Answer Sheet for Assessment 1
L349 - Mobile Health

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700 words (excluding bibliography, headers, and captions)

Part 1: Audio Processing Basics [25 marks]

Task 1.2

Question 1: Discuss any differences between the two files in the time domain, giving possible reasons.

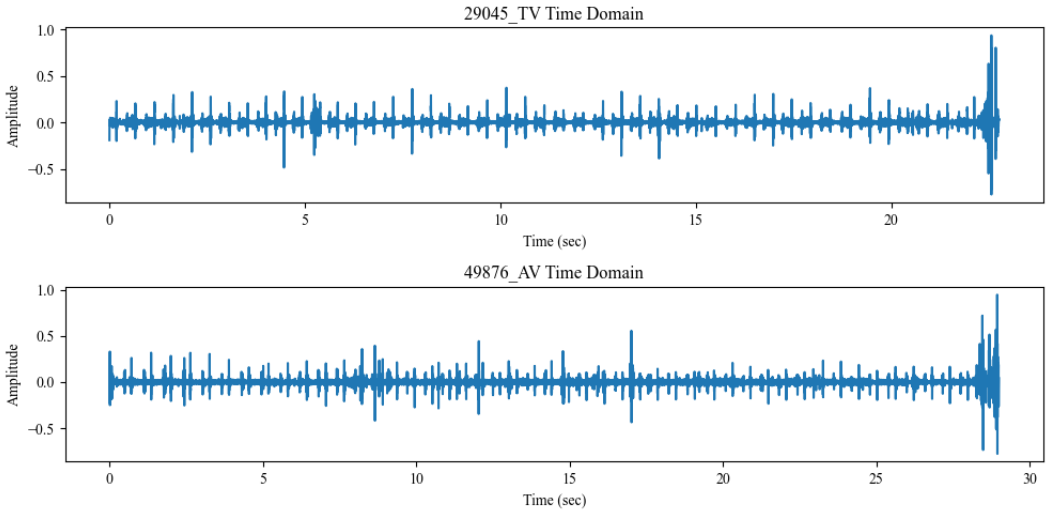

Figure 1: Enter Caption

- 29045_TV:
  - relatively clearly recognizable heartbeats, especially when zoomed in -> reason: clear sound recording, little noise
  - constantly noticeable amplitude **between** S1 and S2, otherwise relatively small amplitude
- 49876_AV
  - heartbeats (incl. S1 & S2) can also be identified, but with greater irregularity and variation in amplitude
  - stronger fluctuations throughout
  - reason: less accurate recording, more noise

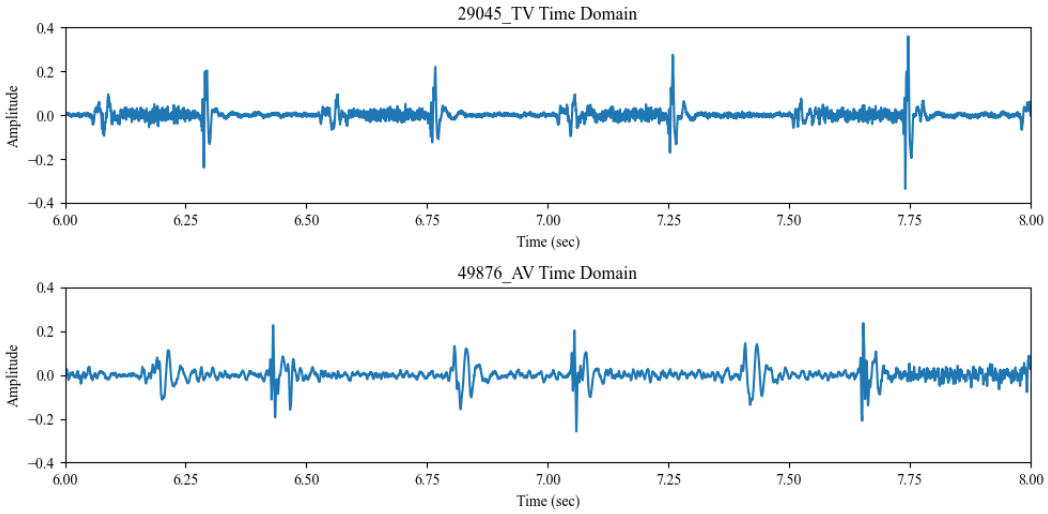

Figure 2: Enter Caption

Question 2: Based on the above, can you visually differentiate between the murmur and non-murmur heart sounds? Predict which is the murmur and which is the non-murmur.

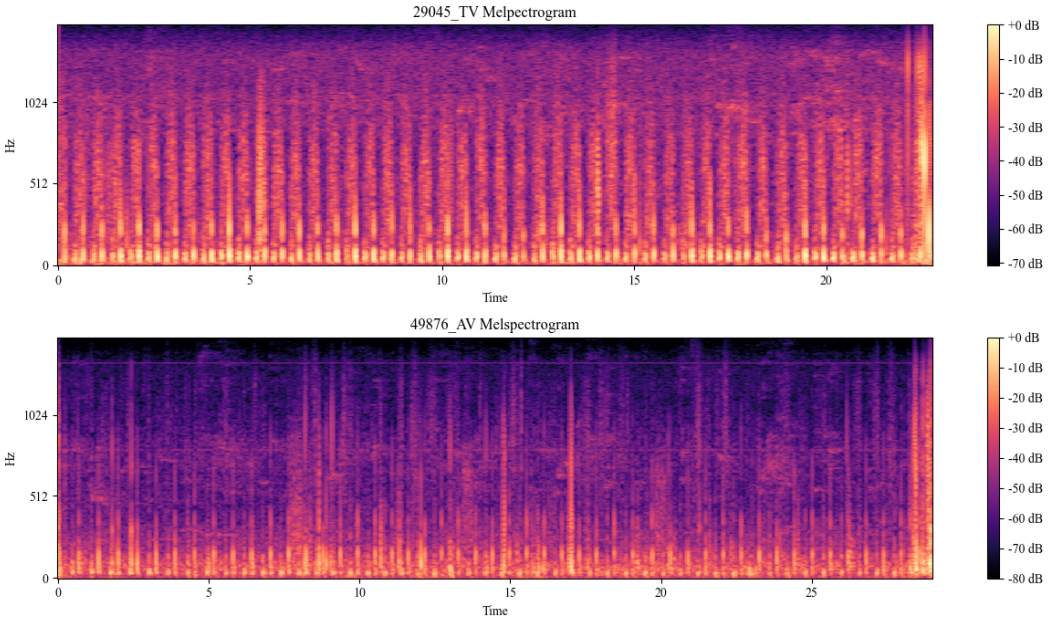

Figure 3: Enter Caption

- 29045_TV looks more regular and less conspicuous at first glance
- nevertheless, possible limitations of the sound file quality (i.e. noise, recording accuracy etc.) must also be taken into account
- research shows: sound development between S1 ("lub") and S2 ("dub") is particularly relevant to identify murmur [22]
- Only **29045_TV** shows noticeable sound here -> could represent "blowing, whooshing, or rasping sound heard during a heartbeat", indicating a murmur [27]
- possible murmur type: pattern is similar to mitral regurgitation ("C" in graphic), but as it is strongly audible at the tricuspid valve, it might indicate a tricuspid regurgitation [9, 14]

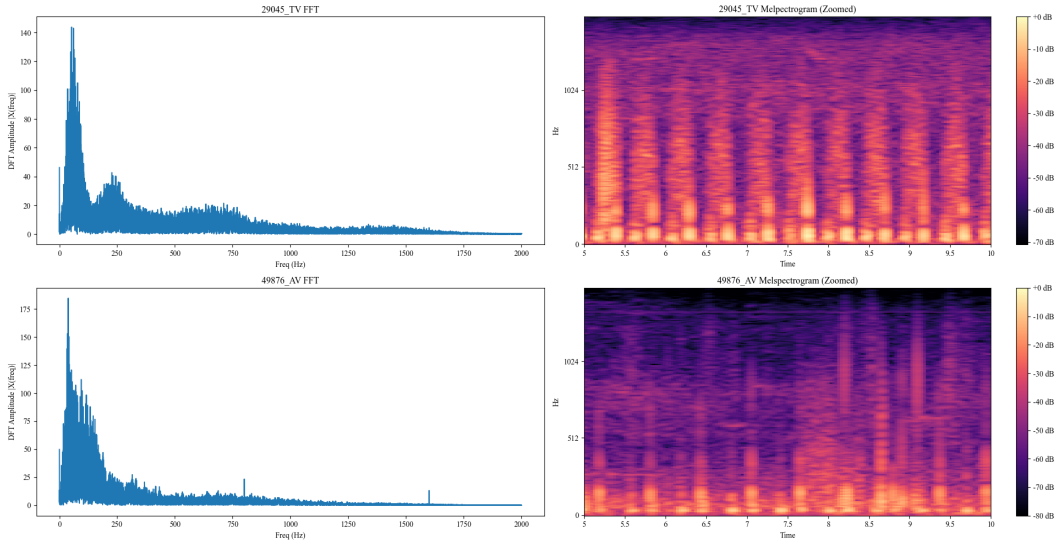

Figure 4: Enter Caption

- -> 29045_TV = murmur, 49876_AV = non-murmur,

Task 1.3

Question 1: Discuss any differences between the frequency domain representations of the murmur and non-murmur files.

- 29045_TV (Murmor):
  - concentration of peaks primarily in low-frequency range, up to ∼150Hz
  - exhibits two further peaks in the distribution of frequencies around ∼250Hz and ∼650Hz
  - generally more spread-out
- 49876_AV (Non-murmor):
  - almost exclusively concentration of peaks in low-frequency range, although slightly higher, up to ∼200Hz
  - exhibits some isolated peaks, likely noise

Question 2: Are there any features that are evident in the frequency domain that you could not distinguish in the time domain?

- time domain was not able to show which frequencies make up the signal –> frequency domain allows conclusions regarding involved frequencies and the extent of their involvement
- graphs reveal that the 29045_TV signal is composed of much stronger higher frequency signals than the 49876_AV signal, which, in line with scholarship [e.g. 2, 11, 24] confirms the classification of 29045_TV as murmur

Task 1.4

Question 1: Discuss and provide reasons for your choice of filter type and cutoffs.

- 1. Step: consider findings of initial visual analysis of (unfiltered) frequency domain graphs -> Figure 4 exhibits relevant peaks to a maximum of ∼1000Hz –> cutoff latest after 1000Hz
- 2. Step: confirm and identify detailed cutoffs as well as filter types by consulting relevant scientific research about the typical frequency range for heart sounds and murmurs, and settings typically used in heart sound analyses -> Table 1 informed decision to use **6th-order Butterworth bandpass filter (BBF) with cutoff frequency from 20 to 600 Hz** (should cover nearly all heart sounds and murmurs)

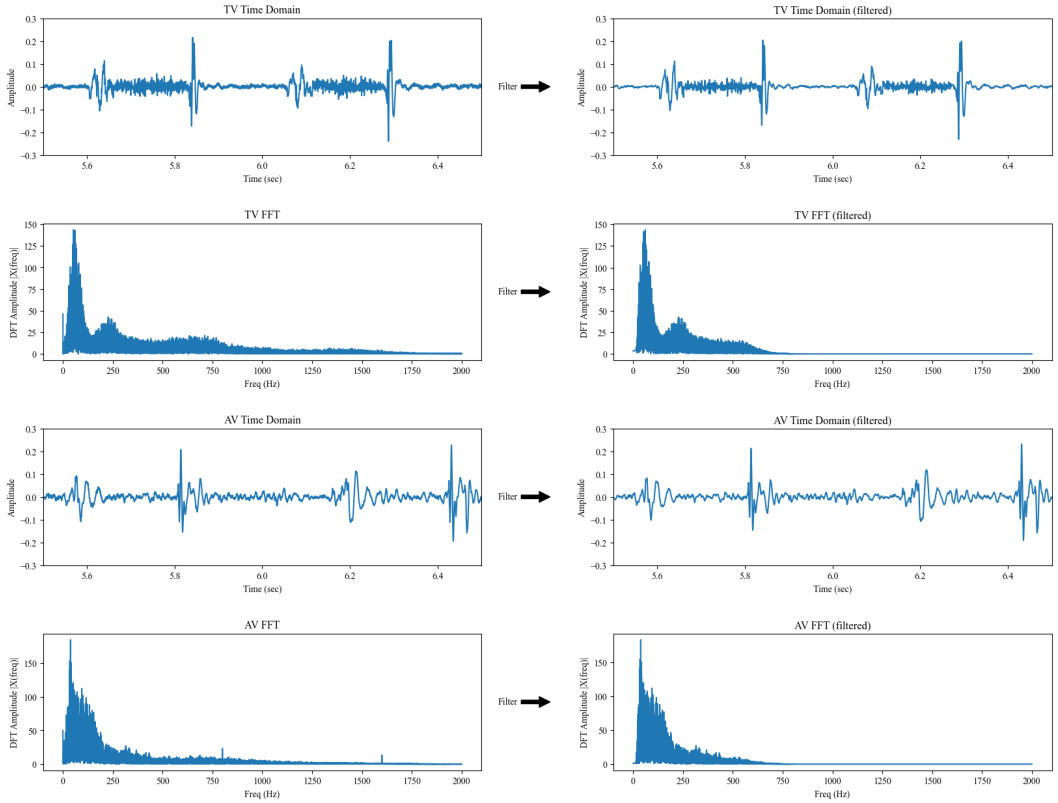

Figure 5: Enter Caption

Element of Interest	Relevant Frequencies	Filter Specified?	Source
Cardiopulmonary auscultation	50-1200 Hz	N/A	Charbonneau and Sudraud [1]
Heart sound	40-1100 Hz	BFF	El-Segaier et al. [4] Markaki et al. [13]
Heart sound	25-900 Hz	6th-order BBF	Chakir et al. [16]
Heart beat	40-500 Hz	4th-order BBF	Shekhar et al. [24]
S1 and S2	50-500 Hz	N/A	Spencer and Pennington [15]
S3 and S4	20-200 Hz	N/A	Spencer and Pennington [15]
Critical heartbeat	70-120 Hz	N/A	Bankaitis [26]
Murmurs	80-500 Hz	N/A	Tomas et al. [11]
Murmurs	200-410 Hz	N/A	Donnerstein [2]
Murmurs	< 300 Hz	N/A	Spencer and Pennington [15]
Murmurs	20-150 Hz, < 500 Hz	N/A	Rennert et al. [3]
Most murmurs	< 200 Hz	N/A	Debbal and Bereksi-Reguig [6]

Table 1: Overview of selected frequency and filter settings for analysing heartbeat and murmur sounds in scientific literature

Question 2: Provide a discussion of the differences between the raw and filtered data, and thus on the importance of filtering in signal processing. Are there any potential disadvantages or tradeoffs of applying signal processing?

Differences between data:

- filtered signal in time domain is visually "thinner"
- isolated and clear outliers (i.e. "noise") are removed
- filtered FFT plots reveal focus on strong frequencies and regions with relatively high amplitude
- filtered time domain plots exhibit less noise around regions of interest (i.e. heartbeat sound between S1 & S2) -> indicates reason for signal processing

Importance of filtering in signal processing:

- one of the most important, and typical first steps in analysis of (heart) sounds [25, 18]
- goal: reveal information in measurements/signal [7, 12], remove undesired/unwanted signal components (e.g. noise), increase reliability, facilitate analysis of relevant signal portion [10]

Disadvantages & Trade-offs:

- filtering is extremely challenging [5]
- facilitates analysis but also brings the danger of accidentally removing relevant sound components, especially in heart sound recording where noise often lies in same frequency range [25]

Task 1.5

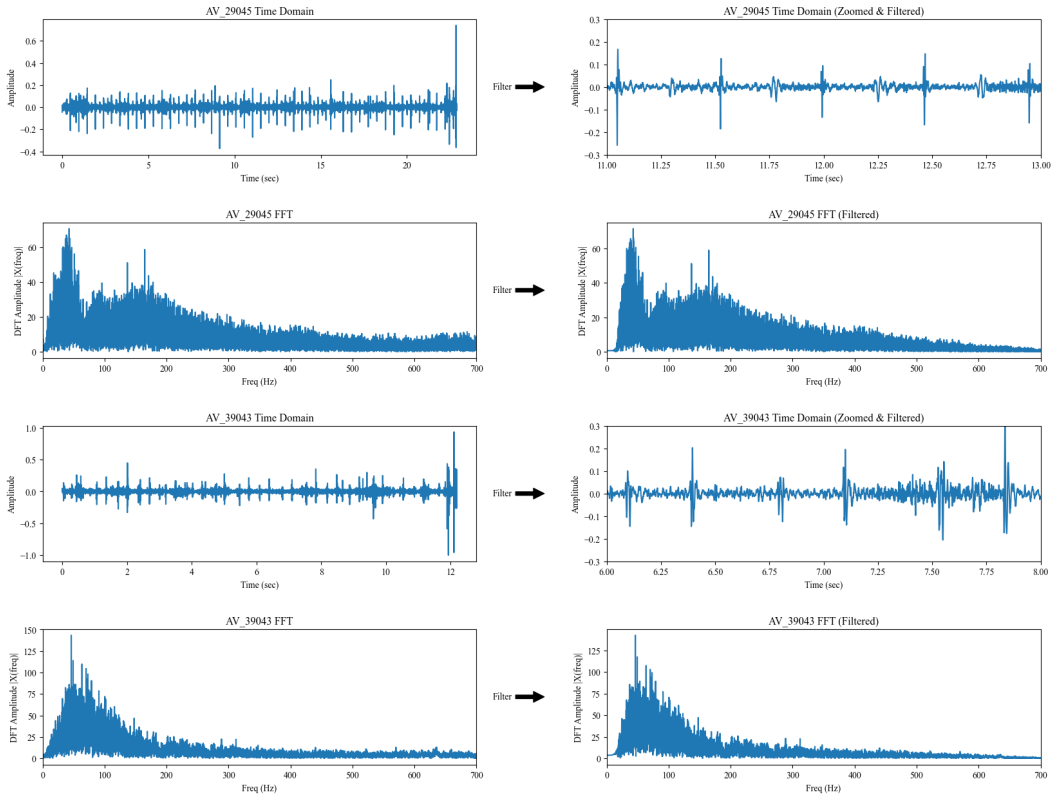

Figure 6: Enter Caption

Question 1: Discuss whether you can differentiate between the signals or not and if not, why not.

- both files show numerous irregularities in the signal in their time domain graphs (unfiltered & filtered) -> heartbeats can be visually detected, but not as clearly analysed as in Task 1.2

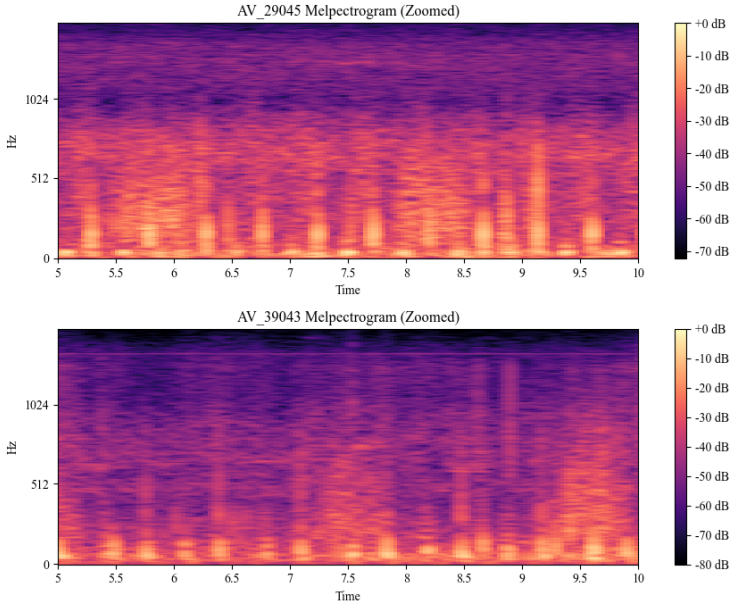

Figure 7: Enter Caption

- FFT diagrams and melspectograms (Figure 7 might suggest that AV_29045 is the murmur, due to stronger higher frequencies and two regions with peaks, but AV_39043 exhibits strong energy in these areas as well
- -> overall no clear visual classification possible

Part 2: Dataset processing [15 marks]

Task 2.2

Question 1: What is the ratio of normal to murmur patients? And what is the ratio of normal to murmur samples? Can you think of any implications of this?

- #Normal Patients: 135, #Murmur Patients: 56, **Ratio: 2.41**
- #Normal Samples: 584, #Murmur Samples: 180, **Ratio: 3.24**
- Implications: identified ratios show that dataset is imbalanced -> strong negative impact on model performance!
  - bias: models might be biased towards predicting majority class (i.e. normal diagnoses), due to higher frequency
  - generally, but especially given class imbalance, accuracy is not a good evaluation metric
  - data resampling needed to mitigate imbalance!
  - common problem in medical and heartbeat sound datasets [8, 21]

Question 2: Prepare some graphs representing basic demographic split across classes, such as sex, age, etc. Make sure you use the correct type of graph for your data to display the information intuitively.

Question 3: What significance does the demographic split carry in datasets used for ML?

- significant relevance for identifying potential biases in models and datasets -> if imbalanced, model might only perform well on majority class [17]
- diverse dataset necessary for model to generalise well across gender, age, different populations etc. [19] –> important regulatory and ethical implications: healthcare is sensitive domain and models should not discriminate against selected groups! [23]

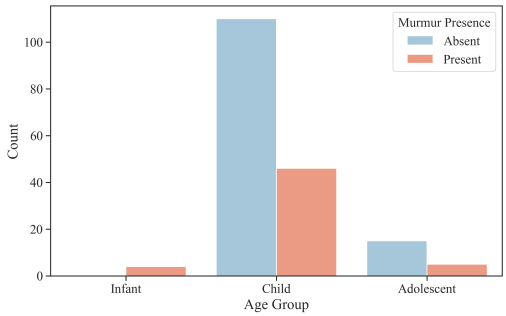

Figure 8: Age Distribution of Patients with and without Murmur

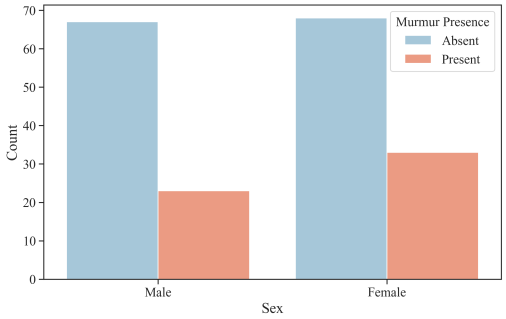

Figure 9: Sex Distribution of Patients with and without Murmur

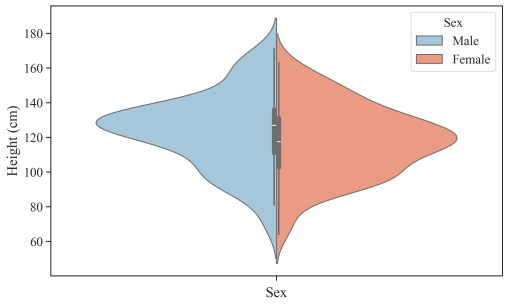

Figure 10: Height Distribution by Sex

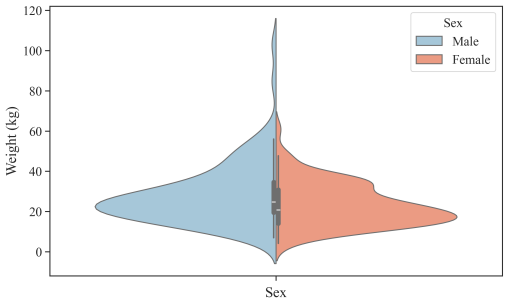

Figure 11: Weight Distribution by Sex

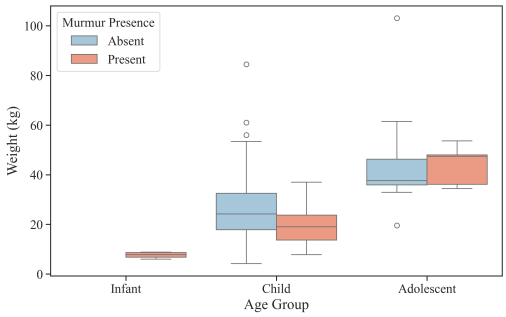

Figure 12: Weight Across Age Groups

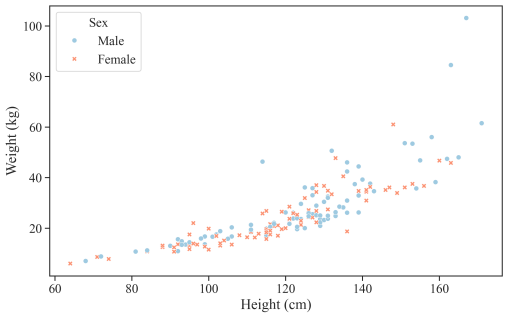

Figure 13: Height vs. Weight

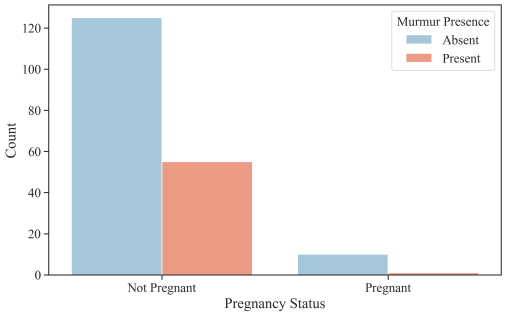

Figure 14: Pregnancy Status Distribution

- demographic information can be used to inform personalised treatment plans, drug development etc.

Task 2.4

Question 1: What is the effect of tackling the imbalance on the resulting classification performance? Give results to compare different methods of tackling imbalance.

Part 3: Feature extraction [30 marks]

Task 3.1

Question 1: Which features did you choose and why? Use literature and/or performance assessments to inform your decisions.

[16]

-

[20]

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Question 2: What parameters have you chosen for the features that you extracted (e.g. hop length, window size, etc.) and why?

Task 3.4

Question 1: Describe the full preprocessing pipeline that you used.

–> see Chen et al. Figure 3 for process [20]

1. resampling
2. filtering
3. feature extraction

Question 2: Which features or combination of features yield the best performance and why?

Question 3: Which classifier is yielding the best overall performance?

Question 4: What effect do individual preprocessing steps have on the final result?

Part 4: Your Own Data [10 marks]

Task 4.1

Question 1: What differences are there between the frequency spectrums of your recording and the files we provided? Discuss why there might be differences.

700 words (excluding bibliography, headers, and captions)

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