Package ‘ricu’

July 12, 2022

Title Intensive Care Unit Data with R

Description Focused on (but not exclusive to) data sets hosted on PhysioNet (<https://physionet.org>), 'ricu' provides utilities for download, setup and access of intensive care unit (ICU) data sets. In addition to functions for running arbitrary queries against available data sets, a system for defining clinical concepts and encoding their representations in tabular ICU data is presented.

Version 0.5.3

License GPL-3

Encoding UTF-8

Language en-US


BugReports https://github.com/eth-mds/ricu/issues

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NeedsCompilation no

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Description

Making a dataset available to ricu consists of 3 steps: downloading (download_src()), importing (import_src()) and attaching (attach_src()). While downloading and importing are one-time procedures, attaching of the dataset is repeated every time the package is loaded. Briefly, downloading loads the raw dataset from the internet (most likely in .csv format), importing consists of some preprocessing to make the data available more efficiently and attaching sets up the data for use by the package.
Usage

attach_src(x, ...)

## S3 method for class 'src_cfg'
attach_src(x, assign_env = NULL, data_dir = src_data_dir(x), ...)

## S3 method for class 'character'
attach_src(x, assign_env = NULL, data_dir = src_data_dir(x), ...)

detach_src(x)

setup_src_env(x, ...)

## S3 method for class 'src_cfg'
setup_src_env(x, data_dir = src_data_dir(x), link_env = NULL, ...)

Arguments

x
Data source to attach

... Forwarded to further calls to attach_src()

assign_env, link_env Environment in which the data source will become available

data_dir Directory used to look for fst::fst() files; NULL calls data_dir() using the source name as subdir argument

Details

Attaching a dataset sets up two types of S3 classes: a single src_env object, containing as many src_tbl objects as tables are associated with the dataset. A src_env is an environment with an id_cfg attribute, as well as sub-classes as specified by the data source class_prefix configuration setting (see load_src_cfg()). All src_env objects created by calling attach_src() represent environments that are direct descendants of the data environment and are bound to the respective dataset name within that environment. For more information on src_env and src_tbl objects, refer to new_src_tbl().

If set up correctly, it is not necessary for the user to directly call attach_src(). When the package is loaded, the default data sources (see auto_attach_srcs()) are attached automatically. This default can be controlled by setting as environment variable RICU_SRC_LOAD a comma separated list of data source names before loading the library. Setting this environment variable as

Sys.setenv(RICU_SRC_LOAD = "mimic Demo,eicu Demo")

will change the default of loading both MIMIC-III and eICU, alongside the respective demo datasets, as well as HiRID and AUMC, to just the two demo datasets. For setting an environment variable upon startup of the R session, refer to base::.First.sys().

Attaching a dataset during package namespace loading will both instantiate a corresponding src_env in the data environment and for convenience also assign this object into the package namespace, such that for example the MIMIC-III demo dataset not only is available as ricu::data::mimic Demo,
but also as ricu::mimic_demo (or if the package namespace is attached, simply as mimic_demo). Dataset attaching using `attach_src()` does not need to happen during namespace loading, but can be triggered by the user at any time. If such a convenience link as described above is desired by the user, an environment such as `.GlobalEnv` has to be passed as `assign_env` to `attach_src()`. Data sets are set up as `src_env` objects irrespective of whether all (or any) of the required data is available. If some (or all) data is missing, the user is asked for permission to download in interactive sessions and an error is thrown in non-interactive sessions. Downloading demo datasets requires no further information but access to full-scale datasets (even though they are publicly available) is guarded by access credentials (see `download_src()`).

While `attach_src()` provides the main entry point, `src_env` objects are instantiated by the S3 generic function `setup_src_env()` and the wrapping function serves to catch errors that might be caused by config file parsing issues as to not break attaching of the package namespace. Apart from this, `attach_src()` also provides the convenience linking into the package namespace (or a user-specified environment) described above.

A `src_env` object created by `setup_src_env()` does not directly contain `src_tbl` objects bound to names, but rather an active binding (see `base::makeActiveBinding()`) per table. These active bindings check for availability of required files and evaluate to corresponding `src_tbl` objects if these checks are passed and ask for user input otherwise. As `src_tbl` objects are intended to be read-only, assignment is not possible except for the value `NULL` which resets the internally cached `src_tbl` that is created on first successful access.

### Value

Both `attach_src()` and `setup_src_env()` are called for side effects and therefore return invisibly. While `attach_src()` returns `NULL`, `setup_src_env()` returns the newly created `src_env` object.

### Examples

```r
## Not run:
Sys.setenv(RICU_SRC_LOAD = "")
library(ricu)

ls(envir = data)
exists("mimic_demo")

attach_src("mimic_demo", assign_env = .GlobalEnv)

ls(envir = data)
exists("mimic_demo")

mimic_demo

## End(Not run)
```
ICU datasets such as MIMIC-III or eICU typically represent patients by multiple ID systems such as patient IDs, hospital stay IDs and ICU admission IDs. Even if the raw data is available in only one such ID system, given a mapping of IDs alongside start and end times, it is possible to convert data from one ID system to another. The function `change_id()` provides such a conversion utility, internally either calling `upgrade_id()` when moving to an ID system with higher cardinality and `downgrade_id()` when the target ID system is of lower cardinality.

### Usage

```r
change_id(x, target_id, src, ..., keep_old_id = TRUE, id_type = FALSE)
upgrade_id(x, target_id, src, cols = time_vars(x), ...)
downgrade_id(x, target_id, src, cols = time_vars(x), ...)
```

- `x` icu_tbl object for which to make the id change
- `target_id` The destination id name
- `src` Passed to `as_id_cfg()` and `as_src_env()`
- `...` Passed to `upgrade_id()`/`downgrade_id()`
- `keep_old_id` Logical flag indicating whether to keep the previous ID column
- `id_type` Logical flag indicating whether `target_id` is specified as ID name (e.g. icustay_id on MIMIC) or ID type (e.g. icustay)
- `cols` Column names that require time-adjustment
Details

In order to provide ID system conversion for a data source, the (internal) function `id_map()` must be able to construct an ID mapping for that data source. Constructing such a mapping can be expensive w.r.t. the frequency it might be re-used and therefore, `id_map()` provides caching infrastructure. The mapping itself is constructed by the (internal) function `id_map_helper()`, which is expected to provide source and destination ID columns as well as start and end columns corresponding to the destination ID, relative to the source ID system. In the following example, we request for `mimic_demo`, with ICU stay IDs as source and hospital admissions as destination IDs.

```r
id_map_helper(mimic_demo, "icustay_id", "hadm_id")
```

## # An `id_tbl`: 136 x 4
## # Id var:  `icustay_id`
## icustay_id hadm_id hadm_id_start hadm_id_end
## <int> <int> <drttn> <drttn>
## 1  201006  198503  -3290 mins  9114 mins
## 2  201204  114648   -2 mins   6949 mins
## 3  203766  126949  -1336 mins  8818 mins
## 4  204132  157609   -1 mins  10103 mins
## 5  204201  177678  -368 mins   9445 mins
## ... 132 295043  170883 -10413 mins  31258 mins
## 133 295741  176805   -1 mins   3153 mins
## 134 296804  110244 -1294 mins   4599 mins
## 135 297782  167612   -1 mins   207 mins
## 136 298685  151323   -1 mins  19082 mins
## ... with 126 more rows

Both start and end columns encode the hospital admission windows relative to each corresponding ICU stay start time. It therefore comes as no surprise that most start times are negative (hospital admission typically occurs before ICU stay start time), while end times are often days in the future (as hospital discharge typically occurs several days after ICU admission).

In order to use the ID conversion infrastructure offered by ricu for a new dataset, it typically suffices to provide an `id_cfg` entry in the source configuration (see `load_src_cfg()`), outlining the available ID systems alongside an ordering, as well as potentially a class specific implementation of `id_map_helper()` for the given source class, specifying the corresponding time windows in 1 minute resolution (for every possible pair of IDs).

While both up- and downgrades for `id_tbl` objects, as well as downgrades for `ts_tbl` objects are simple merge operations based on the ID mapping provided by `id_map()`. ID upgrades for `ts_tbl` objects are slightly more involved. As an example, consider the following setting: we have data associated with `hadm_id` IDs and times relative to hospital admission:

```
1 2 3 4 5 6 7 8
---+-----------------------------
3h 10h 18h 27h 35h 43h 52h 59h
```

HADM_1
The mapping of data points from `hadm_id` to `icustay_id` is created as follows: ICU stay end times mark boundaries and all data that is recorded after the last ICU stay ended is assigned to the last ICU stay. Therefore data points 1-3 are assigned to ICU_1, while 4-8 are assigned to ICU_2. Times have to be shifted as well, as timestamps are expected to be relative to the current ID system. Data points 1-3 therefore are assigned to time stamps -4h, 3h and 11h, while data points 4-8 are assigned to -10h, -2h, 6h, 15h and 22h. Implementation-wise, the mapping is computed using an efficient `data.table` rolling join.

**Value**

An object of the same type as `x` with modified IDs.

**Examples**

```r
if (require(mimic.demo)) {
  tbl <- mimic.demo$labevents
  dat <- load_difftime(tbl, itemid == 50809, c("charttime", "valuenum"))
  dat

  change_id(dat, "icustay_id", tbl, keep_old_id = FALSE)
}
```

**Description**

The Laboratory for Computational Physiology (LCP) at MIT hosts several large-scale databases of hospital intensive care units (ICUs), two of which can be either downloaded in full (MIMIC-III and eICU) or as demo subsets (MIMIC-III demo and eICU demo), while a third data set is available only in full (HiRID). While demo data sets are freely available, full download requires credentialed access which can be gained by applying for an account with PhysioNet. Even though registration is required, the described datasets are all publicly available. With AmsterdamUMCdb, a non-PhysioNet hosted data source is available as well. As with the PhysioNet datasets, access is public but has to be granted by the data collectors.
Format

The exported data environment contains all datasets that have been made available to ricu. For datasets that are attached during package loading (see attach_src()), shortcuts to the datasets are set up in the package namespace, allowing the object ricu::data::mimic_demo to be accessed as ricu::mimic_demo (or in case the package namespace has been attached, simply as mimic_demo). Datasets that are made available after the package namespace has been sealed will have their proxy object by default located in .GlobalEnv. Datasets are represented by src_env objects, while individual tables are src_tbl and do not represent in-memory data, but rather data stored on disk, subsets of which can be loaded into memory.

Details

Setting up a dataset for use with ricu requires a configuration object. For the included datasets, configuration can be loaded from

```r
system.file("extdata", "config", "data-sources.json", package = "ricu")
```

by calling load_src_cfg() and for dataset that are external to ricu, additional configuration can be made available by setting the environment variable RICU_CONFIG_PATH (for more information, refer to load_src_cfg()). Using the dataset configuration object, data can be downloaded (download_src()), imported (import_src()) and attached (attach_src()). While downloading and importing are one-time procedures, attaching of the dataset is repeated every time the package is loaded. Briefly, downloading loads the raw dataset from the internet (most likely in .csv format), importing consists of some preprocessing to make the data available more efficiently (by converting it to .fst format) and attaching sets up the data for use by the package. For more information on the individual steps, refer to the respective documentation pages.

A dataset that has been successfully made available can interactively be explored by typing its name into the console and individual tables can be inspected using the $ function. For example for the MIMIC-III demo dataset and the icustays table, this gives

```r
mimic_demo
```

```r
## <mimic_demo_env[25]>
## admissions        callout       caregivers     charitevents
## [129 x 19]         [77 x 24]    [7,567 x 4]    [758,355 x 15]
## cptevents          d_cpt         d_icd_diagnoses d_icd_procedures
## [1,579 x 12]       [134 x 9]    [14,567 x 4]    [3,882 x 4]
## d_items            d_labitems    datetimeevents  diagnoses_icd
## [12,487 x 10]      [753 x 6]    [15,551 x 14]   [1,761 x 5]
## drgcodes           icustays      inputevents_cv  inputevents_mv
## [297 x 8]          [136 x 12]   [34,799 x 22]   [13,224 x 31]
## labevents          microbiologyevents outputevents        patients
## [76,074 x 9]       [2,003 x 16] [11,320 x 13]   [100 x 8]
## prescriptions procedureevents_mv procedures_icd  services
## [10,398 x 19]      [753 x 25]  [506 x 5]        [163 x 6]
## transfers
## [524 x 13]
```
mimic_demo$icustays

## # <mimic_tbl>: [136 x 12]
## # ID options: subject_id (patient) < hadm_id (hadm) < icustay_id (icustay)
## # Defaults: `intime` (index), `last_careunit` (val)
## # Time vars: `intime`, `outtime`
## row_id subject_id hadm_id icustay_id dbsource first_careunit last_careunit
## <int> <int> <int> <int> <chr> <chr> <chr>
## 1 12742 10006 142345 206504 carevue MICU MICU
## 2 12747 10011 105331 232110 carevue MICU MICU
## 3 12749 10013 165520 264446 carevue MICU MICU
## 4 12754 10017 199207 204881 carevue CCU CCU
## 5 12755 10019 177759 228977 carevue MICU MICU
## ... 132 42676 44083 198330 286428 metavis~ CCU CCU
## 133 42691 44154 174245 217724 metavis~ MICU MICU
## 134 42709 44212 163189 239396metavis~ MICU MICU
## 135 42712 44222 192189 238186 metavis~ CCU CCU
## 136 42714 44228 103379 217992 metavis~ SICU SICU
## ... with 126 more rows, and 5 more variables: first_wardid <int>,
## last_wardid <int>, intime <dttm>, outtime <dttm>, los <dbl>

Table subsets can be loaded into memory for example using the `base::subset()` function, which uses non-standard evaluation (NSE) to determine a row-subsetting. This design choice stems from the fact that some tables can have on the order of 10^8 rows, which makes loading full tables into memory an expensive operation. Table subsets loaded into memory are represented as `data.table` objects. Extending the above example, if only ICU stays corresponding to the patient with `subject_id == 10124` are of interest, the respective data can be loaded as

```r
subset(mimic_demo$icustays, subject_id == 10124)
```

```r
## row_id subject_id hadm_id icustay_id dbsource first_careunit last_careunit
## 1: 12863 10124 182664 261764 carevue MICU MICU
## 2: 12864 10124 170883 222779 carevue MICU MICU
## 3: 12865 10124 170883 295043 carevue CCU CCU
## 4: 12866 10124 170883 237528 carevue MICU MICU
## first_wardid last_wardid intime outtime los
## 1: 23 23 2192-03-29 10:46:51 2192-04-01 06:36:00 2.8258
## 3: 7 7 2192-04-24 02:29:49 2192-04-26 23:59:45 2.8958
```  

Much care has been taken to make `ricu` extensible to new datasets. For example the publicly available ICU database `AmsterdamUMCdb` provided by the Amsterdam University Medical Center, currently is not part of the core datasets of `ricu`, but code for integrating this dataset is available on `github.`
MIMIC-III

The Medical Information Mart for Intensive Care (MIMIC) database holds detailed clinical data from roughly 60,000 patient stays in Beth Israel Deaconess Medical Center (BIDMC) intensive care units between 2001 and 2012. The database includes information such as demographics, vital sign measurements made at the bedside (~1 data point per hour), laboratory test results, procedures, medications, caregiver notes, imaging reports, and mortality (both in and out of hospital). For further information, please refer to the MIMIC-III documentation.

The corresponding demo dataset contains the full data of a randomly selected subset of 100 patients from the patient cohort with conformed in-hospital mortality. The only notable data omission is the noteevents table, which contains unstructured text reports on patients.

eICU

More recently, Philips Healthcare and LCP began assembling the eICU Collaborative Research Database as a multi-center resource for ICU data. Combining data of several critical care units throughout the continental United States from the years 2014 and 2015, this database contains de-identified health data associated with over 200,000 admissions, including vital sign measurements, care plan documentation, severity of illness measures, diagnosis information, and treatment information. For further information, please refer to the eICU documentation.

For the demo subset, data associated with ICU stays for over 2,500 unit stays selected from 20 of the larger hospitals is included. An important caveat that applied to the eICU-based datasets is considerable variability among the large number of hospitals in terms of data availability.

HiRID

Moving to higher time-resolution, HiRID is a freely accessible critical care dataset containing data relating to almost 34,000 patient admissions to the Department of Intensive Care Medicine of the Bern University Hospital, Switzerland. The dataset contains de-identified demographic information and a total of 681 routinely collected physiological variables, diagnostic test results and treatment parameters, collected during the period from January 2008 to June 2016. Dependent on the type of measurement, time resolution can be on the order of 2 minutes.

AmsterdamUMCdb

With similar time-resolution (for vital-sign measurements) as HiRID, AmsterdamUMCdb contains data from 23,000 admissions of adult patients from 2003-2016 to the department of Intensive Care, of Amsterdam University Medical Center. In total, nearly $10^9$ individual observations consisting of vitals signs, clinical scoring systems, device data and lab results data, as well as nearly $5*10^6$ million medication entries, alongside de-identified demographic information corresponding to the 20,000 individual patients is spread over 7 tables.

MIMIC-IV

With the recent v1.0 release of MIMIC-IV, experimental support has been added in ricu. Building on the success of MIMIC-III, this next iteration contains data on patients admitted to an ICU or the emergency department between 2008 - 2019 at BIDMC. Therefore, relative to MIMIC-III, patients admitted prior to 2008 (whose data is stored in a Care Vue-based system) has been removed, while data onward of 2012 has been added. This simplifies data queries considerably, as
the CareVue/MetaVision data split in MIMIC-III no longer applies. While addition of ED data is planned, this is not part of the initial v1.0 release and currently is not supported by ricu. For further information, please refer to the MIMIC-III documentation.

References


Elbers, Dr. P.W.G. (Amsterdam UMC) (2019): AmsterdamUMCdb v1.0.2. DANS. https://doi.org/10.17026/dans-22u-f8vd


---

data_dir

**File system utilities**

**Description**

Determine the location where to place data meant to persist between individual sessions.
Usage

data_dir(subdir = NULL, create = TRUE)

src_data_dir(srcs)

auto_attach_srcs()

config_paths()

get_config(name, cfg_dirs = config_paths(), combine_fun = c, ...)

set_config(x, name, dir = file.path("inst", "extdata", "config"), ...)

Arguments

subdir A string specifying a directory that will be made sure to exist below the data directory.
create Logical flag indicating whether to create the specified directory
srcs Character vector of data source names, an object for which an src_name() method is defined or an arbitrary-length list thereof.
name File name of the configuration file (.json will be appended)
cfg_dirs Character vector of directories searched for config files
combine_fun If multiple files are found, a function for combining returned lists
... Passed to jsonlite::read_json() or jsonlite::write_json()
x Object to be written
dir Directory to write the file to (created if non-existent)

Details

For data, the default location depends on the operating system as

<table>
<thead>
<tr>
<th>Platform</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linux</td>
<td>~/.local/share/ricu</td>
</tr>
<tr>
<td>macOS</td>
<td>~/Library/Application Support/ricu</td>
</tr>
<tr>
<td>Windows</td>
<td>%LOCALAPPDATA%/ricu</td>
</tr>
</tbody>
</table>

If the default storage directory does not exists, it will only be created upon user consent (requiring an interactive session).

The environment variable RICU_DATA_PATH can be used to overwrite the default location. If desired, this variable can be set in an R startup file to make it apply to all R sessions. For example, it could be set within:

- A project-local .Renviron;
- The user-level .Renviron;
- A file at 
  \$(R \text{RHOME})/\text{etc}/\text{Renviron.site}\) 

Any directory specified as environment variable will recursively be created. 

Data source directories typically are sub-directories to \texttt{data_dir()} named the same as the respective dataset. For demo datasets corresponding to \texttt{mimic} and \texttt{eicu}, file location however deviates from this scheme. The function \texttt{src_data_dir()} is used to determine the expected data location of a given dataset.

Configuration files used both for data source configuration, as well as for dictionary definitions potentially involve multiple files that are read and merged. For that reason, \texttt{get_config()} will iterate over directories passed as \texttt{cfg_dirs} and look for the specified file (with suffix .json appended and might be missing in some of the queried directories). All found files are read by \textbf{\texttt{jsonlite::read_json()}} and the resulting lists are combined by reduction with the binary function passed as \texttt{combine_fun}.

With default arguments, \texttt{get_config()} will simply concatenate lists corresponding to files found in the default config locations as returned by \texttt{config_paths()}: first the directory specified by the environment variable \texttt{RICU_CONFIG_PATH} (if set), followed by the directory at

\begin{verbatim}
system.file("extdata", "config", package = "ricu")
\end{verbatim}

Further arguments are passed to \texttt{jsonlite::read_json()}, which is called with slightly modified defaults: \texttt{simplifyVector = TRUE}, \texttt{simplifyDataFrame = FALSE} and \texttt{simplifyMatrix = FALSE}.

The utility function \texttt{set_config()} writes the list passed as \texttt{x} to file \texttt{dir/name.json}, using \texttt{jsonlite::write_json()} also with slightly modified defaults (which can be overridden by passing arguments as \texttt{...}): \texttt{null = "null"}, \texttt{auto_unbox = TRUE} and \texttt{pretty = TRUE}.

Whenever the package namespace is attached, a summary of dataset availability is printed using the utility functions \texttt{auto_attach_srcs()} and \texttt{src_data_avail()}. While the former simply returns a character vector of data sources that are configured for automatically being set up on package loading, the latter returns a summary of the number of available tables per dataset. \texttt{is_data_avail()} returns a named logical vector indicating which data sources have all required data available.

\section*{Value}

Functions \texttt{data_dir()}, \texttt{src_data_dir()} and \texttt{config_paths()} return file paths as character vectors, \texttt{auto_attach_srcs()} returns a character vector of data source names, \texttt{src_data_avail()} returns a \texttt{data.frame} describing availability of data sources and \texttt{is_data_avail()} a named logical vector. Configuration utilities \texttt{get_config()} and \texttt{set_config()} read and write list objects to/from JSON format.

\section*{Examples}

\begin{verbatim}
Sys.setenv(RICU_DATA_PATH = tempdir())
identical(data_dir(), tempdir())

dir.exists(file.path(tempdir(), "some_subdir"))
some_subdir <- data_dir("some_subdir")
dir.exists(some_subdir)
\end{verbatim}
download_src

Data download utilities

Description
Making a dataset available to ricu consists of 3 steps: downloading (`download_src()`), importing (`import_src()`) and attaching (`attach_src()`). While downloading and importing are one-time procedures, attaching of the dataset is repeated every time the package is loaded. Briefly, downloading loads the raw dataset from the internet (most likely in `.csv` format), importing consists of some preprocessing to make the data available more efficiently (by converting it to `.fst` format) and attaching sets up the data for use by the package.

Usage
```r
download_src(x, data_dir = src_data_dir(x), ...)  
## S3 method for class 'src_cfg'
download_src(x, data_dir = src_data_dir(x), tables = NULL, force = FALSE, ...)
## S3 method for class 'aumc_cfg'
download_src(x, data_dir = src_data_dir(x), tables = NULL, force = FALSE, token = NULL, verbose = TRUE, ...)
## S3 method for class 'character'
download_src(x, data_dir = src_data_dir(x), tables = NULL, force = FALSE, user = NULL, pass = NULL, verbose = TRUE,
```
Arguments

- **x**: Object specifying the source configuration
- **data_dir**: Destination directory where the downloaded data is written to.
- **force**: Logical flag; if TRUE, existing data will be re-downloaded
- **token**: Download token for AmsterdamUMCdb (see 'Details')
- **verbose**: Logical flag indicating whether to print progress information
- **user, pass**: PhysioNet credentials; if NULL and environment variables RICU_PHYSIONET_USER/RICU_PHYSIONET_PASS are not set, user input is required

Details

Downloads by ricu are focused data hosted by PhysioNet and tools are currently available for downloading the datasets MIMIC-III, eICU and HiRID (see data). While credentials are required for downloading any of the three datasets, demo dataset for both MIMIC-III and eICU are available without having to log in. Even though access to full dataset is credentialled, the datasets are in fact publicly available. For setting up an account, please refer to the registration form.

PhysioNet credentials can either be entered in an interactive session, passed as function arguments user/pass or as environment variables RICU_PHYSIONET_USER/RICU_PHYSIONET_PASS. For setting environment variables on session startup, refer to `base::.First.sys()` and for setting environment variables in general, refer to `base::Sys.setenv()` If the openssl package is available, SHA256 hashes of downloaded files are verified using `openssl::sha256()`.

Demo datasets MIMIC-III demo and eICU demo can either be installed as R packages directly by running

```r
c(package = c("mimic.demo", "eicu.demo"),
repos = "https://eth-mds.github.io/physionet-demo"
)```

or downloaded and imported using `download_src()` and `import_src()`. Furthermore, ricu specifies mimic.demo and eicu.demo as Suggests dependencies therefore, passing dependencies = TRUE when calling `install.packages()` for installing ricu, this will automatically install the demo datasets as well.

While the included data downloadees are intended for data hosted by PhysioNet, `download_src()` is an S3 generic function that can be extended to new classes. Method dispatch is intended to occur on objects that inherit from or can be coerced to `src_cfg`. For more information on data source configuration, refer to `load_src_cfg()`.

As such, with the addition of the AmsterdamUMCdb dataset, which unfortunately is not hosted on PhysioNet. A separate downloader for that dataset is available as well. Currently this requires
both availability of the CRAN package xml2, as well as the command line utility 7zip. Furthermore, data access has to be requested and for non-interactive download the download token has to be made available as environment variable RICU_AUMC_TOKEN or passed as token argument to download_src(). The download token can be retrieved from the URL provided when granted access as by extracting the string followed by token=:

https://example.org/?s=download&token=0c27af59-72d1-0349-aa59-00000a8076d9

would translate to

Sys.setenv(RICU_AUMC_TOKEN = "0c27af59-72d1-0349-aa59-00000a8076d9")

If the dependencies outlined above are not fulfilled, download and archive extraction can be carried out manually into the corresponding folder and import_src() can be run.

Value
Called for side effects and returns NULL invisibly.

Examples

## Not run:
dir <- tempdir()
list.files(dir)
download_datasource("mimic_demo", data_dir = dir)
list.files(dir)
unlink(dir, recursive = TRUE)

## End(Not run)

Description

ICU data as handled by ricu is mostly comprised of time series data and as such, several utility functions are available for working with time series data in addition to a class dedicated to representing time series data (see ts_tbl()). Some terminology to begin with: a time series is considered to have gaps if, per (combination of) ID variable value(s), some time steps are missing. Expanding and collapsing mean to change between representations where time steps are explicit or encoded as interval with start and end times. For sliding window-type operations, slide() means to iterate over time-windows, slide_index() means to iterate over certain time-windows, selected relative to the index and hop() means to iterate over time-windows selected in absolute terms.
Usage

expand(
  x,
  start_var = index_var(x),
  end_var = NULL,
  step_size = time_step(x),
  new_index = start_var,
  keep_vars = NULL,
  aggregate = FALSE
)

collapse(
  x,
  id_vars = NULL,
  index_var = NULL,
  start_var = "start",
  end_var = "end",
  env = NULL,
  as_win_tbl = TRUE,
  ...
)

has_no_gaps(x)

has_gaps(...)

is_regular(x)

fill_gaps(x, limits = collapse(x), start_var = "start", end_var = "end")

remove_gaps(x)

slide(x, expr, before, after = hours(0L), ...)

slide_index(x, expr, index, before, after = hours(0L), ...)

hop(
  x,
  expr,
  windows,
  full_window = FALSE,
  lwr_col = "min_time",
  upr_col = "max_time",
  left_closed = TRUE,
  right_closed = TRUE,
  eval_env = NULL,
  ...
)
Arguments

- **x**: ts_tbl object to use
- **start_var, end_var**: Name of the columns that represent lower and upper windows bounds
- **step_size**: Controls the step size used to interpolate between `start_var` and `end_var`
- **new_index**: Name of the new index column
- **keep_vars**: Names of the columns to hold onto
- **aggregate**: Function for aggregating values in overlapping intervals
- **id_vars, index_var**: ID and index variables
- **env**: Environment used as parent to the environment used to evaluate expressions
- **as_win_tbl**: Logical flag indicating whether to return a win_tbl or an id_tbl
- **limits**: Passed to `hop_quo()` and ultimately to `data.table::[[()]`
- **expr**: Expression (quoted for `_qu` and unquoted otherwise) to be evaluated over each window
- **before, after**: Time span to look back/forward
- **index**: A vector of times around which windows are spanned (relative to the index)
- **windows**: An icu_tbl defining the windows to span
- **full_window**: Logical flag controlling how the situation is handled where the sliding window extends beyond available data
- **lwr_col, upr_col**: Names of columns (in `windows`) of lower/upper window bounds
- **left_closed, right_closed**: Logical flag indicating whether intervals are closed (default) or open.
- **eval_env**: Environment in which `expr` is substituted; NULL resolves to the environment in which `expr` was created

Details

A gap in a ts_tbl object is a missing time step, i.e. a missing entry in the sequence `seq(min(index), max(index), by = interval)` in at least one group (as defined by `id_vars()`), where the extrema are calculated per group. In this case, `has_gaps()` will return TRUE. The function `is_regular()` checks whether the time series has no gaps, in addition to the object being sorted and unique (see `is_sorted()` and `is_unique()`). In order to transform a time series containing gaps into a regular time series, `fill_gaps()` will fill missing time steps with NA values in all `data_vars()` columns, while `remove_gaps()` provides the inverse operation of removing time steps that consist of NA values in `data_vars()` columns.

An `expand()` operation performed on an object inheriting from `data.table` yields a ts_tbl where time-steps encoded by columns `start_var` and `end_var` are made explicit with values in `keep_vars` being appropriately repeated. The inverse operation is available as `collapse()`, which groups
by `id_vars`, represents `index_var` as group-wise extrema in two new columns `start_var` and `end_var` and allows for further data summary using `...`. An aspect to keep in mind when applying `expand()` to a `win_tbl` object is that values simply are repeated for all time-steps that fall into a given validity interval. This gives correct results when a `win_tbl` for example contains data on infusions as rates, but might not lead to correct results when infusions are represented as drug amounts administered over a given time-span. In such a scenario it might be desirable to evenly distribute the total amount over the corresponding time steps (currently not implemented).

Sliding-window type operations are available as `slide()`, `slide_index()` and `hop()` (function naming is inspired by the CRAN package slider). The most flexible of the three, `hop` takes as input a `ts_tbl` object `x` containing the data, an `id_tbl` object `windows`, containing for each ID the desired windows represented by two columns `lwr_col` and `upr_col`, as well as an expression `expr` to be evaluated per window. At the other end of the spectrum, `slide()` spans windows for every ID and available time-step using the arguments `before` and `after`, while `slide_index()` can be seen as a compromise between the two, where windows are spanned for certain time-points, specified by `index`.

Value

Most functions return `ts_tbl` objects with the exception of `has_gaps()`, `has_no_gaps()` and `is_regular()`, which return logical flags.

Examples

```r
tbl <- ts_tbl(x = 1:5, y = hours(1:5), z = hours(2:6), val = rnorm(5),
              index_var = "y")
exp <- expand(tbl, "y", "z", step_size = 1L, new_index = "y",
            keep_vars = c("x", "val"))
col <- collapse(exp, start_var = "y", end_var = "z", val = unique(val))
all.equal(tbl, col, check.attributes = FALSE)

tbl <- ts_tbl(x = rep(1:5, 1:5), y = hours(sequence(1:5)), z = 1:15)
win <- id_tbl(x = c(3, 4), a = hours(c(2, 1)), b = hours(c(3, 4)))
hop(tbl, list(z = sum(z)), win, lwr_col = "a", upr_col = "b")
slide_index(tbl, list(z = sum(z)), hours(c(4, 5)), before = hours(2))
slide(tbl, list(z = sum(z)), before = hours(2))

tbl <- ts_tbl(x = rep(3:4, 3:4), y = hours(sequence(3:4)), z = 1:7)
has_no_gaps(tbl)
is_regular(tbl)

tbl[1, 2] <- hours(2)
has_no_gaps(tbl)
is_regular(tbl)

tbl[6, 2] <- hours(2)
has_no_gaps(tbl)
is_regular(tbl)
```
id_tbl

Tabular ICU data classes

Description

In order to simplify handling or tabular ICU data, ricu provides S3 classes, id_tbl, ts_tbl, and win_tbl. These classes essentially consist of a data.table object, alongside some meta data and S3 dispatch is used to enable more natural behavior for some data manipulation tasks. For example, when merging two tables, a default for the by argument can be chosen more sensibly if columns representing patient ID and timestamp information can be identified.

Usage

id_tbl(..., id_vars = 1L)

is_id_tbl(x)

as_id_tbl(x, id_vars = NULL, by_ref = FALSE)

ts_tbl(..., id_vars = 1L, index_var = NULL, interval = NULL)

is_ts_tbl(x)

as_ts_tbl(x, id_vars = NULL, index_var = NULL, interval = NULL, by_ref = FALSE)

win_tbl(..., id_vars = NULL, index_var = NULL, interval = NULL, dur_var = NULL)

is_win_tbl(x)

as_win_tbl(
  x,
  id_vars = NULL,
  index_var = NULL,
  interval = NULL,
  dur_var = NULL,
  by_ref = FALSE
)

## S3 method for class 'id_tbl'
as.data.table(x, keep.rownames = FALSE, by_ref = FALSE, ...)

## S3 method for class 'id_tbl'
as.data.frame(x, row.names = NULL, optional = FALSE, ...)

validate_tbl(x)
id_tbl

Arguments

... forwarded to `data.table::data.table()` or generic consistency
id_vars Column name(s) to be used as id column(s)
x Object to query/operate on
by_ref Logical flag indicating whether to perform the operation by reference
index_var Column name of the index column
interval Time series interval length specified as scalar-valued `difftime` object
dur_var Column name of the duration column
keep.rownames Default is FALSE. If TRUE, adds the input object's names as a separate column named "rn". keep.rownames = "id" names the column "id" instead.
row.names NULL or a character vector giving the row names for the data frame. Missing values are not allowed.
optional logical. If TRUE, setting row names and converting column names (to syntactic names: see `make.names`) is optional. Note that all of R's base package as.data.frame() methods use optional only for column names treatment, basically with the meaning of `data.frame(*, check.names = !optional)`. See also the make.names argument of the matrix method.

Details

The introduced classes are designed for several often encountered data scenarios:

- **id_tbl** objects can be used to represent static (with respect to relevant time scales) patient data such as patient age and such an object is simply a data.table combined with a non-zero length character vector valued attribute marking the columns tracking patient ID information (id_vars). All further columns are considered as data_vars.

- **ts_tbl** objects are used for grouped time series data. A data.table object again is augmented by attributes, including a non-zero length character vector identifying patient ID columns (id_vars), a string, tracking the column holding time-stamps (index_var) and a scalar `difftime` object determining the time-series step size interval. Again, all further columns are treated as data_vars.

- **win_tbl**: In addition to representing grouped time-series data as does a ts_tbl, win_tbl objects also encode a validity interval for each time-stamped measurement (as dur_var). This can for example be useful when a drug is administered at a certain infusion rate for a given time period.

Owing to the nested structure of required meta data, ts_tbl inherits from id_tbl and win_tbl from ts_tbl. Furthermore, both classes inherit from data.table. As such, data.table reference semantics are available for some operations, indicated by presence of a by_ref argument. At default, value, by_ref is set to FALSE as this is in line with base R behavior at the cost of potentially incurring unnecessary data copies. Some care has to be taken when passing by_ref = TRUE and enabling by reference operations as this can have side effects (see examples).

For instantiating ts_tbl objects, both index_var and interval can be automatically determined if not specified. For the index column, the only requirement is that a single `difftime` column is present, while for the time step, the minimal difference between two consecutive observations...
is chosen (and all differences are therefore required to be multiples of the minimum difference). Similarly, for a win_tbl, exactly two difftime columns are required where the first is assumed to be corresponding to the index_var and the second to the dur_var.

Upon instantiation, the data might be rearranged: columns are reordered such that ID columns are moved to the front, followed by the index column and a `data.table::key()` is set on meta columns, causing rows to be sorted accordingly. Moving meta columns to the front is done for reasons of convenience for printing, while setting a key on meta columns is done to improve efficiency of subsequent transformations such as merging or grouped operations. Furthermore, NA values in either ID or index columns are not allowed and therefore corresponding rows are silently removed. Coercion between id_tbl and ts_tbl (and win_tbl) by default keeps intersecting attributes fixed and new attributes are by default inferred as for class instantiation. Each class comes with a class-specific implementation of the S3 generic function validate_tbl() which returns TRUE if the object is considered valid or a string outlining the type of validation failure that was encountered. Validity requires

1. inheriting from data.table and unique column names
2. for id_tbl that all columns specified by the non-zero length character vector holding onto the id_vars specification are available
3. for ts_tbl that the string-valued index_var column is available and does not intersect with id_vars and that the index column obeys the specified interval.
4. for win_tbl that the string-valued dur_var corresponds to a difftime vector and is not among the columns marked as index or ID variables

Finally, inheritance can be checked by calling `is_id_tbl()` and `is_ts_tbl()`. Note that due to ts_tbl inheriting from id_tbl, `is_id_tbl()` returns TRUE for both id_tbl and ts_tbl objects (and similarly for win_tbl), while `is_ts_tbl()` only returns TRUE for ts_tbl objects.

Value

Constructors id_tbl()/ts_tbl()/win_tbl(), as well as coercion functions as_id_tbl()/as_ts_tbl()/as_win_tbl() return id_tbl/ts_tbl/win_tbl objects respectively, while inheritance testers is_id_tbl()/is_ts_tbl()/is_win_tbl() return logical flags and validate_tbl() returns either TRUE or a string describing the validation failure.

Relationship to data.table

Both id_tbl and ts_tbl inherit from data.table and as such, functions intended for use with data.table objects can be applied to id_tbl and ts_tbl as well. But there are some caveats: Many functions introduced by data.table are not S3 generic and therefore they would have to be masked in order to retain control over how they operate on objects inheriting form data.table. Take for example the function `data.table::setnames()`, which changes column names by reference. Using this function, the name of an index column of an id_tbl object can me changed without updating the attribute marking the column as such and thusly leaving the object in an inconsistent state. Instead of masking the function setnames(), an alternative is provided as rename_cols(). In places where it is possible to seamlessly insert the appropriate function (such as `base::names<-()` or `base::colnames<-()`) and the responsibility for not using `data.table::setnames()` in a way that breaks the id_tbl object is left to the user.
Owing to data.table heritage, one of the functions that is often called on id_tbl and ts_tbl objects is base S3 generic \([\text{base::[]}()]\). As this function is capable of modifying the object in a way that makes it incompatible with attached meta data, an attempt is made at preserving as much as possible and if all fails, a data.table object is returned instead of an object inheriting form id_tbl. If for example the index column is removed (or modified in a way that makes it incompatible with the interval specification) from a ts_tbl, an id_tbl is returned. If however the ID column is removed the only sensible thing to return is a data.table (see examples).

### Examples

```r
tbl <- id_tbl(a = 1:10, b = rnorm(10))
is_id_tbl(tbl)
is_ts_tbl(tbl)

dat <- data.frame(a = 1:10, b = hours(1:10), c = rnorm(10))
tbl <- as_ts_tbl(dat, "a")
is_id_tbl(tbl)
is_ts_tbl(tbl)

tmp <- as_id_tbl(tbl)
is_ts_tbl(tbl)
is_ts_tbl(tmp)

tmp <- as_id_tbl(tbl, by_ref = TRUE)
is_ts_tbl(tbl)
is_ts_tbl(tmp)

tbl <- id_tbl(a = 1:10, b = rnorm(10))
names(tbl) <- c("c", "b")
tbl

tbl <- id_tbl(a = 1:10, b = rnorm(10))
validate_tbl(data.table::setnames(tbl, c("c", "b")))

tbl <- id_tbl(a = 1:10, b = rnorm(10))
validate_tbl(rename_cols(tbl, c("c", "b")))

tbl <- ts_tbl(a = rep(1:2, each = 5), b = hours(rep(1:5, 2)), c = rnorm(10))
tbl[, c("a", "c"), with = FALSE]
tbl[, c("b", "c"), with = FALSE]
tbl[, list(a, b = as.double(b), c)]
```

### Description

The two data classes id_tbl and ts_tbl, used by ricu to represent ICU patient data, consist of a data.table alongside some meta data. This includes marking columns that have special
meaning and for data representing measurements ordered in time, the step size. The following utility functions can be used to extract columns and column names with special meaning, as well as query a ts_tbl object regarding its time series related meta data.

Usage

\texttt{id_vars(x)}
\texttt{id_var(x)}
\texttt{id_col(x)}
\texttt{index_var(x)}
\texttt{index_col(x)}
\texttt{dur_var(x)}
\texttt{dur_col(x)}
\texttt{dur_unit(x)}
\texttt{meta_vars(x)}
\texttt{data_vars(x)}
\texttt{data_var(x)}
\texttt{data_col(x)}
\texttt{interval(x)}
\texttt{time_unit(x)}
\texttt{time_step(x)}
\texttt{time_vars(x)}

Arguments

\texttt{x} Object to query

Details

The following functions can be used to query an object for columns or column names that represent a distinct aspect of the data:

- \texttt{id_vars()}: ID variables are one or more column names with the interaction of corresponding columns identifying a grouping of the data. Most commonly this is some sort of patient identifier.
• \texttt{id_var()}: This function either fails or returns a string and can therefore be used in case only
a single column provides grouping information.
• \texttt{id_col()}: Again, in case only a single column provides grouping information, this column
can be extracted using this function.
• \texttt{index_var()}: Suitable for use as index variable is a column that encodes a temporal ordering
of observations as \texttt{difftime} vector. Only a single column can be marked as index variable
and this function queries a \texttt{ts_tbl} object for its name.
• \texttt{index_col()}: similarly to \texttt{id_col()}, this function extracts the column with the given des-
ignation. As a \texttt{ts_tbl} object is required to have exactly one column marked as index, this
function always returns for \texttt{ts_tbl} objects (and fails for \texttt{id_tbl} objects).
• \texttt{dur_var()}: For \texttt{win_tbl} objects, this returns the name of the column encoding the data
validity interval.
• \texttt{dur_col()}: Similarly to \texttt{index_col()}, this returns the \texttt{difftime} vector corresponding to the
dur_var().
• \texttt{meta_vars()}: For \texttt{ts_tbl} objects, meta variables represent the union of ID and index vari-
ables (for \texttt{win_tbl}, this also includes the \texttt{dur_var()}), while for \texttt{id_tbl} objects meta variables
consist pf ID variables.
• \texttt{data_vars()}: Data variables on the other hand are all columns that are not meta variables.
• \texttt{data_var()}: Similarly to \texttt{id_var()}, this function either returns the name of a single data
variable or fails.
• \texttt{data_col()}: Building on \texttt{data_var()}, in situations where only a single data variable is
present, it is returned or if multiple data column exists, an error is thrown.
• \texttt{time_vars()}: Time variables are all columns in an object inheriting from \texttt{data.frame} that
are of type \texttt{difftime}. Therefore in a \texttt{ts_tbl} object the index column is one of (potentially)
several time variables. For a \texttt{win_tbl}, however the \texttt{dur_var()} is not among the \texttt{time_vars()}.
• \texttt{interval()}: The time series interval length is represented a scalar valued \texttt{difftime} object.
• \texttt{time_unit()}: The time unit of the time series interval, represented by a string such as "hours"
or "mins" (see \texttt{difftime}).
• \texttt{time_step()}: The time series step size represented by a numeric value in the unit as returned
by \texttt{time_unit()}.  

\textbf{Value}

Mostly column names as character vectors, in case of \texttt{id_var()}, \texttt{index_var()}, \texttt{data_var()} and
\texttt{time_unit()} of length 1, else of variable length. Functions \texttt{id_col()}, \texttt{index_col()} and \texttt{data_col()}
return table columns as vectors, while \texttt{interval()} returns a scalar valued \texttt{difftime} object and
\texttt{time_step()} a number.

\textbf{Examples}

```r
tbl <- id_tbl(a = rep(1:2, each = 5), b = rep(1:5, 2), c = rnorm(10),
              id_vars = c("a", "b"))

id_vars(tbl)
tryCatch(id_col(tbl), error = function(...) "no luck")
```
import_src

### Description

Making a dataset available to ricu consists of 3 steps: downloading (`download_src()`) and attaching (`attach_src()`). While downloading and importing are one-time procedures, attaching of the dataset is repeated every time the package is loaded. Briefly, downloading loads the raw dataset from the internet (most likely in .csv format), importing consists of some preprocessing to make the data available more efficiently and attaching sets up the data for use by the package.

### Usage

```r
import_src(x, ...)
```

```r
## S3 method for class 'src_cfg'
import_src(
  x,
  data_dir = src_data_dir(x),
  tables = NULL,
  force = FALSE,
  verbose = TRUE,
  ...
)
```

```r
## S3 method for class 'aumc_cfg'
import_src(x, ...)
```

```r
## S3 method for class 'character'
```
import_src(x, 
  data_dir = src_data_dir(x), 
  tables = NULL, 
  force = FALSE, 
  verbose = TRUE, 
  cleanup = FALSE, 
  ... 
)

import_tbl(x, ...)

## S3 method for class 'tbl_cfg'
import_tbl(x, 
  data_dir = src_data_dir(x), 
  progress = NULL, 
  cleanup = FALSE, 
  ... 
)

### Arguments

- **x**: Object specifying the source configuration
- **...**: Passed to downstream methods (finally to readr::read_csv/readr::read_csv_chunked)/generic consistency
- **data_dir**: Destination directory where the downloaded data is written to.
- **tables**: Character vector specifying the tables to download. If NULL, all available tables are downloaded.
- **force**: Logical flag; if TRUE, existing data will be re-downloaded
- **verbose**: Logical flag indicating whether to print progress information
- **cleanup**: Logical flag indicating whether to remove raw csv files after conversion to fst
- **progress**: Either NULL or a progress bar as created by progress::progress_bar()

### Details

In order to speed up data access operations, ricu does not directly use the PhysioNet provided CSV files, but converts all data to fst::fst() format, which allows for random row and column access. Large tables are split into chunks in order to keep memory requirements reasonably low.

The one-time step per dataset of data import is fairly resource intensive: depending on CPU and available storage system, it will take on the order of an hour to run to completion and depending on the dataset, somewhere between 50 GB and 75 GB of temporary disk space are required as tables are uncompressed, in case of partitioned data, rows are reordered and the data again is saved to a storage efficient format.

The S3 generic function import_src() performs import of an entire data source, internally calling the S3 generic function import_tbl() in order to perform import of individual tables. Method
dispatch is intended to occur on objects inheriting from src_cfg and tbl_cfg respectively. Such objects can be generated from JSON based configuration files which contain information such as table names, column types or row numbers, in order to provide safety in parsing of .csv files. For more information on data source configuration, refer to load_src_cfg().

Current import capabilities include re-saving a .csv file to .fst at once (used for smaller sized tables), reading a large .csv file using the readr::read_csv_chunked() API, while partitioning chunks and reassembling sub-partitions (used for splitting a large file into partitions), as well as re-partitioning an already partitioned table according to a new partitioning scheme. Care has been taken to keep the maximal memory requirements for this reasonably low, such that data import is feasible on laptop class hardware.

Value

Called for side effects and returns NULL invisibly.

Examples

```r
## Not run:
dir <- tempdir()
list.files(dir)
download_src("mimic_demo", dir)
list.files(dir)
import_src("mimic_demo", dir)
list.files(dir)
unlink(dir, recursive = TRUE)

## End(Not run)
```

---

**load_concepts**

Load concept data

Description

Concept objects are used in ricu as a way to specify how a clinical concept, such as heart rate can be loaded from a data source. Building on this abstraction, load_concepts() powers concise loading of data with data source specific preprocessing hidden away from the user, thereby providing a data source agnostic interface to data loading. At default value of the argument merge_data, a tabular data structure (either a ts_tbl or an id_tbl, depending on what kind of concepts are requested), inheriting from data.table, is returned, representing the data in wide format (i.e. returning concepts as columns).
load_concepts

Usage

load_concepts(x, ...)

## S3 method for class 'character'
load_concepts(
  x,
  src = NULL,
  concepts = NULL,
  ..., 
  dict_name = "concept-dict",
  dict_dirs = NULL
)

## S3 method for class 'concept'
load_concepts(
  x,
  src = NULL,
  aggregate = NULL,
  merge_data = TRUE,
  verbose = TRUE,
  ...
)

## S3 method for class 'cncept'
load_concepts(x, aggregate = NULL, ..., progress = NULL)

## S3 method for class 'num_cncept'
load_concepts(x, aggregate = NULL, ..., progress = NULL)

## S3 method for class 'unt_cncept'
load_concepts(x, aggregate = NULL, ..., progress = NULL)

## S3 method for class 'fct_cncept'
load_concepts(x, aggregate = NULL, ..., progress = NULL)

## S3 method for class 'lgl_cncept'
load_concepts(x, aggregate = NULL, ..., progress = NULL)

## S3 method for class 'rec_cncept'
load_concepts(
  x,
  aggregate = NULL,
  patient_ids = NULL,
  id_type = "icustay",
  interval = hours(1L),
  ..., 
  progress = NULL
)
## S3 method for class 'item'
load_concepts(
  x,
  patient_ids = NULL,
  id_type = "icustay",
  interval = hours(1L),
  progress = NULL,
  ...
)

## S3 method for class 'itm'
load_concepts(
  x,
  patient_ids = NULL,
  id_type = "icustay",
  interval = hours(1L),
  ...
)

### Arguments

- **x**: Object specifying the data to be loaded
- **...**: Passed to downstream methods
- **src**: A character vector, used to subset the concepts; NULL means no subsetting
- **concepts**: The concepts to be used or NULL in which case `load_dictionary()` is called
- **dict_name, dict_dirs**: In case not concepts are passed as concepts, these are forwarded to `load_dictionary()` as name and file arguments
- **aggregate**: Controls how data within concepts is aggregated
- **merge_data**: Logical flag, specifying whether to merge concepts into wide format or return a list, each entry corresponding to a concept
- **verbose**: Logical flag for muting informational output
- **progress**: Either NULL, or a progress bar object as created by `progress::progress_bar`
- **patient_ids**: Optional vector of patient ids to subset the fetched data with
- **id_type**: String specifying the patient id type to return
- **interval**: The time interval used to discretize time stamps with, specified as `base::difftime()` object

### Details

In order to allow for a large degree of flexibility (and extensibility), which is much needed owing to considerable heterogeneity presented by different data sources, several nested S3 classes are involved in representing a concept and `load_concepts()` follows this hierarchy of classes recursively when resolving a concept. An outline of this hierarchy can be described as
load_concepts

- concept: contains many cncpt objects (of potentially differing sub-types), each comprising of some meta-data and an item object
- item: contains many itm objects (of potentially differing sub-types), each encoding how to retrieve a data item.

The design choice for wrapping a vector of cncpt objects with a container class concept is motivated by the requirement of having several different sub-types of cncpt objects (all inheriting from the parent type cncpt), while retaining control over how this homogeneous w.r.t. parent type, but heterogeneous w.r.t. sub-type vector of objects behaves in terms of S3 generic functions.

Value

An id_tbl/ts_tbl or a list thereof, depending on loaded concepts and the value passed as merge_data.

Concept

Top-level entry points are either a character vector, which is used to subset a concept object or an entire concept dictionary, or a concept object. When passing a character vector as first argument, the most important further arguments at that level control from where the dictionary is taken (dict_name or dict_dirs). At concept level, the most important additional arguments control the result structure: data merging can be disabled using merge_data and data aggregation is governed by the aggregate argument.

Data aggregation is important for merging several concepts into a wide-format table, as this requires data to be unique per observation (i.e. by either id or combination of id and index). Several value types are acceptable as aggregate argument, the most important being FALSE, which disables aggregation, NULL, which auto-determines a suitable aggregation function or a string which is ultimately passed to dt_gforce() where it identifies a function such as sum(), mean(), min() or max(). More information on aggregation is available as aggregate(). If the object passed as aggregate is scalar, it is applied to all requested concepts in the same way. In order to customize aggregation per concept, a named object (with names corresponding to concepts) of the same length as the number of requested concepts may be passed.

Under the hood, a concept object comprises of several cncpt objects with varying sub-types (for example num_cncpt, representing continuous numeric data or fct_cncpt representing categorical data). This implementation detail is of no further importance for understanding concept loading and for more information, please refer to the concept documentation. The only argument that is introduced at cncpt level is progress, which controls progress reporting. If called directly, the default value of NULL yields messages, sent to the terminal. Internally, if called from load_concepts() at concept level (with verbose set to TRUE), a progress::progress_bar is set up in a way that allows nested messages to be captured and not interrupt progress reporting (see msg_progress()).

Item

A single cncpt object contains an item object, which in turn is composed of several itm objects with varying sub-types, the relationship item to itm being that of concept to cncpt and the rationale for this implementation choice is the same as previously: a container class used representing a vector of objects of varying sub-types, all inheriting form a common super-type. For more information on the item class, please refer to the relevant documentation. Arguments introduced at item level include patient_ids, id_type and interval. Acceptable values for interval are
scalar-valued `base::difftime()` objects (see also helper functions such as `hours()`) and this argument essentially controls the time-resolution of the returned time-series. Of course, the limiting factor raw time resolution which is on the order of hours for data sets like MIMIC-III or eICU but can be much higher for a data set like HiRID. The argument `id_type` is used to specify what kind of id system should be used to identify different time series in the returned data. A data set like MIMIC-III, for example, makes possible the resolution of data to 3 nested ID systems:

- `patient (subject_id)`: identifies a person
- `hadm (hadm_id)`: identifies a hospital admission (several of which are possible for a given person)
- `icustay (icustay_id)`: identifies an admission to an ICU and again has a one-to-many relationship to hadm.

Acceptable argument values are strings that match ID systems as specified by the data source configuration. Finally, `patient_ids` is used to define a patient cohort for which data can be requested. Values may either be a vector of IDs (which are assumed to be of the same type as specified by the `id_type` argument) or a tabular object inheriting from `data.frame`, which must contain a column named after the data set-specific ID system identifier (for MIMIC-III and an `id_type` argument of `hadm`, for example, that would be `hadm_id`).

### Extensions

The presented hierarchy of S3 classes is designed with extensibility in mind: while the current range of functionality covers settings encountered when dealing with the included concepts and datasets, further data sets and/or clinical concepts might necessitate different behavior for data loading. For this reason, various parts in the cascade of calls to `load_concepts()` can be adapted for new requirements by defining new sub-classes to `cncpt` or `itm` and providing methods for the generic function `load_concepts()` specific to these new classes. At `cncpt` level, method dispatch defaults to `load_concepts.cncpt()` if no method specific to the new class is provided, while at `itm` level, no default function is available.

Roughly speaking, the semantics for the two functions are as follows:

- `cncpt`: Called with arguments `x` (the current `cncpt` object), `aggregate` (controlling how aggregation per time-point and ID is handled), ... (further arguments passed to downstream methods) and `progress` (controlling progress reporting), this function should be able to load and aggregate data for the given concept. Usually this involves extracting the `itm` object and calling `load_concepts()` again, dispatching on the `itm` class with arguments `x` (the given `itm`), arguments passed as ... , as well as `progress`.

- `itm`: Called with arguments `x` (the current object inheriting from `itm`, `patient_ids` (NULL or a patient ID selection), `id_type` (a string specifying what ID system to retrieve), and `interval` (the time series interval), this function actually carries out the loading of individual data items, using the specified ID system, rounding times to the correct interval and subsetting on patient IDs. As return value, on object of class as specified by the `target` entry is expected and all data_vars() should be named consistently, as data corresponding to multiple `itm` objects concatenated in row-wise fashion as in `base::rbind()`.

### Examples

```r
if (require(mimic.demo)) {
}```
load_concepts("glu", "mimic_demo")

gluc <- concept("gluc",
    item("mimic_demo", "labevents", "itemid", list(c(50809L, 50931L)))
  )

identical(load_concepts(gluc), dat)

class(dat)
class(load_concepts(c("sex", "age"), "mimic_demo"))

load_dictionary

Load concept dictionaries

Description

Data concepts can be specified in JSON format as a concept dictionary which can be read and parsed into concept/item objects. Dictionary loading can either be performed on the default included dictionary or on a user- specified custom dictionary. Furthermore, a mechanism is provided for adding concepts and/or data sources to the existing dictionary (see the Details section).

Usage

load_dictionary(
    src = NULL,
    concepts = NULL,
    name = "concept-dict",
    cfg_dirs = NULL
  )

calendar_availability(dict = NULL, include_rec = FALSE, ...)

explain_dictionary(
    dict = NULL,
    cols = c("name", "category", "description"),
    ...
  )

Arguments

src

NULL or the name of one or several data sources

concepts

A character vector used to subset the concept dictionary or NULL indicating no subsetting

name

Name of the dictionary to be read

cfg_dirs

File name of the dictionary
dict A dictionary (concept object) or NULL
include_rec Logical flag indicating whether to include rec_concpt concepts as well
... Forwarded to load_dictionary() in case NULL is passed as dict argument
cols Columns to include in the output of explain_dictionary()

Details

A default dictionary is provided at

```r
system.file(
    file.path("extdata", "config", "concept-dict.json"),
    package = "ricu"
)
```

and can be loaded in to an R session by calling `get_config("concept-dict")`. The default dictionary can be extended by adding a file `concept-dict.json` to the path specified by the environment variable `RICU_CONFIG_PATH`. New concepts can be added to this file and existing concepts can be extended (by adding new data sources). Alternatively, `load_dictionary()` can be called on non-default dictionaries using the `file` argument.

In order to specify a concept as JSON object, for example the numeric concept for glucose, is given by

```
{
  "glu": {
    "unit": "mg/dL",
    "min": 0,
    "max": 1000,
    "description": "glucose",
    "category": "chemistry",
    "sources": {
      "mimic_demo": [
        {
          "ids": [50809, 50931],
          "table": "labevents",
          "sub_var": "itemid"
        }
      ]
    }
  }
}
```

Using such a specification, constructors for `cncpt` and `itm` objects are called either using default arguments or as specified by the JSON object, with the above corresponding to a call like

```r
concept(
  name = "glu",
  items = item(
```
The arguments src and concepts can be used to only load a subset of a dictionary by specifying a character vector of data sources and/or concept names.

A summary of item availability for a set of concepts can be created using `concept_availability()`. This produces a logical matrix with TRUE entries corresponding to concepts where for the given data source, at least a single item has been defined. If data is loaded for a combination of concept and data source, where the corresponding entry is FALSE, this will yield either a zero-row id_tbl object or an object inheriting form id_tbl where the column corresponding to the concept is NA throughout, depending on whether the concept was loaded alongside other concepts where data is available or not.

Whether to include rec_cncpt concepts in the overview produced by `concept_availability()` can be controlled via the logical flag `include_rec`. A recursive concept is considered available simply if all its building blocks are available. This can, however lead to slightly confusing output as a recursive concept might not strictly depend on one of its sub-concepts but handle such missingness by design. In such a scenario, the availability summary might report FALSE even though data can still be produced.

**Value**

A concept object containing several data concepts as cncpt objects.

**Examples**

```r
if (require(mimic.demo)) {
  head(load_dictionary("mimic_demo"))
  load_dictionary("mimic_demo", c("glu", "lact"))
}
```

---

**load_id**

*Load data as id_tbl or ts_tbl objects*

**Description**

Building on functionality provided by `load_src()` and `load_difftime()`, `load_id()` and `load_ts()` load data from disk as id_tbl and ts_tbl objects respectively. Over `load_difftime()` both `load_id()` and `load_ts()` provide a way to specify `meta_vars()` (as id_var and index_var arguments), as well as an interval size (as interval argument) for time series data.
Usage

load_id(x, ...)

## S3 method for class 'src_tbl'
load_id(
  x,
  rows,
  cols = colnames(x),
  id_var = id_vars(x),
  interval = hours(1L),
  time_vars = ricu::timeVars(x),
  ...
)

## S3 method for class 'character'
load_id(x, src, ...)

## S3 method for class 'itm'
load_id(
  x,
  cols = colnames(x),
  id_var = id_vars(x),
  interval = hours(1L),
  time_vars = ricu::timeVars(x),
  ...
)

## S3 method for class 'fun_itm'
load_id(x, ...)

## Default S3 method:
load_id(x, ...)

load_ts(x, ...)

## S3 method for class 'src_tbl'
load_ts(
  x,
  rows,
  cols = colnames(x),
  id_var = id_vars(x),
  index_var = ricu::index_var(x),
  interval = hours(1L),
  time_vars = ricu::timeVars(x),
  ...
)

## S3 method for class 'character'
load_ts(x, src, ...)  

## S3 method for class 'itm'  
load_ts(x, ...)  
  
## S3 method for class 'fun_itm'  
load_ts(x, ...)  

## Default S3 method:  
load_ts(x, ...)  
load_win(x, ...)  

## S3 method for class 'src_tbl'  
load_win(x, ...)  

## S3 method for class 'character'  
load_win(x, src, ...)  

## S3 method for class 'itm'  
load_win(x, ...)
## S3 method for class 'fun_itm'
load_win(x, ...)

## Default S3 method:
load_win(x, ...)

### Arguments

- **x**: Object for which to load data
- **...**: Generic consistency
- **rows**: Expression used for row subsetting (NSE)
- **cols**: Character vector of column names
- **id_var**: The column defining the id of ts_tbl and id_tbl objects
- **interval**: The time interval used to discretize time stamps with, specified as `base::difftime()`
- **time_vars**: Character vector enumerating the columns to be treated as timestamps and thus returned as `base::difftime()` vectors
- **src**: Passed to `as_src_tbl()` in order to determine the data source
- **index_var**: The column defining the index of ts_tbl objects
- **dur_var**: The column used for determining durations
- **dur_is_end**: Logical flag indicating whether to use durations as-is or to calculated them by subtracting the `index_var` column

### Details

While for `load_difftime()` the ID variable can be suggested, the function only returns a best effort at fulfilling this request. In some cases, where the data does not allow for the desired ID type, data is returned using the ID system (among all available ones for the given table) with highest cardinality. Both `load_id()` and `load_ts()` are guaranteed to return an object with `id_vars()` set as requested by the `id_var` argument. Internally, the change of ID system is performed by `change_id()`.

Additionally, while times returned by `load_difftime()` are in 1 minute resolution, the time series step size can be specified by the `interval` argument when calling `load_id()` or `load_ts()`. This rounding and potential change of time unit is performed by `change_interval()` on all columns specified by the `time_vars` argument. All time stamps are relative to the origin provided by the ID system. This means that for an `id_var` corresponding to hospital IDs, times are relative to hospital admission.

When `load_id()` (or `load_ts()` is called on `itm` objects instead of `src_tbl` objects that can be coerced to `src_tbl`). The row-subsetting is performed according the the specification as provided by the `itm` object. Furthermore, at default settings, columns are returned as required by the `itm` object and `id_var` (as well as `index_var`) are set accordingly if specified by the `itm` or set to default values for the given `src_tbl` object if not explicitly specified.
**Value**

An id_tbl or a ts_tbl object.

**Examples**

```r
if (require(mimic.demo)) {
  load_id("admissions", "mimic_demo", cols = "admission_type")

  dat <- load_ts(mimic_demo$labevents, itemid %in% c(50809L, 50931L),
                  cols = c("itemid", "valuenum"))

  glu <- new_itm(src = "mimic_demo", table = "labevents",
                  sub_var = "itemid", ids = c(50809L, 50931L))

  identical(load_ts(glu), dat)
}
```

---

**Description**

Data loading involves a cascade of S3 generic functions, which can individually be adapted to the specifics of individual data sources. At the lowest level, `load_src` is called, followed by `load_difftime()`. Functions up the chain, are described in `load_id()`.

**Usage**

```r
load_src(x, ...)
```

```
## S3 method for class 'src_tbl'
load_src(x, rows, cols = colnames(x), ...)

## S3 method for class 'character'
load_src(x, src, ...)

load_difftime(x, ...)

## S3 method for class 'mimic_tbl'
load_difftime(  
x,  
rows,  
cols = colnames(x),  
id_hint = id_vars(x),  
time_vars = ricu::time_vars(x),  
...  
)
```
## S3 method for class 'eicu_tbl'
load_difftime(
  x,
  rows,
  cols = colnames(x),
  id_hint = id_vars(x),
  time_vars = ricu::time_vars(x),
  ...
)

## S3 method for class 'hirid_tbl'
load_difftime(
  x,
  rows,
  cols = colnames(x),
  id_hint = id_vars(x),
  time_vars = ricu::time_vars(x),
  ...
)

## S3 method for class 'aumc_tbl'
load_difftime(
  x,
  rows,
  cols = colnames(x),
  id_hint = id_vars(x),
  time_vars = ricu::time_vars(x),
  ...
)

## S3 method for class 'miiv_tbl'
load_difftime(
  x,
  rows,
  cols = colnames(x),
  id_hint = id_vars(x),
  time_vars = ricu::time_vars(x),
  ...
)

## S3 method for class 'character'
load_difftime(x, src, ...)

### Arguments

- **x**
  - Object for which to load data

- **...**
  - Generic consistency
**Details**

A function extending the S3 generic `load_src()` is expected to load a subset of rows/columns from a tabular data source. While the column specification is provided as character vector of column names, the row subsetting involves non-standard evaluation (NSE). Data-sets that are included with ricu are represented by `prt` objects, which use `rlang::eval_tidy()` to evaluate NSE expressions. Furthermore, `prt` objects potentially represent tabular data split into partitions and row-subsetting expressions are evaluated per partition (see the `part_safe` flag in `prt::subset.prt()`). The return value of `load_src()` is expected to be of type `data.table`.

Timestamps are represented differently among the included data sources: while MIMIC-III and HiRID use absolute date/times, eICU provides temporal information as minutes relative to ICU admission. Other data sources, such as the ICU dataset provided by Amsterdam UMC, opt for relative times as well, but not in minutes since admission, but in milliseconds. In order to smoothen out such discrepancies, the next function in the data loading hierarchy is `load_difftime()`. This function is expected to call `load_src()` in order to load a subset of rows/columns from a table stored on disk and convert all columns that represent timestamps (as specified by the argument `time_vars`) into `base::difftime()` vectors using `mins` as time unit.

The returned object should be of type `id_tbl`, with the ID vars identifying the ID system the times are relative to. If for example all times are relative to ICU admission, the ICU stay ID should be returned as ID column. The argument `id_hint` may suggest an ID type, but if in the raw data, this ID is not available, `load_difftime()` may return data using a different ID system. In MIMIC-III, for example, data in the `labevents` table is available for `subject_id` (patient ID) or `hadm_id` (hospital admission ID). If data is requested for `icustay_id` (ICU stay ID), this request cannot be fulfilled and data is returned using the ID system with the highest cardinality (among the available ones). Utilities such as `change_id()` can the later be used to resolve data to `icustay_id`.

**Value**

A `data.table` object.

**Examples**

```r
if (require(mimic.demo)) {
  tbl <- mimic_demo$labevents
  col <- c("charttime", "value")

  load_src(tbl, itemid == 50809)

  colnames(
    load_src("labevents", "mimic_demo", itemid == 50809, cols = col)
  )
}
```
load_diff_time(tbl, itemid == 50809)

colnames(
  load_diff_time(tbl, itemid == 50809, col)
)

id_vars(
  load_diff_time(tbl, itemid == 50809, id_hint = "icustay_id")
)

id_vars(
  load_diff_time(tbl, itemid == 50809, id_hint = "subject_id")
)

---

load_src_cfg

Load configuration for a data source

Description

For a data source to be accessible by ricu, a configuration object inheriting from the S3 class `src_cfg` is required. Such objects can be generated from JSON based configuration files, using `load_src_cfg()`. Information encoded by this configuration object includes available ID systems (mainly for use in `change_id()`), default column names per table for columns with special meaning (such as index column, value columns, unit columns, etc.), as well as a specification used for initial setup of the dataset which includes file names and column names alongside their data types.

Usage

```r
load_src_cfg(src = NULL, name = "data-sources", cfg_dirs = NULL)
```

Arguments

- `src` (Optional) name(s) of data sources used for subsetting
- `name` String valued name of a config file which will be looked up in the default config directories
- `cfg_dirs` Additional directory/ies to look for configuration files

Details

Configuration files are looked for as files name with added suffix `.json` starting with the directory (or directories) supplied as `cfg_dirs` argument, followed by the directory specified by the environment variable `RICU_CONFIG_PATH`, and finally in `extdata/config` of the package install directory. If files with matching names are found in multiple places they are concatenated such that in cases of name clashes, the earlier hits take precedent over the later ones. The following JSON code blocks show excerpts of the config file available at
A data source configuration entry in a config file starts with a name, followed by optional entries class_prefix and further (variable) key-value pairs, such as an URL. For more information on class_prefix, please refer to the end of this section. Further entries include id_cfg and tables which are explained in more detail below. As outline, this gives for the data source mimic_demo, the following JSON object:

```json
{
  "name": "mimic_demo",
  "class_prefix": ["mimic_demo", "mimic"],
  "url": "https://physionet.org/files/mimiciii-demo/1.4",
  "id_cfg": {
    ... 
  },
  "tables": {
    ... 
  }
}
```

The id_cfg entry is used to specify the available ID systems for a data source and how they relate to each other. An ID system within the context of ricu is a patient identifier of which typically several are present in a data set. In MIMIC-III, for example, three ID systems are available: patient IDs (subject_id), hospital admission IDs (hadm_id) and ICU stay IDs (icustay_id). Furthermore there is a one-to-many relationship between subject_id and hadm_id, as well as between hadm_id and icustay_id. Required for defining an ID system are a name, a position entry which orders the ID systems by their cardinality, a table entry, alongside column specifications id, start and end, which define how the IDs themselves, combined with start and end times can be loaded from a table. This gives the following specification for the ICU stay ID system in MIMIC-III:

```json
{
  "icustay": {
    "id": "icustay_id",
    "position": 3,
    "start": "intime",
    "end": "outtime",
    "table": "icustays"
  }
}
```

Tables are defined by a name and entries files, defaults, and cols, as well as optional entries num_rows and partitioning. As files entry, a character vector of file names is expected. For all of MIMIC-III a single .csv file corresponds to a table, but for example for HiRID, some tables are distributed in partitions. The defaults entry consists of key-value pairs, identifying columns in a table with special meaning, such as the default index column or the set of all columns that represent timestamps. This gives as an example for a table entry for the chartevents table in MIMIC-III a JSON object like:
```json
{
"chartevents": {
    "files": "CHARTEVENTS.csv.gz",
    "defaults": {
      "index_var": "charttime",
      "val_var": "valuenum",
      "unit_var": "valueuom",
      "time_vars": ["charttime", "storetime"]
    },
    "num_rows": 330712483,
    "cols": {
      ...
    },
    "partitioning": {
      "col": "itemid",
      "breaks": [127, 210, 425, 549, 643, 741, 1483, 3458, 3695, 8440, 8553, 220274, 223921, 224085, 224859, 227629]
    }
  }
}
```

The optional `num_rows` entry is used when importing data (see `import_src()`) as a sanity check, which is not performed if this entry is missing from the data source configuration. The remaining table entry, `partitioning`, is optional in the sense that if it is missing, the table is not partitioned and if it is present, the table will be partitioned accordingly when being imported (see `import_src()`). In order to specify a partitioning, two entries are required, `col` and `breaks`, where the former denotes a column and the latter a numeric vector which is used to construct intervals according to which `col` is binned. As such, currently `col` is required to be of numeric type. A partitioning entry as in the example above will assign rows corresponding to `itemid` 1 through 126 to partition 1, 127 through 209 to partition 2 and so on up to partition 17.

Column specifications consist of a name and a `spec` entry alongside a name which determines the column name that will be used by rici. The `spec` entry is expected to be the name of a column specification function of the `readr` package (see `readr::cols()`) and all further entries in a `cols` object are used as arguments to the `readr` column specification. For the admissions table of MIMIC-III the columns `hadm_id` and `admittime` are represented by:

```json
{
  ...
  "hadm_id": {
    "name": "HADM_ID",
    "spec": "col_integer"
  },
  "admittime": {
    "name": "ADMITTIME",
    "spec": "col_datetime",
    "format": "%Y-%m-%d %H:%M:%S"
  }
  ...
}
```
load_src_cfg

Internally, a `src_cfg` object consists of further S3 classes, which are instantiated when loading a JSON source configuration file. Functions for creating and manipulating `src_cfg` and related objects are marked `internal` but a brief overview is given here nevertheless:

- **src_cfg**: wraps objects `id_cfg`, `col_cfg` and optionally `tbl_cfg`
- **id_cfg**: contains information in ID systems and is created from `id_cfg` entries in config files
- **col_cfg**: contains column default settings represented by `defaults` entries in table configuration blocks
- **tbl_cfg**: used when importing data and therefore encompasses information in `files`, `num_rows` and `cols` entries of table configuration blocks

A `src_cfg` can be instantiated without corresponding `tbl_cfg` but consequently cannot be used for data import (see `import_src()`). In that sense, table config entries `files` and `cols` are optional as well with the restriction that the data source has to be already available in `.fst` format.

An example for such a slimmed down config file is available at

```r
system.file("extdata", "config", "demo-sources.json", package = "ricu")
```

The `class_prefix` entry in a data source configuration is used to create sub-classes to `src_cfg`, `id_cfg`, `col_cfg` and `tbl_cfg` classes and passed on to constructors of `src_env` (`new_src_env()`) and `src_tbl` (`new_src_tbl()`) objects. As an example, for the above `class_prefix` value of `c("mimic_demo", "mimic")`, the corresponding `src_cfg` will be assigned classes `c("mimic_demo_cfg", "mimic_cfg", "src_cfg")` and consequently the `src_tbl` objects will inherit from `"mimic_demo_tbl", "mimic_tbl"` and `"src_tbl"`. This can be used to adapt the behavior of involved S3 generic functions to specifics of the different data sources. An example for this is how `load_difftime()` uses theses sub-classes to smoothen out different time-stamp representations. Furthermore, such a design was chosen with extensibility in mind. Currently, `download_src()` is designed around data sources hosted on PhysioNet, but in order to include a dataset external to PhysioNet, the `download_src()` generic can simply be extended for the new class.

**Value**

A list of data source configurations as `src_cfg` objects.

**Examples**

```r
cfg <- load_src_cfg("mimic_demo")
str(cfg, max.level = 1L)
cfg <- cfg[["mimic_demo"]]
str(cfg, max.level = 1L)

cols <- as_col_cfg(cfg)
index_var(head(cols))
time_vars(head(cols))
as_id_cfg(cfg)
```
### Utility functions

**Description**

Several utility functions exported for convenience.

**Usage**

- `min_or_na(x)`
- `max_or_na(x)`
- `is_val(x, val)`
- `not_val(x, val)`
- `is_true(x)`
- `is_false(x)`
- `last_elem(x)`
- `first_elem(x)`

**Arguments**

- `x` Object to use
- `val` Value to compare against or to use as replacement

**Details**

The two functions `min_or_na()` and `max_or_na()` overcome a design choice of `base::min()` (or `base::max()`) that can yield undesirable results. If called on a vector of all missing values with `na.rm = TRUE`, `Inf` (and `-Inf` respectively) are returned. This is changed to returning a missing value of the same type as `x`.

The functions `is_val()` and `not_val()` (as well as analogously `is_true()` and `is_false()`) return logical vectors of the same length as the value passed as `x`, with non-base R semanticists of comparing against `NA`: instead of returning `c(NA, TRUE)` for `c(NA, 5) == 5`, `is_val()` will return `c(FALSE, TRUE)`. Passing `NA` as `val` might lead to unintended results but no warning is thrown.

Finally, `first Elem()` and `last Elem()` has the same semantics as `utils::head()` and `utils::tail()` with `n = 1L` and `replace_na()` will replace all occurrences of `NA` in `x` with `val` and can be called on both objects inheriting from `data.table` in which case internally `data.table::setnafill()` is called or other objects.
Value

- `min_or_na()`/`max_or_na()`: scalar-valued extrema of a vector
- `is_val()`/`not_val()`/`is_true()`/`is_false()`: Logical vector of the same length as the object passed as `x`
- `first_elem()`/`last_elem()`: single element of the object passed as `x`
- `replace_na()`: modified version of the object passed as `x`

Examples

```r
some_na <- c(NA, sample(1:10, 5), NA)
identical(min(some_na, na.rm = TRUE), min_or_na(some_na))

all_na <- rep(NA, 5)
min(all_na, na.rm = TRUE)
min_or_na(all_na)

is_val(some_na, 5)
some_na == 5

is_val(some_na, NA)
identical(first_elem(letters), head(letters, n = 1L))
identical(last_elem(letters), tail(letters, n = 1L))

replace_na(some_na, 11)
replace_na(all_na, 11)
replace_na(1:5, 11)

tbl <- ts_tbl(a = 1:10, b = hours(1:10), c = c(NA, 1:5, NA, 8:9, NA))
res <- replace_na(tbl, 0)
identical(tbl, res)
```

Description

In order to not interrupt progress reporting by a `progress::progress_bar`, messages are wrapped with class `msg_progress` which causes them to be captured printed after progress bar completion. This function is intended to be used when signaling messages in callback functions.

Usage

```r
msg_progress(..., envir = parent.frame())

fmt_msg(msg, envir = parent.frame(), indent = 0L, exdent = 0L)
```
Arguments

... Passed to `base::.makeMessage()`

`envir` Environment in this objects from `msg` are evaluated

`msg` String valued message

`indent`, `exdent` Vector valued and mapped to `fansi::strwrap2_ctl()`

Value

Called for side effects and returns `NULL` invisibly.

Examples

```r
msg_progress("Foo", "bar")

capt_fun <- function(x) {
  message("captured: ", conditionMessage(x))
}

tryCatch(msg_progress("Foo", "bar"), msg_progress = capt_fun)
```

---

**new_cncpt**

*Data Concepts*

Description

Concept objects are used in `ricu` as a way to specify how a clinical concept, such as heart rate can be loaded from a data source and are mainly consumed by `load_concepts()`. Several functions are available for constructing (and related auxiliary) objects either from code or by parsing a JSON formatted concept dictionary using `load_dictionary()`.

Usage

```r
new_cncpt(
  name,
  items,
  description = name,
  category = NA_character_,
  aggregate = NULL,
  ...,  
  target = "ts_tbl",
  class = "num_cncpt"
)

is_cncpt(x)

init_cncpt(x, ...)
```
new_cncpt

## S3 method for class 'num_cncpt'
init_cncpt(x, unit = NULL, min = NULL, max = NULL, ...)

## S3 method for class 'unt_cncpt'
init_cncpt(x, unit = NULL, min = NULL, max = NULL, ...)

## S3 method for class 'fct_cncpt'
init_cncpt(x, levels, ...)

## S3 method for class 'cncpt'
init_cncpt(x, ...)

## S3 method for class 'rec_cncpt'
init_cncpt(
  x,
  callback = paste0("rename_data_var\(\text{"}, x[\"name\]], \".\)\")
)

new_concept(x)

concept(...)

is_concept(x)

as_concept(x)

Arguments

name The name of the concept
items Zero or more itm objects
description String-valued concept description
category String-valued category
aggregate NULL or a string denoting a function used to aggregate per id and if applicable per time step
... Further specification of the cncpt object (passed to init_cncpt())
target The target object yielded by loading
class NULL or a string-valued sub-class name used for customizing concept behavior
x Object to query/dispatch on
unit A string, specifying the measurement unit of the concept (can be NULL)
min, max Scalar valued; defines a range of plausible values for a numeric concept
levels A vector of possible values a categorical concept may take on
callback Name of a function to be called on the returned data used for data cleanup operations
interval Time interval used for data loading; if NULL, the respective interval passed as argument to load_concepts() is taken

Details

In order to allow for a large degree of flexibility (and extensibility), which is much needed owing to considerable heterogeneity presented by different data sources, several nested S3 classes are involved in representing a concept. An outline of this hierarchy can be described as

- concept: contains many cncpt objects (of potentially differing sub-types), each comprising of some meta-data and an item object
- item: contains many itm objects (of potentially differing sub-types), each encoding how to retrieve a data item.

The design choice for wrapping a vector of cncpt objects with a container class concept is motivated by the requirement of having several different sub-types of cncpt objects (all inheriting from the parent type cncpt), while retaining control over how this homogeneous w.r.t. parent type, but heterogeneous w.r.t. sub-type vector of objects behaves in terms of S3 generic functions.

Each individual cncpt object contains the following information: a string-valued name, an item vector containing itm objects, a string-valued description (can be missing), a string-valued category designation (can be missing), a character vector-valued specification for an aggregation function and a target class specification (e.g. id_tbl or ts_tbl). Additionally, a sub-class to cncpt has to be specified, each representing a different data-scenario and holding further class-specific information.

The following sub-classes to cncpt are available:

- num_cncpt: The most widely used concept type is intended for concepts representing numerical measurements. Additional information that can be specified includes a string-valued unit specification, alongside a plausible range which can be used during data loading.
- fct_cncpt: In case of categorical concepts, such as sex, a set of factor levels can be specified, against which the loaded data is checked.
- lgl_cncpt: A special case of fct_cncpt, this allows only for logical values (TRUE, FALSE and NA).
- rec_cncpt: More involved concepts, such as a SOFA score can pull in other concepts. Recursive concepts can build on other recursive concepts up to arbitrary recursion depth. Owing to the more complicated nature of such concepts, a callback function can be specified which is used in data loading for concept-specific post-processing steps.
- unt_cncpt: A recent (experimental) addition which inherits from num_cncpt but instead of manual unit conversion, leverages

Class instantiation is organized in the same fashion as for item objects: concept() maps vector-valued arguments to new_cncpt(), which internally calls the S3 generic function init_cncpt(), while new_concept() instantiates a concept object from a list of cncpt objects (created by calls to new_cncpt()). Coercion is only possible from list and cncpt, by calling as_concept() and inheritance can be checked using is_concept() or is_cncpt().

Value

Constructors and coercion functions return cncpt and concept objects, while inheritance tester functions return logical flags.
Examples

```r
if (require(mimic.demo)) {
  gluc <- concept("glu",
                  item("mimic_demo", "labevents", "itemid", list(c(50809L, 50931L)),
                  description = "glucose", category = "chemistry",
                  unit = "mg/dL", min = 0, max = 1000
  )

  is_concept(gluc)
  identical(gluc, load_dictionary("mimic_demo", "glu"))

  gl1 <- new_cncpt("glu",
                  item("mimic_demo", "labevents", "itemid", list(c(50809L, 50931L)),
                  description = "glucose"
  )

  is_cncpt(gl1)
  is_concept(gl1)

  conc <- concept(c("glu", "lact"),
                  list(
                    item("mimic_demo", "labevents", "itemid", list(c(50809L, 50931L)),
                    item("mimic_demo", "labevents", "itemid", 50813L)
                  ),
                  description = c("glucose", "lactate")
  )

  conc

  identical(as_concept(gl1), conc[1L])
}
```

---

**Description**

Item objects are used in ricu as a way to specify how individual data items corresponding to clinical concepts (see also `concept()`), such as heart rate can be loaded from a data source. Several functions are available for constructing item (and related auxiliary) objects either from code or by parsing a JSON formatted concept dictionary using `load_dictionary()`.

**Usage**

```r
new_itm(src, ..., interval = NULL, target = NA_character_, class = "sel_itm")

is_itm(x)
```
init_itm(x, ...)
## S3 method for class 'sel_itm'
init_itm(x, table, sub_var, ids, callback = "identity_callback", ...)
## S3 method for class 'hrd_itm'
init_itm(x, table, sub_var, ids, callback = "identity_callback", ...)
## S3 method for class 'col_itm'
init_itm(x, table, unit_val = NULL, callback = "identity_callback", ...)
## S3 method for class 'rgx_itm'
init_itm(x, table, sub_var, regex, callback = "identity_callback", ...)
## S3 method for class 'fun_itm'
init_itm(x, callback, ...)
## S3 method for class 'itm'
init_itm(x, ..., )

new_item(x)
item(...)
as_item(x)
is_item(x)

Arguments

src  The data source name
...
Further specification of the itm object (passed to init_itm())
interval  A default data loading interval (either specified as scalar difftime or string such as "00:01:00")
target  Item target class (e.g. "id_tbl"), NA indicates no specific class requirement
class  Sub class for customizing itm behavior
x  Object to query/dispatch on
table  Name of the table containing the data
sub_var  Column name used for subsetting
ids  Vector of ids used to subset table rows. If NULL, all rows are considered corresponding to the data item
callback  Name of a function to be called on the returned data used for data cleanup operations (or a string that evaluates to a function)
unit_val  String valued unit to be used in case no unit_var is available for the given table
regex  String-valued regular expression which will be evaluated by base::grepl() with ignore.case = TRUE
Details

In order to allow for a large degree of flexibility (and extensibility), which is much needed owing to considerable heterogeneity presented by different data sources, several nested S3 classes are involved in representing a concept. An outline of this hierarchy can be described as

- **concept**: contains many `concept` objects (of potentially differing sub-types), each comprising of some meta-data and an `item` object
- **item**: contains many `item` objects (of potentially differing sub-types), each encoding how to retrieve a data item.

The design choice for wrapping a vector of `item` objects with a container class `item` is motivated by the requirement of having several different sub-types of `item` objects (all inheriting from the parent type `item`), while retaining control over how this homogeneous w.r.t. parent type, but heterogeneous w.r.t. sub-type vector of objects behaves in terms of S3 generic functions.

The following sub-classes to `item` are available, each representing a different data-scenario:

- **sel_item**: The most widely used item class is intended for the situation where rows of interest can be identified by looking for occurrences of a set of IDs (ids) in a column (sub_var). An example for this is heart rate hr on mimic, where the IDs 211 and 220045 are looked up in the itemid column of chartevents.
- **col_item**: This item class can be used if no row-subsetting is required. An example for this is heart rate (hr) on eicu, where the table vitalperiodic contains an entire column dedicated to heart rate measurements.
- **rgx_item**: As alternative to the value-matching approach of `sel_item` objects, this class identifies rows using regular expressions. Used for example for insulin in eicu, where the regular expression `^insulin (250.+)?\((ml|units)/hr\)?\)$` is matched against the drugname column of infusiondrug. The regular expression is evaluated by `base::grepl()` with `ignore.case = TRUE`.
- **fun_item**: Intended for the scenario where data of interest is not directly available from a table, this `item` class offers most flexibility. A function can be specified as callback and this function will be called with arguments x (the object itself), patient_ids, id_type and interval (see `load_concepts()`) and is expected to return an object as specified by the target entry.
- **hrd_item**: A special case of `sel_item` for HiRID data where measurement units are not available as separate column, but as separate table with units fixed per concept.

All `item` objects have to specify a data source (`src`) as well as a sub-class. Further arguments then are specific to the respective sub-class and encode information that define data loading, such as the table to query, the column name and values to use for identifying relevant rows, etc. The S3 generic function `init_item()` is responsible for input validation of class-specific arguments as well as class initialization. A list of `item` objects, created by calls to `new_item()` can be passed to `new_item` in order to instantiate an `item` object. An alternative constructor for `item` objects is given by `item()` which calls `new_item()` on the passed arguments (see examples). Finally `as_item()` can be used for coercion of related objects such as list, concept, and the like. Several additional S3 generic functions exist for manipulation of `item`-like objects but are marked internal (see item/concept utilities).

Value

Constructors and coercion functions return `item` and `item` objects, while inheritance tester functions return logical flags.
Examples

```r
if (require(mimic.demo)) {
  gluc <- item("mimic_demo", "labevents", "itemid", list(c(50809L, 50931L)),
              unit_var = TRUE, target = "ts_tbl")

  is_item(gluc)

  all.equal(gluc, as_item(load_dictionary("mimic_demo", "glu")))

  hr1 <- new_itm(src = "mimic_demo", table = "chartevents",
                  sub_var = "itemid", ids = c(211L, 220045L))

  hr2 <- item(src = c("mimic_demo", "eicu_demo"),
              table = c("chartevents", "vitalperiodic"),
              sub_var = list("itemid", NULL),
              val_var = list(NULL, "heartrate"),
              ids = list(c(211L, 220045L), FALSE),
              class = c("sel_itm", "col_itm"))

  hr3 <- new_itm(src = "eicu_demo", table = "vitalperiodic",
                  val_var = "heartrate", class = "col_itm")

  identical(as_item(hr1), hr2[1])
  identical(new_item(list(hr1)), hr2[1])
  identical(hr2, as_item(list(hr1, hr3)))
}
```

---

**pafi**

**Concept callback functions**

**Description**

Owing to increased complexity and more diverse applications, recursive concepts (class `rec_cncpt`) may specify callback functions to be called on corresponding data objects and perform post-processing steps.

**Usage**

```r
pafi(
  ..., 
  match_win = hours(2L),
  mode = c("match_vals", "extreme_vals", "fill_gaps"),
  fix_na_fio2 = TRUE,
  interval = NULL
)
```

```r
safi(
  ..., 
  ...,
```
vent_ind(..., match_win = hours(6L), min_length = mins(30L), interval = NULL)

gcs(
  ..., 
  valid_win = hours(6L), 
  sed_impute = c("max", "prev", "none", "verb"), 
  set_na_max = TRUE, 
  interval = NULL 
)

urine24(
  ..., 
  min_win = hours(12L), 
  limits = NULL, 
  start_var = "start", 
  end_var = "end", 
  interval = NULL 
)

vaso60(..., max_gap = mins(5L), interval = NULL)

vaso_ind(..., interval = NULL)

supp_o2(..., interval = NULL)

avpu(..., interval = NULL)

bmi(..., interval = NULL)

norepi_equiv(..., interval = NULL)

Arguments

... Data input used for concept calculation
match_win Time-span during which matching of values is allowed
mode Method for matching PaO\textsubscript{2} and FiO\textsubscript{2} values
fix_na_fio2 Logical flag indicating whether to impute missing FiO\textsubscript{2} values with 21
interval Expected time series step size (determined from data if NULL)
min_length Minimal time span between a ventilation start and end time
valid_win Maximal time window for which a GCS value is valid if no newer measurement is available
sed_impute: Imputation scheme for values taken when patient was sedated (i.e. unconscious).
set_na_max: Logical flag controlling imputation of missing GCS values with the respective maximum values
min_win: Minimal time span required for calculation of urine/24h limits
Passed to \texttt{fill_gaps()} in order to expand the time series beyond first and last measurements
start_var, end_var: Passed to \texttt{fill_gaps()}
max_gap: Maximum time gap between administration windows that are merged (can be negative).

Details
Several concept callback functions are exported, mainly for documenting their arguments, as default values oftentimes represent somewhat arbitrary choices and passing non-default values might be of interest for investigating stability with respect to such choices. Furthermore, default values might not be ideal for some datasets and/or analysis tasks.

\texttt{pafi}: In order to calculate the PaO$_2$/FiO$_2$ (or Horowitz index), for a given time point, both a PaO$_2$ and a FiO$_2$ measurement is required. As the two are often not measured at the same time, some form of imputation or matching procedure is required. Several options are available:

- \texttt{match_vals} allows for a time difference of maximally \texttt{match_win} between two measurements for calculating their ratio
- \texttt{extreme_vals} uses the worst PaO$_2$ and a FiO$_2$ values within the time window spanned by \texttt{match_win}
- \texttt{fill_gaps} represents a variation of \texttt{extreme_vals}, where ratios are evaluated at every time-point as specified by \texttt{intervals} as opposed to only the time points where either a PaO$_2$ or a FiO$_2$ measurement is available

Finally, \texttt{fix_na_fio2} imputes all remaining missing FiO$_2$ with 21, the percentage (by volume) of oxygen in (tropospheric) air.

\texttt{vent_ind}: Building on the atomic concepts \texttt{vent_start} and \texttt{vent_end}, \texttt{vent_ind} determines time windows during which patients are mechanically ventilated by combining start and end events that are separated by at most \texttt{match_win} and at least \texttt{min_length}. Durations are represented by the \texttt{dur_var} column in the returned \texttt{win_tbl} and the \texttt{data_var} column simply indicates the ventilation status with \texttt{TRUE} values. Currently, no clear distinction between invasive an non-invasive ventilation is made.

\texttt{sed_gcs}: In order to construct an indicator for patient sedation (used within the context of \texttt{gcs}), information from the two concepts \texttt{ett_gcs} and \texttt{rass} is pooled: A patient is considered sedated if intubated or has less or equal to -2 on the Richmond Agitation-Sedation Scale.

\texttt{gcs}:
Aggregating components of the Glasgow Coma Scale into a total score (whenever the total score
`tgcs` is not already available) requires coinciding availability of an eye (`egcs`), verbal (`vgcs`) and
motor (`mgcs`) score. In order to match values, a last observation carry forward imputation
scheme over the time span specified by `valid_win` is performed. Furthermore passing "max" as
`sed_impute` will assume maximal points for time steps where the patient is sedated (as indicated
by `sed_gcs`), while passing "prev", will assign the last observed value previous to the current
sedation window and finally passing FALSE will in turn use raw values. Finally, passing `TRUE`
as `set_na_max` will assume maximal points for missing values (after matching and potentially
applying `sed_impute`).

`urine24`:
Single urine output events are aggregated into a 24 hour moving window sum. At default value of
`limits = NULL`, moving window evaluation begins with the first and ends with the last available
measurement. This can however be extended by passing an `id_tbl` object, such as for example
returned by `stay_windows()` to full stay windows. In order to provide data earlier than 24 hours
before the evaluation start point, `min_win` specifies the minimally required data window and the
evaluation scheme is adjusted for shorter than 24 hour windows.

`vaso60`:
Building on concepts for drug administration rate and drug administration durations, adminis-
tration events are filtered if they do not fall into administrations windows of at least 1h. The
`max_gap` argument can be used to control how far apart windows can be in order to be merged
(negative times are possible as well, meaning that even overlapping windows can be considered
as individual windows).

**Value**

Either an `id_tbl` or `ts_tbl` depending on the type of concept.

---

### rename_cols

**ICU class data utilities**

**Description**

Several utility functions for working with `id_tbl` and `ts_tbl` objects are available, including
functions for changing column names, removing columns, as well as aggregating or removing
rows. An important thing to note is that as `id_tbl` (and consequently `ts_tbl`) inherits from
data.table, there are several functions provided by the data.table package that are capable of
modifying `id_tbl` in a way that results in an object with inconsistent state. An example for this is
data.table::setnames(): if an ID column or the index column name is modified without updat-
ing the attribute marking the column as such, this leads to an invalid object. As data.table::setnames()
is not an S3 generic function, the only way to control its behavior with respect to `id_tbl` ob-
jects is masking the function. As such an approach has its own down-sides, a separate function,
rename_cols() is provided, which is able to handle column renaming correctly.
rename_cols

Usage

rename_cols(
  x,
  new,
  old = colnames(x),
  skip_absent = FALSE,
  by_ref = FALSE,
  ...
)

rm_cols(x, cols, skip_absent = FALSE, by_ref = FALSE)

change_interval(x, new_interval, cols = time_vars(x), by_ref = FALSE)

change_dur_unit(x, new_unit, by_ref = FALSE)

rm_na(x, cols = data_vars(x), mode = c("all", "any"))

## S3 method for class 'id_tbl'
sort(
  x,
  decreasing = FALSE,
  by = meta_vars(x),
  reorder_cols = TRUE,
  by_ref = FALSE,
  ...
)

is_sorted(x)

## S3 method for class 'id_tbl'
duplicated(x, incomparables = FALSE, by = meta_vars(x), ...)

## S3 method for class 'id_tbl'
anyDuplicated(x, incomparables = FALSE, by = meta_vars(x), ...)

## S3 method for class 'id_tbl'
unique(x, incomparables = FALSE, by = meta_vars(x), ...)

is_unique(x, ...)

## S3 method for class 'id_tbl'
aggregate(
  x,
  expr = NULL,
  by = meta_vars(x),
  vars = data_vars(x),
  env = NULL,
rename_cols

...)

dt_gforce(
  x,
  fun = c("mean", "median", "min", "max", "sum", "prod", "var", "sd", "first", "last",
        "any", "all"),
  by = meta_vars(x),
  vars = data_vars(x),
  na_rm = !fun %in% c("first", "last")
)

replace_na(x, val, type = "const", ...)

Arguments

x Object to query
new, old Replacement names and existing column names for renaming columns
skip_absent Logical flag for ignoring non-existent column names
by_ref Logical flag indicating whether to perform the operation by reference
... Ignored
cols Column names of columns to consider
new_interval Replacement interval length specified as scalar-valued difftime object
new_unit New difftime unit for the dur_var column
mode Switch between all where all entries of a row have to be missing (for the selected columns) or any, where a single missing entry suffices
decreasing Logical flag indicating the sort order
by Character vector indicating which combinations of columns from x to use for uniqueness checks
reorder_cols Logical flag indicating whether to move the by columns to the front.
incomparables Not used. Here for S3 method consistency
expr Expression to apply over groups
vars Column names to apply the function to
env Environment to look up names in expr
fun Function name (as string) to apply over groups
na_rm Logical flag indicating how to treat NA values
val Replacement value (if type is "const")
type character, one of "const", "locf" or "nocb". Defaults to "const".
Details

Apart from a function for renaming columns while respecting attributes marking columns a index or ID columns, several other utility functions are provided to make handling of id_tbl and ts_tbl objects more convenient.

Sorting:

An id_tbl or ts_tbl object is considered sorted when rows are in ascending order according to columns as specified by `meta_vars()`. This means that for an id_tbl object rows have to be ordered by `id_vars()` and for a ts_tbl object rows have to be ordered first by `id_vars()`, followed by the `index_var()`. Calling the S3 generic function `base::sort()` on an object that inherits form id_tbl using default arguments yields an object that is considered sorted. For convenience (mostly in printing), the column by which the table was sorted are moved to the front (this can be disabled by passing `FALSE` as `reorder_cols` argument). Internally, sorting is handled by either setting a `data.table::key()` in case `decreasing = FALSE` or be calling `data.table::setorder()` in case `decreasing = TRUE`.

Uniqueness:

On object inheriting form id_tbl is considered unique if it is unique in terms of the columns as specified by `meta_vars()`. This means that for an id_tbl object, either zero or a single row is allowed per combination of values in columns `id_vars()` and consequently for ts_tbl objects a maximum of one row is allowed per combination of time step and ID. In order to create a unique id_tbl object from a non-unique id_tbl object, aggregate() will combine observations that represent repeated measurements within a group.

Aggregating:

In order to turn a non-unique id_tbl or ts_tbl object into an object considered unique, the S3 generic function `stats::aggregate()` is available. This applied the expression (or function specification) passed as `expr` to each combination of grouping variables. The columns to be aggregated can be controlled using the `vars` argument and the grouping variables can be changed using the by argument. The argument `expr` is fairly flexible: it can take an expression that will be evaluated in the context of the data.table in a clean environment inheriting from `env`, it can be a function, or it can be a string in which case `dt_gforce()` is called. The default value `NULL` chooses a string dependent on data types, where numeric resolves to `median`, logical to `sum` and character to `first`.

As aggregation is used in concept loading (see `load_concepts()`), performance is important. For this reason, `dt_gforce()` allows for any of the available functions to be applied using the `GForce` optimization of `data.table` (see `data.table::datatable.optimize`).

Value

Most of the utility functions return an object inheriting from id_tbl, potentially modified by reference, depending on the type of the object passed as `x`. The functions `is_sorted()`, `anyDuplicated()` and `is_unique()` return logical flags, while `duplicated()` returns a logical vector of the length `nrow(x)`.

Examples

```r
tbl <- id_tbl(a = rep(1:5, 4), b = rep(1:2, each = 10), c = rnorm(20),
  id_vars = c("a", "b"))
```
is_unique(tbl)
is_sorted(tbl)

is_sorted(tbl[order(c)])

identical(aggregate(tbl, list(c = sum(c))), aggregate(tbl, "sum"))

tbl <- aggregate(tbl, "sum")
is_unique(tbl)
is_sorted(tbl)

<table>
<thead>
<tr>
<th>secs</th>
<th>Utilities for difftime</th>
</tr>
</thead>
</table>

**Description**

As base::difftime() vectors are used throughout ricu, a set of wrapper functions are exported for convenience of instantiation base::difftime() vectors with given time units.

**Usage**

secs(...)
mins(...)
hours(...)
days(...)
weeks(...)

**Arguments**

... Numeric vector to coerce to base::difftime()

**Value**

Vector valued time differences as difftime object.

**Examples**

hours(1L)
mins(NA_real_)
secs(1:10)
hours(numeric(0L))
Description

The sepsis 3 label consists of a suspected infection combined with an acute increase in SOFA score.

Usage

```r
sep3(
  ..., 
  si_window = c("first", "last", "any"),
  delta_fun = delta_cummin,
  sofa_thresh = 2L,
  si_lwr = hours(48L),
  si_upr = hours(24L),
  keep_components = FALSE,
  interval = NULL
)

delta_cummin(x)

delta_start(x)

delta_min(x, shifts = seq.int(0L, 23L))
```

Arguments

- `...`: Data objects
- `si_window`: Switch that can be used to filter SI windows
- `delta_fun`: Function used to determine the SOFA increase during an SI window
- `sofa_thresh`: Required SOFA increase to trigger Sepsis 3
- `si_lwr, si_upr`: Lower/upper extent of SI windows
- `keep_components`: Logical flag indicating whether to return the individual components alongside the aggregated score
- `interval`: Time series interval (only used for checking consistency of input data)
- `x`: Vector of SOFA scores
- `shifts`: Vector of time shifts (multiples of the current interval) over which `base::pmin()` is evaluated
Details

The Sepsis-3 Consensus (Singer et al.) defines sepsis as an acute increase in the SOFA score (see `sofa_score()`) of 2 points or more within the suspected infection (SI) window (see `susp_inf()`):

A patient can potentially have multiple SI windows. The argument `si_window` is used to control which SI window we focus on (options are “first”, “last”, “any”).

Further, although a 2 or more point increase in the SOFA score is defined, it is not perfectly clear to which value the increase refers. For this the `delta_fun` argument is used. If the increase is required to happen with respect to the minimal SOFA value (within the SI window) up to the current time, the `delta_cummin` function should be used. If, however, we are looking for an increase with respect to the start of the SI window, then the `delta_start` function should be used. Lastly, the increase might be defined with respect to values of the previous 24 hours, in which case the `delta_min` function is used.
References


Description

Making a dataset available to ricu consists of 3 steps: downloading (`download_src()`), importing (`import_src()`), and attaching (`attach_src()`). While downloading and importing are one-time procedures, attaching of the dataset is repeated every time the package is loaded. Briefly, downloading loads the raw dataset from the internet (most likely in .csv format), importing consists of some preprocessing to make the data available more efficiently and attaching sets up the data for use by the package. The download and import steps can be combined using `setup_src_data()`.

Usage

```r
setup_src_data(x, ...)
```

Arguments

- `x` Object specifying the source configuration
- `...` Forwarded to `load_src_cfg()` if `x` is a character vector

Details

If `setup_src_data()` is called on data sources that have all data available with `force = FALSE`, nothing happens apart from a message being displayed. If only a subset of tables is missing, only these tables are downloaded (whenever possible) and imported. Passing `force = TRUE` attempts to re-download and import the entire data set. If the data source is available as a data package (as is the case for the two demo datasets), data is not downloaded and imported, but this package is installed.

In most scenarios, `setup_src_data()` does not need to be called by users, as upon package loading, all configured data sources are set up in a way that enables download of missing data upon first access (and barring user consent). However, instead of accessing all data sources where data missingness should be resolved one by one, `setup_src_data()` is exported for convenience.

Value

Called for side effects and returns `NULL` invisibly.
The SIRS (Systemic Inflammatory Response Syndrome) score is a commonly used assessment tool used to track a patient’s well-being in an ICU.

### Usage

```r
sirs_score(
  ..., 
  win_length = hours(24L),
  keep_components = FALSE,
  interval = NULL
)
```

```r
qsofa_score(
  ..., 
  win_length = hours(24L),
  keep_components = FALSE,
  interval = NULL
)
```

```r
news_score(
  ..., 
  win_length = hours(24L),
  keep_components = FALSE,
  interval = NULL
)
```

```r
mews_score(
  ..., 
  win_length = hours(24L),
  keep_components = FALSE,
  interval = NULL
)
```

### Arguments

- `...` Data input used for score evaluation
- `win_length` Window used for carry forward
- `keep_components` Logical flag indicating whether to return the individual components alongside the aggregated score
- `interval` Time series interval (only used for checking consistency of input data)
sofa_score

SOFA score label

Description

The SOFA (Sequential Organ Failure Assessment) score is a commonly used assessment tool for tracking a patient’s status during a stay at an ICU. Organ function is quantified by aggregating 6 individual scores, representing respiratory, cardiovascular, hepatic, coagulation, renal and neurological systems. The function sofa_score() is used as callback function to the sofa concept but is exported as there are a few arguments that can used to modify some aspects of the presented SOFA implementation. Internally, sofa_score() calls first sofa_window(), followed by sofa_compute() and arguments passed as ... will be forwarded to the respective internally called function.

Usage

sofa_score(
  ..., 
  worst_val_fun = max_or_na, 
  explicit_wins = FALSE, 
  win_length = hours(24L), 
  keep_components = FALSE, 
  interval = NULL 
)

sofa_resp(..., interval = NULL)

sofa_coag(..., interval = NULL)

sofa_liver(..., interval = NULL)

sofa_cardio(..., interval = NULL)

sofa_cns(..., interval = NULL)

sofa_renal(..., interval = NULL)

Arguments

... Concept data, either passed as list or individual argument

worst_val_fun functions used to calculate worst values over windows

explicit_wins The default FALSE iterates over all time steps, TRUE uses only the last time step per patient and a vector of times will iterate over these explicit time points

win_length Time-frame to look back and apply the worst_val_fun

keep_components Logical flag indicating whether to return the individual components alongside the aggregated score (with a suffix _comp added to their names)
sofa_score

interval  Time series interval (only used for checking consistency of input data, NULL will use the interval of the first data object)

Details

The function sofa_score() calculates, for each component, the worst value over a moving window as specified by win_length, using the function passed as worst_val_fun. The default functions max_or_na() return NA instead of -Inf/Inf in the case where no measurement is available over an entire window. When calculating the overall score by summing up components per time-step, a NA value is treated as 0.

Building on separate concepts, measurements for each component are converted to a component score using the definition by Vincent et. al.:

### SOFA score

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO_{2}/FiO_{2} [mmHg]</td>
<td>&lt; 400</td>
<td>&lt; 300</td>
<td>&lt; 200</td>
<td>&lt; 100</td>
</tr>
<tr>
<td>and mechanical ventilation</td>
<td>yes</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coagulation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets ([\times 10^3]/\text{mm}^3)</td>
<td>&lt; 150</td>
<td>&lt; 100</td>
<td>&lt; 50</td>
<td>&lt; 20</td>
</tr>
<tr>
<td><strong>Liver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilirubin [mg/dl]</td>
<td>1.2-1.9</td>
<td>2.0-5.9</td>
<td>6.0-11.9</td>
<td>&gt; 12.0</td>
</tr>
<tr>
<td><strong>Cardiovascular</strong> (^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP &lt; 70 mmHg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>or dopamine</td>
<td>≤ 5</td>
<td>&gt; 5</td>
<td>&gt; 15</td>
<td></td>
</tr>
<tr>
<td>or dobutamine</td>
<td>any dose</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>or epinephrine</td>
<td>≤ 0.1</td>
<td>&gt; 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or norepinephrine</td>
<td>≤ 0.1</td>
<td>&gt; 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Central nervous system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glasgow Coma Score</td>
<td>13-14</td>
<td>10-12</td>
<td>6-9</td>
<td>&lt; 6</td>
</tr>
<tr>
<td><strong>Renal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creatinine [mg/dl]</td>
<td>1.2-1.9</td>
<td>2.0-3.4</td>
<td>3.5-4.9</td>
<td>&gt; 5.0</td>
</tr>
<tr>
<td>or urine output [ml/day]</td>
<td>&lt; 500</td>
<td>&lt; 200</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Adrenergic agents administered for at least 1h (doses given are in \([\mu g/kg \cdot \text{min}]\)

At default, for each patient, a score is calculated for every time step, from the first available measurement to the last. In instead of a regularly evaluated score, only certain time points are of interest, this can be specified using the explicit_wins argument: passing for example hours(24, 48) will yield for every patient a score at hours 24 and 48 relative to the origin of the current ID system (for example ICU stay).

Value

A ts_tbl object.

References

stay_windows

Description

Building on functionality offered by the (internal) function `id_map()`, stay windows as well as (in case of differing values being passed as `id_type` and `win_type`) an ID mapping is computed.

Usage

```r
stay_windows(x, ...)
```

```
## S3 method for class 'src_env'
stay_windows(
  x,
  id_type = "icustay",
  win_type = id_type,
  in_time = "start",
  out_time = "end",
  interval = hours(1L),
  patient_ids = NULL,
  ...
)
```

```
## S3 method for class 'character'
stay_windows(x, ...)
```

```
## S3 method for class 'list'
stay_windows(x, ..., patient_ids = NULL)
```

```
## Default S3 method:
stay_windows(x, ...)
```

Arguments

- `x`  Data source (is coerced to `src_env` using `as_src_env()`)
- `...`  Generic consistency
- `id_type`  Type of ID all returned times are relative to
- `win_type`  Type of ID for which the in/out times is returned
- `in_time, out_time`  column names of the returned in/out times
- `interval`  The time interval used to discretize time stamps with, specified as `base::difftime()` object
- `patient_ids`  Patient IDs used to subset the result
Value
An id_tbl containing the selected IDs and depending on values passed as in_time and out_time, start and end times of the ID passed as win_var.

See Also
change_id

susp_inf  
Suspicion of infection label

Description
Suspected infection is defined as co-occurrence of antibiotic treatment and body-fluid sampling.

Usage
susp_inf(...,
  abx_count_win = hours(24L),
  abx_min_count = 1L,
  positive_cultures = FALSE,
  si_mode = c("and", "or", "abx", "samp"),
  abx_win = hours(24L),
  samp_win = hours(72L),
  by_ref = TRUE,
  keep_components = FALSE,
  interval = NULL
)

Arguments

... Data and further arguments are passed to si_calc()
abx_count_win Time span during which to apply the abx_min_count criterion
abx_min_count Minimal number of antibiotic administrations
positive_cultures Logical flag indicating whether to require cultures to be positive
si_mode Switch between and, or, abx, samp modes
abx_win Time-span within which sampling has to occur
samp_win Time-span within which antibiotic administration has to occur
by_ref Logical flag indicating whether to process data by reference
keep_components Logical flag indicating whether to return the individual components alongside the aggregated score
interval Time series interval (only used for checking consistency of input data)
Details

Suspected infection can occur in one of the two following ways:

- administration of antibiotics followed by a culture sampling within \( \text{samp}_\text{win} \) hours

  \[
  \text{abx}_\text{win} \quad \mid \quad \text{ABX sampling (last possible)}
  \]

- culture sampling followed by an antibiotic administration within \( \text{abx}_\text{win} \) hours

  \[
  \text{samp}_\text{win} \quad \mid \quad \text{sampling} \quad \mid \quad \text{ABX (last possible)}
  \]

The default values of \( \text{samp}_\text{win} \) and \( \text{abx}_\text{win} \) are 24 and 72 hours respectively, as per Singer et al. The earlier of the two times (fluid sampling, antibiotic treatment) is taken as the time of suspected infection (SI time). The suspected infection window (SI window) is defined to start \( \text{si}_\text{lwr} \) hours before the SI time and end \( \text{si}_\text{upr} \) hours after the SI time. The default values of 48 and 24 hours (respectively) are chosen as used by Seymour et al. (see Supplemental Material).

\[
\begin{align*}
48h & \quad \mid \quad (1) \quad \mid \quad 24h \\
\text{SI time} \quad \mid \quad \mid \quad \mid \quad \mid \quad \mid 
\end{align*}
\]

For some datasets, however, information on body fluid sampling is not available for majority of the patients (eICU data). Therefore, an alternative definition of suspected infection is required. For this, we use administration of multiple antibiotics (argument \( \text{abx}_\text{min}_\text{count} \) determines the required number) within \( \text{abx}_\text{count}_\text{win} \) hours. The first time of antibiotic administration is taken as the SI time in this case.

References


Description

For concept loading, item callback functions are used in order to handle item-specific post-processing steps, such as converting measurement units, mapping a set of values to another or for more involved data transformations, like turning absolute drug administration rates into rates that are relative to body weight. Item callback functions are called by `load_concepts()` with arguments `x` (the data), a variable number of name/ string pairs specifying roles of columns for the given item, followed by `env`, the data source environment as `src_env` object. Item callback functions can be specified by their name or using function factories such as `transform_fun()`, `apply_map()` or `convert_unit()`.

Usage

```r
transform_fun(fun, ...)
```

```r
binary_op(op, y)
```

```r
comp_na(op, y)
```

```r
set_val(val)
```

```r
apply_map(map, var = "val_var")
```

```r
convert_unit(fun, new, rgx = NULL, ignore_case = TRUE, ...)
```

Arguments

- `fun` Function(s) used for transforming matching values
- `...` Further arguments passed to downstream function
- `op` Function taking two arguments, such as `+`
- `y` Value passed as second argument to function `op`
- `val` Value to replace every element of `x` with
- `map` Named atomic vector used for mapping a set of values (the names of `map`) to a different set (the values of `map`)
- `var` Argument which is used to determine the column the mapping is applied to
- `new` Name(s) of transformed units
- `rgx` Regular expression(s) used for identifying observations based on their current unit of measurement, NULL means everything
- `ignore_case` Forwarded to `base::grep()`

Details

The most forward setting is where a function is simply referred to by its name. For example in eICU, age is available as character vector due to ages 90 and above being represented by the string “> 89”. A function such as the following turns this into a numeric vector, replacing occurrences of “> 89” by the number 90.
eicu_age <- function(x, val_var, ...) {
  data.table::set(
    data.table::set(x, which(x[[val_var]] == "> 89"), j = val_var,
                    value = 90),
    j = val_var,
    value = as.numeric(x[[val_var]])
  )
}

This function then is specified as item callback function for items corresponding to eICU data sources of the age concept as

item(src = "eicu_demo", table = "patient", val_var = "age",
     callback = "eicu_age", class = "col_itm")

The string passed as callback argument is evaluated, meaning that an expression can be passed which evaluates to a function that in turn can be used as callback. Several function factories are provided which return functions suitable for use as item callbacks: transform_fun() creates a function that transforms the val_var column using the function supplied as fun argument, apply_map() can be used to map one set of values to another (again using the val_var column) and convert_unit() is intended for converting a subset of rows (identified by matching rgx against the unit_var column) by applying fun to the val_var column and setting new as the transformed unit name (arguments are not limited to scalar values). As transformations require unary functions, two utility function, binary_op() and comp_na() are provided which can be used to fix the second argument of binary functions such as * or ==. Taking all this together, an item callback function for dividing the val_var column by 2 could be specified as "transform_fun(binary_op(/, 2))".

The supplied function factories create functions that operate on the data using by-reference semantics. Furthermore, during concept loading, progress is reported by a progress::progress_bar. In order to signal a message without disrupting the current loading status, see msg_progress().

Value

Callback function factories such as transform_fun(), apply_map() or convert_unit() return functions suitable as item callback functions, while transform function generators such as binary_op(), comp_na() return functions that apply a transformation to a vector.

Examples

dat <- ts_tbl(x = rep(1:2, each = 5), y = hours(rep(1:5, 2)), z = 1:10)

subtract_3 <- transform_fun(binary_op("-", 3))
subtract_3(data.table::copy(dat), val_var = "z")

gte_4 <- transform_fun(comp_na(">=", 4))
gte_4(data.table::copy(dat), val_var = "z")

map_letters <- apply_map(setNames(letters[1:9], 1:9))
res <- map_letters(data.table::copy(dat), val_var = "z")
res
write_psv

not_b <- transform_fun(comp_na(`!`=`, "b``))
not_b(res, val_var = "z``)

---

## Description

Support for reading from and writing to pipe separated values (.psv) files as used for the PhysioNet Sepsis Challenge.

## Usage

```r
write_psv(x, dir, na_rows = NULL)
read_psv(dir, col_spec = NULL, id_var = "stay_id", index_var = NULL)
```

## Arguments

- **x**: Object to write to files
- **dir**: Directory to write the (many) files to or read from
- **na_rows**: If TRUE missing time steps are filled with NaN values, if FALSE, rows where all data columns entries are missing are removed and if NULL, data is written as-is
- **col_spec**: A column specification as created by `readr::cols()`
- **id_var**: Name of the id column (IDs are generated from file names)
- **index_var**: Optional name of index column (will be coerced to `difftime`)

## Details

Data for the PhysioNet Sepsis Challenge is distributed as pipe separated values (.psv) files, split into separate files per patient ID, containing time stamped rows with measured variables as columns. Files are named with patient IDs and do not contain any patient identifiers as data. Functions `read_psv()` and `write_psv()` can be used to read from and write to such a data format.

## Value

While `write_psv()` is called for side effects and returns NULL invisibly, `read_psv()` returns an object inheriting from `id_tbl`.

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