

# CoPaSul Manual

## Contour-based, parametric, and superpositional intonation stylization

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Version 0.7.x, Januar 10th, 2018



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# 1 Introduction

The purposes of the CoPaSul toolkit are (1) automatic prosodic annotation and (2) prosodic feature extraction from syllable to utterance level.

CoPaSul stands for *contour-based, parametric, superpositional* intonation stylization. The core model is introduced amongst others in [12]. In this framework intonation is represented as a superposition of global and local contours that are described parametrically in terms of polynomial coefficients. On the global level (usually associated but not necessarily restricted to intonation phrases) the stylization serves to represent register in terms of time-varying F0 level and range. On the local level (e.g. accent groups), local contour shapes are described. From this parameterization several features related to prosodic boundaries and prominence can be derived. Furthermore, by coefficient clustering prosodic contour classes can be derived in a bottom-up way. Next to the stylization-based feature extraction also standard F0 and energy measures (e.g. mean and variance) as well as rhythmic aspects can be calculated.

At the current state **automatic annotation** comprises:

- segmentation into interpausal chunks
- syllable nucleus extraction
- unsupervised localization of prosodic phrase boundaries and prominent syllables

F0 and partly also energy **feature sets** can be extracted for:

- standard measurements (as median and IQR)
- register in terms of F0 level and range
- prosodic boundaries
- local contour shapes
- bottom-up derived contour classes
- Gestalt of accent groups in terms of their deviation from higher level prosodic units
- rhythmic aspects quantifying the relation between F0 and energy contours and prosodic event rates

Please see section 8 for a list of application examples.

## 2 Download and installation

The CoPaSul command-line toolkit can be downloaded from this location:

`http://clara.nytud.hu/~reichelu/copasul.zip`

The toolkit is written in Python 3 and depends on the following Python packages (with the specified version or higher):

- matplotlib 1.3.1
- numpy 1.8.2
- pandas 0.13.1
- scipy 0.13.3
- scikit\_learn 0.17.1

So far the software is tested only for Linux!

**The installation steps are:**

1. unzip the copasul.zip in your target folder DIR
2. change to DIR
3. open *make.py* in a text editor and set the string variable *python\_path* to the Python3 call related to your platform<sup>1</sup>

---

<sup>1</sup><https://docs.python.org/3/using/mac.html>  
<https://docs.python.org/3/using/unix.html>  
<https://docs.python.org/3/using/windows.html>

4. and call
 

```
> python3 make.py
```

 this script adjusts the python path according to your changes in *make.py*, and inserts DIR into the python scripts, so that all copasul modules are found.
5. for a command line test call change to DIR and type
 

```
> copasul.py -c config/test.json
```
6. the result should be found in the test/res/ subfolder and should contain:
  - csv files with analysis results and corresponding R input code template files to read the csv files for further statistical analyses
  - 1 log.txt file with log information
  - 1 pickle file containing the resulting dictionary in binary form for further processing in Python

The target directory now contains several python and Praat scripts [4] as well as a test and config subfolder:

Software Python	
copasul.py	the main script
copasul.root.py	specifies the copasul tool path
copasul.init.py	initializations
copasul.preproc.py	data preprocessing
copasul.augment.py	automatic prosodic annotation
copasul.styl.py	stylization
copasul.clst.py	contour clustering
copasul.resyn.py	F0 generation
futureScipy.py	contains functions not yet in the standard scipy package for Ubuntu 14.04
sigFunc.py	signal processing
mylib.py	general function collection
Software Praat	
extract_f0.praat	f0 extraction for mono files
extract_f0_stereo.praat	f0 extraction for stereo files
Subfolders	
config	JSON configuration files
doc	documentation, legal issues
test	test input and output files

### 3 Call

The main script *copasul.py* can be used in a shell or within the Python3 environment. After having changed to the copasul directory from the shell it is called as follows:

```
> copasul.py -c myConfigFile.json, e.g.
> copasul.py -c config/test.json
```

The content of *myConfigFile.json* is explained in section 9. Within the Python environment the tool is used this way:

```
>>> import copasul as copa
>>> myCopa = copa.copasul({'config':myConfig})
>>> myCopa = copa.copasul({'config':myConfig, 'copa':myCopa})
```

The input argument is a nested dictionary with at least one sub-dictionary *config*, which contains the configurations (see section 9). *copasul()* returns the output dictionary *myCopa* with the extracted feature sets (see section 10.3). In case feature extraction should not start from scratch, but an already existing dictionary should be corrected or expanded, it will be passed to the function via the key *copa* as shown in second example.

For shell calls as well as for calls within the Python environment the stylization output is written to a Python pickle file and to csv table files as specified in the configurations. See section 10.

### 4 Input

For automatic annotation Copasul needs audio and F0 table files. For feature extraction additionally annotation files. Corresponding files do not necessarily need to have the same name stem, but it is assumed that all audio, F0, and annotation files are sorted the same. An example can be found in the *input* subdirectory.

Additionally a configuration file in *JSON* format is needed as further specified in section 9.

## 4.1 Audio files

Currently only wav files are supported. The files can be mono or stereo. For conversion to wav, e.g. *Praat*, *Audacity*, or *Sox* software can be used.

## 4.2 F0 files

Plain text files. Tables with whitespace column separator. The first column contains time information. All further columns contain the F0 of the respective channel. For mono files f0 tables thus consist of 2 columns, for stereo files of 3, etc.

## 4.3 Annotation files

The Praat TextGrid format (long and short) and an XML format of the following form are supported.

```
<?xml version="1.0" encoding="UTF-8"?>
<annotation>
  ...
  <tiers>
    <tier>
      <name>mySegmentTier</name>
      <items>
        <item>
          <label>x</label>
          <t_start>0.3</t_start>
          <t_end>0.9</t_end>
        </item>
        ...
      </items>
    </tier>
    <tier>
      <name>myEventTier</name>
      <items>
        <item>
          <label>y</label>
          <t>0.7</t>
        </item>
        ...
      </items>
    </tier>
    ...
  </tiers>
  ...
</annotation>
```

The tiers need to be stored in the *tiers* subtree right below the root element.

Each tier must have a name assigned by the element *name*. The items of each tier are collected in the *items* subtree, in which each item is stored in an *item* subtree.

Segment tiers (see next section) must contain the elements *label*, *t\_start*, *t\_end*. Event tiers must contain the elements *label*, *t*.

The XML annotation file can be extended by the user as long as it fulfills the specified requirements in the *tiers* subtree.

## 4.4 Annotation tiers

In the following the notation **a:b:...** refers to branches through the configuration dictionary which is introduced in section 9. The annotation files can contain tiers of the following types:

**Segment tiers** contain items defined by a label, a start point and an endpoint. They correspond to Praat IntervalTiers.

**Event tiers** contain items without a temporal extension. They are defined by a label and a time stamp and correspond to Praat TextTiers.

Both segment tiers and event tiers are supported for most of the analyses. Wherever needed, an event is converted to a segment by centering a window of length **preproc:point\_win** on the event as is explained in more detail in section 7.3. Pause information can only be extracted for segment tiers. In TextGrids pauses are considered to be items with empty labels or labeled as **fsys:label:pau**. Both event and segment tiers can serve as:

**Analysis tiers** In the context of automatic annotation these tiers contain or limit the candidate locations for prosodic events. Can be segment or event tiers.

```
fsys:augment:glob:tier
fsys:augment:loc:tier_acc
fsys:augment:loc:tier_ag
```

For feature extraction these segment or event tiers define the units of analysis.

```
fsys:chunk:tier
fsys:glob:tier
fsys:loc:tier_acc
fsys:loc:tier_ag
fsys:bnd:tier
fsys:gnl_f0:tier
fsys:gnl_en:tier
fsys:rhy_f0:tier
fsys:rhy_en:tier
```

**Parent tiers** Parent tiers (1) limit the analysis and normalization windows by their segment boundaries. As an example, normalization across chunk boundaries can be suppressed. (2) They limit the domain of global trends against which local deviation is measured. It's strongly recommended to use segment tiers for this purpose. If not specified, the whole file is treated as a single parenting segment. For automatic annotation parent tiers are to be defined by:

```
fsys:augment:syl:tier_parent
fsys:augment:glob:tier_parent
fsys:augment:loc:tier_parent
```

For *glob*, *bnd*, *gnl\_en*, *gnl\_f0*, *rhy\_en*, *rhy\_f0* feature extraction (see section 8) only speech chunks can serve as parent domains:

```
fsys:chunk:tier
```

Fallback is again the entire file. For *loc* feature extraction only the segments of the *glob* analysis tier can form the parent domain due to the:

**Superpositional framework** Within the CoPaSul approach (see section 7.4) the intonation contour is considered as a superposition of a global and local components. Their domains are defined by the *glob* and *loc* option branches, respectively:

```
fsys:glob:tier
fsys:loc:tier_acc
fsys:loc:tier_ag
```

This has two implications on the annotation tier definitions:

- for each channel only one tier is supported each for the global and the local local domain
- the global domain tier is treated as the parent tier for the local domain tier

**Output tiers** For automatic annotation these tiers are defined by a stem which is always expanded by the recording channel index.

```
fsys:augment:chunk:tier_out_stm
fsys:augment:syl:tier_out_stm
fsys:augment:glob:tier_out_stm
fsys:augment:loc:tier_out_stm
```

As an example, given a stereo file and the chunk output tier name CHUNK, the tiers CHUNK\_1 and CHUNK\_2 will be added to the annotation file. For the sake of an uniform treatment, also for mono files the channel index will be added.

**Tier specification** For all tiers, that were not automatically generated, the user needs to specify the recording channel index it refers to (also for mono files!), e.g.:

```
fsys:channel:'tierA'=1
fsys:channel:'tierB'=2
```

*tierA* thus refers to channel 1, and *tierB* to channel 2. Tier names can be specified as strings, or as list of strings.

```
fsys:bnd:tier='tierA'
```

means, that the *bnd* feature extraction is to be carried out for units defined by the content of *tierA*.

```
fsys:bnd:tier=['tierA','tierB']
```

triggers a *bnd* feature extraction for the content of two tiers. The channels the specified tiers refer to are looked up in `fsys:channel:*`.

The name stem of a tier resulting from automatic annotation (e.g. *CHUNK*) will be expanded automatically, thus for a chunked stereo file these two specifications are equivalent:

```
fsys:bnd:tier='CHUNK'
fsys:bnd:tier=['CHUNK_1', 'CHUNK_2']
```

For the feature sets *bnd*, *gnl\_en*, *gnl\_f0*, *rhy\_en*, *rhy\_f0* (see section 8) an arbitrary number of tiers can be specified for each channel. For *chunk*, *glob*, *loc* only one tier per channel is supported.

## 5 F0 extraction

For F0 extraction in mono or stereo wav files the two Praat scripts contained in this package can be used.

They can be called this way:

```
> praat extract_f0.praat myStepsize myMinFreq myMaxFreq \
    myAudioInputDir myF0OutputDir myAudioExt myF0Ext
```

The usage of `extract_f0.stereo.praat` is the same. Note that subsequent stylization **in any case initiates a resampling to 100 Hz**, so that `myStepsize` here can be directly set to 0.01. *myMinFreq* and *myMaxFreq* refer to the minimum and maximum of allowed F0 values in Hz. Values below or above are considered as measurement errors and are set to 0. The F0 range choice depends on the recorded speakers. As a rule of thumb the parameters can be set to 50 and 400 Hz, respectively.

## 6 Automatic annotation

Automatic unsupervised prosodic annotation comprises chunking, syllable nucleus and boundary extraction, prosodic phrase extraction, and pitch accent localization. Details of the algorithms will be given in [14]. At the beginning of each introductory paragraph it is specified:

**navigation:** *which navigation option to set to True in the configuration file (see section 9)*  
**feature sets:** *which feature sets result from the annotation (see section 8)*  
**option sub-dictionary:** *which configuration sub-dictionaries serve to customize the respective processing (see section 9)*  
**output sub-dictionary:** *which subdirectory of the resulting python nested dictionary contains the extracted feature set (see section 10.3).*

Paths through the configuration dictionary are referred to by `my:path:to:option`.

**navigation:** *do\_augment\_\**  
**feature sets:** –  
**option sub-dictionary:** *fsys:augment:\*.%; augment:\*.%*  
**output sub-dictionary:** *(augmented annotation file)*

### 6.1 Chunking

**navigation:** *do\_augment\_chunk*  
**feature sets:** –  
**option sub-dictionary:** *fsys:augment:chunk:\*.%; augment:chunk:\**  
**output sub-dictionary:** *(augmented annotation file)*



Chunking serves to segment the utterance into interpausal units. It is based on a pause detector, that works the following way: an analysis window  $w_a$  with length `augment:chunk:l` is moved over the lowpass-filtered signal together with a longer reference window  $w_r$  of length `augment:chunk:l_ref` with the same midpoint. A pause is set where the mean energy in  $w_a$  is below a threshold defined relative to the energy in  $w_r$ , i.e. if  $e(w_a) < e(w_r) \cdot \text{augment:chunk:e\_rel}$ . Chunks are then trivially assigned to interpausal intervals. The filtering of the signal can be customized by the sub-dictionary `augment:chunk:flt`. In there `btype` gives the Butterworth filter type (*high, low, band, or none*), `f` the cutoff frequency(ies), and `ord` the order. For pauses as well as for inter-pause intervals minimum lengths can be defined by `augment:min_pau.l` and `min_chunk.l`, respectively. Pauses are then merged across too short chunks, and chunks are merged across too short pauses. The segment tier output will be added to the annotation file. The tier name is specified by `fsys:augment:chunk:tier_out_stm` concatenated with the respective channel index. Standard labels 'x' are assigned to chunk segments, and `fsys:label:pau` to the pauses inbetween.

## 6.2 Syllable nucleus and boundary extraction

**navigation:** `do_augment_syl`  
**feature sets:** –  
**option sub-dictionary:** `fsys:augment:syl:*; augment:syl:*`  
**output sub-dictionary:** (*augmented annotation file*)

For syllable nucleus detection the method proposed by [11] is adopted. Again an analysis  $w_a$  with length `augment:syl:l` and a longer reference window  $w_r$  of length with length `augment:syl:l_ref` with the same midpoint are moved along the signal, which this time is band-pass filtered to focus on the frequency band related to vocalic nuclei. The filter specification in `augment:syl:flt` works as described for chunking. From this energy contour the local maxima are extracted. If for a local maximum the mean energy in  $w_a$  supersedes the mean energy in  $w_r$  by a defined factor, i.e. if  $e(w_a) > e(w_r) \cdot \text{augment:syl:e\_rel}$ , and if  $e(w_a)$  is not below a defined fraction of the energy in the current chunk  $w_c$  (fallback: whole file), i.e.  $e(w_a) \geq e(w_c) \cdot \text{augment:syl:e\_min}$ , a syllable nucleus is set. From which tier to get the current chunk is to be defined by `augment:syl:tier_parent`. E.g. it can be the output tier of a preceding chunking step. A further constraint `augment:syl:d_min` specifies the minimum distance between subsequent syllable nuclei. If two nuclei are too close, they are merged to a single syllable and the point of energy maximum in this interval is assigned to be the nucleus.

Subsequently syllable boundaries are assigned to the energy minimum between adjacent syllable nuclei. They just serve as fallback prosodic boundary candidates.

The output consists of two event tiers for syllable nuclei and boundaries and will be added to the annotation file. The tier name is specified by `fsys:augment:syl:tier_out_stm`. For the nuclei it is concatenated with the respective channel index. For the boundaries it is concatenated with a 'bnd' infix and the channel index. Standard labels 'x' are assigned for both tiers.

## 6.3 Prosodic phrase boundary location

**navigation:** `do_augment_glob`  
**feature sets:** –  
**option sub-dictionary:** `fsys:augment:glob:*; augment:glob:*`  
**output sub-dictionary:** (*augmented annotation file*)

Prosodic phrase boundary decisions are based on nearest centroid classification. The user needs to specify the tier that contains boundary candidates in `fsys:augment:glob:tier`. For segment tiers these candidates are the segment boundaries, for event tiers, the candidates are the time stamps. If no tier is specified, syllable boundaries derived by step 6.2 will be selected as candidates. At each boundary candidate a feature set is extracted that had been proven to be related to prosodic boundaries in former studies [17, 18]. This feature set is introduced in section 7.9. The user needs to specify which of these features should be selected by

```
augment:glob:wgt:myBndFeatset+:myRegister+:myFeat+.
```

In case a phone segment tier is available and if centroids are derived from the entire data set and not separately for each file (see below), in addition z-scored vowel length can be used as a feature. The length of the vowel associated with the prosodic event candidate is divided by its mean length derived from the entire dataset. The associated vowel is the last vowel segment with an onset before the boundary candidate time stamp. The length feature can be added by:

```
augment:glob:wgt:pho=1
```

The phonetic segment tiers (one for each channel) are to be specified in

```
fsys:pho:tier
```

Vowels are identified in these tiers by a regular expression stored in

```
fsys:pho:vow
```

This feature will be beneficial for languages in which phrase boundaries and/or accents are marked by phone segment lengthening.

Furthermore the user can select whether the current feature values at time  $i$ ,  $v_i$ , or the delta values (i.e. the differences to the preceding values  $v_i - v_{i-1}$ ) or both should be taken:

```
augment:glob:measure
```

Some features require units from a parent tier which is to be specified by `augment:glob:tier_parent`, e.g. to measure local F0 trend discontinuities within a superordinate unit and to limit analysis and normalization windows. Such units are e.g. chunks derived from preceding chunking. Fallback is the entire file.

From the features for each of the two classes *boundary B* and *no boundary NB* a centroid can be bootstrapped in several ways given the specification in `augment:glob:cntr_mtd` as described in the following sections. Centroids can be calculated separately for each file or over the entire data set by setting the value of

```
augment:glob:unit
```

to *file* or *batch*, respectively. The latter is strongly recommended for corpora containing lots of short recordings.

### 6.3.1 Percentile split

```
augment:glob:cntr_mtd=split
augment:glob:prct=mySplitPoint
```

Since for all extracted pause length and pitch discontinuity boundary features are positive correlation has been found to perceived boundary strength [17, 18] B and NB centroids can be straight-forwardly derived from high and low feature values, respectively. Centroids are thus derived by splitting each column in the feature matrix at the percentile `augment:glob:prct`. The B centroid is defined by the median of the values above the splitpoint, the NB centroid by the median of the values below. All feature vectors are then assigned to the nearest centroid in a single pass. Boundaries are subsequently inserted at all candidate time points classified as B. This method works for both segment and event tier input.

### 6.3.2 Bootstrapping seed centroids for kMeans

```
augment:glob:cntr_mtd=seed_kmeans
augment:glob:min_l=myMinPhraseLength
```

This procedure works for segment tier input only since it makes use of pauses between adjacent segments. As visualized in Figure 1 B and NB centroids are bootstrapped based on two assumptions: (1) each pause indicates a prosodic boundary (green), and (2) prosodic phrases have a minimum length (red window), thus in the vicinity of pauses there are no further boundaries (blue).

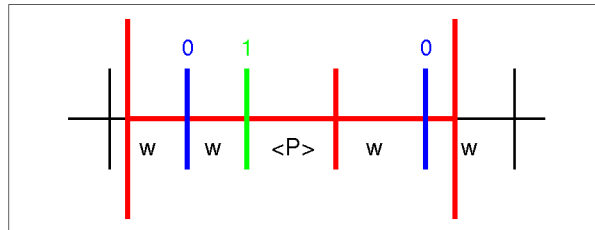


Figure 1: Bootstrapping seed centroids for the classes 1 (boundary) and 0 (no boundary). Word boundaries are indicated by the short vertical lines. Assumptions: each pause indicates a prosodic boundary (green), and prosodic phrases have a minimum length (red window), thus in the vicinity of pauses there are no further boundaries (blue).

### 6.3.3 Bootstrapping seed centroids for percentile split

```
augment:glob:cntr_mtd=seed_prct
augment:glob:prct=mySplitPoint
augment:glob:min_l=myMinPhraseLength
```

The seed centroid bootstrapping works as for the preceding method. Instead of kMeans, for the remaining feature vectors the Euclidean distance to the NB seed centroid is calculated. Vectors with a distance above the *mySplitPoint*-th percentile of all measured distances are assigned to the B class, the others to the NB class.

### 6.3.4 Practical considerations

The percentile split method works for both segment and event tiers, whereas the two centroid bootstrapping methods need segment tier input to infer pause locations. For the two percentile split approaches, the parameter `augment:glob:prct` serves to control for the number of inserted boundaries. The higher, the smaller the B class, thus the fewer boundaries will be assigned.

If a text transcription is at hand the user can ensure that prosodic boundaries only occur at word boundaries by preceding signal-text alignment, e.g. by WebMAUS [21, 8].

### Heuristics

```
augment:glob:heuristics=ORT
```

If set by the user, this heuristics assumes a word segment tier as input and rejects boundaries after too short and thus probably function words ( $< 0.2s$ )

### 6.3.5 Feature selection and weighting

```
augment:glob:wgt:myBndFeatset+:myRegister+:myFeat+=myWeight  
augment:glob:wgt_mtd=myWeightingMethod
```

By the `augment:glob:wgt:myBndFeatset+:myRegister+:myFeat+` branches the user at the same time selects and weights features. As an example

```
augment:glob:wgt:win:ml:rms=1
```

selects the feature `rms` derived from the register representation `ml` within the boundary feature set `win` (see sections 7.9 and 8 for explanations). If the weighting method in `augment:glob:wgt_mtd` is set to 'user', the weight of this feature becomes 1. If no weighting is intended, to all selected features should be assigned the same weight. As an alternative to the definition by the user, weights can also be extracted by correlation to the median or by the cluster silhouette measure.

**Correlation** Each feature is correlated with the medians of the feature vectors. Since as mentioned all boundary features are expected to be positively correlated to boundary strength, and since the median is expected to be more robustly related to boundary strength than single features, the correlation between a feature and the medians to some extent reflects the goodness of this feature to predict boundary strength. Features with a negative correlation to the median will be removed from the pool. All remaining correlations are transformed to weights summing up to 1 by dividing them by the sum of correlations.

**Silhouette** The mean silhouette over all clustered data points measures how well clusters can be separated. Here it is measured separately for each feature within the clearly assignable feature vectors from which the B and NB seed centroids were derived. It is minmax-normalized to the range [0 1].

### 6.3.6 Output

The output consists of a segment tier for each channel with the name `fsys:glob:tier_out_stm + channelId`. Each segment spans the interval between two subsequent B events. If `fsys:glob:tier` is a segment tier, then pauses are taken over from this tier. Standard labels 'x' are assigned to the prosodic phrase segments.

## 6.4 Pitch accent detection

Pitch accents are derived in an analogous bootstrap fashion as prosodic boundaries. The user needs to specify an event tier (default: syllable nuclei) for localization of the pitch accent candidates. Furthermore the user can specify a segment tier (e.g. words) to restrict the maximum number of detected pitch accents within each segment to 1.

```
fsys:augment:loc:tier_acc  
fsys:augment:loc:tier_ag
```

Given a segment tier, the user can furthermore specify (1) whether each segment should get an accent or only the prominent ones

```
augment:loc:ag_select
```

and (2) where within a segment an accent should be placed: left- or rightmost, e.g. for prosodically left- or right-headed languages, or on the most prominent candidate.

```
augment:loc:acc_select
```

Prominence can be parameterized by several feature sets measuring standard F0 and energy features, contour shapes within local segments and their deviation from a global declination trend.

The user can select whether the current feature values at time  $i$ ,  $v_i$ , or the delta values (i.e. the differences to the preceding values  $v_i - v_{i-1}$ ) or both should be taken:

```
augment:loc:measure
```

Some features require units from a parent tier which is to be specified by `augment:loc:tier_parent`, e.g. to measure local F0 deviations relative to some superordinate unit and to limit analysis and normalization windows. Such units are e.g. prosodic phrases derived from preceding phrase extraction. Fallback is the entire file.

From these features for each of the two classes *accented*  $A$  and *not accented*  $NA$  a centroid can be bootstrapped in several ways analogously to the prosodic boundary extraction, this time given the specification in `augment:loc:cntr_mtd`.

Centroids can be calculated separately for each file or over the entire data set by setting the value of

```
augment:loc:unit
```

to *file* or *batch*, respectively. The latter is strongly recommended for corpora containing lots of short recordings.

#### 6.4.1 Percentile split

```
augment:loc:cntr_mtd=split
augment:loc:prct=mySplitPoint
```

Given a user-defined feature set where for each feature high values indicate prominence  $A$  and  $NA$  centroids can be straight-forwardly derived from high and low feature values, respectively. Centroids are thus derived by splitting each column in the feature matrix at the percentile `augment:loc:prct`. The  $A$  centroid is defined by the median of the values above the splitpoint, the  $NA$  centroid by the median of the values below. All feature vectors are then assigned to the nearest centroid in a single pass. Boundaries are then inserted at all candidate time points classified as  $B$ . This method works for both segment and event tier input.

#### 6.4.2 Bootstrapping seed centroids for kMeans

```
augment:loc:cntr_mtd=seed_kmeans
augment:loc:max_l_na=myMaxLengthNA
augment:loc:min_l_a=myMinLengthA
augment:loc:min_l=myMinLengthAG
```

This procedure works only if a segment tier is provided next to the event tier, and if this segment tier contains word-like units. As for the phrase boundary detection described above there are 2 (this time even more) simplifying assumptions to derive seed centroids for cluster initialization (cf. Figure 2): (1) each word longer than `augment:loc:min_l_a` contains an accent, due to its expected high information content. (2) each word shorter than `augment:loc:max_l_na` does not contain an accent due to its expected low information content. Depending on `augment:loc:acc_select` the  $A$  centroid is then calculated from all leftmost, rightmost, or most prominent `tier_acc` candidates in the `tier_ag` segments fulfilling criterion (1). The  $NA$  centroid is calculated from all `tier_acc` candidates in the `tier_ag` segments fulfilling criterion (2). KMeans clustering is then initialized by these two centroids and subdivides all candidates into the  $A$  and  $NA$  cluster. Multiple  $A$  cases within the same segment are reduced by `augment:loc:acc_select`. Furthermore, among  $A$  cases closer than `augment:loc:min_l` only the more prominent ones are kept.

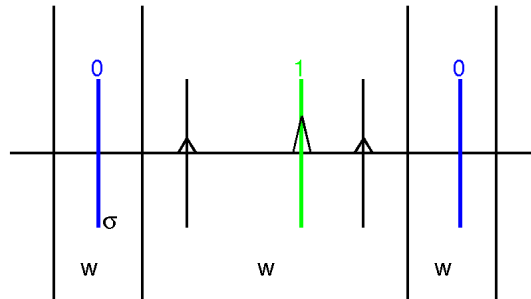


Figure 2: Bootstrapping seed centroids for the classes 1 (accent) and 0 (no accent). Word boundaries are indicated by long vertical lines, and syllable nuclei by short vertical lines. Prominence is encoded by the size of the triangles. Assumptions: each word longer than some threshold contains an accent (green); each word shorter than some threshold does not contain an accent (blue). Within the accented word the accent is placed on the most prominent syllable (as in this example), or on the left- or rightmost syllable.

### 6.4.3 Bootstrapping seed centroids for percentile split

```
augment:loc:cntr_mtd=seed_prct
augment:loc:prct=mySplitPoint
augment:loc:max_l_na=myMaxLengthNA
augment:loc:min_l_a=myMinLengthA
```

The seed centroid bootstrapping works as for the preceding method. Instead of kMeans, for the remaining feature vectors the Euclidean distance to the NA seed centroid is calculated. Vectors with a distance above the *mySplitPoint*-th percentile of all measured distances are assigned to the A class, the others to the NA class.

### 6.4.4 Practical considerations

The percentile split method works with and without segment tiers, whereas the two centroid bootstrapping methods need segment tier input next to the event tier to infer word length. As with boundary detection, the parameter `augment:loc:prct` serves to control for the number of assigned accents. The higher, the smaller the A class, thus the fewer accents will be assigned.

As mentioned for prosodic boundary detection, a supporting word segmentation can be derived by preceding signal-text alignment, e.g. by WebMAUS [21, 8].

### 6.4.5 Feature selection and weighting

```
augment:loc:wgt:myFeatset+:...
```

The same selection and weighting mechanisms apply as described in section 6.3.5.

The following feature sets can be used: *acc*, *gst*, *gnl\_f0*, *gnl\_en* (see section 8). In section 9 examples are given how to expand the corresponding configuration branches.

As for boundary detection also for pitch accent detection z-scored vowel length can be added to the feature set. The vowel interval associated to a pitch accent candidate includes the candidate's time stamp. See section 6.3 for further details. The length feature can be added by:

```
augment:loc:wgt:pho=1
```

### 6.4.6 Output

The output consists of an event tier for each channel with the name *fsys:loc:tier\_out\_stm* + *channelIndex*. Standard labels 'x' are assigned to each accent.

## 7 Stylization

In the following the F0 preprocessing and the F0 and energy stylization steps are introduced. For each stylization step it is specified:

**navigation:** *which navigation option to set to True in the configuration file (see section 9)*

**feature sets:** *which feature sets result from the stylization (see section 8)*

**option sub-dictionary:** *which configuration parts serve to customize the respective processing (see section 9)*

**output sub-dictionary:** *which part of the resulting Python nested dictionary variable contains the extracted feature set (see section 10.3).*

Branches through the configuration as well as through the result dictionary are referred to by `my:branch:to:value`.

### 7.1 F0 preprocessing

F0 preprocessing comprises resampling to 100 Hz, outlier detection, interpolation over outliers and voiceless utterance parts, smoothing, and semitone conversion including speaker normalization.

**Outliers** Outliers are defined in terms of deviation from a mean value. The deviation factor is controlled by `preproc:out:f`, and the mean representation by `preproc:out:m`.

**Interpolation** Only linear interpolation is supported. Horizontal extrapolation is carried out at file boundaries.

**Smoothing** The smoothing method is chosen by `preproc:smooth:mtd`. Median and Savitzky-Golay filtering are supported. Median filtering yields smoother contours, while Savitzky-Golay better preserves local F0 maxima and minima. The higher the window length `preproc:smooth:win`, the more smooth the contours. For the Savitzky-Golay filtering the polynomial order needs to be specified by `preproc:smooth:ord`. The lower, the more the result gets smoothed away from the input data.

```
navigation: do_preproc
feature sets: -
option sub-dictionary: preproc:*
output sub-dictionary: data:myFileIdx:myChannelIdx:f0:*
```

**Semitone conversion** If `preproc:st=1`, Hertz (Hz) values are transformed to semitones (st) as follows:  $F0_{st} = 12 \cdot \log_2(\frac{F0_{Hz}}{b})$ .  $b$  is a base value which is calculated separately for each channel in each F0 file. It is defined as the median of the values below the percentile `preproc:base_prct` and can be used for F0 normalization by file and channel. Alternatively, a grouping variable can be specified, so that for each of its levels a separate F0 base value is calculated. This is done by `preproc:base_prct_grp`. There it can be specified which grouping variable is to be assigned to each channel. The grouping variable must be encoded in the filename and must be extractable from `fsys:grp:lab`. An example: you have stereo F0 files with the name pattern *speakerChannel1\_speakerChannel2*. And you want to calculate separately for each speaker an F0 base value which is the median of the values below the 5th percentile over all this speaker's utterances in the corpus. This is to be configured as follows:

```
fsys:grp:src='f0'
fsys:grp:sep='_'
fsys:grp:lab=['speakerChannel1','speakerChannel2']
preproc:base_prct=5
preproc:base_prct_grp:'1'='speakerChannel1'
preproc:base_prct_grp:'2'='speakerChannel2'
```

This assigns to each channel the grouping variable to be read from the F0 file names. Note, that (1) channel indices need to be written in quotation marks, and (2) a shared semantics across the grouping variables is assumed. E.g. just one base value will be calculated for speaker  $x$ , regardless whether she was recorded in channel 1 or 2.

**Base value subtraction** If `preproc:st` is 0, the base value introduced in the preceding paragraph will be subtracted from the F0 contour without semitone conversion. If you don't want to use any base value, neither for subtraction nor as conversion reference, set `preproc:base_prct=0`.

## 7.2 Energy calculation

The energy contour is simply represented in terms of the root mean squared deviation (RMSD) within the windowed signal. The relevant parameters can be found below `styl:gml_en styl:rhy_en:sig`. `win` defines the window length and `sts` the stepsize. The energy value sample rate is thus  $1/sts$ . `wintyp` and `winparam` give the window type and an additional parameters passed on the `get_window()` function of the `scipy.signal` module. For customizing energy extraction with other than default values, please consult the `scipy.signal` documentation for `get_window()`. `wintyp` and `winparam` can contain any value specified in this documentation.

## 7.3 Analysis and normalization windows

Windows serve (1) to transform time stamps from an event tier to segments, and (2) to locally normalize feature values.

**Time stamps to segments** Most feature sets are calculated for segments, not for time stamps. Thus event tier input is converted to segments by centering a symmetric analysis window with the length `preproc:point_win` on each time stamp as shown in Figure 3. Features are then extracted within this window. The window can also be separately specified for each feature set by `preproc:myFeatureSet:point_win`. For local contour stylization a segment and an event tier can be processed in parallel as explained in section 7.7.

**Normalization** For the feature sets *loc*, *gml\_f0* and *gml\_en* several feature values are additionally locally normalized to capture their relative amount compared to the local environment. This environment length is defined by `preproc:nrm_win`. For event tier input the normalization window is centered on each time stamp. For segment tier input, it is centered on the midpoint of each segment. For parallel segment and event tier input which can be provided for *loc* feature extraction, the window is centered on the event's time stamp within the segment. The window can also be separately specified for each feature set by `preproc:myFeatureSet:nrm_win`.

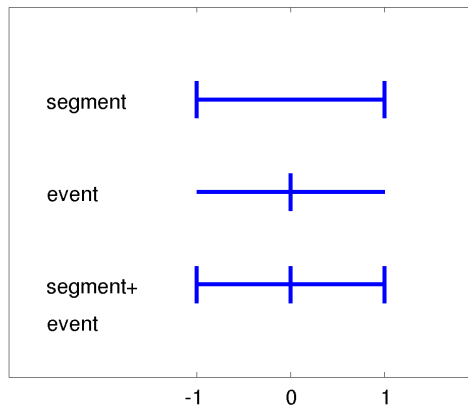


Figure 3: Segment and event tier input. A symmetric analysis window is centered on events. For local contour stylization, segment and event tiers can be integrated for time normalization: the event is set to 0, the pre-event part of the segment to  $[-1\ 0[$ , and the post-event part of the segment to  $]0\ 1]$ .

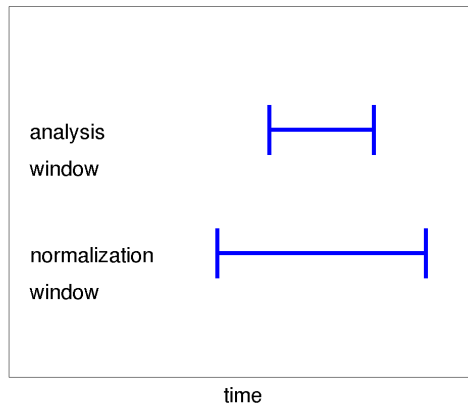


Figure 4: Analysis and longer normalization window. The values derived in the analysis window are divided by the corresponding values in the normalization window.

**Window constraints** Analysis and normalization window are limited to the corresponding segment in the parent tier domain. For *loc* features this domain is given by the global segment tier. For the other features it is given by the speech chunk tier if this tier is defined in *fsys:chunk:tier*. This means that analysis and normalization is not carried out across global segments or chunks, respectively. An exception can be made for the *bnd* feature set, that might be meaningful for chunk boundaries, too. If so, *styl:bnd:cross\_chunk* is to be set to 1. For segment tier input the minimum length of the normalization window is set to the length of the respective segment. This implies that for segments longer than the defined normalization window, normalized feature values are the same as the not normalized ones.

```
navigation: do_preproc
feature sets: -
option sub-dictionary: preproc:*
output sub-dictionary: data:myFileIdx:myChannelIdx:...:{t|to|tn}
```

## 7.4 Superposition

The core concept of CoPaSul is to represent an F0 contour as a superposition of linear global component and polynomial local components as shown in Figure 5.

Stylization is carried out as follows: Within each global segment of the tier *fsys:glob:tier* (e.g. an intonation phrase) a linear register level and range representation is fitted. After subtraction of this global component, within each local segment an n-th order polynomial is fitted to the F0 residual. As an alternative to register level subtraction, the F0 residual can also be derived by normalization of the contour to the register range.

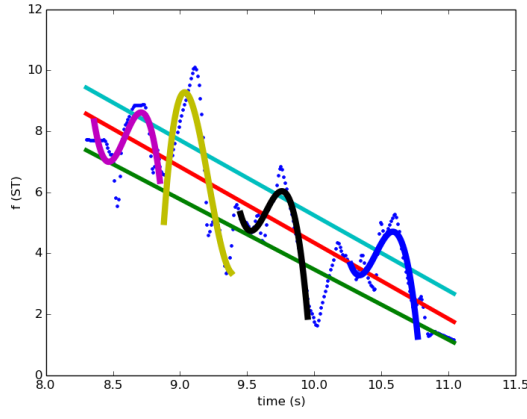


Figure 5: Superposition of one global and four local contours.

## 7.5 Global segments

### 7.5.1 Register

Global segments are represented in terms of a time-varying F0 register. Register aspects are level (midline) and range (topline – baseline).

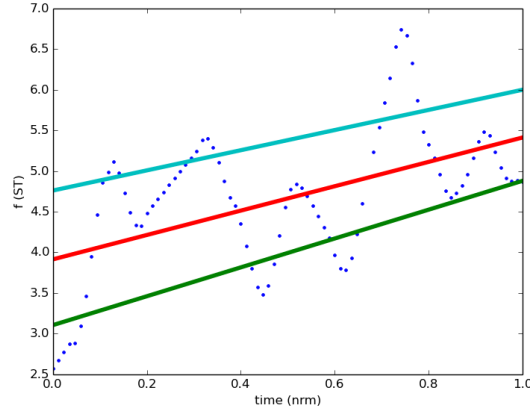


Figure 6: Register (level and range) stylization in global contour segments.

**navigation:** *do\_styl\_glob*  
**feature sets:** glob  
**option sub-dictionary:** *styl:glob:\**  
**output sub-dictionary:** *data:myFileIdx:myChannelIdx:glob:\**

The register fitting procedure consists of the following steps:

- A window of length `styl:glob:decl_win` is shifted along the F0 contour with a step size of 10 ms.
- Within each window the F0 median is calculated
  - of the values below the `styl:glob:prct:bl` percentile for the baseline,
  - of the values above the `styl:glob:prct:tl` percentile for the topline, and
  - of all values for the midline.

This gives 3 sequences of medians, one for the base-, the mid-, and the topline, respectively.

- To each of the three median sequences a linear regression line is fitted. To be able to compare contours across global segments of different lengths, time is normalized as specified by `styl:glob:nrm:mtd` to the range `styl:glob:nrm:rng`.

The motivation for using F0 medians relative to respective percentiles instead of local peaks and valleys is twofold. First, the stylization is less affected by prominent pitch accents and boundary tones. Second, errors resulting from incorrect local peak detection are circumvented. Both enhances stylization robustness as is shown in [18].

The following configuration parameters serve to customize how closely the base- and topline should follow local minima and maxima:



```

styl:glob:prct:bl
styl:glob:prct:tl
styl:glob:decl_win

```

A closer fit to local peaks and valleys is achieved by lowering `styl:glob:prct:bl` and `styl:glob:decl_win`, and by raising `styl:glob:prct:tl`. Note however, that a closer fit will result in a higher percentage of base- and topline crossings. In the resulting Python dictionary such error cases are marked as described here: 10.3.2.

From this stylization, regression line slope and intercept features are collected for the base-, mid-, and topline, as well as for the range. For the latter these features are simply derived by fitting a linear regression line through the point-wise distances between the base- and the topline. A negative slope means that base- and topline converge, whereas a positive slope signals line divergence.

### 7.5.2 Contour classes

Global contour classes for analyses on the categorical level are derived by slope clustering. The cluster method can be chosen by `clst:glob:mtd`. If the user expects a certain number of classes, this number can be specified by `clst:glob:kMeans:n_cluster`. Otherwise, meanShift clustering should be chosen, either as the cluster method, or in combination with kmeans for the sake of centroid initialization. For customizing the clustering settings by non-default values several parameters are provided whose values are passed on to the respective Python *sklearn* functions. These parameters are named as in *sklearn*. If needed, please consult the descriptions of the sklearn functions *KMeans*, *MeanShift*, and *estimate\_bandwidth*. Figure 7 gives an example for global and local contour classes.

```

navigation: do_clst_glob
feature sets: glob
option sub-dictionary: clst:glob:*
output sub-dictionary: data:myFileIdx:myChannelIdx:glob:class

```

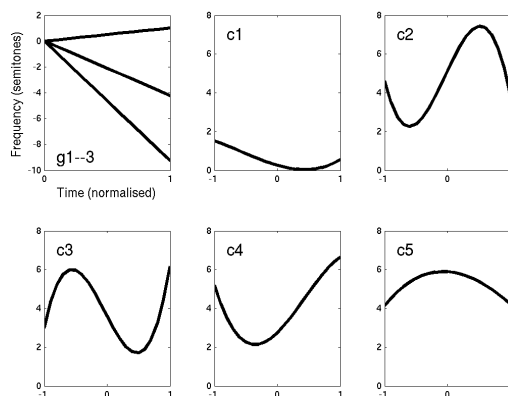


Figure 7: Global and local intonation contour classes derived by clustering.

## 7.6 F0 residual

Dependent on `styl:register` the influence of the global component is removed from the F0 contour in order to derive the F0 residual for subsequent local contour stylization. If `styl:register` is set to *bl*, *ml*, or *tl*, then the base, mid, or topline is subtracted. If the parameter is set to *rng*, each F0 point is normalized to the local F0 range: the corresponding points on the base- and topline are set to 0 and 1, respectively. Thus F0 values between base- and topline are within the range [0 1], F0 values below the baseline are < 0, and values above the topline are > 1. For `styl:register=none` no global component influence is removed.

## 7.7 Local segments

In the annotation files local segments can be defined in 3 ways:

1. by start and end (segment tier input specified in `fsys:loc:tier_ag`)
2. by a center (event tier input specified in `fsys:loc:tier_acc`)
3. by both (segment + event tier input)

For case (2) time stamps are transformed to segments by placing a symmetric window of length `preproc:point_win` on each time stamp. In order to be able to compare contours across different segment lengths, for (1) and (2) time is normalized as specified in `styl:loc:nrm`. `styl:loc:nrm:mtd=minmax` yields a minmax time normalization to the range `styl:loc:nrm:rng`.

For (3) the time stamp within the segment is treated as the zero-center, that is, time is  $[-1\ 0[$  normalized from the segment start to the center, and  $[0\ 1]$  normalized from the center to the segment end. For (3) only those segments in tier `fsys:loc:tier_ag` are considered for feature extraction to which exactly one center is assigned in tier `fsys:loc:tier_acc`.

### 7.7.1 Contour stylization

The F0 residual contour (see section 7.6) in each local segment is stylized by n-th order polynomials. The order is given by `styl:loc:ord`.

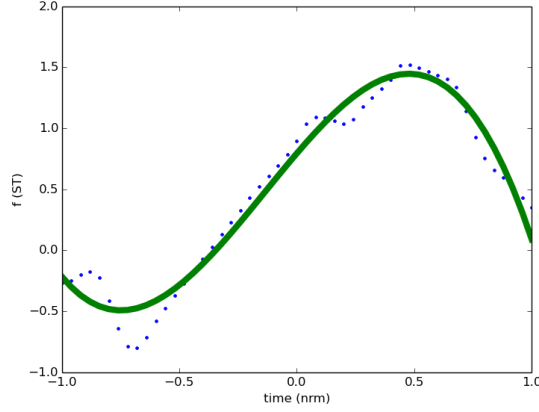


Figure 8: Local contour stylization by means of a 3rd order polynomial. Time is normalized to the range  $[0\ 1]$ .

As can be seen in Figure 9 the polynomial coefficients are related to several aspects of local F0 shapes. Given the polynomial  $\sum_{i=0}^3 s_i \cdot t^i$ ,  $s_0$  is related to the local F0 level relative to the register level.  $s_1$  and  $s_3$  are related to the local F0 trend (rising or falling) and – for annotation cases (2) and (3) – to peak alignment, that is negative values indicate early, and positive values late peaks.  $s_2$  determines the peak shape (convex or concave) and its acuity: positive  $s_2$  values indicate convex (falling-rising) shapes, negative values concave (rising-falling) shapes, and high values indicate stronger acuity.

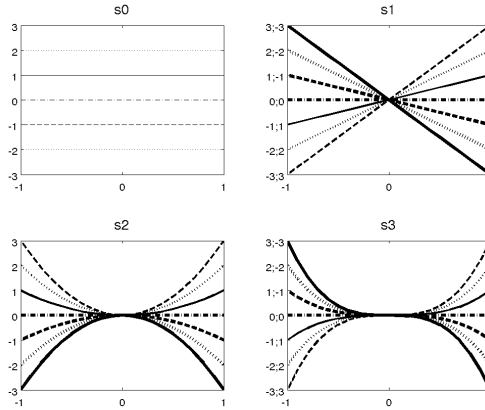


Figure 9: Influence of each coefficient of the third order polynomial  $\sum_{i=0}^3 s_i \cdot t^i$  on the local contour shape. All other coefficients set to 0. For compactness purpose on the y-axis both function and coefficient values are shown if they differ.

**navigation:** `do_styl_loc`  
**feature sets:** `loc`  
**option sub-dictionary:** `styl:loc:*`; `styl:register`  
**output sub-dictionary:** `data.myFileIdx:myChannelIdx:loc:acc:*`

### 7.7.2 Contour classes

Local contour classes for analyses on the categorical level are derived by polynomial coefficient clustering. The cluster method can be chosen by `clst:loc:mtd`. If the user expects a certain number of classes, this number can be specified by `clst:loc:kMeans:n_cluster`. Otherwise, meanShift clustering should be chosen, either as cluster method, or in combination with kmeans for the sake of centroid initialization. For customizing the clustering settings by non-default values several parameters are provided whose values are passed on to the respective Python *sklearn* functions. These parameters are named as in *sklearn*. If needed, please consult the descriptions of the *sklearn* functions *KMeans*, *MeanShift*, and *estimate\_bandwidth*. Figure 7 gives an example for global and local contour classes.

```
navigation: do_clst_loc
feature sets: loc
option sub-dictionary: clst:loc:*
output sub-dictionary: data:myFileIdx:myChannelIdx:loc:class
```

### 7.7.3 Standard features

Standard F0 and energy features are e.g. mean, standard deviation, median, interquartile range, and maximum. They will be calculated for the F0 contours for local contour segments. Additionally, the feature values are locally normalized within a window of length `preproc:nrm_win`. See section 7.3 for window length specifications in dependence of the annotation tier type.

```
navigation: do_styl_loc_ext
feature sets: loc
option sub-dictionary: styl:gnl:*.*
output sub-dictionary: data:myFileIdx:myChannelIdx:loc:gnl:*
```

### 7.7.4 Register features

As with global segments, register features can also be extracted for local features exactly the same way as introduced in section 7.5.1.

```
navigation: do_styl_loc_ext
feature sets: loc
option sub-dictionary: styl:glob:*
output sub-dictionary: data:myFileIdx:myChannelIdx:loc:decl:*
```

### 7.7.5 Gestalt features

Gestalt features quantify the deviation of the local contour register from the global contour register as shown in Figure 10. For this purpose the register properties of the local segment are compared with the properties of the dominating global segment in terms of root mean squared deviations and slope differences. For each register representation (base-, mid-, topline, and range regression line), the RMSD between the local and global declination line is calculated. The higher these values, the more the local contour sticks out from the global contour, which is of relevance for studies on prominence, accent group patterns [2], and prosodic headedness [19].

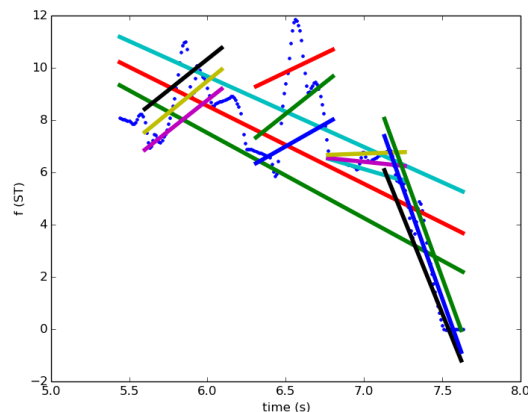


Figure 10: Gestalt stylization: Deviation of the local contour register aspects (base, mid, topline, range) from the global contour register.

The inherent Gestalt properties of the local contours are represented again in terms of polynomial coefficients. For this purpose polynomials of n-th order specified by `styl:loc:ord` are fitted to all supported kinds of F0 residuals: subtraction of base-, mid-, and topline, and range normalization. This yields 4 coefficient vectors, one for each residual.

```
navigation: do_styl_loc_ext
```

**feature sets:** loc  
**option sub-dictionary:** *styl:loc:\**  
**output sub-dictionary:** *data:myFileIdx:myChannelIdx:loc:gst:\**

## 7.8 Standard features

Standard features are e.g. mean, standard deviation, median, interquartile range, and maximum. They will be calculated for F0 and energy contours over the entire file and for segments in an arbitrary number of annotation tiers specified in **fsys:gnl\_f0:tier** and **fsys:gnl\_en:tier**, respectively. For event tiers, the segments are given by centering an analysis window of length *preproc:point\_win* on the time stamps. Additionally, the feature values are locally normalized within a window of length *preproc:nrm\_win*. See section 7.3 for window length specifications in dependence of the annotation tier type. Furthermore, F0 and energy quotients are calculated between the mean values derived in contour initial and final windows and in the respective remainder part of the contour. The length of this window is specified by *styl:gnl\_win*. Finally, a second order polynomial is fitted through the F0 or energy contour, for which time is normalized to the range [0 1].

### 7.8.1 For F0 contours

**navigation:** *do\_styl\_gnl\_f0*  
**feature sets:** gnl\_f0, gnl\_f0\_file  
**option sub-dictionary:** *styl:gnl\_f0:\**  
**output sub-dictionary:** *data:myFileIdx:myChannelIdx:gnl\_f0:\*, data:myFileIdx:myChannelIdx:gnl\_f0\_file:\**

### 7.8.2 For energy contours

An additional standard feature for energy only is spectral balance. It is realized by subtracting the energy value within the analysis window from the energy value within the same window after pre-emphasis of the signal. Pre-emphasis is carried out in the time domain as follows:  $s'[i] = s[i] - \alpha \cdot s[i - 1]$ .  $\alpha$  is specified by *styl:gnl\_en:alpha*.

**navigation:** *do\_styl\_gnl\_en*  
**feature sets:** gnl\_en, gnl\_en\_file  
**option sub-dictionary:** *styl:gnl\_en:\**  
**output sub-dictionary:** *data:myFileIdx:myChannelIdx:gnl\_en:\*, data:myFileIdx:myChannelIdx:gnl\_en\_file:\**

## 7.9 Boundaries

Boundaries are parameterized in terms of discontinuity features of several register representations. Details and an application for perceived prosodic boundary strength prediction can be found in [18].

Boundary features can be extracted for any number of segment or event tiers specified by **fsys:bnd:tier**. Features can be extracted for:

1. **navigate:do\_styl.bnd:** each adjacent segment pair. For event tiers, segments are defined as the intervals between two time stamps. Note that this implies, that pause length is only available for segment tier input, where it is defined as the gap between the second segment's starting point and the first segment's endpoint.
2. **navigate:do\_styl.win:** fixed time windows. For segment tiers, the pre- and post-boundary units are not given by the adjacent segments, but by windows of fixed length. For event tiers the window halves of *preproc:point\_win* centered on a time stamp are considered as pre- and post-boundary units.
3. **navigate:do\_styl.trend:** pre- and post-boundary units, that range from the current chunk start to the boundary, and from the boundary to the chunk end. If no chunking available, the file start and endpoint are taken.

For cases (2) and (3) holds: If **styl:bnd:cross\_chunk** is set to 0, and if a chunk tier is given by **fsys:tier:chunk**, the analyses windows are limited by the start and endpoint of the current chunk.

A boundary is parameterized in terms of pause length (for segment tier input only) and pitch discontinuities. For the latter, register features (as described in section 7.5.1) are extracted three times: for the pre-boundary segment, for the post-boundary segment, and for the concatenation of both segments. Figure 11 illustrates, how discontinuity then is expressed. Let  $\text{seg}_1$ ,  $\text{seg}_2$  be the pre- and post-boundary segments, and  $\text{seg}_{12}$  their concatenation. Then discontinuity is expressed by:

- the RMSD between the register representations (midline, range regression line) of  $\text{seg}_1$  and the corresponding part of  $\text{seg}_{12}$
- the RMSD between the register representations of  $\text{seg}_2$  and the corresponding part of  $\text{seg}_{12}$
- the RMSD between the register representations of  $\text{seg}_1$  and  $\text{seg}_2$  opposed to  $\text{seg}_{12}$
- the reset  $d_{1,2}$ , i.e. the difference between the initial value of the regression line in  $\text{seg}_2$  and the final value of the regression line in  $\text{seg}_1$

- the pairwise slope differences  $s_*$  between the 3 regression lines

All features are calculated 4 times, for the base-, mid- and toplines, as well as for the range regression lines.

In the `styl:bnd` option sub-dictionary `nrm`, `decl_win`, and `prct` have the same purpose right as in the `styl:glob` context, see section 7.5.1. `styl:bnd:win` specifies the window length of `seg12` for window case (2).

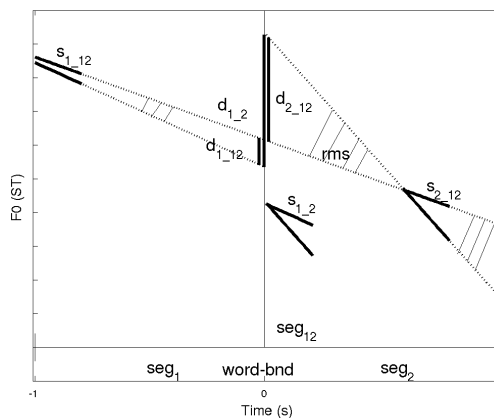


Figure 11: Boundary features describing reset and deviation from a common trend. In this case features are extracted at a word boundary *word-bnd*. The 3 regression lines can refer to F0 baselines, midlines, toplines, and to range. The same features are outputted for these 4 register aspects.

The subsequent paragraphs name the configuration branches associated to the stylization cases (1)–(3), respectively.

### 7.9.1 Of adjacent segments

**navigation:** `do_styl_bnd`  
**feature sets:** `bnd`  
**option sub-dictionary:** `styl:bnd:*`  
**output sub-dictionary:** `data:myFileIdx:myChannelIdx:bnd:std:*`

### 7.9.2 For fixed-length windows

**navigation:** `do_styl_bnd_win`  
**feature sets:** `bnd`  
**option sub-dictionary:** `styl:bnd:*`  
**output sub-dictionary:** `data:myFileIdx:myChannelIdx:bnd:win:*`

### 7.9.3 For global trends

**navigation:** `do_styl_trend`  
**feature sets:** `bnd`  
**option sub-dictionary:** `styl:bnd:*`  
**output sub-dictionary:** `data:myFileIdx:myChannelIdx:bnd:trend:*`

## 7.10 Rhythm

Rhythm features can be extracted for any number of segment or event tiers specified by `fsys:rhy_*:tier`, \* representing *f0* and *en* for the F0 and the energy contour, respectively. Time stamps of event tiers are transformed to segments as introduced in section 7.3.

Rhythm measures consist of:

- spectral moments of a DCT analysis of the contour
- the number of peaks in the absolute-value DCT spectrum
- the frequency associated with the highest peak
- event rates within the analyzed segment
- the influence of these events on the F0 or energy contour within the analyzed segment

To extract the relative weight of the low- and high-frequency components of a contour, a discrete cosine transform (DCT) is applied on the contour as in [6]. For the absolute DCT coefficient values the first *n* `rhy_*:rhy:nsm` spectral

moments are calculated that (up to the forth moment) give the mean, variance, skew, and kurtosis of the DCT coefficient weight distribution, respectively.

Before applying the DCT the contour is weighted by the two parameters `rhy_*:rhy:wintyp` and `rhy_*:rhy:winparam` as introduced in section 7.2.

The events (time stamps or segments) for which rate and influence is to be calculated are read from one or more tier names in `fsys:rhy_*:tier_rate`. Thereby within each recording channel each *analysis tier* in `fsys:rhy_*:tier` is combined with each *rate tier* in `fsys:rhy_*:tier_rate`. Rate is simply measured by counting the events, that fall within the segment of analysis, and dividing it by the length of the analyzed segment. For segment tiers in `fsys:rhy_*:tier_rate` only proportions included in the segment of analysis are added to the count.

The influence  $s$  of events on the F0 or energy contour is quantified as the relative weight of the DCT coefficients around the event rate  $r$  ( $\pm$  `rhy_*:rhy:wgt:rb` Hz) within all coefficients between `rhy_*:rhy:lb` and `rhy_*:rhy:ub` Hz as follows:

$$s = \frac{\sum_{c:r-1 \leq f(c) \leq r+1\text{Hz}} |c|}{\sum_{c:lb \leq f(c) \leq ub\text{Hz}} |c|}$$

The higher  $s$  the higher thus the influence of the event rate on the F0 or energy contour. Figure 12 compares a low event rate with a high impact on the energy contour with a high event rate with low impact (high vs low absolute coefficient values).

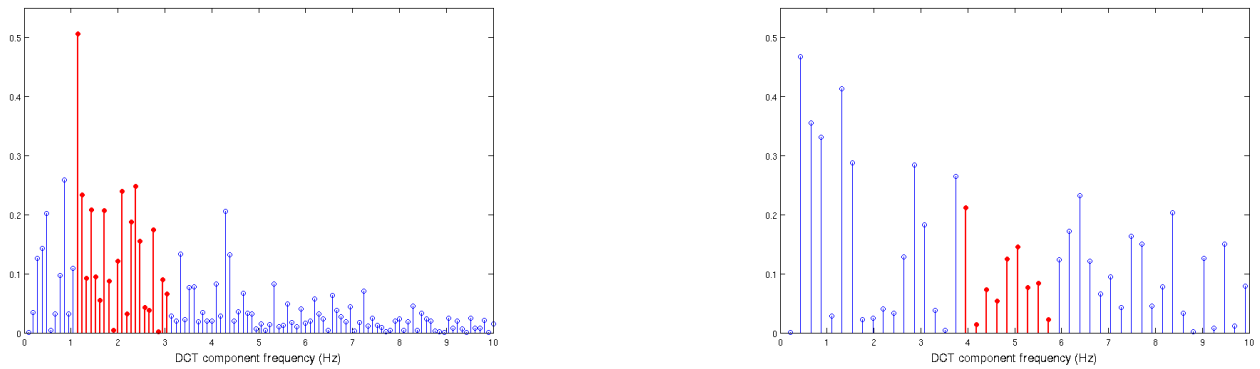


Figure 12: Influence of events on a contour in terms of the relative weight of the DCT coefficients around the event frequency.

The relative weight is outputted to the feature table's columns `myRateTier_prop` (see sections 8 and 10.1). `myRateTier` refers to each entry in `fsys:rhy_*:tier_rate`. The respective analysis tiers from `fsys:rhy_*:tier` are displayed in the `tier` column. The proportion is outputted for each segment in the analysis tiers.

Additionally, the rate of rate tier events in each analysis tier segment is provided by `myRateTier_rate`. Finally, `myRateTier_mae` gives the mean absolute error between the original contour and the inverse cosine transform output that is based on the coefficients with frequencies around the event rates. The following paragraphs name the configuration branches responsible for the rhythmic analyses of the F0 and energy contour, respectively.

`myRateTier_*` parameters are not calculated for analysis/rate tier combinations across recording channels. That is: Given are analysis tier *TA1* and rate tier *RT2* referring to channels 1 and 2, respectively. Then cells in the *RT2\_\** columns are set to *NA* in all *TA1* rows, which are identified by the `tier` column.

The number of peaks  $n_{peak}$  in the DCT spectrum is derived by counting the local amplitude maxima in this spectrum among the values greater or equal than the amplitude related to the center of gravity.

### 7.10.1 Rhythmic aspects of the F0 contour

**navigation:** `do_styl_rhy_f0`  
**feature sets:** `rhy_f0`, `rhy_f0_file`  
**option sub-dictionary:** `styl:rhy_f0:*`  
**output sub-dictionary:** `data:myFileIdx:myChannelIdx:rhy_f0:*`; `data:myFileIdx:myChannelIdx:rhy_f0_file:*`

### 7.10.2 Rhythmic aspects of the energy contour

The energy contour extraction in the analyzed segment is controlled by the `styl:rhy_en:sig:*` sub-dictionary the same way as explained in section 7.2.

**navigation:** `do_styl_rhy_en`  
**feature sets:** `rhy_en`, `rhy_en_file`  
**option sub-dictionary:** `styl:rhy_en:*`  
**output sub-dictionary:** `data:myFileIdx:myChannelIdx:en_f0:*`; `data:myFileIdx:myChannelIdx:rhy_en_file:*`

## 8 Feature sets

All features are subdivided into 6 sets which can be extracted independently of each other. In the subsequent listing **\*\_file** indicates that there is an additional feature extraction on the entire file level with minor deviations from the extraction on smaller domains (e.g. missing normalization).

- **gnl\_f0, gnl\_f0\_file**: general standard F0 features as mean, median, standard deviation, interquartile range; for any number of tiers
- **gnl\_en, gnl\_en\_file**: general standard energy features as mean, median, standard deviation, interquartile range; for any number of tiers
- **glob**: register (level and range) features in larger domains (e.g. intonation phrases); for one tier per channel
- **loc**: shape features in smaller domains (e.g. accent groups) of F0 residuals (after removal of global F0 aspects). Gestalt features, i.e. deviation of accent groups from intonation phrases. This feature set requires the precedent extraction of the *glob* set; for one tier per channel
- **bnd, bnd\_win, bnd\_trend**: boundary features between adjacent segments in the same domain. For *bnd* the features are derived from the stylization of adjacent segments. In *bnd\_win* the stylization is carried out in uniform time windows centered on the segment boundaries irrespective of the segment lengths. In *bnd\_trend* the stylization is carried out from the beginning of a speech chunk to the boundary in question, and from this boundary to the end of the chunk; for any number of tiers
- **rhy\_f0, rhy\_f0\_file**: DCT-based rhythm features; rates of prosodic events (e.g. syllable nuclei, pitch accents) and their influence on the F0 contour; for any number of tiers
- **rhy\_en, rhy\_en\_file**: DCT-based rhythm features; rates of prosodic events and their influence on the energy contour; for any number of tiers

**Application examples** for these feature sets are

application	feature sets
pitch accent prototypes for information status and discourse segmentation [12]	glob, loc
prosodic boundary strength prediction [18]	bnd
parameterization of prosodic headedness [19]	loc
empirical evidence for prosodic constituents (accentual phrases) [2]	loc
interplay of phrasing and prominence [20]	loc, bnd, gnl_en, gnl_f0
dialog act prediction [10]	glob, loc, gnl_f0
personality trait prediction [13]	glob, loc, gnl_f0
entrainment [15]	glob, loc
offtalk detection [9]	glob, loc, gnl_en, gnl_f0
speech disfluencies [1]	loc
pitch accent inventory for low-resource languages [7]	loc
Lombard speech characteristics [3]	bnd
Social media analyses [16]	bnd
Hand-stroke-speech coordination [5]	rhy_en, rhy_f0

The following tables list all currently available features in alphabetical order, give short descriptions and link them to the respective feature set. In these tables *loc* and *glob* within the superpositional setting refer to local (e.g. accent groups) and global segments (e.g. intonation phrases), respectively. For boundary parameterization *pre*, *post*, *joint* refer to the pre- and post-boundary segments, and to their concatenation, respectively. For boundary features *std*, *win*, and *trend* refer to the underlying windowing of neighboring segments, cf. section 7.9. The number of coefficient and spectral moment variables *c\** and *sm\** depend on the polynomial order and spectral moment number specified by the user. For the *rhy\_\** feature sets *myAnalysisTier* stands for the analysis tier, and *myRateTier* for the rate tier, i.e. the rate and influence of events in *myRateTier* within segments of *myAnalysisTier* is measured, and all possible combinations of analysis and rate tiers are outputted.

name	description	feature set
bl_c0	baseline intercept	glob, loc
bl_c1	baseline slope	glob, loc
bl_d_fin	final baseline value diff loc-glob	loc
bl_d_init	initial baseline value diff loc-glob	loc
bl_m	baseline mean value	glob, loc
bl_r	baseline reset	glob
bl_rate	baseline declination rate	glob, loc
bl_rms	baseline RMSD loc-glob, pre/post-joint	loc, bnd
bl_rms_post	baseline RMSD post-joint	bnd
bl_rms_pre	baseline RMSD pre-joint	bnd
bl_sd	slope diff loc-glob	loc
bv	file-domain F0 base value (Hz)	glob, gnl_f0_file
c*	polynomial loc contour coef *	loc, gnl_f0/en(_file)
ci	channel index (starting with 0)	glob, loc
class	contour class	glob, loc
dur	segment duration	glob, loc, gnl_f0/en(_file), rhy_f0/en(_file)
dur_nrm	normalized duration	loc, gnl_f0/en
f_max	freq of coef with max ampl. in DCT spectrum	rhy_f0/en(_file)
fi	file index (starting with 0)	glob, loc, bnd
gi	si value of corresponding row in glob	loc
iqr	F0 interquartile range	glob, loc, gnl_f0/en(_file)
iqr_nrm	nrm'd F0 interquartile range	loc, gnl_f0/en
lab	label	glob, bnd, gnl_f0/en, rhy_f0/en
lab_acc	ACC tier label	loc
lab_ag	AG tier label	loc
lab_next	next segment's label	bnd
m	F0, energy arit. mean	glob, loc, gnl_f0/en(_file)
m_nrm	F0, energy arit. nrm'd mean	loc, gnl_f0/en
max	F0, energy max	glob, loc, gnl_f0/en(_file)
max_nrm	F0, energy nrm'd max	loc, gnl_f0/en
med	F0, energy median	glob, loc, gnl_f0/en(_file)
med_nrm	F0, energy nrm'd median	loc, gnl_f0/en
ml_c0	midline intercept	glob, loc
ml_c1	midline slope	glob, loc
ml_d_fin	final midline value diff loc-glob	loc
ml_d_init	initial midline value diff loc-glob	loc
ml_m	midline mean value	glob, loc
ml_r	midline reset	glob
ml_rate	midline declination rate	glob, loc
ml_rms	midlines RMSD loc-glob; pre/post-joint	loc, bnd
ml_rms_post	midlines RMSD post-joint	bnd
ml_rms_pre	midlines RMSD pre-joint	bnd
ml_sd	midline slope diff loc-glob	loc
n_peak	number of peaks in absolute DCT spectrum	rhy_f0/en(_file)
p	pause length (sec)	bnd
qb	quotient of means of init and fin part	gnl_f0/en(_file)
qf	quotient of means of final and non-fin part	gnl_f0/en(_file)
qi	quotient of means of initial and non-init	gnl_f0/en(_file)
qm	quotient of means max(init, fin) part and remainder	gnl_f0/en(_file)
res_bl_c*	baseline residual poly coef *	loc
res_ml_c*	midline residual poly coef *	loc
res_rng_c*	range line residual poly coef *	loc
res_tl_c*	topline residual poly coef *	loc
rms	overall RMSD	gnl_en
rms_nrm	nrm'd overall RMSD	gnl_en
rng_c0	range line intercept	glob, loc
rng_c1	range line slope	glob, loc
rng_d_fin	final range line value diff loc-glob	loc
rng_d_init	initial range line value diff loc-glob	loc
rng_m	range mean value	glob, loc
rng_r	range line reset	glob
rng_rate	range declination rate	glob, loc
rng_rms	range lines RMSD loc-glob; pre/post-joint	loc, bnd
rng_rms_post	range lines RMSD post-joint	bnd
rng_rms_pre	range lines RMSD pre-joint	bnd
rng_sd	range line slope diff loc-glob	loc



sb	spectral balance	gnl_en
sd	F0, energy standard deviation	glob, loc, gnl_f0/en(_file)
sd_nrm	nrm'd F0, energy standard deviation	loc, gnl_f0, gnl_en
si	segment index (starting with 0)	glob, loc, gnl_f0/en, rhy_f0/en
sm*	*th spectral moment of DCT	rhy_f0/en(_file)
std_bl_r	std, pre-post baseline reset	bnd
std_bl_rms	std, pre/post-joint baseline RMSD	bnd
std_bl_rms_post	std, post-joint baseline RMSD	bnd
std_bl_rms_pre	std, pre-joint baseline RMSD	bnd
std_ml_r	std, pre-post midline reset	bnd
std_ml_rms	std, pre/post-joint midline RMSD	bnd
std_ml_rms_post	std post-joint midline RMSD	bnd
std_ml_rms_pre	std pre-joint midline RMSD	bnd
std_rng_r	std, pre-post range line reset	bnd
std_rng_rms	std pre/post-joint range line RMSD	bnd
std_rng_rms_post	std, post-joint range line RMSD	bnd
std_rng_rms_pre	std, pre-joint range line RMSD	bnd
std_tl_r	std pre-post topline reset	bnd
std_tl_rms	std, pre/post-joint topline RMSD	bnd
std_tl_rms_post	std, post-joint topline RMSD	bnd
std_tl_rms_pre	std, pre-joint topline RMSD	bnd
stm	f0 file name stem	glob, loc
t_off	time offset (sec; bnd: of pre-boundary segment)	glob, loc, gnl_f0/en, rhy_f0/en, bnd
t_on	time onset (sec; bnd: of post-boundary segment)	glob, loc, gnl_f0/en, rhy_f0/en, bnd
tier	tier name	bnd, gnl_f0/en, rhy_f0/en
tl_c0	topline intercept	glob
tl_c1	topline slope	glob
tl_d_fin	final topline value diff loc-glob	loc
tl_d_init	initial topline value diff loc-glob	loc
tl_m	topline mean value	glob, loc
tl_r	initial topline reset	glob
tl_rate	topline declination rate	glob, loc
tl_rms	topline RMSD loc-glob	loc
tl_sd	topline slope diff loc-glob	loc
trend_bl_r	trend, pre-post baseline reset	bnd
trend_bl_rms	trend, pre/post-joint baseline RMSD	bnd
trend_bl_rms_post	trend, post-joint baseline RMSD	bnd
trend_bl_rms_pre	trend, pre-joint baseline RMSD	bnd
trend_ml_r	trend, pre-post midline reset	bnd
trend_ml_rms	trend, pre/post-joint midline RMSD	bnd
trend_ml_rms_post	trend, post-joint midline RMSD	bnd
trend_ml_rms_pre	trend, pre-joint midline RMSD	bnd
trend_rng_r	trend, pre-post range line reset	bnd
trend_rng_rms	trend, pre/post-joint range line RMSD	bnd
trend_rng_rms_post	trend, post-joint range line RMSD	bnd
trend_rng_rms_pre	trend, pre-joint range line RMSD	bnd
trend_tl_r	trend, pre-post topline reset	bnd
trend_tl_rms	trend, pre/post-joint topline RMSD	bnd
trend_tl_rms_post	trend, post-joint topline RMSD	bnd
trend_tl_rms_pre	trend, pre-joint topline RMSD	bnd
win_bl_r	win, pre-post baseline reset	bnd
win_bl_rms	win, pre/post-joint baseline RMSD	bnd
win_bl_rms_post	win, post-joint baseline RMSD	bnd
win_bl_rms_pre	win, pre-joint baseline RMSD	bnd
win_ml_r	win, pre-post midline reset	bnd
win_ml_rms	win, pre/post-joint midline RMSD	bnd
win_ml_rms_post	win, post-joint midline RMSD	bnd
win_ml_rms_pre	win, pre-joint midline RMSD	bnd
win_rng_r	win, pre-post range line reset	bnd
win_rng_rms	win, pre/post-joint range line RMSD	bnd
win_rng_rms_post	win, post-joint range line RMSD	bnd
win_rng_rms_pre	win, pre-joint range line RMSD	bnd
win_tl_r	win, pre-post topline reset	bnd
win_tl_rms	win, pre/post-joint topline RMSD	bnd
win_tl_rms_post	win, post-joint topline RMSD	bnd
win_tl_rms_pre	win, pre-joint topline RMSD	bnd
myRateTier_dgm	difference between rate and frequency of max amplitude coef	rhy_f0/en(_file)
myRateTier_dlm	difference between rate and frequency of nearest peak coef	rhy_f0/en(_file)
myRateTier_mae	meanAbsErr(IDCT(myRateTier),contourOfFile)	rhy_f0/en(_file)
myRateTier_prop	influence of myRateTier on DCT coefs	rhy_f0/en(_file)
myRateTier_rate	event rate of myRateTier	rhy_f0/en(_file)

## 9 Configurations

The configuration file format is *JSON*. Examples can be found in the *config* subfolder of the code distribution. In the following introduction of all configuration parameters, the levels of the JSON dictionary are separated by a colon.

For numeric and boolean parameters the “*values, default*” field contains the default value. For string parameters, the default value is indicated in bold face. If a configuration field is named as *my\** the name is user defined. + indicates “one or more” configuration branches of this kind. Example: `fsys:channel:myTiername+` indicates, that the user needs to specify for all tiers in the annotation files, to which audio channel they belong. Let’s assume there are two tiers *spk1* and *spk2*, the first belongs to channel 1, the second to channel, two, then `fsys:channel:spk1=1` and `fsys:channel:spk2=2`.

### 9.1 Sample rate

fs

**description:** f0 sample frequency

**type:** integer

**values, default:** 100

**remarks:** currently only fs=100 supported. All f0 input will be resampled to this sample rate

---

### 9.2 Navigation

#### 9.2.1 Augmentation

Automatic annotation steps can be carried out independently of each other as long they don’t depend on the output of preceding annotation steps, e.g. if fallback events as syllable boundaries and nuclei are required for phrase boundary and accent detection, or if parent segments are defined to be the result of preceding automatic clustering or prosodic phrasing. Figure 13 displays the possible augmentation pipelines.

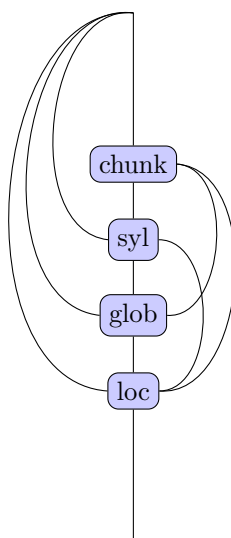


Figure 13: Automatic annotation *do\_augment\_\** workflow

#### 9.2.2 Feature extraction

Processing does not always need to start from scratch. Intermediate feature extraction results are stored in Python pickle format (see `fsys:export` below) and can be reloaded for further processing later on. Processing step dependencies are shown in Figure 14.

Required preceding steps do not need to be carried out in the same session as long as they can be read from the pickle file generated in some earlier session. The name of the pickle file to be loaded is given in

`fsys:export:dir + fsys:export:stm`

In order to continue an analysis of a previous session, the user thus needs to make sure that output directory and file name stem do not change across sessions.

`navigate:do_augment_chunk`

**description:** apply automatic chunking into interpausal units

**type:** boolean

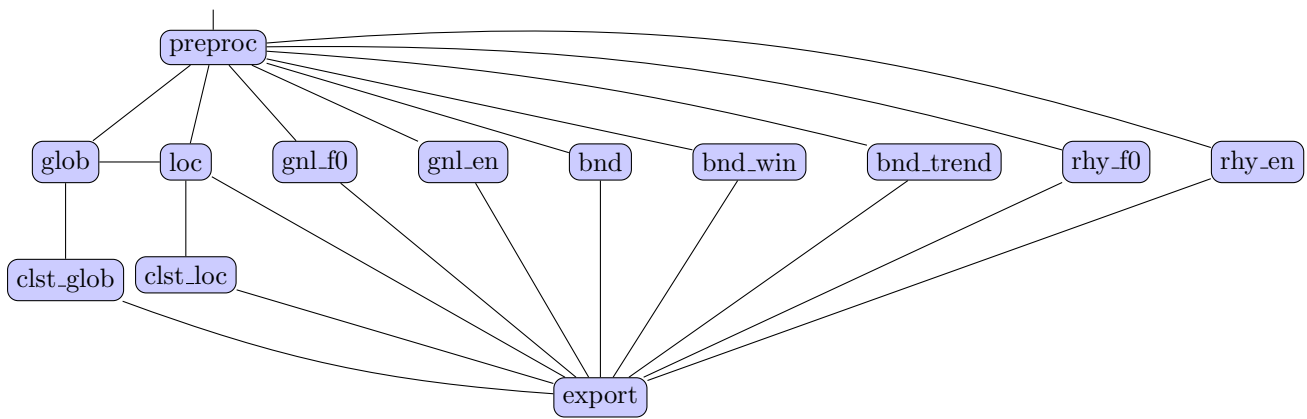


Figure 14: Stylization *do\_styl* and clustering *do\_clst* workflow

**values, default:** 0

**remarks:** If 1, a chunk segment tier is generated for each channel and added to the annotation files.

---

#### navigate:do\_augment\_glob

**description:** apply unsupervised prosodic phrase extraction

**type:** boolean

**values, default:** 0

**remarks:** If 1, for each channel a segment tier with automatically extracted prosodic phrases is generated and added to the annotation files. If no input tier for prosodic boundary candidates is specified, this step requires preceding syllable extraction, since syllable boundaries will then be taken as candidates.

---

#### navigate:do\_augment\_loc

**description:** apply unsupervised pitch accent detection

**type:** boolean

**values, default:** 0

**remarks:** If 1, for each channel an event tier with automatically extracted pitch accent locations is generated and added to the annotation file. If no user-defined pitch accent candidates can be provided, this step requires preceding syllable nucleus extraction, which will then be taken as candidates.

---

#### navigate:do\_augment\_syl

**description:** apply automatic syllable nucleus and boundary detection

**type:** boolean

**values, default:** 0

**remarks:** If 1, for each channel two event tiers – a syllable nucleus and boundary tier – are generated and added to the annotation files.

---

#### navigate:do\_clst\_glob

**description:** apply local contour clustering

**type:** boolean

**values, default:** 0

**remarks:** cluster local contour polynomial coefficients to derive local intonation contour classes.

---

#### navigate:do\_clst\_loc

**description:** apply global contour clustering

**type:** boolean

**values, default:** 0

**remarks:** cluster global contour line slope coefficients to derive global intonation contour classes.

---

#### navigate:do\_export

**description:** export the results

**type:** boolean

**values, default:** 0

**remarks:** generate csv feature table files, and F0 table files

---

#### navigate:do\_plot

**description:** plot

**type:** boolean

**values, default:** 0

**remarks:** online or post-analysis plotting of stylization results. Online plotting serves to check the parameter settings before processing large data.

---

#### navigate:do\_preproc

**description:** apply preprocessing

**type:** boolean

**values, default:** 0

**remarks:** F0 preprocessing and analysis and normalization windowing. If set to 1 at non-initial application to a data set, all information previously gathered from subsequent stylization steps is deleted.

---

#### navigate:do\_styl\_bnd\_trend

**description:** extract boundary features

**type:** boolean

**values, default:** 0

**remarks:** Extract F0 discontinuity features at each segment boundary or time stamp. This time the pre- and post-boundary units range from file start to the boundary, and from the boundary to the file end. If `styl:bnd:cross_chunk` is set to 0, and if a chunk tier is given in `fsys:chunk:tier`, the analyses windows are limited by the start and endpoint of the current chunk.

---

#### navigate:do\_styl\_bnd\_win

**description:** extract boundary features in fixed time windows

**type:** boolean

**values, default:** 0

**remarks:** Extract F0 discontinuity features. For segment tiers, the pre- and post-boundary units are not given by the adjacent segments as for `navigate:do_styl_bnd`, but by windows of fixed length. For event tiers the window halves of `preproc:point_win` centered on a time stamp are considered as pre- and post-boundary units. If `styl:bnd:cross_chunk` is set to 0, and if a chunk tier is given in `fsys:chunk:tier`, the analyses windows are limited by the start and endpoint of the current chunk.

---

#### navigate:do\_styl\_bnd

**description:** extract boundary features

**type:** boolean

**values, default:** 0

**remarks:** Extract F0 discontinuity features across segments (segment tier input) or at time stamps (event tier input). Only for the former the extracted pause length is meaningful. Discontinuity is amongst others expressed in the deviation of the pre- and post-boundary part from a common declination trend. For segment tiers, this common trend is calculated over both segments. For event tiers, the inter-time stamp intervals are considered as segments.

---

#### navigate:do\_styl\_glob

**description:** apply global contour stylization

**type:** boolean

**values, default:** 0

**remarks:** Apply F0 register (level and range) stylizations within global segments as e.g. IPs.

---

#### navigate:do\_styl\_gnl\_en

**description:** extract standard energy features

**type:** boolean

**values, default:** 0

**remarks:** Extract energy mean, variance and the like.

---

#### navigate:do\_styl\_gnl\_f0

**description:** extract standard F0 features

**type:** boolean

**values, default:** 0

**remarks:** Extract F0 mean, variance and the like.

---

#### navigate:do\_styl\_loc\_ext

**description:** extract extended feature set for local F0 contours

**type:** boolean

**values, default:** 0

**remarks:** Extract local register and Gestalt features, i.e. deviation of the local contour from the global register trend.

---

#### navigate:do\_styl\_loc

**description:** apply local contour stylization

**type:** boolean

**values, default:** 0

**remarks:** Apply polynomial F0 contour stylization in local segments as e.g. AGs.

---

#### navigate:do\_styl\_rhy\_en

**description:** extract energy rhythm features

**type:** boolean  
**values, default:** 0  
**remarks:** apply DCT analyses on energy contour within user-defined segments and calculate the influence of events on the contour, in terms of the relative weight of DCT coefficients

---

**navigate:do\_styl\_rhy\_f0**

**description:** extract F0 rhythm features  
**type:** boolean  
**values, default:** 0  
**remarks:** apply DCT analyses on F0 contour within user-defined segments and calculate the influence of events on the contour, in terms of the relative weight of DCT coefficients

---

**navigate:from\_scratch**

**description:** start from scratch  
**type:** boolean  
**values, default:** 0  
**remarks:** If 1, all configurations and analyses results in the pickle file are overwritten.

---

**navigate:overwrite\_config**

**description:** overwrite stored configurations  
**type:** boolean  
**values, default:** 0  
**remarks:** If 1, the configuration stored in the pickle file is overwritten by the current user-defined setting. Useful, if e.g. selected analysis steps should be repeated by different preprocessing settings.

---

## 9.3 Directories, tiers, grouping

**fsys:annot:dir**

**description:** annotation file directory  
**type:** string  
**values, default:**  
**remarks:** Can be nested. Depending on the task, audio, F0, and annotation files are obligatory or not. All obligatory directories must contain the same number of files in the same order. Optimally, same order is guaranteed using the same file name stem for corresponding audio, F0, and annotation files. However, this is not required.

---

**fsys:annot:ext**

**description:** annotation file extension  
**type:** string  
**values, default:** TextGrid, xml  
**remarks:** no default

---

**fsys:annot:typ**

**description:** annotation file type  
**type:** string  
**values, default:** TextGrid, xml  
**remarks:** Currently, only TextGrid and xml (see section 4.3) are supported. No default.

---

**fsys:aud:dir**

**description:** audio file directory  
**type:** string  
**values, default:**  
**remarks:** Can be nested. Depending on the task, audio, F0, and annotation files are obligatory or not. All obligatory directories must contain the same number of files in the same order. Optimally, same order is guaranteed using the same file name stem for corresponding audio, F0, and annotation files. However, this is not required.

---

**fsys:aud:ext**

**description:** audio file extension  
**type:** string  
**values, default:**  
**remarks:** Only files with this extension are collected from the directory.

---

**fsys:aud:typ**

**description:** audio file mimetype  
**type:** string  
**values, default:** wav  
**remarks:** currently only *wav* supported

---

**fsys:augment:chunk:tier\_out\_stm**

**description:** tier name stem of chunking output

**type:** string

**values, default:** chunk

**remarks:** To the name stem the channel index will be added (**also for mono files!**). E.g. given a stereo file and `fsys:augment:chunk:tier_out_stm=CHUNK`, the two segment tiers *CHUNK\_1* and *CHUNK\_2* will be generated for channel 1 and 2, respectively.

---

#### fsys:augment:glob:tier\_out\_stm

**description:** phrasing output tier

**type:** string

**values, default:** glob

**remarks:** tier name stem of phrasing output. To the name stem the channel index will be added (also for mono files!). E.g. given a stereo file and `fsys:augment:glob:tier_out_stm='IP'`, the two segment tiers *IP\_1* and *IP\_2* will be generated for channel 1 and 2, respectively.

---

#### fsys:augment:glob:tier\_parent

**description:** parent tier for prosodic phrase extraction

**type:** string or list of strings

**values, default:** `fsys:augment:chunk:tier_out_stm`

**remarks:** Segment tiers defining the superordinate domain for overall trend measurement from which the pre- and post-candidate-boundary segment deviate. This field can contain a single string (a single tier for mono files or any `fsys:augment:*:tier_out_stm` value which will be expanded by the channel index). The user can also explicitly specify multiple tier names in a list, if several channels are to be processed and the tier names cannot be derived from any `fsys:augment:*:tier_out_stm`. For segment tiers only.

---

#### fsys:augment:glob:tier

**description:** The tier in which to look for the prosodic boundary candidates.

**type:** `fsys:augment:syl:tier_out_stm + '_bnd'`

**values, default:** string or list of strings

**remarks:** This field can contain a single string (a single tier for mono files or any `fsys:augment:*:tier_out_stm` value which will be expanded by the channel index and the syllable boundary infix). The user can also explicitly specify multiple tier names in a list, if several channels are to be processed and the tier names cannot be derived from any `fsys:augment:*:tier_out_stm`. Tiers can be of segment or event type. Default is the `_bnd`-output of `fsys:augment:syl:tier_out_stm`. Note that treating all syllable boundaries as phrase boundary candidates may result in prosodic boundaries within words. Thus a word segmentation tier is strongly recommended.

---

#### fsys:augment:loc:tier\_acc

**description:** Pitch accent extraction event tier

**type:** string or list of strings

**values, default:** [ ]

**remarks:** Pitch accent candidate time stamps, e.g. syllable nucleus midpoints. This field can contain a single string (a single tier for mono files or `fsys:augment:syl:tier_out_stm` which will be expanded by the channel index). The user can also explicitly specify multiple tier names in a list, if several channels are to be processed and the tier names cannot be derived from `fsys:augment:syl:tier_out_stm`. For event tiers only. Field can be empty, but at least one of `fsys:augment:loc:tier_ag` and `fsys:augment:loc:tier_acc` needs to be specified. If only `fsys:augment:loc:tier_ag`: analysis within segment; if only `fsys:augment:loc:tier_acc`: analysis within symmetric window of length `preproc:point_win` centered on the time stamp; if both: analysis within *ag* segment, time normalization so that 0 position is at *acc* time stamp within *ag*.

---

#### fsys:augment:loc:tier\_ag

**description:** pitch accent extraction segment tier

**type:** string or list of strings

**values, default:** [ ]

**remarks:** Tier with segments that are potential accent groups segment domain. This field can contain a single string for mono files or a list of strings for more channels. Tiers can be of segment type only. Field can be empty, but at least one of `fsys:augment:loc:tier_ag` and `fsys:augment:loc:tier_acc` needs to be specified. If only `fsys:augment:loc:tier_ag`: analysis within segment; if only `fsys:augment:loc:tier_acc`: analysis within symmetric window of length `preproc:point_win` centered on the time stamp; if both: analysis within *ag* segment, time normalization so that 0 position is at *acc* time stamp within *ag*.

---

#### fsys:augment:loc:tier\_out\_stm

**description:** accent output tier name stem

**type:** string

**values, default:** acc

**remarks:** To the name stem the channel index will be added (also for mono files!). E.g. given a stereo file and `fsys:augment:loc:tier_out_stm='ACC'`, the two event tiers *ACC\_1* and *ACC\_2* will be generated for channel 1 and 2, respectively.

---

#### fsys:augment:loc:tier\_parent

**description:** name of parent tier for pitch accent candidates

**type:** string or list of strings

**values, default:** [ ]

**remarks:** This parent tier contains segments of a superordinate domain with respect to which the deviation of the accent candidate segments or time stamps is calculated. This might be global segments or chunks. Fallback is file-level. Must be segment tiers. This field can contain a single string (a single tier for mono files or any `fsys:augment*:tier_out_stm` value which will be expanded by the channel index). The user can also explicitly specify multiple tier names in a list, if several channels are to be processed and the tier names cannot be derived from any `fsys:augment*:tier_out_stm`. Tiers can be segment tiers only.

---

#### `fsys:augment:syl:tier_out_stm`

**description:** tier name stem of syllable nucleus and boundary output

**type:** string

**values, default:** `syl`

**remarks:** To the name stem the channel index will be added (also for mono files!). Syllable boundary tiers are further marked by the infix *bnd*. E.g. given a stereo file and `fsys:augment:syl:tier_out_stm='SYL'`, the four event tiers *SYL\_1*, *SYL\_bnd\_1* and *SYL\_2*, *SYL\_bnd\_2* will be generated for syllable nuclei and boundaries and for channel 1 and 2, respectively.

---

#### `fsys:augment:syl:tier_parent`

**description:** parent tier for syllable nucleus extraction

**type:** string or list of strings

**values, default:** `chunk`

**remarks:** The parent tier defines the boundaries over which the reference window for relative energy calculation must not cross. Fallback is file level. This field can contain a single string (a single tier for mono files or any `fsys:augment*:tier_out_stm` value which will be expanded by the channel index). The user can also explicitly specify multiple tier names in a list, if several channels are to be processed and the tier names cannot be derived from any `fsys:augment*:tier_out_stm`.

---

#### `fsys:bnd:tier`

**description:** boundary tier names

**type:** string or list of strings

**values, default:** [ ]

**remarks:** each channel can contain several tiers to be analyzed. Segment or event tiers. For segment tiers the boundary between adjacent segments is parameterized, and for point tiers, the boundary at time stamps.

---

#### `fsys:channel:myTiername+`

**description:** channel index for each relevant tier name in the annotation file

**type:** int

**values, default:** `myChannelIdx`

**remarks:** For augmentation output tiers this configuration branch is generated automatically.

---

#### `fsys:chunk:tier`

**description:** chunk tier names

**type:** string or list of strings

**values, default:** [ ]

**remarks:** one item for each channel. In case of multiple channels and single string, this string (e.g. “chunk”) is expanded to “chunk\_1”, “chunk\_2” ... for each available channel index. If chunk tiers specified, their segments’ boundaries are not crossed by analysis and normalization windows for most feature sets. For the *bnd\_trend* feature set pre- and post-boundary segments are limited by the start and endpoint of the superordinate chunk if `styl:bnd:cross_chunk` set to 1.

---

#### `fsys:export:csv`

**description:** output csv tables

**type:** boolean

**values, default:** 1

**remarks:** If 1, for each extracted feature set a csv file is outputted together with a code template file to read the table in R. The file names are concatenated by `fsys:export:stm` and the name of the feature set.

---

#### `fsys:export:dir`

**description:** output directory

**type:** string

**values, default:**

**remarks:** Directory in which all csv tables, the log file, and the pickle file are stored.

---

#### `fsys:export:f0_preproc`

**description:** output preprocessed f0 contours

**type:** boolean

**values, default:** 0

**remarks:** If 1, preprocessed F0 values are outputted for each input F0 file. The output format is as specified in section 4.2. The output is stored in the subdirectory *f0\_preproc* below the directory `fsys:export:dir`.

---

### **fsys:export:f0\_residual**

**description:** output residual f0 contours

**type:** boolean

**values, default:** 0

**remarks:** If 1, residual F0 contours after register removal are outputted for each input F0 file. The output format is as specified in section 4.2. The output is stored in the subdirectory *f0\_residual* below the directory **fsys:export:dir**.

---

### **fsys:export:f0\_resyn**

**description:** output resynthesized f0 contours

**type:** boolean

**values, default:** 0

**remarks:** If 1, the resynthesized F0 contours as a superposition of global and local contour shapes are outputted for each input F0 file. The output format is as specified in section 4.2. The output is stored in the subdirectory *f0\_resyn* below the directory **fsys:export:dir**.

---

### **fsys:export:fullpath**

**description:** whether or not to write the full path to the csv tables into the R code template files

**type:** boolean

**values, default:** 0

**remarks:** If 1, the full path to the csv tables is written into the R code. 0 is recommended in case the data is shared and further processed at different locations.

---

### **fsys:export:stm**

**description:** output file name stem

**type:** string

**values, default:** copasul

**remarks:** Same file name stem for all csv files, the log file, and the pickle file.

---

### **fsys:export:summary**

**description:** output file/channel summary statistics

**type:** boolean

**values, default:** 0

**remarks:** If 1, mean and variance values are calculated for all continuous-valued features outputted in the feature-set related csv files per file and channel. For categorical features unigram entropies are calculated. A **fsys:export:stm.summary.csv** file is outputted together with an R code template file to read the table in R.

---

### **fsys:f0:dir**

**description:** F0 file directory

**type:** string

**values, default:**

**remarks:** Can be nested. Depending on the task, audio, F0, and annotation files are obligatory or not. All obligatory directories must contain the same number of files in the same order. Optimally, same order is guaranteed using the same file name stem for corresponding audio, F0, and annotation files. However, this is not required.

---

### **fsys:f0:ext**

**description:** F0 file extension

**type:** string

**values, default:**

**remarks:** only files with this extension are collected from the directory

---

### **fsys:f0:typ**

**description:**

**type:** string

**values, default:** tab

**remarks:** Currently only *tab* supported.

---

### **fsys:glob:tier**

**description:** global segment tier names

**type:** string or list of strings

**values, default:** [ ]

**remarks:** analysis tiers for global segment, only one per each channel supported, so that global and local segments can be assigned to each other. If taken over from **fsys:augment:\*:tier\_out\_stm**, the names must be extended by the corresponding channel index, e.g. IP\_1 etc, see **fsys:augment:\*:tier\_out\_stm**. Segment or event tier. Events are expanded to segments by **preproc:point.win**.

---

### **fsys:gnl\_en:tier**



**description:** Tiers for standard energy variable extraction.

**type:** string or list of strings

**values, default:** [ ]

**remarks:** More than one tier per channel supported. Segment or event tiers. Events are expanded to segments by `preproc:point_win`.

---

#### **fsys:gnl\_f0:tier**

**description:** Tiers for standard F0 variable extraction

**type:** string or list of strings

**values, default:** [ ]

**remarks:** More than one tier per channel supported. Segment or event tiers. Events are expanded to segments by `preproc:point_win`.

---

#### **fsys:grp:lab**

**description:** grouping labels with values derived from file names

**type:** list of strings

**values, default:** [ ]

**remarks:** Labels of file-name derived grouping. Non-relevant file parts are indicated by empty strings ". E.g. given the F0 filename stem a\_b\_2. Let's say, "a" represents the speaker ID, "b" is not relevant for the current analysis, and "2" represents the stimulus ID. Then set `fsys:grp:src=f0`, `fsys:grp:sep=.`, and `fsys:grp:lab=['spk', '', 'stim']`. The output csv tables then contain two additional grouping columns `grp_spk` and `grp_stim` with values derived from the file names (in this case "a" and "2"). Note that all grouping values are treated as strings.

---

#### **fsys:grp:sep**

**description:** file name split pattern

**type:** string

**values, default:**

**remarks:** How to split the file name to access the grouping values. The string is interpreted as a regular expression. Thus predefined characters as the dot need to be protected! Thus if file parts are separated by a dot set this option to `"\\."`. If fileparts are separated by more than one symbol, e.g. dot and underscore, use `"(-|\\.)"`.

---

#### **fsys:grp:src**

**description:** grouping source

**type:** string

**values, default:** `f0`, `annot`, `aud`

**remarks:** from which file type to derive the file name based grouping

---

#### **fsys:label:chunk**

**description:** chunk label

**type:** string

**values, default:** `x`

**remarks:** will be used by automatic chunking

---

#### **fsys:label:pau**

**description:** pause label

**type:** string

**values, default:** `<P>`

**remarks:** in annotation files, segments labeled by this symbol are treated as pauses and are not analyzed. For boundary feature extraction these segments define the pause length feature between the preceding and following segment. Note, that this symbol as a pause identifier must be uniform over all analyzed tiers. In Praat TextGrids also not labeled segments are considered as pauses.

---

#### **fsys:label:syl**

**description:** syllable label

**type:** string

**values, default:** `x`

**remarks:** will be used by automatic syllable extraction

---

#### **fsys:loc:tier\_acc**

**description:** local event tier names

**type:** string or list of strings

**values, default:** [ ]

**remarks:** tier (one for each channel) defining pitch accent time stamps. Event tiers only. Field can be empty, but at least one of `fsys:loc:tier_ag` and `fsys:loc:tier_acc` needs to be specified. If only `fsys:loc:tier_ag`: analysis within segment; if only `fsys:loc:tier_acc`: analysis within symmetric window of length `preproc:point_win` centered on the time stamp; if both: analysis within *ag* segment, time normalization so that 0 position is at *acc* time stamp within *ag*.

---

#### **fsys:loc:tier\_ag**

**description:** local segment tier names

**type:** string or list of strings

**values, default:** [ ]

**remarks:** tier (one for each channel) defining accent group-like units. Segment tiers only. Field can be empty, but at least one of `fsys:loc:tier_ag` and `fsys:loc:tier_acc` needs to be specified. If only `fsys:loc:tier_ag`: analysis within segment; if only `fsys:loc:tier_acc`: analysis within symmetric window of length `preproc:point_win` centered on the time stamp; if both: analysis within *ag* segment, time normalization so that 0 position is at *acc* time stamp within *ag*.

---

#### **fsys:pho:tier**

**description:** name of tier with phonetic segments

**type:** string or list of strings

**values, default:** [ ]

**remarks:** one tier per channel. Used for feature extraction in prosodic boundary and accent localization.

---

#### **fsys:pho:vow**

**description:** vowel pattern

**type:** string

**values, default:** [AEIOUYaeiouy29{]

**remarks:** to identify vowel segments in `fsys:pho:tier`. Is interpreted as a regular expression.

---

#### **fsys:pic:dir**

**description:** directory for plotting output

**type:** string

**values, default:**

**remarks:** directory for the png files generated by plotting.

---

#### **fsys:pic:stm**

**description:** file name stem of the plot files

**type:** string

**values, default:** copasul

**remarks:**

---

#### **fsys:rhy\_en:tier**

**description:** Tiers for energy rhythm extraction

**type:** string or list of strings

**values, default:** [ ]

**remarks:** More than one tier per channel supported. Segment or event tiers. Events are expanded to segments by `preproc:point_win`.

---

#### **fsys:rhy\_en:tier\_rate**

**description:** Tiers containing units whose rate is to be calculated within each segment of the `fsys:rhy_f0:tier` tiers

**type:** string or list of strings

**values, default:** [ ]

**remarks:** More than one tier per channel supported. Segment or event tiers.

---

#### **fsys:rhy\_f0:tier**

**description:** Tiers for F0 rhythm extraction

**type:** string or list of strings

**values, default:** [ ]

**remarks:** More than one tier per channel supported. Segment or event tiers. Events are expanded to segments by `preproc:point_win`.

---

#### **fsys:rhy\_f0:tier\_rate**

**description:** Tiers containing units whose rate is to be calculated within each segment of the `fsys:rhy_f0:tier` tiers

**type:** string or list of strings

**values, default:** [ ]

**remarks:** More than one tier per channel supported. Segment or event tiers.

---

## 9.4 F0 preprocessing, windowing

### preproc:base\_prct

**description:** Percentile below which base value for semitone transform is calculated

**type:** float ]0 100[

**values, default:** 5

**remarks:** Base value for semitone transform is defined as median of the values below the specified percentile. If set to 0, the base value will be set to 1, i.e. the semitone transform is carried out without normalization.

---

### preproc:base\_prct\_grp:myChannelIndex

**description:** Grouping variable for which for each of its levels a base value for F0 semitone transform is calculated

**type:** string

**values, default:** ' '

**remarks:** Indicates for each channel index, which grouping variable is relevant. The grouping variable must be extractable from the file name as specified in **fsys:grp**. E.g. **preproc:base\_prct\_grp:1=spkId** requires a *spkId* element in the list of **fsys:grp:lab**. Channel indices must be written in quotation marks as strings.

---

### preproc:loc\_sync

**description:** Extract *gnl\_\** and *rhy\_\** features only at locations where *loc* features can be obtained.

**type:** boolean

**values, default:** 0

**remarks:** Due to the strict hierarchy principle and to window length constraints it is not always possible to extract *loc* features at any location where *gnl* and *rhy* features can be obtained. If the user is interested only in locations where all these feature sets are available, so that the corresponding feature matrices can be concatenated, this option should be set to 1.

---

### preproc:nrm\_win

**description:** normalization window length (in sec)

**type:** float

**values, default:** 1

**remarks:** length of the normalization window. For feature sets *gnl\_\** all mean, max, std values derived in the analysis window are normalized within longer time window which length is defined by this parameter. If segments to be analyzed are longer than the normalization window, this window is set equal to the analyzed segment. **nrm\_win** can also be individually set for each of the feature sets *loc*, *gnl\_f0*, *gnl\_en*, *rhy\_f0*, *rhy\_en* (see section 8) by specifying **preproc:myFeatureSet:nrm\_win**.

---

### preproc:out:f

**description:** outlier definition factor

**type:** float

**values, default:** 2

**remarks:** identifies non-zero F0 values as outliers, that deviate more than this factor times dispersion from the mean value. If **preproc:out:m=median**, the mean value is given by the median and the dispersion by the inter quartile range. If **preproc:out:m=mean**, the mean value is given by the arithmetic mean and the dispersion by the standard deviation.

---

### preproc:out:m

**description:** mean value definition for outlier identification

**type:** string

**values, default:** median, mean

**remarks:** Specifies definition of mean and dispersion, see **preproc:out:f**.

---

### preproc:point\_win

**description:** window length to transform events to segments (in sec)

**type:** float

**values, default:** 0.5

**remarks:** The extraction of the feature sets *glb\_\**, *rhy\_\**, *glob*, *loc* is based on segments. For event tier input, segments are obtained by centering a window of this length on the time stamps. **point\_win** can also be individually set for each of the feature sets *loc*, *gnl\_f0*, *gnl\_en*, *rhy\_f0*, *rhy\_en* (see section 8) by specifying **preproc:myFeatureSet:point\_win**.

---

### preproc:smooth:mtd

**description:** F0 smoothing method

**type:** string

**values, default:** sgolay, med

**remarks:** Savitzky-Golay or median filtering of F0 contour. Median yields stronger smoothing, Savitzky-Golay performs better in keeping local minima and maxima at their place.

---

### preproc:smooth:ord

**description:** polynomial order of smoothing method

**type:** integer

**values, default:** 3

**remarks:** relevant for **preproc:smooth:mtd=sgolay** only.

---

#### preproc:smooth:win

**description:** smoothing window length (in F0 sample indices)  
**type:** int  
**values, default:** 7  
**remarks:** The longer the smoothing window, the more smooth the F0 contours.

---

#### preproc:st

**description:** Hertz to semitone conversion  
**type:** boolean  
**values, default:** 0, 1  
**remarks:** If 1, transformed to semitones.

---

## 9.5 Augmentation: Chunking

#### augment:chunk:e\_rel

**description:** proportion of reference energy below which a pause is assumed  
**type:** float  
**values, default:** 0.0767  
**remarks:** a pause is indicated, if the energy in the analysis window is below this factor times the energy in the longer reference window.

---

#### augment:chunk:fbnd

**description:** assume pause at beginning and end of file  
**type:** boolean  
**values, default:** 1  
**remarks:** If set to 1, forced pause detection at file start and end. These pauses are subtracted from `augment:chunk:n` if set.

---

#### augment:chunk:flt:btype

**description:** filter type  
**type:** string  
**values, default:** low, high, band  
**remarks:** Butterworth filter type to filter the signal for pause detection. Recommended: *low*.

---

#### augment:chunk:flt:f

**description:** filter cutoff frequencies (in Hz)  
**type:** float or list of floats  
**values, default:** 8000  
**remarks:** For `augment:chunk:flt:btype=low`, `high` a single cut-off frequency is expected; for `band` a 2-element list of lower and upper cutoff frequency.

---

#### augment:chunk:flt:ord

**description:** filter order  
**type:** int  
**values, default:** 5  
**remarks:** Butterworth filter order.

---

#### augment:chunk:l\_ref

**description:** reference window length for pause detection (in sec)  
**type:** int  
**values, default:** 5  
**remarks:** Energy in analysis window of length `augment:chunk:l` is compared against the energy within the reference window. Same midpoint as analysis window.

---

#### augment:chunk:l

**description:** length of the analysis window (in sec)  
**type:** float  
**values, default:** 0.1524  
**remarks:** analysis window for which is to be decided, whether or not it is (part of) a pause.

---

#### augment:chunk:min\_chunk\_l

**description:** minimum chunk length (in sec)  
**type:** boolean  
**values, default:** 0.3  
**remarks:** shorter chunks are merged

---

#### augment:chunk:min\_pau\_l

**description:** minimum pause length (in sec)  
**type:** boolean  
**values, default:** 0.3  
**remarks:** shorter pauses are ignored.

---

**augment:chunk:n**

**description:** pre-specified number of pauses [sic!]  
**type:** boolean  
**values, default:** -1  
**remarks:** In this implementation chunks are defined as interpausal units and thus depend on pause detection. If set to -1, no pre-specified pause number.

---

## 9.6 Augmentation: Syllable nucleus detection

**augment:syl:d\_min**

**description:** minimum distance between subsequent syllable nuclei (in sec)  
**type:** float  
**values, default:** 0.05  
**remarks:** If 2 detected nuclei are closer than this distance the weaker candidate is discarded.

---

**augment:syl:e\_min**

**description:** minimum energy factor relative to entire file  
**type:** boolean  
**values, default:** 0.16  
**remarks:** For a syllable nucleus the RMS energy in the analysis window must be above this factor times the energy in the entire file.

---

**augment:syl:e\_rel**

**description:** minimum energy factor relative to reference window  
**type:** boolean  
**values, default:** 1.07  
**remarks:** For a syllable nucleus the RMS energy in the analysis window must be above this factor times the energy in the reference window.

---

**augment:syl:flt:btype**

**description:** filter type  
**type:** string  
**values, default:** low, high, **band**  
**remarks:** Butterworth filter type to filter the signal for syllable nucleus detection. Recommended: *band*.

---

**augment:syl:flt:f**

**description:** filter cutoff frequencies (in Hz)  
**type:** float or list of floats  
**values, default:** [ 200 4000]  
**remarks:** For `augment:syl:flt:btype=low, high` a single cut-off frequency is expected; for *band* a 2-element list of lower and upper cutoff frequency.

---

**augment:syl:flt:ord**

**description:** filter order  
**type:** int  
**values, default:** 5  
**remarks:** Butterworth filter order.

---

**augment:syl:l\_ref**

**description:** reference window length for syllable detection (in sec)  
**type:** boolean  
**values, default:** 0.15  
**remarks:** Energy in analysis window with same midpoint is compared against the energy within the reference window.

---

**augment:syl:l**

**description:** analysis window length (in sec)  
**type:** boolean  
**values, default:** 0.08  
**remarks:** length of window within energy is calculated. Same midpoint as reference window.

---

## 9.7 Augmentation: Prosodic boundary detection

### augment:glob:cntr\_mtd

**description:** how to define cluster centroids

**type:** string

**values, default:** `seed_prct`, `seed_kmeans`, `split`

**remarks:** *seed\_\**: initialize clustering by bootstrapped seed centroids. *seed\_prct*: single-pass clustering of the boundary candidates by their distance to these centroids. Distance values to the no-boundary seed above a specified percentile

**augment:glob:prct** indicate boundaries. *seed\_kmeans*: kmeans clustering initialized by the seed centroids (gives a more balanced amount of boundary/no boundary cases than *seed\_prct*). *split*: centroids are derived by splitting each column in the feature matrix at the percentile **augment:glob:prct**; the boundary centroid is defined by the median of the values above the splitpoint, the no-boundary centroid by the median of the values below; items are then assigned to the nearest centroid in a single pass. Depending on **augment:glob:unit** clustering is either carried out separately within each file and each channel, or over the entire dataset. Fallback: if cluster centroids cannot be bootstrapped, this parameter's value is changed to *split*.

---

### augment:glob:heuristics

**description:** heuristic macro settings

**type:** string

**values, default:** `ORT`

**remarks:** Only *ORT* supported. *ORT* assumes a word segmentation tier for prosodic boundary prediction and rejects boundaries after too short and thus probably function words (< 0.1s). Not necessarily meaningful for any language.

---

### augment:glob:measure

**description:** feature values, or deltas

**type:** string

**values, default:** `abs`, `delta`, `abs+delta`

**remarks:** Which values  $v$  to put in the feature matrix ( $i$ =time index): *abs*: feature values  $v[i]$ ; *delta*: feature deltas  $v[i] - v[i - 1]$ ; *abs+delta*: both

---

### augment:glob:min\_l

**description:** minimum inter-boundary distance (in sec)

**type:** float

**values, default:** 0.5

**remarks:** If 2 detected boundaries are closer than this value, only the stronger one will be kept. This distance is also used in bootstrapping boundary and no-boundary centroids as described in section 6.3.

---

### augment:glob:prct

**description:** percentile of cluster splitpoint

**type:** float ]0 100[

**values, default:** 95

**remarks:** Splitpoint definition for clustering in terms of a percentile value. The higher the fewer boundaries will be detected. For **augment:glob:cntr\_mtd=split** the percentile refers to the feature values, for **augment:glob:cntr\_mtd=seed\_prct**, it refers to the distance to the no-boundary seed centroid.

---

### augment:glob:unit

**description:** derive centroids separately for each file or over entire data set

**type:** string

**values, default:** `batch`, `file`

**remarks:** batch mode recommended for corpora containing lots of short recordings, within which centroids cannot reliably be extracted.

---

### augment:glob:wgt:myBndFeatset+:myRegister+:myFeat+

**description:** user defined feature weights

**type:** float

**values, default:** 1

**remarks:** create one config branch for each selected boundary feature and assign a weight. Only boundary features supported. The weight becomes a dummy in case of **augment:glob:wgt\_mtd** is not *user*. However, the branches must be specified in order to mark which features to be used for boundary prediction. *myBndFeatset*  $\in \{std, win, trend\}$ , *myRegister*  $\in \{bl, ml, tl, rng\}$ , *myFeat*  $\in \{r, rms, rms\_pre, \dots\}$ . The branches must correspond to branches in the sub-dictionary `copa:data:myFileIdx:myChannelIdx:bnd:myTierNameIndex:myBoundaryIndex` (see section 10.3). E.g. `copa:data:myFileIdx:myChannelIdx:bnd:myTierNameIndex:myBoundaryIndex:win:bl:r` is addressed by **augment:glob:wgt:win:bl:r**.

---

### augment:glob:wgt:pho

**description:** use/weight normalized vowel length as feature

**type:** float

**values, default:** 1

**remarks:** only compliant with **augment:glob:unit=batch**.

---

### augment:glob:wgt\_mtd

**description:** feature weighting method

**type:** string

**values, default:** *silhouette*, correlation, user

**remarks:** For *silhouette* an initial clustering is carried out, and for each feature its weight is then defined by its cluster-separating power. For *correlation* weights are defined for each feature by its correlation to the feature vector medians. For *user*, the weights specified in the `augment:glob:wgt:myBndFeatset+:myRegister+:myFeat+` branches are taken.

---

## 9.8 Augmentation: Pitch accent detection

### augment:loc:acc\_select

**description:** which syllable within a segment to select

**type:** string

**values, default:** max, left, right

**remarks:** Choose the accent position among all time stamps in `augment:loc:tier_acc` that are in the same segment of `fsys:augment:loc:tier_ag`. *max*: the most prominent one; *left*, *right*: accent first/last syllable, which might be useful if `fsys:augment:loc:tier_ag` contains word segments, and word stress is fixed.

---

### augment:loc:ag\_select

**description:** which segments to select for accentuation

**type:** string

**values, default:** max, all

**remarks:** *all*: assign an accent to each segment in `fsys:augment:loc:tier_ag`; *max*: assign accents to the most prominent segments only.

---

### augment:loc:cntr\_mtd

**description:** how to define cluster centroids

**type:** string

**values, default:** seed\_prct, seed\_kmeans, split

**remarks:** *seed\_\**: initialize clustering by bootstrapped seed centroids. *seed\_prct*: single-pass clustering of the accent candidates by their distance to these centroids. Distance values to the no-accent seed above a specified percentile `augment:loc:prct` indicate accents. *seed\_kmeans*: kmeans clustering initialized by the seed centroids (gives a more balanced amount of accent/no-accent cases than *seed\_prct*). *split*: centroids are derived by splitting each column in the feature matrix at the percentile `augment:glob:prct`; the accent centroid is defined by the median of the values above the splitpoint, the no-accent centroid by the median of the values below; items are then assigned to the nearest centroid in a single pass. Depending on `augment:loc:unit` clustering is carried out either separately within each file and each channel, or over the entire dataset. Fallback: if cluster centroids cannot be bootstrapped, this parameter's value is changed to *split*.

---

### augment:loc:heuristics

**description:** heuristic macro settings

**type:** string

**values, default:** ORT

**remarks:** only *ORT* supported. *ORT* assumes a word segmentation tier for accent extraction. Short words (see `augment:loc:max_l_na`) will be treated as non-accent seeds, long words (see `augment:loc:min_l_a`) as accent seeds.

---

### augment:loc:max\_l\_na

**description:** maximum length of definitely non-accented words (in sec)

**type:** float

**values, default:** 0.1

**remarks:** from words below that length the *non-accented* seed centroid is derived

---

### augment:loc:measure

**description:** feature values, or deltas

**type:** string

**values, default:** abs, delta, abs+delta

**remarks:** Which values *v* to put in the feature matrix (*i*=time index): *abs*: feature values  $v[i]$ ; *delta*: feature deltas  $v[i] - v[i - 1]$ ; *abs+delta*: both

---

### augment:loc:min\_l\_a

**description:** minimum length of definitely accented words (in sec)

**type:** float

**values, default:** 0.6

**remarks:** from words above that length the *accented* seed centroid is derived

---

### augment:loc:min\_l

**description:** minimum inter-accent distance (in sec)

**type:** float

**values, default:** 0.2

**remarks:** If 2 detected accents are closer than this value, only the more prominent one will be kept.

---

**augment:loc:prct**

**description:** percentile of cluster splitpoint

**type:** float ]0 100[

**values, default:** 90

**remarks:** Splitpoint definition for clustering in terms of a percentile value. The higher the fewer accents will be detected. For **augment:loc:cntr\_mtd=split** the percentile refers to the feature values, for **augment:loc:cntr\_mtd=seed\_prct**, it refers to the distance to the no-accent seed centroid.

---

**augment:loc:unit**

**description:** derive centroids separately for each file or over entire data set

**type:** string

**values, default:** batch, file

**remarks:** batch mode recommended for corpora containing lots of short recordings, within which centroids cannot reliably be extracted.

---

**augment:loc:wgt:myFeatset+...**

**description:** user defined feature weights

**type:** float

**values, default:** 1

**remarks:** create one config branch for each selected prominence feature and assign a weight. *myFeatset*  $\in \{acc, gst, gnl\_f0, gnl\_en\}$ . The weight becomes a dummy in case of **augment:loc:wgt\_mtd** is not *user*. However, the branches must be specified in order to mark which features to be used for accent prediction. The branches must correspond to branches in the sub-dictionary **copa:data:myFileIdx:myChannelIdx:loc** (see section 10.3). E.g. **copa:data:myFileIdx:myChannelIdx:loc:gst:bl:rms** is addressed by **augment:loc:wgt:gst:bl:rms**. If the value at this branch is a list (e.g. the polynomial coefficients in **...augment:loc:wgt:acc:c**) the weight can either be a scalar to weight all list elements equally or a list of same length as the value list, to individually weight each element. (Only) for polynomial coefficients absolute values are taken.

---

**augment:loc:wgt:pho**

**description:** use/weight normalized vowel length as feature

**type:** float

**values, default:** 1

**remarks:** only compliant with **augment:loc:unit=batch**.

---

**augment:loc:wgt\_mtd**

**description:** feature weighting method

**type:** string

**values, default:** silhouette, correlation, user

**remarks:** For *silhouette* an initial clustering is carried out, and for each feature its weight is then defined by its cluster-separating power. For *correlation* weights are defined for each feature by its correlation to the feature vector medians. For *user*, the weights specified in the **augment:loc:wgt:...+** branches are taken.

---

## 9.9 Stylization: Global contours

**styl:glob:decl\_win**

**description:** window length for median calculation (in sec)

**type:** float

**values, default:** 0.1

**remarks:** Within each window a median each for the base-, mid-, and topline is derived.

---

**styl:glob:nrm:mtd**

**description:** time normalization method

**type:** string

**values, default:** minmax

**remarks:** for time normalization in global segment. Currently only *minmax* supported.

---

**styl:glob:nrm:rng**

**description:** normalized time range

**type:** list of floats

**values, default:** [0, 1]

**remarks:** normalized time of segment start and endpoint

---

**styl:glob:prct:bl**

**description:** percentile below which the baseline input medians are calculated

**type:** float ]0 100[

**values, default:** 10



**remarks:** A sequence of lower range medians is calculated along the F0 contour. The baseline is given by linear regression through this sequence.

---

**styl:glob:pct:tl**

**description:** percentile, above which the topline input medians are calculated

**type:** float ]0 100[

**values, default:** 90

**remarks:** A sequence of upper range medians is calculated along the F0 contour. The topline is given by linear regression through this sequence.

---

## 9.10 Stylization: Local contours

**styl:loc:nrm:mtd**

**description:** time normalization method

**type:** string

**values, default:** minmax

**remarks:** for time normalization in the local segment. Currently only *minmax* supported.

---

**styl:loc:nrm:rng**

**description:** normalized time range

**type:** list of floats

**values, default:** [-1, 1]

**remarks:** normalized time of segment start and endpoint. [-1, 1] is recommended to center the polynomial around 0.

---

**styl:loc:ord**

**description:** polynomial order

**type:** int

**values, default:** 3

**remarks:** Each coefficient will get its output column in the exported tables, thus the table size depends on this order.

---

## 9.11 Stylization: Register representation

**styl:register**

**description:** register definition for residual calculation

**type:** string

**values, default:** ml, bl, tl, rng, none

**remarks:** how to remove the global component from the F0 contour to get the residual the local contour is calculated on; *bl*, *ml*, *tl*: base-, mid- or topline subtraction; *rng* pointwise [0 1] normalization of the F0 contour with respect to the base- and topline. Recommended: *ml*, *rng*. *rng* normalizes for range declination (lower F0 amplitudes at the end of prosodic phrases).

---

## 9.12 Stylization: Boundaries

**styl:bnd:cross\_chunk**

**description:** stylization windows across chunks

**type:** boolean

**values, default:** 1

**remarks:** if set to 1, the windows defined by **styl:bnd:win** can cross chunks, else they are limited by the current chunk's boundaries. If set to 1 for **do\_bnd\_trend**, lines are fitted from file start and till file end. Else, they are limited by the current chunk's boundaries.

---

**styl:bnd:decl\_win**

**description:** window length for median calculation (in sec)

**type:** float

**values, default:** 0.1

**remarks:** Within each window a median each for the base-, mid- and topline is derived.

---

**styl:bnd:nrm:mtd**

**description:** time normalization method

**type:** string

**values, default:** minmax

**remarks:** Only minmax supported.

---

**styl:bnd:nrm:rng**

**description:** normalized time range

**type:** list of floats

**values, default:** [0, 1]

**remarks:** to allow for comparisons independent of segment length, time is normalized to this range.

---

**styl:bnd:prct:bl**

**description:** percentile below which the baseline input medians are calculated

**type:** float ]0 100[

**values, default:** 10

**remarks:** A sequence of lower range medians is calculated along the F0 contour. The baseline is given by linear regression through this sequence.

---

**styl:bnd:prct:tl**

**description:** percentile, above which the topline input medians are calculated

**type:** float ]0 100[

**values, default:** 90

**remarks:** A sequence of upper range medians is calculated along the F0 contour. The topline is given by linear regression through this sequence.

---

**styl:bnd:win**

**description:** window length (in sec)

**type:** float

**values, default:** 1

**remarks:** stylization window length for `navigate:do_styl.bnd.win`

---

## 9.13 Stylization: General (energy) features

**styl:gnl:win**

**description:** window length to determine initial and final part of contour

**type:** float

**values, default:** 0.3

**remarks:** Length of window (in sec) for initial and final part of f0 or energy contour to calculate mean f0 pr energy quotients of these parts and the entire contour.

---

**styl:gnl\_en:alpha**

**description:** pre-emphasis factor

**type:** boolean

**values, default:** 0.95

**remarks:** Pre-emphasis is carried out in the time domain as follows:  $s'[i] = s[i] - \alpha \cdot s[i - 1]$ .

---

**styl:gnl\_en:sts**

**description:** step size (in sec)

**type:** float

**values, default:** 0.01

**remarks:** Stepsize by which energy window is shifted.

---

**styl:gnl\_en:winparam**

**description:** window parameter

**type:** string or int

**values, default:** –

**remarks:** Depends on `styl:gnl_en:wintyp`; as required by `scipy.signal.get_window()`.

---

**styl:gnl\_en:wintyp**

**description:** window type

**type:** string

**values, default:** `hamming`, `kaiser`, ...

**remarks:** All window types that are supported by `scipy.signal.get_window()` can be used.

---

**styl:gnl\_en:win**

**description:** window length (in sec)

**type:** float

**values, default:** 0.05

**remarks:** Energy is calculated in terms of RMSD within windows of this length.

---

## 9.14 Stylization: F0 rhythm features

### styl:rhy\_f0:rhy:lb

**description:** Lower frequency boundary of DCT coefficients (in Hz)  
**type:** boolean  
**values, default:** 0  
**remarks:** Can be raised if low-frequency events should be ignored.

---

### styl:rhy\_f0:rhy:nsm

**description:** number of spectral moments  
**type:** int  
**values, default:** 3  
**remarks:** How many spectral moments to calculate from DCT analysis of F0 contour.

---

### styl:rhy\_f0:rhy:rmo

**description:** remove DCT offset  
**type:** boolean  
**values, default:** 0  
**remarks:** Remove first DCT coefficient.

---

### styl:rhy\_f0:rhy:ub

**description:** upper frequency boundary of DCT coefficients (in Hz)  
**type:** float  
**values, default:** 10  
**remarks:** Upper boundary of analyzed DCT spectrum (higher-frequency events assumed not to be influential for prosody).

---

### styl:rhy\_f0:rhy:wgt:rb

**description:** rate band (in Hz)  
**type:** float  
**values, default:** 1  
**remarks:** Frequency band around event frequency, within which the influence of the event in terms of absolute DCT coefficient values is integrated. E.g. for an event rate of 4 Hz and a rate band of 1 Hz the absolute values of the DCT coefficients between 3 and 5 Hz are summed up.

---

### styl:rhy\_f0:rhy:winparam

**description:** window parameter  
**type:** string or int  
**values, default:** 1  
**remarks:** depends on `styl:gml_en:wintyp`; as required by `scipy.signal.get_window()`.

---

### styl:rhy\_f0:rhy:wintyp

**description:** window type for DCT analysis  
**type:** string  
**values, default:** hamming, kaiser, ...  
**remarks:** All window types that are supported by `scipy.signal.get_window()` can be used.

---

## 9.15 Stylization: Energy rhythm features

### styl:rhy\_en:rhy:lb

**description:** lower frequency boundary of DCT coefficients (in Hz)  
**type:** float  
**values, default:** 0  
**remarks:** Can be raised if low-frequency events should be ignored.

---

### styl:rhy\_en:rhy:nsm

**description:** number of spectral moments  
**type:** int  
**values, default:** 3  
**remarks:** How many spectral moments to be calculated from DCT analysis of energy contour.

---

### styl:rhy\_en:rhy:rmo

**description:** remove DCT offset  
**type:** boolean  
**values, default:** 0  
**remarks:** Remove first DCT coefficient.

---

### styl:rhy\_en:rhy:ub

**description:** upper frequency boundary of DCT coefficients (in Hz)  
**type:** float  
**values, default:** 10  
**remarks:** Upper boundary of analyzed DCT spectrum (higher-frequency events assumed not to be influential for prosody).

---

**styl:rhy\_en:rhy:wgt:rb**

**description:** rate band (in Hz)  
**type:** float  
**values, default:** 1  
**remarks:** Frequency band around event frequency, within which the influence of the event in terms of absolute DCT coefficient values is integrated. E.g. for an event rate of 4 Hz and a rate band of 1 Hz the absolute values of the DCT coefficients between 3 and 5 Hz are summed up.

---

**styl:rhy\_en:rhy:winparam**

**description:** DCT window parameter  
**type:** string or int  
**values, default:** 1  
**remarks:** Depends on **styl:rhy\_en:wintyp**; as required by *scipy.signal.get\_window()*.

---

**styl:rhy\_en:rhy:wintyp**

**description:** window type for DCT  
**type:** string  
**values, default:** hamming, kaiser, ...  
**remarks:** All window types that are supported by *scipy.signal.get\_window()*.

---

**styl:rhy\_en:sig:scale**

**description:** scale signal to maximum amplitude 1  
**type:** boolean  
**values, default:** 1  
**remarks:** if set to 1, the signal is scaled to its maximum amplitude. This is suggested especially if signals of different recording conditions are to be compared.

---

**styl:rhy\_en:sig:sts**

**description:** step size (in sec)  
**type:** float  
**values, default:** 0.01  
**remarks:** Step size by which the energy window is shifted.

---

**styl:rhy\_en:sig:winparam**

**description:** window parameter  
**type:** string or int  
**values, default:** –  
**remarks:** Depends on **styl:rhy\_en:wintyp**; as required by *scipy.signal.get\_window()*.

---

**styl:rhy\_en:sig:wintyp**

**description:** window type of energy calculation  
**type:** string  
**values, default:** hamming, kaiser, ...  
**remarks:** all window types that are supported by *scipy.signal.get\_window()*.

---

**styl:rhy\_en:sig:win**

**description:** window length (in sec)  
**type:** float  
**values, default:** 0.05  
**remarks:** Energy is calculated in terms of RMSD within windows of this length.

---

## 9.16 Clustering: Global contours

**clst:glob:estimate\_bandwidth:n\_samples**

**description:** number of samples to estimate bandwidth  
**type:** integer  
**values, default:** 1000  
**remarks:** Computationally expensive, high numbers will require long processing time.

---

**clst:glob:estimate\_bandwidth:quantile**

**description:** estimate\_bandwidth quantile parameter  
**type:** float

**values, default:** 0.3  
**remarks:** Lower values result in higher clusters numbers.

---

**clst:glob:kMeans:init**

**description:** initialization method of kmeans  
**type:** string  
**values, default:** meanShift  
**remarks:** All methods that are supported by *kMeans()* can be used. For *meanShift* the number of clusters does not need to be specified.

---

**clst:glob:kMeans:max\_iter**

**description:** kMeans: maximum number of iterations  
**type:** int  
**values, default:** 300  
**remarks:** When to stop cluster re-adjustment, if not yet converged.

---

**clst:glob:kMeans:n\_cluster**

**description:** kMeans: predefined number of contour classes  
**type:** int  
**values, default:** 3  
**remarks:** Irrelevant, if kmeans centroids are initialized by `clst:glob:kMeans:init=meanShift`.

---

**clst:glob:kMeans:n\_init**

**description:** number of initialization trials  
**type:** int  
**values, default:** 10  
**remarks:** kMeans is repeated with different cluster initializations from which the best clustering result is kept.

---

**clst:glob:meanShift:bandwidth**

**description:** bandwidth parameter for meanShift cluster center initialization  
**type:** float  
**values, default:** 0  
**remarks:** 0 indicates, that the optimal bandwidth is internally calculated.

---

**clst:glob:meanShift:bin\_seeding**

**description:** bin seeding  
**type:** boolean  
**values, default:** 0  
**remarks:** parameter for meanShift clustering

---

**clst:glob:meanShift:min\_bin\_freq**

**description:** minimum number of items in each bin  
**type:** int  
**values, default:** 1  
**remarks:** Parameter for meanShift clustering.

---

**clst:glob:mtd**

**description:** clustering method  
**type:** string  
**values, default:** meanShift, kmeans  
**remarks:** No initial cluster number specification needed for *meanShift*.

---

## 9.17 Clustering: Local contours

**clst:loc:estimate\_bandwidth:n\_samples**

**description:** number of samples to estimate bandwidth  
**type:** int  
**values, default:** 1000  
**remarks:** Computationally expensive, high numbers will require long processing time.

---

**clst:loc:estimate\_bandwidth:quantile**

**description:** estimate\_bandwidth quantile parameter  
**type:** float  
**values, default:** 0.3  
**remarks:** Lower values result in higher clusters numbers.

---

**clst:loc:kMeans:init**

**description:** initialization method of kmeans  
**type:** string  
**values, default:** meanShift  
**remarks:** All methods that are supported by *kMeans()* can be used. For *meanShift* the number of clusters does not need to be specified.

---

**clst:loc:kMeans:max\_iter**

**description:** kMeans: maximum number of iterations  
**type:** int  
**values, default:** 300  
**remarks:** When to stop cluster re-adjustment, if not yet converged.

---

**clst:loc:kMeans:n\_cluster**

**description:** kMeans: predefined number of contour classes  
**type:** int  
**values, default:** 5  
**remarks:** Irrelevant, if kmeans centroids are initialized by `clst:glob:kMeans:init=meanShift`.

---

**clst:loc:kMeans:n\_init**

**description:** number of initialization trials  
**type:** int  
**values, default:** 10  
**remarks:** kMeans is repeated with different cluster initializations from which the best clustering result is kept.

---

**clst:loc:meanShift:bandwidth**

**description:** bandwidth parameter for meanShift cluster center initialization  
**type:** boolean  
**values, default:** 0  
**remarks:**

---

**clst:loc:meanShift:bin\_seeding**

**description:** bin seeding  
**type:** boolean  
**values, default:** 0  
**remarks:** parameter for meanShift clustering

---

**clst:loc:meanShift:min\_bin\_freq**

**description:** minimum number of items in each bin  
**type:** int  
**values, default:** 1  
**remarks:** Parameter for meanShift clustering.

---

**clst:loc:mtd**

**description:** clustering method  
**type:** string  
**values, default:** meanShift, kmeans  
**remarks:** No initial cluster number specification needed for *meanShift*.

---

## 9.18 Plotting: Browsing

**plot:browse:save**

**description:** save plots according to `fsys:pic`  
**type:** boolean  
**values, default:** 0  
**remarks:** Store png files in `fsys:pic:dir` with file name stem `fsys:pic:stm`.

---

**plot:browse:single\_plot:active**

**description:** switch on single plot mode  
**type:** boolean  
**values, default:** 0  
**remarks:** switch on single plot mode if only one segment specified by file index, channel index, and segment index is to be plotted

---

**plot:browse:single\_plot:channel\_i**

**description:** channel index of selected segment  
**type:** integer  
**values, default:** 0

**remarks:** channel index of selected segment to be plotted

---

**plot:browse:single\_plot:file\_i**

**description:** file index of selected segment

**type:** integer

**values, default:** 0

**remarks:** file index of selected segment to be plotted

---

**plot:browse:single\_plot:segment\_i**

**description:** segment index of selected segment

**type:** integer

**values, default:** 0

**remarks:** segment index of selected segment to be plotted

---

**plot:browse:time**

**description:** when to do plotting

**type:** string

**values, default:** *online*, *final*

**remarks:** *online*: plot at stylization stage for immediate check of appropriateness of configurations. *final*: plot segment-wise from the finally stored results. Click on plot: next; press *return*: quit.

---

**plot:browse:type:clst:contours**

**description:** plot global and local intonation class centroids

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:complex:gestalt**

**description:** plot local contour Gestalt stylization

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:complex:superpos**

**description:** plot global and local contour superposition

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:glob:decl**

**description:** plot global contour register stylization

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:loc:acc**

**description:** plot local contour polynomial stylization

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:loc:decl**

**description:** plot local contour register stylization

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:rhy\_en:rhy**

**description:** plot influence of rate tier events on DCT of energy contour in analysis tier

**type:** boolean

**values, default:** 0

**remarks:**

---

**plot:browse:type:rhy\_f0:rhy**

**description:** plot influence of rate tier events on DCT of F0 contour in analysis tier

**type:** boolean

**values, default:** 0

**remarks:**

---

### plot:browse:verbose

**description:** display file, channel and segment index for each plot

**type:** boolean

**values, default:** 0

**remarks:** written to STDOUT

---

### plot:color

**description:** plot in color (1) or black-white (0)

**type:** boolean

**values, default:** 1

**remarks:**

---

## 9.19 Plotting: Grouping

### plot:grp:grouping

**description:** list of selected grouping variables from `fsys:grp:lab`

**type:** list of strings

**values, default:** [ ]

**remarks:** For each combination of grouping factor levels the stylization plot based on the respective parameter mean vector is stored as a png file in `fsys:pic:dir` with file name stem `fsys:pic:stm` and an infix expressing the respective factor level combination.

---

### plot:grp:save

**description:** save plots according to `fsys:pic`

**type:** boolean

**values, default:** 0

**remarks:** Store png files in `fsys:pic:dir` with file name stem `fsys:pic:stm`. One file per group.

---

### plot:grp:type:glob:decl

**description:** plot global contour declination centroid for each group

**type:** boolean

**values, default:** 0

**remarks:** Plots are not displayed but saved as png files to `fsys:pic`.

---

### plot:grp:type:loc:acc

**description:** plot local contour polynomial shape centroid for each group

**type:** boolean

**values, default:** 0

**remarks:** Plots are not displayed but saved as png files to `fsys:pic`.

---

### plot:grp:type:loc:decl

**description:** plot local contour declination centroid for each group

**type:** boolean

**values, default:** 0

**remarks:** Plots are not displayed but saved as png files to `fsys:pic`.

---

## 10 Output

### 10.1 Table files

If `fsys:export:csv` is set to 1, for each feature set selected by the `navigate:*` options a csv table file is generated in `config:fsys:export:dir`. The file name is the underscore-concatenation of `config:fsys:export:stm` and the feature set name. Extension is *csv*. Columns are separated by a comma. The column titles correspond to the feature names given in the tables in section 8, and each row corresponds to one segment or event for which the features were extracted. These feature vectors are additionally linked to the data origin by the following columns:

name	description
ci	channel index (starting with 1)
fi	file index (starting with 0)
ii	item (segment or event) index (starting with 0)
stm	annotation file name stem
t_on	time onset
t_off	time offset (same as t_on for events)
tier	tier name

Finally, if specified by the user an arbitrary number of grouping columns will be added to the tables that are derived from the filenames. Their names are prefixed by `grp`. See the grouping options `fsys:grp:*` in section 9.3 for details. Each table file comes along with an R code template file with the same name and the extension *.R* to read this table by the R software.



## 10.2 Summary table files

By setting `fsys:export:summary` to 1 the table output described in section 10.1 can be summarized per file and channel. Summarization for continuous-valued features is done in terms of their mean, median, standard deviation, and inter-quartile range. For categorical features as intonation contour classes the unigram entropy is calculated. The resulting table is written to the directory `fsys:export:dir` with the file stem `fsys:export:stm` plus the suffix *summary* and the extension *csv*. Columns are separated by a comma. There is one row of statistic values per channel in a file. Each continuous-valued feature within each analysis tier is represented by four columns. For features of the sets *glob* and *loc* for which there is only one analysis tier the column names follow the pattern *feature-Set\_featureName\_statisticMeasure*. The suffixes representing the statistic measurements are listed in the table right below. For features of all other sets with potentially more than one analysis tier the column names are built like this: *featureSet\_analysisTierName\_featureName\_statisticMeasure*. Categorical features are represented by one column each with the same name building schema.

suffix	meaning	feature type
m	arit. mean	continuous
med	median	continuous
sd	standard deviation	continuous
iqr	inter-quartile range	continuous
h	unigram entropy	categorical

File level groupings, i.e. the *grp\_\** columns of the csv tables described in section 10.1, are copied to the summary table. File and channel index are given in the columns *fi* and *ci*, respectively, the file stem is written to column *stm*.

Next to the csv file an R code template file is generated with the same name and the extension *.R* to read the summary table by the R software.

## 10.3 Nested Python dictionary

The pickle file which is outputted in `config:fsys:export:dir` contains a nested dictionary *copa* for the sake of further processing within other Python projects.

On the top level *copa* can be subdivided into the sub-dictionaries

- **config**: configurations underlying the current analysis
- **data**: extracted features in a structured way described below
- **clst**: contour clustering results
- **val**: validation metrics for stylization and clustering

In the subsequent paragraphs all branches through the copasul nested output dictionary are described. The following index key conventions will be used:

fi	file index
ci	channel index
ti	tier index
ii	item (segment or event) index

All indices start with 0, thus channel 1 is represented by index 0, etc. Levels in the dictionary are separated by colons. To give an example for the **data** sub-dictionary how to translate this notation into Python code:

```
data:fi:ci:bnd:ti:ii:lab – with index values:
data:0:0:bnd:0:0:lab
```

refers to: file 1 : channel 1 : boundary feature set : first tier, for which this set was extracted : segment 1 in this tier : label of this segment. In Python this label can be accessed by:

```
copa['data'][0][0]['bnd'][0][0]['lab']
```

Variables to be replaced by annotation-dependent tiernames etc. are marked by **my\***. As an example

```
data:0:0:rhy_f0:0:0:rate:myTierName*
```

is expanded to one branch for each tier in `fsys:rhy_f0:tier_rate` referring to channel 1 in `fsys:channel` (see section 9). Let `fsys:rhy_f0:tier_rate=["syl.1", "syl.2"]`, of which only the former refers to channel 1, i.e. `fsys:channel:syl.1=1`. Then the corresponding rate value of items in tier *syl.1* within file 1, channel 1, segment 1, and analysis tier 1 (*fi=ci=ti=ii=0*) is addressed in Python by:

```
copa['data'][0][0]['rhy_f0'][0][0]['rate']['syl.1']
```

### 10.3.1 Configuration sub-dictionary

This sub-dictionary is accessed by `copa['config']` and simply contains a copy of the user-defined and default configurations which are introduced in section 9.

### 10.3.2 Stylization feature subdirectory

Is accessed by `copa['data']` and can further be subdivided into dictionaries for file information, F0 preprocessing output, chunk segmentation, and feature sets. Time information is always given in seconds and can be accessed by the keys `t`, `tn`, `to`, `tt`. `to` always contains the original time values derived from the annotations, while `t`, `tn`, and `tt` values are rounded to the second decimal place to be in sync with F0 values that are sampled at 100 Hz. The semantics of `t`, `tn`, `to`, `tt` depends on the respective sub-dictionary. In the following all `copa['data']` branches will be described in alphabetical order. If a feature variable at the end of a branch is listed in one of the tables in section 8, here only the feature name is given, which can be looked up in these tables.

**Boundary features** Boundary features can be extracted within an arbitrary number of tiers. These tiers are indexed by the variable *ti*. For segment tiers the index *ii* refers to the segment **preceding** the boundary.

#### data:fi:ci:bnd:ti:ii:decl:bl:c

**description:** F0 baseline coefficients (descending order)

**type:** 2-element list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:bl:y

**description:** stylized baseline values

**type:** list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:err

**description:** True if top- and baseline cross

**type:** boolean

---

#### data:fi:ci:bnd:ti:ii:decl:ml:c

**description:** F0 midline coefficients (descending order)

**type:** 2-element list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:ml:y

**description:** stylized midline values

**type:** list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:rng:c

**description:** F0 range coefficients (descending order)

**type:** 2-element list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:rng:y

**description:** stylized range values

**type:** list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:tl:c

**description:** F0 topline coefficients (descending order)

**type:** 2-element list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:tl:y

**description:** stylized topline values

**type:** list of floats

---

#### data:fi:ci:bnd:ti:ii:decl:tn

**description:** normalized time values (same length as *bl|ml|rng|tl:y*)

**type:** list of floats

---

#### data:fi:ci:bnd:ti:ii:lab

**description:** *lab*

**type:** string

---

#### data:fi:ci:bnd:ti:ii:std:bl:r

**description:** *std\_bl\_r*

**type:** float

<u>data:fi:ci:bnd:ti:ii:std:bl:rms</u>
description: <i>std_bl_rms</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:bl:rms_post</u>
description: <i>std_bl_rms_post</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:bl:rms_pre</u>
description: <i>std_bl_rms_pre</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:ml:r</u>
description: <i>std_ml_r</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:ml:rms</u>
description: <i>std_ml_rms</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:ml:rms_post</u>
description: <i>std_ml_rms_post</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:ml:rms_pre</u>
description: <i>std_ml_rms_pre</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:p</u>
description: <i>p</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:rng:r</u>
description: <i>std_rng_r</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:rng:rms</u>
description: <i>std_rng_rms</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:rng:rms_post</u>
description: <i>std_rng_rms_post</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:rng:rms_pre</u>
description: <i>std_rng_rms_pre</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:tl:r</u>
description: <i>std_tl_r</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:tl:rms</u>
description: <i>std_tl_rms</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:tl:rms_post</u>
description: <i>std_tl_rms_post</i> type: float
<u>data:fi:ci:bnd:ti:ii:std:tl:rms_pre</u>
description: <i>std_tl_rms_pre</i> type: float
<u>data:fi:ci:bnd:ti:ii:t</u>

**description:** segment tier: time start and end of current segment; event tier: interval from the preceding to the current time stamp (for `bnd:...:std` features)  
**type:** 2 element list of floats

---

**data:fi:ci:bnd:ti:ii:tier**

**description:** tier name  
**type:** string

---

**data:fi:ci:bnd:ti:ii:tn**

**description:** start and end of pre-boundary analysis window, start and end of post-boundary analysis window (for `bnd:...:win` features)  
**type:** 4 element list of floats

---

**data:fi:ci:bnd:ti:ii:to**

**description:** t non-rounded  
**type:** 2 element list of floats

---

**data:fi:ci:bnd:ti:ii:trend:bl:r**

**description:** *trend\_bl\_r*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:bl:rms**

**description:** *trend\_bl\_rms*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:bl:rms\_post**

**description:** *trend\_bl\_rms\_post*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:bl:rms\_pre**

**description:** *trend\_bl\_rms\_pre*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:ml:r**

**description:** *trend\_ml\_r*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:ml:rms**

**description:** *trend\_ml\_rms*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:ml:rms\_post**

**description:** *trend\_ml\_rms\_post*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:ml:rms\_pre**

**description:** *trend\_ml\_rms\_pre*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:p**

**description:** *trend\_ml\_rms\_pre*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:rng:r**

**description:** *trend\_rng\_r*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:rng:rms**

**description:** *trend\_rng\_rms*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:rng:rms\_post**

**description:** *trend\_rng\_rms\_post*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:trend:rng:rms\_pre**

<b>description:</b> <i>trend_rng_rms_pre</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:trend:tl:r</u></b> <b>description:</b> <i>trend_tl_r</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:trend:tl:rms</u></b> <b>description:</b> <i>trend_tl_rms</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:trend:tl:rms_post</u></b> <b>description:</b> <i>trend_tl_rms_post</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:trend:tl:rms_pre</u></b> <b>description:</b> <i>trend_tl_rms_pre</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:tt</u></b> <b>description:</b> start and endpoint for 2 trend windows: from file or chunk start (depending on the <i>styl:bnd:cross_chunk</i> value in the configurations, see section 9) till the end of the pre-boundary segment; from the start of the post-boundary segment till file/chunk end (for <b>bnd: . . . :trend</b> features). <b>type:</b> 4 element list of floats
<b><u>data:fi:ci:bnd:ti:ii:win:bl:r</u></b> <b>description:</b> <i>win_bl_r</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:bl:rms</u></b> <b>description:</b> <i>win_bl_rms</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:bl:rms_post</u></b> <b>description:</b> <i>win_bl_rms_post</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:bl:rms_pre</u></b> <b>description:</b> <i>win_bl_rms_pre</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:ml:r</u></b> <b>description:</b> <i>win_ml_r</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:ml:rms</u></b> <b>description:</b> <i>win_ml_rms</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:ml:rms_post</u></b> <b>description:</b> <i>win_ml_rms_post</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:ml:rms_pre</u></b> <b>description:</b> <i>win_ml_rms_pre</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:p</u></b> <b>description:</b> <i>p</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:rng:r</u></b> <b>description:</b> <i>win_rng_r</i> <b>type:</b> float
<b><u>data:fi:ci:bnd:ti:ii:win:rng:rms</u></b>

**description:** *win\_rng\_rms*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:win:rng:rms\_post**

**description:** *win\_rng\_rms\_post*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:win:rng:rms\_pre**

**description:** *win\_rng\_rms\_pre*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:win:tl:r**

**description:** *win\_tl\_r*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:win:tl:rms**

**description:** *win\_tl\_rms*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:win:tl:rms\_post**

**description:** *win\_tl\_rms\_post*  
**type:** float

---

**data:fi:ci:bnd:ti:ii:win:tl:rms\_pre**

**description:** *win\_tl\_rms\_pre*  
**type:** float

---

## Chunks

**data:fi:ci:chunk:ii:lab**

**description:** label  
**type:** string

---

**data:fi:ci:chunk:ii:t**

**description:** time start and end  
**type:** 2 element list of floats

---

**data:fi:ci:chunk:ii:to**

**description:** t non-rounded  
**type:** 2 element list of floats

---

## F0

**data:fi:ci:f0:bv**

**description:** file/channel related F0 base value  
**type:** float

---

**data:fi:ci:f0:r**

**description:** F0 residual after removal of the global F0 component  
**type:** list of floats

---

**data:fi:ci:f0:t**

**description:** time stamps  
**type:** list of floats

---

**data:fi:ci:f0:y**

**description:** F0 values after preprocessing  
**type:** list of floats, same length as t

---

## File information

### data:fi:ci:fsys:annot:dir

**description:** directory of annotation file  
**type:** string

---

### data:fi:ci:fsys:annot:ext

**description:** extension of annotation file  
**type:** string

---

### data:fi:ci:fsys:annot:lab\_chunk

**description:** general chunk label  
**type:** string

---

### data:fi:ci:fsys:annot:lab\_pau

**description:** general pause label  
**type:** string

---

### data:fi:ci:fsys:annot:lab\_syl

**description:** general syllable nucleus label  
**type:** string

---

### data:fi:ci:fsys:annot:stm

**description:** annotation file name stem  
**type:** string

---

### data:fi:ci:fsys:annot:typ

**description:** annotation file type (*xml* or *TextGrid*)  
**type:** string

---

### data:fi:ci:fsys:aud:dir

**description:** directory of audio file  
**type:** string

---

### data:fi:ci:fsys:aud:ext

**description:** extension of audio file  
**type:** string

---

### data:fi:ci:fsys:aud:stm

**description:** audio file name stem  
**type:** string

---

### data:fi:ci:fsys:aud:typ

**description:** audio file type  
**type:** string

---

### data:fi:ci:fsys:augment:channel:myTierName

**description:** channel number of each relevant tier *myTierName* in the annotation. Names of tiers derived by automatic chunking, phrasing, etc. will be added automatically.  
**type:** int

---

### data:fi:ci:fsys:augment:chunk:tier\_out\_stm

**description:** chunk tier output stem. In the augmented annotation file, the stem is concatenated with the respective channel number  
**type:** string

---

### data:fi:ci:fsys:augment:glob:tier

**description:** analysis tier name for prosodic boundaries, i.e. tier with prosodic boundary candidates. Max. 1 for each channel!  
**type:** string

---

### data:fi:ci:fsys:augment:glob:tier\_out\_stm

**description:** prosodic phrase tier output stem. In the augmented annotation file, the stem is concatenated with the respective channel number  
**type:** string

---

### data:fi:ci:fsys:augment:glob:tier\_parent

**description:** name of the parent tier (e.g. chunks), whose boundaries limit the analysis and normalization window boundaries for prosodic phrase extraction

**type:** string

---

**data:fi:ci:fsys:augment:lab\_chunk**

**description:** uniform chunk label

**type:** string

---

**data:fi:ci:fsys:augment:lab\_pau**

**description:** uniform pause label

**type:** string

---

**data:fi:ci:fsys:augment:lab\_syl**

**description:** uniform syllable nucleus label. Syllable boundaries are derived from this string by concatenating *\_bnd*

**type:** string

---

**data:fi:ci:fsys:augment:loc:tier\_acc**

**description:** analysis event tier name for pitch accent detection, i.e. the tier containing the time stamps of pitch accent candidates (e.g. syllable nuclei). Max 1 for each channel.

**type:** list of strings

---

**data:fi:ci:fsys:augment:loc:tier\_ag**

**description:** analysis segment tier name for pitch accent detection, i.e. the tier containing segments within which maximally one pitch accent can be realized (e.g. words)

**type:** string

---

**data:fi:ci:fsys:augment:loc:tier\_out\_stm**

**description:** pitch accent tier output stem. In the augmented annotation file, the stem is concatenated with the respective channel number

**type:** string

---

**data:fi:ci:fsys:augment:loc:tier\_parent**

**description:** name of the parent tier (e.g. prosodic phrases), relative to which the accent Gestalt is measured, and whose boundaries limit the analysis and normalization window boundaries for pitch accent extraction

**type:** string

---

**data:fi:ci:fsys:augment:nc**

**description:** number of channels

**type:** int

---

**data:fi:ci:fsys:augment:stm**

**description:** annotation file name stem

**type:** string

---

**data:fi:ci:fsys:augment:syl:tier\_out\_stm**

**description:** syllable nucleus and boundary tier output stem. In the augmented annotation file, for the syllable boundary tier *\_bnd* is added to the stem, and for both nuclei and boundaries, the stem is concatenated with the respective channel number

**type:** string

---

**data:fi:ci:fsys:augment:syl:tier\_parent**

**description:** name of the parent tier (e.g. chunks), within which reference values are calculated, and whose boundaries limit the analysis and normalization window boundaries for syllable nucleus detection)

**type:** string

---

**data:fi:ci:fsys:bnd:tier**

**description:** analysis tiers for boundary parameterization. Arbitrary number for each channel.

**type:** list of strings

---

**data:fi:ci:fsys:chunk:tier**

**description:** names of tiers that contain a chunk segmentation (only 1 tier for each channel). Names of automatically generated tiers are expanded by channel index *ci*.

**type:** list of strings

---

**data:fi:ci:fsys:f0:dir**

**description:** F0 file directory



<b>type:</b> string
<b><u>data:fi:ci:fsys:f0:ext</u></b>
<b>description:</b> F0 file extension <b>type:</b> string
<b><u>data:fi:ci:fsys:f0:stm</u></b>
<b>description:</b> F0 file name stem <b>type:</b> string
<b><u>data:fi:ci:fsys:f0:typ</u></b>
<b>description:</b> F0 file type <b>type:</b> string
<b><u>data:fi:ci:fsys:glob:tier</u></b>
<b>description:</b> analysis tiers for global contour stylization. Max. 1 tier per channel. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:gnl_en:tier</u></b>
<b>description:</b> names of analysis tiers for standard energy feature extraction. Any number of tiers per channel supported. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:gnl_f0:tier</u></b>
<b>description:</b> names of analysis tiers for standard F0 feature extraction. Any number of tiers per channel supported. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:loc:tier_acc</u></b>
<b>description:</b> time stamp analysis tiers for the 0-center of normalized time within a local contour segment. Max. 1 tier per channel. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:loc:tier_ag</u></b>
<b>description:</b> segment tiers for local contours. Max. 1 tier per channel. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:rhy_en:tier</u></b>
<b>description:</b> names of analysis tiers for energy rhythm feature extraction. Any number per channel. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:rhy_en:tier_rate</u></b>
<b>description:</b> names of rate tiers for energy rhythm feature extraction. Any number per channel. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:rhy_f0:tier</u></b>
<b>description:</b> names of analysis tiers for F0 rhythm feature extraction. Any number per channel. <b>type:</b> list of strings
<b><u>data:fi:ci:fsys:rhy_f0:tier_rate</u></b>
<b>description:</b> names of rate tiers for F0 rhythm feature extraction. Any number per channel. <b>type:</b> list of strings

## Global segment features

data:fi:ci:glob:ii:class

**description:** *class*; global contour class index derived by clustering  
**type:** int

---

data:fi:ci:glob:ii:decl:bl:c

**description:** *bl\_c1*, *bl\_c0*  
**type:** 2 element list of floats

---

data:fi:ci:glob:ii:decl:bl:r

**description:** *bl\_r*  
**type:** float

---

data:fi:ci:glob:ii:decl:bl:rate

**description:** *bl\_rate*  
**type:** float

---

data:fi:ci:glob:ii:decl:bl:y

**description:** stylized F0 baseline values  
**type:** list of floats

---

data:fi:ci:glob:ii:decl:err

**description:** True if base and topline crossing  
**type:** boolean

---

data:fi:ci:glob:ii:decl:ml:c

**description:** *ml\_c1*, *ml\_c0*  
**type:** 2 element list of floats

---

data:fi:ci:glob:ii:decl:ml:r

**description:** *ml\_r*  
**type:** float

---

data:fi:ci:glob:ii:decl:ml:rate

**description:** *ml\_rate*  
**type:** float

---

data:fi:ci:glob:ii:decl:ml:y

**description:** stylized F0 midline values  
**type:** list of floats

---

data:fi:ci:glob:ii:decl:rng:c

**description:** *rng\_c1*, *rng\_c0*  
**type:** 2 element list of floats

---

data:fi:ci:glob:ii:decl:rng:r

**description:** *rng\_r*  
**type:** float

---

data:fi:ci:glob:ii:decl:rng:rate

**description:** *rng\_rate*  
**type:** float

---

data:fi:ci:glob:ii:decl:rng:y

**description:** stylized F0 range values  
**type:** list of floats

---

data:fi:ci:glob:ii:decl:tl:c

**description:** *tl\_c1*, *tl\_c0*  
**type:** 2 element list of floats

---

data:fi:ci:glob:ii:decl:tl:r

**description:** *tl\_r*  
**type:** float

---

data:fi:ci:glob:ii:decl:tl:rate

<b>description:</b> <i>tl_rate</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:decl:tl:y</u></b> <b>description:</b> stylized F0 topline values <b>type:</b> list of floats
<b><u>data:fi:ci:glob:ii:decl:tn</u></b> <b>description:</b> normalized time values (same length as all <i>bl ml tl rng:y</i> ) <b>type:</b> list of floats
<b><u>data:fi:ci:glob:ii:gnl:dur</u></b> <b>description:</b> <i>dur</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:gnl:iqr</u></b> <b>description:</b> <i>iqr</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:gnl:m</u></b> <b>description:</b> <i>m</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:gnl:max</u></b> <b>description:</b> <i>max</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:gnl:med</u></b> <b>description:</b> <i>med</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:gnl:min</u></b> <b>description:</b> <i>min</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:gnl:sd</u></b> <b>description:</b> <i>sd</i> <b>type:</b> float
<b><u>data:fi:ci:glob:ii:lab</u></b> <b>description:</b> <i>lab</i> <b>type:</b> string
<b><u>data:fi:ci:glob:ii:ri</u></b> <b>description:</b> indices of local segments contained in global segment <i>ii</i> <b>type:</b> list of int
<b><u>data:fi:ci:glob:ii:t</u></b> <b>description:</b> global phrase time start and end <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:glob:ii:to</u></b> <b>description:</b> <i>t</i> non-rounded <b>type:</b> 2 element list of floats

## Standard energy features

data:fi:ci:gnl\_en:ti:ii:lab

**description:** *lab*

**type:** string

---

data:fi:ci:gnl\_en:ti:ii:std:dur

**description:** *dur*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:dur\_nrm

**description:** normalized duration

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:iqr

**description:** *iqr*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:iqr\_nrm

**description:** *iqr\_nrm*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:m

**description:** *m*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:m\_nrm

**description:** *m\_nrm*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:max

**description:** *max*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:max\_nrm

**description:** *max\_nrm*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:med

**description:** *med*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:med\_nrm

**description:** *med\_nrm*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:min

**description:** *min*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:min\_nrm

**description:** *min\_nrm*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:rms

**description:** *rms*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:rms\_nrm

**description:** *rms\_nrm*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:sb

**description:** *sb*

**type:** float

---

data:fi:ci:gnl\_en:ti:ii:std:sd

<b>description:</b> <i>sd</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en:ti:ii:std:sd_nrm</u></b> <b>description:</b> <i>sd_nrm</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en:ti:ii:t</u></b> <b>description:</b> analysis window start and endpoint <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:gnl_en:ti:ii:tier</u></b> <b>description:</b> tier name related to index <i>ti</i> <b>type:</b> string
<b><u>data:fi:ci:gnl_en:ti:ii:tn</u></b> <b>description:</b> normalization window start and endpoint <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:gnl_en:ti:ii:to</u></b> <b>description:</b> <i>t</i> non-rounded <b>type:</b> list of floats
<b><u>data:fi:ci:gnl_en:ti:ii:tt</u></b> <b>description:</b> trend window (not used) <b>type:</b> list of floats
<b><u>data:fi:ci:gnl_en_file:dur</u></b> <b>description:</b> <i>dur</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en_file:iqr</u></b> <b>description:</b> <i>iqr</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en_file:m</u></b> <b>description:</b> <i>m</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en_file:max</u></b> <b>description:</b> <i>max</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en_file:med</u></b> <b>description:</b> <i>med</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en_file:min</u></b> <b>description:</b> <i>min</i> <b>type:</b> float
<b><u>data:fi:ci:gnl_en_file:sd</u></b> <b>description:</b> <i>sd</i> <b>type:</b> float

## Standard F0 features

data:fi:ci:gnl\_f0:ti:ii:lab

**description:** *lab*

**type:** string

---

data:fi:ci:gnl\_f0:ti:ii:std:dur

**description:** *dur*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:dur\_nrm

**description:** normalized duration

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:iqr

**description:** *iqr*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:iqr\_nrm

**description:** *iqr\_nrm*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:m

**description:** *m*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:m\_nrm

**description:** *m\_nrm*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:max

**description:** *max*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:max\_nrm

**description:** *max\_nrm*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:med

**description:** *med*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:med\_nrm

**description:** *med\_nrm*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:min

**description:** *min*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:min\_nrm

**description:** *min\_nrm*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:sd

**description:** *sd*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:std:sd\_nrm

**description:** *sd\_nrm*

**type:** float

---

data:fi:ci:gnl\_f0:ti:ii:t

**description:** analysis window start and endpoint

**type:** 2 element list of floats

---

data:fi:ci:gnl\_f0:ti:ii:tier

**description:** tier name related to index *ti*  
**type:** string

---

**data:fi:ci:gnl\_f0:ti:ii:tn**

**description:** normalization window start and endpoint  
**type:** 2 element list of floats

---

**data:fi:ci:gnl\_f0:ti:ii:to**

**description:** *t* non-rounded  
**type:** list of floats

---

**data:fi:ci:gnl\_f0:ti:ii:tt**

**description:** trend window, not used  
**type:** list of floats

---

**data:fi:ci:gnl\_f0\_file:dur**

**description:** *dur*  
**type:** float

---

**data:fi:ci:gnl\_f0\_file:iqr**

**description:** *iqr*  
**type:** float

---

**data:fi:ci:gnl\_f0\_file:m**

**description:** *m*  
**type:** float

---

**data:fi:ci:gnl\_f0\_file:max**

**description:** *max*  
**type:** float

---

**data:fi:ci:gnl\_f0\_file:med**

**description:** *med*  
**type:** float

---

**data:fi:ci:gnl\_f0\_file:min**

**description:** *min*  
**type:** float

---

**data:fi:ci:gnl\_f0\_file:sd**

**description:** *sd*  
**type:** float

---

## Grouping

**data:fi:ci:grp:myGroupVar\***

**description:** myGroupvar refers to the grouping variable names specified in the configuration sub-dictionary **fsys:grp** for file name based grouping. The values are extracted from the file name and are always strings  
**type:** string

---

## Local segment features

**data:fi:ci:loc:ii:acc:c**

**description:** *c\**; polynomial coefficients (highest order first)  
**type:** list of floats

---

**data:fi:ci:loc:ii:acc:tn**

**description:** normalized time values  
**type:** list of floats

---

**data:fi:ci:loc:ii:acc:y**

**description:** polynomial stylization values (same length as tn)  
**type:** list of floats

---

**data:fi:ci:loc:ii:class**

**description:** *class*; local contour class index derived by clustering

<b>type:</b> int
<b><u>data:fi:ci:loc:ii:decl:bl:c</u></b>
<b>description:</b> <i>bl_c1</i> , <i>bl_c0</i> <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:loc:ii:decl:bl:rate</u></b>
<b>description:</b> <i>bl_rate</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:decl:bl:y</u></b>
<b>description:</b> stylized F0 baseline values <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:decl:err</u></b>
<b>description:</b> True if base- and topline cross <b>type:</b> boolean
<b><u>data:fi:ci:loc:ii:decl:ml:c</u></b>
<b>description:</b> <i>ml_c1</i> , <i>ml_c0</i> <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:loc:ii:decl:ml:rate</u></b>
<b>description:</b> <i>ml_rate</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:decl:ml:y</u></b>
<b>description:</b> stylized F0 midline values <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:decl:rng:c</u></b>
<b>description:</b> <i>rng_c1</i> , <i>rng_c0</i> <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:loc:ii:decl:rng:rate</u></b>
<b>description:</b> <i>rng_rate</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:decl:rng:y</u></b>
<b>description:</b> stylized F0 range values <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:decl:tl:c</u></b>
<b>description:</b> <i>tl_c1</i> , <i>tl_c0</i> <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:loc:ii:decl:tl:rate</u></b>
<b>description:</b> <i>tl_rate</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:decl:tl:y</u></b>
<b>description:</b> stylized F0 topline values <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:decl:tn</u></b>
<b>description:</b> normalized time values <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:gnl:dur</u></b>
<b>description:</b> <i>dur</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gnl:dur_nrm</u></b>
<b>description:</b> <i>dur_nrm</i> <b>type:</b> float



<u>data:fi:ci:loc:ii:gnl:iqr</u>
description: <i>iqr</i> type: float
<u>data:fi:ci:loc:ii:gnl:iqr_nrm</u>
description: <i>iqr_nrm</i> type: float
<u>data:fi:ci:loc:ii:gnl:m</u>
description: <i>m</i> type: float
<u>data:fi:ci:loc:ii:gnl:m_nrm</u>
description: <i>m_nrm</i> type: float
<u>data:fi:ci:loc:ii:gnl:max</u>
description: <i>max</i> type: float
<u>data:fi:ci:loc:ii:gnl:max_nrm</u>
description: <i>max_nrm</i> type: float
<u>data:fi:ci:loc:ii:gnl:med</u>
description: <i>med</i> type: float
<u>data:fi:ci:loc:ii:gnl:med_nrm</u>
description: <i>med_nrm</i> type: float
<u>data:fi:ci:loc:ii:gnl:min</u>
description: <i>min</i> type: float
<u>data:fi:ci:loc:ii:gnl:min_nrm</u>
description: <i>min_nrm</i> type: float
<u>data:fi:ci:loc:ii:gnl:sd</u>
description: <i>sd</i> type: float
<u>data:fi:ci:loc:ii:gnl:sd_nrm</u>
description: <i>sd_nrm</i> type: float
<u>data:fi:ci:loc:ii:gst:bl:d_fin</u>
description: <i>bl_d_fin</i> type: float
<u>data:fi:ci:loc:ii:gst:bl:d_init</u>
description: <i>bl_d_init</i> type: float
<u>data:fi:ci:loc:ii:gst:bl:rms</u>
description: <i>bl_rms</i> type: float
<u>data:fi:ci:loc:ii:gst:bl:sd</u>
description: <i>bl_sd</i> type: float
<u>data:fi:ci:loc:ii:gst:ml:d_fin</u>

<b>description:</b> <i>ml_d_fin</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:ml:d_init</u></b> <b>description:</b> <i>ml_d_init</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:ml:rms</u></b> <b>description:</b> <i>ml_rms</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:ml:sd</u></b> <b>description:</b> <i>ml_sd</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:residual:bl:c</u></b> <b>description:</b> $c^*$ ; local contour coefs in descending order. Polynomial fitted on residual after baseline subtraction <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:gst:residual:ml:c</u></b> <b>description:</b> $c^*$ ; local contour coefs in descending order. Polynomial fitted on residual after midline subtraction <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:gst:residual:rng:c</u></b> <b>description:</b> $c^*$ ; local contour coefs in descending order. Polynomial fitted on residual after range normalization <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:gst:residual:tl:c</u></b> <b>description:</b> $c^*$ ; local contour coefs in descending order. Polynomial fitted on residual after topline subtraction <b>type:</b> list of floats
<b><u>data:fi:ci:loc:ii:gst:rng:d_fin</u></b> <b>description:</b> <i>rng_d_fin</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:rng:d_init</u></b> <b>description:</b> <i>rng_d_init</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:rng:rms</u></b> <b>description:</b> <i>rng_rms</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:rng:sd</u></b> <b>description:</b> <i>rng_sd</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:tl:d_fin</u></b> <b>description:</b> <i>tl_d_fin</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:tl:d_init</u></b> <b>description:</b> <i>tl_d_init</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:tl:rms</u></b> <b>description:</b> <i>tl_rms</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:gst:tl:sd</u></b> <b>description:</b> <i>tl_sd</i> <b>type:</b> float
<b><u>data:fi:ci:loc:ii:lab_acc</u></b> <b>description:</b> <i>lab_pnt</i> ; label from local event tier <b>type:</b> string

<u>data:fi:ci:loc:ii:lab_ag</u>	
<b>description:</b> <i>lab</i> ; label from local segment tier <b>type:</b> string	
<u>data:fi:ci:loc:ii:ri</u>	
<b>description:</b> index of global parent segment <b>type:</b> int	
<u>data:fi:ci:loc:ii:t</u>	
<b>description:</b> analysis window starting point, endpoint, and center. For only event tier input, these values are given by start and end of a symmetric window around each time stamp, and the time stamp itself. For only segment tier input, start- and endpoint are given by the segment's on and offset, and the center corresponds to the segment's midpoint. For both event and segment tier input, start- and endpoint are given by the segment's on and offset, and the center by the event's time stamp. <b>type:</b> 3 element list of floats	
<u>data:fi:ci:loc:ii:tn</u>	
<b>description:</b> Normalization window start and endpoint to normalize F0 standard features. <b>type:</b> 2 element list of floats	
<u>data:fi:ci:loc:ii:to</u>	
<b>description:</b> original input time values (1 for events, 2 for segments, 3 for events+segments) <b>type:</b> 1, 2 or 3 element list of floats	
Event rates	
<u>data:fi:ci:rate:myTierName*</u>	
<b>description:</b> for the events or segments of all tier names specified in the configuration by <code>rhy_f0:tier_rate</code> their overall rate is measured within the file. <b>type:</b> float	
Energy rhythm features	
<u>data:fi:ci:rhy_en:ti:ii:lab</u>	
<b>description:</b> <i>lab</i> <b>type:</b> string	
<u>data:fi:ci:rhy_en:ti:ii:rate:myTierName*</u>	
<b>description:</b> <i>myRateTier_rate</i> ; rate of items in <i>myTierName</i> within the current interval <i>ii</i> of tier with index <i>ti</i> <b>type:</b> float	
<u>data:fi:ci:rhy_en:ti:ii:rhy:c</u>	
<b>description:</b> DCT coefficients in user defined frequency band <b>type:</b> list of floats	
<u>data:fi:ci:rhy_en:ti:ii:rhy:c_orig</u>	
<b>description:</b> all DCT coefficients <b>type:</b> list of floats	
<u>data:fi:ci:rhy_en:ti:ii:rhy:cbin</u>	
<b>description:</b> summed DCT coefs within frequency bins <b>type:</b> list of floats	
<u>data:fi:ci:rhy_en:ti:ii:rhy:dur</u>	
<b>description:</b> <i>dur</i> <b>type:</b> float	
<u>data:fi:ci:rhy_en:ti:ii:rhy:f</u>	
<b>description:</b> frequencies of DCT coefs in <i>c</i> (same length as <i>c</i> ) <b>type:</b> list of floats	
<u>data:fi:ci:rhy_en:ti:ii:rhy:f_orig</u>	
<b>description:</b> frequencies of DCT coef in <i>c_orig</i> (same length as <i>c_orig</i> ) <b>type:</b> list of floats	
<u>data:fi:ci:rhy_en:ti:ii:rhy:fbin</u>	

<b>description:</b> lower boundaries of frequency bins (same length as <code>cbin</code> ) <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:m</u></b> <b>description:</b> weighted coefficient mean <b>type:</b> float
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:mae</u></b> <b>description:</b> mean absolute error between IDCT and original contour <b>type:</b> float
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:sd</u></b> <b>description:</b> weighted coefficient standard deviation <b>type:</b> float
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:sm</u></b> <b>description:</b> $sm^*$ ; spectral moments of DCT coefs <b>type:</b> list of floats; length depends on config branch <code>styl:rhy_en:rhy:nsm</code>
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:wgt:myTierName*:mae</u></b> <b>description:</b> <i>myAnalysisTier_myRateTier_mae</i> ; mean absolute error between original contour and IDCT of coefficients around the rate of the items in tier <i>myTierName</i> <b>type:</b> float
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:wgt:myTierName*:prop</u></b> <b>description:</b> <i>myAnalysisTier_myAnalysisTier_prop</i> ; proportion of the coefficient weights around the rate of the items in tier <i>myTierName</i> relative to coefficients' overall sum <b>type:</b> float
<b><u>data:fi:ci:rhy_en:ti:ii:rhy:wgt:myTierName*:rate</u></b> <b>description:</b> <i>myAnalysisTier_myAnalysisTier_rate</i> ; rate of the items in tier <i>myTierName</i> <b>type:</b> float
<b><u>data:fi:ci:rhy_en:ti:ii:ri:myTierName*</u></b> <b>description:</b> item indices in tier <i>myTierName</i> that fall within the segment <i>ii</i> of tier with index <i>ti</i> <b>type:</b> list of int
<b><u>data:fi:ci:rhy_en:ti:ii:t</u></b> <b>description:</b> segment <i>ii</i> start and endpoint <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:rhy_en:ti:ii:tier</u></b> <b>description:</b> tier name related to index <i>ti</i> <b>type:</b> string
<b><u>data:fi:ci:rhy_en:ti:ii:tn</u></b> <b>description:</b> as <i>t</i> , irrelevant <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:rhy_en:ti:ii:to</u></b> <b>description:</b> <i>t</i> non-rounded <b>type:</b> 2 element list of floats
<b><u>data:fi:ci:rhy_en:ti:ii:tt</u></b> <b>description:</b> segment <i>ii</i> start, mid, and endpoint; irrelevant <b>type:</b> 3 element list of floats
<b><u>data:fi:ci:rhy_en_file:c</u></b> <b>description:</b> DCT coefficients in user defined frequency band <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_en_file:c_orig</u></b> <b>description:</b> all DCT coefficients <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_en_file:cbin</u></b>

**description:** summed DCT coefs within frequency bins  
**type:** list of floats

---

**data:fi:ci:rhy\_en\_file:dur**

**description:** *dur*  
**type:** float

---

**data:fi:ci:rhy\_en\_file:f**

**description:** frequencies of DCT coefs in *c* (same length as *c*)  
**type:** list of floats

---

**data:fi:ci:rhy\_en\_file:f\_orig**

**description:** frequencies of DCT coef in *c\_orig* (same length as *c\_orig*)  
**type:** list of floats

---

**data:fi:ci:rhy\_en\_file:fbin**

**description:** lower boundaries of frequency bins  
**type:** list of floats

---

**data:fi:ci:rhy\_en\_file:m**

**description:** weighted coefficient mean  
**type:** string

---

**data:fi:ci:rhy\_en\_file:mae**

**description:** mean absolute error between IDCT and original contour  
**type:** float

---

**data:fi:ci:rhy\_en\_file:sd**

**description:** weighted coefficient standard deviation  
**type:** float

---

**data:fi:ci:rhy\_en\_file:sm**

**description:** *sm\**; spectral moments of DCT coefs  
**type:** list of floats

---

**data:fi:ci:rhy\_en\_file:wgt:myTierName\*:mae**

**description:** *myAnalysisTier\_mae*; mean absolute error between original contour and IDCT of coefficients around the rate of the items in tier *myTierName*  
**type:** float

---

**data:fi:ci:rhy\_en\_file:wgt:myTierName\*:prop**

**description:** *myAnalysisTier\_prop*; proportion of the coefficient weights around the rate of the items in tier *myTierName* relative to coefficients' overall sum  
**type:** float

---

**data:fi:ci:rhy\_en\_file:wgt:myTierName\*:rate**

**description:** *myAnalysisTier\_rate*; rate of the items in tier *myTierName*  
**type:** float

---

## F0 rhythm features

**data:fi:ci:rhy\_f0:ti:ii:lab**

**description:** *lab*  
**type:** string

---

**data:fi:ci:rhy\_f0:ti:ii:rate:myTierName\***

**description:** *myAnalysisTier\_rate*; rate of items in *myTierName* within the current interval *ii* of tier with index *ti*  
**type:** float

---

**data:fi:ci:rhy\_f0:ti:ii:rhy:c**

**description:** DCT coefficients in user defined frequency band  
**type:** list of floats

---

**data:fi:ci:rhy\_en:ti:ii:rhy:c\_orig**

**description:** all DCT coefficients  
**type:** list of floats

<u>data:fi:ci:rhy_f0:ti:ii:rhy:cbin</u>
<b>description:</b> summed DCT coefs within frequency bins <b>type:</b> list of floats
<u>data:fi:ci:rhy_f0:ti:ii:rhy:dur</u>
<b>description:</b> <i>dur</i> <b>type:</b> float
<u>data:fi:ci:rhy_f0:ti:ii:rhy:f</u>
<b>description:</b> frequencies of DCT coefs in <i>c</i> (same length as <i>c</i> ) <b>type:</b> list of floats
<u>data:fi:ci:rhy_f0:ti:ii:rhy:f_orig</u>
<b>description:</b> frequencies of DCT coef in <i>c_orig</i> (same length as <i>c_orig</i> ) <b>type:</b> list of floats
<u>data:fi:ci:rhy_f0:ti:ii:rhy:fbin</u>
<b>description:</b> lower boundaries of frequency bins <b>type:</b> list of floats
<u>data:fi:ci:rhy_f0:ti:ii:rhy:m</u>
<b>description:</b> weighted coefficient mean <b>type:</b> string
<u>data:fi:ci:rhy_f0:ti:ii:rhy:mae</u>
<b>description:</b> mean absolute error between IDCT and original contour <b>type:</b> float
<u>data:fi:ci:rhy_f0:ti:ii:rhy:sd</u>
<b>description:</b> weighted coefficient standard deviation <b>type:</b> float
<u>data:fi:ci:rhy_f0:ti:ii:rhy:sm</u>
<b>description:</b> $sm^*$ ; spectral moments of DCT coefs <b>type:</b> list of floats
<u>data:fi:ci:rhy_f0:ti:ii:rhy:wgt:myTierName*:mae</u>
<b>description:</b> <i>myAnalysisTier_myAnalysisTier_mae</i> ; mean absolute error between original contour and IDCT of coefficients around the rate of the items in tier <i>myTierName</i> <b>type:</b> float
<u>data:fi:ci:rhy_f0:ti:ii:rhy:wgt:myTierName*:prop</u>
<b>description:</b> <i>myAnalysisTier_myAnalysisTier_prop</i> ; proportion of the coefficient weights around the rate of the items in tier <i>myTierName</i> relative to coefficients' overall sum <b>type:</b> float
<u>data:fi:ci:rhy_f0:ti:ii:rhy:wgt:myTierName*:rate</u>
<b>description:</b> <i>myAnalysisTier_myAnalysisTier_rate</i> ; rate of the items in tier <i>myTierName</i> <b>type:</b> float
<u>data:fi:ci:rhy_f0:ti:ii:ri:myTierName</u>
<b>description:</b> item indices in tier <i>myTierName</i> that fall within the segment <i>ii</i> of tier with index <i>ti</i> <b>type:</b> list of int
<u>data:fi:ci:rhy_f0:ti:ii:t</u>
<b>description:</b> segment <i>ii</i> start and endpoint <b>type:</b> 2 element list of floats
<u>data:fi:ci:rhy_f0:ti:ii:tier</u>
<b>description:</b> tier name related to index <i>ti</i> <b>type:</b> string
<u>data:fi:ci:rhy_f0:ti:ii:tn</u>
<b>description:</b> as <i>t</i> , irrelevant

<b>type:</b> 2-element list of floats
<b><u>data:fi:ci:rhy_f0:ti:ii:to</u></b>
<b>description:</b> $t$ non-rounded <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0:ti:ii:tt</u></b>
<b>description:</b> segment $ii$ start, mid, and endpoint; irrelevant <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:c</u></b>
<b>description:</b> DCT coefficients in user defined frequency band <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:c_orig</u></b>
<b>description:</b> all DCT coefficients <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:cbin</u></b>
<b>description:</b> summed DCT coefs within frequency bins <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:dur</u></b>
<b>description:</b> $dur$ <b>type:</b> float
<b><u>data:fi:ci:rhy_f0_file:f</u></b>
<b>description:</b> frequencies of DCT coefs in $c$ (same length as $c$ ) <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:f_orig</u></b>
<b>description:</b> frequencies of DCT coef in $c\_orig$ (same length as $c\_orig$ ) <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:fbin</u></b>
<b>description:</b> lower boundaries of frequency bins <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:m</u></b>
<b>description:</b> weighted coefficient mean <b>type:</b> string
<b><u>data:fi:ci:rhy_f0_file:mae</u></b>
<b>description:</b> mean absolute error between IDCT and original contour <b>type:</b> float
<b><u>data:fi:ci:rhy_f0_file:sd</u></b>
<b>description:</b> weighted coefficient standard deviation <b>type:</b> float
<b><u>data:fi:ci:rhy_f0_file:sm</u></b>
<b>description:</b> $sm^*$ ; spectral moments of DCT coefs <b>type:</b> list of floats
<b><u>data:fi:ci:rhy_f0_file:wgt:myTierName*:mae</u></b>
<b>description:</b> $myAnalysisTier\_mae$ ; mean absolute error between original contour and IDCT of coefficients around the rate of the items in tier $myTierName$ <b>type:</b> float
<b><u>data:fi:ci:rhy_f0_file:wgt:myTierName*:prop</u></b>
<b>description:</b> $myAnalysisTier\_prop$ ; proportion of the coefficient weights around the rate of the items in tier $myTierName$ relative to coefficients' over all sum <b>type:</b> float
<b><u>data:fi:ci:rhy_f0_file:wgt:myTierName*:rate</u></b>
<b>description:</b> $myAnalysisTier\_rate$ ; rate of the items in tier $myTierName$ <b>type:</b> float

### 10.3.3 Clustering result sub-dictionary

This sub-dictionary is accessed by `copa['clst']` and contains the outcome of the clustering of global and local contours (cf. sections 7.5.2 and 7.7.2).

#### Global contour classes

##### clst:glob:c

**description:** slope coef matrix to be clustered  
**type:** 2d array of floats

---

##### clst:glob:cntr

**description:** centroid matrix, one row per contour class  
**type:** 2d array of floats

---

##### clst:glob:ij

**description:** location of each feature vector in `copa:data:fi:ci:glob:ii`: each row contains 3 indices for the file  $f_i$ , the channel  $c_i$ , and the global segment  $ii$ , respectively)  
**type:** 2d array of int

---

##### clst:glob:obj

**description:** clustering object which was used for global contour clustering  
**type:** object

---

##### clst:glob:val

**description:** mean silhouette  
**type:** float

---

#### Local contour classes

##### clst:loc:c

**description:** polynomial coef matrix to be clustered  
**type:** list of floats

---

##### clst:loc:cntr

**description:** centroid matrix, one row per contour class  
**type:** list of strings

---

##### clst:loc:ij

**description:** location of each feature vector in `copa:data:fi:ci:loc:ii`: each row contains 3 indices for the file, the channel, and the local segment, respectively  
**type:** list of floats

---

##### clst:loc:obj

**description:** clustering object which was used for local contour clustering  
**type:** string

---

##### clst:loc:val

**description:** mean silhouette  
**type:** float

---

### 10.3.4 Validation sub-dictionary

This sub-dictionary is accessed by `copa['val']` and contains validation measures for stylization and clustering.

#### Clustering

##### val:clst:glob:sil\_mean

**description:** mean silhouette of all data points for global contour clustering  
**type:** float

---

##### val:clst:loc:sil\_mean

**description:** mean silhouette of all data points for local contour clustering  
**type:** float

---



## Stylization

**val:styl:glob:err\_prop**

**description:** proportion of base/topline crossings over all global segments

**type:** float

---

**val:styl:loc:rms\_mean**

**description:** mean RMSD between original and stylized local contour

**type:** float

---

## 10.4 F0 files

Three types of F0 tables can be exported:

- preprocessed F0
- residual F0 (after removal of the global register component)
- resynthesized F0 (superposition of global and local stylized component)

As the F0 table input format in each output table the first column gives the time stamps, and the second till last columns contain the F0 values (in Hz) for the recording channels. The tables will be stored below **fsys:export:dir** in sub-directories named after the type of F0 output (*f0-preproc*, *f0-residual*, *f0-resyn*). For each input F0 file an output file with the same name is generated.

## 10.5 Log file

The log file in *fsys:export:dir + fsys:export:stm + log.txt* contains warnings, information about too short segments to be skipped, and some validations below the line '# validation':

styl.glob.err_prop	the percentage of global contour segments where base and topline are crossing
styl.loc.rms_mean	the mean RMSD between original and stylized contour over all local contour segments

The log file is not overwritten, but new logging information is appended. Each session starts with the current time string in ISO 8601 format.

## 11 Plotting

To activate plotting, set

```
navigate:do_plot=1
```

**Browsing** Browsing through stylizations can be carried out online (in order to check for appropriate stylization parameter settings) or after feature extraction, which is controlled by

```
plot:browse:time
```

To select the stylization to be plotted the corresponding branches in

```
plot:browse:typ:*:*
```

need to be set to 1. E.g. `plot:browse:typ:complex:superpos=1` produces plots as in Figure 5.

**Grouping** One can also plot stylizations based on parameter centroids for a specified grouping. By

```
plot:grp:typ:*=1
```

the user selects the stylization to be plotted. The grouping is defined by

```
plot:grp:grouping
```

The entries in this list can be *lab* for item labels or the grouping factor names specified in **fsys:grp:lab**. Centroids will be plotted for each factor level combination.

Browsing and grouping plots can be saved as .png files by

```
plot:browse:save=1
```

```
plot:grp:save=1
```

The *browse* mode output file names are the concatenation of **fsys:pic:dir** + **fsys:pic:stm** + *final*|*online* + *typ* + *set* + *fileIndex* + *channelIndex* + *tierName* + *itemIndex*. *typ* and *set* refer to the \*-keys in `plot:browse:typ:*:*` set to 1.

The *grouping* mode output file names are concatenated from **fsys:pic:dir** + **fsys:pic:stm** + *factorLevelCombination*. One file is generated for each factor level combination.

## 12 Known bugs

Not yet all missing or wrong configurations will be reported in the log file but might result in some Python error message. Same with unexpected annotations. If you cannot locate the error, you can send the configuration file, the log file, and the error message to: [uwe.reichel@nytud.mta.hu](mailto:uwe.reichel@nytud.mta.hu)

An error message that includes the line `return json.load(h)` results from a wrongly formatted JSON configuration file. The last line of the error message points you to the erroneous line in the JSON file.

## 13 History

### 13.1 Version 0.2.1, December 30th, 2016

**Batch clustering for phrase boundary and pitch accent extraction.** Additionally to clustering of boundary/pitch accent candidates on the file level, clustering is now also supported on the entire dataset level. This is expected to improve the prosodic structure extraction in short files (e.g. backchannel turns in dialog data), that do not contain enough material for clustering. Dataset vs. file-level clustering is selected by the configuration branches:

```
augment:glob:unit
augment:loc:unit
```

See section 6.3 and 6.4 for further details.

**Phone duration feature for phrase boundary and pitch accent extraction.** In case a phone segment tier is available, z-scored vowel length can be used as a feature for phrase boundary and pitch accent detection. The length of the vowel associated with the prosodic event candidate is divided by its mean length derived from the entire dataset. For boundary candidates the associated vowel is the last vowel segment with an onset before the boundary candidate time stamp. For accent candidates the associated vowel interval includes the candidate time stamp. This feature will be beneficial for languages in which phrase boundaries and/or accents are marked by phone segment lengthening. See section 6.3 and 6.4 for details. The related new configuration branches are:

```
augment:glob:wgt:pho: add vowel length to boundary feature set
augment:loc:wgt:pho: add vowel length to accent feature set
fsys:pho:tier: name(s) of phone segment tier(s)
fsys:pho:vow: vowel pattern
```

### 13.2 Version 0.3.1, January 31st, 2017

**Synchronize locations where to extract *loc*, *loc\_ext*, *gnl\_f0|en*, and *rhy\_f0|en* feature sets** Due to the strict hierarchy principle and to window length constraints it is not always possible to extract *loc* features at any location where *gnl* and *rhy* features can be obtained. If the user is interested only in locations where all these feature sets are available, so that the corresponding feature matrices can be concatenated, then the option

```
preproc:loc_sync
```

is to be set to 1.

**Transforming events to segments separately for each feature set** Next to the global window length setting in

```
opt:preproc:point_win
opt:preproc:nrm_win
```

window lengths can be set individually for each of the feature sets *loc(-ext)*, *gnl\_f0*, *gnl\_en*, *rhy\_f0*, *rhy\_en* by specifying:

```
preproc:myFeatureSet:point_win
preproc:myFeatureSet:nrm_win
```

**New design of *rhy\_f0* and *rhy\_en* output tables** All *myAnalysisTier\_myRateTier\_myParameter* column names are renamed to *myRateTier\_myParameter*. The analysis tier name can be read from the *tier* column. By this the analysis tier can be used as a grouping factor. Analysis/rate tier combinations across recording channels are not considered. Thus, cells in *myRateTier\_myParameter* columns are set to *NA* if *myRateTier* and the analysis tier of the respective row are not derived from the same channel.

**New fullpath switch for R code files** If set to 0, only the file stem is outputted. For 1, the full path is written.

`fsys:export:fullpath`

### 13.3 Version 0.4.1, May 23rd, 2017

**New global segment register features**

- `{bl,ml,tl,rng}_rate`: base-/mid-/topline/range rate (ST or Hz per sec)

**New local segment register features (extended feature set)**

- `{bl,ml,tl,rng}_{c0,c1,rate}`: base-/mid-/topline/range intercept, slope, and rate (ST or Hz per sec)

**New option for rhythm analyses of energy contours**

- `styl:rhy_en:sig:scale` – if set to 1, the signal is scaled to its maximum amplitude. This is suggested especially if signals of different recording conditions are to be compared.

### 13.4 Version 0.4.2, July 18th, 2017

**New options for selected segment plotting and index printing**

- `plot:browse:single_plot:active`
- `plot:browse:single_plot:file_i`
- `plot:browse:single_plot:channel_i`
- `plot:browse:single_plot:segment_i`
- `plot:browse:verbose`
- `plot:color`

### 13.5 Version 0.4.3, September 5th, 2017

**Time stamps added to boundary feature output** Columns `t_off` and `t_on` added to boundary features output. `t_off` gives the end time of the pre-boundary segment, `t_on` the start time of the post-boundary segment.

### 13.6 Version 0.5.1, October 12th, 2017

**Summary table output** Output of a csv summary file, that contains mean and variance values for each feature per file and channel.

`fsys:export:summary`

### 13.7 Version 0.6.1, November 20th, 2017

**F0 reference value by any grouping variable** So far the F0 reference value for semitone conversion was calculated separately for each file and each channel. Now it can be calculated for each level of a grouping variable (most relevant: speaker ID) which can be read from the file name as to be specified in `fsys:grp`.

`preproc:base_prct_grp`

### 13.8 Version 0.6.2, November 23rd, 2017

**New features for sets *glob* and *loc*** Mean values for base-, mid-, topline, and range (`bl_m`, `ml_m`, `tl_m`, `rng_m`).

### 13.9 Version 0.6.3, December 11th, 2017

**New features for sets *rhy\_en* and *rhy\_f0*** Number of peaks in absolute DCT spectrum (`n_peak`), corresponding frequency for coefficient with amplitude maximum (`f_max`), and frequency difference for each selected prosodic event rate to `f_max` (`dgm`) and to the nearest peak (`dln`).

### 13.10 Version 0.7.1, January 10th, 2018

**New features for sets *gnl\_en* and *gnl\_f0*** F0 and energy quotients: `mean(initPart)/mean(nonInit)` (`qi`), `mean(finalPart)/mean(nonFinal)` (`qf`), `mean(initialPart)/mean(finalPart)` (`qb`), `mean(maxPart)/mean(nonMax)` (`qm`). 2nd order polynomial fit through contour (`c0`, `c1`, `c2`). Option: `styl:gnl:win` to determine length of initial and final part (in seconds).

## References

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- [4] BOERSMA, P. and D. WEENINK: *PRAAT, a system for doing phonetics by computer*. Techn. Rep., Institute of Phonetic Sciences of the University of Amsterdam, 1999. 132–182.
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