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| **ITU – Telecommunications Standardization Sector**  STUDY GROUP 16 Question 6  **Video Coding Experts Group (VCEG)**  71st Meeting: 24-28 April 2023, Antalya | Document: VCEG-BT01 |

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| Question: | Q.6/SG16 (VCEG) | | |
| Source: | **Thomas Wiegand (AHG chair)** | Email: | thomas.wiegand@hhi.fraunhofer.de |
| Title: | AHG report on the coding of medical and general waveform data | | |
| Purpose: | Information | | |

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**Abstract**

This document contains a report of the Ad Hoc Group on the coding of medical and general waveform data. The AHG was requested to do the following:

* Perform gap analysis
* Study requirements
* Collect example signal data for experimentation
* Produce a draft A.1 justification for development of a Recommendation on the subject
* Communicate with DICOM on the above goals

1. **Background**

This AHG was established following receipt of a liaison statement [TD 103/Gen](https://na01.safelinks.protection.outlook.com/?url=http%3A%2F%2Fwww.itu.int%2Fmd%2Fmeetingdoc.asp%3Flang%3Den%26parent%3DT22-SG16-230710-TD-GEN-0103&data=05%7C01%7C%7Cf93d93f41ec743329b3208daf6438636%7C84df9e7fe9f640afb435aaaaaaaaaaaa%7C1%7C0%7C638093067122342522%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=8%2FKJ476FS6B0ZjOxkx9v8iHU12DPdG3CgkyUboBv0Fo%3D&reserved=0) from DICOM WG32. The liaison statement reported a need for the coding of time-based neurophysiology signal data. It noted that there is no well-accepted codec for biomedical waveform data such as electrocardiography (ECG), electroencephalography (EEG), and electromyography (EMG) signals.

1. **Activities**

The VCEG email reflector was used for communication related to the AHG.

Relevant publications [1]-[4] have been mentioned either on the reflector or by other means.

Results on lossless compression experiments with different state-of-the-art codecs for compressing data from the PTB-XL electrocardiography (ECG) dataset (<https://physionet.org/content/ptb-xl/1.0.3/>) [5][6] have been reported in DICOM. Compression gains range from 35% to 71% bitrate reduction for the three general purpose compression schemes GZip, LZMA, and BZip2, as well as the audio compression scheme FLAC and the ISO/IEC 15938-17 Neural Network Coding (NNC) standard.

Other experts confirmed that these results are in line with their own observations for compression of EEG data and suggested to additionally conduct compression experiments using lossy audio codecs.

As a response, it was suggested to define common test conditions regarding distortion measure, datasets and reporting formats on the upcoming VCEG meeting before conduction lossy compression experiments.

1. **Gap analysis**

Waveform data can be encoded using audio compression technology while disabling the use of psycho-acoustic masking and potentially overcoming limitations on channel number and block size. However, the following aspects are noted:

* There is a need for very high quality coding, with near-lossless and potentially lossless coding capabilities
* Lossless coding for audio is typically achieved by having a special mode of lossless operation (e.g. MPEG-4 ALS or FLAC), and the bit rate savings (relative to the bit rate of PCM input data) for lossless operation is modest
* Some audio formats already support large numbers of channels, a variety of input bit depths, arbitrary sampling rates, etc. (again MPEG-4 ALS)
* Lossless coding can instead be achieved with a scalable approach, where a basic signal representation is enhanced with a lossless residual signal. MPEG-4 SLS is one such approach.

1. **Requirements**

The following requirements are suggested:

* Support for 16 to 24 bits per sample (possibly higher)
* Support for various sampling rates (clinically usually up to 500–2000 sample/s, up to 40k samples/s for research)
* Support for a large number of channels (up to hundreds)
* Near-lossless and lossless capability; a lossless approach will not produce better than a 2-3X compression ratio, which is not sufficient.
* The use of mutual information between channels to improve compression performance may be considered.
* Blocking and indexing is necessary for rapid access within large datasets. Block size should be optimized for the type of compression. Index to blocks can be stored outside of encapsulated bitstream (such as in fragments/frames encoding in DICOM).
* All channels will probably have the same (fixed) sampling rate and reference timeline, but this will need to be discussed.

1. **Example signal data for experimentation**

PTB-XL electrocardiography (ECG) dataset (<https://physionet.org/content/ptb-xl/1.0.3/>) [5][6]; others to be identified.

Creation of a testing dataset composed of scalp EEG, intracranial EEG, ECG, and EMG data is desired. The testing dataset should include approximately 30 datasets from each category that contain signals with relevant features (such as epileptiform discharges and seizures for EEG).

1. **Draft A.1 justification**

An initial draft A.1 justification for a proposed draft new ITU-T Recommendation on this topic is attached as an annex to this report.

**References**

1. K. Konstantinides and B. K. Natarajan, “An architecture for lossy compression of waveforms using piecewise-linear approximation”, *IEEE Transactions on Signal Processing*, vol. 42, no. 9, pp. 2449-2454, Sept. 1994, doi: <https://doi.org/10.1109/78.317866>.
2. Giuseppe Campobello, *et al.*, Theoretical and Experimental Investigation of an Efficient SVD-based Near-lossless Compression Algorithm for Multichannel EEG Signals, *IEEE International Symposium on Medical Measurements and Applications* (MeMeA), 2022.
3. Justin Dauwels, *et al.*, “Near-Lossless Multichannel EEG Compression, Based on Matrix and Tensor Decompositions”, *IEEE Journal of Biomedical and Health Informatics*, Vol. 17, No. 3, May 2013.
4. Benjamin H. Brinkmann, *et al.*, “Large-scale electrophysiology: Acquisition, compression, encryption, and storage of big data”, *Journal of Neuroscience Methods* 180 (2009) 185–192.
5. Wagner, P., Strodthoff, N., Bousseljot, R., Samek, W., & Schaeffter, T. (2022). PTB-XL, a large publicly available electrocardiography dataset (version 1.0.3). *PhysioNet*. <https://doi.org/10.13026/kfzx-aw45>.
6. Wagner, P., Strodthoff, N., Bousseljot, R.-D., Kreiseler, D., Lunze, F.I., Samek, W., Schaeffter, T. (2020), PTB-XL: A Large Publicly Available ECG Dataset. *Scientific Data*. <https://doi.org/10.1038/s41597-020-0495-6>.

**New normative work item A.1 justification template**

***Start of template***

**Annex 1  
A.1 justification for** **proposed draft new ITU-T B.xyz "Coding of Neurophysiology signals and similar waveforms"**

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| **Question:** | Q6/16 | **Proposed new ITU-T Recommendation** | Online or Venue, day-day month year | | |
| **Reference and title:** | Neurophysiology Waveform Codec | | | | |
| **Base text:** | SGy-Cnnn or SGy-TDnn[/WPn] | | | **Timing:** | YYYY-MM |
| **Editor(s):** | Name, membership, e-mail address | | | **Approval process:** | AAP |
| **Scope**  A compressed coding format for neurophysiology data which can be used by DICOM and possibly other organizations | | | | | |
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| **Summary** (provides a brief overview of the purpose and contents of the Recommendation, thus permitting readers to judge its usefulness for their work): | | | | | |
| An impediment to advancing standardization for neurophysiology and electrocardiography data is the lack of a codec designed for these types of biomedical signals. Current audio codecs have significant limitations when applied to biomedical waveform data due to application of psychoacoustic masking approaches and limitations on channel number and block size. An option for a lossless and near-lossless codec/transmission-syntax specifically for biomedical waveform data is almost certainly needed.  Neurophysiology data currently consists of 16-24 bit data with between 21 and several hundred channels sampled at between 256 and 40K Hz. Clinical scalp EEG is typically 21 channels sampled at between 256 and 1000 Hz. Clinical intracranial EEG consists of between 64 and several hundred channels sampled with a bit depth of 16 or 24 bits at around 2000 Hz. Research intracranial EEG (human and animal neurophysiology) involves up to several hundred channels sampled at a bit depth of 16 or 24 bits and a sampling rate up to approximately 40K Hz.  The codec will require:   1. Lossy or near-lossless design to optimize compression. A lossless approach will not produce better than a 2-3X compression ratio, which is not sufficient. 2. Blocking and indexing is necessary for rapid access within large datasets. Block size should be optimized for the type of compression. Index to blocks can be stored outside of encapsulated bitstream (such as in fragments/frames encoding in DICOM). 3. Optional use of mutual information between channels to improve compression performance 4. All channels will probably have the same sampling rate, but this will need to be discussed. | | | | | |
| **Relations to ITU-T Recommendations or to other standards** (approved or under development)**:** | | | | | |
| TBD | | | | | |
| **Liaisons with other study groups or with other standards bodies:** | | | | | |
| DICOM WG32 | | | | | |
| **Supporting members that are committing to contributing actively to the work item:** | | | | | |
| List names of supporting Member States, Sector Members, Associates, Academia | | | | | |

***End of template***

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