

# Computer-Assisted Musical Instrument Tutoring with Targeted Exercises

Graham Keith Percival

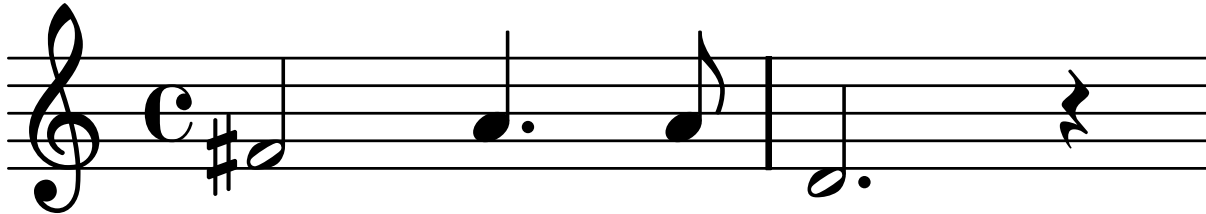
- Why CAMIT?
- Objective analysis of audio
- Creating exercises
- Putting it all together: Musician Evaluation and AWdition for Strings (MEAWS)

# Do we need CAMIT?

- “What’s wrong with human music teachers?”
  - When one is available, nothing!
  - However, they are not always available.
- Accurate self-verification is hard, especially for beginners.
  - Ear training takes years.
  - (audio example) is this good, bad, or ugly?
  - “it was bad”: now how do you fix it? Which note(s) were bad, and in what way?
- CAMIT: provides objective feedback.

# Not only intonation

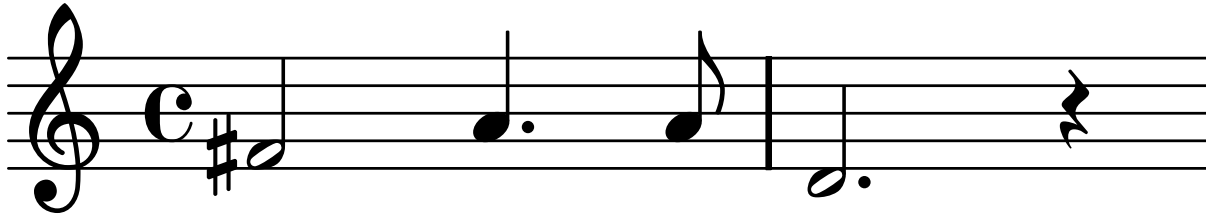
- Verification is still a problem for fixed-pitch instruments like pianos.
- Consider the rhythm in this music fragment:



(clap example) Was that correct?

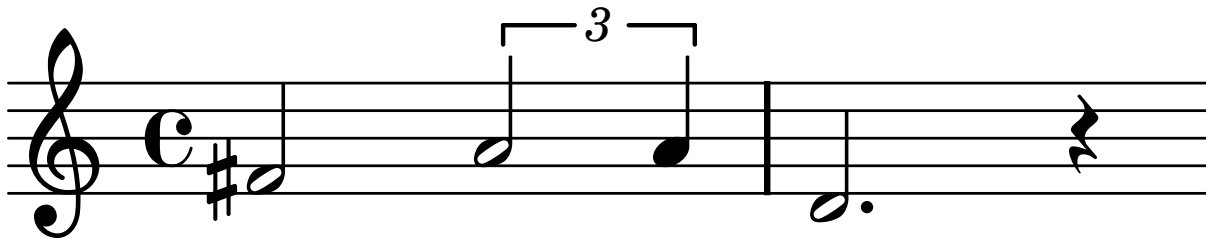
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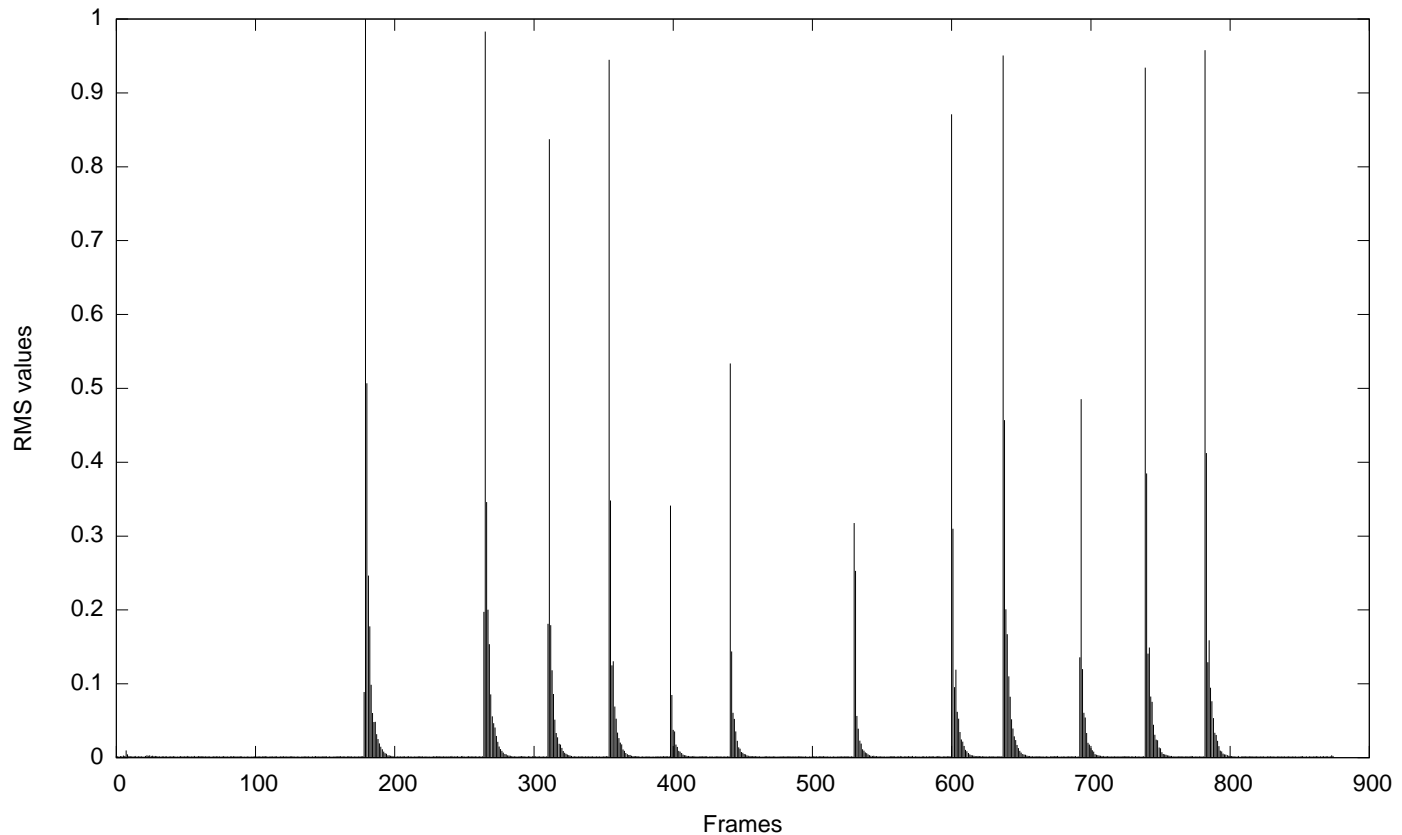
- I actually clapped this:



# Analyzing Rhythms

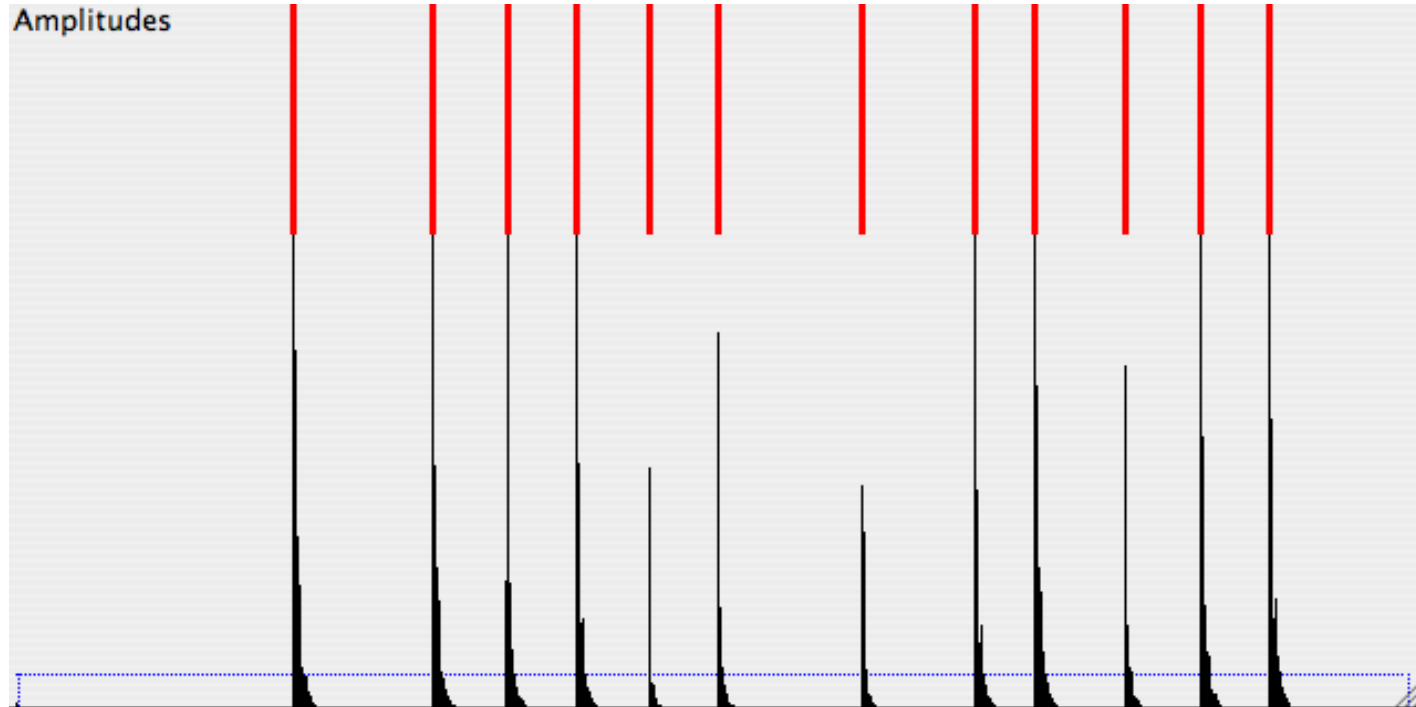
- Begin with a recording of claps and calculate RMS (Root-Mean-Squared) amplitude:

$$F_{rms} = \sqrt{\frac{s_1^2 + s_2^2 + \dots + s_n^2}{n}}$$



# Analyzing Rhythms (cont)

- Pick any peaks which are larger than a threshold value:



- Red bars indicate detected claps; the dotted blue horizontal line indicates the threshold value.

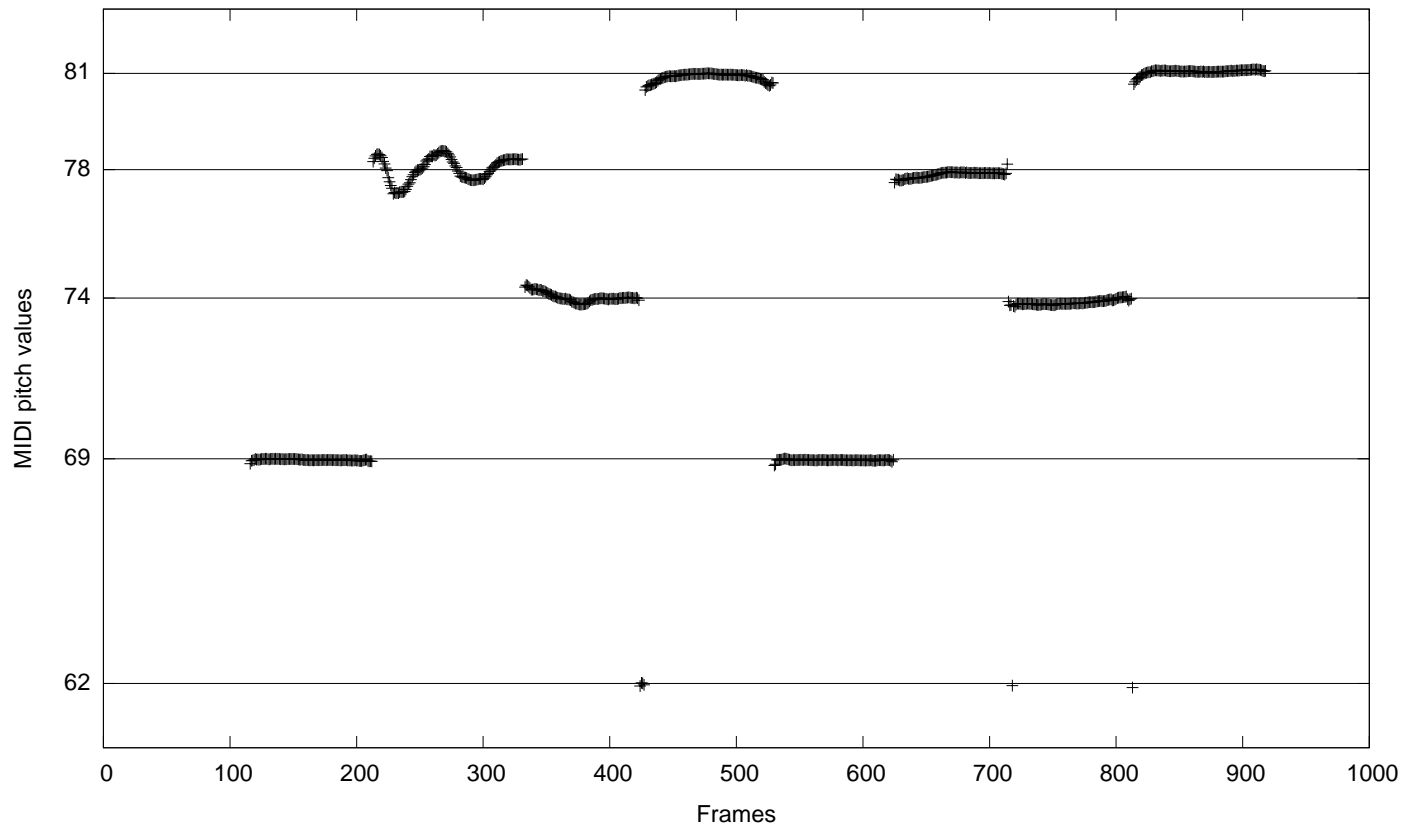
# Grading Rhythms

- Compare the detected claps with the expected claps:

The image displays a musical notation interface for grading rhythms. At the top, a 4/4 time signature is shown. The melody consists of the following notes: a quarter note, an eighth note followed by another eighth note, a quarter note, a quarter note, an eighth note followed by another eighth note, and a quarter note. Below the staff is a grid with 12 vertical lines. Black vertical lines represent the expected claps, and red vertical lines represent the detected claps. The detected claps are present at positions 1, 2, 4, 5, 6, 8, 9, 10, 11, and 12, but missing at positions 3, 4, 5, 6, 7, 8, and 9. At the bottom left, there is a 'Ready' button, and at the bottom right, a 'Score: 68.0%' display.

# Analyzing Intonation

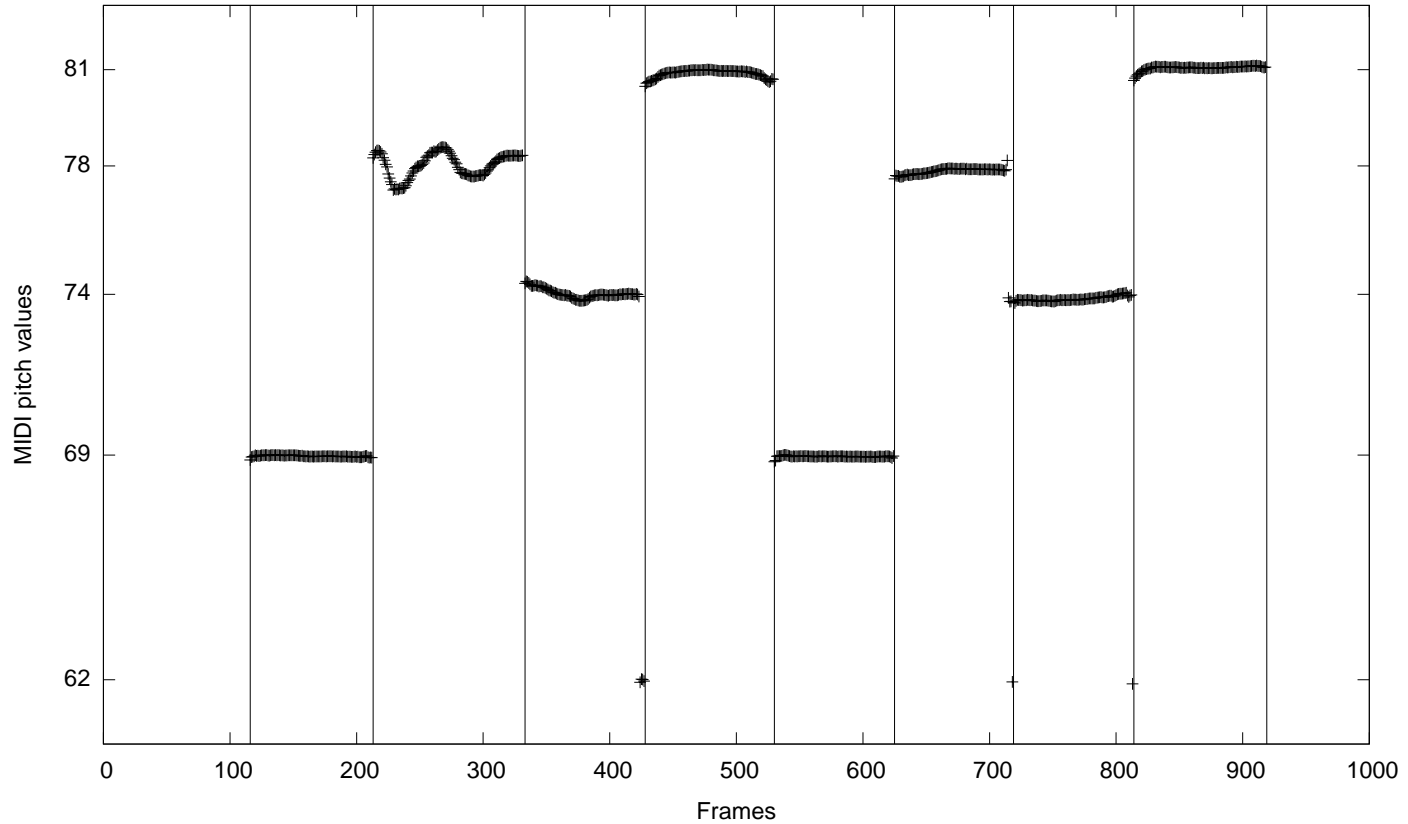
- Begin with a recording of a violin and perform pitch detection using a modified YIN algorithm:





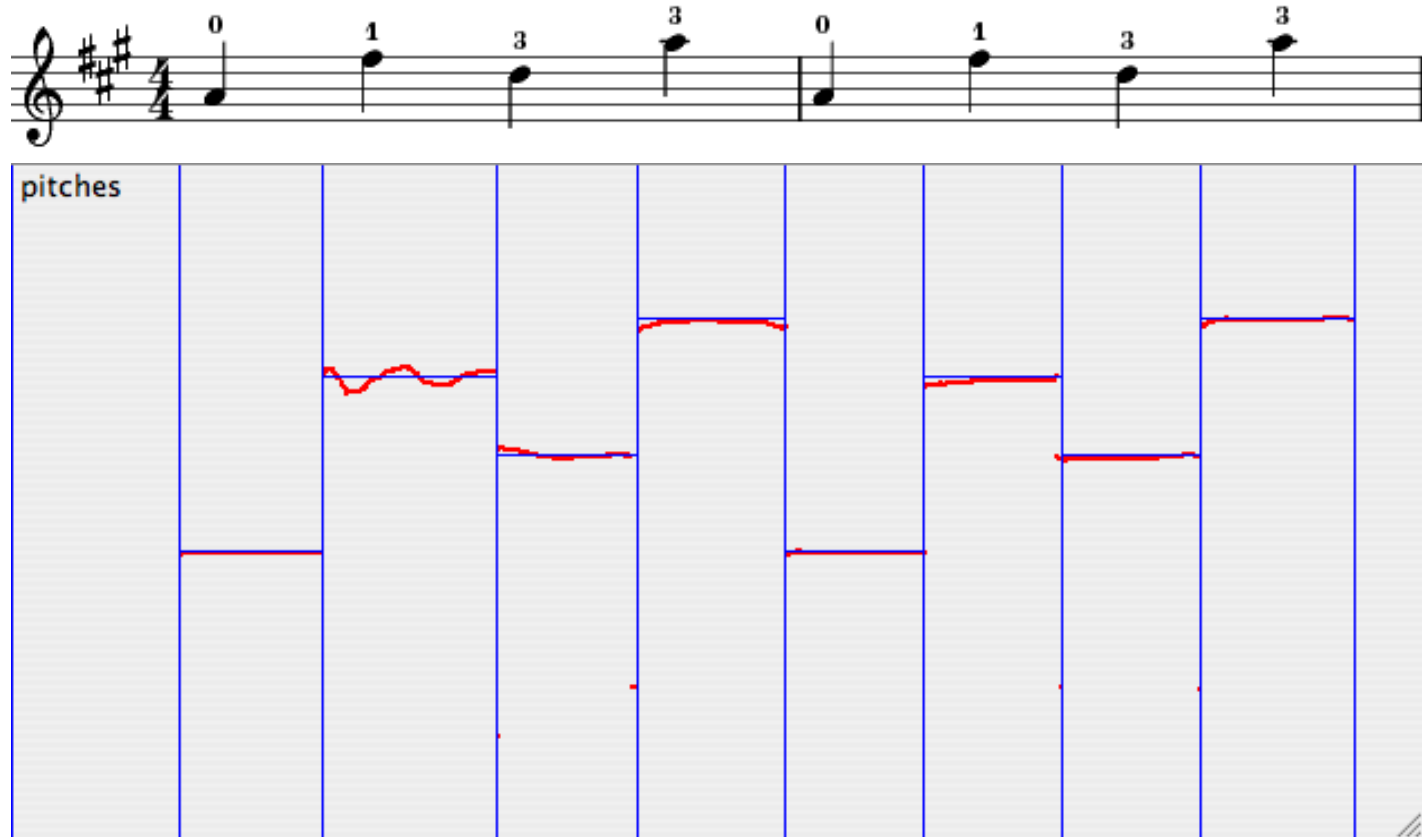
# Analyzing Intonation (cont)

- Group these pitches into notes:



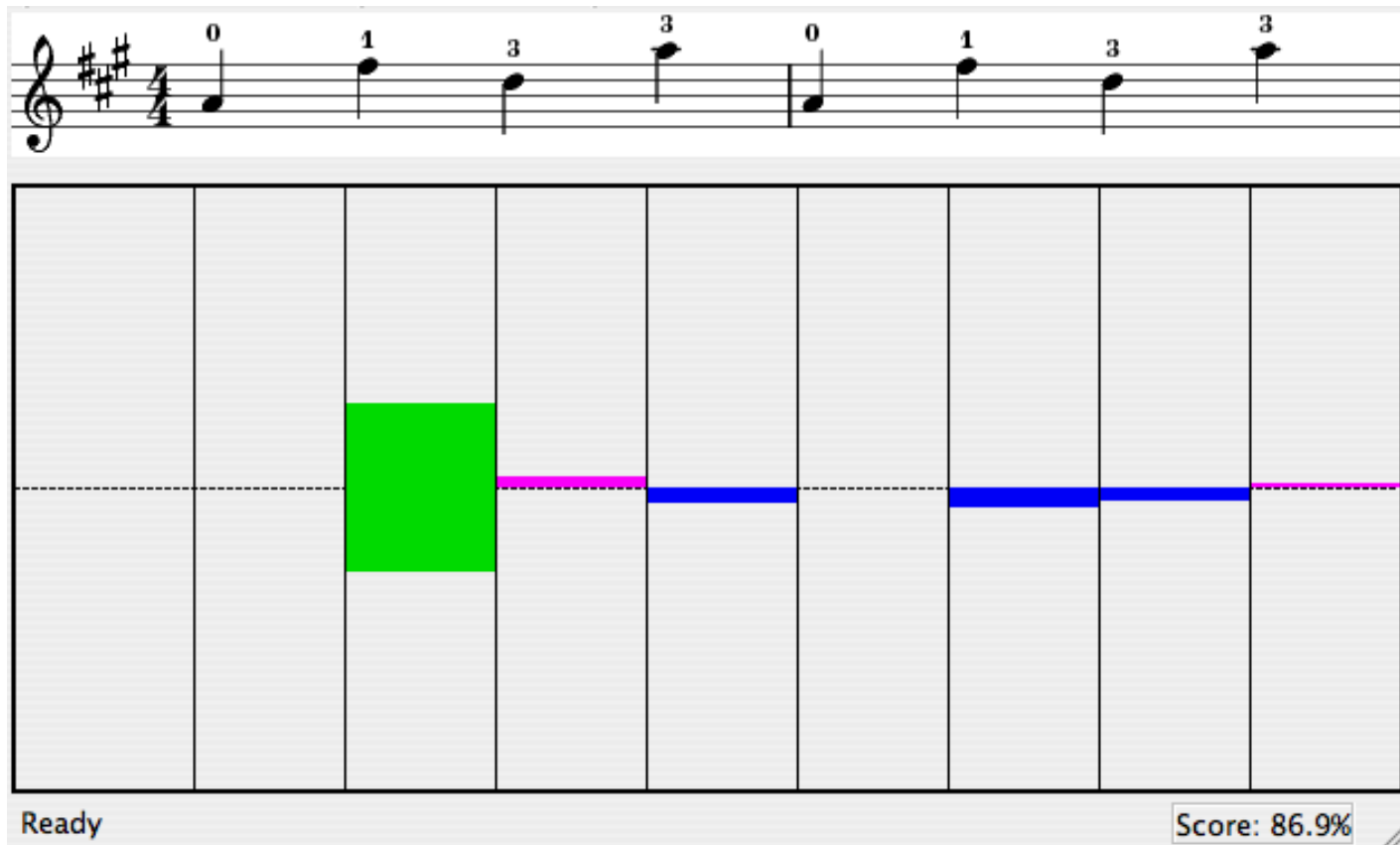
# Grading Intonation

- Compare the pitches inside detected notes with the expected pitches for those notes:



# Grading Intonation (cont)

- Display the results in a simpler format:



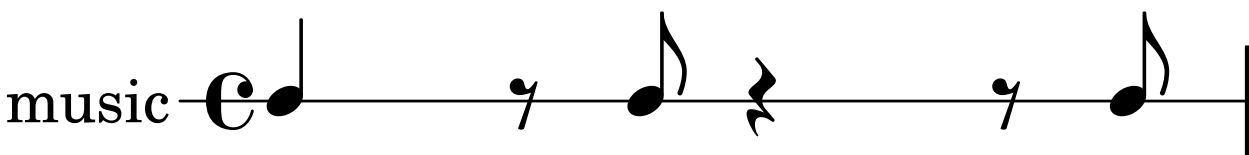
- Center line is perfect intonation. Purple box above indicates too high; blue box below indicates too low; green box above and below indicates both.

# Creating Exercises: general

- We need to create exercises to match our analysis:
  - Intonation exercises cannot repeat pitches in adjacent notes (no “twinkle, twinkle, little star...”).
  - Existing music does not always satisfy this constraint.
- Generate exercises with a computer by representing exercises as a Constraint Satisfaction Problem.
- Requires a mathematical representation of our intuitive sense of musical difficulty.

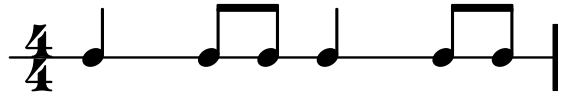

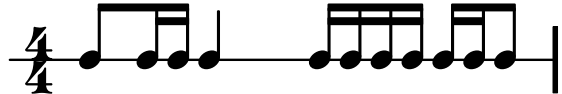
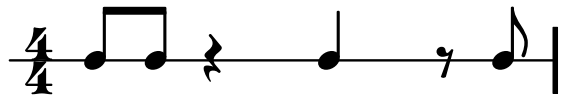
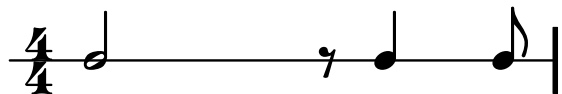
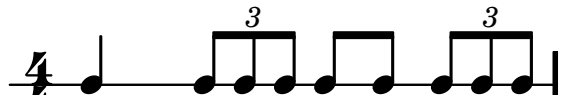
# Creating Exercises: rhythms

- Computer generates 1 bar; we repeat this to form 2-bar exercises.
- Music representation: two lists, with  $N$  variables in each list.  $N$  depends on the tatum (“temporal atom”).
  - **Events**: can be 0 (no change), 1 (new note), or 2 (new rest).
  - **Durations**: any non-negative integer.



music	
time	
events	1 0 2 1 2 0 2 1
durs.	2 0 1 1 2 0 1 1

# Creating Exercises: rhythm levels

Level	Durs.	Tatum	Events constraints	Example
1	$\frac{1}{4} \frac{1}{8}$	2	Must have an event on every beat, and no rests.	
2	$\frac{1}{4} \frac{1}{8} \frac{1}{16}$	4	Must have an event on every beat, no rests, and each beat is divided into equal durations.	
3	$\frac{1}{4} \frac{1}{8} \frac{1}{16}$	4	Must have an event on every beat, no rests, and $\frac{1}{16}$ must occur in pairs replacing an $\frac{1}{8}$ .	
4	$\frac{1}{4} \frac{1}{8}$	2	Must have an event on every beat, and rests can only occur on beats.	
5	$\frac{1}{2} \frac{3}{8} \frac{1}{4} \frac{1}{8}$	2	Must have an event on every second beat, and rests can only occur on beats.	
6	$\frac{1}{4} \frac{1}{8} \frac{1}{12}$	6	Must have an event on every beat, no rests, and each beat is divided into equal durations.	

# Creating Exercises: intonation

- Computer generates 4 quarter notes; we repeat this to form 2-bar exercises.
- Music representation: four lists, with 4 variables (one for each quarter note) in each list.
  - **Pitch**: any integer from 55 to 127 (MIDI pitch values for violin).
  - **String**: four possible values, 1 (the E string) to 4 (the G string).
  - **Hand position**: any integer above 0, although the practical limit is less than 10.
  - **Finger**: any integer from 0 to 4 (inclusive).

# Creating Exercises: intonation levels

Level	Variable domains <sup>a</sup>	Other constraints	Example
1	S: 1 2, H: 1, F: 0 1 2, K: A+	Cannot change strings to a fingered note.	
2	S: 1 2, H: 1, F: 0 1 2 3 4, K: A+	Cannot change strings to a fingered note.	
3	S: 1 2, H: 1, F: 0 1 2 3 4, K: A+	No fingered fifths <sup>b</sup> .	
4	S: 1 2, H: 1, F: 0 1 2 3 4, K: A-	No fingered fifths.	
5	S: 1 2, H: 1, F: 0 1 2 3 4, K: A+	∅	
6	S: 3 4, H: 1, F: 0 1 2 3 4, K: G+	∅	

<sup>a</sup>‘S’ for string, ‘H’ for hand positions, ‘F’ for fingers, and ‘K’ for the key (+ major or - minor).

<sup>b</sup>“Fingered fifths” is a violin term for playing adjacent notes on adjacent strings with the same finger.



# MEAWS

- Musician Evaluation and AWdition for Strings: provides objective feedback for music students.
- Students are presented with an easy exercise (level 0). As they pass exercises, they advance to higher levels.
- MEAWS is published under the GPLv3, and can be easily downloaded and run on MacOS X and Linux machines.

# Conclusion

- Focus on targeted exercises, not “teacher replacement”.
- Computer-generated exercises for specific ability levels.
- MEAWS: implements the audio analysis in an easy-to-use program for music students.