Thessaloniki (Greece) February 2024 – OpenDR "Open Deep Learning Toolkit for Robotics" is a research project funded by the **EU Horizon 2020** research and innovation program. **The project was active during the period January 2020 – December 2024 (48 months) and its main achievement was the development of a modular, open and non-proprietary toolkit for core robotic functionalities by harnessing AI, more specifically deep learning, to provide advanced perception and cognition capabilities, meeting in this way the general requirements of robotics applications in numerous areas including healthcare, agri-food and agile production, which are the project's three use-case areas.** The project was coordinated by Prof. Anastasios Tefas, Aristotle University of Thessaloniki and brought together 5 top-ranked academic and research institutes: Aristotle University of Thessaloniki (Greece), Tampere University (Finland), Aarhus University (Denmark), Delft University of Technology (Netherlands), University of Freiburg (Germany). The consortium also included 3 leading industry partners: Cyberbotics (Switzerland), PAL Robotics (Spain) and AgroIntelli (Denmark) .

Six versions of the OpenDR toolkit have been publicly released in total through its GitHub repository (https://github.com/opendr-eu/opendr). The first one was released in December 2021 providing more than 20 methods related to core robotic functionalities, an intuitive and easy-to-use Python interface, a C language API (Application Programming Interface) for selected tools, a wealth of usage examples and supporting tools, as well as ready-to-use ROS (Robot Operating System) nodes. Subsequent versions focused on expanding the number of available methods, as well as providing performance improvements to existing ones, while the final version provides new tools for face recognition, pose estimation, human detection, object detection, gesture recognition, fall and wave detection etc. All tools are thoroughly documented while demos are also provided. The toolkit. is built to support Webots Open Source Robot Simulator, while it also extensively follows industry standards, such as ONNX model format and OpenAI Gym Interface. The toolkit, which is also available in the AI on Demand Platform, has been **received very positively by the deep learning community**: it has gathered so far more than 590 stars and was downloaded more than 18000 times, a fact which indicates that it will have a significant impact in the robotics and AI fields. The toolkit will be actively maintained in the years to come.

OpenDR produced numerous **publicly available datasets**, data generation software modules and simulation environments that can be used to generate data. Examples include the KITTI panoptic segmentation dataset, the NuScenes LiDAR panoptic segmentation dataset, a multimodal agricultural aerial and ground robotics simulation-based dataset, the AUTH-OpenDR Mixed Image Annotated Dataset for Human-centric Perception Tasks, the ActiveHuman and ActiveFace synthetic datasets, the AUTH-AGI Humans in Fields dataset, the TAU Engine Assembly dataset, the Webots Pick and Place competition simulation environment etc. The datasets are available in the respective GitHub repository (https://github.com/opendr-eu/datasets).

OpenDR also worked towards developing **simulation tools for training efficient DL algorithms**. More specifically, the **Webots simulator** was extended by improving its simulation capabilities, adjusting the simulation environment to make it highly compatible with the ROS framework, and consequently with the corresponding real robotics systems, as well as preparing the infrastructure to run simulations on the web to give a high visibility to the OpenDR results.

Apart from these extremely important achievements, project partners were **very active in research** towards tools that make robotic systems cognitive, giving them the ability to a) interact with people and environments by developing deep learning methods for human centric and environment active perception and cognition, b) learn and categorise by developing deep learning tools for training and inference in common robotics settings, and c) make decisions and derive knowledge by developing deep learning tools for cognitive robot action and decision making. This effort led to

numerous state of the art results from fast and efficient lightweight deep learning models that are suitable for on-board deployment on robots to results that demonstrate the potential of active deep learning perception methods. These results were documented into **more than 100 scientific publications** (journal and conference papers and one edited book). Indeed, the consortium succeeded in generating a wealth of scientific works which were published in the most important robotics and AI journals, including IEEE (Institute of Electrical and Electronics Engineers) ones, such as IEEE Transactions on Neural Networks and Learning Systems, IEEE Transactions on Artificial Intelligence, IEEE Transactions on Image processing, IEEE Robotics and Automation Letters and Neurocomputing, as well as highly influential conferences including IEEE Conference on Computer Vision and Pattern Recognition (CVPR), IEEE International Conference on Multimedia and Expo (ICME), IEEE International Conference on Image Processing (ICIP), IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) etc.

The toolkit is expected to significantly **lower the technical barriers** within the prioritised application areas by providing easy to use tools, which in turn can further enhance innovation capacity and will lead to the creation of new market opportunities. Currently, the market has a strong increasing tendency and the developed technologies are ready to be taken up by the industry, transforming the European robotics industry into a key player in the global market. At the same time, OpenDR is expected to create new market opportunities by providing active deep learning approaches that smoothly co-integrate with simulation environments, providing a new training paradigm for active deep robotics. As a result, the consortium expects OpenDR to have a **significant impact** on small to medium robotics enterprises that cannot devote effort on developing deep learning models from scratch. Moreover, having available a series of tools along with the simulation environment for robotic active human and environment perception and action will enable many new application ideas to reach the market or to be demonstrated at least as TRL3 systems for attracting funding and thus making a significant step to the market.

A significant number of dissemination activities have also been organized, such as two Summer Schools on issues related to deep learning, autonomous systems and smart cities. one workshop related to the presentation of the project objectives, one workshop organized in conjunction with IROS 2021, two tutorials in IEEE International Conference on Image Processing (ICIP) 2020, and IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2022, organization of special sessions in conferences, invited talks etc. Furthermore, the OpenDR project had a very strong presence in the most popular social media networks, such as LinkedIn, X (Twitter), Facebook and Youtube, reaching a large number of followers with interests in the fields of AI, deep learning and robotics, maximizing this way the impact of the project and its results.

The exploitation of the project outcomes includes the use by the industrial partners of the technologies, tools, and know-how developed in OpenDR in their products (such as Agrointelli's Robotti agricultural robot or PAL's TIAGo and ARI assistive robots), or services (such as the Cyberbotics new web services based on Webots.cloud or its new development services around Webots). Academic partners are mainly exploiting the outcomes of the project for educational purposes (educational material, support for student projects in robotics / computer vision courses), new academic research that leverages the OpenDR achievements, and for strengthening their position as key players in the scientific arena and attracting funding.

A very productive four-year journey has come to an end! The project achieved, with hard work and effective partners collaboration, all the goals that it had set. It was a very interesting journey indeed! We hope that our contributions will be a small but important step towards **smarter and more efficient robots** of all kinds.

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For more information visit **OpenDR's** website: www.opendr.eu

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