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# Cheetah Experimental Platform Web 1.0: Cleaning Pupillary Data

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**Abstract.** Recently, researchers started using cognitive load in various settings, e.g., educational psychology, cognitive load theory, or human-computer interaction. Cognitive load characterizes a tasks' demand on the limited information processing capacity of the brain. The widespread adoption of eye-tracking devices led to increased attention for objectively measuring cognitive load via pupil dilation. However, this approach requires a standardized data processing routine to reliably measure cognitive load. This technical report presents CEP-Web, an open source platform to providing state of the art data processing routines for cleaning pupillary data combined with a graphical user interface, enabling the management of studies and subjects. Future developments will include the support for analyzing the cleaned data as well as support for Task-Evoked Pupillary Response (TEPR) studies.

**Keywords:** cheetah experimental platform, pupillometry, eye tracking, cognitive load

## 1 Introduction

In recent years, research started to focus on cognitive load in various settings such as in educational psychology [1], cognitive load theory [2], or human computer interaction [3]. In general, cognitive load characterizes the demands of tasks imposed on the limited information processing capacity of the brain [4]. Cognitive load therefore represents an individual measure depending on available resources interacting with given tasks on a subjective level. Four main approaches to measure cognitive load are common in research. For a detailed overview of cognitive load measures see [5].

### Subjective measures

Subjects are ranking their experienced level of cognitive load using rating scales.

### Performance measures

For example task performance of secondary tasks, critical errors, task completion times, or speed.

**Physiological measures**

Such as heart rate or heart rate variability, galvanic skin response, or pupil dilation.

**Behavioural measures**

Observing behavioural patterns such as mouse-click events or linguistic patterns.

The easier access to eye-tracking devices led to increasing attention for measuring cognitive load via pupil dilation in recent years [5]. In general, pupillary responses can have a variety of causes such as reflex reaction based on light exposure [6] or sexual stimulation [7]. Additionally, pupil dilation also is caused by cognitive load as shown by Beatty [8], who identified pupil dilation to be a reliable indicator of processing load during tasks. Following this insights, several studies utilized pupil dilation measurements to assess cognitive load in various settings (e.g. [3,9,10]).

Pupil dilation data however, needs to run through several cleaning and filtering routines to reliably measure cognitive load [11]. To the best of our knowledge, no common data cleaning and filtering software package is available, resulting in a variety of different techniques and levels of preprocessing pupillary data. Therefore, this technical report describes a state of the art preprocessing routine for pupillary data. To support the execution of the described preprocessing, we introduce Cheetah Experimental Platform Web 1.0 (CEP-Web), following and enhancing the work presented in [12,13].

Following a generic approach, eye-tracking data in stimulus response setting common in psychology as well as data gathered in long running tasks can be prepared for following analyses using CEP-Web. Due to the high amounts of data gathered by eye-tracking systems working at high sampling rates (e.g. 300 Hz for the Tobii TX300) the tool is installed on a server at the University of Innsbruck and therefore able to perform the needed calculations without imposing load on researchers IT components. Interested researcher might also obtain the source code of CEP-Web via our GitLab page<sup>3</sup>. Along with the possibility of calculating the cognitive load within data sets, the opportunity to visualize both, the raw data and the processed data is provided. The visualization of the data allows to verify the changes during the preprocessing and offers a possibility to examine the user's cognitive load trend directly.

We hope providing this infrastructure is aiding the usage of pupil dilation data to assess cognitive load in various fields of research by lowering the demands of needed computing performance and programming skills for researchers. This should lead to more research utilizing cognitive load in various scientific fields, providing deeper insights into human-computer interaction, software design, or design research.

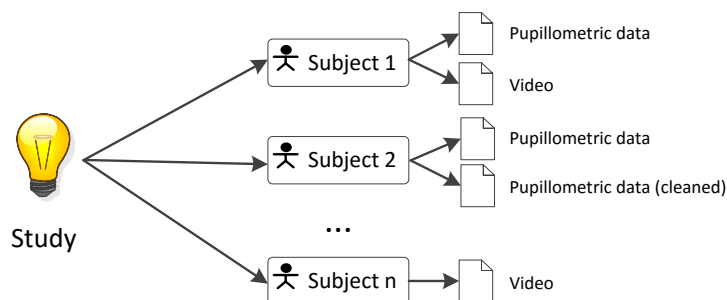
In the remainder of the report is structured as follows. Section 2 describes the CEP-Web's analysis workflow and the available pupillometric cleaning routines. Section 3 presents the technical infrastructure of CEP-Web. Section 4 outlines

<sup>3</sup> <https://git.uibk.ac.at/cheetah-web-group/cheetah-web>

related work and Section 5 concludes the technical report with a brief summary and outlook on future extensions of CEP-Web.

## 2 Analysis workflow

This section describes the workflow and corresponding features for analyzing pupillometric data. Particularly, experimental data is organized in CEP-Web as illustrated in Figure 1: the for each study to be analyzed using CEP-Web, one or more subjects may be assigned. To each subject, in turn, multiple files can be attached—ranging from *raw* input data exported from the eye tracker and associated video data as well as data that was already processed in CEP-Web.



**Fig. 1.** Study with subjects and files

Based on this structure, we recommend the following workflow for the analysis of pupillometric data within CEP-Web:

- *Create study and subject:* As first step, we recommend to create a study for the experiment to be analyzed and also to create all subjects that participated in the study.
- *Upload raw data:* In the second step, export the data from the eye tracker and upload it to CEP-Web. To help with the organization of files, it is mandatory to assign each file to a subject; please note that a subject may have multiple files assigned.
- *Cleaning:* After all data is uploaded, CEP-Web provides a number of filters for processing and cleaning pupillometric data.
- *Data inspection:* To visually inspect whether the cleaning achieved the desired results, CEP-Web provides the possibility to inspect raw and cleaned data by visualizing the data as graphs.
- *Pupil size calculation:* CEP-Web 1.0 provides an initial, rudimentary implementation for computing the average pupil sizes.

In the following, we detail each of the steps. Particularly, Section 2.1 covers study and subject management, Section 2.2 explains the management of data files, whereas Section 2.3 details the cleaning of pupillometric data. Finally, Section 2.4 illustrates how CEP-Web supports the visual inspection of raw and cleaned data.

## 2.1 Study and subject management

The management of subjects is the first step for analyzing data in CEP–Web. In particular, for each experiment that should be analyzed, we recommend to create an individual study and assign all subjects that participated in the study. To facilitate the creation of subjects, an import feature was implemented allowing the creation of several subjects by importing them using a comma-separated values (csv) file.

## 2.2 Data management

The file management of CEP–Web allows for uploading and administering files. Even though the naming of files is up to the user, for the purpose of maintainability, we recommend to follow a certain pattern for naming files:

`subject_id@study.extension`

Thereby, *subject\_id* refers to the identifier of the subject, e.g., subject number, *study* refers to the study the subject participating and *extension* to the extension of the file. In this sense, pupillometric data of subject number *16* participating in study *modeling\_experiment* should be named as follows:

`16@modeling_experiment.tsv`

By adhering to this naming convention, the files will be automatically mapped to the previously created subjects. Otherwise, the mapping of file to subject has to be established manually.

## 2.3 Pupillometric cleaning

For the cleaning of pupillometric data, which is the centerpiece of CEP–Web 1.0, we have implemented a series of *filters*. Basically, a filter takes pupillometric data—left pupil size, right pupil size and timestamp—as input and applies a set of transformation steps on this data. The output provided by one filter can then be directly fed into the next filter, allowing for establishing a filtering chain. Being able to chain filters is of particular interest, since each filter serves a particular purpose in the process of cleaning pupillometric data. Certain filters remove data points, e.g., by removing outliers, whereas other filters are designed to interpolate missing values. In other words, typically filters removing data are applied before filters that interpolate data, since generally the output of the cleaning process should be a continuous series of data without missing values.

Even though CEP–Web allows for freely combining filters, it should be emphasized that not all combination of filters will lead to satisfying results. For instance, applying the Butterworth filter to data that includes missing values, will lead to filtering artifacts. Contrariwise, the blink detection filter will not work properly if missing values—which are used for identifying blinks—have been linearly interpolated before. Therefore, we recommend to apply filters in the following order:

- *Pupil substitution (optional)*: Basic interpolation filter for pupil sizes.
- *Gazepoint substitution (optional)*: Basic interpolation filter for gaze points.
- *Blink detection*: Detect and remove blink artifacts.
- *Standard deviation*: Remove outliers identified by statistics.
- *Linear interpolation*: Linearly interpolate missing values.
- *Butterworth Filter*: Applies a third order lowpass Butterworth filter

For most purposes, the ordering described above will lead to the best results. However, in certain scenarios, it may be useful to shift or omit specific filters. To understand, which filters can be applied for which purpose, we describe all filters provided by CEP–Web in the following.

**Pupil substitution.** The pupil substitution filter is one of the basic filters for interpolating missing data and can be applied for binocular eye trackers only. The idea behind this filter is to substitute missing values from one pupil by the value measured for the other pupil. Hence, the left pupil size is substituted with the right pupil size, if value of the left pupil size is missing and the value of the right pupil size is not missing:

$$filter(value_{left}) = \begin{cases} value_{right} & \text{if } missing(value_{left}) \wedge !missing(value_{right}) \\ value_{left} & \text{else} \end{cases} \quad (1)$$

Analogous, the right pupil size is replaced with the left pupil size, if the value of the right pupil size is missing and the value of the left pupil size is not missing:

$$filter(value_{right}) = \begin{cases} value_{left} & \text{if } missing(value_{right}) \\ value_{right} & \text{else} \end{cases} \quad (2)$$

We would like to mention at this point that the substitution filter should be applied with care, since the size of the left and right pupil may differ considerably.

**Gazepoint substitution.** Similar to the pupil substitution filter, the gaze point substitution filter will replace gaze points, if possible. In particular, we consider a gaze point with screen coordinates  $(x, y)$  missing if either the value of  $x$  (horizontal position in pixel) or  $y$  (vertical position in pixel) is missing:

$$missing(x, y) = \begin{cases} true & \text{if } x \text{ missing} \vee y \text{ missing} \\ false & \text{else} \end{cases} \quad (3)$$

Based on this definition of missing, we substitute the left gaze point with the right gaze point, if the value for the left gaze point is missing and the value for the right gaze point is not missing:

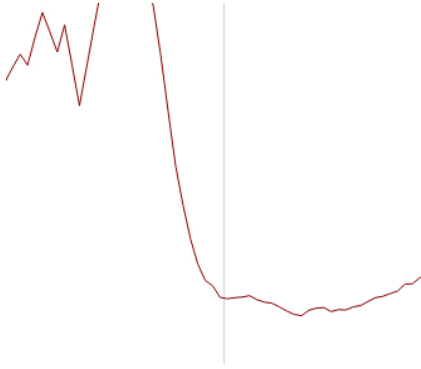
$$filter(gaze_{left}) = \begin{cases} gaze_{right} & \text{if } missing(gaze_{left}) \wedge !missing(gaze_{right}) \\ gaze_{left} & \text{else} \end{cases} \quad (4)$$

Analogous, we substitute the right gaze point with the left gaze point, if the right gaze point is missing and the left gaze point is not missing:

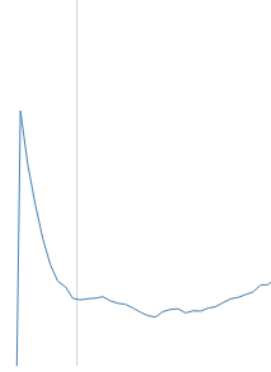
$$\text{filter}(\text{gaze}_{\text{right}}) = \begin{cases} \text{gaze}_{\text{left}} & \text{if } \text{missing}(\text{gaze}_{\text{right}}) \wedge \neg \text{missing}(\text{gaze}_{\text{left}}) \\ \text{gaze}_{\text{right}} & \text{else} \end{cases} \quad (5)$$

**Standard deviation.** The assumption behind the standard deviation filter is that all values that differ more than 3 times from the mean value, should be considered outliers and are removed. More formally:

$$\text{filter}(\text{value}) = \begin{cases} \text{missing} & \text{for } \text{value} > \bar{x} + 3 * \sigma \\ \text{missing} & \text{for } \text{value} < \bar{x} - 3 * \sigma \\ \text{value} & \text{else} \end{cases} \quad (6)$$



**Fig. 2.** Raw data

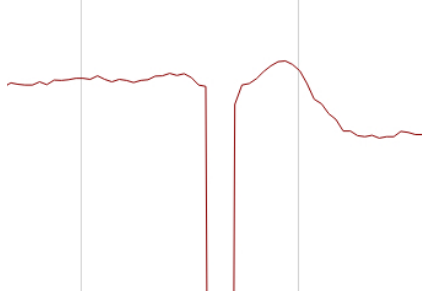


**Fig. 3.** After applying standard deviation filter

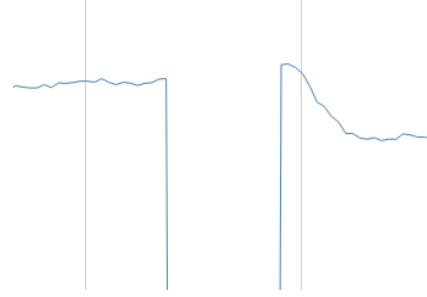
To illustrate the application of the standard deviation filter, consider the graphs in Figures 2 and 3. Particularly, the graph in Figure 2 shows a distortion to an extent that the visualization engine of CEP-Web could not print the graph anymore (all filter examples shown in this document are screenshots from CEP-Web). After applying the standard deviation filter, these anomalies are removed—the resulting missing values could then be substituted by a linear interpolation filter in a second step.

**Blink detection.** The detection of blinks is one of the central aspects when cleaning pupillometric data. Since the blink itself is not an on-off event, but rather a process of closing and opening the eyelid, artifacts are likely to occur shortly before and after the blink. To compensate for these artifacts, CEP-Web implements the blink detection filter, which, based on a heuristic of missing values and gaze position, will detect and clip out blinks (for details, please refer to [11]). To illustrate the application of the blink detection filter, consider the

Figures 4 and 5. As indicated before, the filter recognizes the series of missing data as blink and clips out all values that were measured during blink onset and blink ending.



**Fig. 4.** Raw data

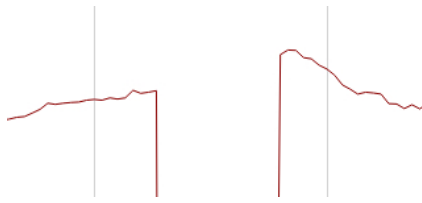


**Fig. 5.** After applying blink detection

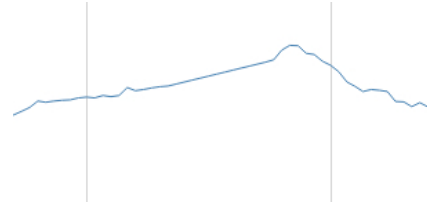
In case the pupil substitution filter or the gaze point substitution filter is intended to be applied before the blink detection filter, we *strongly recommend* to apply these filters only in combination. As described in [11], for detecting blinks, the blink detection filter takes into account whether pupil sizes are available and whether a valid gaze point position could be measured. Hence, the filter will only work properly, if both pupil sizes and gaze points have been substituted. To clarify, the application of pupil substitution filter or gaze point substitution filter is *not* mandatory, but they should only be applied in combination when the blink detection filter should be applied as well.

**Linear interpolation.** Whenever eye trackers are used for collecting pupillometric data, data loss is unavoidable—simply due to the fact that the eye tracker cannot assess the pupil during blinks. This is particularly problematic since certain filters depend on continuous data, such as the the Butterworth filter. To deal with this situation, CEP-Web provides a filter for linearly interpolating missing data. Particularly, for a series of missing values, where  $value_s$  is the last non-missing value at time  $time_s$  and  $value_e$  is the first non-missing value after a series of missing values with the corresponding timestamp  $time_e$ , CEP-Web will linearly interpolate the missing values as follows:

$$value(time) = value_s + (value_e - value_s) * \frac{time - time_s}{time_e - time_s} \quad (7)$$



**Fig. 6.** Raw data



**Fig. 7.** Linearly interpolated data

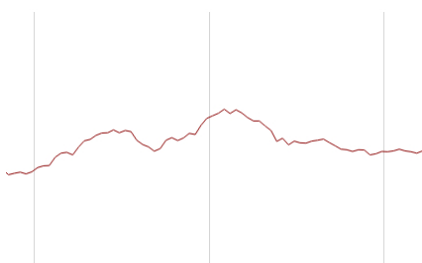


To illustrate linear interpolation in CEP–Web, consider Figures 6 and 7. Clearly, Figure 6 is affected by missing data—in this particular example caused by a blink. After applying the filter, the missing data is linearly interpolated, resulting in continuous data, as shown in Figure 7.

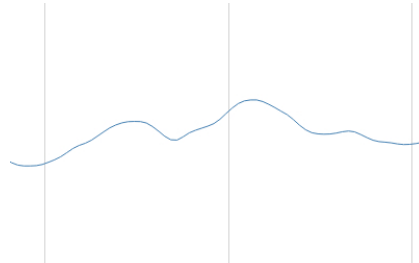
When applying the linear interpolation filter, we *strongly recommend* to apply the blink detection filter first. In particular, values measured during blinks are error-prone due the eyelid being halfway covered, hence the linear interpolation filter should not use these values as start/end points for linear interpolation. Rather, values that can be considered valid, i.e., after the pupil is fully visible and the eye tracker can assess the pupil size correctly, should be used as start/end points for linear interpolation. For achieving this, the blink detection filter can be used, since it will remove values that were measured during a blink, hence removing values that were measured when the eyelid was closing/opening.

Similarly, the eye tracker may deliver spurious measurements during blinks, i.e., the eye tracker incorrectly detects the pupil. Again, respective values must be assumed to be invalid and should not be used for linear interpolation—also for this reason, we *strongly recommend* to apply the blink detection filter before running the linear interpolation.

**Butterworth filter.** CEP–Web provides a third order lowpass Butterworth filter for data cleaning through an open-source library for digital signal processing<sup>4</sup>. Generally, lowpass filters will filter out high frequencies, but do not affect lower frequencies. For data cleaning, lowpass filters are typically used to filter out measurement artifacts such as white noise and are thus used for smoothening data. To illustrate the effect of applying a lowpass filter, consider the illustrations shown in Figures 8 and 9. The raw data shows typical signs of white noise, whereas the filtered data exhibits the same basic features, but is apparently smoothened.



**Fig. 8.** Raw data



**Fig. 9.** Filtered with Butterworth

Even though a lowpass Butterworth filter can be used for processing measurement artifacts, its application introduces a phase response to the filtered signal—in other words, this feature of Butterworth causes the filtered signal to be shifted towards the past. To compensate for this phase response, CEP–Web calculates the expected phase response and automatically re-shifts the processed

<sup>4</sup> <http://www.source-code.biz/dsp/java>

signal so that the phase response is equalized. In particular, the phase shift of a third order lowpass Butterworth filter ( $\phi$ ) can be calculated based upon the angular frequency ( $w$ ) as follows:

$$\phi(w) = -\tan^{-1}\left(\frac{2w - w^3}{1 - 2w^2}\right) \quad (8)$$

## 2.4 Data inspection

As described in Section 2.3, filters need to be applied with care and the effect of applying a filter is not always obvious. Similarly, it is difficult to assess whether the data being analyzed behaves the way it was expected for the experiment or whether it contains unforeseeable artifacts. To counteract this problem, CEP-Web provides the possibility of visualizing pupillometric data in the form of graphs, as illustrated in Figure 10. In this particular example, the user chose to visualize raw data (blue line) to compare them with the cleaned results (red line); on the x-axis the duration is shown in minutes:seconds, on the y-axis the pupil diameter is shown in mm. Furthermore, it can be seen that the cleaning resulted in a smoothing of the graph around 1:51 and the removal of a blink around 1:54.

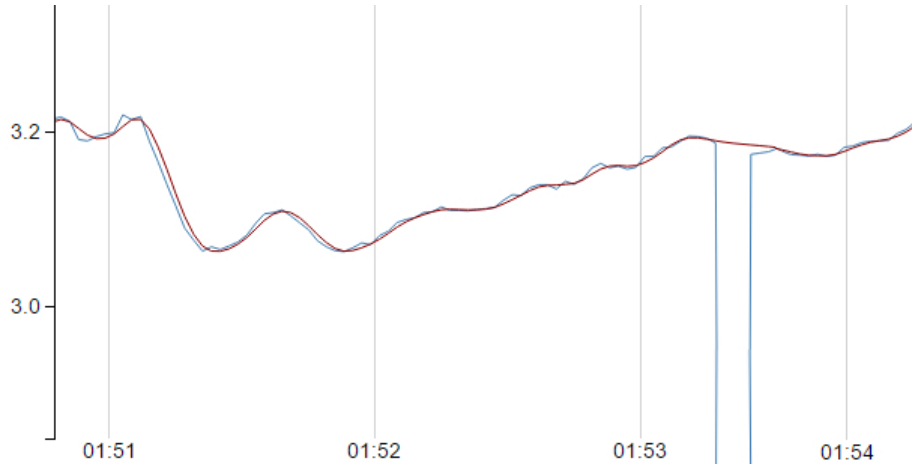


Fig. 10. Visualization of raw data (blue) and cleaned data (red)

## 3 Technical infrastructure

This section explains on the technical infrastructure provided by CEP-Web. Section 3.1 focuses on the technical challenges connected with processing large amounts of data and describes in Section 3.2 how CEP-Web tackles these challenges and supports the analysis workflow described in Section 2.

### 3.1 Technical Challenges

Besides typical challenges of software, such as maintainability, quality and usability, CEP-Web needs to address two challenges particular to the processing of pupillometric data:

**Data volume.** Obviously, the amount of data to be processed strongly depends on the extend of data provided by the eye tracker. This, in turn, is typically mainly influenced by the sampling rate, data fields exported from the eye tracker, as well as the format used for export. First, regarding the sampling rate, modern eye trackers work with a sampling rate of at least 60Hz, i.e., producing 60 data points per second. Depending on the particular field of application, sampling rates of up to 1000Hz are common as well. CEP-Web does not make any assumptions about sampling rates and thus supports arbitrary sampling rates. Second, regarding the data fields exported by the eye tracker, it mainly depends on the eye tracking software provided with the eye tracker. Even though the export may be configured to that only necessary fields will be exported by the eye tracking software, for convenience or simplicity often all available data is exported. Here, the data fields required by CEP-Web depend on the particular application. For instance, for rather simple filters such as standard deviation, timestamps as well as the pupillometric data are sufficient. However, for more complex filters, such as the blink detection, additionally gaze positions may be required. CEP-Web does not require the user to specify these data fields upfront, but will prompt the user as soon as they are required. Third, regarding the data format, compressed or proprietary formats may provide a more succinct representation of data. Since compressed or proprietary formats tend to compromise interoperability, in CEP-Web, we rely on tabular separated value (.tsv) files only.

Given our typical usage scenario with Tobii X300 and considering a sampling rate of 300Hz, one hour of eye tracking will produce about 430MB of data. In the light of our recent study with 115 subjects and eye tracking sessions between 30 minutes and more than 1 hour, 36.34 GB of data needed be processed. Given these numbers, it becomes evident that more elaborated approaches are required to handle this amount of data.

**Processing speed.** Closely connected to the volume of data is the time and processing power required for analyzing respective data. Apparently, the more data needs to be processed and the more complex the computations to be conducted, the longer the data analysis will take. Given the amount of data at hand, optimizing the individual computations (e.g., cleaning or filtering) is not enough to keep the processing duration at an acceptable level. Rather, it is of vital importance to provide support for the parallel processing of computation for providing reasonable computation times.

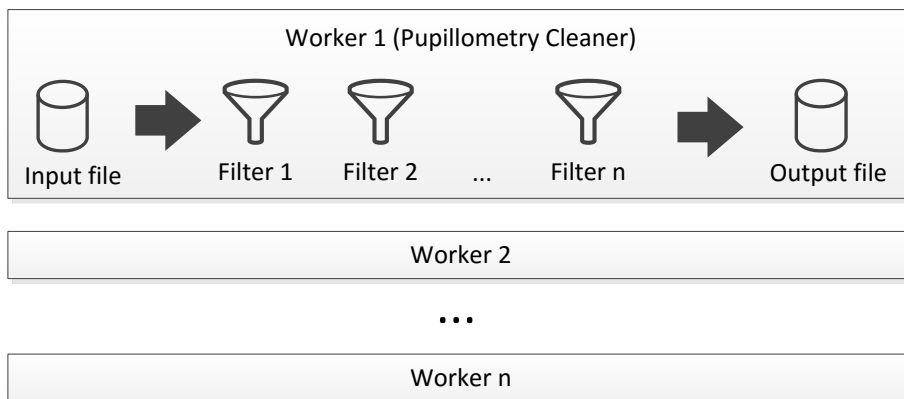
To exemplify the need for parallel processing, consider our recent study in which the have tracked 115 subjects with a sampling rate of 300Hz, resulting in

a data set with 96,676,561 data points. For each of these data points, we were required to run the pupil substitution filter, standard deviation filter, linear interpolation filter as well as Butterworth filter. Apparently, running this kind of analysis on a single CPU will not be enough to provide results in acceptable time.

### 3.2 Software architecture

To address the described challenges with respect to data volume and processing speed, we have developed CEP-Web that allows for data inspection in real-time, whenever possible, but also provides the possibility to schedule long-lasting tasks in the background. Particularly, as described in the following, we provide a worker infrastructure for parallelizing long-lasting tasks, as well as means for pre-processing data for real-time analysis.

**Worker infrastructure.** Even though the clock speed of modern CPUs is currently restricted by physical limits and cannot be expected to be increased any further, modern computers provide performance gains through the parallel operation of several CPU cores. However, to harness the power of parallel processing, the software needs to provide the respective infrastructure as well. In CEP-Web, we employ the thread pool pattern (also known as replicated workers or worker-crew model) [14] to parallelize the long-lasting computations. In particular, we seek to encapsulate each task in the form of an independent *worker*, as illustrated in Figure 11. Therein, the task of *Worker 1* is to read an input file, apply a set of  $n$  filters to the input file and finally write the processed file as output of the worker. In parallel to *Worker 1*, several other workers may be processing data as well—again, each worker will encapsulate the work to be done and can be run as independent computation.



**Fig. 11.** Worker infrastructure

The crucial part of this worker infrastructure is the scheduling of work to be conducted. Too few parallel workers will result in a low utilization of CPUs, while a too high number of parallel workers will negatively impact performance when several workers need to share on CPU. In CEP-Web we decided to allow exactly one worker on single-core machines. On multi-core machines, we reserve one core for housekeeping work and use the remaining cores for workers, i.e., the number of workers in parallel is the number number of CPU cores - 1. Workers that cannot be started yet due to this restriction are kept in the worker queue and will be started as soon as one of the active workers has finished.

**Preparation of data for real-time analysis.** As described in Section 2, CEP-Web also provides the possibility to inspect raw as well as processed data in real-time. As described in Section 3.1, particularly eye trackers with high sampling rates easily produces data files are several hundreds of MB large. Even though modern hard drives can easily store and read this amount of data, it still requires the user to wait until the system has loaded and processed the file. To minimize this waiting time and enable real-time data inspection, data files are optimized along three stages:

- *Uncompressed data.* Data that is uploaded by the user or being stored from a worker as result of applying filters typically contains data fields that are not necessary for real-time data inspection and implies that unnecessary data is loaded from the hard disk. For performance reasons, CEP-Web does not provide real-time data inspection for these files.
- *Compressed data.* To make uncompressed data amenable for analysis, CEP-Web strips of all unnecessary data from uncompressed files and stores these compressed files in new, *compressed* data files. Since this typically involves reading, processing and storing several hundreds of MBs, the compressing of data is executed as a task within the worker infrastructure.
- *Cached data.* Even though compressed data can be read faster than uncompressed data, the waiting times for disk I/O operations are still to large for ensuring acceptable waiting times during real-time analysis. To finally achieve acceptable waiting times, CEP-Web holds the data currently under analysis in memory to allow for instant access. Hence, whenever a data file should be analyzed, its content is loaded into memory, imposing a one-time waiting time. For the remainder of the analysis, data will be read from memory, thereby minimizing waiting times.

### 3.3 Implementation

CEP-Web is implemented as typical web application on top of Tomcat on the server side and relying on AngularJS on the client side. In the following, we will describe details that may be interesting for readers interested in extended CEP-Web. For a more up-to-date technical description of CEP-Web, please visit our GitLab page<sup>5</sup>.

<sup>5</sup> <https://git.uibk.ac.at/cheetah-web-group/cheetah-web>

**Server side.** CEP–Web builds upon Tomcat 6 and Java 7. For storing data, we rely on MySQL 5.6; access to the database is provided by the MySQL JDBC driver. For migrating our database, we rely on LiquiBase; respective changelogs are available in our GitLab account. CEP–Web does not have any operating system depending components and has so far been used on Windows 10 and CentOS 6.7.

**Client side.** For the client side, we rely on AngularJS and Bootstrap. Hence, CEP–Web generally supports all our modern browsers—best results can be expected with Google Chrome and Mozilla Firefox.

### 3.4 Hardware setup

The minimum requirements on hardware are difficult to describe, since they heavily depend on the data to be analyzed and the filters that should be applied. From our experience on analyzing data, we know:

- The need of memory for cleaning data in parallel workers does not increase linearly with each worker. Rather, the first worker will require a proportionally larger share of memory than any additional worker. Technically, this behaviour can be explained by the effect of sharing String objects (String pooling) that is performed by Java, i.e., identical Strings are not recreated, but rather shared throughout the virtual machine. Hence, the first worker will fill the String pool—requiring proportionally more memory—whereas any additional worker will reuse the Strings from the pool.
- For our recent study, we cleaned data with up to 500MB on a machine with 24 GB RAM and 12 cores. As described in Section 3.2, on this setup, only 11 cores will be used at the same time for cleaning, i.e., at most 11 workers will run in parallel. For this amount of workers, the memory was easily sufficient for cleaning the data and computing the average pupil size.

## 4 Related work

In [10] several preprocessing steps are described in a generic way, such as blink detection, linear interpolation in blink phases, and removing high frequency artifacts. All of those are addressed by CEP–Web as described in Section 2. The eye blink detection approach presented in [11] and a corresponding handling of blinks during eye tracking is implemented in CEP–Web. To remove high frequency artifacts we are following [15] by using a third order lowpass Butterworth filter also described in Section 2.

For an exhaustive overview regarding the theory for cognitive load, it’s measurement and examples for research please see [5].

## 5 Summary

This technical report provided a brief overview of the current capabilities of CEP-Web in terms of managing, cleaning, and visualizing pupillometric data. More specifically, we presented the handling of studies and subjects and their associated pupillometric data. Further, the available filters of CEP-Web are presented. This way, users are capable of performing state of the art data processing, even on large numbers of files. The integrated visualization tool allows users to inspect their data prior and after cleaning to ensure the correct application of the filters.

Future developments for CEP-Web will include the evaluation of pupil dilation during tasks and sub-tasks. For this, we are planning an infrastructure that splits the data stream into smaller chunks and provides capabilities for calculating and reporting mean, median, and/or standard deviation. In a similar vein, we intend to include support for facilitating the analysis of Task-Evoked Pupillary Response (TEPR) studies. For this, we plan to integrate the definition of data processing routines that include not only cleaning, but also partitioning the data into trials and evaluating the pupillary responses after the stimulus. The data will be aggregated and presented for all participants of the study, allowing a more efficient data analysis.

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