- APROVIS3D -

Analog PROcessing of bioinspired VIsion Sensors for 3D reconstruction

Document Reference:		
Title: **D6.2.2 Exploitation Report**		
Contractor: **UNIWA**		
Prepared by: **Emmanouil Oikonomou**		
Document Type: **Deliverable**		
Version: **1**		Pages: **6**
Classification: **External document**		

Document Track

Version	Date	Remarks and Authors
1.0	19/12/2023	First draft (O. Oikonomou - UNIWA)

Authors

	Role / Function	Name	Organisation
Prepared by	WP6L	O. Oikonomou	UNIWA
Checked by	Quality	All partners	All
Released by	WP6L	O. Oikonomou	UNIWA
Approved by	Project Coordinator	J. Martinet	UCA

Table of contents

1. Exploitation Milestones 4
2. Individual Exploitation 5
2.1 Exploitation from Academic Partners 5
2.2.1. Exploitation of Partner UCA 5
2.2.2. Exploitation of Partner INT 5
2.2.3. Exploitation of Partner IMSE 5
2.2.4. Exploitation of Partner UNIWA 5
2.2.5. Exploitation of Partner NTUA 6
2.2.6. Exploitation of Partner ETHZ 6

1. Exploitation Milestones

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 demonstration scenario of the vehicle took place, establishing the communication between the internal controller of the vehicle with the onboard PC (NVIDIA Jetson AGX Xavier Developer Kit) aiming at the autonomous flight. An extensive study of the current state of the art related to event-triggered model predictive visual servo control able to handle asynchronous feedback data from a Dynamic Vision Sensor (DVS). Multiple sessions of DVS field data were collected during flight of the UAV above the coastline and shared with the consortium. Establishment also took place of the HW and SW interface between the IMSE DVS prototype, the SpiNN-3 board and the vehicle's onboard PC (NVIDIA Jetson AGX Xavier Developer Kit). Experimental validation of the developed visual servoing strategy for coastline tracking using an unmanned aerial vehicle (paper submitted in 30th Mediterranean Conference on Control and Automation 2022). Development of a robust event-triggered vision based model predictive controller for coastline tracking using a multirotor which was experimentally validated (paper submitted in IEEE/RSJ International Conference on Intelligent Robots and Systems 2022). UCA exploited SNN and Reinforcement Learning for in two scenarios: feature extraction and robot control. The feature extraction part is inspired from Multiscale Spatio-Temporal features MuST [Liu, TNNLS 2020], with a HMAX-like architecture.

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

Two technical reports were delivered:

- WP2: Technical specification for the foveal sensor (21/01/2021)
- WP4: Technical specifications for integration (16/02/2021)

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

UCA has participated in finalising the demonstrator with activities (1) on a simple 3D (ground) demonstrator using Prophesee cameras acquired on another UCA budget, and a host laptop connected to the cameras and a SpiNN-3 board), and (2) on the main flying demonstrator finalized by NTUA, UL, and INT.

The project final event took place at IMSE on September 14-15, 2023. The consortium has organised an industrial session with several companies (Inivation, Sony, Yumain, IMRA Europe, Renault Software labs, Synsense, Ucandrone) that came for two online sessions: one session where the companies have been offered the opportunity to pitch their products, and one session where the consortium did advertise the main project results to the companies. A live demonstrator is under development, in the form of a UAV autonomously following a specific ground feature. 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.

3. Individual Exploitation

2.1. Exploitation of Partner UCA

UCA released on March 31, 2021, a **short video** advertising the project for the CHIST-ERA video contest.

UCA participated in the new French ANR-funded DeepSee project, that focuses on the use of SNN for the intelligence of embedded systems, with an automotive application.

Invited talk during the **Technical Workshop on Integrated machine-learning hardware for near-sensor computing applications**, organized by CHIST-ERA **JEDAI** project.

Advertised the project to the local CNRS-UCA GéoAzur lab, which coordinates an ongoing IRD project with Luxcarta (Sophia Antipolis, expert in geodata, geospatial products, RF 3D maps of landscapes, cities), and CNRS-CNES-IRD Legos lab (Toulouse. Expert in geophysics, costal oceanography).

Organization of interactive local conference "Mind Yourself! How does computer science interact with neuro- sciences?" during the Brain week 2022 at UCA by A. Gruel at Learning Centre SophiaTech (approx. 40 participants).

2.2. Exploitation of Partner INT

INT started the ANR AgileNeuroBot project in synergy with the APROVIS3D project.

INT presented neuromorphic algorithm at CBMI by applying the results to a larger palette of existing datasets, and by bridging the neuromorphic algorithm with the building blocks which form Spiking Neural Networks.

INT initiated the installation and maintenance of a data-sharing infrastructure on a privately owned server and domain name Spik.xyz. This server was allocated using funding from a previous source obtained by the consortium, under the coordination of INT, spikeAI.

2.3. Exploitation of Partner IMSE

http://www2.imse-cnm.csic.es/neuromorphs/index.php/Projects, organization of a special session on Bio-inspired circuits, systems and algorithms for multimedia during CBMI'2021, Lille, France.

IMSE has developed the code for the microcontroller embedded in the PCB of the 128x128 EF-DVS. A Graphical User Interface (GUI) has also been developed.

IMSE Patent: T. Serrano-Gotarredona and B. Linares-Barranco, 'Electronically Foveated Dynamic Vision Sensor', ES1641.1671.

2.4. Exploitation of Partner UNIWA

Advertisement of the project in the 3rd educational visit (14-17 March 2022 in Athens) of Erasmus+ project, GeoDRR (Geomatics for Disaster Risk Reduction) by spreading out dissemination results to gain attention from future PhD candidates in the subject of automated coastline detection for risk reduction.
UNIWA proposed a study case of mapping the coastal zone with the APROVIS3D UAV set-up. The proposed area is a small pocket-beach located in the South-eastern Attica in Greece, it is easily accessible for repeatability of experiments, and it offers considerable seasonal changes of its coastline.

Furthermore, HCMR (Hellenic Center for Marine Research) is located onsite, offering the possibility of static monitoring event camera setup to capture extreme weather events (beach before and after a sea storm).

2.5. Exploitation of Partner NTUA

- implementation of a hybrid MB/DD approach for the coastline motion estimation. The actual multirotor velocity, The estimated errors are incorporated as feedback into a PVS planning and tracking control scheme to achieve the octorotor's autonomous vision-based navigation along a shoreline
- experimental validation of the developed visual servoing strategy for coastline tracking using an unmanned aerial vehicle (paper published in MDPI Drones Special Issue on UAVs for Coastal Surveying)
- utilization of an event-based Neuromorphic implementation of the Hough Transform on a neuromorphic chip (SpiNN-3 board) for line detection
- development of a tracking algorithm with conventional computing (NVIDIA Jetson AGX Xavier Developer Kit)
- design, development and testing of the visual servoing algorithms that will be able to handle event-based asynchronous data deriving from the DVS configuration and the SNN detection algorithms
- experimental validation of the developed visual servoing strategy for pavement tracking using an unmanned aerial vehicle (paper submitted in IEEE/RSJ International Conference on Intelligent Robots and Systems 2023)
- Parallel collaboration with UCA and INT for the development of a newly trained SNN for coastline detection which will be utilized in coastline tracking applications using the UAV.

2.6. Exploitation of Partner ETHZ

ETHZ put the majority of effort to have a fully working prototype around the Kraken SoC to have the first ever fully neruomorphic UAV. ETH is working on implementing and designing spiking neural network algorithm for event-based data on real platform such as the Intel Loihi Platform and the ETH system on chip Kraken. ETHZ focused on the implementation of a multi-object detection spinking algorithm on Intel Loihi in collaboration with UCA. In autumn 2021 a visit from UCA has been organized and hosted to work in collaboration on the algorithm and its implementation. The results of this collaboration have been included in a recent publication at IEEE AICAS 2022 and it will be presented at the conference in June 2022. ETH also collaborated with IMSE to support the connection with Spinnaker of their camera and use the DVS Camera to extract samples. Finally, ETHZ worked on the system architecture definition for the final prototype of the drone that will be included the IMSE camera, a neuromorphic platform with one of the 2 current adopted neuromorphic processors SpiNNaker and Intel Loihi, and the control unit based on standard digital hardware such the NVIDIA jetson.