D6.2.1 Exploitation Plan

	[WP6 – Dissemination and Exploitation]
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[1] **Use one of the following codes:**
R: Document, report (excluding the periodic and final reports) DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc. OTHER: Software, technical diagram, etc.

[2] **Please choose the appropriate reference and delete the rest:**
PU = Public, fully open, e.g. web;
CO = Confidential, restricted under conditions set out in Model Grant Agreement; CI = Classified, information as referred to in Commission Decision 2001/844/EC.

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Executive Summary

This deliverable presents a first draft outline of the exploitation plan for the project APROVIS3D regarding both joint exploitation objectives, as well as partner-specific plans. Moreover, it describes the exploitation potential emerging during the first year of the project, whilst further exploitation activities will also be reported at the end of the third and final year of the project (D6.2.2).

The deliverable is structured as follows:

- Chapter 1: it gives a more accurate overview of the exploitation plan.
- Chapter 2: it describes the overall exploitation strategy in relation to specific Work Packages. It starts with the joint aims, ambition and objectives for the project and follows with the exploitation plan.
- Chapter 3: it presents the partner-specific exploitation plans along with a list of exploitation strategies that can be used by the project partners as a guideline for formulating their own exploitation plans.
- Chapter 4: The fourth chapter presents a potential business model that may follow the field deployment case-case.
- Chapter 5: presents the timeline in the second and third-year for the strengthening and long-term sustainability after the end of funding.
- Chapter 6: This short chapter presents the conclusions of exploitation.

1. Introduction

The APROVIS3D project (*Analog PROcessing of bioinspired VIsion Sensors for 3D reconstruction*) targets the analog computing for artificial intelligence in the form of Spiking Neural Networks (SNNs) on a mixed analog and digital architecture.

The principal ambition of the project is to develop a new design of event-based vision system, based on:

(a) improved event-based vision sensors
(b) new neuromorphic algorithms, and
(c) their implementation on a mixed analog-digital architecture.

The main goal is to extend the project approach to stereopsis, which is one of the most important features that enables machine vision systems to perceive 3D environment. For this reason, concerning technical details, the project aims at an analog processing chain including the three following parts:

(a) An **analog sensing device** composed of a stereo-DVS with foveation capability: two foveated DVS sensors will be mounted in a stereoscopic configuration, allowing to capture the scene with two calibrated left and right event sensors. In such a sensor, events represent pixel-wise elementary positive/negative variation of light.
(b) A **set of analog processing algorithms** based on SNN processing for visual data: the received spikes are delivered to destination synapse circuits, and output address-events represent spikes produced by the source neurons. For 3D reconstruction, the real-time analysis of sensors' data will generate depth maps. Left and right events coming from the event stereo pair will be matched by analysing time and space correlations, and the left-right disparity of each event pair will contribute to build a sparse depth map. 3.
(c) **A mixed analog-digital implementation** of the algorithms, using SpiNNaker and Loihi architecture. This mixed analog-digital strategy will enable both a realistic analog implementation of SNN for light processing tasks, and high-level heavier processing abilities.

Based on the above technical approach, the project is to design and to develop the whole analog vision sensor platform and its interface with a UAV (Unmanned Aerial Vehicle), dealing with heterogeneity at the hardware level and allow an optimal execution of the node tasks with a balanced distribution within different levels of the hardware architecture.

Ultimately, the analog sensing and processing system will be integrated with the motion control of a multi-rotor UAV, resulting in a novel visual servo control scheme for application in autonomous coastal surveillance. Field experiments will be conducted in a coastal region of interest by evaluating the performance and robustness of the overall system. Upon completion of these fields tests, the project aims at examining further applications and industry liaisons that may emerge.

A key measure of the project success is the relation with both scientific community and manufacturing industry and application potential around the proposed system to be implemented in the years to follow the end of the project.

1.1 Relation to other Deliverables and Work Packages

The exploitation plan is a part in a series of five main deliverables of WP6 (Dissemination and exploitation) that describe the planned and performed dissemination and exploitation activities of the project, thus, it will be subsequently updated during the second and third year of the project. The documents are as follows:

D6.1.1. Dissemination Plan (Editor: UNIWA, due M3, completed):

The aim is to present the strategy of disseminating the project progress and results to the relevant scientific communities, stakeholders and potentially industrial audience, as well as to promote the benefits of the methodology adopted by APROVIS3D.

D6.1.2. Public website (Editor: UNIWA, due M6, completed): The public website is designed and developed within the project objectives. Materials (such as publications and upcoming events) will be updated frequently, based on comments and suggestions from participants and other potentially involved users.

http://aprovis3d.eu/

D6.2.1 Preliminary Exploitation Plan (Editor: UNIWA, due M18): In D6.2.1 (this document) the first version of exploitation plan is presented, aligned with the consortium partners' individual plans and market evaluation.

D6.1.3. Dissemination report (Editor: UNIWA, due M36): the final version of the dissemination activities and results within the duration of the project

D6.2.2. Complete Exploitation Report (Editor: UNIWA, due M36): In D6.2.2 an update of D6.2.1 with exploitation activities already performed including propositions/initiatives for market adoption of the project results, along with a list of exploitation activities performed during the last year of the project will be reported.

There are three major project milestones with special relevance for exploitation in APROVIS3D, involving the following work packages assigned:

Milestone 1: Scenarios, use cases, and requirements (WP1), due M6:

The definition of the scenarios and use cases relevant to the target application, along with performing a scientific and technological survey to complement the overview of relevant and potential technologies in the domain of bio-inspired analog sensing and processing. The aim is to translate the necessary functional into technical requirements and specifications, together with defining the scope of the demonstrator. Moreover, this outcome defines the technical specifications for all subsequent developments for WP2 to WP5, influencing the potential exploitation of such specifications for WP6.

Milestone 2: Implementation of the Analog processing subsystem (WP2, 3 and 4), due M18:

Initially WP2 (Leader UCA) is to develop and integrate the bio-inspired sensors, and more specifically, a low-power event-based stereopsis system, whereas other sensors (e.g., navigation) will be mounted on the system to acquire data synchronously for ground truth recording. The main tasks of WP2 are the Design of electronic foveated DVS sensor (T2.1) and the event-based stereopsis (T2.2). WP3 (Leader INT) studies generic learning algorithms for SNNs (Spiking Neural Networks) adapted to the analog input provided by the DVS sensors and aimed at being integrated into the UAV hardware. WP3 involves SNN-based ML (Machine Learning) adapted for DVS signals (T3.1), the event-based algorithm for depth detection (T3.2) and the Coastline detection in a foveated sensor (T3.3). WP 4 (Leader ETHZ) then designs and develops the whole analog vision sensor platform and its interface with the UAV, by focusing on Analog-digital architecture (T4.1) and Definition of software/firmware (T4.2).

Milestone 3: Components final version integration into the flying demonstrator, ready for validation (WP2, 3, 4 and 5), due M30:

Following the development of Milestone 2, WP2 is dealing with the bio-inspired stereoscopic algorithm design and based on the pairing of spatiotemporal information of the events coming from the DVS pair. This algorithm will be designed in accordance with the foveation system and with the goal of a Real-time implementation, along with the upgrade of the stereoscopic system with the electronic controlled foveated DVSs. The deliverables are an Electronic foveated DVS sensor (D2.1.1), an Electronic foveated DVS sensor being tested and integrated (D2.1.2), a Stereo System with two standard DVS sensors being designed (D2.2.1) and a Stereo System being upgraded with two foveated DVS sensors (D.2.2.2).

The foveated sensor will then accordingly adapt biologically inspired ML for vision implemented in coastline detection. For this reason, WP3 aims to adapt the object-detection process on the whole image and to define ROI (Region of Interest) in a ML driven system. Of particular interest is the definition of two streams of events: (a) primarily one for a low-resolution image used to detect "*where"* an object is, and (b) to detect *"what"* stream of the high-resolution DVS sub-image centred at this position and directed to an object-detection algorithm, which then will provide the input to the UAV servoing.

Bringing together the results from WP2 and WP3, the WP4 will develop a working prototype that fits the application scenario requirements in terms of form, factor, and energy consumption. The WP4 will realise both hardware and software algorithms. More specifically, the bio-inspired vision outputs derived from WP2 and WP3 will be implemented on using either: (a) the Loihi neuromorphic research chips along with Lava (an open-source software), and (b) the SpiNNaker parallel computing platform. WP4 deals also with the hardware-software co-design for improving the energy efficiency of the solution and to have a working prototype that will be used on WP5 to carry out the experimental evaluation.

The finalised prototype then will be used in the WP5 for evaluation purposes with an application in coastal surveillance from an appropriately adapted UAV, with the Tasks:

- T5.1. Servoing: interfacing of analog vision and UAV, with the aim to integrate the ML vision algorithms with the visual servoing notion, resulting in a ML visual servo control algorithm.

- T5.2. Field data collection, where several sets of annotated visual data will be collected for the training and validation of the ML algorithms in real flight scenarios.

- T5.3. Benchmarking and validation to evaluate both the hardware and software implementations developed within the project, via a set of real-time field experiments using a multi-rotor UAV.

The field experiments are to be conducted in a coastal region of interest by evaluating the performance and robustness of the bio-inspired Dynamic Vision Sensor and the ML-SNN vision detection algorithms. Furthermore, the data logged will be used for field volumetric calculation of physical coastal formations and coastline events, e.g., wave regime.

2. Consortia Exploitation Plan

2.1 Joint Exploitation Effort

The exploitation of the APROVIS3D results is the key element for the success of the project, with the overall objective being to develop new networks for bringing dual benefit of implementing unsupervised learning by using STDP (Spike-Timing Dependent Plasticity) and allowing hardware implementations in real field conditions. Therefore, the main exploitation challenges for the projects are:

(a) overcoming drawbacks in both energy and computational efficiency when combining ML and computer vision, especially in applications involving stereopsis.

(b) Explore the effective use of SNNs to tackle modern computer vision problems in real field conditions, which is a promising but still a relative new domain.

The project team aims to approach the above exploitation challenges by:

(a) analog neural networks and DVS vision sensors enabling online and continuous learning with adaptation capabilities. The project investigates both single and stereo vision algorithm that can process SNNs from one or two DVS. In this way the stereo vision may provide information about the depth in the FOV (Field Of View), the extraction of which and with the use of SNN remains an open research challenge not achieved by the current state of the art, thus, offering space for exploitation potential.

(b) the implementation of properly tested and designed algorithm and subsystems in an overall system that will be evaluated to control a UAV under real field conditions. With this experimental set-up, the aim is to demonstrate the feasibility and exploitability of such end-to-end analog event-based approach, which then may equally attract the interest of both computing manufacturing and software developers.

Depending on the success of the above system implementation, both in controlled testing and real conditions, the project offers the ability to design a platform including analog sensing and analog processing, implemented on analog or neuromorphic hardware. Therefore, there are open exploitation opportunities for analog AI and potential impact on, to mention the least, event detection, ML, IoT (Internet of Things), IT hardware design, robotics, autonomous vehicles and navigation.

The general project exploitation strategy also encompasses the following activities:

- **Intellectual property protection**. While the project's main deliverable will be open source and publicly available, it will be made via a licensing type that is consistent with integration in commercial use.
- The project team will perform **demonstrations** for interested industry stakeholders during open project meetings specifically aiming into helping them exploit the project's results.
- The project team will engage in **transfer activities** of our findings into the development, product, and service organisations.
- The project team will engage in **continuous analysis** of technology transfer opportunities, adjusting the project, when necessary to ensure the best possible outcome.

- The project team will **investigate economic benefits** from the impact of the results, through continuous evaluation of the advancement in the research outcomes against potential user requirements/needs throughout the project, and with the help and input by all the partners and apply adjustments when necessary.

2.1.1 Delivering Innovation to the Market

The plan of the project for delivering our innovations to the market is as follows:

(a) Implement neuromimetic architecture and appropriate algorithms to perform pattern recognition and detect analogies with Spiking Neural Networks. The exploitation potential emerges for further enhancing image analysis software and programming

(b) Adjust accordingly image classification process(es) to remodel from an offline pattern categorization into a real-time and event-based one. Initial results within the first year of the APROVIS3D project show exploitation potential to develop the SNN version of the method and to extend it into a fully event-driven approach in realistic field conditions, such as coastline and wave regime detection, for ultra-fast object categorization.

(a) Investigate the exploitation potential of such methodology approach when implementing the SpiNNaker parallel computing platform and for a first time on a UAV system SpiNNaker may provide a platform for high-performance of massively parallel processing appropriate for the simulation of large-scale neural networks in real-time, therefore acting as a research tool for and in liaison with neuroscientists, computer scientists and roboticists.

(b) In addition, the Intel's Loihi neuromorphic research chip, along with Lava open-source software framework, are to be also tested in implementing neuromimetic architecture in image analysis, whereas further applications include robotic arms, neuromorphic skins and olfactory sensing. Loihi's architecture may support new classes of neuro-inspired algorithms, providing faster processing, greater resource density, and ultimately an improved energy efficiency.

(c) The above neuromorphic networks offer solutions to a diverse range of problems, performing in a of brain-like computation, such as event-based data processing, adaptive control, constrained optimization, sparse feature regression, and graph search.

(d) Finally, the overall methodology is to be tested in real conditions and the results to be compared against (near simultaneously) known monitoring techniques and sensors (i.e. conventional RGB UAV cameras) and post-field analysis, thus, offering a further opportunity to explore the added and innovative value of the system developed within the project.

2.1.2 Developers Community

APROVIS3D offers liaison with two major neuromorphic computing and research groups along with commercially viable technology. In addition, APROVIS3D relates to European and global open-source fora that may offer new efficient programming models, adaptation of algorithms, interfacing with existing neuromorphic, ML frameworks, and support for real-time embedded, robotic systems and sensors, which represent the field application proposed bt he current project.

2.1.3 Standardization

WP 1 is devoted on the Specifications and demonstration definition of functional requirements for real-time optimization, planning and decision-making system. In this way, the project targets to improve flexibility by integrating faster, standardized I/O interfaces for supporting Ethernet connections and vision sensors, and improve the compatibility with robots and UAVs. Furthermore, these standards and specifications are then to be tested under real time condition over coastal area.

2.2 Open-Source Outcomes

What outcomes are to be open-source?

3. Individual Exploitation Plans

3.1 Overview

This chapter contains the individual exploitation plans by the project's partners. Initially, we propose some general exploitation strategy advice that can serve as a guideline for the partners to formulate their individual exploitation plans, followed by the partner-specific exploitation plans.

3.2 Exploitation Strategy Guideline

The goal of exploitation is to ensure the sustainability of the project's results beyond the project end and to demonstrate how APROVIS3D may further contribute into technological advancement through:

- *Financial exploitation*, building products, projects, or services based on the project results;
- *Research & development*, by engaging new projects (EU-funded or sponsored by other sources), based on the experiences gained within the project;
- *Education*, e.g. courses, at the university level or in continuing education, etc.;
- *Community-building* around the topics of the project, raising awareness for the addressed problems and the proposed solutions;
- *Knowledge transfer*, from academia to industry by collaboration(s);
- *Contributions to open-source projects* and *standardization*, providing public access to the project results and encourage their use in commercial and public systems for interested parties.

3.2.1 Guideline for Industrial Partners

General strategy

- Focus on the main results from the project (products, services) and their commercial viability.
- Consider new business and operating models that become possible with the project for bringing the project results to customers/interested parties. Explore the role of third parties (not participating in the project).
- Identify drivers for a successful exploitation and consider how those drivers can be harnessedand strengthened.
- If there are obstacles to a successful exploitation of the project from today's perspective,address them early on.
- Put a strong focus on how European stakeholders (customers of cloud services, providersof cloud services) can profit from the exploitation of the results.
- Develop a timeline for exploitation, showing how the exploitation can be structured in phases. Identify the prospective time frame after the end of the project to bring the results to the market.

- Identify concrete customer needs that are addressed with the solution and product, and describe ways to quantitatively measure the success.
- Involve potential marketing.
- Consider synergies for exploitation with other projects, possibly also funded ones.

Economic factors

- Aim at a quick access to the market. If necessary, create new markets for a successful exploitation.
- Address the market analysis, prognoses, technical developments and trents.
- Assess the competition for the developed results, in Europe and worldwide.
- Provide innovation in project results, ensure there are advantages compared to other already available systems.

Scientific and technical goals

- Assess the impact of general technological progress on the exploitation scenarios.
- Pay attention to non-technical developments (legal and privacy aspects) and their influence on exploitation.

Intellectual property

- Consider protecting intellectual property, for example, through patents.

3.2.2 Guideline for Academic Partners

General strategy

- Identify drivers for a successful exploitation and consider how those drivers can be harnessed and strengthened.
- If there are obstacles to a successful exploitation of the project from today's perspective, address them early on.
- Put a strong focus on how European stakeholders (software and hardware developers, image analysts) can profit from the exploitation of the results.

- Develop a timeline for exploitation, showing how the exploitation can be structured in phases. Identify the prospective time frame after the end of the project to bring the results to the market.
- Identify research student and staff needs that may be addressed.
- If possible, start exploitation of intermediate results already during the project.
- Consider synergies for exploitation with other projects, possibly also funded ones.

Scientific and technical goals

- Assess the impact of general technological progress on the exploitation scenarios.
- Pay attention to non-technical developments (legal and privacy aspects) and their influence on exploitation.
- Pay attention to the competition for the developed results, in Europe and worldwide.
- Provide innovation in project results, ensure there are advantages compared to competitors.

Intellectual property

- Consider to protect intellectual property, for example, through patents.

Academic impact and education

- Offer (life, online) seminars, lectures, lab-courses and the-like with topics related to the project.
- Consider to exploit the research in the project for improving the contributions to European research, like building liaisons with scientific communities, organizing or participating in workshops and conferences.
- The project should help to attract new researchers and students.
- Engage in improved dissemination activities through the project, for presenting work in conferences (industrial and academic), journals, and so on.
- Explore new scientific communities or try to get into other, relevant ones.

Sustainability

- Make the results of the work available as open-source.
- Contribute results to established open-source projects.
- Invest in maintaining the project results after the project ended, through continuously supporting the project's website after the project completion.
- Plan follow-up projects the build on the results.

- Form new relations during the duration of the project and engage with new partners in future collaborations.
- Exploit the project for acquiring new projects and further funding.

Technology transfer

- Trigger interest in the industry for the APROVIS3D project results.
- Ensure that students gain valuable knowledge by their work in the project, which they will take to industry.

3.3 Exploitation Plans from Academic Partners

In this section, the project's academic partners present their individual exploitation plans. This typically includes the offering of courses and seminars with topics related to the project. Through that, they can attract researchers and new students to work on and improve the ideas of the project.

Another area of focus for the academic partners within PANORAMIX is the exploitation of their work and project results through contributions to open-source software, particularly the PANORAMIX mix-net framework as major outcome of the project. Its maintenance presents an equally important objective to ensure that the results of PANORAMIX will remain available and relevant long after the project terminates. This can be supported by building and engaging a developer community around PANORAMIX.

The PANORAMIX software and the community that we anticipate to build around the framework will form a foundation for further research and development in the area of privacy preserving IT services. The availability of the PANORAMIX framework and API is expected to be a valuable asset for all academic partners in terms of building new partnerships, engaging in future projects and acquiring further funding at the national and EU level.

3.3.1 Exploitation Plan of Partners UCA

3.3.2 Exploitation Plan of Partner INT

3.3.3 Exploitation Plan of Partner IMSE

3.3.4 Exploitation Plan of Partner UNIWA

3.3.5 Exploitation Plan of Partner NTUA

For testing the prototype, several flights will be conducted from different heights to collect visual data (i.e., RGB images) of the same area and to obtain, through photogrammetric processing, different analysis and 3D spatial models. The 3D representation of the experimental coastal area is then to be considered as the "true data" for the final evaluation of the products resulting from the implementation of the DVS sensor data. Emphasis is given on the frequency of image collection, the size of the final ground pixel as a function of the flight height, the desired radiometric characteristics, and their intended coatings to ensure that the extraction of the 3D information complies with the requested analysis, accuracy, and visual fidelity. Therefore, the field implementation within the APROVIS3D offers exploiting and valuating the project results in comparison with known conventional sensors, such as drone/UAV RGB sensors, 3D analysis and volume reconstruction photogrammetric software, such as Agisoft, and point cloud data collected by terrestrial 3D laser scanners. In addition, Structure from Motion (SfM) algorithms for the creation of coastal orthophoto maps and multiscale deep spatial feature extraction may further explore the potential of the project prototype field implementation along coastal areas and potentially other applications.

3.3.6 Exploitation Plan of Partner ETHZ

3.3.7 Exploitation Plan of Partner UL

The contributions of UL in the project will be part of the global demonstrator. In addition, in synergy with several other on going projects at UL (ANR ULP COCHLEA, Luxant-ANVI industrial chair, Cornelia State-Region project), the knowledge, skills, software and hardware acquired or developed in the Aprovis3d project contribute to the building of a neuromorphic research platform at IRCICA, the building where the UL researchers are located. This platform is used to support several research and teaching actions in the field of embedded artificial intelligence in an interdisciplinary setting (nano-electronics, computer architecture, computer vision). In particular, we have recently created courses in neuromorphic computing in two master programs (in electronics and in computer science). These courses benefit from the results of Aprovis3d as concrete illustrations of the use of such technologies.

We have a long standing policy of contribution to open science: all our publications are available openly on the HAL archive and all our software is available with a free and open source license, both our own software packages (the N2S3 and CSNN simulators, the VS2N simulation trace visualization tool) and our contributions to other open source software packages (such as the Nengo simulator for the current project).

We also regularly participate to the dissemination of science to the general public and we will showcase the results of Aprovis3d in such events.

Activities performed in the first year.

Activities performed in the second year.

4. Third-Year Exploitation and Long-TermProject Sustainability Plan

5. Conclusions