

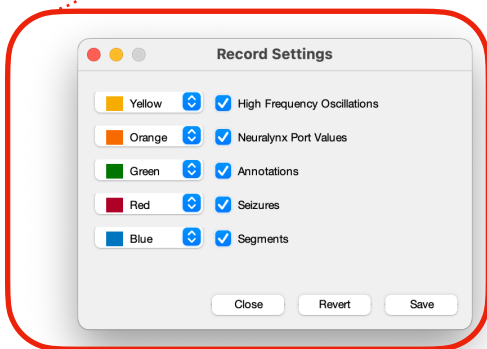
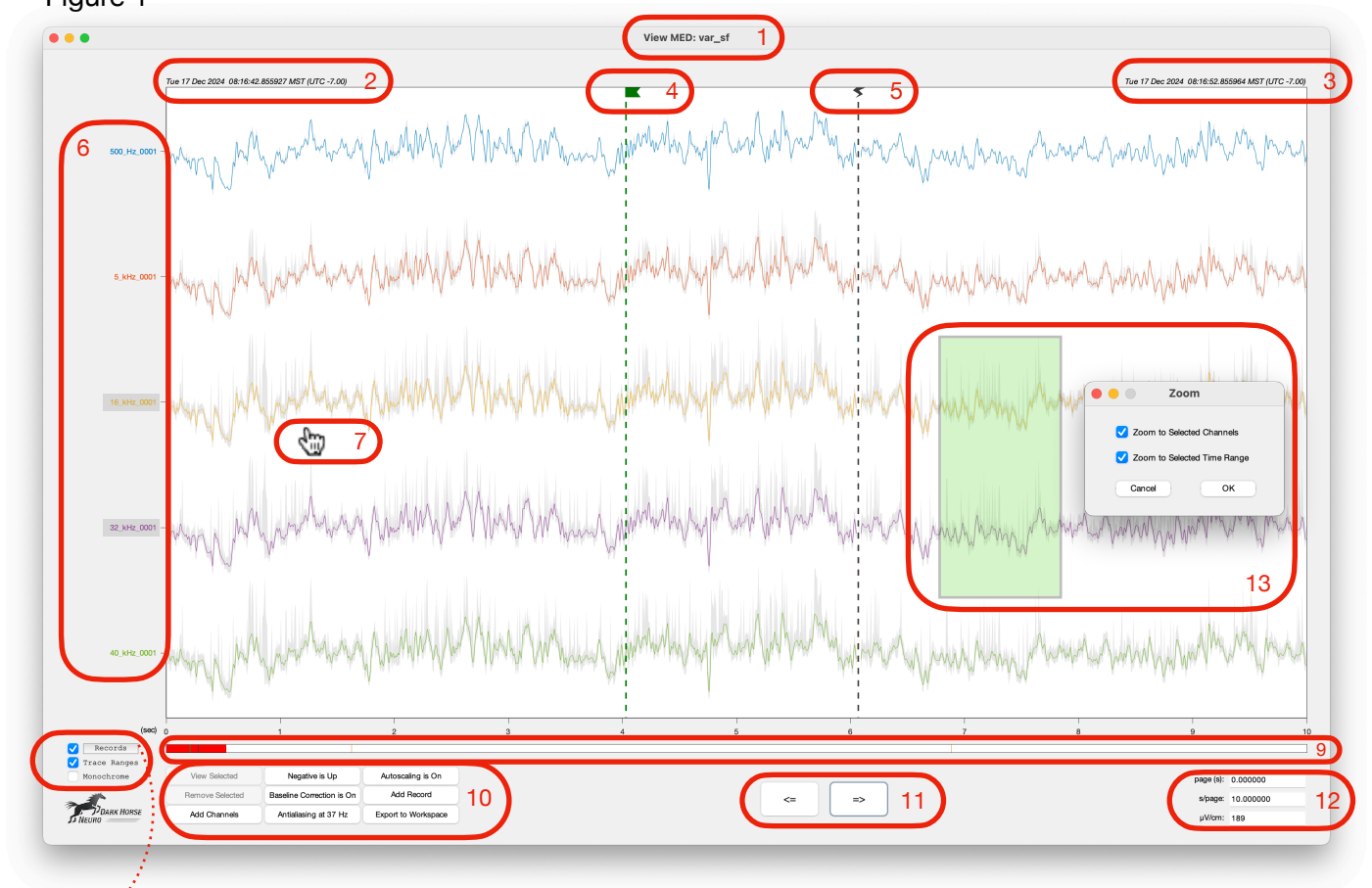


Matlab[™] Software Suite, version 1.2

User Manual

view_MED

Figure 1



Prototype: `view_MED([page], [password])`

- “page” & “password” are optional
- “page” is a slice structure obtained from `read_MED()`, or exported from `view_MED()`
- If “page” is passed, `view_MED()` will open the session with the channels set described in the slice at the page described by the slice
- If “password” is passed it will be used to read the session
- If not, only unencrypted data will be readable, unless a default password is set, and it is valid for the session
- There are three defaults that can be set at the top of `view_MED.m`:
 - `DEFAULT_PASSWORD`
 - `DEFAULT_DATA_DIRECTORY`
 - `DEFAULT_WINDOW_USECS`

Main Screen (figure 1):

1. Session name
2. Page start time
 - a. Clicking on this rotates though:
 - True or offset calendar time of recording (depending on password access level)
 - True μ UTC time (if password allows access)
 - Offset μ UTC time (oUTC)
 - b. Each click copies all available page start information to the system clipboard
3. Page end time
 - a. Clicking on this rotates though:
 - True or offset calendar time of recording (depending on password access level)
 - True μ UTC time (if password allows access)
 - Offset μ UTC time (oUTC)
 - b. Each click copies all available page end information to the system clipboard
4. MED Record
 - a. Clicking on the flag shows the record time & contents
 - b. Clicking on the flag copies the information to the clipboard
 - c. Deletion of the selected record can be done via this dialog
5. Discontinuity
 - a. Clicking on the zag shows the discontinuity time
 - b. Clicking on the zag copies the information to the clipboard
6. Channel labels:
 - a. Channel Labels are selectable. Hold shift for multiple select.
 - b. The “Deselect All” button appears below the channel labels whenever channels are selected
 - c. The “View Selected” & “Remove Selected” buttons are enabled whenever any channels are selected.
7. Page Drag / Zoom: Click & hold for a second until the hand icon appears, and then drag the screen to manually reposition the page data. Click & drag immediately to zoom (#13 below).
8. Trace Ranges, Records, & Monochrome checkboxes:
 - a. The “Trace Ranges” checkbox shows the minimum & maximum for each pixel in a trace in light gray. They are displayed in this figure.
 - b. The “Show Records” checkbox shows the session record as green lines in the session map, & any records that are present in the current window as green dashed lines with flag: clicking the flag shows more information about the record. The records button allows selection of which record types to display (8b).
 - c. Monochrome makes all the traces the same color.
9. Session map:
 - a. The full box (red plus white regions) represents the session extents
 - b. The red portion of the box represents the current page within the session
 - c. Clicking within session map will move the page start to the clicked point
 - d. If the “Show Records” checkbox is checked, session records are displayed in the session map as green lines.
 - e. Discontinuities are shown as gray regions
10. Control buttons:
 - a. “View Selected”: If channels labels are selected, it removes unselected channels from the viewer
 - b. “Remove Selected”: If channels labels are selected, it removes selected channels from the viewer
 - c. “Add Channels”: Brings up a dialog to select channels to add to the viewer from the current session. Channels from different MED sessions cannot be added.

- d. "Negative is Up": Amplitude orientation on the screen. If clicked the button title changes to "Negative is Down". The button toggles between these two modes.
 - e. "Baseline Correction is On": The extents of each trace on the screen have a least absolute deviation fit subtracted from them to keep them straight and centered on their channel label. Clicked this button will change the button title to "Baseline Correction is Off". The button toggles between these two modes.
 - f. "Antialiasing at x Hz": The traces are filtered to prevent screen aliasing. The lowpass cutoff is set at four samples per cycle and depends on the screen pixel width, sampling frequency of each trace, and window time extents. If clicked, the button title changes to "Antialiasing is Off". The button toggles between these two modes. If screen aliasing is not possible on any channel (e.g. small time window), the button will automatically switch to "Antialiasing is Off".
 - g. "Autoscaling is Off": The amplitude scale of the channels can be selected automatically to fit 95% channel sample values within their channel label bands on the screen. If clicked, the button title changes to "Autoscaling is On" and this scaling is activated. The button toggles between these two modes.
 - h. "Add Record": opens a dialog that allows addition of annotations to the MED file. Once pressed, move the cursor within the window to place the flag
 - i. "Export to Workspace": If clicked, a dialog appears asking for a variable name, and then exports the current page extents to the base Matlab workspace as a MED session structure of the specified name. The data contained in the exported structure are the values as stored, i.e. not decimated and filtered as for display.
11. Page Movement Buttons:
- a. The right facing arrow moves the page forward by the value in the "s/page" page parameter box.
 - b. The left facing arrow moves the page backward by the value in the "s/page" page parameter box.
 - c. The keyboard left & right arrows perform the same function as clicking these buttons.
 - d. Clicking these buttons while holding "Command" moves the page by one-third of the value in the "s/page" page parameter box.
 - e. Clicking these buttons while holding "Option" moves the page by one-tenth of the value in the "s/page" page parameter box.
 - f. Up & down arrows default to changing trace amplitudes when the Page Movement Buttons are highlighted.
12. Page Parameter Boxes:
- a. "Page (s)": The page start, in seconds, relative to the session start. Values can be entered into this box to go to a specific time in a session. The box auto-updates with page movement. If this box is highlighted, the up and down arrows can be used to change the value, and the "Option" & "Command" buttons can be used to modify the step size.
 - b. "s/page": The current page width in seconds. Values can be entered into this box to change the page width. If this box is highlighted, the up and down arrows can be used to change the value, and the "Option" & "Command" buttons can be used to modify the step size.
 - c. " $\mu\text{V}/\text{cm}$ ": The amplitude of the traces. Values can be entered into this box to change the amplitude. If this box is highlighted, the up and down arrows can be used to change the value, and the "Option" & "Command" buttons can be used to modify the step size.
13. Zoom:
- a. Clicking and immediately dragging on the axes will result in the option to zoom to either the selected time or channel range, or both.
 - b. The difference between activating the zoom and page drag functions (#7 above), is that a brief pause is required to activate the drag function. Immediate dragging activates the zoom function.

Directory Chooser

Figure 2 (MacOS & Linux)

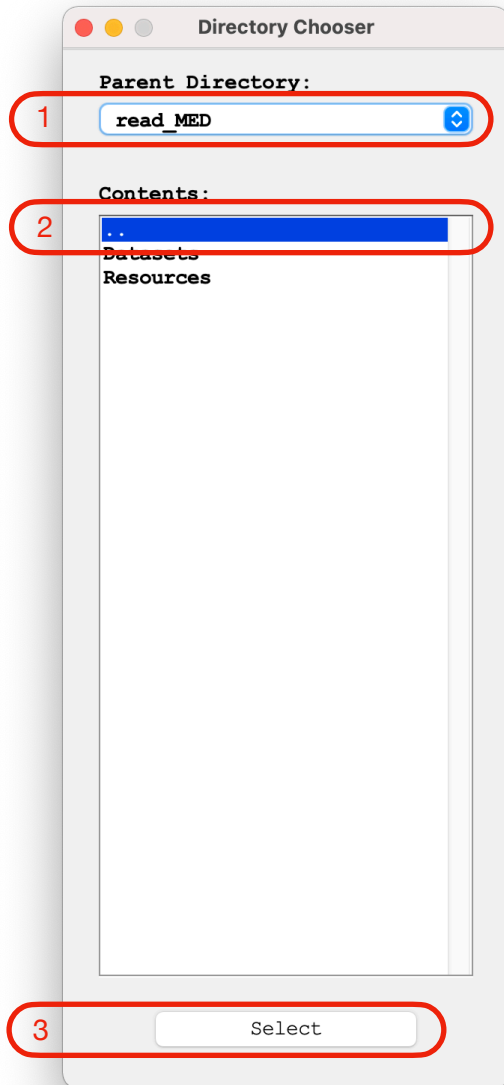
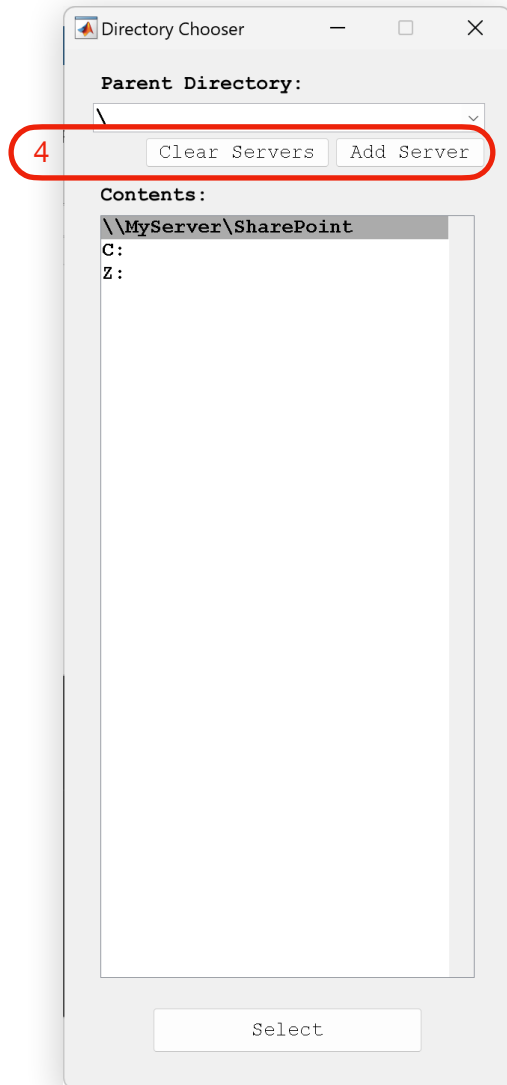


Figure 2 (Windows)



Directory Chooser (MED Open Dialog, figure 2):

1. Directory tree drop down menu
2. “..” parent directory. Rest of window shows contents of current directory
3. Choose MED session or set of MED channels

Behavior:

- Multiple channels can be selected contiguously (with Shift) or discontinuously (with Cmd/Ctrl)
- Only one session can be selected
- Double-clicking opens a directory, not selects it

Stored Servers (Windows only):

- Navigate to root (“\”) in Parent Directory popup menu
- Two buttons will appear: “Clear Servers” & “Add Server” (#4 above)
- Push “Add Server” to store a server & share point
- Enter the server name & share point: e.g. \\MyServer\SharePoint
- Push “Clear Servers” to clear the saved server list

read_MED

`read_MED()` is a function that returns a MED slice structure that can be used from the Matlab console or within functions & scripts.

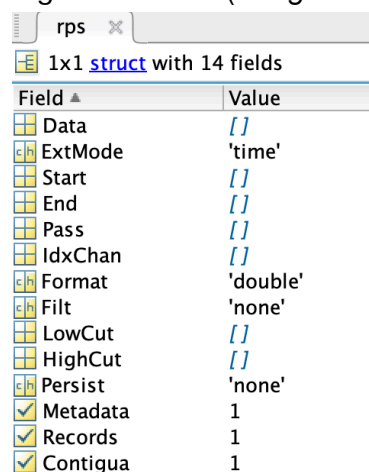
Prototype:

```
[slice, rps] = read_MED([rps], [parameter pairs], [numeric]);
```

`read_MED` operates primarily from a `read_MED` Parameter Structure (**RPS**). The elements of the RPS can be modified with key/value pairs. Some parameter keys have both string and indexed values. String values must be matched, so index values may be substituted for efficiency, at the expense of human readability. The “numeric” option will return parameters with indexed values.

The RPS interface mechanism represents a significant departure from previous `read_MED()` versions. This change has been made to accomodate an increasing options and parameters, now and going forward. Every effort has been made to make the new interface flexible and intuitive.

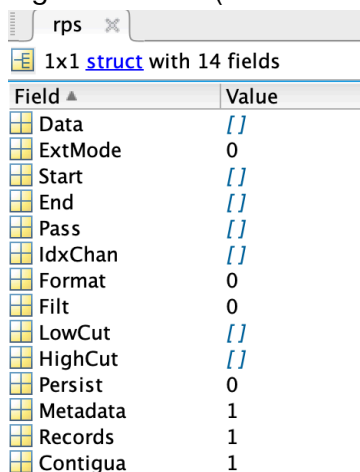
Figure 3a: RPS (*string values*)



The screenshot shows a MATLAB variable editor window for a variable named 'rps'. It is a 1x1 struct with 14 fields. The fields and their values are:

Field	Value
Data	[]
ExtMode	'time'
Start	[]
End	[]
Pass	[]
IdxChan	[]
Format	'double'
Filt	'none'
LowCut	[]
HighCut	[]
Persist	'none'
Metadata	1
Records	1
Contigua	1

Figure 3b: RPS (*numeric values*)



The screenshot shows a MATLAB variable editor window for a variable named 'rps'. It is a 1x1 struct with 14 fields. The fields and their values are:

Field	Value
Data	[]
ExtMode	0
Start	[]
End	[]
Pass	[]
IdxChan	[]
Format	0
Filt	0
LowCut	[]
HighCut	[]
Persist	0
Metadata	1
Records	1
Contigua	1

An RPS (figure 3), prefilled with default values, can be obtained as follows:

```
rps = read_MED; or rps = read_MED('numeric');
```

The non-default field values can then be set to your requirements, e.g:

```
rps.Data = '/Users/dhn/read_MED/example_data.medd';
```

Or, for a specific channel set:

```
rps.Data = {'example_data.medd/chan_0001.ticd', 'example_data.medd/chan_0002.ticd'};
```

(Note: if “example_data.medd” is in Matlab’s current working directory, the full path does not need to be specified.)

Alternatively, this can be done on initialization, e.g:

```
[slice, rps] = read_MED('Data', '/Users/dhn/read_MED/example_data.medd');
```

To update values in an existing RPS, prior to a read operation, include the RPS as the first parameter:

```
[slice, rps] = read_MED(rps, 'Start', -30000000, 'End', -59999999);
```

RPS Elements: (defaults are in square brackets, & the first choice in all applicable fields)

Data: char array or string, or cell array of char arrays or strings; entries can contain regular expressions (regexp)

ExtMode: how matrix slice extents are specified; specified as ['time'] or 'indices'

Start: slice start limit (time or index value, set by ExtMode)

End: slice end limit (time or index value, set by ExtMode)

Pass: data password (or empty if not encrypted)

IdxChan: applies when limits defined by indices; if empty and necessary, defaults to first channel in set

Format (output sample size & type) specified as:

- 'double': 8-byte signed float
- 'single': 4-byte signed float
- 'int32': 4-byte signed integer
- 'int16': 2-byte signed integer

Filt (filter type) specified as:

- 'none': no filtering
- 'lowpass': cutoff passed in HighCutoff (Hz)
- 'highpass': cutoff passed in LowCutoff (Hz)
- 'bandpass': low cutoff passed in LowCut, high cutoff passed in HighCut (Hz)
- 'bandstop': low cutoff passed in LowCut, high cutoff passed in HighCut (Hz)

LowCut: (filter cutoff frequency) required for highpass, bandpass, & bandstop filters

HighCut: (filter cutoff frequency) required for lowpass, bandpass, & bandstop filters

Persist specified as:

- 'none': single read behavior (identical to 'read close' below)
- 'open': close any open session, open new session, & return
- 'close': close & free any open session & return
- 'read': read current session (& open if not)
- 'read_new': close any open session, open & read new session
- 'read_close': read current session (& open if not), close on return

Metadata: return slice session & channel metadata; specified as [true] or false

Records: return slice records; specified as [true] or false

Contigua: return slice contiguous; specified as [true] or false

Notes:

If persistence is used ("open", "read", "read new" modes), it is best practice is to close the session when you are finished with it ("close" or "read close" modes).

In MED, times are preferable to indices as they are independent of sampling frequencies

- times are natively in offset μ UTC (oUTC), but unoffset times may be used
- negatives times are considered to be relative to the session start
- if indices are used, index numbering begins at 1, per Matlab convention

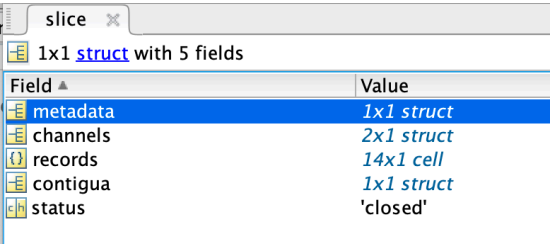
In sessions with varying sampling frequencies, the "indices reference channel" is used to determine the slice extents on all channels when delimited by indices

As with view_MED.m, read_MED.m has some defaults at the top of the code:

- DEFAULT_PASSWORD
- NUMERIC_VALUES

MED Slice Structure

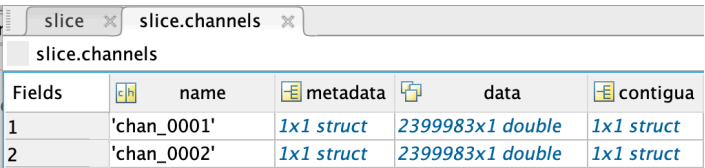
Figure 4: Slice Structure



Field	Value
metadata	1x1 struct
channels	2x1 struct
records	14x1 cell
contigua	1x1 struct
status	'closed'

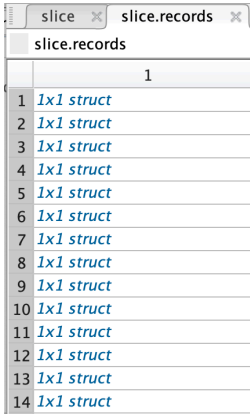
The 'status' variable refers to persistence of session on Matlab memory: 'open' indicates the session is already resident in memory; 'closed' indicates that it is not. Open sessions should be closed before opening new ones.

Figure 5: Slice Channels



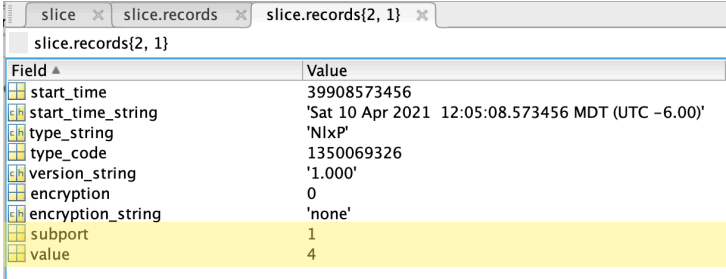
Fields	name	metadata	data	contigua
1	'chan_0001'	1x1 struct	2399983x1 double	1x1 struct
2	'chan_0002'	1x1 struct	2399983x1 double	1x1 struct

Figure 6a: Slice Records



1	1x1 struct
2	1x1 struct
3	1x1 struct
4	1x1 struct
5	1x1 struct
6	1x1 struct
7	1x1 struct
8	1x1 struct
9	1x1 struct
10	1x1 struct
11	1x1 struct
12	1x1 struct
13	1x1 struct
14	1x1 struct

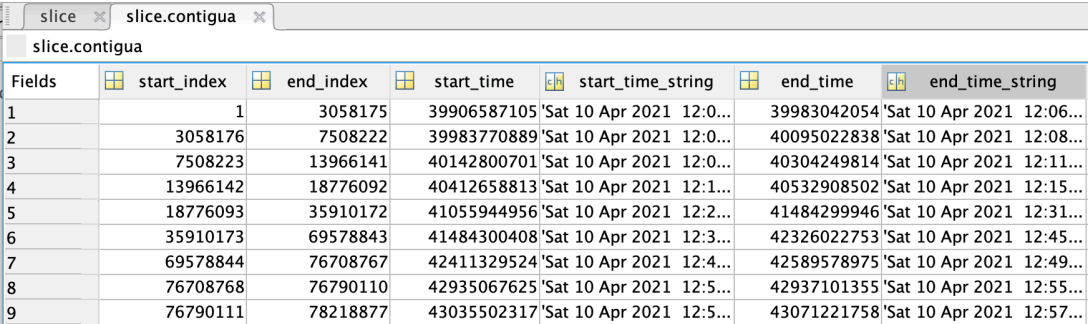
Figure 6b: Slice Record



Field	Value
start_time	39908573456
start_time_string	'Sat 10 Apr 2021 12:05:08.573456 MDT (UTC -6.00)'
type_string	'NlxP'
type_code	1350069326
version_string	'1.000'
encryption	0
encryption_string	'none'
support	1
value	4

The highlighted region is record-type specific. In this case it is a Neuralynx Port Record which has a support & port value. Other record types will have different information in this region.

Figure 7: Slice Contigua



Fields	start_index	end_index	start_time	start_time_string	end_time	end_time_string
1	1	3058175	39906587105	'Sat 10 Apr 2021 12:0...	39983042054	'Sat 10 Apr 2021 12:06...
2	3058176	7508222	39983770889	'Sat 10 Apr 2021 12:0...	40095022838	'Sat 10 Apr 2021 12:08...
3	7508223	13966141	40142800701	'Sat 10 Apr 2021 12:0...	40304249814	'Sat 10 Apr 2021 12:11...
4	13966142	18776092	40412658813	'Sat 10 Apr 2021 12:1...	40532908502	'Sat 10 Apr 2021 12:15...
5	18776093	35910172	41055944956	'Sat 10 Apr 2021 12:2...	41484299946	'Sat 10 Apr 2021 12:31...
6	35910173	69578843	41484300408	'Sat 10 Apr 2021 12:3...	42326022753	'Sat 10 Apr 2021 12:45...
7	69578844	76708767	42411329524	'Sat 10 Apr 2021 12:4...	42589578975	'Sat 10 Apr 2021 12:49...
8	76708768	76790110	42935067625	'Sat 10 Apr 2021 12:5...	42937101355	'Sat 10 Apr 2021 12:55...
9	76790111	78218877	43035502317	'Sat 10 Apr 2021 12:5...	43071221758	'Sat 10 Apr 2021 12:57...

A contiguon (plural “contigua”) is a structure that contains extent information for regions of data between discontinuities. There will be at least one contiguon for every slice.

Contents:

1. Start index: this may contain a “no entry” value in session level contigua, if the sampling frequencies vary across channels
2. End index: this may contain a “no entry” value in session level contigua, if the sampling frequencies vary across channels
3. Start Time: this will always be present
4. End Time: this will always be present

Figure 8: Slice Metadata (Level 1 Access)

Field *	Value
path	'/Volumes/dhndev/read_MED/example_data.medd'
slice_start_time	39906587105
slice_end_time	39966587104
slice_start_time_string	'Day 0001 11:05:06.587105 oUTC'
slice_end_time_string	'Day 0001 11:06:06.587104 oUTC'
session_start_time	39906587105
session_end_time	43071221764
session_start_time_string	'Day 0001 11:05:06.587105 oUTC'
session_end_time_string	'Day 0001 11:57:51.221764 oUTC'
slice_start_sample_number	1
slice_end_sample_number	2399983
session_number_of_samples	78218877
session_name	'example_data'
channel_name	'
index_channel_name	'chan_0001'
anonymized_subject_ID	'
session_UID	2472478125758159870
channel_UID	0
session_description	'
channel_description	'
equipment_description	'Neuralynx Atlas / Pegasus acquisition system'
acquisition_channel_number	-1
reference_description	'Source 01 Reference 1'
sampling_frequency	40000
low_frequency_filter_setting	0.1000
high_frequency_filter_setting	9000
notch_filter_frequency_setting	-1
AC_line_frequency	60
amplitude_units_conversion_factor	1
amplitude_units_description	'microvolts'
time_base_units_conversion_factor	1
time_base_units_description	'microseconds'
recording_time_offset	0
standard_UTC_offset	0
standard_timezone_string	'Offset Coordinated Universal Time'
standard_timezone_acronym	'oUTC'
daylight_timezone_string	'no access'
daylight_timezone_acronym	'no access'
subject_name_1	'no access'
subject_name_2	'no access'
subject_name_3	'no access'
subject_ID	'no access'
recording_country	'no access'
recording_territory	'no access'
recording_locality	'no access'
recording_institution	'no access'

Figure 8: Slice Metadata (Level 2 Access)

Field *	Value
path	'/Volumes/dhndev/read_MED/example_data.medd'
slice_start_time	39906587105
slice_end_time	39966587104
slice_start_time_string	'Sat 10 Apr 2021 12:05:06.587105 MDT (UTC -6.00)'
slice_end_time_string	'Sat 10 Apr 2021 12:06:06.587104 MDT (UTC -6.00)'
session_start_time	39906587105
session_end_time	43071221764
session_start_time_string	'Sat 10 Apr 2021 12:05:06.587105 MDT (UTC -6.00)'
session_end_time_string	'Sat 10 Apr 2021 12:57:51.221764 MDT (UTC -6.00)'
slice_start_sample_number	1
slice_end_sample_number	2399983
session_number_of_samples	78218877
session_name	'example_data'
channel_name	'
index_channel_name	'chan_0001'
anonymized_subject_ID	'
session_UID	2472478125758159870
channel_UID	0
session_description	'
channel_description	'
equipment_description	'Neuralynx Atlas / Pegasus acquisition system'
acquisition_channel_number	-1
reference_description	'Source 01 Reference 1'
sampling_frequency	40000
low_frequency_filter_setting	0.1000
high_frequency_filter_setting	9000
notch_filter_frequency_setting	-1
AC_line_frequency	60
amplitude_units_conversion_factor	1
amplitude_units_description	'microvolts'
time_base_units_conversion_factor	1
time_base_units_description	'microseconds'
recording_time_offset	1618038000000000
standard_UTC_offset	-25200
standard_timezone_string	'Mountain Standard Time'
standard_timezone_acronym	'MST'
daylight_timezone_string	'Mountain Daylight Time'
daylight_timezone_acronym	'MDT'
subject_name_1	'
subject_name_2	'
subject_name_3	'
subject_ID	'
recording_country	'United States'
recording_territory	'Montana'
recording_locality	'Bozeman'
recording_institution	'Dark Horse Neuro'

The highlighted region is information from section 3 of the MED metadata format which, in this recording, was set to require a higher level of access.

read_MED_GUI

read_MED_GUI() is read_MED() in the form of a GUI. It is designed as a general purpose tool, but also as a means of demonstrating how to call read_MED, or it's corresponding mex function, read_MED_exec(), directly.

As with read_MED.m, read_MED_GUI.m defines several defaults at the top of the code:

- DEFAULT_DATA_DIRECTORY
- DEFAULT_PASSWORD
- DEFAULT_SLICE_NAME
- DEFAULT_PARAMETERS_NAME
- SHOW_READ_MED_COMMAND

These can be edited to your preferences. Setting SHOW_READ_MED_COMMAND to false, will stop display of the equivalent read_MED command.

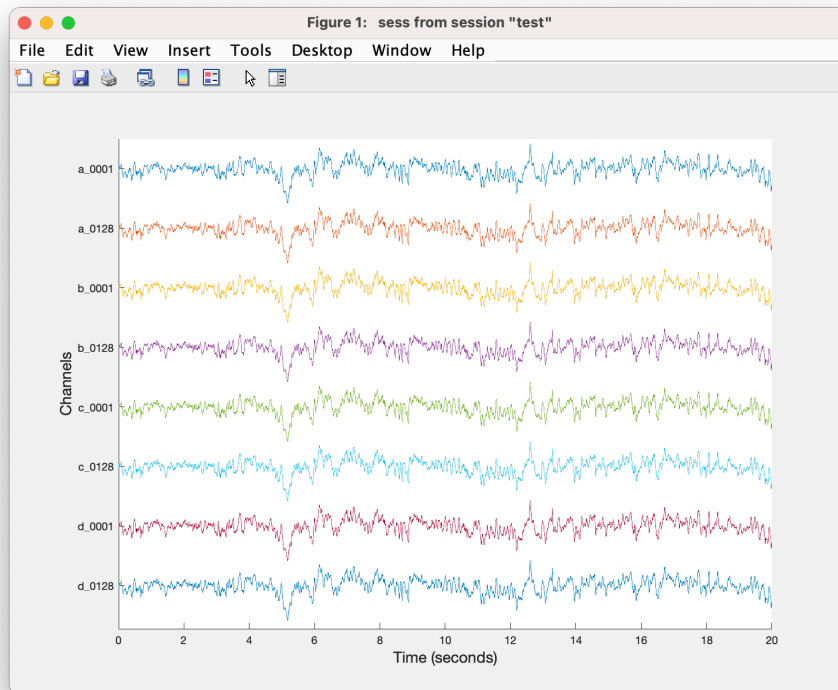
Figure 9

The screenshot shows the 'Read MED GUI' window. It features a 'Session Directory' field (1) containing a file path. Below it is a 'Channel List' (2) with a scrollable list of channels. To the right of the channel list are several control fields: 'Password' (3), 'Slice Extents' (4) with radio buttons for 'times' and 'indices', and 'absolute' and 'relative' options; 'Start Time' (5) and 'End Time' (6) fields; 'Units' (6) with radio buttons for 'seconds' and 'usecs'; 'Filter' (7) dropdown set to 'highpass' and 'Low Cutoff' (7) field set to '600'; 'Format' (8) dropdown set to 'double'; checkboxes for 'Metadata' (9), 'Records' (9), and 'Contigua' (9); 'Persistence' (10) dropdown set to 'none'; 'Slice Name' (11) field set to 'slice'; 'Parameters Name' (13) field set to 'rps'. At the bottom left are three buttons: 'Select Session/Channels' (12), 'Trim to Selected', and 'Remove Selected'. At the bottom right are two buttons: 'Plot' (14) and 'Export to Workspace' (15).

Figure 9:

1. The path to the MED session directory. This field is editable.
2. The selected MED channels in the session.
Note: if all channels in the session are to be read, the RPS 'Data' parameter can just be the session directory. If a subset of channels is desired, the 'Data' parameter will be a cell array of the requested channels. The list can be edited with the buttons below (#12). This field is multi-selectable with Shift & Cmd/Ctrl modifier keys.
3. Password to read the session, if encrypted.
4. Slice Extents Descriptors:
 - Contents can be times or indices (specified by radio buttons)
 - Contents can be absolute or relative to session start (specified by radio buttons)
 - If contents are indices, index channel selection controls appear.
5. Start and End points of the portion of the slice to be read:
 - 'start' and 'end' keywords may be used for both times & indices
 - If contents are times:
 - a) Positive values represent absolute μ UTC times (offset or unoffset => software will differentiate).
 - b) Values ≤ 0 represent μ s from session start. E.g:
 - start == 0, end == -10,000,000 retrieves the first 10 seconds of the file
 - start == -10,000,000, end == -20,000,000 retrieves the next 10 seconds
 - ...
6. Times may be set in seconds or microseconds (specified by radio buttons).
Note: this is specific to the GUI, read_MED time parameters are always specified in microseconds.
7. Filtering parameters
8. Data Format Options. Export sample values as:
 - Double precision (8 byte) floating point numbers (Matlab default)
 - Single precision (4 byte) floating point numbers (singles can precisely describe all integers up to 24 bits & are supported by most Matlab functions)
 - 32 bit (4 byte) integers (MED native storage format)
 - 16 bit (2 byte) integers (a common format for electrophysiological data)
9. Return slice Metadata, Records, & Contigua
10. Persistence mode for opening for opening or closing a session with multiple reads.
11. Matlab workspace variable name.
12. Buttons to choose channels (or session):
 - If channels are selected within the Channel List "Trim to Selected" will remove all other channels.
 - If channels are selected within the Channel List "Remove Selected" will remove those channels.
13. Matlab workspace RPS (read_MED parameters structure) name
14. Calls plot_MED() (figure 10) to visualize the specified data. It does not export to the Matlab workspace.
15. Button to export the data to the Matlab workspace named as the value in "Variable Name" field (#11).

Figure 10: plot_MED



plot_MED(slice) from the Matlab console plots the data in the passed MED slice structure using standard Matlab plotting routines. MED slice structures are obtained from `read_MED()` or `view_MED()`. Typical output is shown in figure 10.

If `SHOW_READ_MED_COMMAND` is true (set at top of `read_MED_GUI.m`), the code displays the equivalent `read_MED` commands in the Matlab console as text. For example:

```
Executed:
data_path = {'/Volumes/dhndev/read_MED/example_data.medd'};
```

```
Executed:
[slice, rps] = read_MED('Data', data_path, 'End', -60000000, 'Pass', '<password>',
'Filt', 'bandpass', 'LowCut', 600, 'HighCut', 6000);
```

Here the 'Data' RPS element is first set as a workspace variable, as this can be a long cell array of channels, rather than just a session name, as here.

Then the required call to `read_MED` is displayed; no default values need to be specified.

If you then update `read_MED_GUI` to read the next minute, the following is displayed:

```
Executed:
[slice, rps] = read_MED(rps, 'Start', -60000000, 'End', -119999999);
```

Because `read_MED_GUI` keeps a copy of the most recent RPS in memory, only the fields which have been changed need to be passed to `read_MED`.

This can also be accomplished explicitly, if preferable:

```
rps.Start = -60000000;
rps.End = -119999999;
[slice, rps] = read_MED(rps);
```

For efficiency, you can also bypass the Matlab wrapper entirely as follows:

```
slice = read_MED_exec(rps);
```

Note, the mex function (`read_MED_exec`) does not return the passed RPS.

matrix_MED

matrix_MED() is a function that returns MED data in a **two-dimensional matrix** of channel by sample dimensions. Data from channels are up or downsampled to the specified sample dimension.

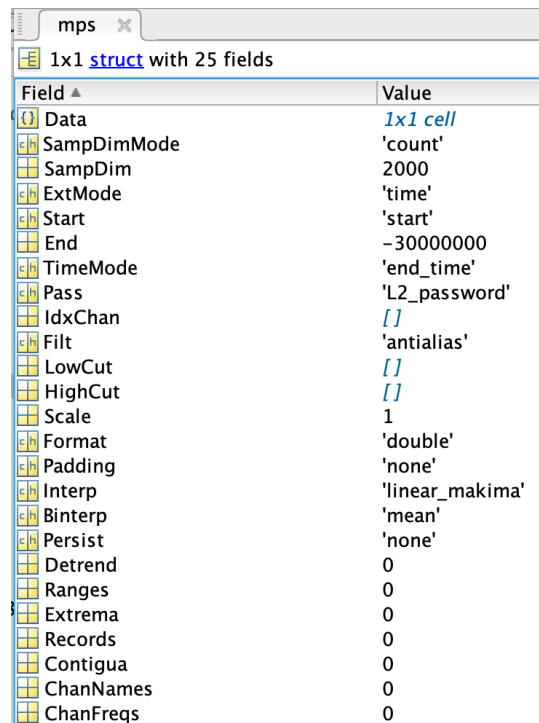
Prototype:

```
[mat, mps] = matrix_MED([mps], [parameter pairs], [numeric]);
```

matrix_MED operates primarily from a matrix_MED Parameter Structure (**MPS**). The elements of the MPS can be modified with key/value pairs. Some parameter keys have both string and indexed values. String values must be matched, so index values may be substituted for efficiency, at the expense of human readability. The “numeric” option will return parameters with indexed values.

The MPS interface mechanism represents a significant departure from previous matrix_MED() versions. This change has been made to accomodate an increasing options and parameters, now and going forward. Every effort has been made to make the new interface flexible and intuitive.

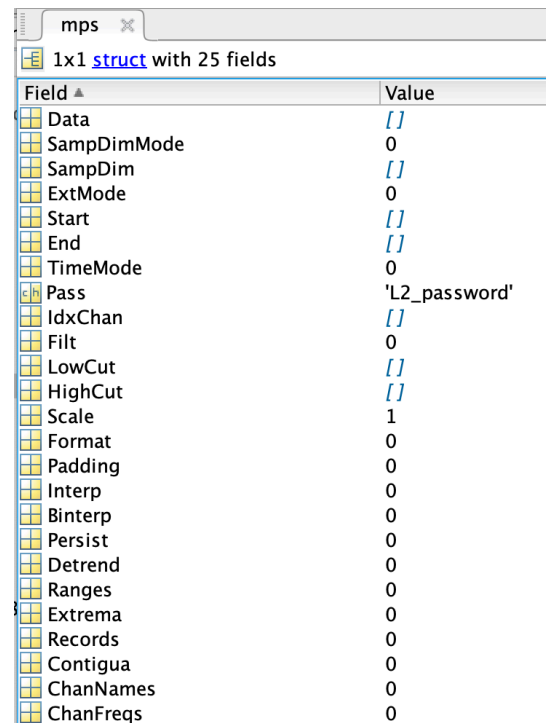
Figure 11a: MPS (*string values*)



1x1 struct with 25 fields

Field	Value
Data	1x1 cell
SampDimMode	'count'
SampDim	2000
ExtMode	'time'
Start	'start'
End	-30000000
TimeMode	'end_time'
Pass	'L2_password'
IdxChan	[]
Filt	'antialias'
LowCut	[]
HighCut	[]
Scale	1
Format	'double'
Padding	'none'
Interp	'linear_makima'
Binterp	'mean'
Persist	'none'
Detrend	0
Ranges	0
Extrema	0
Records	0
Contigua	0
ChanNames	0
ChanFreqs	0

Figure 11b: MPS (*numeric values*)



1x1 struct with 25 fields

Field	Value
Data	[]
SampDimMode	0
SampDim	[]
ExtMode	0
Start	[]
End	[]
TimeMode	0
Pass	'L2_password'
IdxChan	[]
Filt	0
LowCut	[]
HighCut	[]
Scale	1
Format	0
Padding	0
Interp	0
Binterp	0
Persist	0
Detrend	0
Ranges	0
Extrema	0
Records	0
Contigua	0
ChanNames	0
ChanFreqs	0

An MPS (figure 11), prefilled with default values, can be obtained as follows:

```
mps = matrix_MED; or mps = matrix_MED('numeric');
```

The non-default field values can then be set to your requirements, e.g:

```
Mps.Data = '/Users/dhn/read_MED/example_data.medd';
```

Or, for a specific channel set:

```
mps.Data = {'example_data.medd/chan_0001.ticd', 'example_data.medd/chan_0002.ticd'};
```

(Note: if "example_data.medd" is in Matlab's current working directory, the full path does not need to be specified.)

Alternatively, this can be done on initialization, e.g:

```
[mat, mps] = matrix_MED('Data', '/Users/dhn/read_MED/example_data.medd', 'SampDim', 2000);
```

To update values in an existing MPS, prior to a read operation, include the MPS as the first parameter:

```
[mat, mps] = matrix_MED(mps, 'Start', -30000000, 'End', -59999999);
```

MPS Elements: (defaults are in square brackets, & the first choice in all applicable fields)

Data: char array or string, or cell array of char arrays or strings (entries can contain regexp)

SampDimMode: how sample dimension is specified; specified as ['count'] or 'rate'

SampDim: the matrix sample count or sampling frequency

ExtMode: how matrix slice extents are specified; specified as ['time'] or 'indices'

Start: slice start limit (time or index, set by ExtMode)

End: slice end limit (time or index, set by ExtMode)

TimeMode: applies only to time limits; specified as ['duration'] or 'end_time'

Password: data password (or empty if not encrypted)

IdxChan: applies when limits defined by indices; if empty and necessary, defaults to first channel in set

Filt specified as:

- ['antialias']: lowpass, rolloff begins at 4 samples / cycle (downsampling only)
- 'none': no filtering
- 'lowpass': cutoff passed in HighCut (Hz)
- 'highpass': cutoff passed in LowCut (Hz)
- 'bandpass': low cutoff passed in LowCut, high passed in HighCut (Hz)
- 'bandstop': low cutoff passed in LowCut, high passed in HighCut (Hz)

LowCut: required for highpass, bandpass, & bandstop filters

HighCut: required for lowpass, bandpass, & bandstop filters

Scale: factor by which to scale output; [1.0] for no scaling

Format (output sample size & type) specified as:

- ['double']: 8-byte signed float
- 'single': 4-byte signed float
- 'int32': 4-byte signed integer
- 'int16': 2-byte signed integer

Padding (pad discontinuities) specified as:

- ['none']: no padding between discontinuities (contigua specify breaks)
- 'zero': zero padding between discontinuities
- 'nan': NaN padding between discontinuities

Interp specified as:

- ['linear_makima']: downsample using linear, sample using makima (modified Akima)
- 'linear_spline': downsample using linear, sample using spline
- 'linear': up & downsample using linear interpolation
- 'spline': up & downsample using cubic spline interpolation
- 'makima': up & downsample using modified Akima interpolation
- 'binterp': downsample using bin interpolation (upsampling not defined for binterp; current version uses spline to upsample)

Binterp (required mode for bin interpolation) specified as:

- 'mean': use bin mean (fastest without ranges)
- 'median': use bin median (slowest, but least sensitive to outliers)
- 'center': use bin center (fastest with ranges)
- 'fast': use bin mean or center, depending on whether ranges requested

Persist specified as:

- 'none': single read behavior (default: this is identical to 'read close' below)
- 'open': close & free any open session, open new session, & return
- 'close': close & free any open session & return
- 'read': read current session (& open if none exists), replace existing parameters with non-empty passed parameters
- 'read_new': close any open session, open & read new session
- 'read_close': read current session (& open if none exists), close session on return

Detrend: subtract linear regression line (minimum absolute deviation) from each channel; specified as [false] or true

Ranges: return minima & maxima traces of samples in each matrix column contributing to output samples; specified as [false] or true

Extrema: return minima & maxima of matrix output channels; specified as [false] or true

Records: return slice records; specified as [false] or true

Contigua: return slice contigua; specified as [false] or true

ChanNames: return array of channel names; specified as [false] or true

ChanFreqs: return array of input channel sampling frequencies; specified as [false] or true

Notes:

If persistence is used (“open”, “read”, “read new” modes), it is best practice is to close the session when you are finished with it (“close” or “read close” modes).

In MED, times are preferable to indices as they are independent of sampling frequencies

- times are natively in offset μ UTC (oUTC), but unoffset times may be used
- negatives times are considered to be relative to the session start
- if indices are used, index numbering begins at 1, per Matlab convention

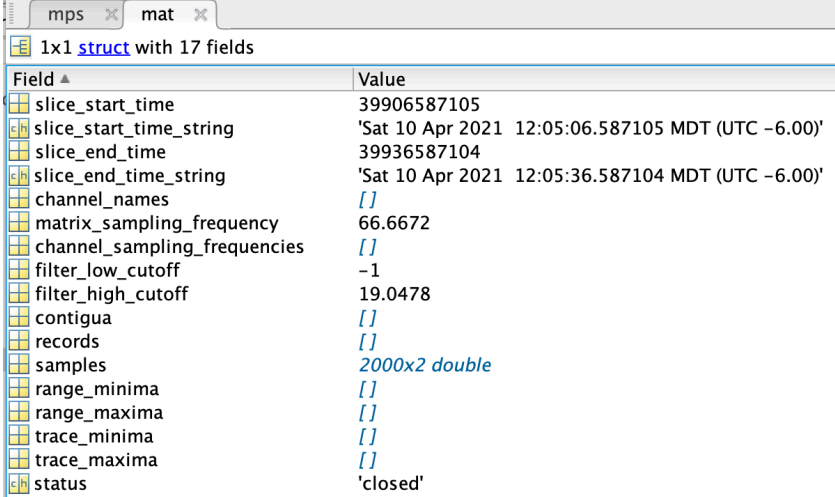
In sessions with varying sampling frequencies, the “indices reference channel” is used to determine the slice extents on all channels when delimited by indices

As with view_MED.m, matrix_MED.m has some defaults at the top of the code:

- DEFAULT_PASSWORD
- NUMERIC_VALUES

MED Matrix Structure

Figure 12: Matrix Structure



The image shows a MATLAB variable viewer window with two tabs: 'mps' and 'mat'. The 'mat' tab is active, displaying a 1x1 struct with 17 fields. The fields and their values are listed in a table below.

Field	Value
slice_start_time	39906587105
slice_start_time_string	'Sat 10 Apr 2021 12:05:06.587105 MDT (UTC -6.00)'
slice_end_time	39936587104
slice_end_time_string	'Sat 10 Apr 2021 12:05:36.587104 MDT (UTC -6.00)'
channel_names	[]
matrix_sampling_frequency	66.6672
channel_sampling_frequencies	[]
filter_low_cutoff	-1
filter_high_cutoff	19.0478
contigua	[]
records	[]
samples	2000x2 double
range_minima	[]
range_maxima	[]
trace_minima	[]
trace_maxima	[]
status	'closed'

The 'status' variable refers to persistence of session on Matlab memory: 'open' indicates the session is already resident in memory; 'closed' indicates that it is not. Open sessions should be closed before opening new ones.

matrix_MED_GUI

matrix_MED_GUI() is matrix_MED() in the form of a GUI. As with read_MED_GUI(), the matrix_MED_GUI displays the commands required to make the same call to matrix_MED() without the GUI. The interface is shown in figure 13.

Figure 13

The screenshot shows the 'Matrix MED GUI' window. It features a 'Session Directory' field (1) containing '/Volumes/dhndev/read_MED/example_data.medd'. Below this is a 'Channel List' (2) showing 'chan_0001' and 'chan_0002'. To the right of the channel list are several configuration sections: 'Sample Dimension' (3) with radio buttons for 'count' (selected) and 'rate (Hz)', and a text field for '2000'; 'Password' (4) with a masked field '*****'; 'Slice Extents' (5) with radio buttons for 'times' (selected) and 'indices', and sub-options for 'absolute' (selected) and 'relative'; 'Time Mode' (6) with radio buttons for 'duration' and 'end time' (selected); 'Units' (7) with radio buttons for 'seconds' (selected) and 'usecs'; 'Start Time' (8) and 'End Time' (9) with dropdown menus; 'Filter' (9) with a dropdown menu set to 'antialias'; 'Format' (10) with a dropdown menu set to 'double'; 'Padding' (11) with a dropdown menu set to 'none'; 'Interp' (12) with a dropdown menu set to 'linear_makima'; 'Persist Mode' (13) with a dropdown menu set to 'none'; 'Scale' (14) with a text field set to '1.0'; a group of checkboxes (16) including 'Detrend', 'Ranges', 'Extrema', 'Records', 'Contigua', 'Channel Names', and 'Channel Frequencies'; 'Matrix Name' (17) with a text field set to 'mat'; 'Parameters Name' (17) with a text field set to 'mps'; and three buttons at the bottom: 'Select Session/Channels' (15), 'Trim to Selected' (15), and 'Remove Selected' (15); 'Plot' (18); and 'Export to Workspace' (19).

As with view_MED.m, matrix_MED.m has some defaults at the top of the code:

- DEFAULT_DATA_DIRECTORY
- DEFAULT_PASSWORD
- DEFAULT_MATRIX_NAME
- DEFAULT_PARAMETERS_NAME
- SHOW_MATRIX_MED_COMMAND

Figure 13:

1. The path to the MED session directory. This field is editable.
2. The selected MED channels in the session.
Note: if all channels in the session are to be read, the MPS 'Data' parameter can just be the session directory. If a subset of channels is desired, the 'Data' parameter will be a cell array of the requested channels. The list can be edited with the buttons below (#12). This field is multi-selectable with Shift & Cmd/Ctrl modifier keys.
3. The matrix sample dimension. Can be specified in sample count ('count') or sampling frequency ('rate'), set by radio buttons. Sampling frequency is in Hz.
4. Password to read the session, if encrypted.
5. Slice Extents Descriptors:
 - Contents can be times or indices (specified by radio buttons)
 - Contents can be absolute or relative to session start (specified by radio buttons)
 - If contents are indices, index channel selection controls appear.
6. Time Mode: '**Duration**' specifies a period of contiguous sampling following the start time (specified in #7). The duration is calculated from the end minus the start times as a "requested" duration, the matrix will deliver that amount of sampled time, ignoring discontinuities, so the final sample time may be significantly different from the requested time. The location of discontinuities in resultant matrix occurred can be obtained from the contigua. '**End Time**' is absolute time; the resultant matrix will deliver only samples that exist up until this time, and may be truncated as a result (unless padding was selected #11).
7. Times may be set in seconds or microseconds (specified by radio buttons).
Note: this is specific to the GUI, matrix_MED time parameters are always specified in microseconds.
8. Start and End points of the portion of the slice to be read:
 - 'start' and 'end' keywords may be used for both times & indices
 - If contents are times:
 - a) Positive values represent absolute μ UTC times (offset or unoffset => software will differentiate).
 - b) Values ≤ 0 represent μ s from session start. E.g:
 - start == 0, end == -10,000,000 retrieves the first 10 seconds of the file
 - start == -10,000,000, end == -20,000,000 retrieves the next 10 seconds
 - ...
9. Filtering: cutoffs textboxes will appear as required for different filtering options
10. Data Format:
 - Double precision (8 byte) floating point numbers (Matlab default)
 - Single precision (4 byte) floating point numbers (singles can precisely describe all integers up to 24 bits & are supported by most Matlab functions)
 - 32 bit (4 byte) integers (MED native storage format)
 - 16 bit (2 byte) integers (a common format for electrophysiological data)
11. Padding (discontinuities):
 - none: no padding
 - zero: fill discontinuities with zeroes (central but valid value in most cases)

- nan: fill discontinuities with NaNs (invalid value, ignored by Matlab plotting, check with `isnan()`)
12. Interpolation algorithms:
 - 'linear_makima': downsample using linear interpolation, upsample using Modified Akima (cubic)
 - 'linear_spline': downsample using linear interpolation, upsample using spline (cubic)
 - 'linear': up & downsample using linear interpolation
 - 'spline': up & downsample using cubic spline interpolation
 - 'makima': up & downsample using makima interpolation
 - 'binterp': downsample using bin interpolation. ('binterp' is not defined for upsampling, so currently upsampling is done using cubic spline, when needed). If 'binterp' is selected, 'binterp' mode options will be displayed which select how interpolated points are determined within bins.
 13. Persistence mode for opening for opening or closing a session with multiple reads.
 14. Scale: multiplicative factor applied to sample values prior to return in matrix. 1.0 indicates no scaling.
 15. Buttons to choose channels (or session):
 - If channels are selected within the Channel List "Trim to Selected" will remove all other channels.
 - If channels are selected within the Channel List "Remove Selected" will remove those channels.
 16. Return:
 - 'Detrend': channels are individually detrended using least absolute deviations regression
 - 'Ranges': minimum & maximum values from each bin are returned in addition to the interpolated trace value for each channel
 - 'Extrema': the minimum & maximum values from each channel are returned
 - 'Records': records are returned
 - 'Contigua': contiguous are returned (in matrix frame)
 - 'Channel Names': channel names are returned
 - 'Channel Frequencies': channel sampling frequencies are returned
 17. Matlab workspace variable & MPS (matrix_MED parameters structure) names
 18. Calls `plot_MED()` (figure 10) to visualize the specified data. It does not export to the Matlab workspace.
 19. Button to export the data to the Matlab workspace named as the value in "Variable Name" field (#17).

MED_sample_for_time

Prototype:

```
sample_number(s) = MED_sample_for_time(time(s), MED_directory, [password]);
```

MED_sample_for_time() returns sample number(s) for specified time(s), in Matlab index schema, i.e. (1:n) rather than 0:(n-1)

Input Arguments:

time(s): scalar or array of scalars specifying time(s) ('start' & 'end' are also accepted)

MED_directory: string specifying channel or session

password: if empty/absent, proceeds as if unencrypted (but, may error out)

Arguments in square brackets are optional => '[]' will substitute default values

As with view_MED.m, MED_sample_for_time.m has some defaults at the top of the code:

- DEFAULT_PASSWORD

MED_time_for_sample

Prototype:

```
time(s) = MED_time_for_sample(sample_number(s), MED_directory, [password]);
```

MED_time_for_sample() returns time(s) for specified sample number(s)

Arguments in square brackets are optional => '[]' will substitute default values

Input Arguments:

sample_number(s): scalar or array of scalars specifying sample number(s) ('start' & 'end' are also accepted)

sample_number(s) are in Matlab index schema: (1:n) rather than 0:(n-1)

MED_directory: string specifying channel or session

password: if empty/absent, proceeds as if unencrypted (but, may error out)

As with view_MED.m, MED_time_for_sample has some defaults at the top of the code:

- DEFAULT_PASSWORD

MED_session_stats

Prototype:

```
session = MED_session_stats(file_list, [password], [return_channels],  
[return_contigua], [return_records]);
```

MED_session_stats returns a single Matlab structure with information about a particular session.

Arguments in square brackets are optional => '[]' will substitute default values

Input Arguments:

- file_list: string array, strings can contain regexp
- password: if empty/absent, proceeds as if unencrypted (but, will return an error if necessary data are encrypted)
- return_channels: if empty/absent, defaults to false (options: true, false)
- return_contigua: if empty/absent, defaults to false (options: true, false)
- return_records: if empty/absent, defaults to false (options: true, false)

As with view_MED.m, MED_session_stats has some defaults at the top of the code:

- DEFAULT_PASSWORD

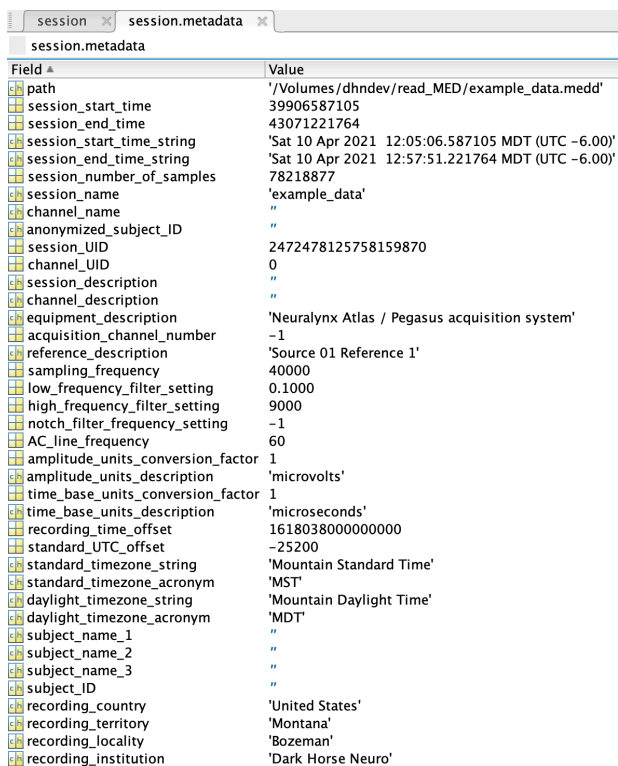
Figure 14a: MED Session Stats session structure



The image shows a MATLAB variable viewer window titled 'session'. It displays a 1x1 struct with 4 fields. The fields and their values are:

Field	Value
metadata	1x1 struct
channels	2x1 struct
records	407x1 cell
contigua	9x1 struct

Figure 14b: MED Session Stats metadata structure



The image shows a MATLAB variable viewer window titled 'session' with a sub-window titled 'session.metadata'. It displays a struct with 33 fields. The fields and their values are:

Field	Value
path	'/Volumes/dhndev/read_MED/example_data.medd'
session_start_time	39906587105
session_end_time	43071221764
session_start_time_string	'Sat 10 Apr 2021 12:05:06.587105 MDT (UTC -6.00)'
session_end_time_string	'Sat 10 Apr 2021 12:57:51.221764 MDT (UTC -6.00)'
session_number_of_samples	78218877
session_name	'example_data'
channel_name	''
anonymized_subject_ID	''
session_UID	2472478125758159870
channel_UID	0
session_description	''
channel_description	''
equipment_description	'Neuralynx Atlas / Pegasus acquisition system'
acquisition_channel_number	-1
reference_description	'Source 01 Reference 1'
sampling_frequency	40000
low_frequency_filter_setting	0.1000
high_frequency_filter_setting	9000
notch_filter_frequency_setting	-1
AC_line_frequency	60
amplitude_units_conversion_factor	1
amplitude_units_description	'microvolts'
time_base_units_conversion_factor	1
time_base_units_description	'microseconds'
recording_time_offset	1618038000000000
standard_UTC_offset	-25200
standard_timezone_string	'Mountain Standard Time'
standard_timezone_acronym	'MST'
daylight_timezone_string	'Mountain Daylight Time'
daylight_timezone_acronym	'MDT'
subject_name_1	''
subject_name_2	''
subject_name_3	''
subject_ID	''
recording_country	'United States'
recording_territory	'Montana'
recording_locality	'Bozeman'
recording_institution	'Dark Horse Neuro'