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## Data Article

## Doppler ultrasound dataset for the development of automatic emboli detection algorithms



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## ABSTRACT

The article describes a dataset of doppler ultrasound audio tracks taken on a sample of 30 divers according to the acquisition protocol defined by the Divers Alert Network. The audio tracks are accompanied by a medical evaluation for the decompression sickness risk according to the Spencer's scale levels.

During the acquisition campaign, each diver in the post-dive phase was subjected to a double doppler ultrasound examination of approximately 45 seconds each one in the precordial area using a Huntleigh FD1 Fetal doppler probe. The two measurements were separated by a time of 8–10 seconds necessary for carrying out specific physical exercises designed to free the bubbles trapped in the tissues. The audio tracks were stored without compression via the TASCAM DP-004 recorder and processed in order to eliminate the noise generated by the positioning of the probe and the time interval between the two measurements.

The audio tracks recorded during the acquisition campaign have been evaluated by experts belonging to three independent blind teams in order to provide an assessment of the decompression sickness risk according to Extended Spencer's scale. The specific typology of doppler ultrasound audio tracks and the associated medical evaluation according to the Spencer's scale levels make this dataset useful for the development, testing, and performance

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evaluation of new audio processing algorithms capable of automatically detecting bubbles in the blood vessels.

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#### Specifications Table

Subject	Electrical and Electronic Engineering
Specific subject area	Audio signal processing for embolic detection
Type of data	Audio wave (.WAV) files Text file
How data were acquired	Doppler probe (FD1 2-MHz, Huntleigh Ltd, Cardiff, UK) Digital recorder (Tascam DP-004; TEAC America Inc., Montebello, CA, USA)
Data format	Raw, Filtered and analyzed
Parameters for data collection	The subjects involved in the dataset were 30 professionals and amateurs scuba divers (18 males and 12 women), aged between 25 and 65 years. Doppler ultrasound acquisitions were performed in the divers about 35 minutes after surfacing. Diving activities were carried out in the Maldives and Madagascar area. All participants who volunteered gave their informed consent before each acquisition.
Description of data collection	The ultrasound doppler signals were acquired in the precordial area with two consecutive measurements of about 45 seconds each interspersed with about 10 seconds of motor activity to free the bubbles trapped in the tissues. The audio tracks once acquired have been filtered eliminating a few seconds at the beginning and at the end of the entire recording and the interval between the two measurements in order to reduce the unwanted noise due to doppler probe positioning. For each acquisition an assessment of the circulating bubbles according to the extended Spencer scale has been provided by experts.
Data source location	Department of Information Engineering, Università Politecnica delle Marche, Ancona, Italy
Data accessibility	With the article
Related research article	Paola Pierleoni, Lorenzo Palma, Alberto Belli, Massimo Pieri, Lorenzo Maurizi, Marco Pellegrini and Alessandro Marroni "An EMD-Based Algorithm for Emboli Detection in Echo Doppler Audio Signals" Electronics <a href="https://doi.org/10.3390/electronics8080824">https://doi.org/10.3390/electronics8080824</a> [1]

#### Value of the Data

- Data are useful to develop and test new audio processing algorithms for emboli events detection and evaluation of the decompression sickness risk level.
- Researchers and developers who want to implement systems for emboli detection using doppler ultrasound acquisition.
- Data can be used as a benchmark for performance evaluations of different algorithms able to automatically detect gas bubbles in blood vessels.
- In addition to the previously introduced values, this dataset is the only one that provides doppler ultrasound acquisitions accompanied by medical evaluation for sickness risk according to the Spencer's scale.
- Dataset could be exploited for teaching to operators on how to evaluate a doppler ultrasound track accordingly to Spencer's scale levels.

## 1. Data

The proposed dataset provides a complete set of Doppler Ultrasound (DU) audio tracks acquired from scuba divers after the emersion. Each DU audio track was evaluated by experts in order to assess the decompression sickness risk according to the Extended Spencer's scale (ESS) [2].

The dataset is contained in Dataset\_DU.zip file accessible as a supplementary file of this article. Within Dataset\_DU.zip, data are organized in one main directory, Dataset\_DU, containing the DU audio tracks and a file Eval.txt. The Eval.txt file contains a table which provides the level of the ESS associated

with each DU audio track. In Eval.txt file the first column indicates the file number (X) of the DU audio track and the second indicates the relative level of the Extended Spencer's scale. The analysis and the subsequent evaluation according to the ESS was conducted by DAN medical staff.

Each DU audio track is a WAVEform audio file format called DU\_X.wav, where X = 1, 2, ..., 30 indicates the file number. Table 1 shows the number of DU audio tracks contained in the dataset for each Spencer level:

## 2. Experimental design, materials, and methods

The data of the proposed dataset were acquired based on the guidelines defined in the acquisition protocol set by the Divers Alert Network (DAN) [3] which defines the precordial region as the optimal zone of the human body for the detection of bubbles in the blood vessels [4]. In fact, numerous studies have shown that this region, although affected by cardiac noise that can be eliminated through signal processing algorithms [5–7], allows to obtain a complete evaluation of all the bubbles present in the blood vessel.

The protocol also defines the exact acquisition procedure to follow in order to obtain an overall analysis of the bubble situation of each diver. The protocol provides for alternating measurements in the precordial zone with a series of exercises to free the bubbles entrapped in the tissues. The exercises defined by the DAN medical team, are 2/3 folds on the legs, repeated a few times and performed freely according to the scuba divers' abilities and physical conditions, all to avoid endangering the person's health.

The acquisition procedure of the protocol starts approximately 35 minutes after scuba diver emersion in order to allow the formation of bubbles. In fact, according to some studies [8], the peak time for release of the bubbles is between 30 min and 60 min after surfacing. It consists of three consecutive phases:

- 45 seconds during which a measurement of the doppler signal of blood vessels in the precordial is performed
- 8–10 seconds in where the scuba diver performs the series of exercises
- 45 seconds during which a measurement of the doppler signal of blood vessels in the precordial is performed

According to the previous protocol DU audio tracks were collected in a specific acquisition campaign which was conducted on 30 scuba divers (60% male and 40% female) between professionals and amateurs, aged between 25 and 65 years during the diving activities in the Maldives and Madagascar. The audio tracks presented were collected through a Huntleigh FD1 Fetal Doppler with 2 MHz probe (FD1, Huntleigh Ltd., Cardiff, UK) and a digital recorder (Tascam DP-004, TEAC America Inc., Santa Fe Springs, California, USA) which does not compress audio files and uses a linear pulse code modulation (LPCM) format for data storage. Moreover, great care has been taken in adjusting the input signal of the recorder to a level that avoids audio saturation because it could irreparably compromise the recorded file. It was decided to process the audio tracks in order to eliminate any unwanted noise generated by the doppler probe positioning during the initial and final phase of the measurement, as well as in the interval between the two acquisitions. For this reason, at the beginning and at the end of the recording 1–2 seconds of acquisition were cut, but also the whole interval between the two measurements.

The dataset provided also presents an evaluation of the decompression sickness risk which was performed by experts belonging to three independent blind teams. The DU audio tracks of the proposed dataset were evaluated by each blind team that provide file's annotations report containing the

**Table 1**  
Number of DU audio tracks in the dataset for each ESS level.

ESS Level	0	0,5	1	1,5	2,5
Number of tracks	9	6	10	3	2

number of embolic event and the corresponding Extended Spencer's scale level. The level of the ESS indicated in this dataset was derived from a subsequent analysis of the file's annotations reports carried out by DAN medical staff.

## Acknowledgments

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## Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dib.2019.104739>.

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