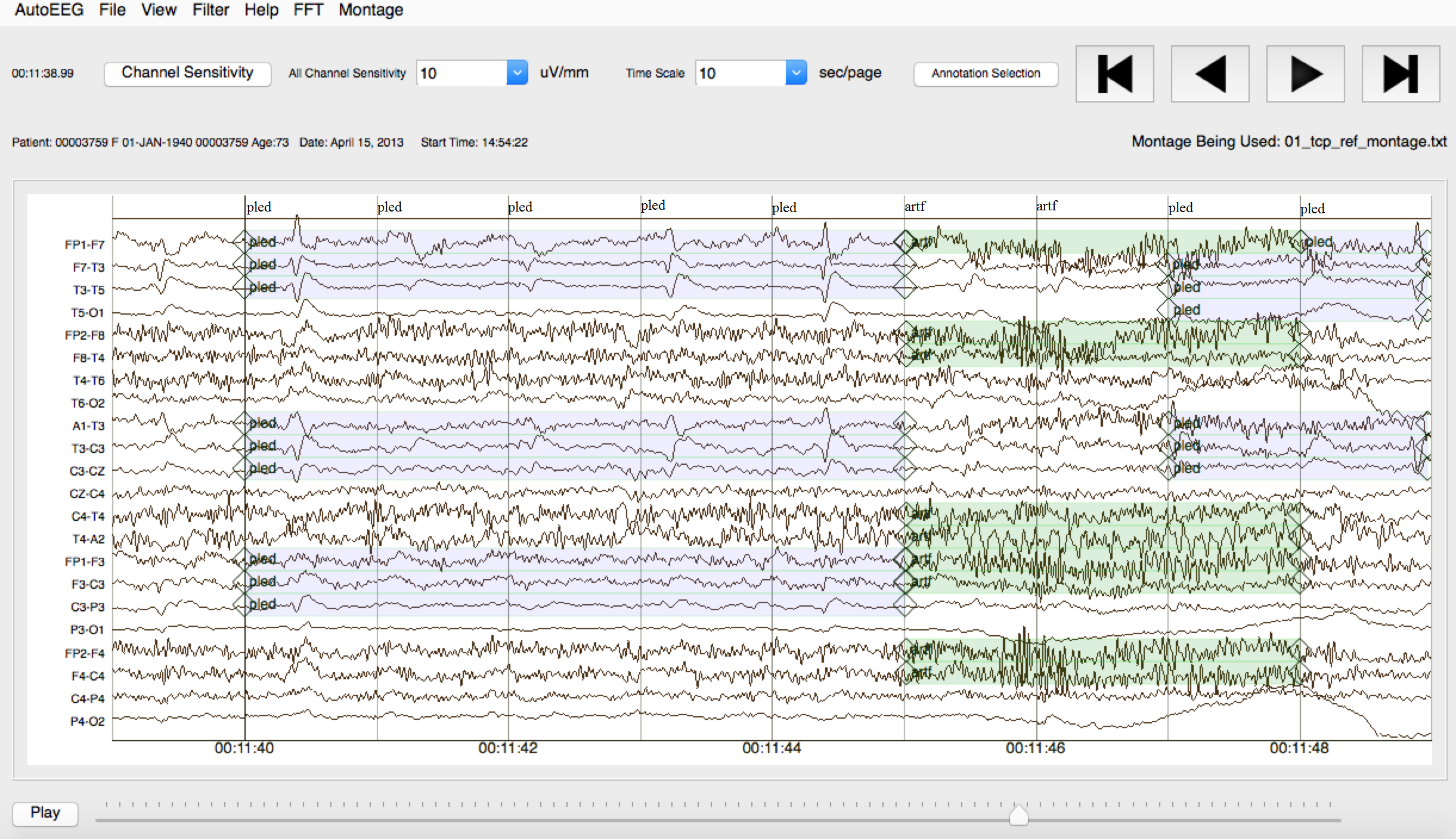
**The Temple University Hospital EEG Corpus:**

**Annotation File Formats**



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1. **Introduction**

The goal of this document is to describe the file formats used to store annotations for the Temple University Hospital EEG (TUEG) Corpus (Obeid & Picone, 2016). Subsets of the corpus have been manually annotated (Veloso et al., 2017) and are available from our project web site (Choi et al., 2017). These annotations are stored in two formats: a label file (\*.lbl\*) that represents an annotation as a hierarchical graph, and a time-synchronous event file (\*.tse\*) that represents an annotation as a flat series of events with start and stop times, type of seizure, and probability. In this document, we describe each of these formats. Tools to read and display this information are also available from our project web site (Capp et al., 2018; McHugh & Picone, 2016).

In this report, we discuss one particular subset of TUEG that has been extensively annotated: The TUH EEG Seizure Corpus (TUSZ). This corpus was developed to support the development of automatic seizure detection technology (Golmohammadi et al., 2018) and contains four different types of annotations. An example of the annotations available for this corpus are shown in . There are six types of files available in this corpus:

total 68

drwxrwsr-x 2 tug90975 isip 4096 Aug 9 03:44 ./

drwxrwsr-x 3 tug90975 isip 4096 Aug 9 03:44 ../

lrwxrwxrwx 1 tug90975 isip 91 Aug 9 03:44 00010861\_s001.txt

lrwxrwxrwx 1 tug90975 isip 96 Aug 9 03:44 00010861\_s001\_t000.edf

-rw-rw-r-- 1 tug90975 isip 29297 Aug 9 03:44 00010861\_s001\_t000.lbl

-rw-rw-r-- 1 tug90975 isip 29295 Aug 9 03:44 00010861\_s001\_t000.lbl\_bi

-rw-rw-r-- 1 tug90975 isip 233 Aug 9 03:44 00010861\_s001\_t000.tse

-rw-rw-r-- 1 tug90975 isip 233 Aug 9 03:44 00010861\_s001\_t000.tse\_bi

Figure 1. A typical directory is shown for the TUSZ Corpus. The \*.txt file contains an EEG report. The \*.edf file contains the EDF signal data. There are four types of annotation files included. These are described in this report.

\*.edf: the EEG sampled data in European Data Format (edf)

\*.txt: the EEG report corresponding to the patient and session

\*.tse: term-based annotations using all available seizure types (multi-class)

\*.tse\_bi: same as \*.tse except only two types of labels are used (bi-class: seizure/background)

\*.lbl: event-based annotations using all available seizure types (multi-class)

\*.lbl\_bi: same as \*.lbl except only two types of labels are used (bi-class: seizure/background)

These annotations use one of two formats: (1) *event-based:* annotations of start time, stop time, and seizure type on a specific channel; (2) *term-based:* all channels share the same annotation, which is an aggregation of the per-channel annotations. There are also two classes of annotations that are useful for machine learning research: (1) *multi-class:* annotations that provide users with the specific type of seizure event; (2) *bi-class:* simply describe whether or not a seizure has occurred. The purpose of this document is to describe these annotation standards and document the file formats used to store this information.

1. **Annotation Labels**

We currently annotate EEG data using twenty-seven labels and these are briefly described in . This table is distributed as part of the documentation directory, \_DOCS, that is released with the data. This list of labels is used in all of our manual annotations involving EEG data. Each of the subsets we have developed use a specific set of labels from the twenty-seven available. We maintain this global set of symbols and do not override them or create overlapping conventions. We typically add new symbols to this list, but do not change existing symbols without a community-wide discussion (and re-mapping of existing data).

The TUH EEG Events Corpus (TUEV) introduces a six-way classification system and uses six of the twenty-seven labels. These were the original labels described in our initial work on automatic interpretation of EEGs (Harati et al., 2013). The annotations we developed describe six patterns of clinical interest. The first three patterns are useful in diagnosing brain disorders are:

Table 1. A summary of the labels used to annotate EEG data is shown.

|  |  |  |
| --- | --- | --- |
| **Index** | **Label** | **Description** |
| 0 | null | An undefined annotation. Should not be seen in the data. |
| 1 | spsw | Spike and/or slow wave. A short duration epileptiform event involving an electrographic spike in activity and/or a slow wave (low frequency wave). Usually no more than 1 sec. in duration. |
| 2 | gped | Generalized periodic epileptiform discharge. Periodic diffuse spike/sharp wave discharges across multiple regions or hemispheres. |
| 3 | pled | Periodic lateral epileptiform discharge. A regular, periodically occurring spike/sharp wave seen in a certain locality of the scalp. |
| 4 | eybl | Eyeblink. A specific, sharp, high amplitude eye movement artifact corresponding to blinks. |
| 5 | artf | Artifact. Any non-brain activity electrical signal, such as those due to equipment or environmental factors. |
| 6 | bckg | All other non-seizure cerebral signals. |
| 7 | seiz | Seizure. A basic annotation for seizures. |
| 8 | fnsz | Focal nonspecific seizure. A large category of seizures occurring in a specific focality. |
| 9 | gnsz | Generalized seizure. A large category of seizures occurring in most if not all of the brain. |
| 10 | spsz | Simple partial seizure. Brief seizures that start in one location of the brain (and may spread) where the patient is fully aware and able to interact. |
| 11 | cpsz | Complex partial seizure. Same as simple partial seizure but with impaired awareness. |
| 12 | absz | Absence seizure. Brief, sudden seizure involving lapse in attention. Usually lasts no more than 5 seconds and commonly seen in children. |
| 13 | tnsz | Tonic seizure. A seizure involving the stiffening of the muscles. Usually associated with and annotated as tonic-clonic seizures, but not always (rarely there is no clonic phase). |
| 14 | cnsz | Clonic seizure. A seizure involving sustained, rhythmic jerking. Not seen in our datasets, as it is always associated with tonic clonic seizures and is annotated as such. |
| 15 | tcsz | Tonic-clonic seizure. A seizure involving loss of consciousness and violent muscle contractions. |
| 16 | atsz | Atonic seizure. A seizure involving the loss of tone of muscles in the body. Also never seen as it is always associated with an occasionally occurring phase before a tonic clonic seizure. |
| 17 | mysz | Myoclonic seizure. A seizure associated with brief involuntary twitching or myoclonus. |
| 18 | nesz | Non-epileptic seizure. Any non-epileptic seizure observed. Contains no electrographic signs. |
| 19 | intr | Interesting patterns. Any unusual or interesting patterns observed that don't fit into the above classes. |
| 20 | slow | Slowing. A brief decrease in frequency. |
| 21 | eyem | Eye movement. A very common frontal/prefrontal artifact seen when the eyes move. |
| 22 | chew | Chewing. A specific artifact involving multiple channels that corresponds with patient chewing, “bursty” |
| 23 | shiv | Shivers. A specific, sustained sharp artifact that corresponds with patient shivering. |
| 24 | musc | Muscle artifact. A very common, high frequency, sharp artifact that corresponds with agitation/nervousness in a patient. |
| 25 | elpp | Electrode pop. A short artifact characterized by channels using the same electrode “spiking” with perfect symmetry. |
| 26 | elst | Electrostatic artifact. Artifact caused by movement or interference on the electrodes, variety of morphologies. |

1. *spike and/or sharp waves (SPSW):* patterns of EEGs observed during epileptic seizures.
2. *periodic lateralized epileptiform discharges (PLED)*: patterns observed in the context of destructive structural lesions of the cortex. PLED events manifest themselves by the presence of a pattern of repetitive periodic, focal, or hemispheric epileptiform discharges like sharp waves, spikes, spike and waves and polyspikes, at intervals ranging from 0.5 secs to 3 secs in duration.
3. *generalized periodic epileptiform discharges (GPED)*: manifest themselves as periodic short-interval diffuse discharges, periodic long-interval diffuse discharges and suppression-burst patterns. GPEDs are encountered in metabolic encephalopathy, cerebral hypoxia and ischemia. They are similar to PLEDs. In fact, if periodic complexes are limited to a focal brain area they are called as PLEDs, but if periodic complexes are observed over both hemispheres in a symmetric, diffuse and synchronized manner, they are defined as GPEDs.

The second three patterns, which are used by our machine learning technology to model non-seizure signals such as background noise, artifacts, muscle movements, head movements and chewing are:

1. *eye movement (EYEM)*: spike-like signals that occur during patient eye movement.
2. *artifacts (ARTF)*: recorded electrical activity that is not of cerebral origin including physiologic artifacts generated from sources other than the brain. This class also includes extraphysiologic artifacts arising from outside the body such as noise generated from the recording equipment.
3. *background (BCKG)*: a class used to denote all other data that does not fall in the five classes above. This class usually plays an instrumental role in machine learning systems and needs to include a rich variety of artifacts that are not events of clinical interest.

The annotation files available within TUSZ contain thirteen different labels that consist of seizure events and background annotations. In multi-class annotations, there are eleven specific seizure labels used: (1) focal non specific seizure (FNSZ), (2) generalized seizure (GNSZ), (3) simple partial seizure (SPSZ), (4) complex partial seizure (CPSZ), (5) absence seizure (ABSZ), (6) tonic seizure (TNSZ), (7) clonic seizure (CNSZ), (8) tonic-clonic seizure (TCSZ), (9) atonic seizure (ATSZ), (10) myoclonic seizure (MYSZ), and (11) non-epileptic seizure (NESZ). In bi-class annotations the specific seizure is not annotated, only whether a seizure is occuring or not and this is labeled as seizure (SEIZ). The only non-seizure annotation within TUSZ is used to signify background and this is simply labeled as background (BCKG).

Six labels are used to define specific artifact annotations in an EEG signal file: (1) eye movement (EYEM), (2) chewing (CHEW), (3) shivering (SHIV), (4) muscle artifact (MUSC), (5) electrode pop (ELPP), and (6) electrostatic artifact (ELST). The TUH EEG Slowing corpus contains slowing (SLOW) annotations that signify a brief decrease in frequency (von Weltin et al., 2017). Any unusual or interesting patterns observed in an EEG file that don’t fit with the previously mentioned annotations are defined as interesting (INTR) annotations. An undefined annotation that should not be seen in EEG data is denoted as null (NULL). We use NULL to facilitate and simplify software development. Next, we discuss how these labels are stored in the two file formats we support.

1. **File FORMATS**

We decided not to use an XML format because in our experience this is a bit of a challenge for our typical users to comprehend. XML parsing is not difficult in Python, but many of the researchers we support do not have this type of programming support within their small research groups. Similarly, in our research group it is uncommon that our undergraduate programmers have experience with XML parsing. Hence, we decided to keep the formats very simple ASCII text-based formats. We support two types of file formats: \*.tse and \*.lbl. In this section we describe these formats.

* 1. **The Time-Synchronous Event (\*.TSE) FILE Format**

The time-synchronous event files use term-based annotations using all available seizure type classes in TUSZ. These annotation files use one label that applies to all channels for each event. These are extremely useful for machine learning research because the overall classification of a segment is the only concern, not the individual channels. The format of a typical time-synchronous event file is shown in .

The specific version of the tse file is defined on the first line of each file. The current version is v1.0.0 and stored as a text string in a name/value pair in the first line of the file. The values on each line following the version declaration use a simple format that consist of four fields: (1) the start time in seconds, (2) the stop time in seconds, (3) the annotation label, and (4) probability of the label. The last field is set to 1.0 by default for manually annotated files. For machine generated files, such as a recognition hypothesis, it is set to a posterior probability, confidence value, or the equivalent.

nedc\_000 [1]: cat 00000492\_s003\_t004.tse

version = tse\_v1.0.0

0.0000 10.2775 bckg 1.0000

10.2775 35.7775 gnsz 1.0000

35.7775 102.2525 bckg 1.0000

102.2525 142.9800 gnsz 1.0000

142.9800 339.0000 bckg 1.0000

Figure 2. A typical tse file in TUSZ.

For the example provided in Figure 2, line three corresponds to a background (BCKG) annotation from 0.0000 seconds to 10.2775 seconds with a probability of the defined label being 1.0000. The following line describes a generalized seizure (GNSZ) from 10.2775 seconds to 35.7775 seconds, and the probability of that annotation being 1.0000. The remaining lines follow the same format.

We typically use four decimal places for these numbers so that precision extends slightly beyond the number of decimal places required to uniquely describe each signal sample. EEG files are often sampled at a frequency that ranges between 250 Hz, which corresponds to a sample period or duration of 4 ms (0.004 secs), and 1000 Hz, which corresponds to a sample duration of 1 ms (0.001 secs). Therefore, a sample of the signal is uniquely identifiable by four decimal places of precision. There is no requirement that the precision be limited to four decimal places, though extending this precision slightly increases the amount of disk space required to store these files.

A time-synchronous event file need not account for the entire signal duration. There can be gaps or only portions of the signal can be annotated. However, we typically annotate the entire signal duration using our annotation tools (Capp et al., 2017).

* 1. **The Label (\*.LBL) File Format**

Label files use event-based annotations that are more complicated compared to time-synchronous event files and essentially describe a graph that can represent a hierarchical annotation (e.g., FNSZ and GNSZ map to SEIZ). These files describe the specific channel or set of channels an event occurred on. Channel labels are provided within the file in order to represent the exact channel for which the event occurred on. An example label file within TUSZ is provided in .

The structure of an \*.lbl file is as follows:

* *Version Number:* similar to a \*.tse file, a \*.lbl file begins with the version number on the first line stored as a name/value pair.
* *Montage Block:* The section of text following the version declaration is the montage definition for that specific patient session. This is described in more detail in Ferrell et al. (2019). The format for this section is a name/value pair that lists each component of the montage using the channel index, the label, and the labels for the original channels used to form this output channel.
* *Level Block:* The next two fields following the montage definition section describe the number of levels and sublevels which are used to create a hierarchical graph. For TUAZ, we only use one level for seizure annotations. As example of this is shown in Figure 3.

s003\_2003\_07\_18 : cat /01\_tcp\_ar/004/00000492/s003\_2003\_07\_18/00000492\_s003\_t004.lbl

version = lbl\_v1.0.0

montage = 0, FP1-F7: EEG FP1-REF -- EEG F7-REF

montage = 1, F7-T3: EEG F7-REF -- EEG T3-REF

...

montage = 20, C4-P4: EEG C4-REF -- EEG P4-REF

montage = 21, P4-O2: EEG P4-REF -- EEG O2-REF

number\_of\_levels = 1

level[0] = 1

symbols[0] = {0: '(null)', 1: 'spsw', 2: 'gped', 3: 'pled', 4: 'eyem', 5: 'artf', 6: 'bckg', 7: 'seiz', 8: 'fnsz', 9: 'gnsz', 10: 'spsz', 11: 'cpsz', 12: 'absz', 13: 'tnsz', 14: 'cnsz', 15: 'tcsz', 16: 'atsz', 17: 'mysz', 18: 'nesz', 19: 'intr', 20: 'slow', 21: 'eyem', 22: 'chew', 23: 'shiv', 24: 'musc', 25: 'elpp', 26: 'elst'}

label = {0, 0, 0.0000, 10.2775, 0, [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]}

label = {0, 0, 10.2775, 35.7775, 0, [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]}

label = {0, 0, 35.7775, 102.3525, 0, [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]}

...

label = {0, 0, 35.7775, 102.3525, 21, [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]}

label = {0, 0, 102.3525, 142.9800, 21, [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]}

label = {0, 0, 142.9800, 339.0000, 21, [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0]}

Figure 3. A typical \*.lbl file is shown for an example signal selected from the TUSZ Corpus.

* *Symbol Block:* This block defines the symbols used for annotation. It is a mapping of text labels to indices that are used in the following block. These labels are listed as a dictionary mapping the annotation indices to annotation abbreviations (i.e., 0 is mapped to NULL, 1 is mapped to SPSW, etc.).
* *Label Block*: The last section within a label file portrays the channel indexes in numerical order following the format: level, sublevel, start time in seconds, stop time in seconds, channel, and a vector of probabilities for each label. These are normally set to 0 or 1 for manually generated annotations, but for machine learning outputs a full range of values can be present, and more than one element can be non-zero.

The first annotation labeled in is background on channel 0. This event extends over the range [0.0000, 10.2775]. Because the 7th value in the label field vector is equal to 1.0, and the 7th label in the symbol vector is “6: bckg”, this label denotes an event labeled “bckg” or background. The next annotation for channel 0 covers the range [10.2775, 35.775] and indicates a seizure has occurred. The 10th index in the label field is 1.0, which corresponds to a label of “spsz”. This indicates a simple partial seizure has occurred.

The labels continue for channel 0, and then for channel 1, 2, ..., 21. Note that the last label shown in accounts for the interval [142.9800, 339.000] on channel 21, which indicates this file is 339.0000 secs long. This interval is marked as “bckg” because the 7th index has a non-zero probability.

In Figure 4 we provide an example of a multi-level annotation. The first digit identifies the level of the annotation. Levels can define various tags. In this instance, the level denotes differentiates between x, x, x, and x. Probabilities of each are shown in the brackets at the end of the line. Levels form a hierarchy. For instance, level 0 (shown below) differentiates between x and x and level 1 differentiates between more specific instances of x and x such as x and x and x and x. The second digit identifies the sublevel of the annotation. Sublevels have robust application and can be defined to accommodate a multitude of tasks. A sublevel can be used to show the probabilities in different formats, or differentiate between annotations created by separate systems. In the TUH EEG corpus, only a single sublevel is used, sublevel 0. This sublevel denotes annotations as created by the annotators at NEDC. The third and fourth digits are for the start and stop times, in seconds, of the annotations respectively. The fifth digit denotes the channel of the annotation. In this example, the channel is x which relates to the x-x channel of the EDF file. As stated previously, the remaining values in the brackets denote the probabilities of the events defined by the level. [...explain this in detail walk through the lbl file and explain how the hierarchy is implemented ...]

1. **SUMMARY**

Large open source corpora with manually annotations of the data are the foundations upon which modern machine learning technology is development. NEDC has released a number of valuable annotated corpora involving clinical EEG data. These corpora are available from our project web site: *https://www.isip.piconepress.com/projects/tuh\_eeg/downloads*. To register to access these resources, please complete the following form: *https://www.isip.piconepress.com/projects/tuh\_eeg/html/request\_access.php*. The process is completed automated.

In this document, we have described the file formats used to store our annotations. Two formats have been presented: a label file (\*.lbl\*) that represents an annotation as a hierarchical graph, and a time-synchronous event file (\*.tse\*) that represents an annotation as a flat series of events with start and stop times, type of seizure, and probability. We also described the four different types of annotations that we provide. We use one of two formats: (1) *event-based:* annotations of start time, stop time, and seizure type on a specific channel; (2) *term-based:* all channels share the same annotation, which is an aggregation of the per-channel annotations. There are also two classes of annotations that are useful for machine learning research: (1) *multi-class:* annotations that provide users with the specific type of seizure event; (2) *bi-class:* simply describe whether or not a seizure has occurred. This document describes the format of this data so that programmers can develop software to manipulate these files. Example programs manipulating these files are available from our project web site.

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the official views of any of these organizations.

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Show a simple three-level annotation and a graphical representation of the annotation.

Figure 4. An example of a multi-level annotation.