Reading a Reed

Name: Paul Chang
Advisor: Szymon Rusinkiewicz

What is a clarinet reed?

Motivation

Reeds look the same but play different

- Time consuming reed selection process

Goal

Predict the sound of a reed given a subset of its features, without playing on the reed

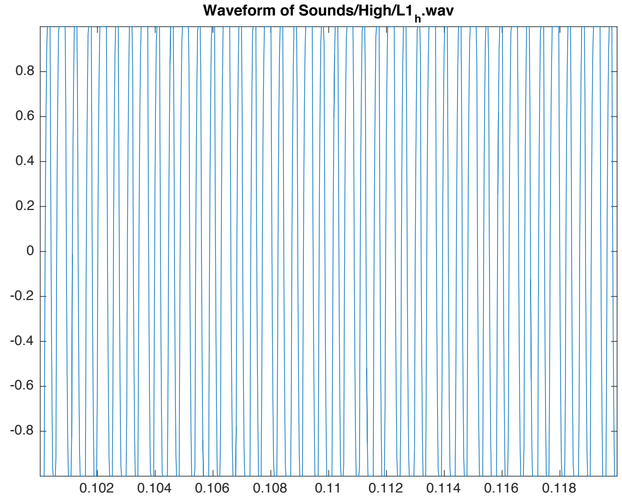
Sound

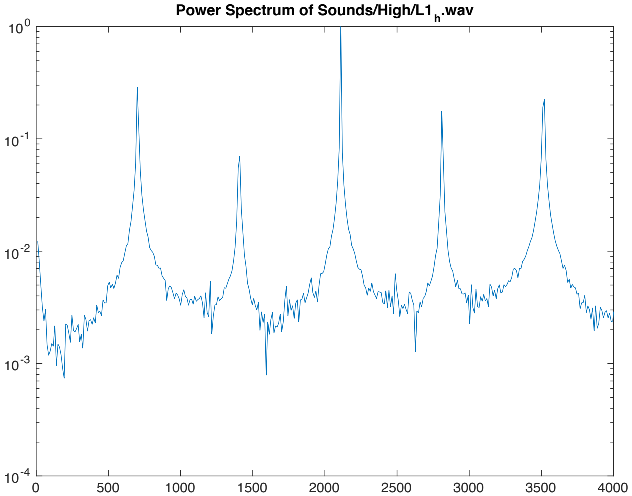
Quantitative:

H. v. Helmoltz (1862) : Musical timbre is characterized by distribution of partials summarized by spectral centroid.

Subjective:

Bright and Dark





How to link quantitative to subjective?

J.M. Grey (1975): Spectral centroid is positively correlated with brightness.

Goal:

Predict brightness of reed given a subset of its features, without playing on it:

Part 1: Predict spectral centroid from reed's features

Part 2: Verify: high spectral centroid => bright sound

Related Work

- Physics of a reed:
  - John Backus (acoustician):
    - Small Vibration Theory of Clarinet (1962)
    - Vibrations of the Reed and the Air Column (1961)
- Reed to sound mapping:
  - Andre Almeida (2013):
    - How reed “hardness” affects spectral centroid.

Approaches for Part 1

- One approach: Use knowledge of physics to run computer simulations

- My approach: Machine learning algorithms:
  - Little knowledge of physics required
  - Train algorithms with data set mapping features to spectral centroid.

Data Collection

- Create data set that maps features to spectral centroids.
- No public data set available.

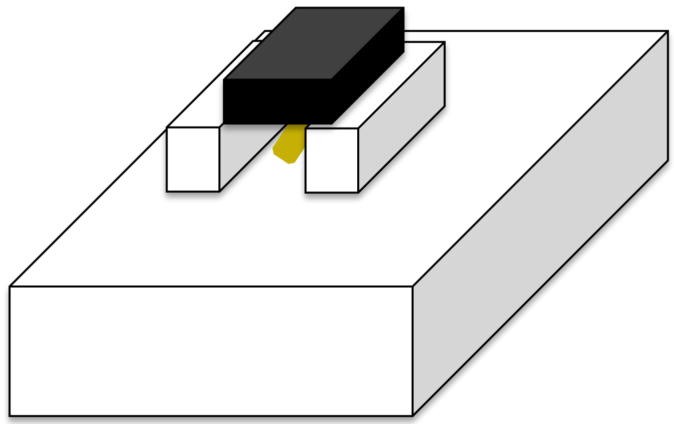
Key questions:

- Which features to measure?
- How to obtain consistent recordings?

Features

- Water content of reed:
  - Measure moisture absorption:
    - Mass of reed before and after soaking in water for 10 sec.
- Time stamp:
  - Use categories: 0, 1, 2, (3-5), >5
- Thickness across reed:
  - Take pictures and do image processing.

Image Processing



Light Box Apparatus:

- Take pictures at constant angle and height
- Use low flutter camera

Example Reeds:

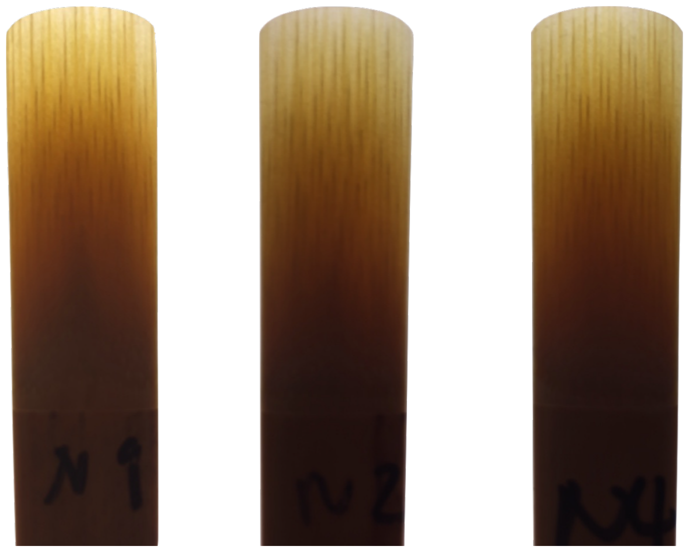
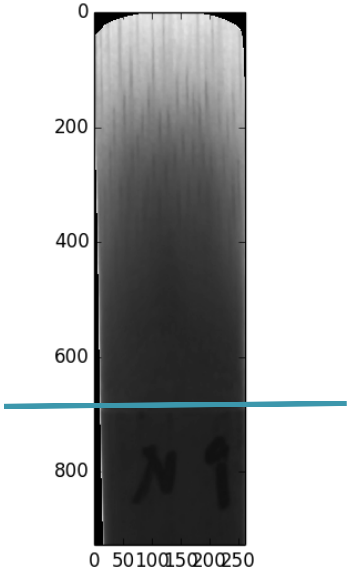


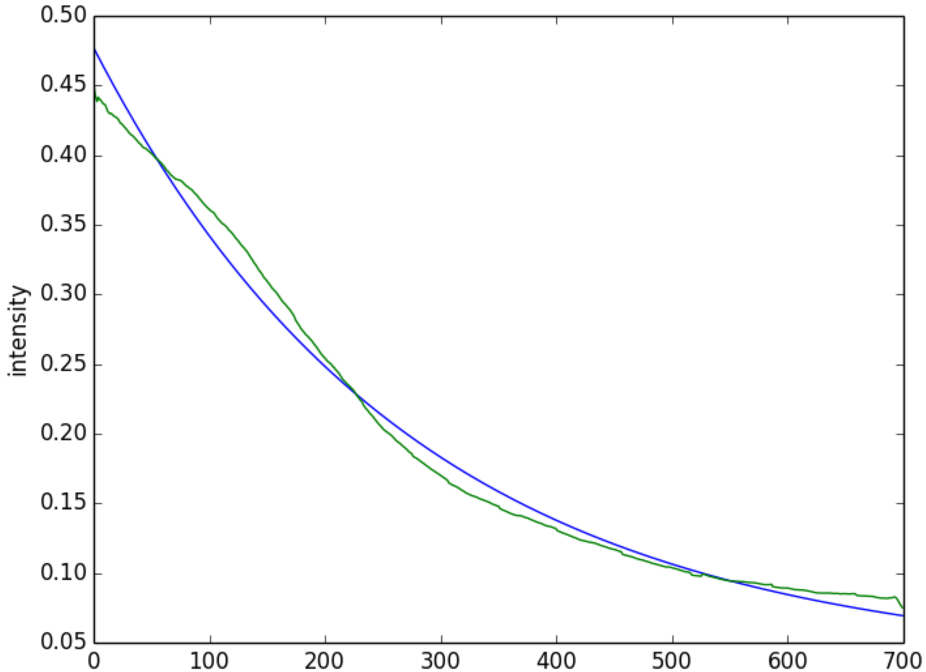
Image Processing



High Intensity: Bright; Little wood

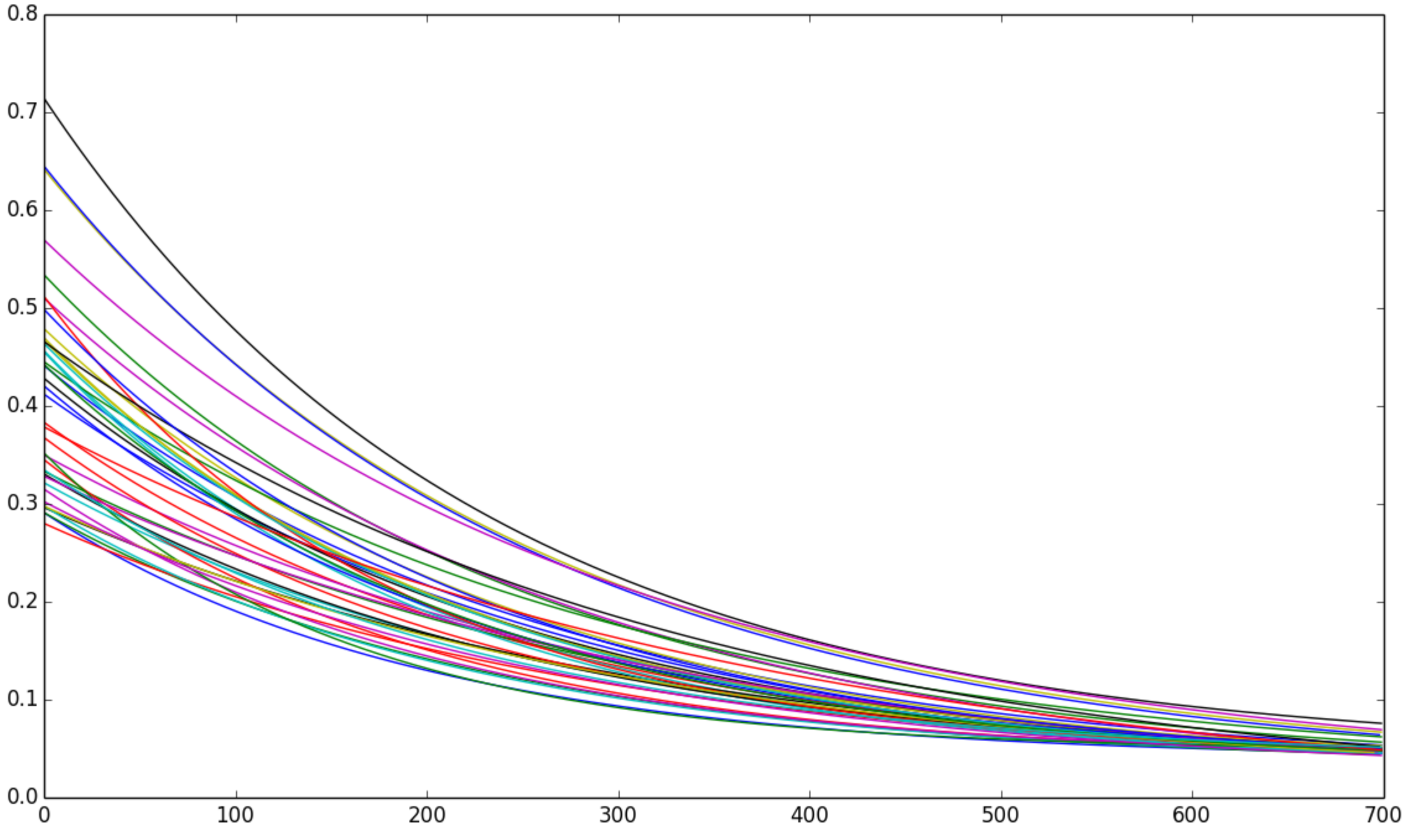
Low Intensity: Dark; A lot of wood

Intensity = ae^(-b(row)) + c



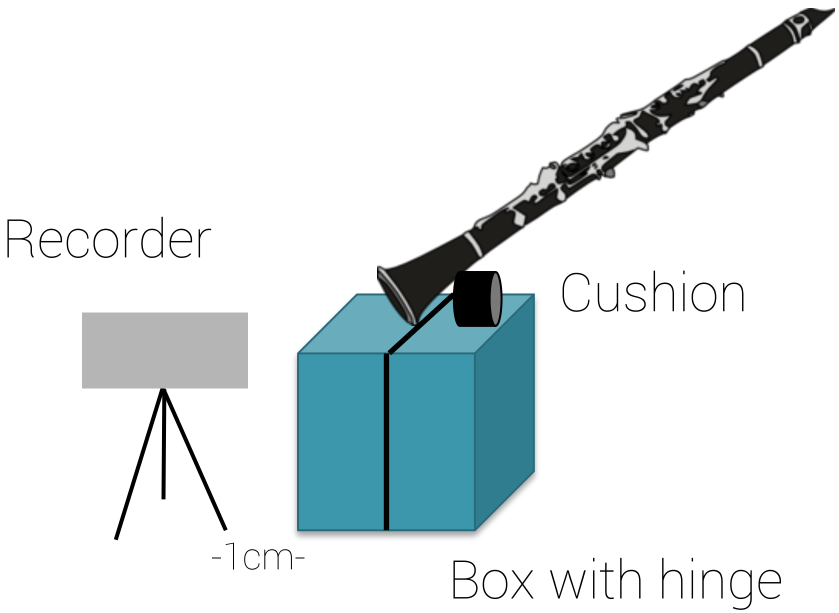
To describe image: [a, b, c]

Fitted Exponentials for 40 reeds



Recording Apparatus

Play G4 and G5



Constants:

- Pitch (440 Hz)
- Noise level (90 dB)
- Angle of clarinet
- Distance to recorder
- Amount of reed in mouth
- Humidity/ Temperature
- Equipment

Sample data

Label	a	b	c	Mass Before	Mass After	% increase	Time	G4	G5
U3	0.39542561	0.00463563	0.03304037	0.83	0.85	0.0240963855422	4	1	0
N14o	0.3551609	0.0026928	-0.00961562	0.79	0.83	0.0506329113924	1	1	1
N7t	0.25542317	0.003115	0.01497096	0.84	0.87	0.0357142857143	2	0	1
U2	0.23445603	0.00343772	0.02109684	0.83	0.85	0.0240963855422	4	1	1
O19	0.55150036	0.00311107	-0.01788694	0.87	0.92	0.0574712643678	0	1	1
S6	0.45923965	0.00357429	0.00623756	0.81	0.86	0.0617283950617	3	1	1
N11t	0.42998426	0.00434756	0.02492862	0.90	0.94	0.0444444444444	2	1	0
O18t	0.39708	0.00384055	0.01293716	0.81	0.83	0.0246913580247	2	0	1
O26o	0.47616811	0.0042569	0.01935778	0.91	0.95	0.043956043956	1	1	0
O2	0.25851544	0.00315042	0.0131129	0.95	1.01	0.0631578947368	0	1	1
N2o	0.42857277	0.00304434	-0.00358304	0.92	0.98	0.0652173913043	1	1	0
O21o	0.55674834	0.0034604	-0.00257139	0.86	0.89	0.0348837209302	1	1	0
L4	0.53603925	0.00398534	0.01481729	0.91	0.97	0.0659340659341	0	0	0
N9	0.27208165	0.00364001	0.02132159	0.90	0.98	0.0888888888889	0	1	1
O10	0.46344939	0.00361318	0.00716057	0.87	0.90	0.0344827586207	0	1	1

120 rows – 240 recordings

80 training, 40 test

Results

G5

Algorithm	Percentage Correct	Precision	Recall	F-Beta	Area under ROC curve
Gaussian Naïve Bayes	45%	0.60	0.46	0.57	0.51
Decision Tree	60%	0.68	0.57	0.66	0.61
K-Neighbors	57.5%	0.63	0.65	0.63	0.54
Random Forest	70%	0.77	0.77	0.77	0.60

Results

G4

Algorithm	Percentage Correct	Precision	Recall	F-Beta	Area under ROC curve
Gaussian Naïve Bayes	45%	0.60	0.46	0.57	0.51
Decision Tree	60%	0.69	0.69	0.69	0.63
K-Neighbors	70%	0.77	0.77	0.77	0.69
Random Forest	62.5%	0.79	0.57	0.74	0.61

Part 2: Random Sampler Experiment

- Verification that spectral centroid correlates to brightness.
- Experiment steps:
  1. Choose 2 random sound samples (both G4 or G5)
  2. Ask user which is brighter
  3. Verify user input by checking true spectral centroid values

Random Sampler Experiment

- 10 experiments, each experiment with 10 pairs
- ~40% accuracy

Spectral centroids are not practical.

Conclusion

- Generated informative data set
- Mapping reed's features to bright and dark can be accurate but not practical

Future work

- Tune algorithm parameters
- New quantitative measure
  - Noise/signal ratio was not effective
- Transform into regression problem