NIST Open Speech Analytic Technologies 2019
Evaluation Plan
(OpenSAT19)

11/05/18 Section 3, Planned Schedule was updated.
02/06/19 Section 3, Planned Schedule updated again.

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1 Introduction

The National Institute of Standards and Technology (NIST) OpenSAT 2019 is a continuation of the OpenSAT Evaluation Series that started with the 2017 Pilot and organized by NIST. As was in the Pilot, the OpenSAT 2019 is planned to have three data domains: data that simulates acoustic and speech conditions in English-speaking public safety communications, conversational telephone speech in a low resource language (LRL), and English-speaking audio extracted from YouTube videos. The data for all three domains are expected to be challenging for systems to process with a high degree of accuracy.

The public safety communications dataset will be a newly collected public-safety speech corpus that contains simulated first-responder type backround noises and speech affects. This data domain is of particular interest for this evaluation and therefore highly encouraged that all participants include this data domain as part of their dataset portfolio for system analytics. NIST expects to continue with the public-safety speech corpus for the next few years, and this will provide an opportunity to measure year-to-year system performance.

The OpenSAT 2019 is also planned to have the same three speech analytic tasks as was in the Pilot: *Speech Activity Detection (SAD)*, *Key Word Search* (KWS), and *Automatic Speech Recognition (ASR)*.

Like the Pilot, the OpenSAT 2019 evaluation will have many of the same characteristics including registration, data license agreements, system descriptions, and results reporting. The OpenSAT series is intended to encourage researchers from different speech analytic tasks, such as SAD, ASR, KWS, to interact with and leverage shared interests. A workshop will follow the evaluation period. During the registration process, teams will agree to have at least one member participate in the workshop.

Interested researchers may choose to participate in any or all three of the tasks and for any or all three of the data domains[1]. The OpenSAT 2019 evaluation time period will include a systems development period of approximately four months after the initial release of the development data followed by a one-month evaluation period after the initial release of the evaluation data. System evaluation will be accomplished by submission of a system's output to the NIST web-based scoring server. A resulting system score as well as overall ranking will be provided to developers after the evaluation period has ended and a system description (see Appendix V) has been submitted to NIST. Multiple primary and contrastive submissions will be allowed throughout the evaluation period; however, the last primary-system output submitted during the evaluation period will be used for calculating a score and ranking.

Contact opensat_poc@nist.gov for questions relevant to OpenSAT 2019 not covered in this evaluation plan. A general purpose OpenSAT mailing list OpenSAT@nist.gov, where, e.g., evaluation news or participants questions or comments will be posted, is also available. Documents, tools, etc. will be posted on the OpenSat website.

Site registration will be required in order to participate. NIST will send an announcement to the OpenSAT@nist.gov mailing list with registration instructions once registration is open.

2 Objectives

The objectives of the OpenSAT 2019 evaluation are to continue evaluating system analytic performance for specific tasks when exposed to a variety of challenging data domains, to provide a forum for the community to further test and develop speech analytic technologies, to enable opportunities for sharing and leveraging

[1] Researchers are strongly encouraged to submit results across all three domains and in particular the public safety communications domain.

knowledge by bringing together developers whose primary focus may be on different speech analytic tasks, and to provide developers an opportunity to apply different speech analytic systems on common data in parallel with other developers.

3 Planned Schedule

Key Milestones	Begin Date	End Date
Registration period (Start date is tentative.)	March 1, 2019	June 14, 2019
Release of development data for development/training period	March 29, 2019	June 14, 2019
Registration for NIST workshop	TBD, 2019	TBD, 2019
Evaluation data released for evaluation period	June 17, 2019	July 1, 2019
Last date to upload system output from evaluation data to NIST server		July 2, 2019
System output results and evaluation reference data released		July 15, 2019
NIST workshop (Date may change and may be one day instead of two)	August 20, 2019	August 21, 2019

4 Data

4.1 Training Data

OpenSAT participants may use any data that is publicly available to develop and train their system. This includes data that may require a fee or membership dues paid to access the data. Training data, if used, should be described in the system-description document to assist in the sharing and transferring of research knowledge.

4.2 Development Data

Development data will consist of audio samples with annotation for each of the three data domains and will be distributed to registered participants by the domain(s) they have signed up for.

4.3 Evaluation Data

Evaluation data will consist of audio samples without annotation for each of the three domains. Participants are strongly encouraged to upload system's output for evaluation from system's analytics in all three data domains.

4.4 Annotation

The annotation guideline used for each data domain will be available when receiving the trainng dataset for the domain.

4.5 Data Domains

4.5.1 Public Safety Communications (PSC)

The PSC data will be newly collected data that is designed specifically for speech analytic systems in support of the public safety communications community. The data is intended to simulate a combination of characteristics found in public safety communications, for example, background noises and channel transmission noises typical in first responder environments, and voicing characteristics like the Lombard effect, stress, or sense of urgency for the speaker. The PSC data will have the following characteristics that may present challenges for speech analyics:

- Varying first responder related background noise types
- Varying background noise levels
- Effects on speech when performed during loud background noise and/or stressful events
- Land Mobile Radio (LMR) or Long Term Evolution (LTE) transmission noise/effects

4.5.2 Low Resourced Language (LRL)

The LRL data will be data drawn from the Intelligence Advanced Research Projects Activity (IARPA) Babel collection that consists of conversational telephone speech (CTS) recordings. This is a follow-on use of the Babel data to continue previous efforts developed for the IARPA Babel program. The identity of the language will be announced before the development period for OpenSAT 2019.

The LRL Babel data will have the following characteristics that may present challenges for speech analyics:

- Foreign language
- Conversational telephone speech (CTS)
- Natural environments

4.5.3 Audio from Video (AfV)

The AfV data will be audio extracted from the Video Annotation for Speech Technologies (VAST) dataset consisting of a collection of videos from YouTube. The AfV data will have the following characteristics that may present challenges for speech analyics:

- Audio compression
- Diverse topics
- Diverse recording equipment
- Diverse background and environment scenarios

5 Tasks - Overview and Performance Metrics

5.1 Speech Activity Detection (SAD)

The goal in the SAD task is to automatically detect the presence of speech segments in an audio recordings of variable duration. A system output is scored by comparing the system produced start and end times of speech and non-speech segments in audio recordings to human annotated start and end times. Correct, incorrect, and partially correct segments will determine error probabilities for systems and will be used to measure a system's SAD performance by calculating the Detection Cost Function (DCF) value. The DCF is a function of false-positive (false alarm) and false-negative (missed detection) rates calculated from comparison to the human annotation that will be the reference for the comparison (see Appendix I for more details). The goal for system developers will be to determine and select their system detection threshold, θ, that minimizes the DCF value.

5.2 Key Word Search (KWS)

The goal of the KWS task is to automatically detect all occurrences of keywords in an audio recording A keyword is a pre-defined single word or phrase that is transcribed with the spelling convention use in the language's original orthography. Each such detected keyword will have beginning and ending time-stamps.

KWS performance is measured by the Term-Weighted Value (TWV), a function of false-positive (false-alarm) and false-negative (missed detection) rates for the keyword, and is determined by comparison to the reference. An Actual Term-Weighted Value (ATWV) is calculated from a system's hard decision threshold (see Appendix II for TWV and ATWV details).

5.3 Automatic Speech Recognition (ASR)

The goal of the ASR task is to automatically produce a verbatim, case-insensitive transcript of all words spoken in an audio recording. ASR performance is measured by the word error rate (WER), calculated as the sum of errors (deletions, insertions and substitutions) divided by the total number of words from the reference (see Appendix III for more details).

6 Evaluation Conditions

The content and makeup of the evaluation datasets are shown in Table 1.

Table 1: Data planned for use in OpenSAT 2019 Evaluation

Domain	Tasks	Language
Public Safety Communications (From the PSC dataset)	SAD, ASR, KWS	English
Low Resource Language (LRL) (From the Babel dataset)	SAD,ASR,KWS	TBD
Audio from Video (AfV) (From the VAST dataset)	SAD, ASR	English

7 Evaluation Rules

There is no cost to participate in the OpenSAT evaluation series. Participation is open to all who are able to comply with the evaluation rules set forth within this plan. Development data and evaluation data will be freely made available to registered participants. Investigation of the evaluation data prior to submission of all systems outputs is not allowed. Human probing is prohibited. Participants will apply their system's analytic to the data locally and upload their system's output to the NIST server for scoring. See Appendix IV for system output submission packaging. It is required that participants agree to process the data in accordance with the following rules.

- For KWS:
    - **Keyword Interactions,** each keyword must be processed separately and independently during keyword detection. The system-generated detection outputs for a keyword (as derived from processing an audio recording) must not influence the detection of other keywords. To facilitate this independence, the search results for each keyword are to be output prior to performing detection on the next keyword.
    - **Language Specific Peculiarities (LSP) Resources,** the LSP documentation contains an inventory of phonemes for the low resource language used. Evaluation participants are allowed to leverage that information. The LSP may also include links to other resources that can be utilized.

- The participants agree to follow the guidelines below governing the publication of results.
    - Participants can publish results for their own system but will not publicly compare their results – including rankings and score differences - with other participants without their explicit, written consent.
    - Participants will not make advertising claims about winning the evaluation or claim NIST endorsement of their system(s). The following language in the U.S. Code of Federal Regulations (15 C.F.R. § 200.113) shall be respected:

        NIST does not approve, recommend, or endorse any proprietary product or proprietary material. No reference shall be made to NIST, or to reports or results furnished by NIST in any advertising or sales promotion which would indicate or imply that NIST approves, recommends, or endorses any

proprietary product or proprietary material, or which has as its purpose an intent to cause directly or indirectly the advertised product to be used or purchased because of NIST test reports or results.

- At the conclusion of the evaluation, NIST will generate a report summarizing all of the systems' results for conditions of interest. These results/charts will not contain participant names of the systems involved. Participants may publish, or otherwise disseminate these charts, unaltered and with appropriate reference to their system.
- The report that NIST creates cannot be construed or represented as endorsements for any participant's system or commercial product, or as official findings on the part of NIST or the U.S. Government.

8 Evaluation Protocol

To facilitate information exchange between the participants and NIST, all evaluation activities will be conducted over a web-interface.

8.1 Signing up and Setting up an Account

Participants must sign up to perform any evaluation activities. To sign up, go to https://sat.nist.gov.

8.2 Data License Agreement and Accessing Data

Once an account is set up for a team, the team representative must complete the data license agreement and upload it. After the license agreement is confirmed by LDC, LDC will provide instructions for accessing the data.

9 System Input, Output, and Performance Metrics

For SAD, see Appendix I,
For KWS, see Appendix II,
For ASR, see Appendix III.

Appendix I SAD

SAD System Input Format

1) Audio files – All audio files are currently expected to be in SPHERE format (reference SPHERE header for sample rate and encoding.
2) Test definition files – XML formatted files that define the test to be performed on the audio files. The XML schema for the SAD test definition file will be available at the OpenSAT website.

   Example:

```
<TestSet id="OpenSAD" audio="/path/to/audio/root" task="SAD">
    <TEST id="SADTestDataset1">
                        <SAMPLE id="SAD_sampleFile1" file="set1/G/file1.sph" />
    <SAMPLE id="SAD_sampleFile2" file="set1/G/file2.sph" />
    ...
    </TEST>
</TestSet>
```

SAD System Output Format

System output is to be formatted as a single tab-separated ASCII text file with nine columns, see Table 2.

Table 2: SAD system output

Column	Output	Description
1	Test	Test Definition File name (name of an XML file containing the test definition content)
2	TestSet ID	contents of the id attribute of the TestSet tag
3	Test ID	contents of the id attribute of the TEST tag
4	Task	SAD <== a literal text string, without quotation marks
5	File ID	contents of the id attribute of the File tag
6	Interval start	an offset, in seconds, from the start of the audio file for the **start** of a speech/non-speech interval
7	Interval end	an offset, in seconds, from the start of the audio file for the **end** of a speech/non-speech interval
8	Type	In system output: "speech" or "non-speech" (with no quotation marks). In the reference: S, NS (for Speech, Non-Speech).
9	Confidence (*optional*)	A value in the range 0.0 through 1.0, with higher values indicating greater confidence about the presence/absence of speech

Example of four lines shown for a SAD system output file:

Cluster_01	OpenSAT18_01	Babel	SAD	20703_2017	0.0	4.61	non-speech	1
Cluster_01	OpenSAT18_01	Babel	SAD	20703_2017	4.61	7.08	speech	1
Cluster_01	OpenSAT18_01	Babel	SAD	20703_2017	7.08	7.49	non-speech	1
Cluster_01	OpenSAT18_01	Babel	SAD	20703_2017	7.49	9.34	speech	1

Interval overlapping will be dissalowed and will fail in validation when uploading to the NIST server.
Example of overlapping:

Cluster_01	OpenSAT18_01	Babel	SAD	20703_2017	0.0	**4.61**	non-speech	0.8
Cluster_01	OpenSAT18_01	Babel	SAD	20703_2017	**4.50**	7.08	speech	0.6

SAD System Output Evaluation

Four system output possibilities are considered:

1. True Positive (TP) - system correctly identifies start-stop times of speech segments compared to the reference (manual annotation),
2. True Negative (TN) - system correctly identifies start-stop times of non-speech segments compared to reference,
3. False Positive (FP) - system incorrectly identifies speech in a segment where the reference identifies the segment as non-speech, and
4. False Negative (FN) - system missed identification of speech in a segment where the reference identifies a segment as speech.

SAD error rates represent a measure of the amount of time that is misclassified by the system's segmentation of the test audio files. Missing, or failing to detect, actual speech is considered a more serious error than mis-identifying its start and end times.

A 0.5 s collar, a "buffer zone", at the beginning and end of each speech region will not be scored. If a segment of non-speech between collars is not 0.1 s or greater, then the collars involved are expanded to include the less-than 0.1 s non-speech. For example, no resulting non-speech segment with a duration of just 0.099 s can exist. Similarly, for a region of non-speech before a collar at the beginning of the file or a region of non-speech after a collar at the end of the file, the resulting non-speech segment must last at least 0.1 s or else the collar will expand to include it. In all other circumstances the collars will be exactly the nominal length. Figure 1 illustrates the collars expanding to include a 0.09 s non-speech segment between the collars.

Figure 1: Shows how a < 0.1 s non-speech segment (0.09 s) is added to the collars and not used in scoring.

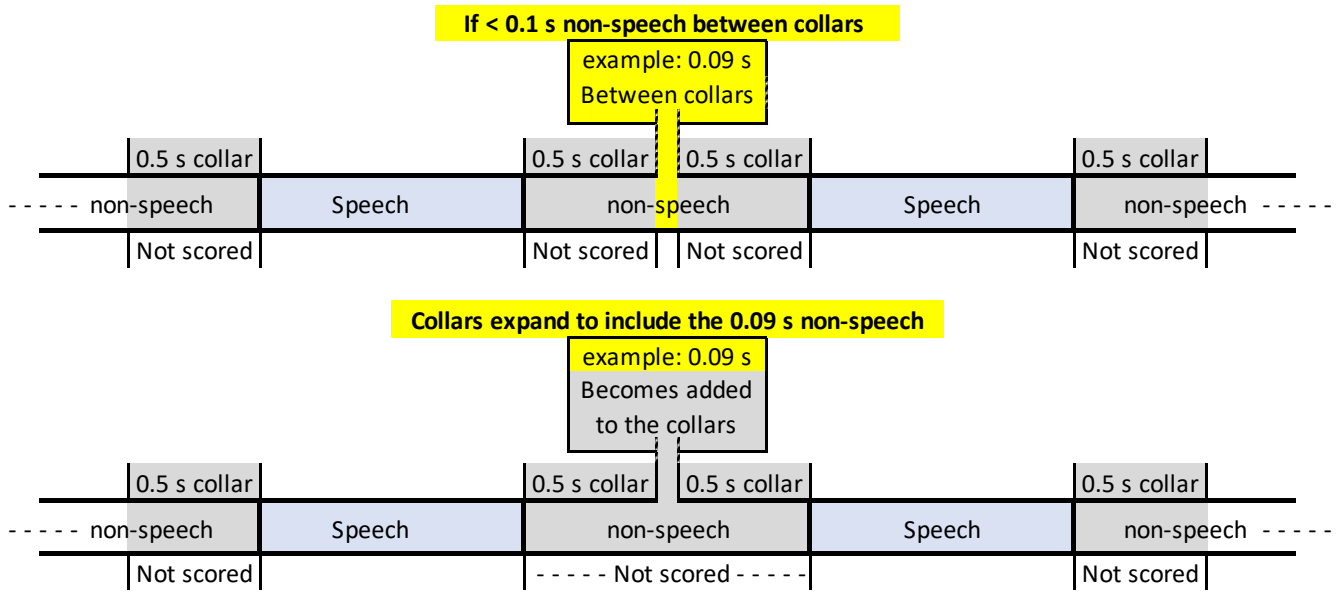
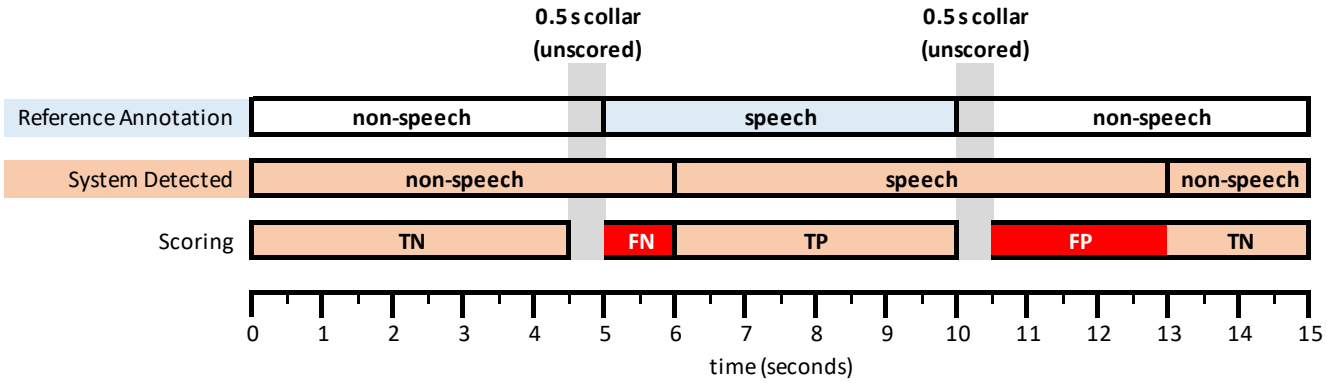


Figure 2 illustrates the relationship between human annotation, the scoring regions resulting from application of the collars, a hypothetical system detected output, and the resulting time intervals from the four system output possibilities. The scoring collars also help compensate for ambiguities in noisy channel annotation. Non-speech collars of half a second in length will define those regions that will not be scored. As can be seen, with collars applied to the annotation, parts of system-detected non-speech and potentially speech are not used in scoring. Below illustrates an example of a system detected output and the resulting scoring zones relative to the

annotation with 0.5 s collars applied. The figure shows the resulting four possibilities (TN, FN, TP, FP) considered in the scoring. The gray areas preceding and trailing the annotated speech are the 0.5 s collar regions.

Figure 2: Hypothetical system output compared to the annotation of the same file showing the resulting four possible outcomes that are used for scoring.



Scoring Procedure

Information for downloading the scoring software will be available at the OpenSAT website.
The four system output possibilities mentioned above determine the probability of a false positive (P_{FP}) and the probability of a false negative (P_{FN}). Developers are responsible for determining a hypothetical optimum setting (θ) for their system that minimizes the DCF value.

P_{FP} = detecting speech where there is no speech, also called a "false alarm"
P_{FN} = missed detection of speech, i.e., not detecting speech where there is speech, also called a "miss"

$$P_{FP} = \frac{total\ FP\ time}{annotated\ total\ nonspeech\ time}$$

$$P_{FN} = \frac{total\ FN\ time}{annotated\ total\ speech\ time}$$

DCF (θ) is the detection cost function value for a system at a given system decision-threshold setting.

$$DCF\ (\theta) = 0.75 \times P_{FN}\ (\theta) + 0.25 \times P_{FP}\ (\theta)$$

P_{FN} and P_{FP} are weighted 0.75 and 0.25, respectively,
θ - denotes a given system decision-threshold setting,

Appendix II KWS

KWS System Input Format

1) **Audio file** - All audio files are currently expected to be in SPHERE format.
2) **KWS Experimental Control Files (ECF)** - ECF files are XML formatted files that define the excerpts within audio files to be used for a specific evaluation and the language/source type of each file.

   NIST-supplied ECFs are the mechanism the evaluation infrastructure uses to specify time regions within an audio recording, the language, and the source type specified for the experimental condition. A *system input ECF* file will be provided for KWS and ASR tasks to indicate what audio data is to be indexed and searched by the system. The evaluation code also uses an ECF file to determine the range of data needed to evaluate the system. In the event a problem is discovered with the data, a special *scoring ECF* file will be used to specify the time regions to be scored.

   ECF File Format Description - An ECF file consists of two, hierarchically organized, XML nodes: "ecf", and "excerpt". The following is a conceptual description of an ECF file.

   The "ecf" node contains a list of "excerpt" nodes. The "ecf" node has the following attributes:
   - source_signal_duration: a floating-point number indicating the total duration in seconds of recorded speech
   - version: A version identifier for the ECF file
   - language: language of the original source material. Each "excerpt" tag is a non-spanning node that specifies the excerpt from a recording that is part of the evaluation. The "excerpt" has the following attributes:
   - audio_filename: The attribute indicates the file id, excluding the path and extension of the waveform to be processed.
   - source_type: The source type of the recording either "bnews", "cts", "splitcts", or "confmtg".
   - channel: The channel in the waveform to be processed.
   - start: The beginning time of the segment to processes. The time is measured in seconds from the beginning of the recording which is time 0.0.
   - end: The ending time of the segment to processes. The time is measured in seconds from the beginning of the recording which is time 0.0.

   Example for an ecf file:

```
<ecf source_signal_duration="340.00" version="20060618_1400" language="english" >
<excerpt audio_filename="audio/dev04s/english/confmtg/NIST_20020214-1148" channel="1" tbeg="0.0"
        dur="291.34" source_type="confmtg"/>
<excerpt audio_filename="audio/eval03/english/bnews/ABC_WNN_20020214_1148.sph" channel="1"
        tbeg="0.0" dur="291.34" source_type="bnews"/>
…
</ecf>
```

   XML schemas for KWS Input/output files - The XML schemas for the files below can be found at https://www.nist.gov/itl/iad/mig/tools, select F4DE-3.5.0, download the tar/zip file, then go to KWSEval/data/

   KWSEval-ecf.xsd for ecf file - input
   KWSEval-kwlist.xsd for kwlist file - input
   KWSEval-kwslist.xsd for kwslist file – ouput

3) KWS KWList Files

KWList files defines the keywords to search for in the indexed corpus, e.g.,
/KWlist
    /Babel/[keyword1 in xml format].xml
    /VAST/[keyword2 in xml format].xml
    /PSC/[keyword3 in xml format].xml

Keyword List files (KWList) are NIST-supplied, XML-formatted, text files that end with the ".kwlist.xml" extension. These files define the search keywords to be processed by a KWS system. Each keyword is identified by a keyword ID (kwid), which is used to track keywords through the evaluation process and specify keyword texts with a flexible set of attributes.

KWList files consist of three hierarchically organized XML nodes: "kwlist", "kw", and potentially several nodes under "kw". The XML schema for a KWList file can be found in the F4DE-3.5.0 software package at
F4DE-3.5.0/KWSEval/data/KWSEval-kwlist.xsd from https://www.nist.gov/itl/iad/mig/tools.

The following is a conceptual description of a KWList file. The "kwlist" node contains a list of "keyword" nodes and has the following attributes:

- ecf_filename: The basename of the ECF file associated with this Kwlist file. (Basename of a file excludes the directory names and extensions. For example, the basename of "the/directory/file.txt" is "file".)
- version: A version identifier for the file.
- language: Language of the original source material.
- encoding: The character encoding of the text data. Only "UTF-8" is currently accepted.
- compareNormalize: The function used to normalize the text before comparison. Current legal values are blank (which applies no normalization) and "lowercase".

Each "kw" node is a spanning XML tag that contains a set of additional XML nodes to specify the keyword. There is a single attribute 'kwid'.

- kwid: A string identifying the keyword.

The "kw" tag contains two sub-nodes "kwtext" (which is the keyword text) and the "kwinfo" tag (which contains a flexible attribute/value structure).

The "kwtext" tag is a spanning tag that contains the CDATA (character) string for the keyword. The leading and trailing white space of the keyword string is NOT considered part of the keyword while single internal white space(s) are.

The "kwinfo" tag is a spanning tag that contains one or more "attr" tags that specify an attribute name and value with a "name" and "value" tag respectively. Both contents of "name" and "value" tags are CDATA.

Example for a KWlist file:

```
<kwlist ecf_filename="english_1" version ="20060511-0900" language="english" encoding="UTF-8"
compareNormalize="lowercase">
        <kw kwid="dev06-0001">
            <kwtext>find</kwtext>
                <kwinfo>
```

```
                    <attr>
                        <name>NGram Order</name>
                        <value>1-grams</value>
                    </attr>
                </kwinfo>
            </kw>
            <kw kwid=”dev06-0002”>
                <kwtext>many items</kwtext></kw>
                <kwinfo>
                    <attr>
                        <name>NGram Order</name>
                        <value>2-grams</value>
                    </attr>
                </kwinfo>
            </kw>
</kwlist>
```

KWS System Output Format

KWS system output is to be formatted as three, hierarchically organized, xml nodes in a single KWSList file as shown below and use the extension ‘kwslist.xml’. It contains all the runtime information as well as the search output generated by the system. Below is a content description of the XML nodes and attributes. The XML schema for a KWSList file can be found in the F4DE-3.5.0 software package at F4DE-3.5.0/KWSEval/data/KWSEval-kwslist.xsd from https://www.nist.gov/itl/iad/mig/tools.

The three nodes for a KWSList file are:

1. kwslist – the system inputs and parameters used to generate the results.

   The “kwslist” node contains a set of “detected_kwlist” nodes: one for each search keyword. The “kwlist” node contains three attributes:
   - kwlist_filename: The name of the KWList file used to generate this system output.
   - language: Language of the source material.
   - system_id: A text field supplied by the participant to describe the system.

2. detected_kwlist – a collection of “kw” nodes which are the putative detected keywords.

The “detected_kwlist” node has three attributes and contains the system output for a single keyword in “kw” nodes. The “detected_kwlist” node attributes are:

1. kwid: The keyword id from the KWList file.
2. search_time: (optional for backward compatibility) A floating point number indicating the number of CPU seconds spent searching the corpus for this particular keyword.
3. oov_count: An integer reporting the number of tokens in the keyword that are Out-Of-Vocabulary (OOV) for the system and/or the training and development language data. If the system does not use a word dictionary, the value should be “NA”.

3. kw – six attribute fields for the location and detection score for each detected keyword.

The “kw” node is a non-spanning XML node that contains the location and detection score for each detected keyword. The six “kw” node attributes are as follows:

- file: The basename of the audio file as specified in the ECF file.
- channel: the channel of the audio file where the keyword was found.

- tbeg: Offset time from the start (0.0 secs) of the audio file where the keyword starts
- dur: The duration of the keyword in seconds
- score: The detection score indicating the likelihood of the detected keyword.
- decision: [YES | NO] The binary decision of whether or not the keyword should have been detected to make the optimal score.

Below is an example of a KWS system output for keyword ID "dev06-0001":

- file = NIST_20020214_d05
- channel = 1
- tbeg = 6.956
- dur = 0.53
- score = 4.115
- decision = YES

Below shows the above system output for keyword ID "dev06-0001" in KWSList xml file format for submission:

```
<kwslist
        kwlist_filename="expt_06_std_eval06_mand_all_spch_expt_1_Dev06.tlist.xml"    language="english"
        system_id="Phonetic subword lattice search">
 <detected_kwlist kwid="dev06-0001"
                search_time="24.3" oov _count="0">
      <kw file="NIST_20020214-1148_d05_NONE" channel="1" tbeg="6.956" dur="0.53" score="4.115"      decision="NO"/>
      <kw file="NIST_20020214-1148_d05_NONE" channel="1" tbeg="45.5"   dur="0.3"   score="4.65"   cision="YES"/>
 </detected_kwlist>
</kwslist>
```

KWS System Output Evaluation

Keyword detection performance will be measured as a function of Missed Detection/False Negative (FN) and False Alarm/False Positive (FP) error types.

Four system output possibilities are considered for scoring regions:

1. TP – correct system detection of a keyword (matches the reference location and spelling)
2. TN - system does not detect a keyword occurrence where a keyword does not exist
3. FN - system misses detection or location of a keyword, or miss-spells a keyword
4. FP - system detects a keyword that is not in the reference or not in the correct location

Scoring Procedure

Scoring protocol will be the "Keyword Occurrence Scoring" protocol that evaluates system accuracy based on the three steps below. For more detailed information see the DRAFT KWS16 KEYWORD SEARCH EVALUATION PLAN, https://w3auth.nist.gov/sites/default/files/documents/itl/iad/mig/KWS16-evalplan-v04.pdf.

Information for accessing and downloading the scoring software will be available at the OpenSAT website.

1. Reference-to-system keyword alignment

- The KWS evaluation uses the Hungarian Solution to the Bipartite Graph matching problem[2] to compute the minimal cost for 1:1 alignment (mapping) of reference keywords to system output keywords.

2. Performance metric computation (TWV, ATWV)
   - Uses probability values derived for FP, and FN.
   - System Actual TWV (ATWV): a measure of keyword detection performance at a given system's threshold setting (θ).
   - System Maximum TWV (MTWV): an oracle measure of keyword detection performance at the system's optimal θ setting. (The difference between ATWV and MTWV indicates the loss in performance due to a less-than-optimal system threshold (θ) setting for ATWV when determining the θ for ATWV.)
3. Detection Error Tradeoff (DET) Curves
   - Curve depicts the tradeoff between missed detections versus false alarms for a range of θ settings.

Term Weighted Value (TWV)

$$TWV(\theta) = 1 - \left[P_{FN}(\theta) + \beta \cdot P_{FA}(\theta)\right]$$

Choosing θ:

- Developers choose a decision threshold for their "Actual Decisions" to optimize their term-weighted value: All the "YES" system occurrences
  - Called the "**Actual Term Weighted Value**" (ATWV)
- The evaluation code searches for the system's optimum decision score threshold
  - Called the "**Maximum Term Weighted Value**" (MTWV)

[2] Harold W. Kuhn, "The Hungarian Method for the assignment problem", *Naval Research Logistic Quarterly*, **2**:83-97, 1955.

Appendix III ASR

ASR System Input Format

1) **Audio Files** - Currently, all audio files are expected to be in SPHERE format.
2) **ASR Experimental Control Files (ECF)** (same as KWS) - ECF files are XML formatted files that define the excerpts within audio files to be used for a specific evaluation and the language/source type of each file.

   NIST-supplied ECFs are the mechanism the evaluation infrastructure uses to specify time regions within an audio recording, the language, and the source type specified for the experimental condition. A *system input ECF* file will be provided for KWS and ASR tasks to indicate what audio data is to be indexed and searched by the system. The evaluation code also uses an ECF file to determine the range of data needed to evaluate the system. In the event a problem is discovered with the data, a special *scoring ECF* file will be used to specify the time regions to be scored.

   ECF File Format Description - An ECF file consists of two, hierarchically organized, XML nodes: "ecf", and "excerpt". The following is a conceptual description of an ECF file.

   The "ecf" node contains a list of "excerpt" nodes. The "ecf" node has the following attributes:
   - source_signal_duration: a floating-point number indicating the total duration in seconds of recorded speech
   - version: A version identifier for the ECF file
   - language: language of the original source material. Each "excerpt" tag is a non-spanning node that specifies the excerpt from a recording that is part of the evaluation. The "excerpt" has the following attributes:
   - audio_filename: The attribute indicates the file id, excluding the path and extension of the waveform to be processed.
   - source_type: The source type of the recording either "bnews", "cts", "splitcts", or "confmtg".
   - channel: The channel in the waveform to be processed.
   - start: The beginning time of the segment to processes. The time is measured in seconds from the beginning of the recording which is time 0.0.
   - end: The ending time of the segment to processes. The time is measured in seconds from the beginning of the recording which is time 0.0.

   Example for an ecf file:

```
<ecf source_signal_duration="340.00" version="20060618_1400" language="english" >
<excerpt audio_filename="audio/dev04s/english/confmtg/NIST_20020214-1148" channel="1" tbeg="0.0"
        dur="291.34" source_type="confmtg"/>
<excerpt audio_filename="audio/eval03/english/bnews/ABC_WNN_20020214_1148.sph" channel="1"
        tbeg="0.0" dur="291.34" source_type="bnews"/>
…
</ecf>
```

   XML schema for the ecf input file - The XML schema for the ecf file can be found at https://www.nist.gov/itl/iad/mig/tools, select F4DE-3.5.0, download the tar/zip file, then go to KWSEval/data/KWSEval-ecf.xsd.

ASR System Output Format

ASR system output will be a Conversation Time Marked (CTM) file using the .ctm extension and consisting of a stream of lexical tokens formatted in a tab-separated six column ASCII text and use the .ctm extension. Each line represents a single token emitted by the system. The six columns plus an example are shown below.

Table 4: ASR system output

Column	Output	Description
1	file	The waveform file base name (i.e., without path names or extensions).
2	chnl	Channel ID, The waveform channel (e.g., "1").
3	tbeg	The beginning time of the token, in seconds, measured from the start time of the file.
4	tdur	The duration of the object, in seconds
5	ortho	The orthographic rendering (spelling) of the token.
6	conf	Confidence Score, the probability with a range [0:1] that the token is correct. If conf is not available, omit the column.

Example of four lines for an ASR system output file:

```
7654    A    11.34    0.2    YES    0.9
7654    A    12.00    0.34   YOU    0.8
7654    A    13.30    0.5    CAN    1
7654    A    17.50    0.2    ASK    0.75
```

ASR System Output Evaluation

Four system output possibilities are considered:

1. Correct - system correctly locates [system and reference map] and correctly spells a lexical token item (token) compared to the reference lexical token location and spelling,
2. Deletion (Del) - system output misses the detection of a reference lexical token,
3. Insertion (Ins) - system outputs a lexical token where it does not exist (no mapping) in the reference,
4. Substitution (Subst) - system output correctly locates but miss-spells a lexical token compared to the mapped reference token.

Scoring Procedure

NIST will use the NIST Scoring Toolkit (SCTK) scoring software to calculate WER. The SCTK scoring software is available at https://www.nist.gov/itl/iad/mig/tools. The SCTK software generates an optimum word-to-word mapping (lowest error) between the system output and the reference file.

Lexical Tokenization and Scoring

Lexical tokenization will use space as the delineator.
System scoring includes three steps:
Step 1 Token normalization, - filtering for three types of tokens:

1) Scorable tokens (i.e., reference tokens that are expected to be recognized by the system),

   - All words are transcribed as specified by domain-specific guideline.

2) Optionally deletable tokens (i.e., reference tokens that may be omitted by the system without penalty)

   - Fragments (marked with a -) in the reference transcript. System tokens with token-initial text matching the fragment's text will be scored as correct (e.g. /theory/ would be correct for fragment/th-/). The same test is applied to the obverse, token-final fragments /-tter/ matching /latter/.
   - The hesitation tags (<hes>).

3) Non-scored tokens/speech segments (i.e., reference tokens/speech segments removed from both the reference and system transcripts prior to scoring)

- Codeswitch tags.
- Speaker change tags.
- Unintelligible speech tags.
- Non-lexical punctuation.
- Non-lexical, speaker-produced sounds (<lipsmack>, <cough>, <breath>, etc. as defined in the data specification document).
- Segments containing the <overlap>, unintelligible [(()) tags], and <prompt> tags.
- Segments containing transcript tokens that were unable to be force aligned in the reference.

Step 2 Reference-to-System alignment - Scorable reference tokens are aligned with system output tokens

- Alignment is performed using Levenshtein distances computed by Dynamic Programming Solution (DPS) to string the alignment
- System tokens are weighted per DPS priori transition costs for alignment computation
  - Substitution = 4, Insertions = 3, Deletions = 3, Correct = 0

Step 3 System performance metric computation

- An overall Word Error Rate (WER) will be computed as the fraction of token recognition errors per maximum number of reference tokens (scorable and optionally deletable tokens):

$$\text{WER} = \frac{(N_{Del} + N_{Ins} + N_{Subst})}{N_{Ref}}$$

where

N_{Del} = number of unmapped reference tokens (tokens missed, not detected, by the system)
N_{Ins} = number of unmapped system outputs tokens (tokens that are not in the reference)
N_{Subst} = number of system output tokens mapped to reference tokens but non-matching to the reference spelling
N_{Ref} = the maximum number of reference tokens (includes scorable and optionally deletable reference tokens)

Appendix IV SAD, KWS, and ASR - System Output Submission Packaging

Each submission shall be an archive file named as follows:

<SysLabel>.tgz

Submit a separate .tgz file for each system output (e.g., a separate .tgz file for Primary, Contrastive1, and Contrastive2 systems).

<SysLabel> shall be an alphanumeric [a-zA-Z0-9] that is a performer-assigned identifier for their submission.

There should be no parent directory when the submission file is untarred. The tar command should be:
> tar MySystemSubmissionFile.tgz

Prior to uploading the submission file to the NIST scoring server, performers will be asked for information about the submission. The scoring server will attach the following information to the submission filename to catorigize and uniquely identify the submission:

Field	Information	Method
<TeamID>	[Team]	obtained from login information
<Task>	{SAD | ASR | KWS}	select from drop-down menu
<SubmissionType>	{primary | contrastive}	select from drop-down menu
<Training Condition>	{unconstrained}	default - hard-coded
<EvalPeriod>	{2019}	default - hard-coded
<DatasetName>	{PSC | VAST | Babel}	select from drop-down menu
<Date>	{YYYYMMDD}	obtained from NIST scoring server at submission date
<TimeStamp>	{HHMMSS}	obtained from NIST scoring server at submission time

Below is an example of a resulting filename:
NIST_ASR_primary_uncontrained_2019_PSC_20190415_163026_ MySystemSubmissionFile.tgz

The NIST scoring server will validate the submission file content to make sure the system output files conform to the format described in each task system output format section above.

Each team is required to submit a system description (See Appendix V) for a system's output submitted for evaluation in order to receive the system's score and ranking results. Evaluation results will be provided only after a system description is received and verified to conform to system description guidelines in Appendix V.

Appendix V SAD, KWS, and ASR - System Descriptions and Auxiliary Condition Reporting

Each submitted system must be accompanied by a system description. Documenting each system is vital to interpreting evaluation results and disseminating them to potential end users. System descriptions are expected to be of sufficient detail for a fellow researcher to both understand the approach and the data/computational resources used to train and run the system.
In order to make system description preparation and format as simple and consistent as possible, developers are encouraged to use one of the Micorsft Word IEEE Manuscript Templates for Conference Proceedings, https://www.ieee.org/conferences/publishing/templates.html.

For purposes of having comparable and informative system descriptions the following is recommended to be included.

Section 1: Abstract
Section 2: Notable highlights
Section 3: Data resources
Section 4: Algorithmic description
Section 5: Results on the DEV set
Section 6: Hardware description and timing report

Section 1: Abstract

A few sentences describing the system at the highest level. This should help orient the reader to the type of system being described and how the components fit together.

Section 2: Notable Highlights

For each task, a brief summary of what is different or any notable highlights. Examples of highlights could be differences among systems submitted; novel or unusual approaches, or approaches or features that led to a significant improvement in system performance.

Section 3: Data Resource

Data resources used by the system, including Linguistic Data Consortium (LDC) obtained, NIST-provided, or other publically available data.

Section 4: Algorithmic Description/Approach

Details on each component of the system and how each was implemented. You should be very brief or omit altogether components that are standard in the field. For system combinations, there should be a section for each subsystem.

For each subsystem, provide subsections for each major phase. Exclude this if not relevant or if only standard methods are used (e.g., no need to describe how Mel-frequency cepstral coefficients (MFCCs) are computed or 25 ms window and 10 ms step). They may also refer to other subsystems or reference system descriptions if they share components.

Suggested Subsections:

- Signal processing - e.g., enhancement, noise removal, crosstalk detection/removal.
- Low level features - e.g., PLP, Gabor filterbank.
- Speech/Nonspeech –
- Learned features – e.g., MLP tandem features, DNN bottleneck features, etc.
- Acoustic models – e.g., DNN, GMM/HMM, RNN, etc.
- Language Models – methods used
- Adaptation – e.g., speaker, channel, etc. Specify how much of the evaluation data was used as well as the computational costs (memory and time).
- Normalization - Normalizations not covered in other sections
- Lexicon – methods used to update
- Decoding – e.g., Single pass, multipass, contexts,etc.
- OOV handling – e.g., Grapheme, syllable, phoneme,etc.
- Keyword index generation –
- Keyword search –
- System combination methods – e.g., posting list, score, features, lattices.

Section 5: Results on the DEV Set

Report the performance of the submission systems on the "dev" set when using the scoring software provided by NIST (to enable across systems comparison). Teams are encouraged to quantify the contribution of their major system components that they believe resulted in significant performance gains, if any.

Section 6: Hardware Description

Description of the architecture elements that relate directly to system execution time and memory requirements. Report the system execution times to process a single recording for the various system components.

- OS (type, version, 32- vs 64-bit, etc.)
- Total number of used CPUs
- Descriptions of used CPUs (model, speed, number of cores)
- Total number of used GPUs
- Descriptions of used GPUs (model, number of cores, memory)
- Total available RAM
- RAM per CPU
- Used Disk Storage (Temporary & Output)