MISSIONE 4
ISTRUZIONE RICERCA

RESTART

THE COBS4FUN PROJECT

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1 Introduction

This repository will host the tools developed and the deliverables produced as part of the COBS4FUN project. COBS4FUN stands for *"Compression of Biometric Signals for FUture Networks applications"* and was a cascade call project of the structural project S7 FUN-Media, coordinated by the Politecnico di Torino (Spoke 4) and funded by the European Union – NextGenerationEU as part of the NRRP – M4C2, Investment 1.3, program "RESearch and innovation on future Telecommunications systems and networks, to make Italy more smART" (RESTART), PE00000001.

The research activities within the COBS4FUN project were developed entirely by a research team at the University of Messina, under the supervision of Prof. Giuseppe Campobello, who acted as the Principal Investigator.

The main objective of COBS4FUN was to develop new formats and compression techniques for the efficient encoding and transmission of biometric signals, with a strong emphasis on their applicability to future network environments, including Metaverse and Digital Twins use cases.

In the following sections, we provide a summary of the research outcomes and tools developed within the COBS4FUN project. The results will be released at the end of the project in accordance with the disclosure policies established by the Spoke and the RESTART Foundation that funded the project.

2 COBS4FUN: Main Results

The COBS4FUN project was structured around four work packages (WPs), which guided the development of the project. Each work package addressed key challenges and milestones, from the initial analysis of the state of the art of biometric signals and compression techniques to the development of a comprehensive framework for managing biometric signals and traits.

2.1 WP1: Compression Techniques for Biometric Signals and Traits: State of the Art and Use Cases

In WP1 we conducted a comprehensive and systematic review of the state of the art regarding the use of biometric signals for Digital Twin and Metaverse applications, with a specific focus on signals that require new compression techniques. As outlined in **Milestone 1**, the analysis led to the identification

of the most relevant physiological signals for future Digital Twin applications. Additionally, the most significant publicly available datasets for these signals and their related biometric applications were identified.

As part of **Milestone 2**, an in-depth analysis was conducted on state-of-the-art compression techniques for biometric signals, specifically EEG, ECG, PPG, and EMG. The review covered existing encoding, transformation, and deep learning techniques used in the compression of these biometric signals. The study examined their technological limitations, effective performance metrics, and identified areas for improvement.

Two key deliverables were produced as a result of WP1:

D1.1: *"Biometric Signals and Traits for Digital Twin Applications: State of the Art"*

D1.2: *"Compression Techniques for Biometric Signals and Traits: State of the Art"*

2.2 WP2: Compression Techniques for Biometric Signals and Traits: Performance Analysis and Impact Assessment

WP2 was dedicated to the experimental evaluation and comparison of state-of-the-art compression algorithms for biometric signals, specifically focusing on lossy and near-lossless techniques. Key activities and results are as follows:

1. *Experimental Analysis of Compression Algorithms*: A comprehensive comparison of 15 state-of-the-art compression algorithms was performed using 18 publicly available datasets. These datasets included 9 EEG, 7 EMG, 1 ECG, and 1 iris image dataset (comprising over 7200 iris images), and required over 800 hours of data processing. The algorithms were assessed in terms of their trade-off between distortion and compression efficiency, with a focus on the impact of key compression parameters. Among the algorithms analyzed, particular attention was given to the VAWC codec, developed by Fraunhofer HHI in September 2024 and proposed for standardization by ITU and DICOM, as well as BrainCodec, developed in February 2025 by IBM and ETH Zurich. These findings are documented in *Deliverable D2.1: "Compression Techniques for Biometric Signals and Traits: Performance Analysis."*

2. *Energy Consumption Analysis*: As part of the project's **Milestone 3**, a measurement setup was developed to assess the energy consumption of different compression techniques. This setup enabled the comparison of algorithms in terms of their energy efficiency, identifying those most suitable for integration into wearable devices with limited energy resources. Furthermore, according to **Milestone 5**, we demonstrated the feasibility of implementing near-lossless compression codecs with low energy consumption and acceptable distortion levels, ensuring their suitability for biometric applications. The results and evidence of Milestones 3 and 5 are provided in Deliverable D2.1.

3. *Impact of Compression on Biometric Applications*: According to **Milestone 4**, the maximum acceptable distortion introduced by lossy and near-lossless compression techniques was determined for several key biometric applications of interest to the Digital Twin and Metaverse paradigms. The analysis focused on the impact of compression on heart rate estimation, seizure detection using EEG signals, gesture recognition using EMG signals, and iris-based biometric recognition. The findings regarding acceptable distortion thresholds for these applications are detailed in *Deliverable D2.2: "Impact Evaluation of Compression Techniques on Biometric Applications."*

2.3 WP3: Development of Codecs and Data Exchange Formats for Multimodal and Energy-Efficient Biometric Applications

The activities carried out within WP3 have led to the development of a comprehensive framework for managing biometric signals and traits, capable of making the exchange of biometric data more efficient in biomedical, Metaverse and Digital Twin applications. Specifically:

- A new format for biometric data, called **BMD**, has been designed to overcome the limitations of existing formats. The new format allows for the representation of multimodal biometric data - including multichannel physiological signals and images - in addition to annotations and metadata. The format is open and easily extensible, thanks to its support for dynamic fields, and it handles both compressed and uncompressed data. It also provides the ability to encrypt or remove personal information to protect privacy, as well as supporting the application of digital signatures to ensure data authenticity. The completion of this task fulfilled **Milestone 6**, which involved the full definition of the new data exchange format for biometric signals and traits. This work is detailed in *Deliverable D3.2 "BMD: A New Data Exchange Format for Biometric Signals and Traits"*, which provides a comprehensive description of the BMD format;

- A graphical tool, called **BMDComposer**, has been developed specifically for creating and managing biometric data archives compliant with the new BMD format. The tool, implemented in Python, has a modular architecture and offers an intuitive interface that simplifies the entire workflow, from the management, visualization, and annotation of biometric data to compression, encryption, and digital signing. The tool's development and integration into the BMD framework, as described in Deliverable D3.2, contributes directly to the objectives of Milestone 6, providing the necessary software to support the new format's adoption.

- Two new codecs have been developed: one lossless, RAKE LS, which is designed to be general and applicable to all types of biometric signals, and one near-lossless, RAKE4EMG, which is specifically optimized for EMG signals. Both codecs are compatible with the computational and energy resources of the capturing devices used for extended reality (XR) and Digital Twin applications. Experimental results confirming their performance are documented in *Deliverable D3.3* titled *"Low-Complexity Compression Techniques for Wearable Capturing Systems."* This deliverable includes experimental data on energy consumption and processing times, demonstrating the codecs' applicability for wearable devices with limited bandwidth and energy resources, in line with **Milestone 7**.

- The **COBS** (Compression of Biometric Signals) tool has been developed, providing advanced capabilities for the development, integration, and evaluation of compression algorithms, while supporting research and experimentation activities in the field of biometric data compression. The functionalities of the COBS toolkit, including the graphical interface and the integrated compression techniques, are detailed in *Deliverable D3.1* titled *"COBS: A New Toolkit for Compression of Biometric Signals and Traits."* This deliverable also discusses the various tools integrated within the toolkit for prediction, encoding, and transformation tasks.

  The release of the COBS toolkit marked the achievement of **Milestone 8**, which was focused on providing an open-source solution to facilitate biometric signal compression research.

2.4 WP4: Dissemination and Technology Transfer Activities

WP4 has been dedicated at disseminating, sharing, and transferring the fundamental knowledge, the methodologies, and the technologies gained during the project. With the aim of enhancing the scientific dissemination of the achieved results, WP4 has been originally scheduled for the final six month

of the project. Nevertheless, it should be pointed out that the dissemination activities were continuously developed and coordinated by the project's coordinator throughout the entire duration of the project. These activities are considered essential and pervasive, and have therefore been carried out across all work packages, with active participation from all researchers involved in the project. The promotion and dissemination of the project activities and outcomes have been performed throughout the project lifetime by employing multiple channels of knowledge transfer, with the goal of reaching all possible beneficiaries and stakeholders who are interested in the project's outcomes (the scientific community, industries, other public and private actors). As part of **Milestone 9**, the deliverable *D4.1*, entitled *"The COBS4FUN project: Main Results and Dissemination Activities*, provides a comprehensive overview of the dissemination and technology transfer results, including publications, event organization efforts and standardization activities. It also includes an evaluation of the impact and effectiveness of these activities in reaching the relevant stakeholders.

3 Related Publications

1. F. Battaglia, M. Galanti, G. Gugliandolo, S. Rampp, J. Remi, A. Parashos, S. Sharma, S. Bhatia, B. C. Dean, E. Kutluay, Z. Campbell, S. Schmitt, N. Donato, J. J. Halford, and G. Campobello, "Neurophysiology Signal Codecs for the DICOM® Standard: Preliminary Results," *2024 IEEE International Symposium on Medical Measurements and Applications (MeMeA)*, Eindhoven, Netherlands, 26-28 June 2024, pp. 1-6, doi: 10.1109/MeMeA60663.2024.10596834 (link: https://ieeexplore.ieee.org/document/10596834)

2. J. J. Halford, G. Campobello, B. H. Brinkmann, M. Stead, S. Rampp, J. Rémi, K. B. Nilsen, J. Dauwels, M. Galanti, B. C. Dean, S. Winkler, J. A. Ehrenberg, J. Pfaff, and G. J. Sullivan, "Letter to the Editor: Announcement of a Call for Proposals for biomedical waveform coding," *Clinical Neurophysiology*, vol. 165, pp. 88-89, September 2024, doi.org/10.1016/j.clinph.2024.06.010 (link: https://www.sciencedirect.com/science/article/abs/pii/S1388245724001834?via%3Dihub)

3. R. Albano, F. Battaglia, E. Maiorana, G. Campobello, and P. Campisi, "Effects of Compression on Attention-based Iris Presentation Attack Detection," *33rd European Signal Processing Conference (EUSIPCO2025)*, Palermo, Italy, 8-12 September 2025, pp. 1347-1351. (link: https://eusipco2025.org/wp-content/uploads/pdfs/0001347.pdf)

4. R. Albano, F. Battaglia, A. Gnutti, E. Maiorana, F. Guerrini, G. Campobello, P. Migliorati, and P. Campisi, "Transformers for Iris Presentation Attack Detection: Effectiveness and Behavior under Image Compression," *24th International Conference of the Biometrics Special Interest Group (BIOSIG 2025)*, Darmstadt, Germany, 25-26 September 2025, pp. 1-10.

4 Acknowledgement

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