# Background Reading Report

Project: Improve Content Validity of Virtual Drilling Simulator

Group: 14

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**Paper chosen: "Automatic Identification of Hard and Soft Bone Tissues by Analyzing Drilling Sounds" by Vahid Zakeri and Antony J. Hodgson**

The paper, "Automatic Identification of Hard and Soft Bone Tissues by Analyzing Drilling Sounds" aimed to assess whether bone drilling sounds could be used in classifying bone tissues. A Support Vector Machine (SVM) algorithm was trained using the acquired data and tested for two scenarios, which will be discussed in the results. Tibia bones from cows were used to drill on for recordings. The paper also aimed to check whether the approach could be generalized across bones and still provide distinction between hard (cortical) and soft (cancellous) bones.

## Reason for choosing:

The paper mentioned above was chosen as background reading since it highlights how densities affect audio and provided an in-depth procedure on signal processing. Our project involves collecting audio data and studying its relationship with densities of material along with forces applied. We ultimately aim to use this data to model the relationship between audio, density, and force.

## Technical Approach and Experiment:

### Data Collection:

Six bovine tibia pieces were drilled during the paper's study duration. The bones were fixed in a vice. The cortical (hard) and soft (cancellous) tissues of each bone were drilled three times. Drilling was done perpendicular to the bone surface using a Conmed Linvatec Hall Mpower2, Pr06202M surgical handpiece. 36 recordings were recorded using a Briiel & Kjrer 4165 microphone. The cortical tissues and cancellous tissues were drilled 18 times for an average duration of 6 and 4 seconds, respectively.

### Signal Processing:

The recordings were collected at 20 kHz and were analyzed in different frequency regions. The Shannon-Nyquist theorem was used to determine the maximum frequency in the spectrum. The recordings were used to plot spectrograms, which were then passed through five different types of filtering. After filtering, each region was windowed using a 50 ms Hamming window with a 50% overlap. These data windows were considered to be one sample each, and this study had a total of 7248 samples. Using the short-time Fourier transform (STFT), all samples were transformed into the frequency domain, and the bins obtained from the samples were considered to be the features of the data set.

Classification Algorithm:

For classification, a Support Vector Machine (SVM) algorithm with a Gaussian kernel was applied, as it can handle nonlinear feature-label relations. Two scenarios were tested out. The first scenario was called LOBO (leave one bone out). It considered the training set to be a recording of all bones except one, which was called the test bone (TB). The recordings of the excluded bone were considered the testing data set. The second scenario, known as BSP (Bone Specific), considered all recordings, including TB recordings, to be part of the training set.

Results:

For 120 bins (640 features) extracted from the samples, BSP performed better with an accuracy of 83% as compared to 70.9% accuracy in LOBO scenarios. The variability of most statistical measures was also lower in the BSP scenario. Modification of the SVM classifiers' threshold could lead to better results. These results were expected since BSP used the TB as part of its training set. This study also showed that generalizability across bone specimens is reasonable, albeit not great.

Significance:

1. Signal processing of audio was explained in-depth. Our project requires us to do similar audio signal processing to extract audio features for modelling. Extraction of audio samples and features from these recordings was also covered.
2. There is great potential for audio feedback in drilling procedures. Works by the same author show that these classification results were much better than the classification survey done with surgeons (which was only 51.4% for judged answers).
3. Object density can be related to pitch of drilling sound. Our project has been modified to consider the density of the phantom after these background readings.

Key Takeaways:

1. Audio data needs to be processed with more than just filters in order to be studied properly.
2. Addition of a machine learning element during implementation can be considered.

Limitations:

1. The drilling in the paper was done perpendicular to the surface of the bone. Surgeons very rarely drill at such an extreme angle, and it is possible that the recordings could be different than what a surgeon hears in an operation theatre.
2. There are various factors that affect the pitch of the recording such as RPM of the drill, drill-bit used, angle of drilling etc. The data collection procedure could have mentioned more about if these factors were kept constant when drilling.

References:


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