MUSYS

MUSIC UNDERSTANDING SYSTEM

BY

Intelligent Gadgets

MUSYS is a music understanding system developed for Apple iPad/iPhone/iPod Touch platforms. Use MUSYS to learn music theory, to figure out a song, as an aid when jamming, or just for fun. See music while you listen to it – from the sound spectrum, to notes on a musical staff, to scales, chords, and key changes in the circle of fifths.

MUSYS "understands" the theory of Western music in terms of notes, scales, chords, and keys. It starts by detecting musical pitches in an audio signal. After correcting for overtones (since sometimes the harmonics of musical instruments are louder than the fundamental pitch), and removing correlated background sounds (e.g., from percussion instruments), pitches are converted into notes that are displayed on a standard musical staff. Next, MUSYS uses model-based techniques to fit musical scales to melodies and chords to harmonies. 2-D maps show the chords and scales that best match the music being played. Finally, MUSYS uses the match scores of scales as "votes" for the current musical key in the circle of fifths.

Figure 1 shows the major processing functions within MUSYS. Five screens can be viewed in the app: (F) frequency spectrum, (N) musical notation, (S) scales, (C) chords, and (K) musical key.

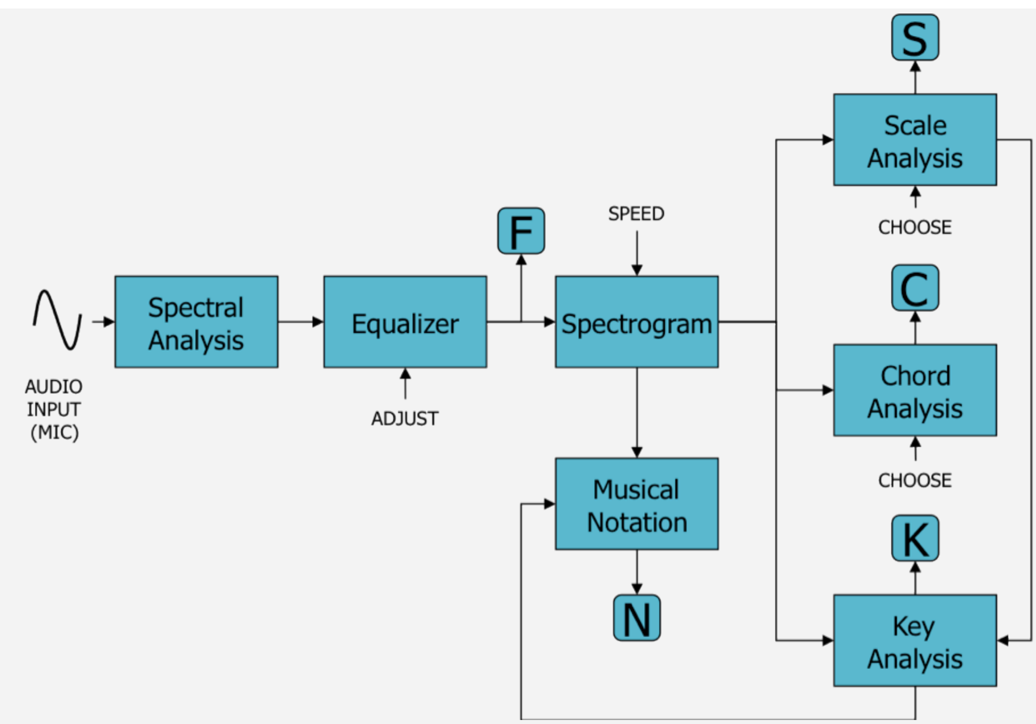

Figure 1 MUSYS functional architecture

Input audio from the microphone passes through a bank of 60 narrow-band spectral filters tuned to musical pitches from C2 to C7 – from 2 octaves below middle C on the piano to 3 octaves above (A4 = 440 Hz). (The frequency response of the built-in microphone limits performance below C2.) An equalizer allows the user to adjust the frequency response for variations in the source (instruments or speakers), acoustical environment, and microphone. The frequency spectrum display (Figure 2) shows the harmonic content of the sound. It can be used to tune an instrument to any pitch by varying the tuning until the corresponding filter response is maximized. The pitch of the strongest detected note is displayed in the upper left corner of the screen.

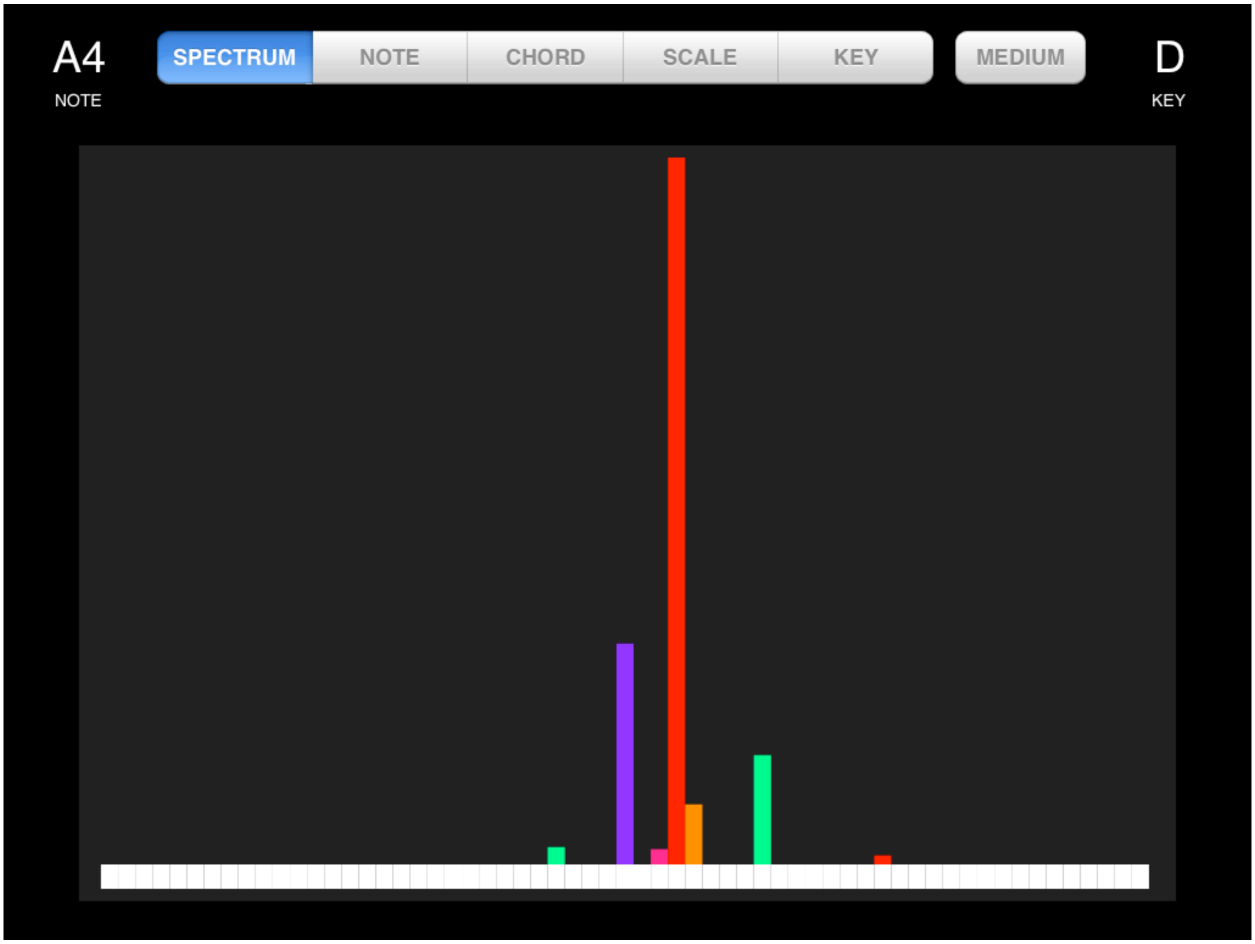

Figure 2 Frequency spectrum (F) display. Tap along the horizontal axis to increase the frequency response in certain parts of the spectrum (e.g., emphasize low frequencies).

A sampled short-time representation of the frequency spectrum (spectrogram) is used for music display, chord, scale and key analysis. The speed control button (top right) adjusts the sampling rate from 5 to 20 samples per second (time window is 12.8 to 3.2 seconds). Pitch vs. time information in the spectrogram is mapped to a standard piano staff (Figure 3) using a musical notation algorithm, which estimates the current key to assign sharps or flats as appropriate[1]. In addition to placing the

[1] Music notion software currently uses sharps or flats (but not both) so a song in G minor will contain Bb, Eb, and Gb (instead of F#). We hope to improve upon this in future releases.

note at the proper position on the staff, the display also assigns a color to the note. The same color scheme is used in all displays. Any display can be stopped ("frozen" in time) using the speed control.

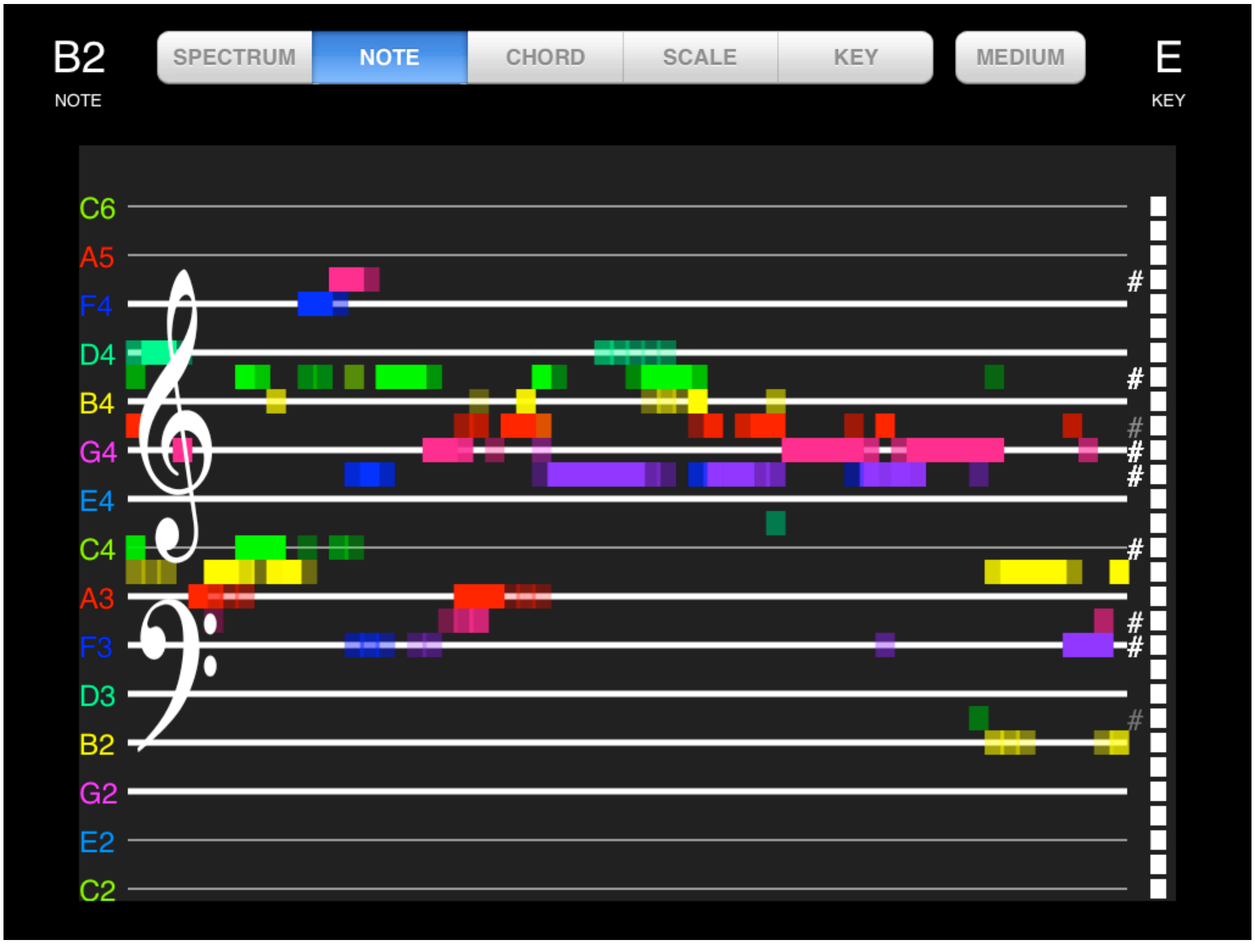

Figure 3 Musical notation (N) display. The speed control (top right button) changes the time scale of the display. Tap along the vertical axis to increase the frequency response in a particular register(s).

Scale analysis compares a standard set of musical scales in all keys against the spectrogram to determine the melodic content of the sound. Twelve scales are defined[2]:

- Major
- Harmonic minor
- Melodic minor
- Major pentatonic
- Minor pentatonic
- Blues
- Bebop dominant
- Bebop major
- Double harmonic

---

[2] Scales from other (non-Western) musical traditions like those in contained in *Mandala Music* will be incorporated into future products.

- Whole tone
- Major Locrian
- Diminished

The best fitting model is the one with the minimum description length (the simplest model that best explains the data). A scale map (Figure 4) is generated that shows which musical scales best match the music being played. The notes: C, C#, ... are displayed above the map. Their brightness depends on how often they occur over the time interval of the spectrogram, which can be varied with the speed control. The twelve scales types are shown on the right. Brightly lit colors indicate matching scales. Each square in the scale map is a root note – scale type combination. Touching a square in the scale map shows the notes in the scale below the map. For example, choosing D bebop dominant displays the notes: D, E, F#, G, A, B, C, and C#.

The scale map is a useful tool for improvisation. Instead of trying to figure out what scales can be played with a chord progression, just play the chords and let MUSYS suggest candidate scales.

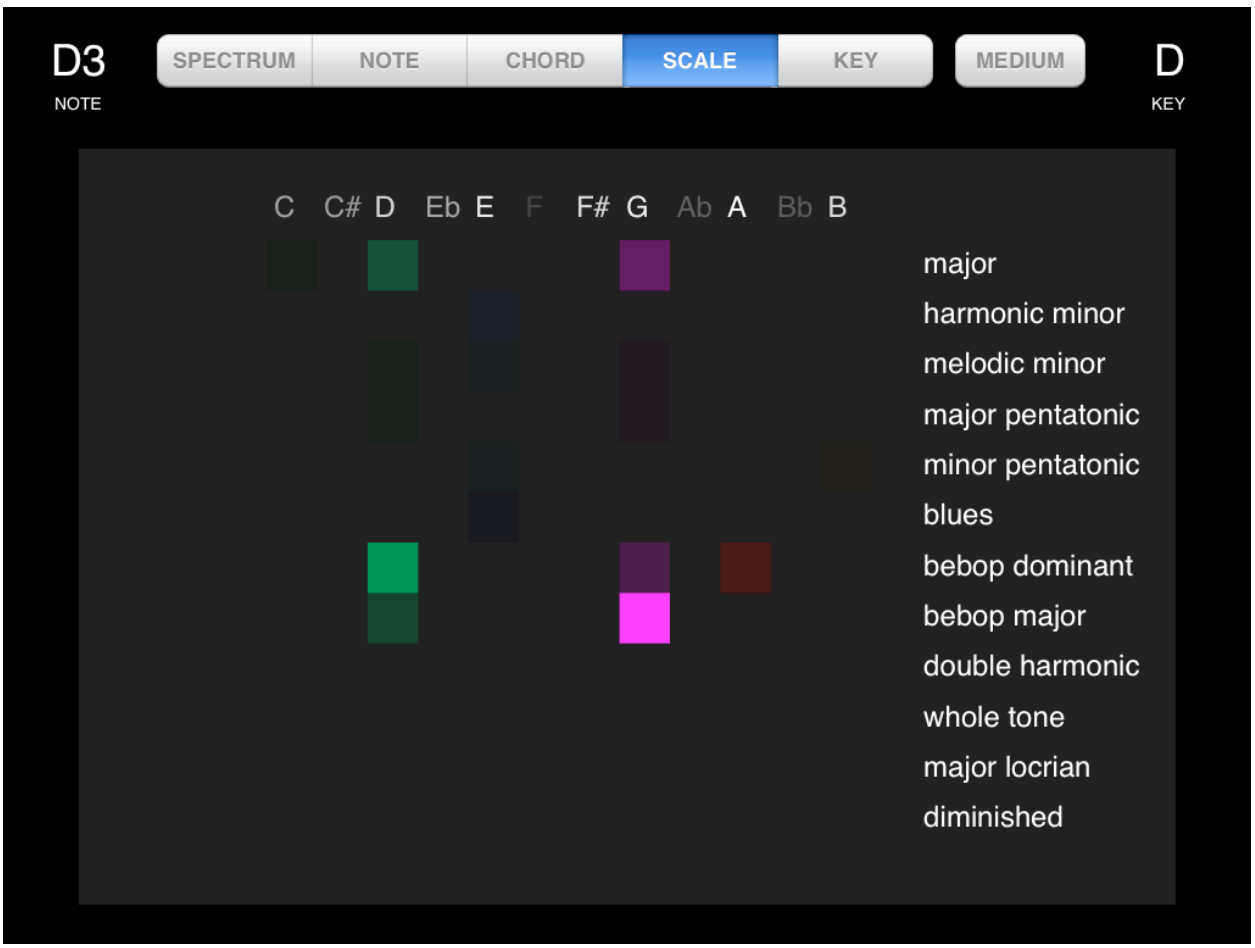

Figure 4 Scale map (S) display. Tap a colored square to see the notes in the scale.

Chord analysis compares a basic set of chords in all keys against the spectrogram to determine the harmonic content of the sound. Twelve chord types are defined:

- 5th (no 3rd)
- Major
- Minor
- Diminished
- Augmented
- Dominant 7th
- Minor 7th
- Major 7th
- Sustained 4th
- Diminished 7th
- Minor 7th with flat 5th
- Minor with #7th

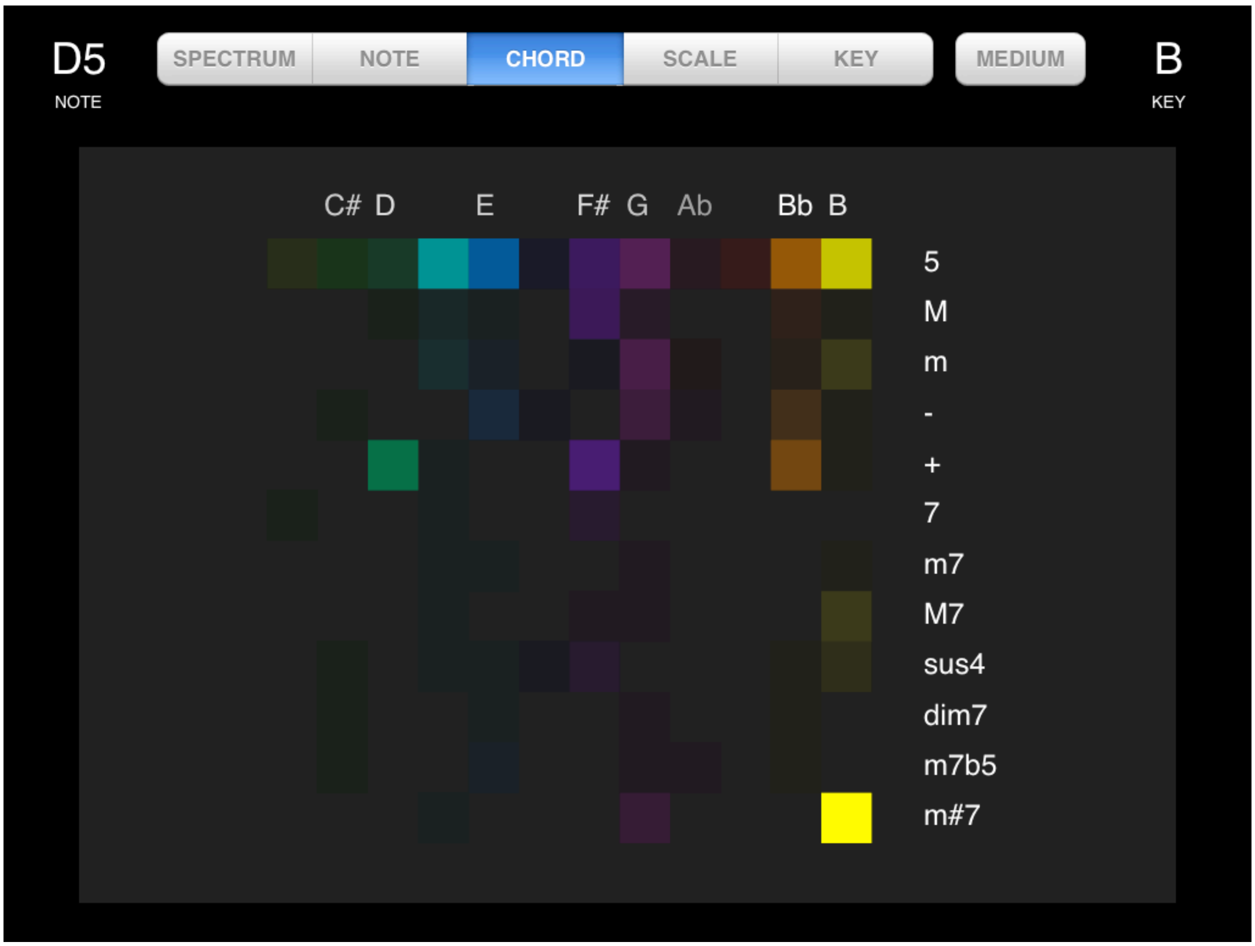

Figure 5 Chord map (C) display. Tap a colored square to see the notes in the chord.

A chord map (Figure 5) is generated that shows which chords best match the music being played. Like the scale map, the notes: C, C#, ... are displayed above the map. Their brightness depends on how often they occur over the time interval of the spectrogram. The twelve chord types are shown on the right. Brightly lit colors indicate matching chords. Each square in the chord map is a root note – chord type combination. Touching a square in the chord map shows the notes in the chord below the map. For example, choosing Gm#7 displays the notes: G, Bb, D, and F#. The chord map is helpful in trying to figure out the harmonic structure of a song.

Key analysis uses the results from scale analysis to determine the current key. Scales vote for keys. The number of votes a particular scale casts for a key depends on how well that scale matches the music being played. Votes are accumulated in a two-dimensional space representing the "circle of fifths," where the "direction" of a vote depends on the key. For example if C is along the positive x-axis (0°), G, D, A, E, B, F#, Db, Ab, Eb, Bb, and F are at 30°, 60°, 90°, 120°, 150°, 180°, 210°, 240°, 270°, 300°, and 330°, respectively. Scales that vote for "nearby" keys like C and G add, where those that vote for different keys like C and F# cancel. The net result shown in Figure 6 is a 2-D color-coded key map that peaks at the location of the current key. The key map changes as a song modulates from one key to the next. It is a useful tool in music theory and a practical DJ tool for harmonic mixing.

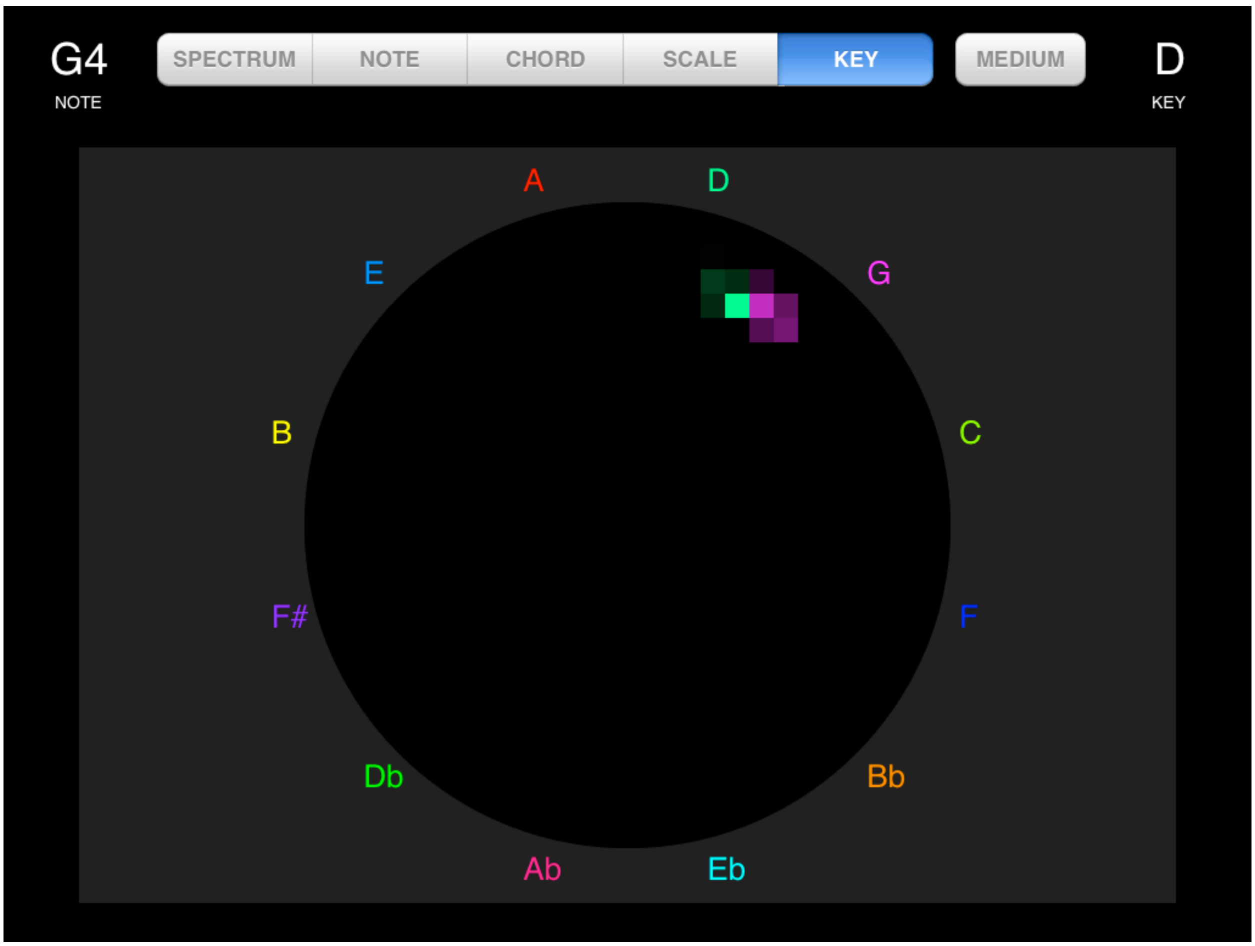

Figure 6 Key map (K) display. Varying the speed control (top right button) controls the amount of smoothing (generalization).

The performance of MUSYS algorithms depends on the quality of the sound and the amount of ambient noise. MUSYS can be used along with your iPod player app, but for the best results use a high-quality external microphone. MUSYS has an automatic gain control, which operates over a fairly wide range of volume levels. If the display begins to blank out, increase the volume of your audio source and/or move it closer to the speaker or musical instrument.

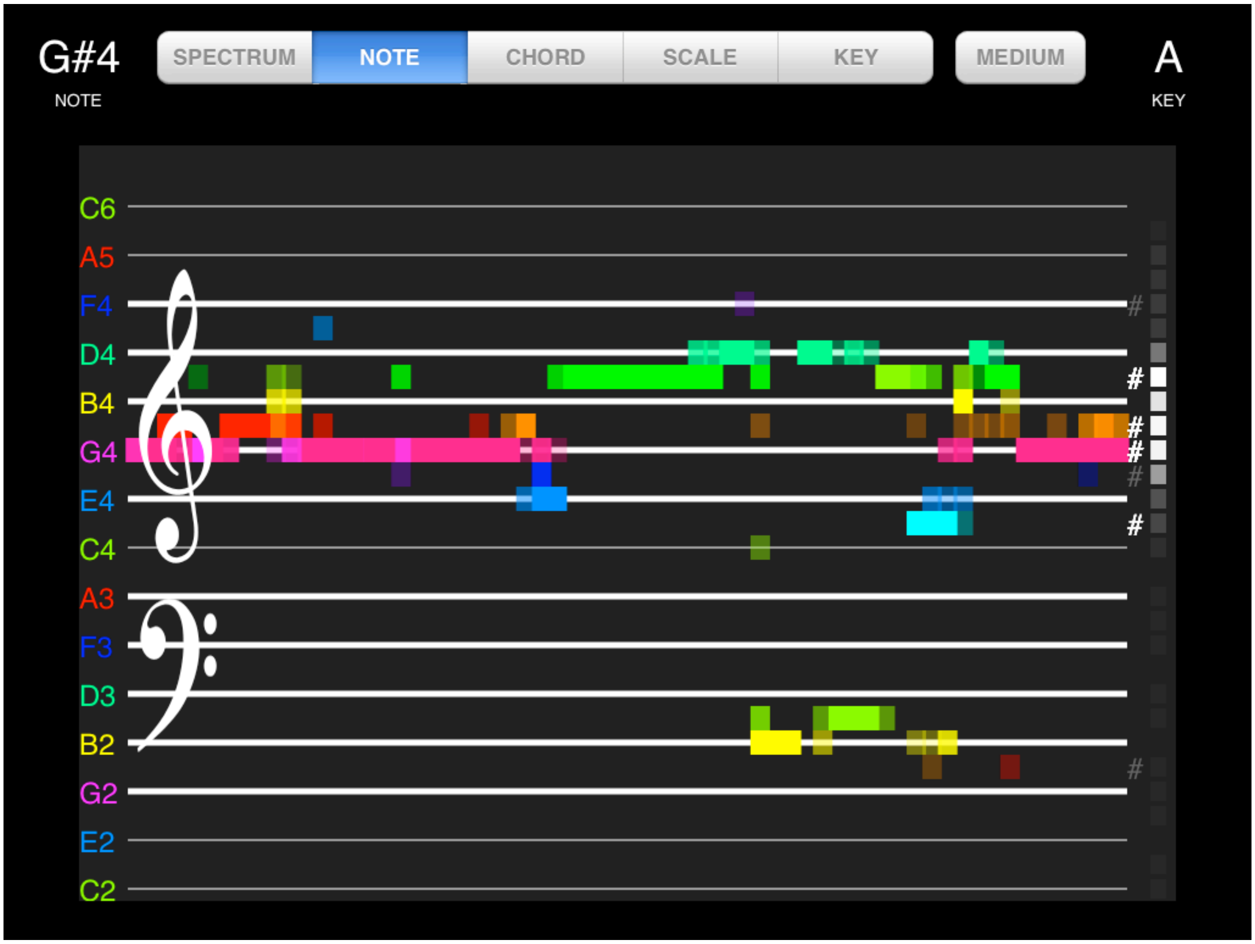

Figure 7 Tapping the equalizer strip along the right side of the note display (or the bottom of the spectrum display) changes the frequency response of the spectrum analyzer.

The equalizer (Figure 7) can be used to manually compensate for frequency response variations, and to enhance certain registers over others in order to pick out a particular part such as an instrumental solo, or singing.

Scales can be turned off/on by tapping the name of the scale along the right side of scale map. Since the musical key depends on scale, turning off scales that do not apply to a particular song will improve accuracy.

MUSYS uses pattern recognition algorithms to "understand" music. The performance of these algorithms is not perfect; e.g., a detected note may sometimes be an overtone, matching chords/scales may be harmonically/melodically similar to the correct chord/scale, and the detected key may be "close" to the true key. Please keep this in mind when using MUSYS.