Improved Robotic Platform to perform Maintenance and Upgrading Roadworks: The HERON Approach

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D8.10: Annual Magazine Issue (third version)

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Document Control Sheet

Version history table			
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0.1	01/04/2024	Basic structure of the deliverable	Iason Katsamenis
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1.0	31/05/2024	Final version ready for submission	Nikos Bakalos, Iason Katsamenis

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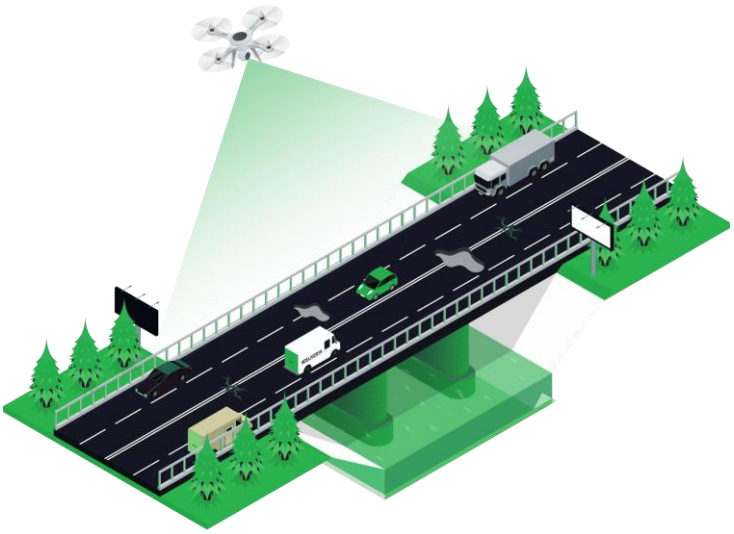
Improved Robotic Platform to perform Maintenance and Upgrading Roadworks: The HERON Approach



HERON aims to develop an integrated automated system to perform maintenance and upgrading roadworks tasks, such as sealing cracks, patching potholes, asphalt rejuvenation, autonomous replacement of CUD elements and paint markings, but also supporting the pre-/post-intervention phase, including visual inspections and dispensing and removing traffic cones in an automated and controlled manner.

In this magazine: Exploring the deployment of aerial drones, designed to support the **HERON** robotic vehicle.

The road so far: The deployment and integration of drones with the **HERON** UGV enhance maintenance operations and the pre-/post-intervention phases. This integration interfaces with various technical aspects of the project, including computer vision systems, motion and high-level planning, and an integrated incident management system for supporting road operators and managers. The perception and localization methodologies undergo rigorous testing, evaluation, and refinement during field integration, demonstration, and validation activities.

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Real-time traffic cone detection

For the upcoming **HERON** trial activities, the DJI Matrice 350 RTK takes center stage, revolutionizing how we approach aerial surveying and road inspection tasks. This state-of-the-art drone, renowned for its precise RTK positioning, offers unparalleled accuracy, making it an invaluable asset for mapping and data collection. Equipped with advanced obstacle sensing, the Matrice 350 RTK ensures safe operation even in complex environments. Its robust design, capable of withstanding harsh weather conditions, and an impressive flight time of up to 55 minutes, allow for extended missions without frequent interruptions. This combination of reliability and endurance significantly enhances our operational efficiency and data quality.

The versatility of the DJI Matrice 350 RTK extends to its payload capacity, supporting a variety of sensors and cameras essential for diverse industrial applications. For instance, integrating high-resolution RGB cameras and thermal imaging sensors enables detailed inspections and precise thermal mapping, crucial for road infrastructure monitoring and emergency response. The drone's seamless connectivity and real-time data transmission capabilities streamline decision-making processes, providing our team with immediate insights and actionable information. Through this project, the Matrice 350 RTK is not just a tool but a pivotal component driving innovation and excellence in **HERON**'s aerial operations.

The **HERON** project has conducted extensive data-capturing sessions to gather crucial data for drone operations. This data collection serves two primary purposes: evaluating the performance of existing deep learning models and acquiring additional training samples to enhance these models' operational capabilities. These activities were carried out in two locations: the University campus of the National Kapodistrian University in Athens, Greece, and the Gustave Eiffel University premises in Bouguenais, near Nantes. By leveraging diverse environments, the **HERON** project ensures robust datasets, driving continuous improvement in drone technology and AI integration.

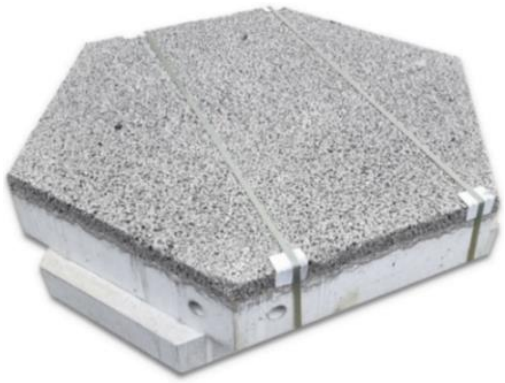
Data-capturing session at the National Kapodistrian University

The National Kapodistrian University, Athens' largest educational institution, is located in the Zografou borough. In the summer of 2023, a portion of the campus roads sustained significant damage due to extreme weather events. Proximity to ICCS and its location within the same urban area of Athens allowed for drone operations without special permits, leading to its selection for data-capturing activities. During the autumn and winter of 2023-2024, three comprehensive data-capturing sessions were conducted. These sessions utilized drones at various altitudes and under diverse weather and lighting conditions, ensuring a robust and versatile dataset for research and development.

Data-capturing session at the Gustave Eiffel University

In February 2024, the **HERON** project focused on the Removable Urban Pavement (RUP) use case with a targeted data-capturing session in the Nantes region of France. The test section, constructed by Gustave Eiffel University in 2020, measures 8.51 meters in length and 2.31 meters in width. This section comprises slabs with a 46 cm edge and 23 cm thickness, including a surface layer of 4 cm porous concrete for the 22 double-layer hexagonal slabs with a weight of around 280 kg, 4 cm hydraulic concrete for the 15 half-edge slabs, and 2 single-layer quarter-slabs.

These slabs have undergone an accelerated test with a fatigue carousel. Since 1984, Gustave Eiffel University has had a system to test pavements under heavy vehicle loads at speeds up to 100 km/h. This helps validate new structures by testing for fatigue before moving to larger road tests. So, from November 2020 to February 2021, the RUPs structure was subjected to 200,000 cycles of loading by a half-axle with dual wheels loaded at 65 kN (which corresponds on average to traffic between 45 and 91 buses/day/direction for 20 years). The main current objective is to identify potential structural anomalies of RUPs through multi-technique methods on the surface and subsurface.



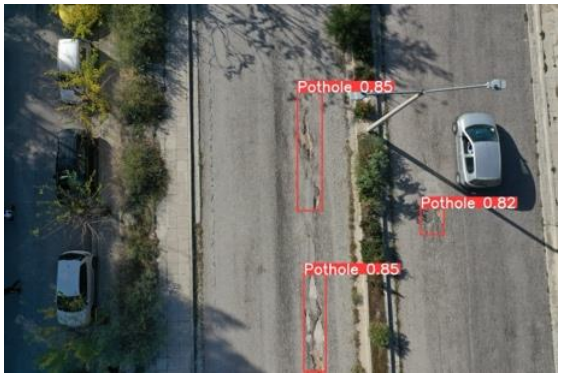
The RUP concept

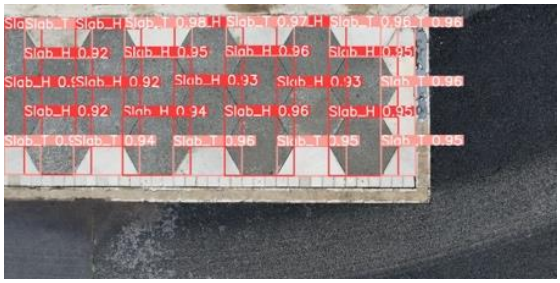
Ultimately, **HERON** facilitates a modular design of the operational system, enhancing capabilities and adaptability for transportation infrastructures. This approach reduces human risks, maintenance expenses, and traffic disturbances, thereby enhancing network efficiency. One of the innovative structures under scrutiny within the project is RUP. Gustave Eiffel University is actively engaged in designing, implementing, testing, and validating RUP on various test sites in France and various load conditions. This facilitates comprehensive trials where the **HERON** project integrates with a multi-technique Non-Destructive Techniques framework.

RUP is a pavement that can be quickly opened and closed, using lightweight equipment, and allows easy access to the sub-base and the underground networks. This original design is based on hexagonal prefabricated concrete slabs, supported by an original excavatable and draining cement-treated base, all on a supporting platform reminding the multilayer structures of a standard pavement. A straight RUP structure comprises various elements: whole hexagons in the center of the pavement, half-hexagons arranged at the edges, all interconnected with a "concrete key" (shoulder located at the base of the slab), and pavers surrounding the entire structure. Sanded joints seal the gaps between the slabs. It is noted that the presence of vertical holes allows water drainage.

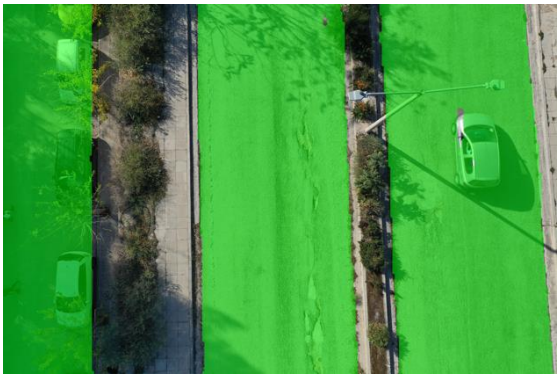
Perception using aerial imaging data

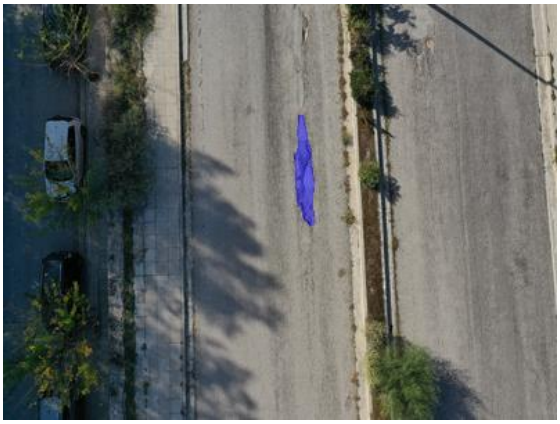
YOLO is a leading real-time object detection model, performing detection in a single neural network pass. It divides an image into a grid, predicting bounding boxes and class probabilities for each cell. It has evolved to enhance accuracy, speed, and efficiency, making it ideal for applications requiring instant and precise object recognition.





Segmentation of captured images is also a key research focus of **HERON**. While defect segmentation guides robot repairs, UAV imaging aims to capture broader area information, like delineating the road surface. In semantic segmentation, a significant advancement is the use of U-Nets. With their encoder-decoder structure, they excel in capturing intricate details, making them ideal for high-precision tasks like identifying and mapping road defects, boosting the accuracy and reliability of **HERON**'s imaging capabilities. Another groundbreaking advancement is SAM, developed by Meta AI. SAM addresses one of the toughest challenges in computer vision: segmenting a wide array of objects in images, even those it has not been explicitly trained on. This marks a significant departure from traditional models, which require extensive training on labeled data for each specific object category they need to recognize and segment.





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