vallenae

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LIBRARY DOCUMENTATION

Extract and analyze Acoustic Emission measurement data.

The IO module `vallenae.io` enables reading (and writing) of Vallen Systeme SQLite database files:

- ***.pridb**: Primary database
- ***.tradb**: Transient data
- ***.trfdb**: Transient features

The remaining modules are system-independent and try to comprise the most common state-of-the-art algorithms in Acoustic Emission:

- `vallenae.features`: Extraction of Acoustic Emission features
- `vallenae.timepicker`: Timepicking algorithms for arrival time estimations

CHAPTER

ONE

IO

Read/write Vallen Systeme database and setup files.

1.1 Database classes

Classes to read/write pridb, tradb and trfdb database files.

Warning: Writing is still experimental

`PriDatabase`(filename[, mode])	IO Wrapper for pridb database file.
`TraDatabase`(filename[, mode, compression])	IO Wrapper for tradb database file.
`TrfDatabase`(filename[, mode])	IO Wrapper for trfdb (transient feature) database file.

1.1.1 vallenae.io.PriDatabase

class `vallenae.io.`**`PriDatabase`**(*filename*, *mode='ro'*)

IO Wrapper for pridb database file.

Attributes

`connected`	Check if connected to SQLite database.
`filename`	Filename of database.

vallenae.io.PriDatabase.connected

property `PriDatabase.`**`connected`**

Check if connected to SQLite database.

Return type `bool`

vallenae.io.PriDatabase.filename

property `PriDatabase.`**`filename`**

Filename of database.

Return type str

Methods

__init__(filename[, mode])	Open pridb database file.
channel()	Get list of channels.
close()	Close database connection.
columns()	Columns of data table.
connection()	Get SQLite connection object.
create(filename)	Create empty pridb.
fieldinfo()	Read fieldinfo table.
globalinfo()	Read globalinfo table.
iread_hits(*[, channel, time_start, . . .])	Stream hits with returned iterable.
iread_markers(*[, time_start, time_stop, . . .])	Stream markers with returned iterable.
iread_parametric(*[, time_start, time_stop, . . .])	Stream parametric data with returned iterable.
iread_status(*[, channel, time_start, . . .])	Stream status data with returned iterable.
read(**kwargs)	Read all data set types (hits, markers, parametric data, status data) from pridb to Pandas DataFrame.
read_hits(**kwargs)	Read hits to Pandas DataFrame.
read_markers(**kwargs)	Read marker to Pandas DataFrame.
read_parametric(**kwargs)	Read parametric data to Pandas DataFrame.
read_status(**kwargs)	Read status data to Pandas DataFrame.
rows()	Number of rows in data table.
tables()	Get table names.
write_fieldinfo(field, info)	Write to fieldinfo table.
write_hit(hit)	Write hit to pridb.
write_marker(marker)	Write marker to pridb.
write_parametric(parametric)	Write parametric data to pridb.
write_status(status)	Write status data to pridb.

vallenae.io.PriDatabase.__init__

PriDatabase.**__init__**(*filename*, *mode='ro'*)

Open pridb database file.

Parameters

- **filename** (str) – Path to pridb database file
- **mode** (str) – Define database access: **"ro"** (read-only), **"rw"** (read-write), **"rwc"** (read-write and create empty database if it does not exist)

vallenae.io.PriDatabase.channel

PriDatabase.**channel**()

Get list of channels.

Return type Set[int]

vallenae.io.PriDatabase.close

`PriDatabase.close()`

Close database connection.

vallenae.io.PriDatabase.columns

`PriDatabase.columns()`

Columns of data table.

Return type `Tuple`[`str`, ...]

vallenae.io.PriDatabase.connection

`PriDatabase.connection()`

Get SQLite connection object.

Raises `RuntimeError` – If connection is closed

Return type `Connection`

vallenae.io.PriDatabase.create

`static PriDatabase.create(`*filename*`)`

Create empty pridb.

Parameters `filename` (`str`) – Path to new pridb database file

vallenae.io.PriDatabase.fieldinfo

`PriDatabase.fieldinfo()`

Read fieldinfo table.

The fieldinfo table stores informations about columns of the data table (like units).

Return type `Dict`[`str`, `Dict`[`str`, `Any`]]

Returns Dict of column names and informations (again a dict)

vallenae.io.PriDatabase.globalinfo

`PriDatabase.globalinfo()`

Read globalinfo table.

Return type `Dict`[`str`, `Any`]

vallenae.io.PriDatabase.iread_hits

`PriDatabase.iread_hits(`*, *channel=None*, *time_start=None*, *time_stop=None*, *set_id=None*, *query_filter=None*`)`

Stream hits with returned iterable.

Parameters

- **channel** (Union[None, int, Sequence[int]]) – None if all channels should be read. Otherwise specify the channel number or a list of channel numbers
- **time_start** (Optional[float]) – Start reading at relative time (in seconds). Start at beginning if *None*
- **time_stop** (Optional[float]) – Stop reading at relative time (in seconds). Read until end if *None*
- **set_id** (Union[None, int, Sequence[int]]) – Read by SetID
- **query_filter** (Optional[str]) – Optional query filter provided as SQL clause, e.g. "Amp > 5000 AND RiseT < 1000"

Return type SizedIterable[HitRecord]

Returns Sized iterable to sequential read hits

vallenae.io.PriDatabase.iread_markers

PriDatabase.**iread_markers**(*, *time_start=None*, *time_stop=None*, *set_id=None*, *query_filter=None*)

Stream markers with returned iterable.

Parameters

- **time_start** (Optional[float]) – Start reading at relative time (in seconds). Start at beginning if *None*
- **time_stop** (Optional[float]) – Stop reading at relative time (in seconds). Read until end if *None*
- **set_id** (Union[None, int, Sequence[int]]) – Read by SetID
- **query_filter** (Optional[str]) – Optional query filter provided as SQL clause, e.g. "Number > 11 AND Data LIKE '%TimeZone%'"

Return type SizedIterable[MarkerRecord]

Returns Sized iterable to sequential read markers

vallenae.io.PriDatabase.iread_parametric

PriDatabase.**iread_parametric**(*, *time_start=None*, *time_stop=None*, *set_id=None*, *query_filter=None*)

Stream parametric data with returned iterable.

Parameters

- **time_start** (Optional[float]) – Start reading at relative time (in seconds). Start at beginning if *None*
- **time_stop** (Optional[float]) – Stop reading at relative time (in seconds). Read until end if *None*
- **set_id** (Union[None, int, Sequence[int]]) – Read by SetID
- **query_filter** (Optional[str]) – Optional query filter provided as SQL clause, e.g. "PA0 >= -5000 AND PA0 < 5000"

Return type SizedIterable[ParametricRecord]

Returns Sized iterable to sequential read parametric data

vallenae.io.PriDatabase.iread_status

`PriDatabase.iread_status(*, channel=None, time_start=None, time_stop=None, set_id=None, query_filter=None)`

Stream status data with returned iterable.

Parameters

- **channel** (Union[None, int, Sequence[int]]) – None if all channels should be read. Otherwise specify the channel number or a list of channel numbers
- **time_start** (Optional[float]) – Start reading at relative time (in seconds). Start at beginning if *None*
- **time_stop** (Optional[float]) – Stop reading at relative time (in seconds). Read until end if *None*
- **set_id** (Union[None, int, Sequence[int]]) – Read by SetID
- **query_filter** (Optional[str]) – Optional query filter provided as SQL clause, e.g. "RMS < 300 OR RMS > 500"

Return type `SizedIterable[StatusRecord]`

Returns Sized iterable to sequential read status data

vallenae.io.PriDatabase.read

`PriDatabase.read(**kwargs)`

Read all data set types (hits, markers, parametric data, status data) from pridb to Pandas DataFrame.

Parameters ****kwargs** – Arguments passed to *iread_hits*, *iread_markers*, *iread_parametric* and *iread_status*

Return type `DataFrame`

Returns Pandas DataFrame with all pridb data set types

vallenae.io.PriDatabase.read_hits

`PriDatabase.read_hits(**kwargs)`

Read hits to Pandas DataFrame.

Parameters ****kwargs** – Arguments passed to *iread_hits*

Return type `DataFrame`

Returns Pandas DataFrame with hit data

vallenae.io.PriDatabase.read_markers

`PriDatabase.read_markers(**kwargs)`

Read marker to Pandas DataFrame.

Parameters ****kwargs** – Arguments passed to *iread_markers*

Return type `DataFrame`

Returns Pandas DataFrame with marker data

vallenae.io.PriDatabase.read_parametric

`PriDatabase.read_parametric(**kwargs)`

Read parametric data to Pandas DataFrame.

Parameters `**kwargs` – Arguments passed to *iread_parametric*

Return type `DataFrame`

Returns Pandas DataFrame with parametric data

vallenae.io.PriDatabase.read_status

`PriDatabase.read_status(**kwargs)`

Read status data to Pandas DataFrame.

Parameters `**kwargs` – Arguments passed to *iread_status*

Return type `DataFrame`

Returns Pandas DataFrame with status data

vallenae.io.PriDatabase.rows

`PriDatabase.rows()`

Number of rows in data table.

Return type `int`

vallenae.io.PriDatabase.tables

`PriDatabase.tables()`

Get table names.

Return type `Set[str]`

vallenae.io.PriDatabase.write_fieldinfo

`PriDatabase.write_fieldinfo(field, info)`

Write to fieldinfo table.

Parameters

- **field** (`str`) – Column name of data table
- **info** (`Dict[str, Any]`) – Dict of properties and values, e.g. {“Unit”: “[Hz]”}

Raises `ValueError` – If field is not a column of data table

vallenae.io.PriDatabase.write_hit

`PriDatabase.write_hit(hit)`

Write hit to pridb.

Caution: *HitRecord.set_id* is ignored and automatically incremented.

Parameters **hit** (`HitRecord`) – Hit data set

Returns Index (SetID) of inserted row

Todo: Status flag

vallenae.io.PriDatabase.write_marker

`PriDatabase.write_marker(marker)`

Write marker to pridb.

Caution: `MarkerRecord.set_id` is ignored and automatically incremented.

Parameters **marker** (`MarkerRecord`) – Marker data set

Returns Index (SetID) of inserted row

vallenae.io.PriDatabase.write_parametric

`PriDatabase.write_parametric(parametric)`

Write parametric data to pridb.

Caution: `ParametricRecord.set_id` is ignored and automatically incremented.

Parameters **parametric** (`ParametricRecord`) – Parametric data set

Returns Index (SetID) of inserted row

Todo: Status flag

vallenae.io.PriDatabase.write_status

`PriDatabase.write_status(status)`

Write status data to pridb.

Caution: `StatusRecord.set_id` is ignored and automatically incremented.

Parameters **status** (`StatusRecord`) – Status data set

Returns Index (SetID) of inserted row

Todo: Status flag

1.1.2 vallenae.io.TraDatabase

class `vallenae.io.TraDatabase(filename, mode='ro', *, compression=False)`

IO Wrapper for tradb database file.

Attributes

connected	Check if connected to SQLite database.
filename	Filename of database.

vallenae.io.TraDatabase.connected

property TraDatabase.**connected**
Check if connected to SQLite database.

Return type bool

vallenae.io.TraDatabase.filename

property TraDatabase.**filename**
Filename of database.

Return type str

Methods

__init__(filename[, mode, compression])	Open tradb database file.
channel()	Get list of channels.
close()	Close database connection.
columns()	Columns of data table.
connection()	Get SQLite connection object.
create(filename)	Create empty tradb.
fieldinfo()	Read fieldinfo table.
globalinfo()	Read globalinfo table.
iread(*[, channel, time_start, time_stop, ...])	Stream transient data with returned Iterable.
read(**kwargs)	Read transient data to Pandas DataFrame.
read_continuous_wave(channel[, time_start, ...])	Read transient signal of specified channel to a single, continuous array.
read_wave(trai[, time_axis])	Read transient signal for a given TRAI (transient recorder index).
rows()	Number of rows in data table.
tables()	Get table names.
write(tra)	Write transient data to pridb.
write_fieldinfo(field, info)	Write to fieldinfo table.

vallenae.io.TraDatabase.__init__

TraDatabase.**__init__**(*filename*, *mode='ro'*, *, *compression=False*)
Open tradb database file.

Parameters

- **filename** (str) – Path to tradb database file
- **mode** (str) – Define database access: **"ro"** (read-only), **"rw"** (read-write), **"rwc"** (read-write and create empty database if it does not exist)
- **compression** (bool) – Enable/disable FLAC compression data BLOBs for writing

vallenae.io.TraDatabase.channel

`TraDatabase.channel()`

Get list of channels.

Return type Set[int]

vallenae.io.TraDatabase.close

`TraDatabase.close()`

Close database connection.

vallenae.io.TraDatabase.columns

`TraDatabase.columns()`

Columns of data table.

Return type Tuple[str, ...]

vallenae.io.TraDatabase.connection

`TraDatabase.connection()`

Get SQLite connection object.

Raises RuntimeError – If connection is closed

Return type Connection

vallenae.io.TraDatabase.create

`static TraDatabase.create(filename)`

Create empty tradb.

Parameters **filename** (str) – Path to new tradb database file

vallenae.io.TraDatabase.fieldinfo

`TraDatabase.fieldinfo()`

Read fieldinfo table.

The fieldinfo table stores informations about columns of the data table (like units).

Return type Dict[str, Dict[str, Any]]

Returns Dict of column names and informations (again a dict)

vallenae.io.TraDatabase.globalinfo

`TraDatabase.globalinfo()`

Read globalinfo table.

Return type Dict[str, Any]

vallenae.io.TraDatabase.iread

`TraDatabase.iread(*, channel=None, time_start=None, time_stop=None, trai=None, query_filter=None)`

Stream transient data with returned Iterable.

Parameters

- **channel** (Union[None, int, Sequence[int]]) – None if all channels should be read. Otherwise specify the channel number or a list of channel numbers
- **time_start** (Optional[float]) – Start reading at relative time (in seconds). Start at beginning if *None*
- **time_stop** (Optional[float]) – Stop reading at relative time (in seconds). Read until end if *None*
- **trai** (Union[None, int, Sequence[int]]) – Read data by TRAI (transient recorder index)
- **query_filter** (Optional[str]) – Optional query filter provided as SQL clause, e.g. "Pretrigger == 500 AND Samples >= 1024"

Return type SizedIterable[TraRecord]

Returns Sized iterable to sequential read transient data

vallenae.io.TraDatabase.read

`TraDatabase.read(**kwargs)`

Read transient data to Pandas DataFrame.

Parameters ****kwargs** – Arguments passed to *iread*

Return type DataFrame

Returns Pandas DataFrame with transient data

vallenae.io.TraDatabase.read_continuous_wave

`TraDatabase.read_continuous_wave(channel, time_start=None, time_stop=None, *, time_axis=True, show_progress=True)`

Read transient signal of specified channel to a single, continuous array.

Time gaps are filled with 0's.

Parameters

- **channel** (int) – Channel number to read
- **time_start** (Optional[float]) – Start reading at relative time (in seconds). Start at beginning if *None*
- **time_stop** (Optional[float]) – Stop reading at relative time (in seconds). Read until end if *None*
- **time_axis** (bool) – Create the correspondig time axis. Default: *True*
- **show_progress** (bool) – Show progress bar. Default: *True*

Return type Union[Tuple[ndarray, ndarray], Tuple[ndarray, int]]

Returns

If *time_axis* is *True*

- Array with transient signal
- Time axis

If *time_axis* is *False*

- Array with transient signal
- Samplerate

vallenae.io.TraDatabase.read_wave

`TraDatabase.`**`read_wave`**`(`*trai*, *time_axis=True*`)`

Read transient signal for a given TRAI (transient recorder index).

This method is useful in combination with *`PriDatabase.read_hits`*, that will store the TRAI in a DataFrame.

Parameters

- **`trai`** (`int`) – Transient recorder index (unique key between pridb and tradb)
- **`time_axis`** (`bool`) – Create the correspondig time axis. Default: *True*

Return type `Union`[`Tuple`[`ndarray`, `ndarray`], `Tuple`[`ndarray`, `int`]]

Returns

If `time_axis` is *True*

- Array with transient signal
- Time axis

If `time_axis` is *False*

- Array with transient signal
- Samplerate

vallenae.io.TraDatabase.rows

`TraDatabase.`**`rows`**`()`

Number of rows in data table.

Return type `int`

vallenae.io.TraDatabase.tables

`TraDatabase.`**`tables`**`()`

Get table names.

Return type `Set`[`str`]

vallenae.io.TraDatabase.write

TraDatabase.**write**(*tra*)
Write transient data to pridb.

Parameters **tra** (TraRecord) – Transient data set

Return type int

Returns Index (SetID) of inserted row

Todo: Status flag

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vallenae.io.TraDatabase.write_fieldinfo

TraDatabase.**write_fieldinfo**(*field*, *info*)
Write to fieldinfo table.

Parameters

- **field** (str) – Column name of data table
- **info** (Dict[str, Any]) – Dict of properties and values, e.g. {"Unit": "[Hz]"}

Raises **ValueError** – If field is not a column of data table

1.1.3 vallenae.io.TrfDatabase

class vallenae.io.**TrfDatabase**(*filename*, *mode='ro'*)
IO Wrapper for trfdb (transient feature) database file.

Attributes

connected	Check if connected to SQLite database.
filename	Filename of database.

vallenae.io.TrfDatabase.connected

property TrfDatabase.**connected**
Check if connected to SQLite database.

Return type bool

vallenae.io.TrfDatabase.filename

property TrfDatabase.**filename**
Filename of database.

Return type str

Methods

`__init__`(filename[, mode])	Open trfdb database file.
`close`()	Close database connection.
`columns`()	Columns of data table.
`connection`()	Get SQLite connection object.
`create`(filename)	Create empty trfdb.
`fieldinfo`()	Read fieldinfo table.
`globalinfo`()	Read globalinfo table.
`iread`(*[, trai])	Stream features with returned iterable.
`read`(*[, trai])	Read features to Pandas DataFrame.
`rows`()	Number of rows in data table.
`tables`()	Get table names.
`write`(feature_set)	Write feature record to trfdb.
`write_fieldinfo`(field, info)	Write to fieldinfo table.

vallenae.io.TrfDatabase.__init__

`TrfDatabase.__init__`(*filename*, *mode='ro'*)

Open trfdb database file.

Parameters

- **`filename`** (`str`) – Path to trfdb database file
- **`mode`** (`str`) – Define database access: **"ro"** (read-only), **"rw"** (read-write), **"rwc"** (read-write and create empty database if it does not exist)

vallenae.io.TrfDatabase.close

`TrfDatabase.close`()

Close database connection.

vallenae.io.TrfDatabase.columns

`TrfDatabase.columns`()

Columns of data table.

Return type `Tuple`[`str`, ...]

vallenae.io.TrfDatabase.connection

`TrfDatabase.connection`()

Get SQLite connection object.

Raises **`RuntimeError`** – If connection is closed

Return type `Connection`

vallenae.io.TrfDatabase.create

static `TrfDatabase.create`(*filename*)

Create empty trfdb.

Parameters **filename** (str) – Path to new trfdb database file

vallenae.io.TrfDatabase.fieldinfo

`TrfDatabase.fieldinfo()`

Read fieldinfo table.

The fieldinfo table stores informations about columns of the data table (like units).

Return type Dict[str, Dict[str, Any]]

Returns Dict of column names and informations (again a dict)

vallenae.io.TrfDatabase.globalinfo

`TrfDatabase.globalinfo()`

Read globalinfo table.

Return type Dict[str, Any]

vallenae.io.TrfDatabase.iread

`TrfDatabase.iread(*, trai=None)`

Stream features with returned iterable.

Parameters **trai** (Union[None, int, Sequence[int]]) – Read data by TRAI (transient recorder index)

Return type SizedIterable[FeatureRecord]

Returns Sized iterable to sequential read features

vallenae.io.TrfDatabase.read

`TrfDatabase.read(*, trai=None)`

Read features to Pandas DataFrame.

Parameters **trai** (Union[None, int, Sequence[int]]) – Read data by TRAI (transient recorder index)

Return type DataFrame

Returns Pandas DataFrame with features

vallenae.io.TrfDatabase.rows

`TrfDatabase.rows()`

Number of rows in data table.

Return type int

vallenae.io.TrfDatabase.tables

`TrfDatabase.tables()`

Get table names.

Return type Set[str]

vallenae.io.TrfDatabase.write

`TrfDatabase.write(feature_set)`

Write feature record to trfdb.

Parameters **feature_set** (FeatureRecord) – Feature set

Return type int

Returns Index (trai) of inserted row

vallenae.io.TrfDatabase.write_fieldinfo

`TrfDatabase.write_fieldinfo(field, info)`

Write to fieldinfo table.

Parameters

- **field** (str) – Column name of data table
- **info** (Dict[str, Any]) – Dict of properties and values, e.g. {“Unit”: “[Hz]”}

Raises **ValueError** – If field is not a column of data table

All database classes implement two different interfaces to access data:

Standard `read_*`

Read data to `pandas.DataFrame`, e.g. with *PriDatabase.read_hits*

```
>>> pridb = vae.io.PriDatabase("./examples/steel_plate/sample.pridb")
>>> df = pridb.read_hits()  # save all hits to pandas dataframe
>>> df[["time", "channel"]]  # output columns hit and channel
            time  channel
set_id
10      3.992771        3
11      3.992775        2
12      3.992813        4
13      3.992814        1
```

Streaming `iread_*`

Iterate through the data row by row. This is a memory-efficient solution ideal for batch processing. The return types are specific `typing.NamedTuple`, see *Data types*.

Example with *PriDatabase.iread_hits*:

```
>>> pridb = vae.io.PriDatabase("./examples/steel_plate/sample.pridb")
>>> for hit in pridb.iread_hits():
...     print(f"time: {hit.time:0.4f}, channel: {hit.channel}")
...
time: 3.9928,   channel: 3
time: 3.9928,   channel: 2
```

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```
time: 3.9928,   channel: 4
time: 3.9928,   channel: 1
>>> type(hit)
<class 'vallenae.io.datatypes.HitRecord'>
```

1.2 Data types

Records of the database are represented as `typing.NamedTuple`. Each record implements a class method `from_sql` to init from a SQLite row dictionary (column name: value).

HitRecord	Hit record in pridb (SetType = 2).
MarkerRecord	Marker record in pridb (SetType = 4, 5, 6).
StatusRecord	Status data record in pridb (SetType = 3).
ParametricRecord	Parametric data record in pridb (SetType = 1).
TraRecord	Transient data record in tradb.
FeatureRecord	Transient feature record in trfdb.

1.2.1 vallenae.io.HitRecord

class vallenae.io.**HitRecord**

Hit record in pridb (SetType = 2).

Attributes

amplitude	Peak amplitude in volts
cascade_counts	Summed counts of hits in the same hit-cascade
cascade_energy	Summed energy of hits in the same hit-cascade
cascade_hits	Total number of hits in the same hit-cascade
cascade_signal_strength	disable=line-too-long
channel	Channel number
counts	Number of positive threshold crossings
duration	Hit duration in seconds
energy	Energy (EN 1330-9) in eu (1e-14 V^2s)
param_id	Parameter ID of table ae_params for ADC value conversion
rise_time	Rise time in seconds
rms	RMS of the noise before the hit in volts
set_id	Unique identifier for data set in pridb
signal_strength	Signal strength in nVs (1e-9 Vs)
threshold	Threshold amplitude in volts
time	Time in seconds
trai	Transient recorder index (foreign key between pridb and tradb)

vallenae.io.HitRecord.amplitude

property HitRecord.**amplitude**
Peak amplitude in volts

vallenae.io.HitRecord.cascade_counts

property HitRecord.**cascade_counts**
Summed counts of hits in the same hit-cascade

vallenae.io.HitRecord.cascade_energy

property HitRecord.**cascade_energy**
Summed energy of hits in the same hit-cascade

vallenae.io.HitRecord.cascade_hits

property HitRecord.**cascade_hits**
Total number of hits in the same hit-cascade

vallenae.io.HitRecord.cascade_signal_strength

property HitRecord.**cascade_signal_strength**
disable=line-too-long

Type Summed signal strength of hits in the same hit-cascade # noqa # pylint

vallenae.io.HitRecord.channel

property HitRecord.**channel**
Channel number

vallenae.io.HitRecord.counts

property HitRecord.**counts**
Number of positive threshold crossings

vallenae.io.HitRecord.duration

property HitRecord.**duration**
Hit duration in seconds

vallenae.io.HitRecord.energy

property HitRecord.**energy**
Energy (EN 1330-9) in eu (1e-14 V^2s)

vallenae.io.HitRecord.param_id

property HitRecord.**param_id**
Parameter ID of table ae_params for ADC value conversion

vallenae.io.HitRecord.rise_time

property HitRecord.**rise_time**
Rise time in seconds

vallenae.io.HitRecord.rms

property HitRecord.**rms**
RMS of the noise before the hit in volts

vallenae.io.HitRecord.set_id

property HitRecord.**set_id**
Unique identifier for data set in pridb

vallenae.io.HitRecord.signal_strength

property HitRecord.**signal_strength**
Signal strength in nVs (1e-9 Vs)

vallenae.io.HitRecord.threshold

property HitRecord.**threshold**
Threshold amplitude in volts

vallenae.io.HitRecord.time

property HitRecord.**time**
Time in seconds

vallenae.io.HitRecord.trai

property HitRecord.**trai**
Transient recorder index (foreign key between pridb and tradb)

Methods

`__init__`	Initialize self.
`count`	Return number of occurrences of value.
`from_sql`(row)	Create HitRecord from SQL row.
`index`	Return first index of value.

vallenae.io.HitRecord.__init__

HitRecord.**__init__**()

Initialize self. See help(type(self)) for accurate signature.

vallenae.io.HitRecord.count

HitRecord.**count**()

Return number of occurrences of value.

vallenae.io.HitRecord.from_sql

classmethod HitRecord.**from_sql**(*row*)

Create HitRecord from SQL row.

Parameters **row** (Dict[str, Any]) – Dict of column names and values

Return type HitRecord

vallenae.io.HitRecord.index

HitRecord.**index**()

Return first index of value.

Raises ValueError if the value is not present.

1.2.2 vallenae.io.MarkerRecord

class vallenae.io.**MarkerRecord**

Marker record in pridb (SetType = 4, 5, 6).

A marker can have different meanings depending on its SetType:

- 4: label
- 5: datetime data set, as it is inserted whenever recording is started by software
- 6: a section start marker. E.g. new sections are started, if acquisition settings changed

Attributes

data	Content of marker (label text or datetime)
number	Marker number
set_id	Unique identifier for data set in pridb
set_type	Marker type (see above)
time	Time in seconds

vallenae.io.MarkerRecord.data

property MarkerRecord.**data**

Content of marker (label text or datetime)

vallenae.io.MarkerRecord.number

property MarkerRecord.**number**

Marker number

vallenae.io.MarkerRecord.set_id

property MarkerRecord.**set_id**

Unique identifier for data set in pridb

vallenae.io.MarkerRecord.set_type

property MarkerRecord.**set_type**

Marker type (see above)

vallenae.io.MarkerRecord.time

property MarkerRecord.**time**

Time in seconds

Methods

__init__	Initialize self.
count	Return number of occurrences of value.
from_sql(row)	Create MarkerRecord from SQL row.
index	Return first index of value.

vallenae.io.MarkerRecord.__init__

MarkerRecord.**__init__**()

Initialize self. See help(type(self)) for accurate signature.

vallenae.io.MarkerRecord.count

MarkerRecord.**count**()

Return number of occurrences of value.

vallenae.io.MarkerRecord.from_sql

classmethod MarkerRecord.**from_sql**(*row*)

Create MarkerRecord from SQL row.

Parameters **row** (Dict[str, Any]) – Dict of column names and values

Return type MarkerRecord

vallenae.io.MarkerRecord.index

`MarkerRecord.index()`

Return first index of value.

Raises ValueError if the value is not present.

1.2.3 vallenae.io.StatusRecord

`class vallenae.io.StatusRecord`

Status data record in pridb (SetType = 3).

Attributes

channel	Channel number
energy	Energy (EN 1330-9) in eu (1e-14 V^2s)
param_id	Parameter ID of table ae_params for ADC value conversion
rms	RMS in volts
set_id	Unique identifier for data set in pridb
signal_strength	Signal strength in nVs (1e-9 Vs)
threshold	Threshold amplitude in volts
time	Time in seconds

vallenae.io.StatusRecord.channel

`property StatusRecord.channel`

Channel number

vallenae.io.StatusRecord.energy

`property StatusRecord.energy`

Energy (EN 1330-9) in eu (1e-14 V^2s)

vallenae.io.StatusRecord.param_id

`property StatusRecord.param_id`

Parameter ID of table ae_params for ADC value conversion

vallenae.io.StatusRecord.rms

`property StatusRecord.rms`

RMS in volts

vallenae.io.StatusRecord.set_id

`property StatusRecord.set_id`

Unique identifier for data set in pridb

vallenae.io.StatusRecord.signal_strength

property StatusRecord.**signal_strength**
Signal strength in nVs (1e-9 Vs)

vallenae.io.StatusRecord.threshold

property StatusRecord.**threshold**
Threshold amplitude in volts

vallenae.io.StatusRecord.time

property StatusRecord.**time**
Time in seconds

Methods

__init__	Initialize self.
count	Return number of occurrences of value.
from_sql(row)	Create StatusRecord from SQL row.
index	Return first index of value.

vallenae.io.StatusRecord.__init__

StatusRecord.**__init__**()
Initialize self. See help(type(self)) for accurate signature.

vallenae.io.StatusRecord.count

StatusRecord.**count**()
Return number of occurrences of value.

vallenae.io.StatusRecord.from_sql

classmethod StatusRecord.**from_sql**(*row*)
Create StatusRecord from SQL row.

Parameters **row** (Dict[str, Any]) – Dict of column names and values

Return type StatusRecord

vallenae.io.StatusRecord.index

StatusRecord.**index**()
Return first index of value.

Raises ValueError if the value is not present.

1.2.4 vallenae.io.ParametricRecord

class vallenae.io.**ParametricRecord**

Parametric data record in pridb (SetType = 1).

Attributes

pa0	Amplitude of parametric input 0 in volts
pa1	Amplitude of parametric input 1 in volts
pa2	Amplitude of parametric input 2 in volts
pa3	Amplitude of parametric input 3 in volts
pa4	Amplitude of parametric input 4 in volts
pa5	Amplitude of parametric input 5 in volts
pa6	Amplitude of parametric input 6 in volts
pa7	Amplitude of parametric input 7 in volts
param_id	Parameter ID of table ae_params for ADC value conversion
pcta	Analog hysteresis counter
pctd	Digital counter value
set_id	Unique identifier for data set in pridb
time	Time in seconds

vallenae.io.ParametricRecord.pa0

property ParametricRecord.**pa0**

Amplitude of parametric input 0 in volts

vallenae.io.ParametricRecord.pa1

property ParametricRecord.**pa1**

Amplitude of parametric input 1 in volts

vallenae.io.ParametricRecord.pa2

property ParametricRecord.**pa2**

Amplitude of parametric input 2 in volts

vallenae.io.ParametricRecord.pa3

property ParametricRecord.**pa3**

Amplitude of parametric input 3 in volts

vallenae.io.ParametricRecord.pa4

property ParametricRecord.**pa4**

Amplitude of parametric input 4 in volts

vallenae.io.ParametricRecord.pa5

property ParametricRecord.**pa5**
Amplitude of parametric input 5 in volts

vallenae.io.ParametricRecord.pa6

property ParametricRecord.**pa6**
Amplitude of parametric input 6 in volts

vallenae.io.ParametricRecord.pa7

property ParametricRecord.**pa7**
Amplitude of parametric input 7 in volts

vallenae.io.ParametricRecord.param_id

property ParametricRecord.**param_id**
Parameter ID of table ae_params for ADC value conversion

vallenae.io.ParametricRecord.pcta

property ParametricRecord.**pcta**
Analog hysteresis counter

vallenae.io.ParametricRecord.pctd

property ParametricRecord.**pctd**
Digital counter value

vallenae.io.ParametricRecord.set_id

property ParametricRecord.**set_id**
Unique identifier for data set in pridb

vallenae.io.ParametricRecord.time

property ParametricRecord.**time**
Time in seconds

Methods

__init__	Initialize self.
count	Return number of occurrences of value.
from_sql(row)	Create ParametricRecord from SQL row.
index	Return first index of value.

vallenae.io.ParametricRecord.__init__

ParametricRecord.**__init__**()

Initialize self. See help(type(self)) for accurate signature.

vallenae.io.ParametricRecord.count

ParametricRecord.**count**()

Return number of occurrences of value.

vallenae.io.ParametricRecord.from_sql

classmethod ParametricRecord.**from_sql**(*row*)

Create ParametricRecord from SQL row.

Parameters **row** (Dict[str, Any]) – Dict of column names and values

Return type ParametricRecord

vallenae.io.ParametricRecord.index

ParametricRecord.**index**()

Return first index of value.

Raises ValueError if the value is not present.

1.2.5 vallenae.io.TraRecord

class vallenae.io.**TraRecord**

Transient data record in tradb.

Todo: Remove RMS

Attributes

channel	Channel number
data	Transient signal in volts
data_format	Data format (0 = uncompressed, 2 = FLAC compression)
param_id	Parameter ID of table tr_params for ADC value conversion
pretrigger	Pretrigger samples
rms	RMS of the noise before the hit
samplerate	Samplerate in Hz
samples	Number of samples
threshold	Threshold amplitude in volts
time	Time in seconds

Continued on next page

Table 17 – continued from previous page

trai	Transient recorder index (foreign key between pridb and tradb)

vallenae.io.TraRecord.channel

property TraRecord.**channel**
Channel number

vallenae.io.TraRecord.data

property TraRecord.**data**
Transient signal in volts

vallenae.io.TraRecord.data_format

property TraRecord.**data_format**
Data format (0 = uncompressed, 2 = FLAC compression)

vallenae.io.TraRecord.param_id

property TraRecord.**param_id**
Parameter ID of table tr_params for ADC value conversion

vallenae.io.TraRecord.pretrigger

property TraRecord.**pretrigger**
Pretrigger samples

vallenae.io.TraRecord.rms

property TraRecord.**rms**
RMS of the noise before the hit

vallenae.io.TraRecord.samplerate

property TraRecord.**samplerate**
Samplerate in Hz

vallenae.io.TraRecord.samples

property TraRecord.**samples**
Number of samples

vallenae.io.TraRecord.threshold

property TraRecord.**threshold**
Threshold amplitude in volts

vallenae.io.TraRecord.time

property TraRecord.**time**
Time in seconds

vallenae.io.TraRecord.trai

property TraRecord.**trai**
Transient recorder index (foreign key between pridb and tradb)

Methods

__init__	Initialize self.
count	Return number of occurrences of value.
from_sql(row)	**rtype** TraRecord
index	Return first index of value.

vallenae.io.TraRecord.__init__

TraRecord.**__init__**()
Initialize self. See help(type(self)) for accurate signature.

vallenae.io.TraRecord.count

TraRecord.**count**()
Return number of occurrences of value.

vallenae.io.TraRecord.from_sql

classmethod TraRecord.**from_sql**(*row*)

Return type TraRecord

vallenae.io.TraRecord.index

TraRecord.**index**()
Return first index of value.

Raises ValueError if the value is not present.

1.2.6 vallenae.io.FeatureRecord

class vallenae.io.**FeatureRecord**
Transient feature record in trfdb.

Attributes

features	Feature dictionary (feature name -> value)
trai	Transient recorder index

vallenae.io.FeatureRecord.features

property FeatureRecord.**features**
Feature dictionary (feature name -> value)

vallenae.io.FeatureRecord.trai

property FeatureRecord.**trai**
Transient recorder index

Methods

__init__	Initialize self.
count	Return number of occurrences of value.
from_sql(row)	**rtype** FeatureRecord
index	Return first index of value.

vallenae.io.FeatureRecord.__init__

FeatureRecord.**__init__**()
Initialize self. See help(type(self)) for accurate signature.

vallenae.io.FeatureRecord.count

FeatureRecord.**count**()
Return number of occurrences of value.

vallenae.io.FeatureRecord.from_sql

classmethod FeatureRecord.**from_sql**(*row*)

Return type FeatureRecord

vallenae.io.FeatureRecord.index

FeatureRecord.**index**()
Return first index of value.

Raises ValueError if the value is not present.

1.3 Compression

Transient signals in the tradb are stored as BLOBs of 16-bit ADC values – either uncompressed or compressed (FLAC). Following functions convert between BLOBs and arrays of voltage values.

decode_data_blob(data_blob, data_format, ...)	Decodes (compressed) 16-bit ADC values from BLOB to array of voltage values.
encode_data_blob(data, data_format, ...)	Encodes array of voltage values to BLOB of 16-bit ADC values for memory-efficient storage.

1.3.1 vallenae.io.decode_data_blob

vallenae.io.**decode_data_blob**(*data_blob*, *data_format*, *factor_millivolts*)

Decodes (compressed) 16-bit ADC values from BLOB to array of voltage values.

Parameters

- **data_blob** (bytes) – Blob from tradb
- **data_format** (int) –
  - 0: uncompressed
  - 2: FLAC compression
- **factor_millivolts** (float) – Factor from int16 representation to millivolts. Stored in tradb -> tr_params as 'TR_mV'

Return type ndarray

Returns Array of voltage values

1.3.2 vallenae.io.encode_data_blob

vallenae.io.**encode_data_blob**(*data*, *data_format*, *factor_millivolts*)

Encodes array of voltage values to BLOB of 16-bit ADC values for memory-efficient storage.

Parameters

- **data** (ndarray) – Array with voltage values
- **data_format** (int) –
  - 0: uncompressed
  - 2: FLAC compression
- **factor_millivolts** (float) – Factor from int16 representation to millivolts. Stored in tradb -> tr_params as 'TR_mV'

Return type bytes

Returns Data blob

CHAPTER

TWO

FEATURES

2.1 Acoustic Emission

peak_amplitude(data)	Compute maximum absolute amplitude.
peak_amplitude_index(data)	Compute index of peak amplitude.
is_above_threshold(data, threshold)	Checks if absolute amplitudes are above threshold.
first_threshold_crossing(data, threshold)	Compute index of first threshold crossing.
rise_time(data, threshold, samplerate[, . . .])	Compute the rise time.
energy(data, samplerate)	Compute the energy of a hit.
signal_strength(data, samplerate)	Compute the signal strength of a hit.
counts(data, threshold)	Compute the number of positive threshold crossings of a hit (counts).
rms(data)	Compute the root mean square (RMS) of an array.

2.1.1 vallenae.features.peak_amplitude

features.**peak_amplitude**(*data*)

Compute maximum absolute amplitude.

Parameters **data** (ndarray) – Input array

Return type float

Returns Peak amplitude of the input array

2.1.2 vallenae.features.peak_amplitude_index

features.**peak_amplitude_index**(*data*)

Compute index of peak amplitude.

Parameters **data** (ndarray) – Input array

Return type int

Returns Index of peak amplitude

2.1.3 vallenae.features.is_above_threshold

features.**is_above_threshold**(*data*, *threshold*)

Checks if absolute amplitudes are above threshold.

Parameters

- **data** (ndarray) – Input array
- **threshold** (float) – Threshold amplitude

Return type bool

Returns True if input array is above threshold, otherwise False

2.1.4 vallenae.features.first_threshold_crossing

features.**first_threshold_crossing**(*data*, *threshold*)

Compute index of first threshold crossing.

Parameters

- **data** (ndarray) – Input array
- **threshold** (float) – Threshold amplitude

Return type Optional[int]

Returns Index of first threshold crossing. None if threshold was not exceeded

2.1.5 vallenae.features.rise_time

features.**rise_time**(*data*, *threshold*, *samplerate*, *first_crossing=None*, *index_peak=None*)

Compute the rise time.

The rise time is the time between the first threshold crossing and the peak amplitude.

Parameters

- **data** (ndarray) – Input array (hit)
- **threshold** (float) – Threshold amplitude (in volts)
- **samplerate** (int) – Sample rate of the input array
- **first_crossing** (Optional[int]) – Precomputed index of first threshold crossing to save computation time
- **index_peak** (Optional[int]) – Precomputed index of peak amplitude to save computation time

Return type float

2.1.6 vallenae.features.energy

features.**energy**(*data*, *samplerate*)

Compute the energy of a hit.

Energy is the integral of the squared AE-signal over time (EN 1330-9). The unit of energy is eu. 1 eu corresponds to 1e-14 V^2s.

Parameters

- **data** (ndarray) – Input array (hit)
- **samplerate** (int) – Sample rate of input array in Hz

Return type float

Returns Energy of input array (hit)

2.1.7 vallenae.features.signal_strength

features.**signal_strength**(*data*, *samplerate*)

Compute the signal strength of a hit.

Signal strength is the integral of the rectified AE-signal over time. The unit of Signal Strength is nVs (1e-9 Vs).

Parameters

- **data** (ndarray) – Input array (hit)
- **samplerate** (int) – Sample rate of input array in Hz

Return type float

Returns Signal strength of input array (hit)

2.1.8 vallenae.features.counts

features.**counts**(*data*, *threshold*)

Compute the number of positive threshold crossings of a hit (counts).

Parameters

- **data** (ndarray) – Input array
- **threshold** (float) – Threshold amplitude

Return type int

Returns Number of positive threshold crossings

2.1.9 vallenae.features.rms

features.**rms**(*data*)

Compute the root mean square (RMS) of an array.

Parameters **data** (ndarray) – Input array

Return type float

Returns RMS of the input array

References

https://en.wikipedia.org/wiki/Root_mean_square

2.2 Conversion

amplitude_to_db(amplitude[, reference])	Convert amplitude from volts to decibel (dB).
db_to_amplitude(amplitude_db[, reference])	Convert amplitude from decibel (dB) to volts.

2.2.1 vallenae.features.amplitude_to_db

`vallenae.features.amplitude_to_db`(*amplitude*, *reference=1e-06*)

Convert amplitude from volts to decibel (dB).

Parameters

- **amplitude** (`float`) – Amplitude in volts
- **reference** (`float`) – Reference amplitude. Defaults to 1 µV for dB(AE)

Return type `float`

Returns Amplitude in dB(ref)

2.2.2 vallenae.features.db_to_amplitude

`vallenae.features.db_to_amplitude`(*amplitude_db*, *reference=1e-06*)

Convert amplitude from decibel (dB) to volts.

Parameters

- **amplitude_db** (`float`) – Amplitude in dB
- **reference** (`float`) – Reference amplitude. Defaults to 1 µV for dB(AE)

Return type `float`

Returns Amplitude in volts

CHAPTER

THREE

TIMERPICKER

The determination of signal arrival times has a major influence on the localization accuracy. Usually, arrival times are determined by the first threshold crossing (either fixed or adaptive). Following popular methods have been proposed in the past to automatically pick time of arrivals:

hinkley(arr[, alpha])	Hinkley criterion for arrival time estimation.
aic(arr)	Akaike Information Criterion (AIC) for arrival time estimation.
energy_ratio(arr[, win_len])	Energy ratio for arrival time estimation.
modified_energy_ratio(arr[, win_len])	Modified energy ratio method for arrival time estimation.

3.1 vallenae.timepicker.hinkley

timepicker.**hinkley**(*arr*, *alpha=5*)

Hinkley criterion for arrival time estimation.

The Hinkley criterion is defined as the partial energy of the signal (cumulative square sum) with an applied negative trend (characterized by alpha).

The starting value of alpha is reduced iteratively to avoid wrong picks within the pre-trigger part of the signal. Usually alpha values are chosen to be between 2 and 200 to ensure minimal delay. The chosen alpha value for the Hinkley criterion influences the results significantly.

Parameters

- **arr** (ndarray) – Transient signal of hit
- **alpha** (int) – Divisor of the negative trend. Default: 5

Return type Tuple[ndarray, int]

Returns

- Array with computed detection function
- Index of the estimated arrival time (max value)

Todo: Weak performance, if used with default parameter alpha

References

- Molenda, M. (2016). Acoustic Emission monitoring of laboratory hydraulic fracturing experiments. Ruhr-Universität Bochum.
- van Rijn, N. (2017). Investigating the Behaviour of Acoustic Emission Waves Near Cracks: Using the Finite Element Method. Delft University of Technology.

3.2 vallenae.timepicker.aic

`timepicker.`**`aic`**`(`*arr*`)`

Akaike Information Criterion (AIC) for arrival time estimation.

The AIC picker basically models the signal as an autoregressive (AR) process. A typical AE signal can be subdivided into two parts. The first part containing noise and the second part containing noise and the AE signal. Both parts of the signal contain non deterministic parts (noise) describable by a Gaussian distribution.

Parameters **`arr`** (`ndarray`) – Transient signal of hit

Return type `Tuple`[`ndarray`, `int`]

Returns

- Array with computed detection function
- Index of the estimated arrival time (max value)

References

- Molenda, M. (2016). Acoustic Emission monitoring of laboratory hydraulic fracturing experiments. Ruhr-Universität Bochum.
- Bai, F., Gagar, D., Foote, P., & Zhao, Y. (2017). Comparison of alternatives to amplitude thresholding for onset detection of acoustic emission signals. Mechanical Systems and Signal Processing, 84, 717–730.
- van Rijn, N. (2017). Investigating the Behaviour of Acoustic Emission Waves Near Cracks: Using the Finite Element Method. Delft University of Technology.

3.3 vallenae.timepicker.energy_ratio

`timepicker.`**`energy_ratio`**`(`*arr*, *win_len=100*`)`

Energy ratio for arrival time estimation.

Method based on preceding and following energy collection windows.

Parameters

- **`arr`** (`ndarray`) – Transient signal of hit
- **`win_len`** (`int`) – Samples of sliding windows. Default: 100

Return type `Tuple`[`ndarray`, `int`]

Returns

- Array with computed detection function
- Index of the estimated arrival time (max value)

References

- Han, L., Wong, J., & Bancroft, J. C. (2009). Time picking and random noise reduction on microseismic data. CREWES Research Report, 21, 1–13.

3.4 vallenae.timepicker.modified_energy_ratio

timepicker.**modified_energy_ratio**(*arr*, *win_len=100*)

Modified energy ratio method for arrival time estimation.

The modifications improve the ability to detect the onset of a seismic arrival in the presence of random noise.

Parameters

- **arr** (ndarray) – Transient signal of hit
- **win_len** (int) – Samples of sliding windows. Default: 100

Return type Tuple[ndarray, int]

Returns

- Array with computed detection function
- Index of the estimated arrival time (max value)

References

- Han, L., Wong, J., & Bancroft, J. C. (2009). Time picking and random noise reduction on microseismic data. CREWES Research Report, 21, 1–13.

CHAPTER

FOUR

EXAMPLES

A collection of examples how to read and analyse Acoustic Emission data.

4.1 Read pridb

```
import os

import matplotlib.pyplot as plt

import vallenae as vae

HERE = os.path.dirname(__file__) if "__file__" in locals() else os.getcwd()
PRIDB = os.path.join(HERE, "steel_plate/sample.pridb")
```

4.1.1 Open pridb

```
pridb = vae.io.PriDatabase(PRIDB)

print("Tables in database: ", pridb.tables())
print("Number of rows in data table (ae_data): ", pridb.rows())
print("Set of all channels: ", pridb.channel())
```

Out:

```
Tables in database:  {'acq_setup', 'ae_params', 'ae_data', 'ae_markers', 'ae_fieldinfo
↪', 'data_integrity', 'ae_globalinfo'}
Number of rows in data table (ae_data):  18
Set of all channels:  {1, 2, 3, 4}
```

4.1.2 Read hits to Pandas DataFrame

```
df_hits = pridb.read_hits()
# Print a few columns
print(df_hits[["time", "channel", "amplitude", "counts", "energy"]])
```

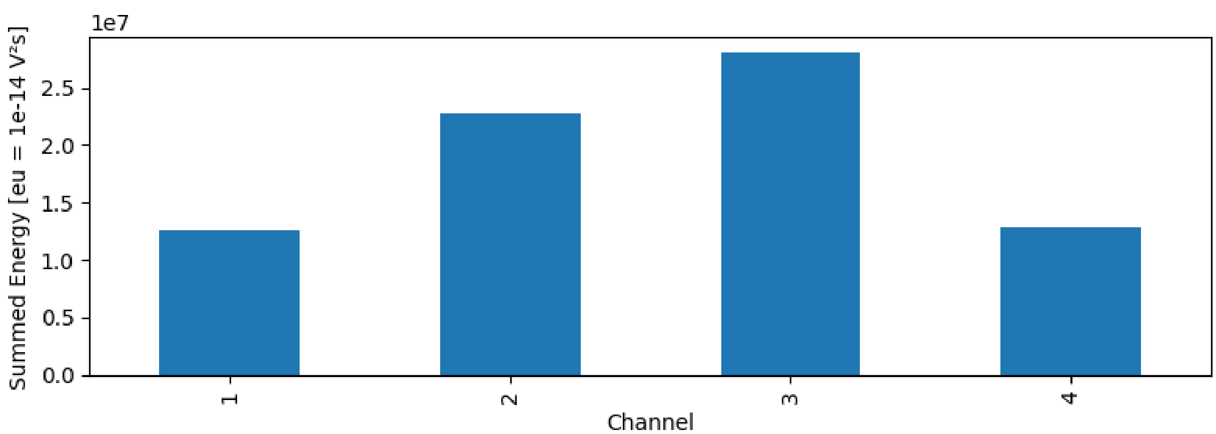
Out:

```
Hits:   0%|          | 0/4 [00:00<?, ?it/s]
Hits: 100%|##########| 4/4 [00:00<00:00, 3746.59it/s]
            time  channel  amplitude  counts        energy
set_id
10      3.992771        3   0.046539    2180  2.799510e+07
11      3.992775        2   0.059621    2047  2.276279e+07
12      3.992813        4   0.034119    1854  1.286700e+07
13      3.992814        1   0.029115    1985  1.265275e+07
```

4.1.3 Query Pandas DataFrame

DataFrames offer powerful features to query and aggregate data, e.g. plot summed energy per channel

```
ax = df_hits.groupby("channel").sum()["energy"].plot.bar(figsize=(8, 3))
ax.set_xlabel("Channel")
ax.set_ylabel("Summed Energy [eu = 1e-14 V²s]")
plt.tight_layout()
plt.show()
```



4.1.4 Read markers

```
df_markers = pridb.read_markers()
print(df_markers)
```

Out:

```
Marker:   0%|          | 0/5 [00:00<?, ?it/s]
Marker: 100%|##########| 5/5 [00:00<00:00, 24966.10it/s]
          time  set_type                                       data  number
set_id
1         0.00         6                                                  1
2         0.00         4                                10:52 Resume      1
3         0.00         5                         2019-09-20 10:54:52   <NA>
4         0.00         4  TimeZone: +02:00 (W. Europe Standard Time)      2
18      100.07         4                               10:56 Suspend      3
```

4.1.5 Read parametric data

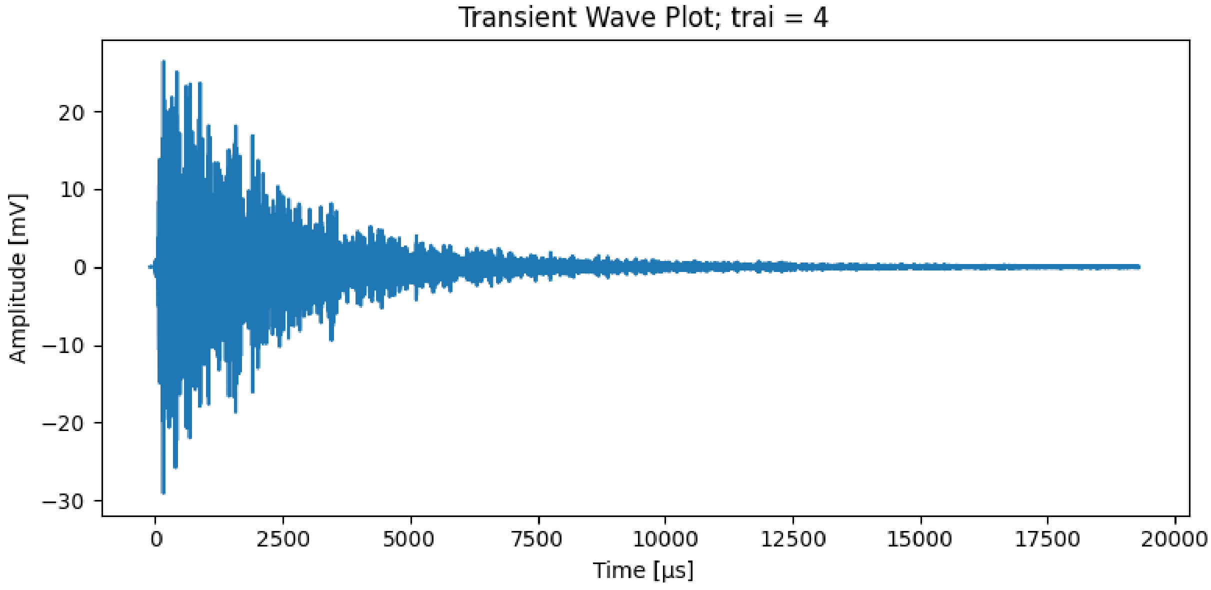
```
df_parametric = pridb.read_parametric()
print(df_parametric)
```

Out:

```
Parametric:   0%|          | 0/9 [00:00<?, ?it/s]
Parametric: 100%|##########| 9/9 [00:00<00:00, 23031.57it/s]
        time  param_id  pctd  pcta
set_id
5       0.00         1     0     0
6       1.00         1     0     0
7       2.00         1     0     0
8       3.00         1     0     0
9       3.99         1     0     0
14      4.00         1     0     0
15      5.00         1     0     0
16      6.00         1     0     0
17      6.45         1     0     0
```

Total running time of the script: (0 minutes 0.471 seconds)

4.2 Read and plot transient data




```
import os

import matplotlib.pyplot as plt

import vallenae as vae

HERE = os.path.dirname(__file__) if "__file__" in locals() else os.getcwd()
```

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```
TRADB = os.path.join(HERE, "steel_plate/sample_plain.tradb")  # uncompressed
TRAI = 4  # just an example, no magic here


def main():
    # Read waveform from tradb
    with vae.io.TraDatabase(TRADB) as tradb:
        y, t = tradb.read_wave(TRAI)

    y *= 1e3  # in mV
    t *= 1e6  # for µs

    # Plot waveforms
    plt.figure(figsize=(8, 4), tight_layout=True)
    plt.plot(t, y)
    plt.xlabel("Time [µs]")
    plt.ylabel("Amplitude [mV]")
    plt.title(f"Transient Wave Plot; trai = {TRAI}")
    plt.show()


if __name__ == "__main__":
    main()
```

Total running time of the script: (0 minutes 0.224 seconds)

4.3 Timepicker

Following example showcases the results of different timepicking methods. For more informations, please refer to the functions documentation (*vallenae.timepicker*).

```
import os
import time

import matplotlib.pyplot as plt
import numpy as np

import vallenae as vae

HERE = os.path.dirname(__file__) if "__file__" in locals() else os.getcwd()
TRADB = os.path.join(HERE, "steel_plate/sample_plain.tradb")

TRAI = 4
SAMPLES = 2000

plt.ioff()  # Turn interactive mode off; plt.show() is blocking
```

4.3.1 Read waveform from tradb

```
tradb = vae.io.TraDatabase(TRADB)

y, t = tradb.read_wave(TRAI)
```

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```
# crop first samples
t = t[:SAMPLES]
y = y[:SAMPLES]
# unit conversion
t *= 1e6  # convert to µs
y *= 1e3  # convert to mV
```

4.3.2 Prepare plotting with time-picker results

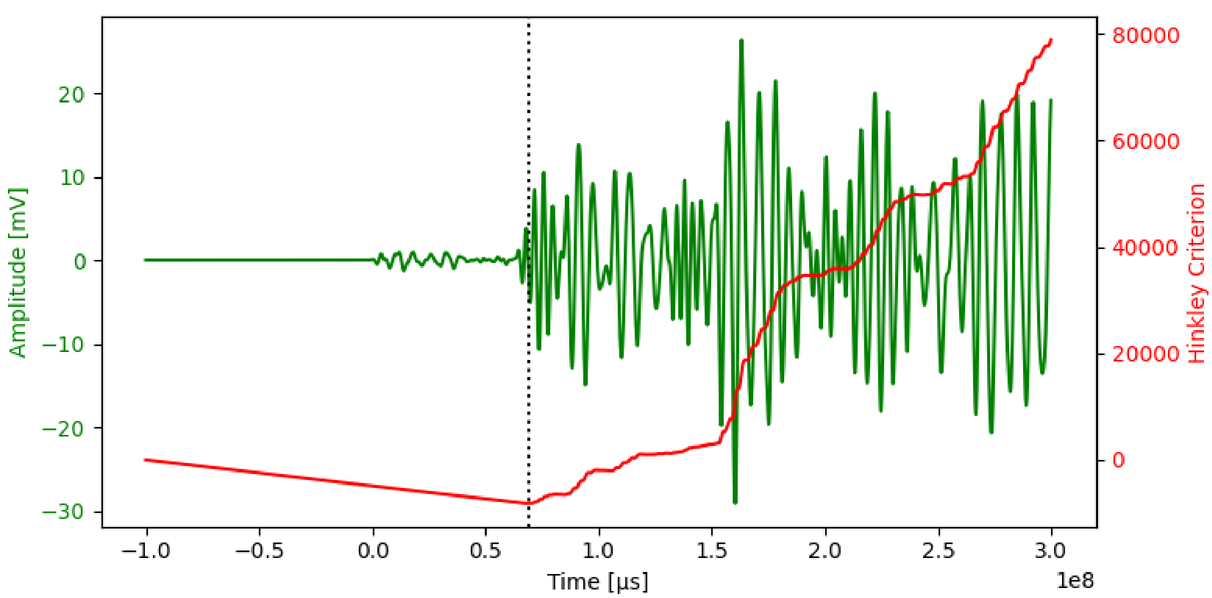
```
def plot(t_wave, y_wave, y_picker, index_picker, name_picker):
    _, ax1 = plt.subplots(figsize=(8, 4), tight_layout=True)
    ax1.set_xlabel("Time [µs]")
    ax1.set_ylabel("Amplitude [mV]", color="g")
    ax1.plot(t_wave, y_wave, color="g")
    ax1.tick_params(axis="y", labelcolor="g")

    ax2 = ax1.twinx()
    ax2.set_ylabel(f"{name_picker}", color="r")
    ax2.plot(t_wave, y_picker, color="r")
    ax2.tick_params(axis="y", labelcolor="r")

    plt.axvline(t_wave[index_picker], color="k", linestyle=":")
    plt.show()
```

4.3.3 Hinkley Criterion

```
hc_arr, hc_index = vae.timepicker.hinkley(y, alpha=5)
plot(t, y, hc_arr, hc_index, "Hinkley Criterion")
```

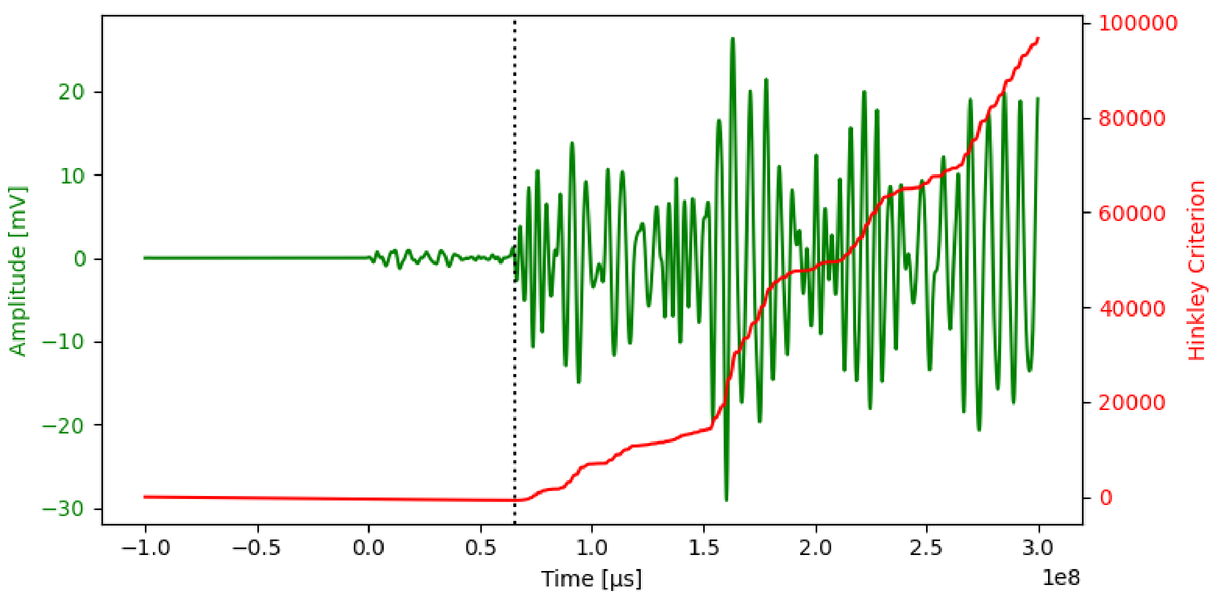


Out:

```
/home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/
↪importlib/_bootstrap.py:219: RuntimeWarning: numpy.ufunc size changed, may indicate␣
↪binary incompatibility. Expected 192 from C header, got 216 from PyObject
  return f(*args, **kwds)
```

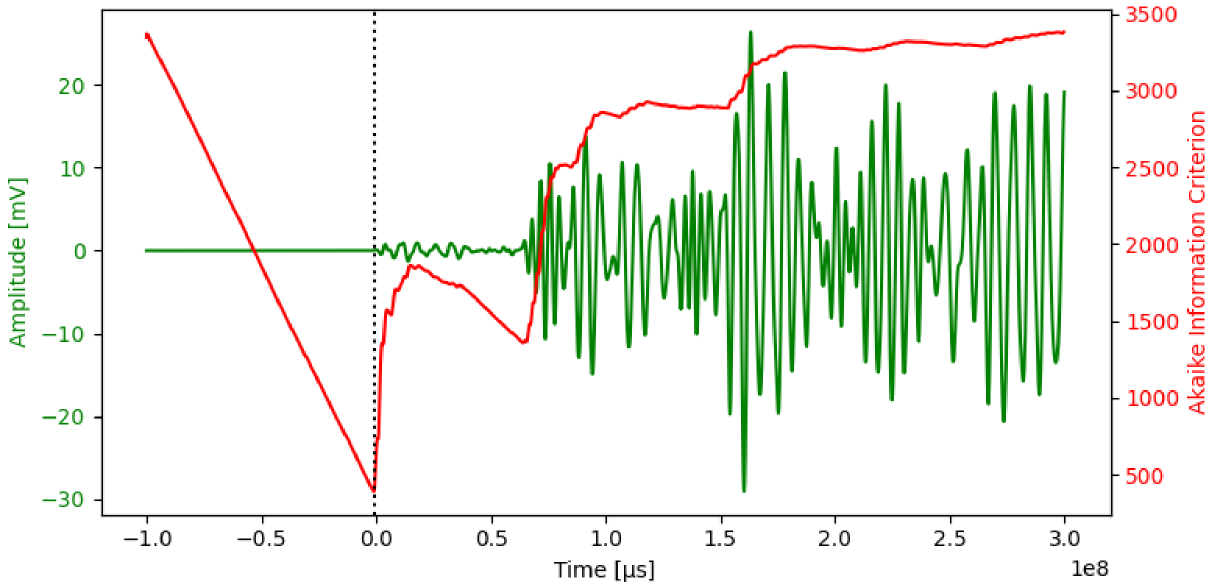
The negative trend correlates to the chosen alpha value and can influence the results strongly. Results with **alpha = 50** (less negative trend):

```
hc_arr, hc_index = vae.timepicker.hinkley(y, alpha=50)
plot(t, y, hc_arr, hc_index, "Hinkley Criterion")
```



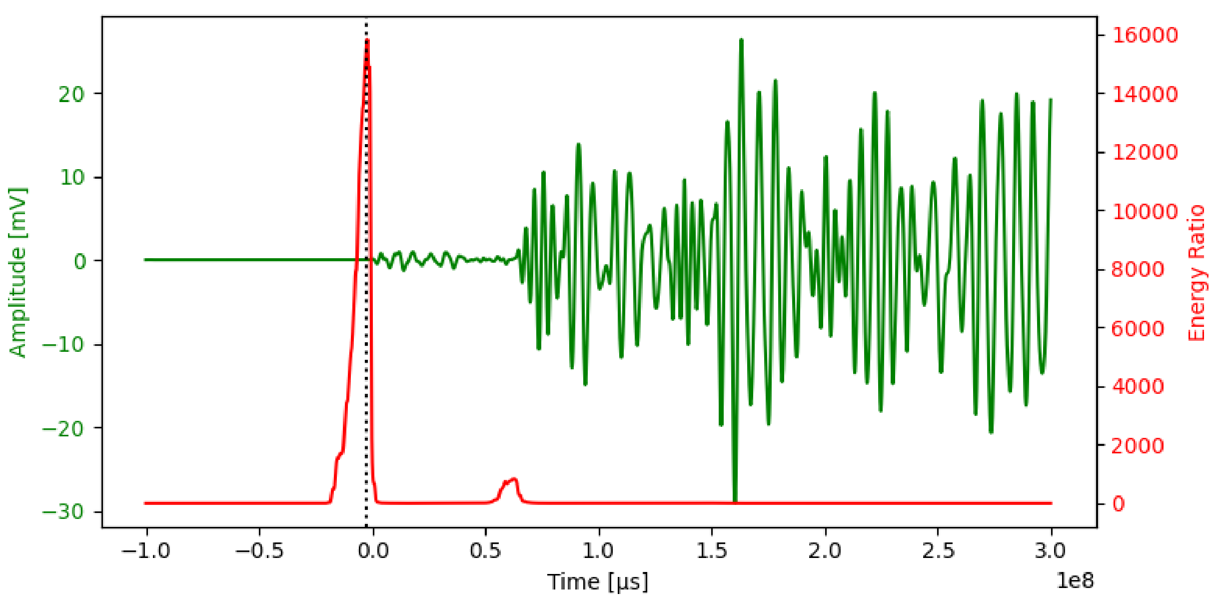
4.3.4 Akaike Information Criterion (AIC)

```
aic_arr, aic_index = vae.timepicker.aic(y)
plot(t, y, aic_arr, aic_index, "Akaike Information Criterion")
```



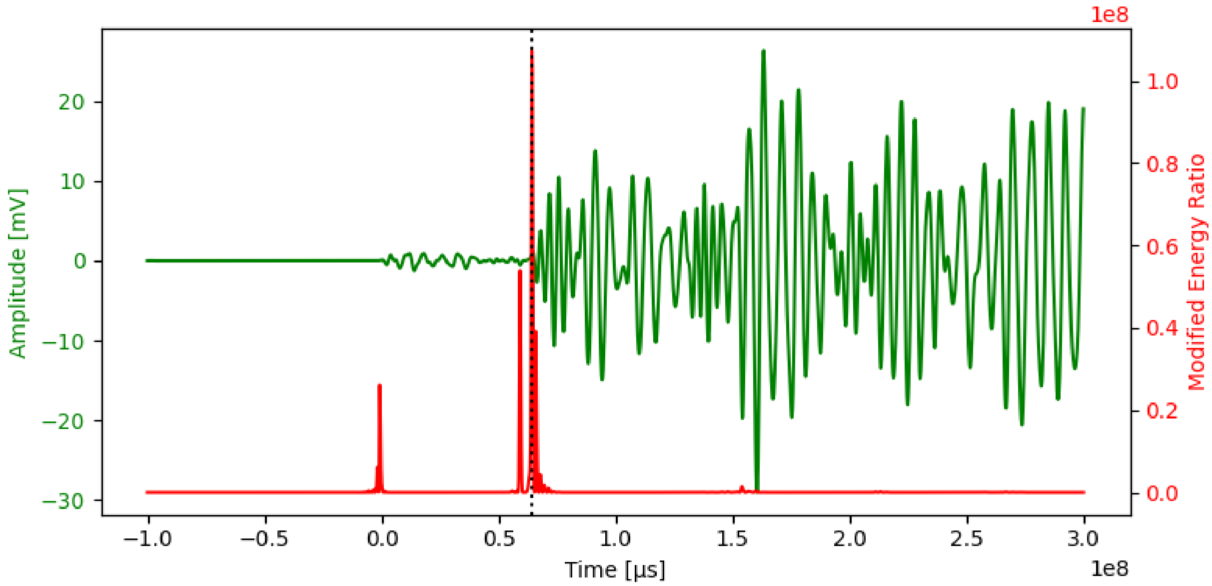
4.3.5 Energy Ratio

```
er_arr, er_index = vae.timepicker.energy_ratio(y)
plot(t, y, er_arr, er_index, "Energy Ratio")
```



4.3.6 Modified Energy Ratio

```
mer_arr, mer_index = vae.timepicker.modified_energy_ratio(y)
plot(t, y, mer_arr, mer_index, "Modified Energy Ratio")
```



4.3.7 Performance comparison

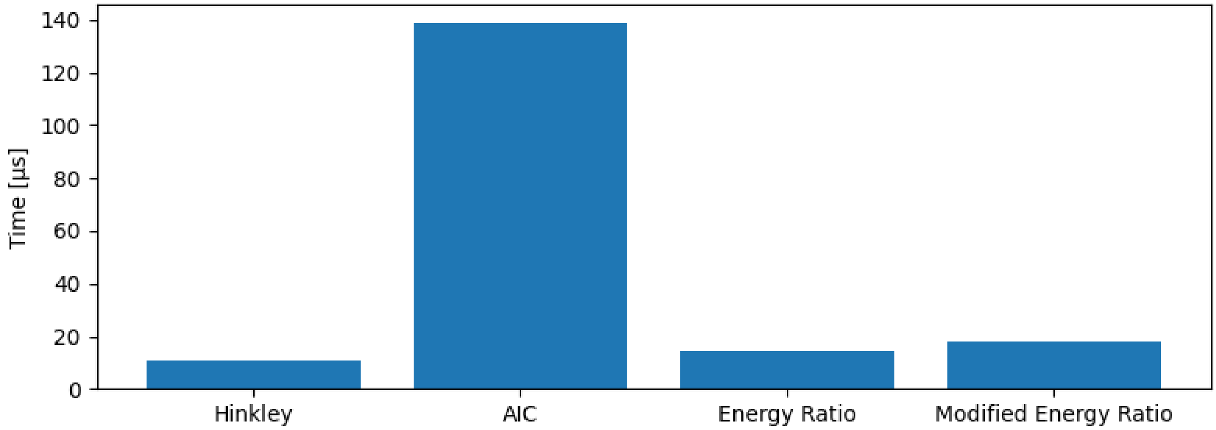
All timepicker implementations are using Numba for just-in-time (JIT) compilations. Usually the first function call is slow, because it will trigger the JIT compiler. To compare the performance to a native or numpy implementation, the average of multiple executions should be compared.

```
def timeit(callable, loops=100):
    time_start = time.perf_counter()
    for _ in range(loops):
        callable()
    return 1e6 * (time.perf_counter() - time_start) / loops  # elapsed time in µs

timer_results = {
    "Hinkley": timeit(lambda: vae.timepicker.hinkley(y, 5)),
    "AIC": timeit(lambda: vae.timepicker.aic(y)),
    "Energy Ratio": timeit(lambda: vae.timepicker.energy_ratio(y)),
    "Modified Energy Ratio": timeit(lambda: vae.timepicker.modified_energy_ratio(y)),
}

for name, time in timer_results.items():
    print(f"{name}: {time:0.3f} µs")

plt.figure(figsize=(8, 3), tight_layout=True)
plt.bar(timer_results.keys(), timer_results.values())
plt.ylabel("Time [µs]")
plt.show()
```



Out:

```
Hinkley: 10.744 µs
AIC: 138.931 µs
Energy Ratio: 14.124 µs
Modified Energy Ratio: 17.850 µs
```

Total running time of the script: (0 minutes 3.722 seconds)

4.4 Timepicker batch processing

Following examples shows how to stream transient data row by row, compute timepicker results and save the results to a feature database (trfdb).

```
import os
from shutil import copyfile
from tempfile import gettempdir

import matplotlib.pyplot as plt
import pandas as pd

import vallenae as vae

HERE = os.path.dirname(__file__) if "__file__" in locals() else os.getcwd()
TRADB = os.path.join(HERE, "steel_plate/sample_plain.tradb")
TRFDB = os.path.join(HERE, "steel_plate/sample.trfdb")
TRFDB_TMP = os.path.join(gettempdir(), "sample.trfdb")
```

4.4.1 Open tradb (readonly) and trfdb (readwrite)

```
copyfile(TRFDB, TRFDB_TMP)  # copy trfdb, so we don't overwrite it

tradb = vae.io.TraDatabase(TRADB)
trfdb = vae.io.TrfDatabase(TRFDB_TMP, mode="rw")  # allow writing
```

4.4.2 Read current trfdb

```
print(trfdb.read())
```

Out:

```
          FFT_CoG     FFT_FoM         PA  ...  CTP          FI          FR
trai                                      ...
2      144.042969  139.160156  59.450512  ...   35  182.291672   98.019981
1      147.705078  134.277344  46.483864  ...   11  222.672058  110.182449
3      155.029297  164.794922  33.995209  ...   55  155.191879   95.493233
4      159.912109  139.160156  29.114828  ...   29  181.023727  101.906227

[4 rows x 8 columns]
```

4.4.3 Compute arrival time offsets with different timepickers

To improve localisation, time of arrival estimates using the first threshold crossing can be refined with timepickers. Therefore, arrival time offsets between the first threshold crossings and the timepicker results are computed.

```
def dt_from_timepicker(timepicker_func, tra: vae.io.TraRecord):
    # Index of the first threshold crossing is equal to the pretrigger samples
    index_ref = tra.pretrigger
    # Only analyse signal until peak amplitude
    index_peak = vae.features.peak_amplitude_index(tra.data)
    data = tra.data[:index_peak]
    # Get timepicker result
    _, index_timepicker = timepicker_func(data)
    # Compute offset in µs
    dt_us = (index_timepicker - index_ref) * 1e6 / tra.samplerate
    return dt_us
```

Transient data is streamed from the database row by row using *vallenae.io.TraDatabase.iread*. Only one transient data set is loaded into memory at a time. That makes the streaming interface ideal for batch processing. The timepicker results are saved to the trfdb using *vallenae.io.TrfDatabase.write*.

```
for tra in tradb.iread():
    # Calculate arrival time offsets with different timepickers
    feature_set = vae.io.FeatureRecord(
        trai=tra.trai,
        features={
            "ATO_Hinkley": dt_from_timepicker(vae.timepicker.hinkley, tra),
            "ATO_AIC": dt_from_timepicker(vae.timepicker.aic, tra),
            "ATO_ER": dt_from_timepicker(vae.timepicker.energy_ratio, tra),
            "ATO_MER": dt_from_timepicker(vae.timepicker.modified_energy_ratio, tra),
        }
    )
    # Save results to trfdb
    trfdb.write(feature_set)
```

4.4.4 Read results from trfdb

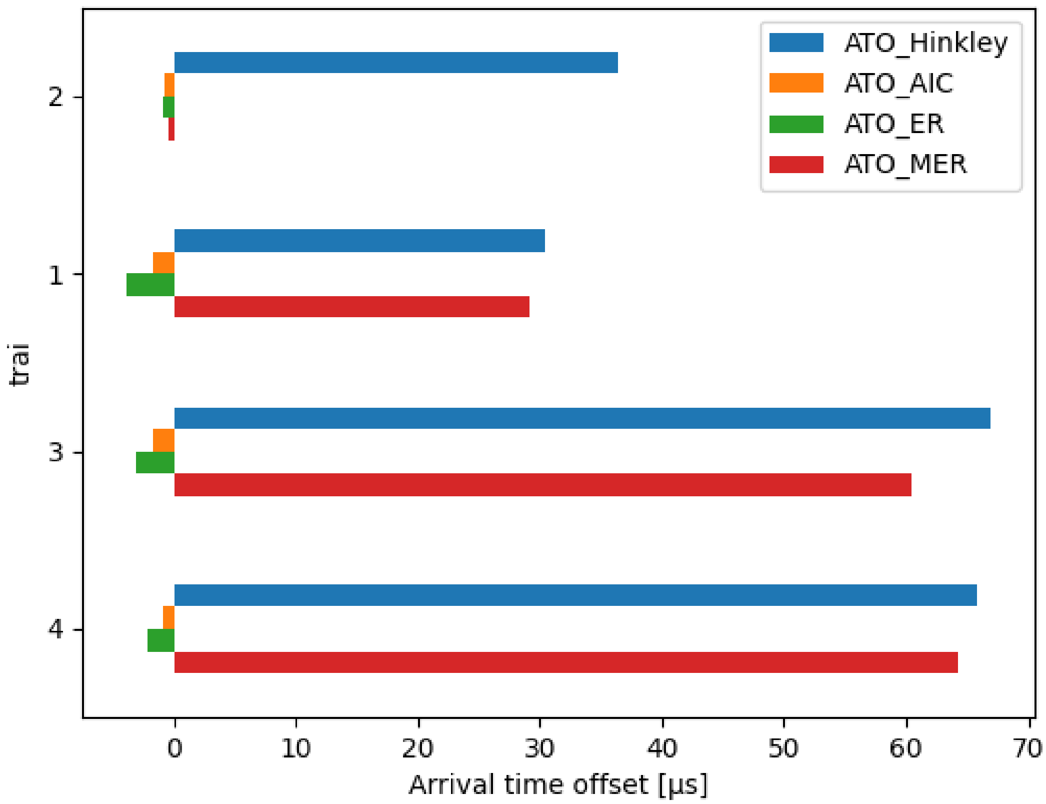
```
print(trfdb.read().filter(regex="ATO"))
```

Out:

```
      ATO_Hinkley  ATO_AIC  ATO_ER  ATO_MER
trai
2            36.4     -0.8    -1.0     -0.4
1            30.4     -1.8    -4.0     29.2
3            67.0     -1.8    -3.2     60.4
4            65.8     -1.0    -2.2     64.2
```

4.4.5 Plot results

```
ax = trfdb.read()[["ATO_Hinkley", "ATO_AIC", "ATO_ER", "ATO_MER"]].plot.barh()
ax.invert_yaxis()
ax.set_xlabel("Arrival time offset [µs]")
plt.show()
```



4.4.6 Plot waveforms and arrival times

```
_, axes = plt.subplots(4, 1, tight_layout=True, figsize=(8, 8))
for row, ax in zip(trfdb.read().itertuples(), axes):
    trai = row.Index
```

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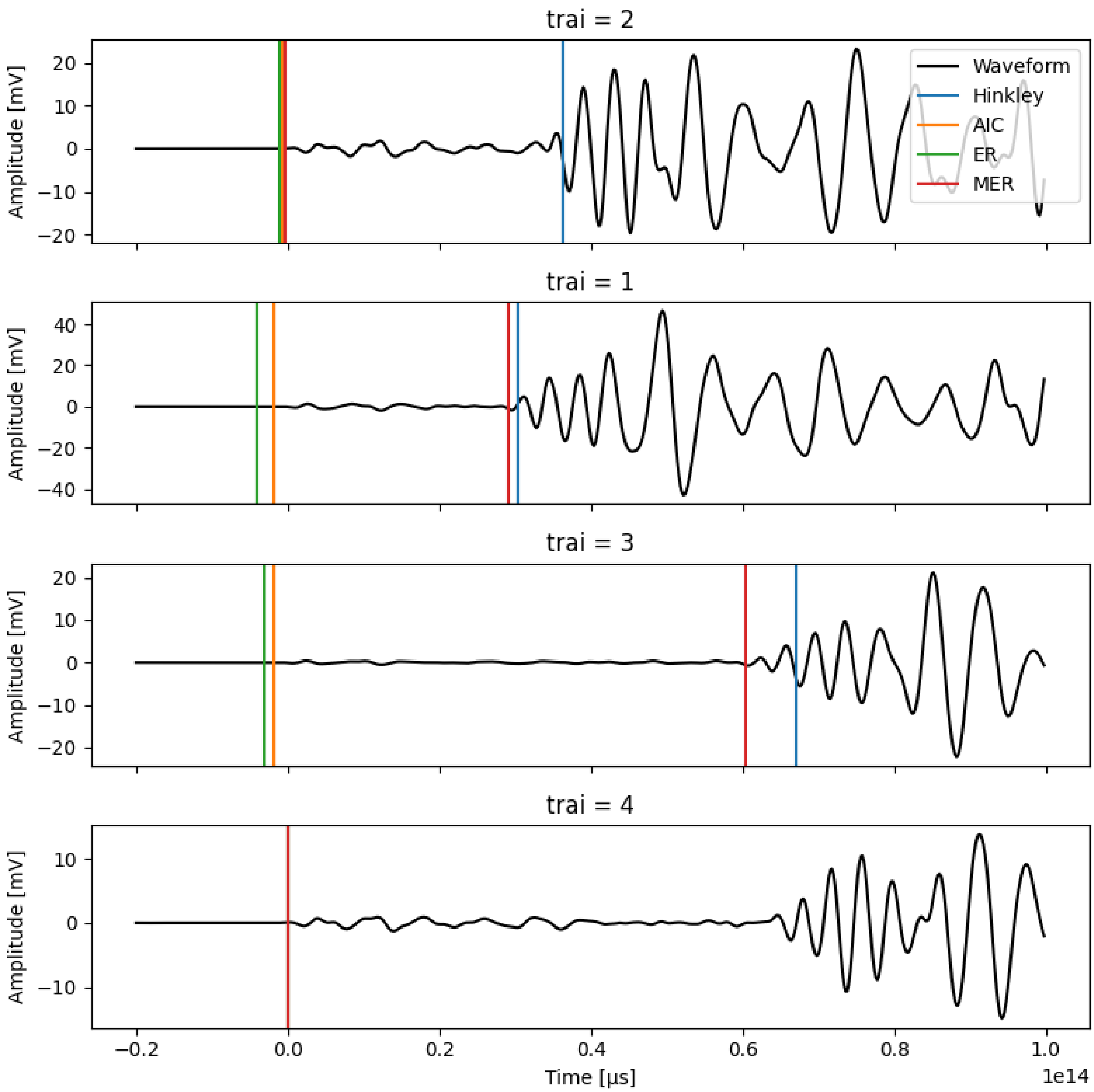
```
    # read waveform from tradb
    y, t = tradb.read_wave(trai)

    # plot waveform
    ax.plot(t[400:1000] * 1e6, y[400:1000] * 1e3, "k")  # crop and convert to µs/mV
    ax.set_title(f"trai = {trai}")
    ax.set_xlabel("Time [µs]")
    ax.set_ylabel("Amplitude [mV]")
    ax.label_outer()
    # plot arrival time offsets
    ax.axvline(row.ATO_Hinkley, color="C0")
    ax.axvline(row.ATO_AIC, color="C1")
    ax.axvline(row.ATO_ER, color="C2")
    ax.axvline(row.ATO_MER, color="C3")

axes[0].legend(["Waveform", "Hinkley", "AIC", "ER", "MER"])
plt.show()
```



4.4.7 Use results in VisualAE

The computed arrival time offsets can be directly used in VisualAE. We only need to specify the unit. VisualAE requires them to be in µs. Units and other column-related meta data is saved in the *trf_fieldinfo* table. Field infos can be retrieved with `vallenae.io.TrfDatabase.fieldinfo`:

```
print(trfdb.fieldinfo())
```

Out:

```
{'FFT_CoG': {'SetTypes': 2, 'Unit': '[kHz]', 'LongName': 'F(C.o.Gravity)',
↪'Description': 'Center of gravity of spectrum', 'ShortName': None, 'FormatStr':
↪None}, 'FFT_FoM': {'SetTypes': 2, 'Unit': '[kHz]', 'LongName': 'F(max. Amp.)',
↪'Description': 'Frequency of maximum of spectrum', 'ShortName': None, 'FormatStr':
↪None}, 'PA': {'SetTypes': 8, 'Unit': '[mV]', 'LongName': 'Peak Amplitude',
↪'Description': None, 'ShortName': None, 'FormatStr': None}, 'RT': {'SetTypes': 8,
↪'Unit': '[µs]', 'LongName': 'Rise Time', 'Description': None, 'ShortName': None,
↪'FormatStr': None}, 'Dur': {'SetTypes': 8, 'Unit': '[µs]', 'LongName': 'Duration
↪(available)', 'Description': None, 'ShortName': None, 'FormatStr': None}, 'CTP': {
↪'SetTypes': 8, 'Unit': None, 'LongName': 'Cnts to peak', 'Description': None,
↪'ShortName': None, 'FormatStr': '#'}, 'FI': {'SetTypes': 8, 'Unit': '[kHz]',
```

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```
```

Show results as table:

```
print(pd.DataFrame(trfdb.fieldinfo()))
```

Out:

```
                               FFT_CoG  ...                   FR
SetTypes                             2  ...                    8
Unit                             [kHz]  ...                [kHz]
LongName                F(C.o.Gravity)  ...  Reverberation Freq.
Description  Center of gravity of spectrum  ...                 None
ShortName                         None  ...                 None
FormatStr                         None  ...                 None

[6 rows x 8 columns]
```

Write units to trfdb

Field infos can be written with *vallenae.io.TrfDatabase.write_fieldinfo*:

```
trfdb.write_fieldinfo("ATO_Hinkley", {"Unit": "[µs]", "LongName": "Arrival Time␣
↪Offset (Hinkley)"})
trfdb.write_fieldinfo("ATO_AIC", {"Unit": "[µs]", "LongName": "Arrival Time Offset␣
↪(AIC)"})
trfdb.write_fieldinfo("ATO_ER", {"Unit": "[µs]", "LongName": "Arrival Time Offset (ER)
↪"})
trfdb.write_fieldinfo("ATO_MER", {"Unit": "[µs]", "LongName": "Arrival Time Offset␣
↪(MER)"})

print(pd.DataFrame(trfdb.fieldinfo()).filter(regex="ATO"))
```

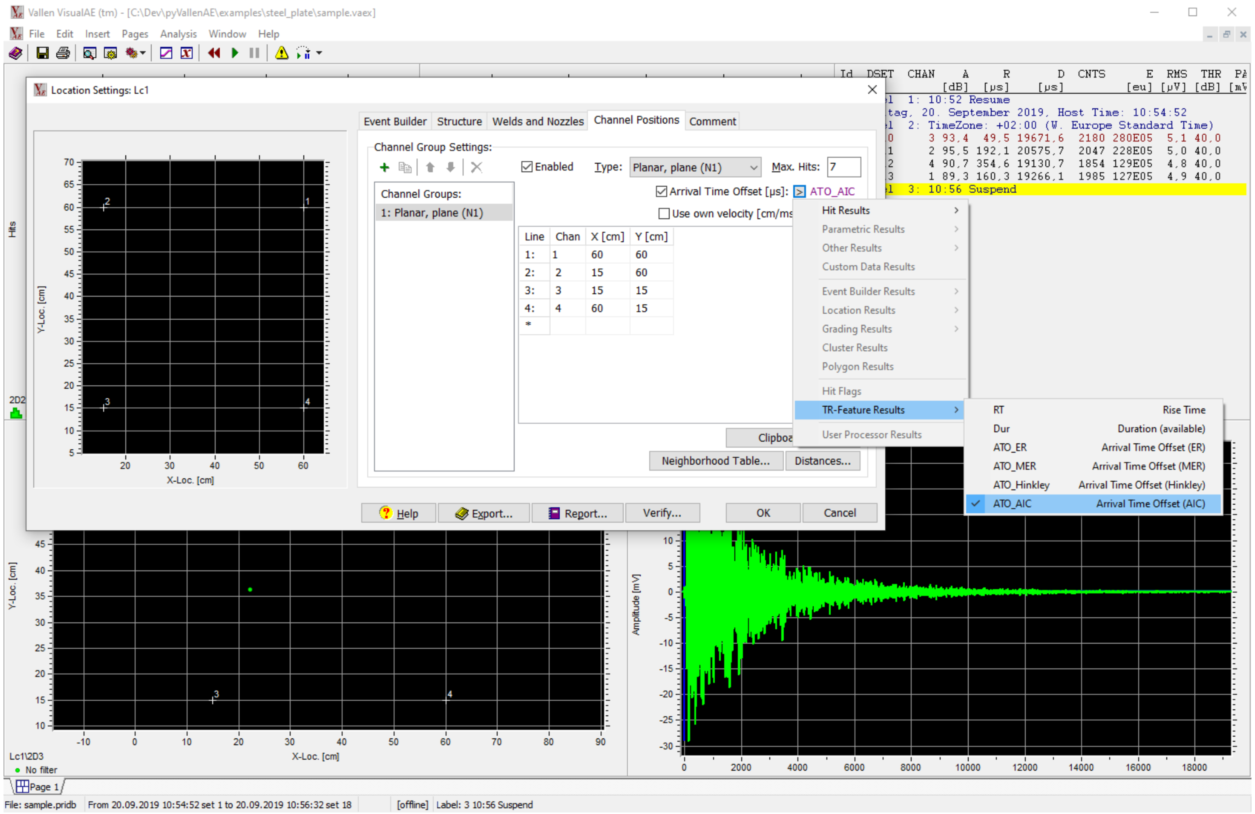
Out:

```
                             ATO_Hinkley  ...                      ATO_MER
SetTypes                            None  ...                         None
Unit                                [µs]  ...                         [µs]
LongName     Arrival Time Offset (Hinkley)  ...  Arrival Time Offset (MER)
Description                         None  ...                         None
ShortName                           None  ...                         None
FormatStr                           None  ...                         None

[6 rows x 4 columns]
```

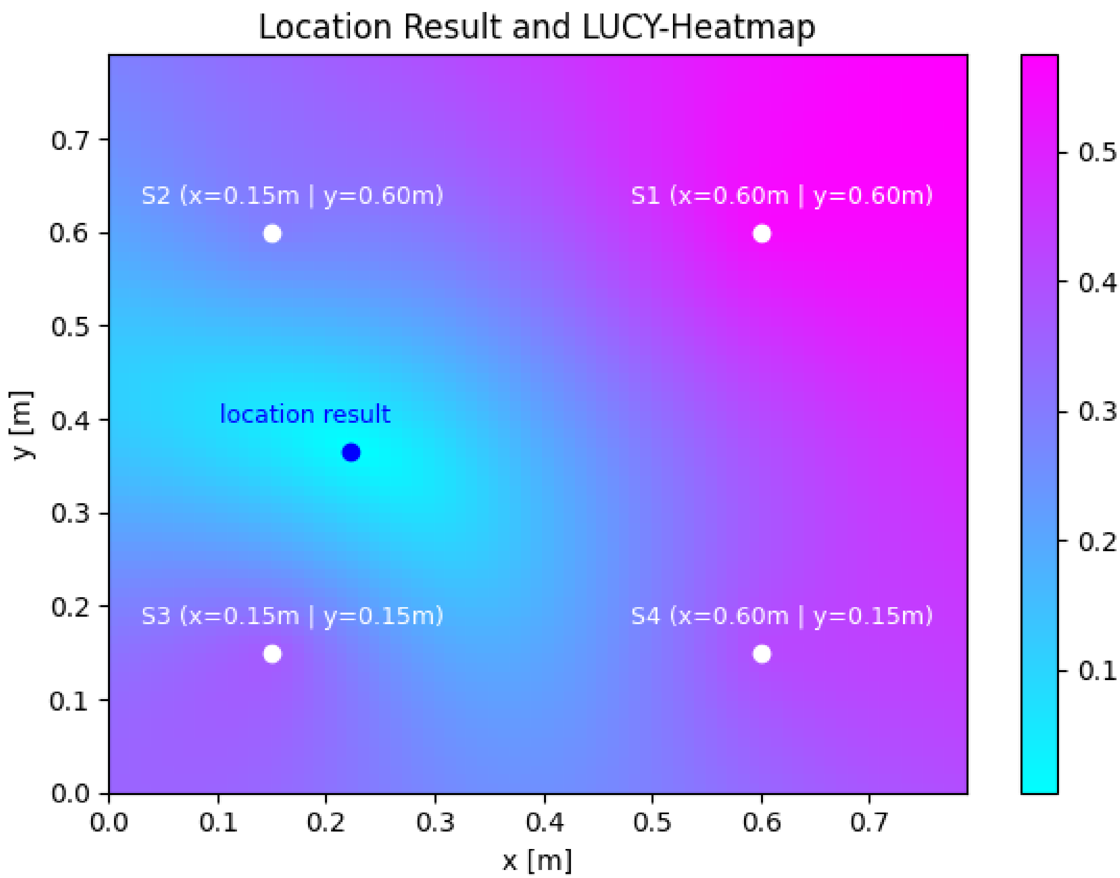
Load results in VisualAE

Time arrival offsets can be specified in the settings of *Location Processors - Channel Positions - Arrival Time Offset*. (Make sure to rename the generated trfdb to match the filename of the pridb.)



Total running time of the script: (0 minutes 1.083 seconds)

4.5 Localisation



Out:

```
/home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/
↪importlib/_bootstrap.py:219: RuntimeWarning: numpy.ufunc size changed, may indicate␣
↪binary incompatibility. Expected 192 from C header, got 216 from PyObject
  return f(*args, **kwds)

Hits:   0%|          | 0/4 [00:00<?, ?it/s]
Hits: 100%|##########| 4/4 [00:00<00:00, 11252.32it/s]
/home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/checkouts/0.3.0/examples/
↪ex5_location.py:122: MatplotlibDeprecationWarning: shading='flat' when X and Y have␣
↪the same dimensions as C is deprecated since 3.3.  Either specify the corners of␣
↪the quadrilaterals with X and Y, or pass shading='auto', 'nearest' or 'gouraud', or␣
↪set rcParams['pcolor.shading'].  This will become an error two minor releases later.
  plt.pcolormesh(x_grid, y_grid, z_grid, cmap="cool")
Runtime for 1 call to differential_evolution(): 0.5295 s
     fun: 0.001115888186564851
     jac: array([-0.00047919,  0.00028014])
 message: 'Optimization terminated successfully.'
    nfev: 7535
     nit: 93
 success: True
       x: array([0.22165211, 0.36565958])
```

```python
import math
import os
import time
import xml.etree.ElementTree as ElementTree
from typing import Dict, Optional, Tuple

import matplotlib.pyplot as plt
import numpy as np
from numba import f8, njit
from numpy.linalg import norm
from scipy.optimize import differential_evolution

import vallenae as vae

HERE = os.path.dirname(__file__) if "__file__" in locals() else os.getcwd()
SETUP = os.path.join(HERE, "steel_plate/sample.vaex")
PRIDB = os.path.join(HERE, "steel_plate/sample.pridb")
NUMBER_SENSORS = 4


@njit(f8(f8[:], f8, f8[:, :], f8[:]))
def lucy_error_fun(
    test_pos: np.ndarray,
    speed: float,
    sens_poss: np.ndarray,
    measured_delta_ts: np.ndarray,
) -> float:
    """
    Implementation of the LUCY computation in 2D as documented in
    the Vallen online help.

    Args:
        test_pos: Emitter position to test.
        speed: Assumed speed of sound in a plate-like structure.
        sens_poss: Sensor positions, often a 4x2 array, has to match
            the sorting of the delta-ts.
        measured_delta_ts: The measured time differences in seconds, has to
            match the order of the sensor positions.

    Returns:
        The LUCY value as a float. Ideally 0, in practice never 0, always positive.
    """
    m = len(measured_delta_ts)
    n = m + 1
    measured_delta_dists = speed * measured_delta_ts
    theo_dists = np.zeros(n)
    theo_delta_dists = np.zeros(m)
    for i in range(n):
        theo_dists[i] = norm(test_pos - sens_poss[i, :])
    for i in range(m):
        theo_delta_dists[i] = theo_dists[i + 1] - theo_dists[0]

    # LUCY definition taken from the vallen online help:
    lucy_val = norm(theo_delta_dists - measured_delta_dists) / math.sqrt(n - 1)
```

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```
    return lucy_val


def get_channel_positions(setup_file: str) -> Dict[int, Tuple[float, float]]:
    tree = ElementTree.parse(setup_file)
    nodes = tree.getroot().findall(".//ChannelPos")
    if nodes is None:
        raise RuntimeError("Can not retrieve channel positions from %s", setup_file)
    channel_positions = {
        int(elem.get("Chan")): (float(elem.get("X")), float(elem.get("Y")))  # type:␣
↪ignore
        for elem in nodes if elem is not None
    }
    return channel_positions


def get_velocity(setup_file: str) -> Optional[float]:
    tree = ElementTree.parse(setup_file)
    node = tree.getroot().find(".//Location")
    if node is not None:
        velocity_str = node.get("Velocity")
        if velocity_str is not None:
            return float(velocity_str) * 1e3  # convert to m/s
    raise RuntimeError("Can not retrieve velocity from %s", setup_file)


def main():
    # Consts plotting
    text_delta_y = 0.03
    text_delta_x = -0.12

    # Consts LUCY grid
    grid_delta = 0.01
    location_search_bounds = [(0.0, 0.80), (0.0, 0.80)]

    # Read from pridb
    pridb = vae.io.PriDatabase(PRIDB)
    hits = pridb.read_hits()
    pridb.close()

    channel_order = hits["channel"].to_numpy()
    arrival_times = hits["time"].to_numpy()
    delta_ts = (arrival_times - arrival_times[0])[1:]

    # Get localisation parameters from .vaex file
    velocity = get_velocity(SETUP)
    pos_dict = get_channel_positions(SETUP)

    # Order sensor positions by hit occurence
    pos_ordered = np.array([pos_dict[ch] for ch in channel_order])

    # Compute heatmap
    lucy_instance_2args = lambda x, y: lucy_error_fun(
        np.array([x, y]), velocity, pos_ordered, delta_ts
    )

    x_range = np.arange(location_search_bounds[0][0], location_search_bounds[0][1],␣
↪grid_delta)
```

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```
    y_range = x_range
    x_grid, y_grid = np.meshgrid(x_range, y_range)
    z_grid = np.vectorize(lucy_instance_2args)(x_grid, y_grid)

    # Plot heatmap
    plt.figure(tight_layout=True)
    plt.pcolormesh(x_grid, y_grid, z_grid, cmap="cool")
    plt.colorbar()
    plt.title("Location Result and LUCY-Heatmap")
    plt.xlabel("x [m]")
    plt.ylabel("y [m]")

    # Compute location
    lucy_instance_single_arg = lambda pos: lucy_error_fun(
        pos, velocity, pos_ordered, delta_ts
    )

    start = time.perf_counter()
    # These are excessive search / overkill parameters:
    location_result = differential_evolution(
        lucy_instance_single_arg,
        location_search_bounds,
        popsize=40,
        polish=True,
        strategy="rand1bin",
        recombination=0.1,
        mutation=1.3,
    )
    end = time.perf_counter()
    print(f"Runtime for 1 call to differential_evolution(): {(end - start):0.4} s")
    print(location_result)

    # Plot location result
    x_res = location_result.x[0]
    y_res = location_result.x[1]
    plt.plot([x_res], [y_res], "bo")
    plt.text(
        x_res + text_delta_x,
        y_res + text_delta_y,
        "location result",
        fontsize=9,
        color="b",
    )

    # Plot sensor positions
    for channel, (x, y) in pos_dict.items():
        text = f"S{channel} (x={x:0.2f}m | y={y:0.2f}m)"
        plt.scatter(x, y, marker="o", color="w")
        plt.text(x + text_delta_x, y + text_delta_y, text, fontsize=9, color="w")

    plt.show()


if __name__ == "__main__":
    main()
```

Total running time of the script: (0 minutes 1.630 seconds)

4.6 Go fast with multiprocessing

The streaming interfaces with iterables allow efficient batch processing as shown *here*. But still only one core/thread will be utilized. We will change that will multiprocessing.

Following example shows a batch feature extraction procedure using multiple CPU cores.

```
import os
import time
import multiprocessing
from typing import Dict, Iterable
from itertools import cycle
import __main__

import numpy as np
from scipy import stats
import matplotlib.pyplot as plt

import vallenae as vae

HERE = os.path.dirname(__file__) if "__file__" in locals() else os.getcwd()
TRADB = os.path.join(HERE, "steel_plate/sample_plain.tradb")
```

Out:

```
/home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/
↪importlib/_bootstrap.py:219: RuntimeWarning: numpy.ufunc size changed, may indicate␣
↪binary incompatibility. Expected 192 from C header, got 216 from PyObject
  return f(*args, **kwds)
```

4.6.1 Prepare streaming reads

```
tradb = vae.io.TraDatabase(TRADB)
```

Our sample tradb only contains four data sets. That is not enough data for demonstrating batch processing. Therefore, we will simulate more data by looping over the data sets with following generator/iterable:

```
def tra_generator(loops: int = 1000) -> Iterable[vae.io.TraRecord]:
    for loop, tra in enumerate(cycle(tradb.iread())):
        if loop > loops:
            break
        yield tra
```

4.6.2 Define feature extraction function

Following function will be applied to all data sets and returns computed features:

```
def feature_extraction(tra: vae.io.TraRecord) -> Dict[str, float]:
    # compute random statistical features
    return {
        "Std": np.std(tra.data),
        "Skew": stats.skew(tra.data),
    }
```

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```
# Fix to use pickle serialization in sphinx gallery
setattr(__main__, feature_extraction.__name__, feature_extraction)
```

4.6.3 Compute with single thread/core

Note: The examples are executed on the CI / readthedocs server with limited resources. Therefore, the shown computation times and speedups are below the capability of modern machines.

Run computation in a single thread and get the time:

```
time_elapsed_ms = lambda t0: 1e3 * (time.perf_counter() - t0)

time_start = time.perf_counter()
for tra in tra_generator():
    results = feature_extraction(tra)
    # do something with the results
time_single_thread = time_elapsed_ms(time_start)

print(f"Time single thread: {time_single_thread:.2f} ms")
```

Out:

```
Time single thread: 953.75 ms
```

4.6.4 Compute with multiple processes/cores

First get number of available cores in your machine:

```
cores_total = os.cpu_count()
cores_available = len(os.sched_getaffinity(0))  # https://docs.python.org/3/library/
↪os.html#os.cpu_count
print(f"Available / total CPU cores: {cores_available} / {cores_total}")
```

Out:

```
Available / total CPU cores: 2 / 2
```

But how can we utilize those cores? The common answer for most programming languages is multithreading. Threads run in the same process and heap, so data can be shared between them (with care). Sadly, Python uses a global interpreter lock (GIL) that locks heap memory, because Python objects are not thread-safe. Therefore, threads are blocking each other and no speedups are gained by using multiple threads.

The solution for Python is multiprocessing to work around the GIL. Every process has its own heap and GIL. Multiprocessing will introduce overhead for interprocess communication and data serialization/deserialization. To reduce the overhead, data is sent in bigger chunks.

Run computation on 4 cores with chunks of 128 data sets and get the time / speedup:

```
with multiprocessing.Pool(4) as pool:
    time_start = time.perf_counter()
```

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```
    for results in pool.imap(feature_extraction, tra_generator(), chunksize=128):
        pass  # do something with the results
    time_multiprocessing = time_elapsed_ms(time_start)

print(f"Time multiprocessing: {time_multiprocessing:.2f} ms")
print(f"Speedup: {(time_single_thread / time_multiprocessing):.2f}")
```

Out:

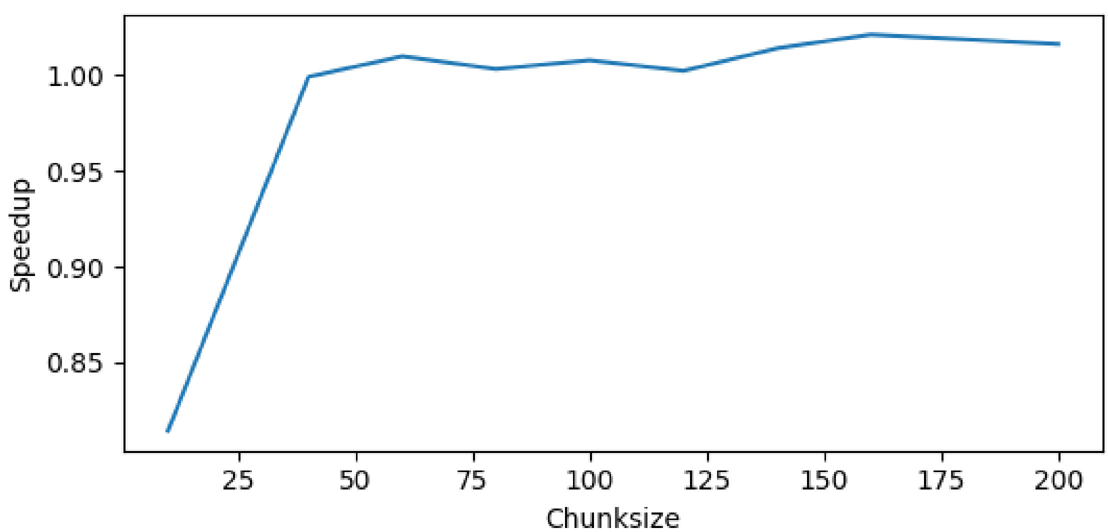
```
Time multiprocessing: 1034.86 ms
Speedup: 0.92
```

Variation of the chunksize

Following results show how the chunksize impacts the overall performance. The speedup is measured for different chunksizes and plotted against the chunksize:

```
chunksizes = (10, 40, 60, 80, 100, 120, 140, 160, 200)
speedup_chunksizes = []
with multiprocessing.Pool(4) as pool:
    for chunksize in chunksizes:
        time_start = time.perf_counter()
        for results in pool.imap(feature_extraction, tra_generator(),␣
↪chunksize=chunksize):
            pass  # do something with the results
        speedup_chunksizes.append(time_single_thread / time_elapsed_ms(time_start))

plt.figure(tight_layout=True, figsize=(6, 3))
plt.plot(chunksizes, speedup_chunksizes)
plt.xlabel("Chunksize")
plt.ylabel("Speedup")
plt.show()
```



Total running time of the script: (0 minutes 11.379 seconds)

CHAPTER

FIVE

CHANGELOG

5.1 0.3.0

2020-11-05

New features

- Add optional query filter for pridb/tradb (i)read functions (https://github.com/vallen-systems/pyVallenAE/issues/18)

5.2 0.2.4

2020-11-01

Bug fixes

- SQL schemas for pridb/tradb/trfdb creation, add fieldinfos

5.3 0.2.3

2020-09-01

Bug fixes

- AIC timepicker
- add threshold for monotonic time check (1 ns) to ignore rounding issues
- suppress exception chaining

5.4 0.2.2

2020-07-10

Optimizations

- database classes are now pickable and can be used in multiprocessing
- SQLite transactions for all writes
- faster blob encoding (`vallenae.io.encode_data_blob`)
- faster RMS computation with Numba (`vallenae.features.rms`)

Bug fixes

- catch possible global_info table parsing errors

5.5 0.2.1

2020-02-10

Bug fixes

- examples outputs if not run as notebook
- out-of-bound time_start, time_stop with SQL binary search
- optional signal strength for spotWave data acquisition

5.6 0.2.0

2020-02-06

New features

- database creation with *mode="rwc"*, e.g. `vallenae.io.PriDatabase.__init__`

Bug fixes

- number field in `vallenae.io.MarkerRecord` optional
- scaling of parametric inputs optional
- keep column order of query if new columns are added to the database
- return array with float32 from `vallenae.io.TraDatabase.read_continuous_wave` (instead of float64)

5.7 0.1.0

2020-01-24

Initial public release

CHAPTER

SIX

TODOS

Todo: Status flag

(The original entry is located in /home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/site-packages/vallenae/io/pridb.py:docstring of vallenae.io.PriDatabase.write_hit, line 10.)

Todo: Status flag

(The original entry is located in /home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/site-packages/vallenae/io/pridb.py:docstring of vallenae.io.PriDatabase.write_parametric, line 10.)

Todo: Status flag

(The original entry is located in /home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/site-packages/vallenae/io/pridb.py:docstring of vallenae.io.PriDatabase.write_status, line 10.)

Todo: Status flag

(The original entry is located in /home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/site-packages/vallenae/io/tradb.py:docstring of vallenae.io.TraDatabase.write, line 9.)

Todo: Remove RMS

(The original entry is located in /home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/site-packages/vallenae/io/datatypes.py:docstring of vallenae.io.TraRecord, line 3.)

Todo: Weak performance, if used with default parameter alpha

(The original entry is located in /home/docs/checkouts/readthedocs.org/user_builds/pyvallenae/envs/0.3.0/lib/python3.7/site-packages/vallenae/__init__.py:docstring of vallenae.timepicker.hinkley, line 22.)

CHAPTER

SEVEN

INDICES AND TABLES

- genindex
- modindex

PYTHON MODULE INDEX

V

INDEX

Symbols

A

C

D

E

F

T

V

W