netherlands eScience center

The title of the project

The subtitle of the project

N.B.: Here you can add a brief summary of your project such that someone can quickly see what it is about, do not spend more than two lines on it.

Maintainer:
Maya Toitovna (*mtoitovna*), Mars Center for Outstanding Developments

Contributors:

Maya Toitovna	(*mtoitovna*),	Mars Center for Outstanding Developments
Frank Chalmers	(*fchalmers*),	Mars Institute of Technology
Ann Clayborne	(*aclayborne*),	Mars Laboratory for Great Achievements
Arkady Bogdanov	(*abogdanov*),	Mars University of Fundamental Research

1 Overview

1. Key: maintainer, Name: Maya Toitovna, id: mtoitovna, Institution: Mars Center for Outstanding Developments
2. Key: chalmers, Name: Frank Chalmers, id: fchalmers, Institution: Mars Institute of Technology
3. Key: ann, Name: Ann Clayborne, id: aclayborne, Institution: Mars Laboratory for Great Achievements
4. Key: arkadybogdanov, Name: Arkady Bogdanov, id: abogdanov, Institution: Mars University of Fundamental Research

In this section one should introduce what the research is abLout, in a high level so you can do a simple explanation of the topic and the research challenges that you are facing.

During the cardiac cycle, the heart firstly generates the electrical activity and then the electrical activity causes atrial and ventricular contractions. This in turn forces blood between the chambers of the heart and around the body. The opening and closure of the heart valves is associated with accelerations-decelerations of blood, giving rise to vibrations of the entire cardiac structure (the heart sounds and murmurs). These vibrations are audible at the chest wall, and listening for specific heart sounds can give an indication of the health of the heart. The phonocardiogram (PCG) is the graphical representation of a heart sound recording. Figure 0.1 illustrates a short section of a PCG recording.

Then all the contributors: Name: Maya Toitovna Name: Frank Chalmers Name: Ann Clayborne Name: Arkady Bogdanov

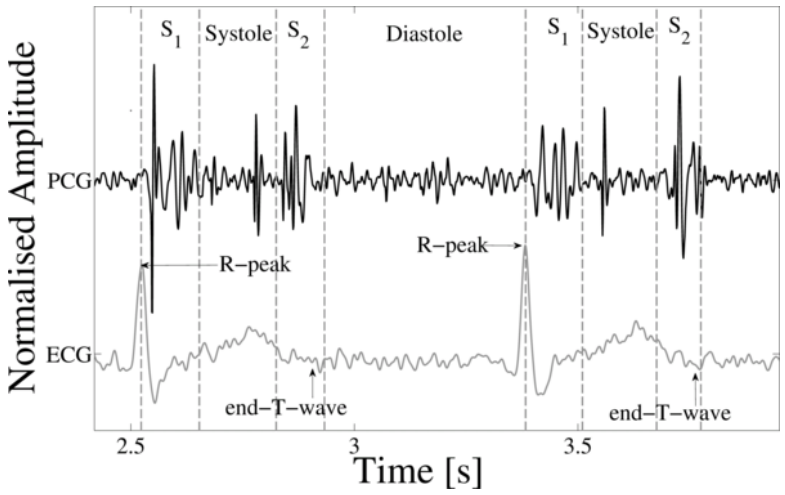


Figure 1.1: A PCG (center tracing), with simultaneously recorded ECG (lower tracing) and the four states of the PCG recording; S1, Systole, S2 and Diastole.

The objective of the challenge is to create a model is able to correctly discriminate between the two classes given just the PCG recordings. Challenges include:

- Data is subject to temporal variations due to variations in the heart rate.
- Inter-patient differences make difficult a learn a model that generalizes well across patients.
- Differences introduced by heterogeneity in the collection of the recordings can render a classifier trained on one population useless when applied to another

2 Meetings

2022-05-15: aclayborne

This is what happened in the meeting.

$$\int_\Omega \varphi(x)\,\mathrm{d}x \tag{2.1}$$

Quisque ullamcorper placerat ipsum. Cras nibh. Morbi vel justo vitae lacus tincidunt ultrices. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. In hac habitasse platea dictumst. Integer tempus convallis augue. Etiam facilisis. Nunc elementum fermentum wisi. Aenean placerat. Ut imperdiet, enim sed gravida sollicitudin, felis odio placerat quam, ac pulvinar elit purus eget enim. Nunc vitae tortor. Proin tempus nibh sit amet nisl. Vivamus quis tortor vitae risus porta vehicula.

2022-05-11: abogdanov

We discussed that the `MeetingMinutes` environment produces alternating background colours for easier visualisation.

$$\int_\Omega \varphi(x)\,\mathrm{d}x \tag{2.2}$$

Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

We can anything inside meeting minutes, including (high priority) todo notes inside the minutes on the same day (or any other day)

2022-05-10, **fchalmers**: Compute the error between mode-downsampled segmentation state vectors at 1000 Hz and state vectors computed at 400 Hz. This needs to be performed to check that the segmentation algorithm is not overfitted to 1000Hz. If error is significant, retrain segmentation at 400 Hz or use 1000 just for segmentation (if Matlab 2016a improvements are true there should be no problem)

or a (low priority) todo note by another contributor, for example

2022-05-12, **aclayborne**: Do not forget to first check this less important aspect.

2022-05-10: fchalmers

This time, these meeting minutes, were written by the contributor Frank Chalmers, as can be seen by the id fchalmers on the header of the box.

During this meeting the following points have been addressed

- This first very important point.
- Followed by this second also important point.
- This other less important point was also discussed at the end.

For this meeting this equation was important

$$\int_\Omega \varphi(x)\,\mathrm{d}x\,. \tag{2.3}$$

Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

Meeting minutes boxes can extend over to the next page (or more) if needed.

2022-05-09: mtoitovna

This first meeting's minutes were added by Maya Toitovna (the maintainer of this project logbook), as can be seen by the id mtoitovna on the header of the box.

In this first meeting the following equation was discussed

$$\int_{\Omega} \varphi(x)\,\mathrm{d}x\,. \tag{2.4}$$

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

3 Topic A to focus on

We can use sections organize the text into different parts such that specific topics are addressed in their own section.

Each section starts in a new page. All floating objects are printed before the start of the new section and then a new page is added with the section at the top.

With a fancy title

The `HighlightedNotes` environment that generates these fancy boxes, can be used with a title `\begin{HighlightedNotes}{the_title_text}`, as in this case, or without a title `\begin{HighlightedNotes}{}`, as in the previous case.

In most Machine Learning research projects you will be using some kind of samples from a Dataset to learn a model. Thus it is extremely important that you carefully describe the dataset and why you believe is a good dataset for the project and what type of preprocessing are you going to apply.

Early approaches failed to build a reliable model due to lack of a large enough data set, so this challenge provides the largest dataset to this day. Heart sound recordings were sourced from several contributors around the world, collected at either a clinical or nonclinical environment, from both healthy subjects and pathological patients. The Challenge training set consists of five databases (A through E) containing a total of 3,126 heart sound recordings, lasting from 5 seconds to just over 120 seconds. As said in [1] and also in [2].

A main problem found when working with these recordings is the strong similarity between the records coming from the same population as well as the strong class imbalance of roughly 6:1 of Normal to Abnormal.

Table 2.1 summarizes the sizes of the different populations as well as their class imbalance

	A	N	S	A/S
a	292	117	409	0.714
b	104	386	490	0.212
c	24	7	31	0.774
d	28	27	55	0.509
e	183	1958	2141	0.085
	631	2495	3126	0.202

(a) Training Set

	A'	N'	S'	A'/S'	S'/S
a	40	40	80	0.5	0.20
b	49	49	98	0.5	0.20
c	4	3	7	0.57	0.23
d	5	5	10	0.5	0.18
e	53	53	106	0.5	0.05
	151	150	301	0.50	0.10

(b) Validation Set

Table 3.1: Population properties $A \equiv$ Abnormal, $N \equiv$ Normal, $S \equiv A + N$

3.1 Preprocessing

There is a high heterogeneity since it was compiled in different environments with diverse systems and devices. The DTW affinity between representative heartbeats is completely biased if we do not apply any kind of preprocessing.

To prevent this a simple zero mean unit variance normalization approach is used to get closer distances. Nevertheless with a reasonable $\sigma = 10^{2.5}$ we can note that the population distances are still there except less noticeable.

$$x_i' \leftarrow \frac{x_i - \bar{x}}{\sigma} \tag{3.1}$$

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad \sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x}) \tag{3.2}$$

All the provided records were sampled at $f_s = 2\,\text{kHz}$. The segmentation algorithm resamples them[1] to $f'_s = 1\,\text{kHz}$.

Strike-through

Often you will be wrong on your assumptions, but do not throw them away completely, just cross them out in case you need them later using the `\sout` command and it will look like ~~this~~ or `\soutthick` command and it will look like ~~this~~

~~Medoid computation is perfomed at $f''_s = f'_s/5 = 200\,\text{kHz}$ to speed computation. Simple analysis was performed to check that the features extracted from these 200Hz-medoids were approximately the same as the ones extracted from the 1khz-medoids.~~

~~Downsampling can be seen as a problem of information loss in the frequency spectrum. If the frequency content $f > f_s/(2N)$ is mostly empty for N when we downsample by said N we will only be losing information in that range.~~

TODOs

You will often have pending tasks that you need to track. This research journal allows you to include both high and low priority todos that will be summarized in a list at the end of the file. Use the commands `\hightodo` and `\lowtodo`, including a date is recommended for tracking purposes.
Note: define your `userId` in the preamble

2016-05-23, **fchalmers**: Compute the error between mode-downsampled segmentation state vectors at 1000 Hz and state vectors computed at 400 Hz. This needs to be performed to check that the segmentation algorithm is not overfitted to 1000Hz. If error is significant, retrain segmentation at 400 Hz or use 1000 just for segmentation (if Matlab 2016a improvements are true there should be no problem)

2016-05-27, **mtoitovna**: Do DRYRUN with new Matlab 2016a and check the segmentation quota

[1] Resampling = Low Pass Filter + Downsampling by M. The filter will have $\omega_c = \pi/N$ to prevent aliasing

4 Methods

4.1 Algorithms

Sometimes the most straightforward way to explain a procedure is just to give it in a algorithmic format, it takes a little time but it will force you to go thorugh the steps and you will most likely be able to reuse it on you paper. Note: You will need to have `\ALGORITHMStrue` in the preamble to enable algorithms

Algorithm 1 Euclid's algorithm

procedure EUCLID(a, b) ▷ The g.c.d. of a and b
  $r \leftarrow a \bmod b$
  while $r \neq 0$ **do** ▷ We have the answer if r is 0
    $a \leftarrow b$
    $b \leftarrow r$
    $r \leftarrow a \bmod b$
  return b ▷ The gcd is b

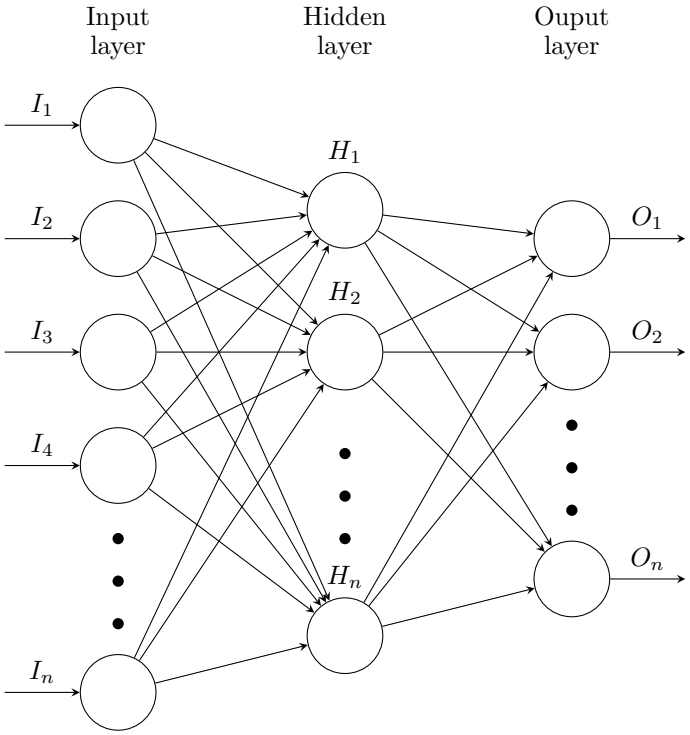
4.2 Code

If the algorithm is to vague and you feel like you need the source code you can also insert it. You can put LaTeX code inside by using `<@ @>` delimiters and highlight it with `<| |>` delimiters
Note: you will need to have `\LISTINGStrue` in the preamble.

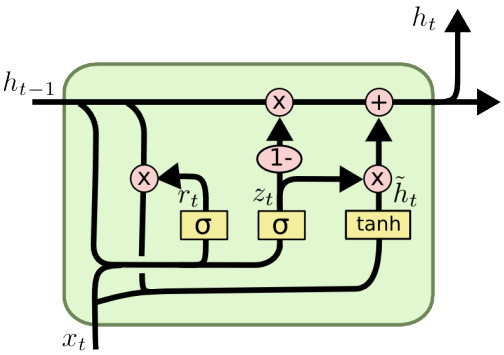
```
def DTW_distance(s1, s2):
    """
    Function to compute the Dynamic Time Warping in Python between two signals
    """
    DTW={}

    for i in range(len(s1)):
        DTW[(i, -1)] = float('inf') # By default ∞
    for i in range(len(s2)):
        DTW[(-1, i)] = float('inf') # By default ∞
    DTW[(-1, -1)] = 0

    for i in range(len(s1)):
        for j in range(len(s2)):
            dist= (s1[i]-s2[j])**2
            DTW[(i, j)] = dist + min(DTW[(i-1, j)],DTW[(i, j-1)], DTW[(i-1, j-1)])

    return sqrt(DTW[len(s1)-1, len(s2)-1])
```

4.3 Diagrams

For simple diagrams I highly recommend learning TiKZ, you will be drawing the diagrams in pure LaTeXwhich has a steep learning curve but once you get used to it, it can be quite easy to display and do `for` loops to draw multiples line at once.
Note: you will need to have `\TiKZtrue` in the preamble



However, sometimes you will need more complicated diagrams (or maybe you do not like TiKZ, in that case I recommend a vector drawing tool such as Inkscape which allows LaTeX embedding)



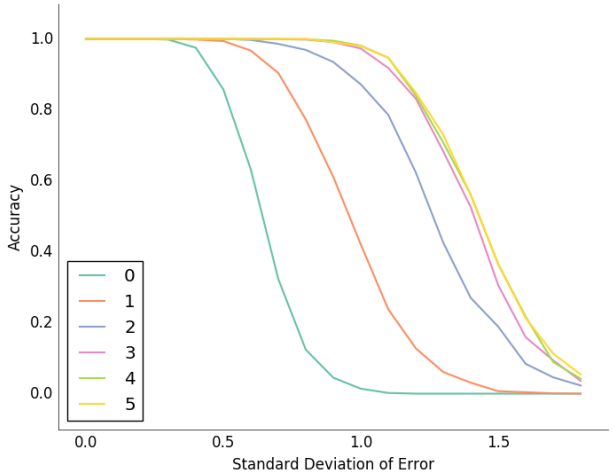
$$z_t = \sigma\left(W_z \cdot [h_{t-1}, x_t]\right)$$
$$r_t = \sigma\left(W_r \cdot [h_{t-1}, x_t]\right)$$
$$\tilde{h}_t = \tanh\left(W \cdot [r_t * h_{t-1}, x_t]\right)$$
$$h_t = (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t$$

Figure 4.1: Gate Recurrent Unit in a Long Short Term Memory Neural Netwok (GRU-LSTM).
Credit to https://colah.github.io/posts/2015-08-Understanding-LSTMs/

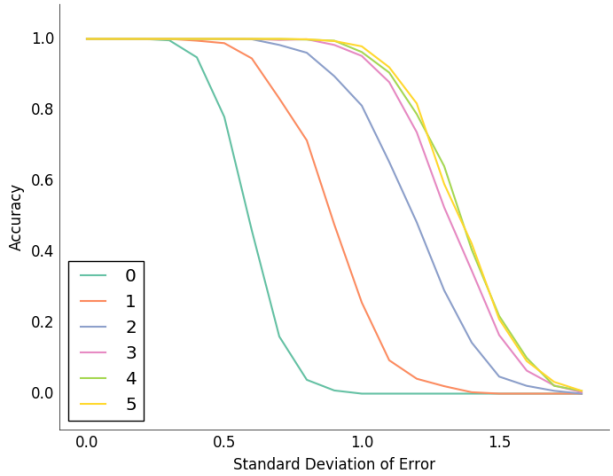
5 Results

5.1 Figures

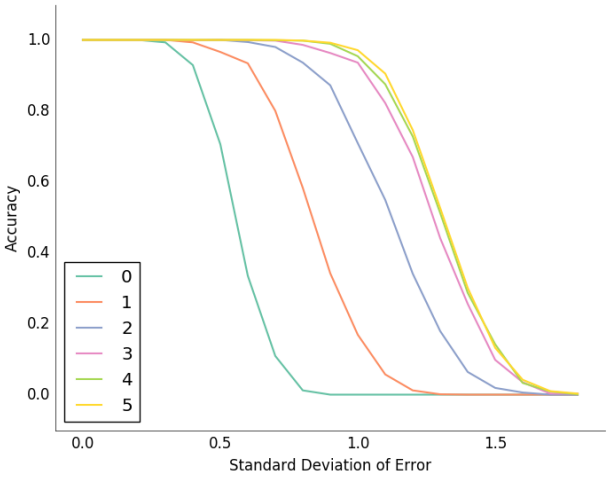
In general the best way to visualize your results will be some figures, I recommend Python's matplotlib for generating them or R's ggplot2.



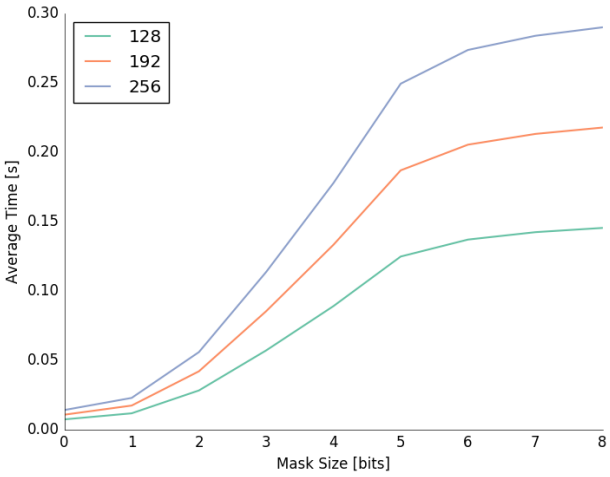
(a) Average accuracies for 128-bit key



(b) Average accuracies for 192-bit key



(c) Average accuracies for 256-bit key



(d) Average Runtimes for various mask sizes

Figure 5.1: Results of simulation of the LMS algorithm with correction

5.2 Tables

LaTeX booktab environments are really good to showcase and track your results, however they can get fairly messy. My suggestion is to generate them via Python automatically and store the results in either a plain text file or a spreadsheet (there are packages to read spreadsheets with Python)

$\sigma \setminus \tau$	0	1	2	3	4	5	6	7	8
0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0.6	98.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
0.8	84.7	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	28.1	98.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0
1.2	1.3	88.7	99.4	99.9	99.8	99.9	100.0	99.9	100.0
1.4	0.0	57.1	96.2	99.3	99.0	99.3	99.4	99.8	99.7
1.6	0.0	18.6	81.2	93.0	93.7	94.8	95.6	92.3	93.3
1.8	0.0	2.4	42.8	67.0	70.1	72.1	69.0	69.1	68.6
2.0	0.0	0.1	9.0	23.1	24.5	26.9	28.2	27.3	27.3
t(ms)	27.92	40.23	77.30	157.27	252.05	342.18	381.46	399.85	413.72

Table 5.1: Performance of the algorithm for 128-bit key and with multiple readings per key

A Resources

It is a good idea to record sources that explain concepts or provide tools so the research is both better documented and if someone has to continue with it, there is enough supporting documentation.

- Quick read in DTW and Keogh Lower Bounding.
  http://alexminnaar.com/time-series-classification-and-clustering-with-python.html
  http://nbviewer.jupyter.org/github/alexminnaar/time-series-classification-and-clustering/blob/master/Time%20Series%20Classification%20and%20Clustering.ipynb
- Parallelizing DTW – Good article on making a parallel version of DTW. Uses Keogh lower bound not as a linear approximation but as a pruning device.
  https://www.andrew.cmu.edu/user/mmohta/15418Project/finalreport.html
- Deep Learning
  - Intro to LSTM
    https://colah.github.io/posts/2015-08-Understanding-LSTMs
  - Intro to CNN
    https://colah.github.io/posts/2014-07-Conv-Nets-Modular/
  - Why are LSTMs are so useful, impressive result in character pattern and syntax learning
    https://karpathy.github.io/2015/05/21/rnn-effectiveness/

B References

Do not forget to cite the papers that you are using in your research, this way your work will be infinitely easier to write down and to review when the time comes.

[1] Albert Einstein. "Zur Elektrodynamik bewegter Körper. (German) [On the electrodynamics of moving bodies]." In: Annalen der Physik 322.10 (1905), pp. 891–921. DOI: http://dx.doi.org/10.1002/andp.19053221004.

[2] Donald E. Knuth. "Fundamental Algorithms." In: Addison-Wesley, 1973. Chap. 1.2.

C TO DO

Here you will have all your TODOs grouped with anchor links to the parts of the document where they are. Really handy if you do not know where to continue with your project.

Todo list