar, PhD
- Prof. Damir Žarko, PhD

Department of Power Systems
- Prof. Zvonimir Guzović, PhD
- Prof. Vitomir Komen, PhD
- Prof. Igor Kuzle, PhD
- Prof. Alfredo Višković, PhD

Department of Civil Engineering and Geodesy
- Prof. Meho Saša Kovačević, PhD

Department of Graphical Engineering
- Prof. Nikola Mrvac, PhD

Department of Chemical Engineering
- Prof. Stanislav Kurajica, PhD

Department of Mechanical Engineering and Naval Architecture
- Prof. Igor Karšaj, PhD
- Prof. Branimir Pavković, PhD

Department of Textile Technology
- Prof. Snježana Firšt Rogale, PhD
- Prof. Tanja Pušić, PhD

The status of the new emeritus members of the Academy was acquired by:

Department of Civil Engineering and Geodesy
- Prof. Emeritus Miljenko Lapaine, PhD

Department of Mechanical Engineering and Naval Architecture
- Prof. Antun Galović, PhD

The Croatian Academy of Engineering bestowed the following **awards** during the Assembly for the year 2021:

"The Power of Knowledge" Award for Lifetime Achievement

Prof. Dubravko Rogale, PhD

Academician Karolj Skala

Rikard Podhorsky *Annual Award*

Prof. Domagoj Jakobović, PhD

Prof. Drago Žagar, PhD

Prof. Jadranka Frece, PhD

Young Scientist Award "Vera Johanides" (for research)

Hrvoje Leventić,
Assistant Prof., PhD

Ivan Pavić,
Assistant Prof., PhD

Lana Virag,
Assistant Prof., PhD

Tomislava Vukušić
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