Music Understanding and the Future of Music

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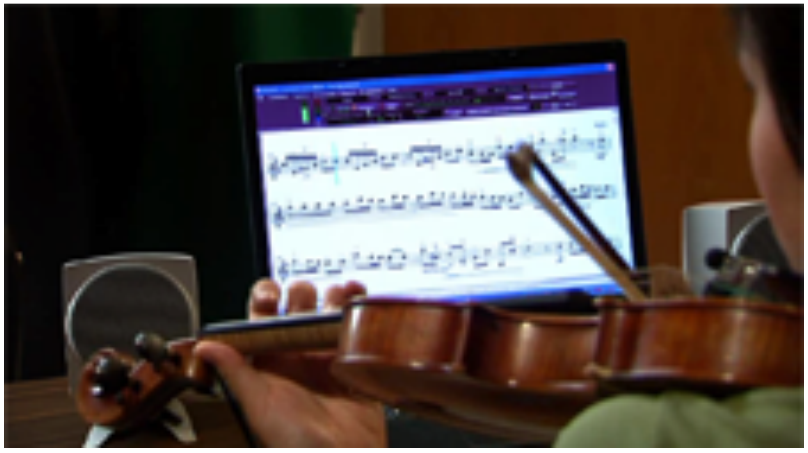
Why Computers and Music?

- Music in every human society!
- Computers are everywhere!
- Music is technological!
- Computing can make music:
  - More Fun
  - More Available
  - Higher Quality
  - More Personal



My Background

- Always interested in math and music and making things
- Trumpet player since age 11
- Discovered synthesizers in high school
- Discovered computers about the same time
- Discovered computer music in college
- Musical Acoustics with Art Benade
- Research motivated by musical experience:
  - Computers as performers
  - Expressive programming languages for music
  - Audacity Audio Editor (co-creator)

Overview

- Introduction

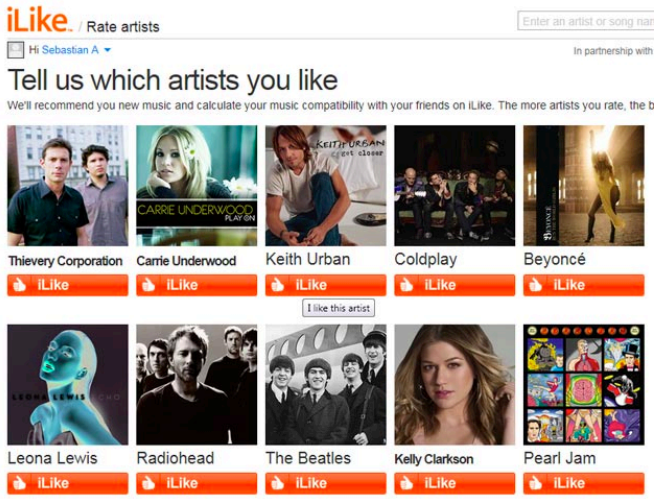
- How Is Computation Used in Music Today?
- New Capabilities:
  What Can Computers Do Tomorrow?
- What Will Music Be Like in the Future?

How Is Computation Used in Music Today?

Indabamusic.com

making-music.blogspot.com

http://venturebeat.com/



Music Computation Today

Production: digital recording, editing, mixing

- Nearly all music production today...
  - Records audio to (digital) disk
  - Edit/manipulate audio digitally
    - Equalization
    - Reverberation
  - Convert to media:
    - CD
    - MP3
    - Etc.

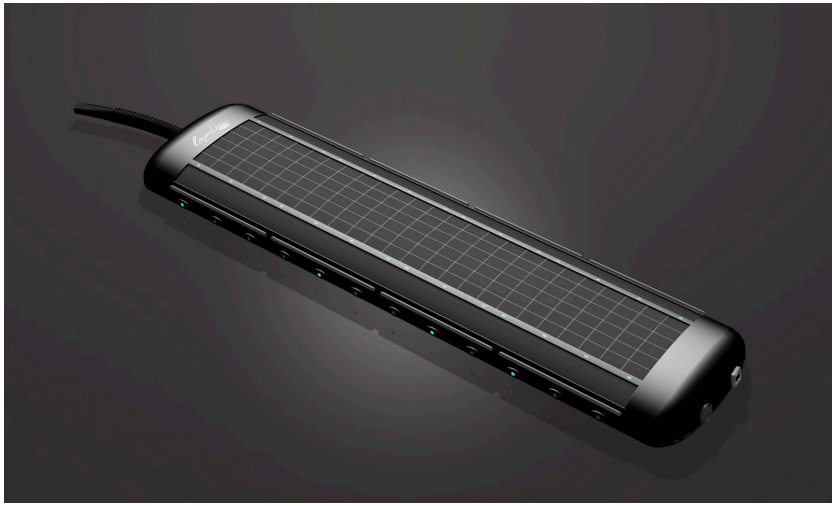
protools.com

Music Computation Today

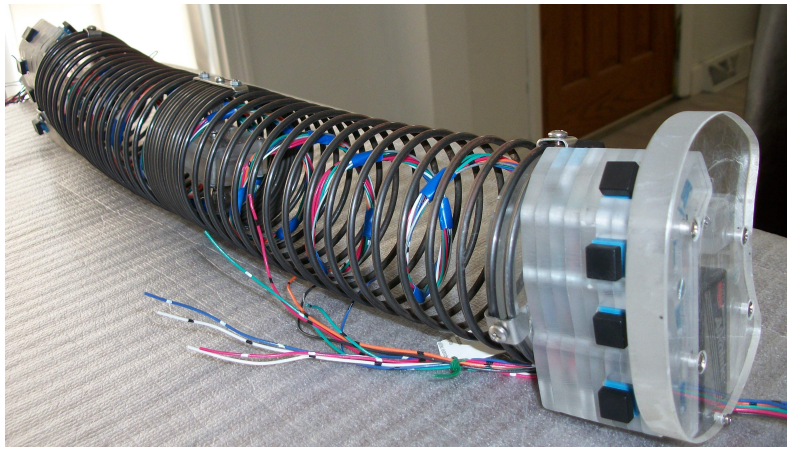
Musical Instruments: synthesizers and controllers

Synthesizer (Solaris)

Drum Machine (Yamaha)



Linnstrument (Roger Linn)



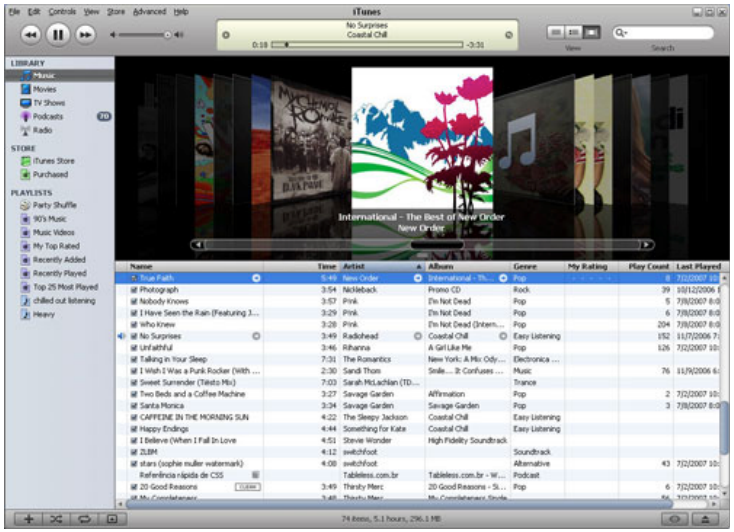
Sonic Spring (Tomas Henriques)

Music Computation Today

Distribution: compression, storage, networks

Napster

Apple iPod

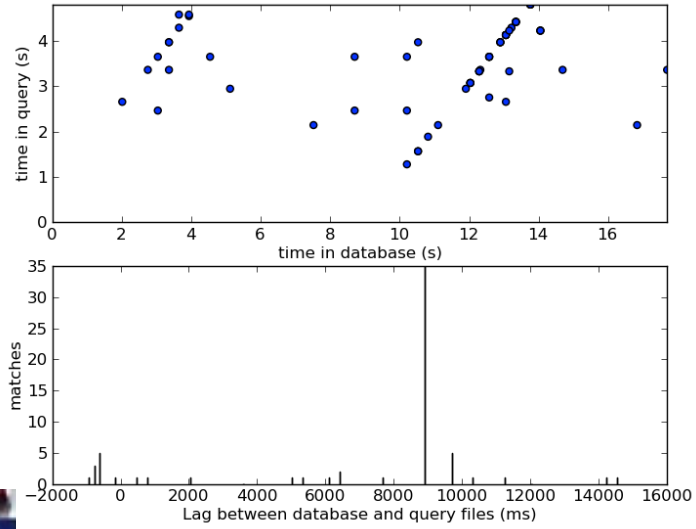


Apple iTunes

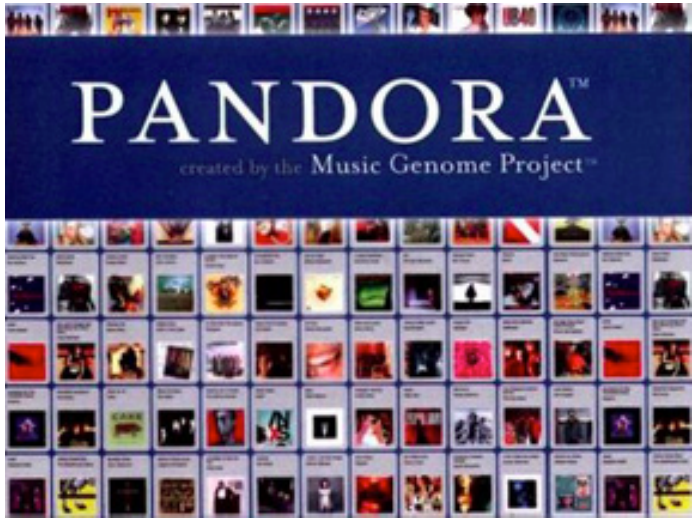
Music Computation Today

Search, recommendation, music fingerprinting

Google Music China



Music Fingerprinting



Pandora
Music Recommendation

Overview

- Computer Music Introduction
- How Is Computation Used in Music Today?

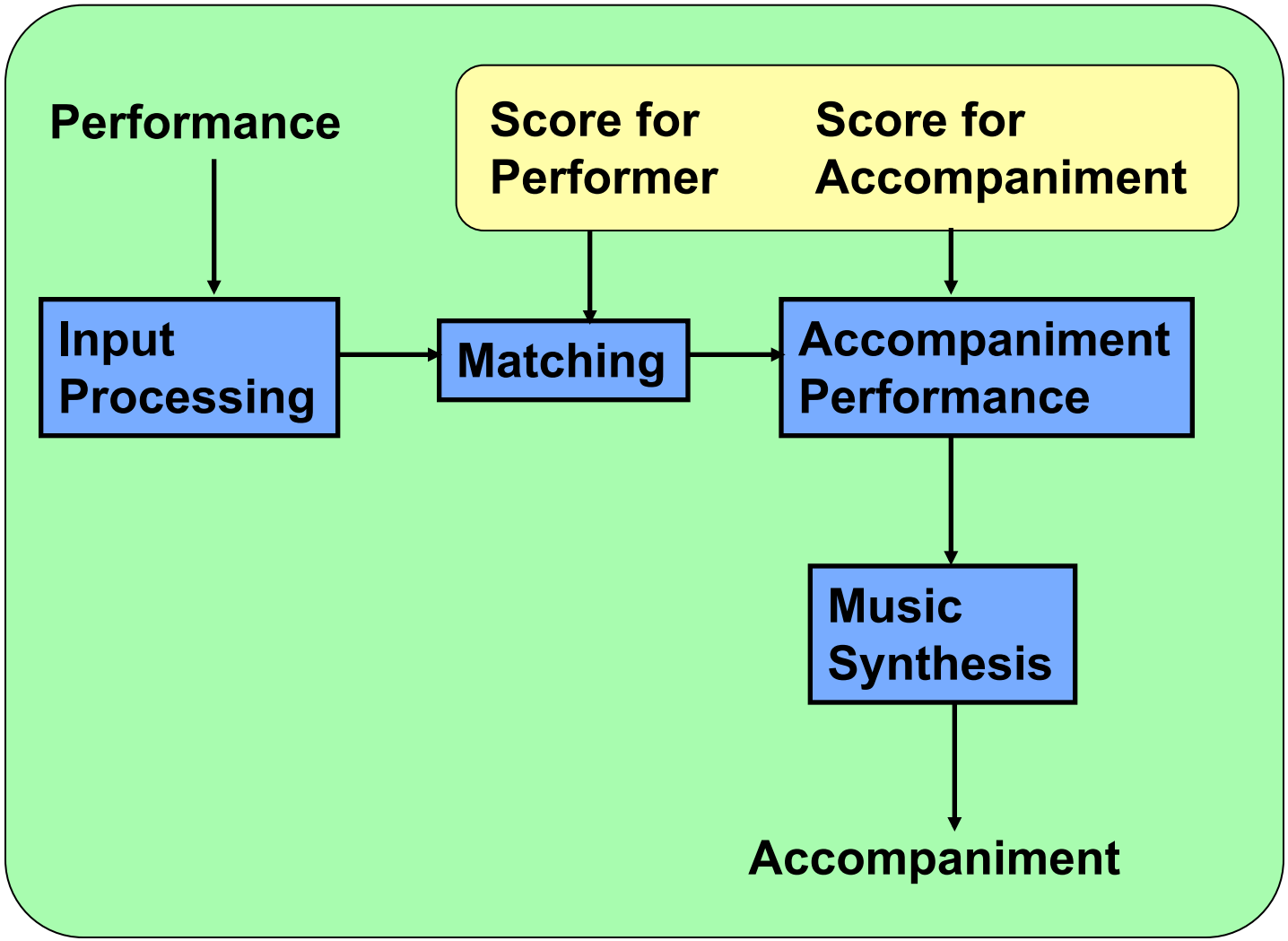
- New Capabilities:
  What Can Computers Do Tomorrow?
- What Will Music Be Like in the Future?

New Capabilities: What Can Computers Do Tomorrow?

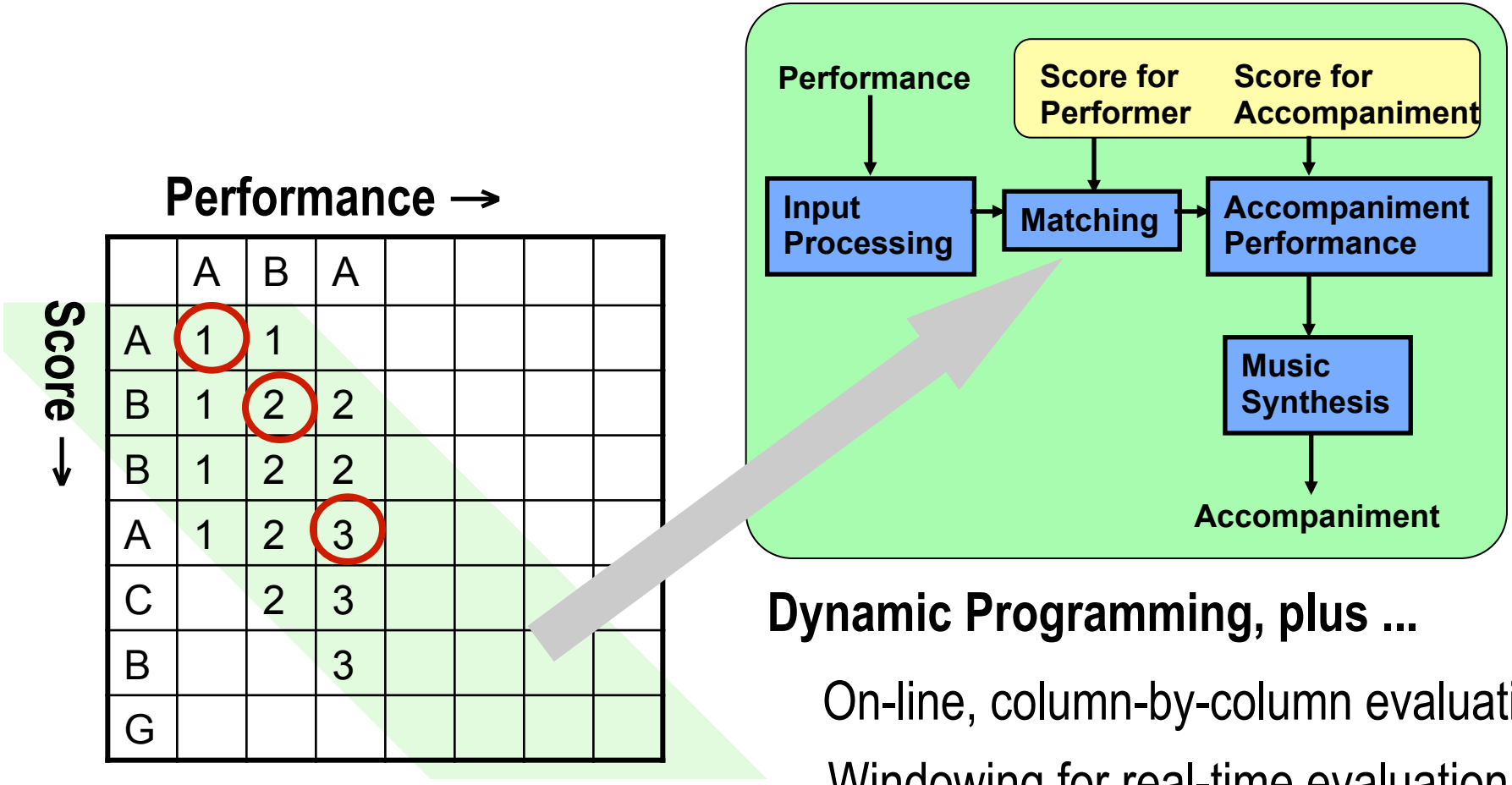
- Computer accompaniment
- Style classification
- Score alignment
- Onset detection
- Sound synthesis

Accompaniment Video

Computer Accompaniment



Computer Accompaniment



Dynamic Programming, plus ...

On-line, column-by-column evaluation

Windowing for real-time evaluation

Heuristics for best-yet matching

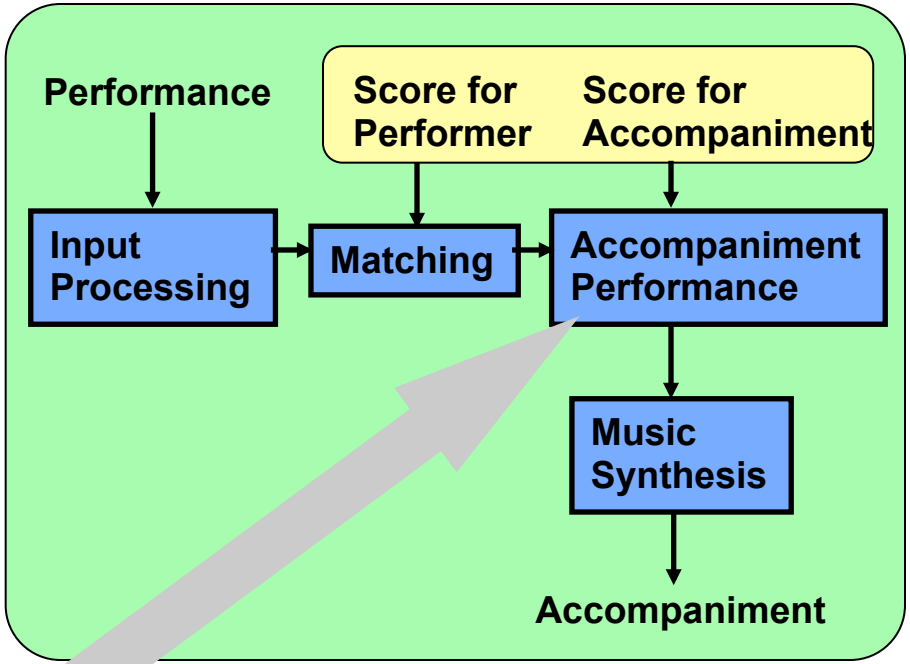
Penalty for skipping notes

Computer Accompaniment

Rule-based system:

E.g. If matcher is confident and accompaniment is ahead < 0.1s, stop until synchronized.

If matcher is confident and accompaniment is behind <0.5s, speed up until synchronized.



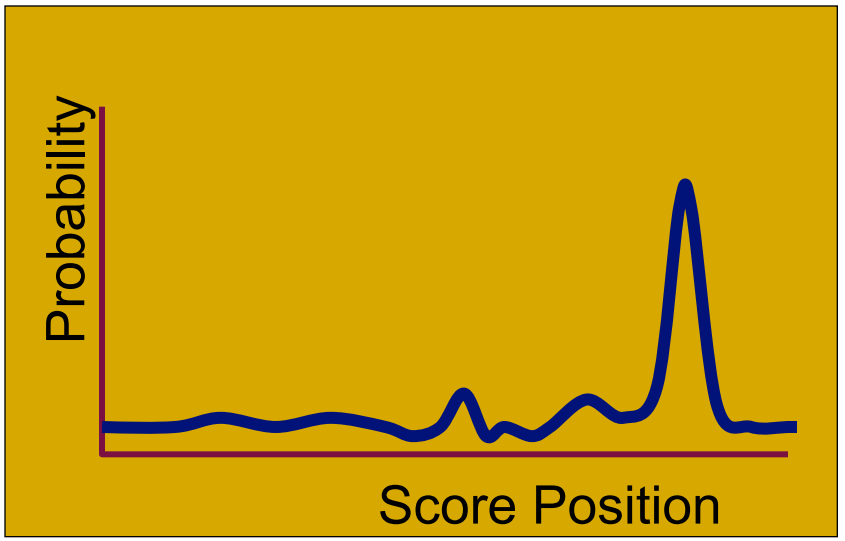
Vocal Accompaniment

- Lorin Grubb's Ph.D. (CMU CSD)
- Machine learning used to:
  - Learns what kinds of tempo variation are likely
  - Characterize sensors
    - When is a notated G sensed as a G#?
- Machine learning necessary for good performance

Vocal Accompaniment

How It Works

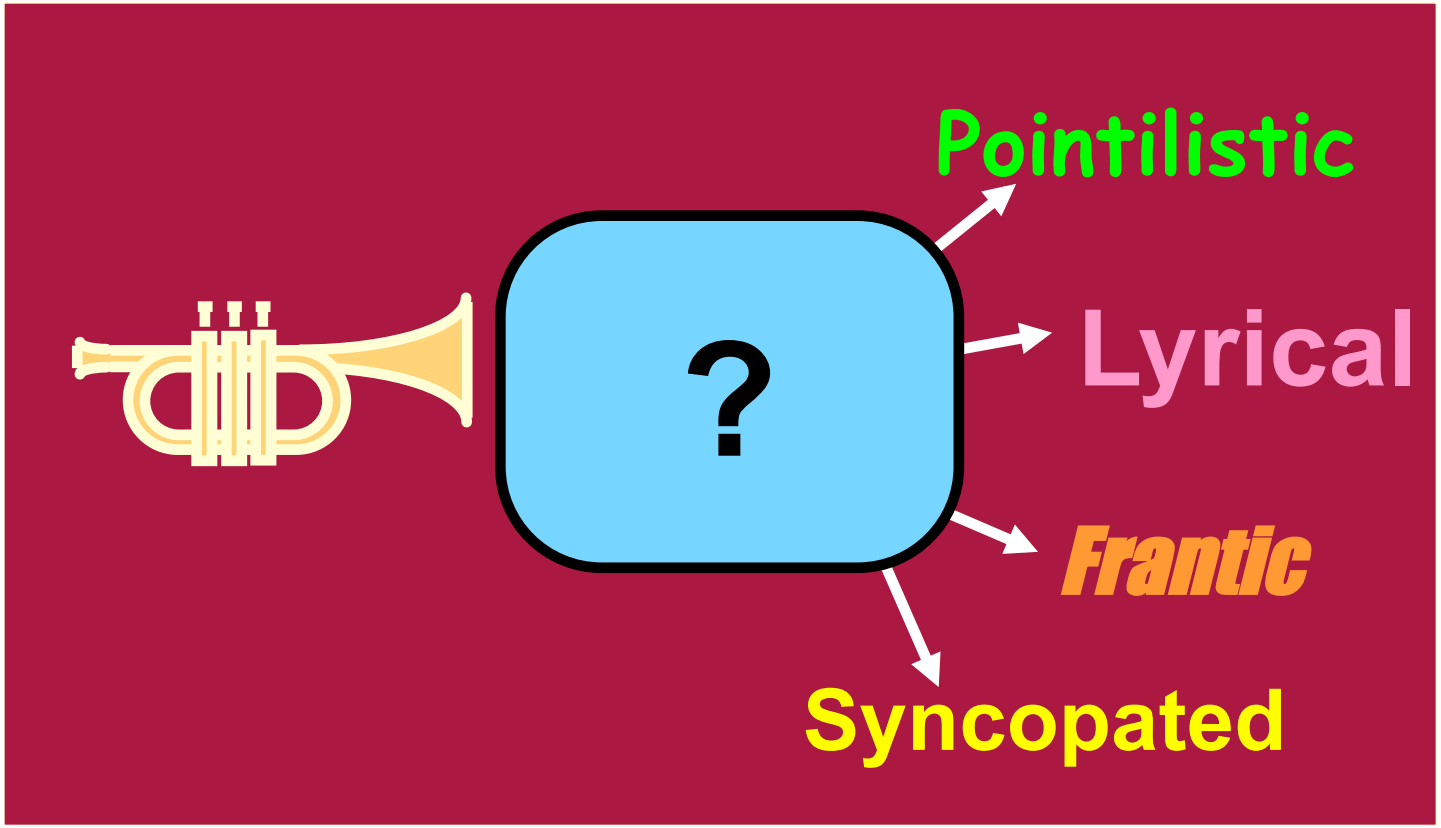
- Score position modeled as a probability density function
- Bayesian update rule: $P(s|o) \propto P(o|s)P(s)$
- P(o|s) is e.g. "probability of observing pitch G if the score says play an A." Simple statistics on labeled training data.
- Prior P(s) by fast *convolution* with a log normal (describes tempo and tempo variation)



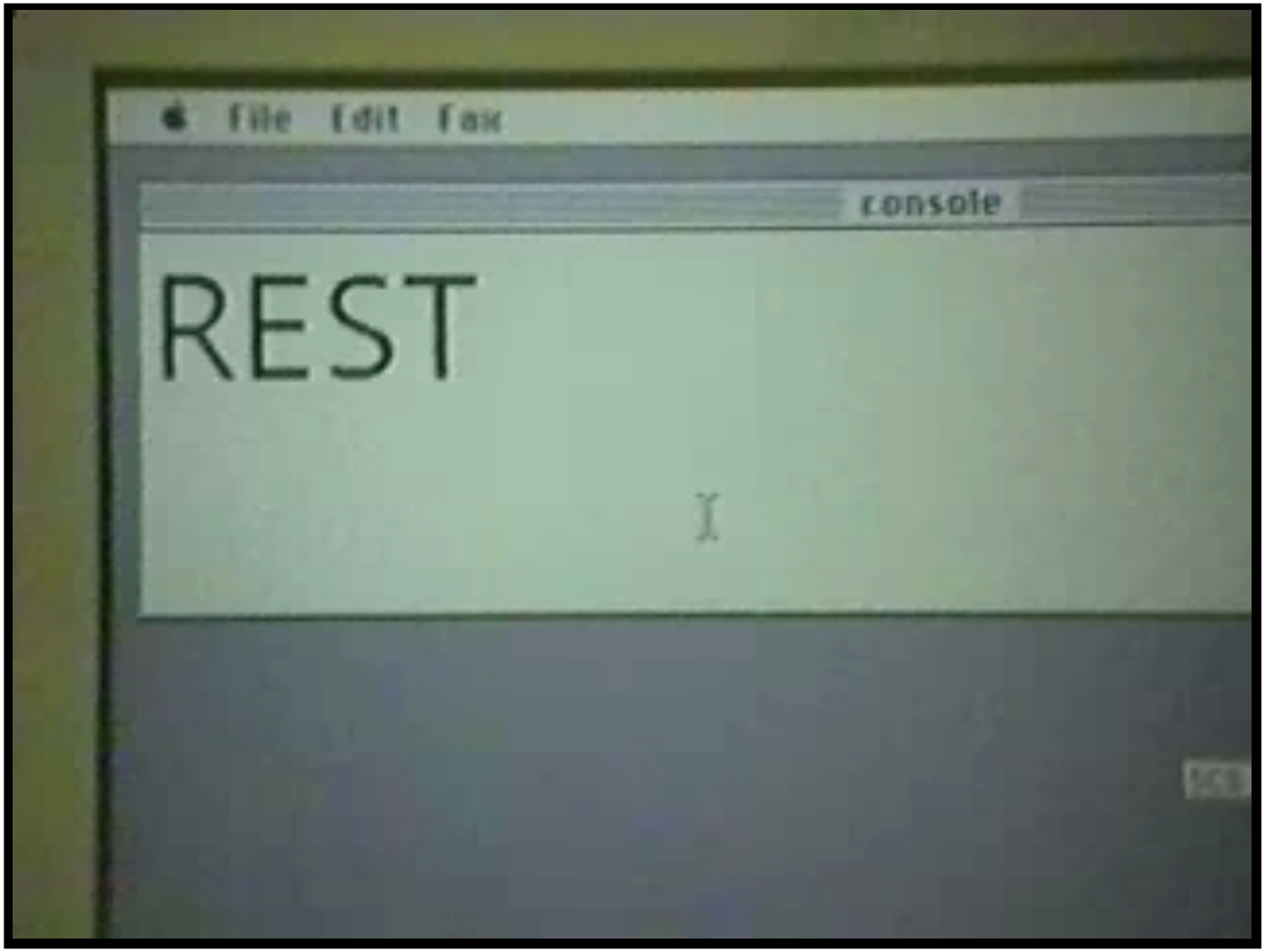
Commercial Implementation

rtsp://qt.partner-streaming.com/makemusic/wm_03_l.mov rtsp://qt.partner-streaming.com/makemusic/wm_04_l.mov

Style Classification: Listening to Jazz Styles



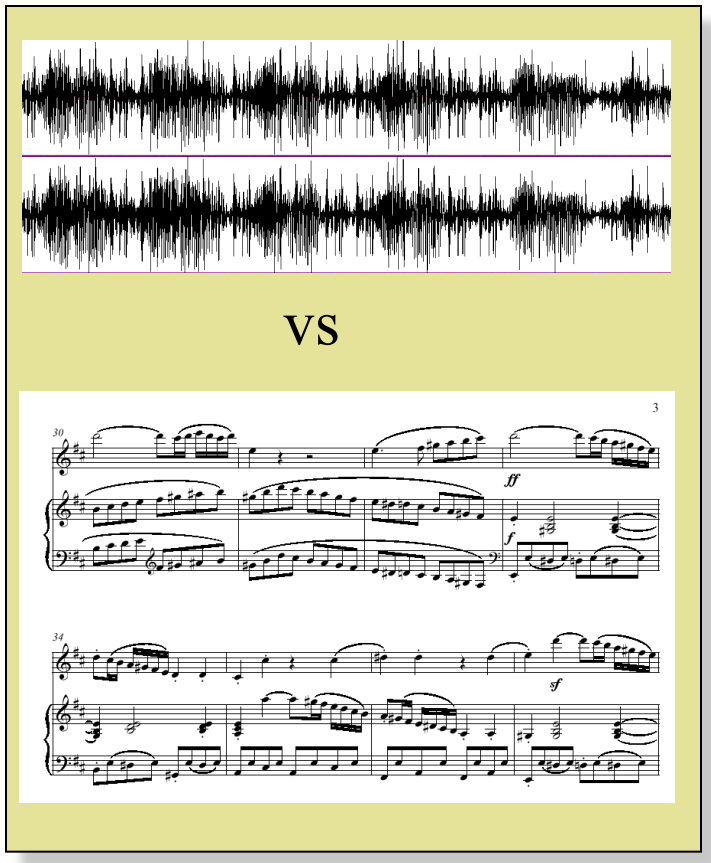
Jazz Style Recognition

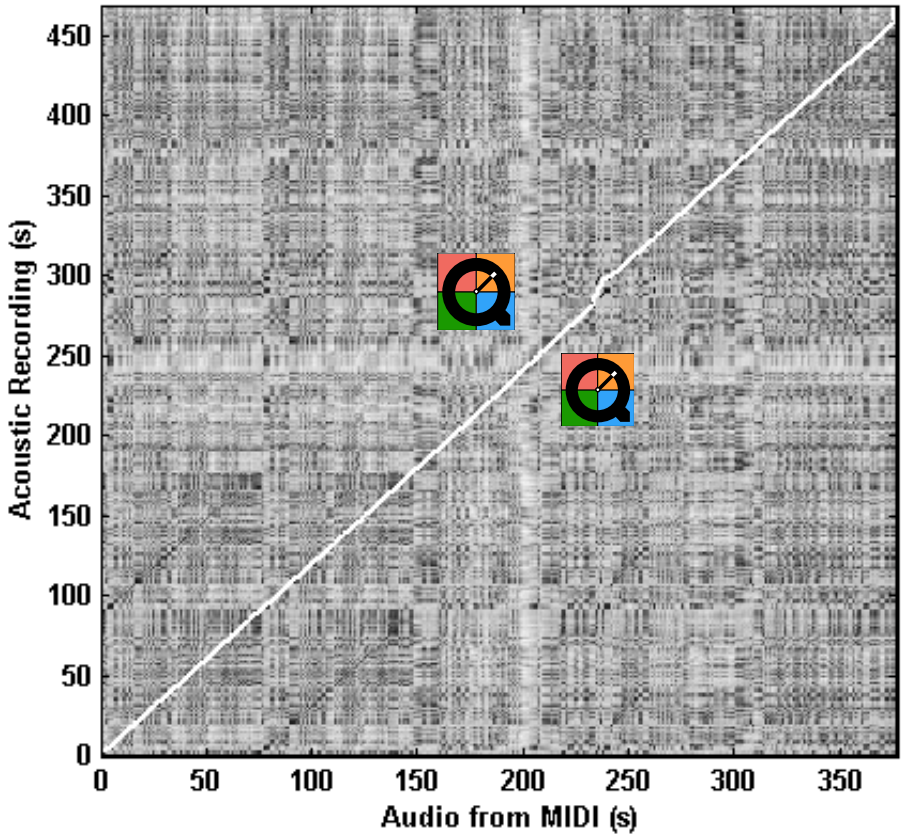


Techniques

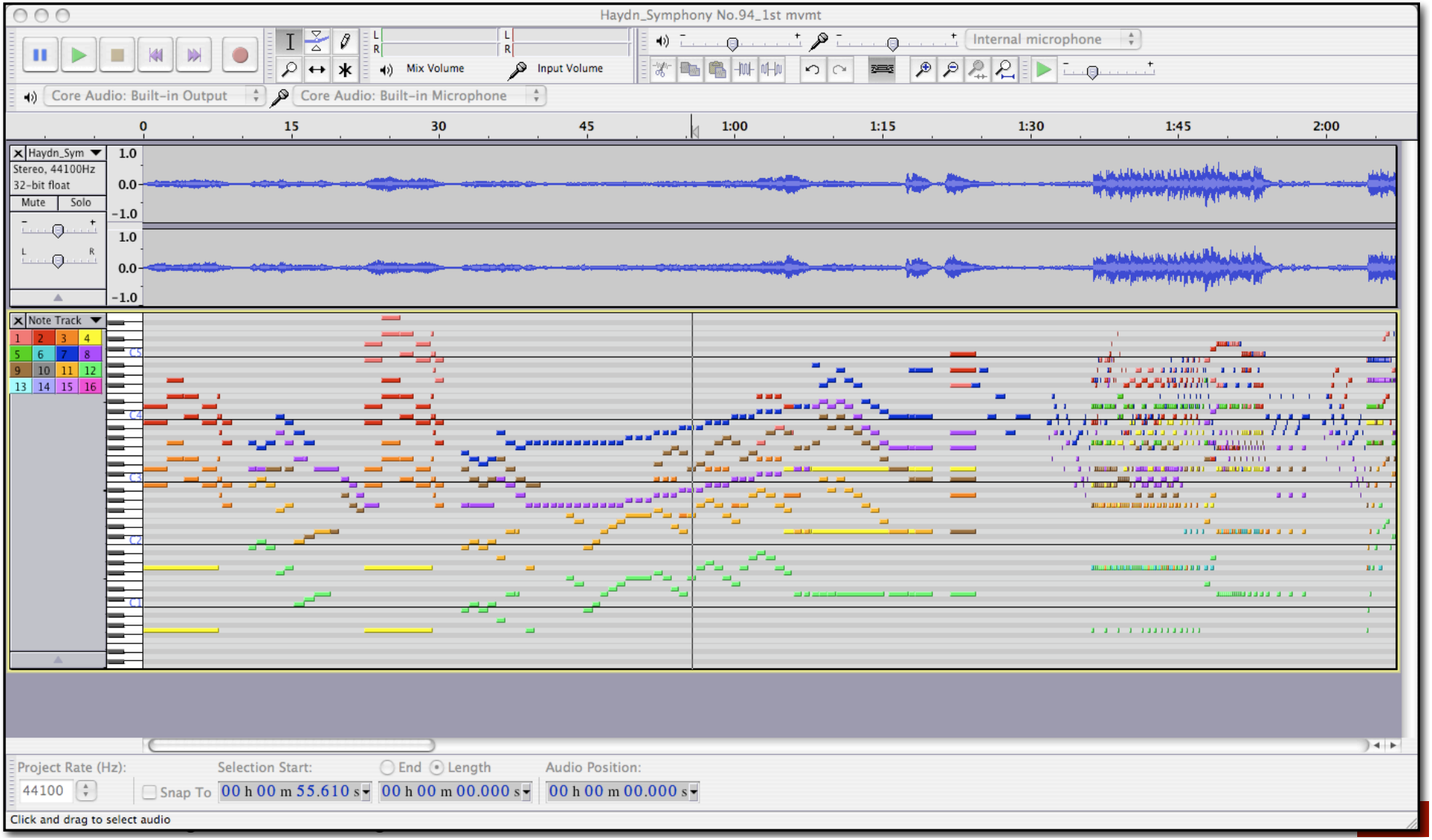
- Extract features from audio:
  - Note density
  - Mean & Std. Dev. of pitch range
  - Mean & Std. Dev. of pitch intervals
  - Silence vs. Sounding ("duty factor")
  - ... and many more
- Features over 5-second windows
- Standard Classifiers (Naive Bayes, Linear, Neural Net)

Polyphonic Audio-to-Score Alignment



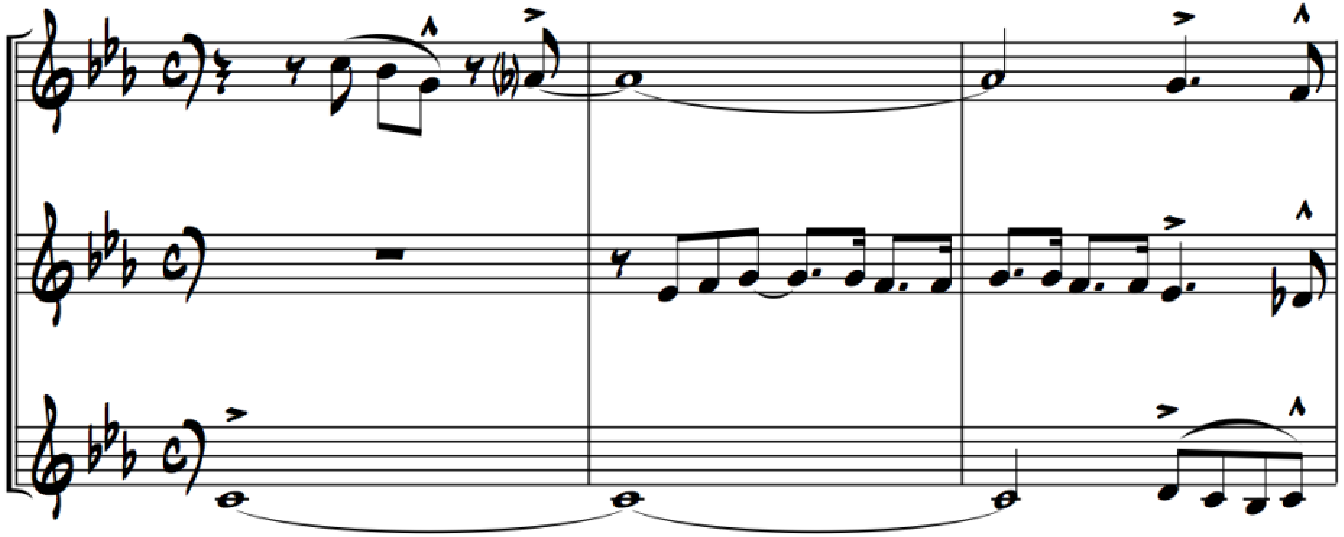


Audacity Editor with Automatic Audio-to-MIDI Alignment



Intelligent Audio Editor

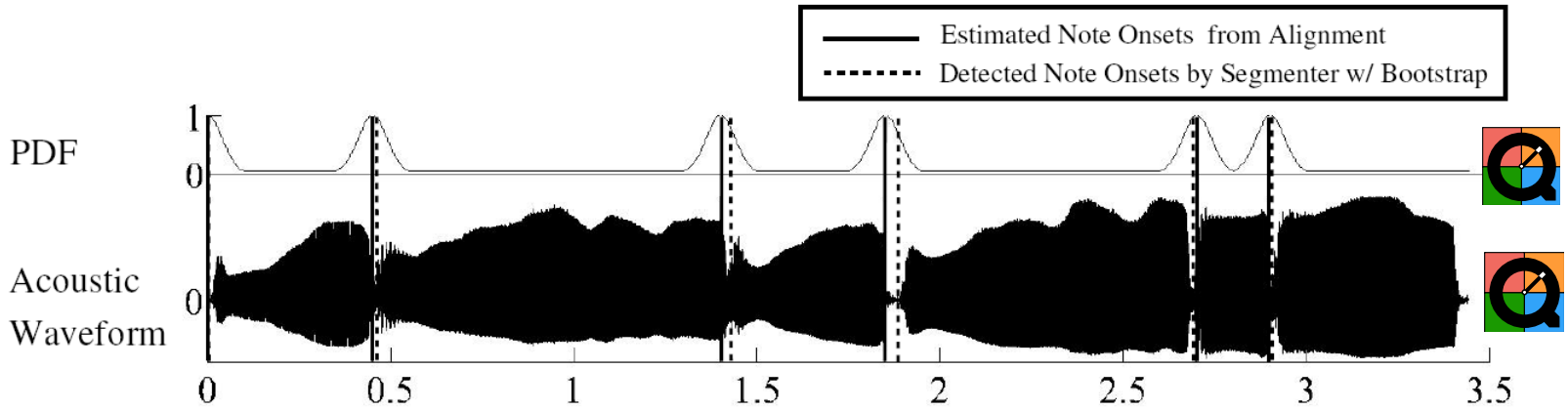
- This excerpt is included in the audio examples:



- Before:  After: 

Finding Note Onsets
(How to segment music audio into notes.)

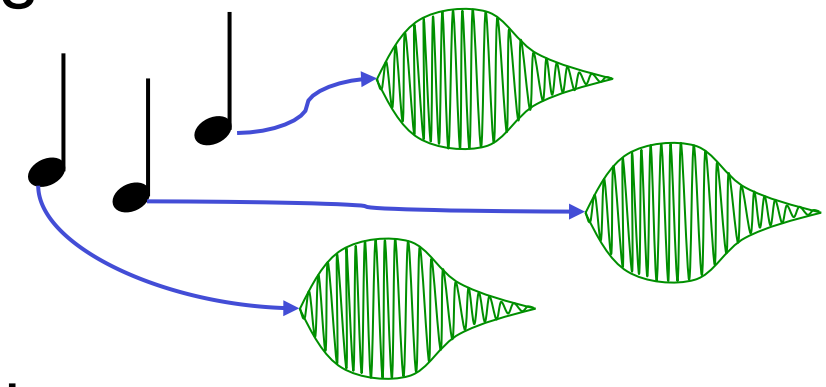
- Not all attacks are clean
- Slurs do not have obvious (or fast) transitions
- We can use score alignment to get a rough idea of where the notes are (~1/10 second)
- Then, machine learning can create programs that do an even better job (bootstrap learning).



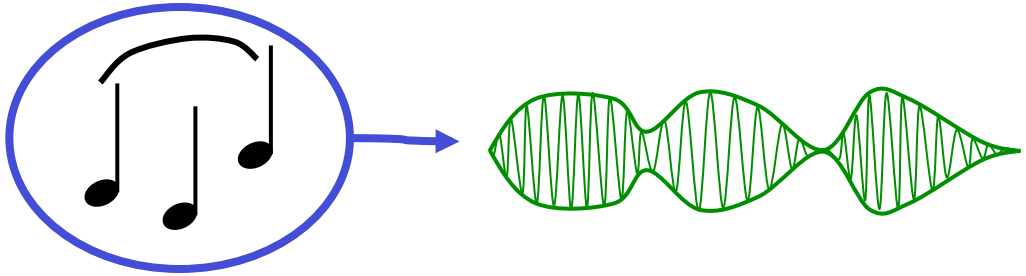
Expressive Performance

Phrase-based Synthesis

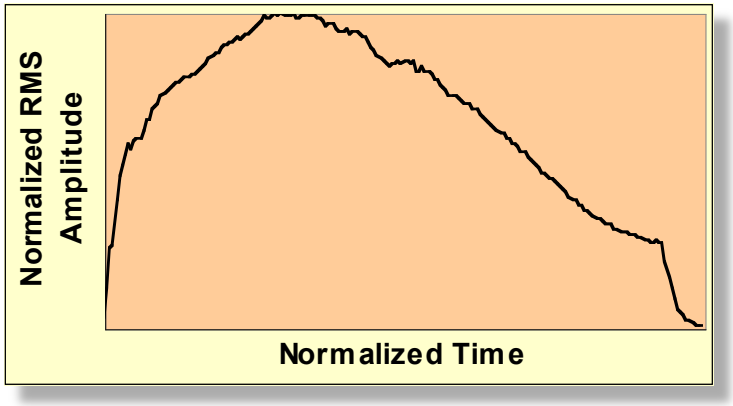
Note-by-Note Synthesis



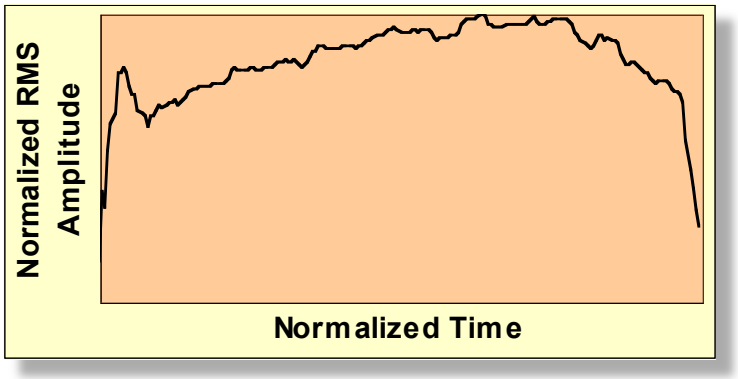
Phrase-based Synthesis



Example Envelopes



Tongued Note



Slurred Note

Synthesis Examples

- Good trumpet sounds, mechanically performed: 
- Same sounds, but performed with AI-based model of trumpet performance: 
- Another example: 
- Trumpet example from Ning Hu's thesis: 
- Bassoon example from Ning Hu's thesis: 

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Human Computer Music Performance

- OPPORTUNITY
  - State-of-the-art computer music systems for popular music performance
  - *Autonomous Intelligent Machine Musicians*

Example

- Suppose you want to get together and play music ... BUT, you're missing a _____ player.

bass

credit: Green Day

What Research Is Needed?

- Synchronization
  - Signal processing
  - Machine learning
  - Human interface
- Digital Music Display
  - Representation issues
- Improvisation
  - Models of style
- Sound Production
  - Phrase-based synthesis?
- Modularity/Systems issues
  - Real-time systems
  - Software architecture
- Interaction
  - HCI

Is There a Market? What's the Impact?

- $8B annual US music sales
  - ***Excluding*** recordings, education, performances
- 5 million musical instruments per year
- Performance revenue is on the order of $10B
- Recording revenue is similar; order of $10B
- Approximately 1/2 of all US households have a practicing musician
- ... so *very roughly* $10+B and 100M people!

Rock Prodigy

- Guitar Hero for Real Guitars
- Game design, content, animation, etc. by others
- (Play Video)

Rock Prodigy

- Unsolicited comment: "The best part about it is polyphonic pitch detection"

An Example

Arrangements: Flexibly Adapting Music Data for Live Performance

Roger B. Dannenberg
Andrew Russell

Carnegie Mellon University

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Another Application: Internet Drum Circle

- Latency is key:

OK

Shakers with 0.1s delay

- Can computers
  - Play drums?
  - Lead humans to keep it interesting 24x7?
  - Help keep the beat steady?

Online, collaborative development of creative content is already here…

wikifonia

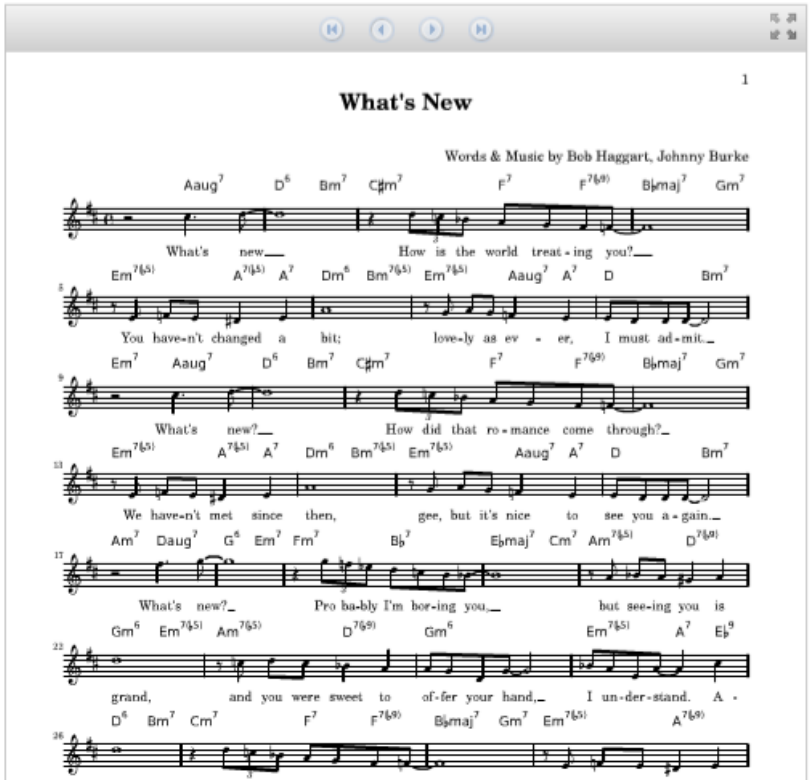
sign up | help | Log in

lead sheets | artists | forum

C Eb Bb VERSION SEARCH Artist Title Go PUBLISH

What's New

Music by Bob Haggart
Words by Johnny Burke
Performed by Frank Sinatra, Helen Forrest



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What Will People Do With HCMP?

- Practice with virtual bands.
- Create their own arrangements.
- Post machine-readable music online, share.
- Blend conventional performance with algorithmic composition, new sounds, new music.
- Robot performers.
- Eventually ... new art forms
- Think of the electric guitar, drum machine in music, camera in visual art, ...

Conclusion

- Automating Music Understanding (and Human Computer Music Performance) will *enrich musical experiences* for millions of people, including both amateurs and professionals.

- If we build computers that use understanding and intelligence to perform popular music, *great music will be made*.
  That is the future of music performance.