Music and Audio Applications

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App Areas

- New Computer-Based Musical Instruments
- Audio and Music Delivery Systems
- Hearing Aids
- Computer Aided Composition
- Music Information Retrieval

Voices, Streams, Channels, Tracks, and Lines

Music's Low Hanging Fruit Ripe for Parallelism

Usually a mix of task parallelism and data parallelism

Computational Patterns in Music and Audio Applications

- Spectral Methods
- Dense and Sparse Linear Algebra
- Structured and Unstructured Grids
- Graphical Models
- Dynamic Programing
- Graph Algorithms
- Transcendental Functions

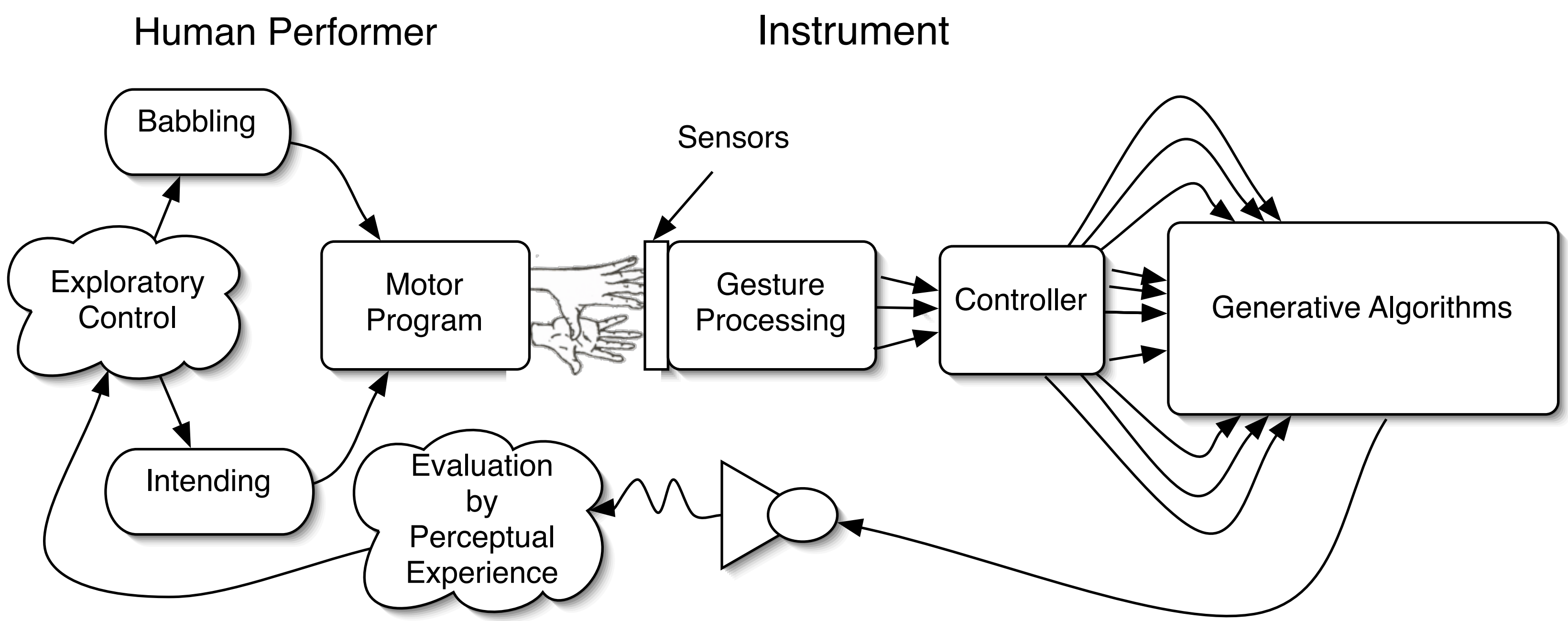
Structural Patterns

- Pipe-and-Filter
- Agent and Repository
- Process Control
- Event-based Invocation
- Model-view Controller
- Map Reduce
- Arbtrary Static Task Graph
- Puppeteer

New Musical Instruments

- Primary Design Criteria
  - Bodily Engagement
  - Musically Expressive and Inspiring
  - Easy to Play at the Entry Level
  - BUT! Accepting of Lifelong Development of Virtuosity

Musical Instrumentation



Some numbers for real-time scheduling for audio, media, and music applications

Channel Synchronization < 10 micro-sec

Audio Input to Output < 1 milli-sec

Flams < 1 milli-sec

Gesture to Audio < 10 milli-sec

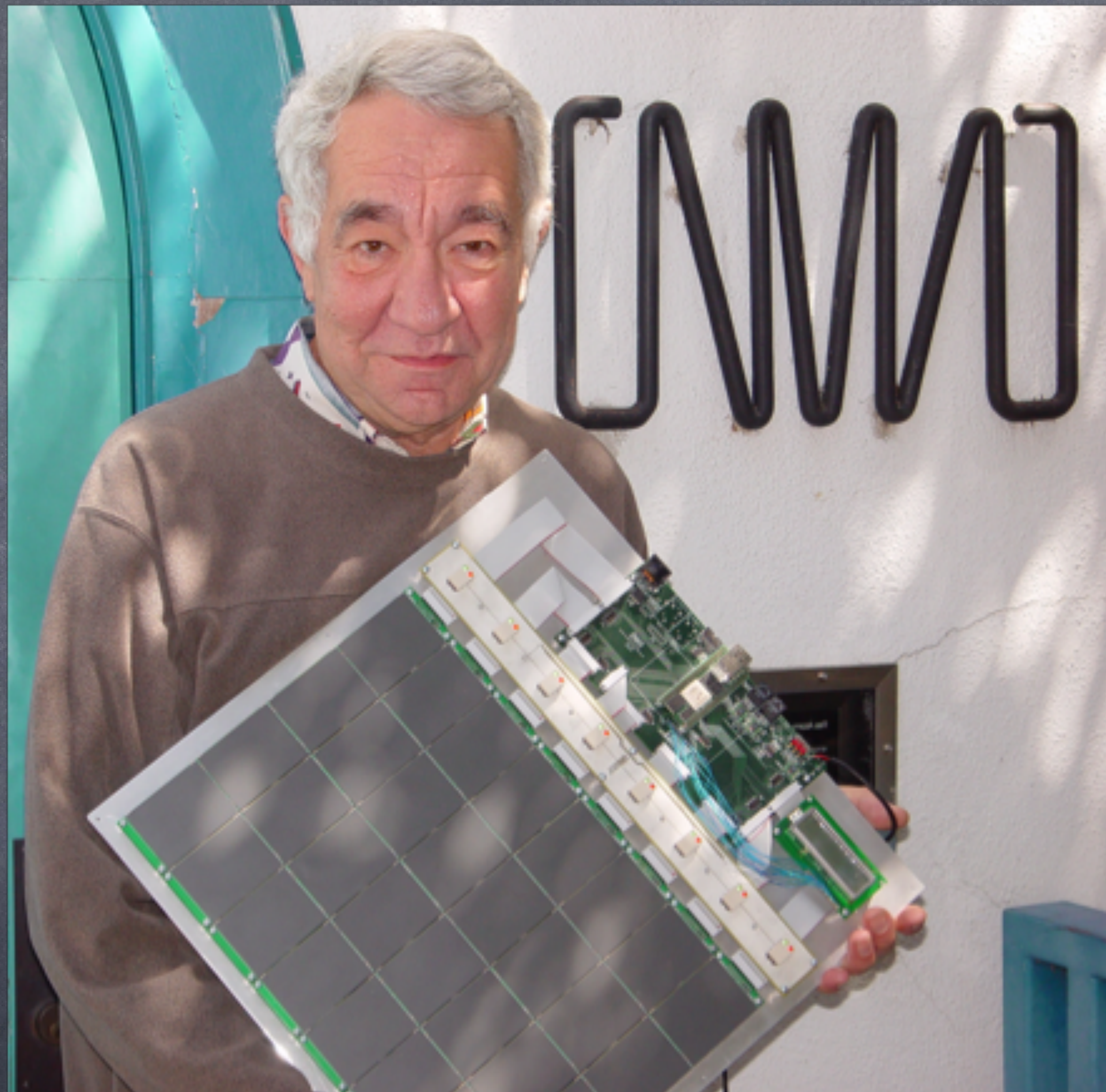
Audio-Visual Sych < 30 milli-sec

Images (no flicker) < 50 milli-sec

For audio jitter is forbidden.

Video is more tolerant.

High Bandwidth does not imply low latency



Voices, Streams, Channels, Tracks, and Lines

Music's Low Hanging Fruit Ripe for Parallelism

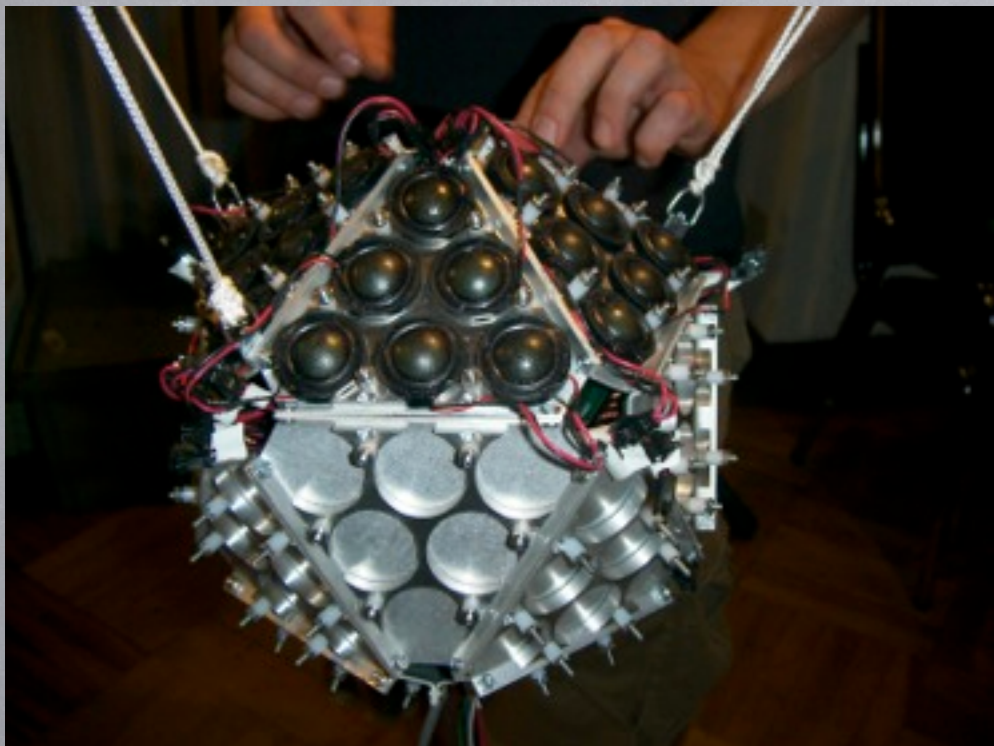
The new version of the **poly~** abstraction in Max/MSP (version 5) assigns voices and collections of voices to multiple cores.

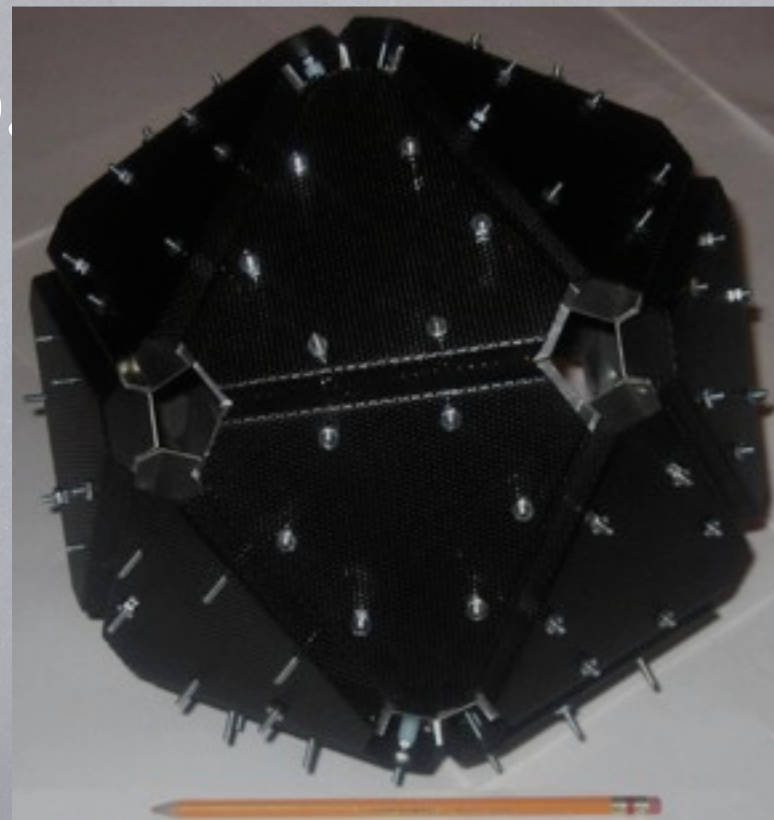
Open Sound Control (OSC)

* Open-ended, dynamic, URL-style symbolic naming scheme
* Symbolic and high-resolution numeric argument data
* Pattern matching language to specify multiple recipients of a single message
* High resolution time tags
* "Bundles" of messages whose effects must occur simultaneously

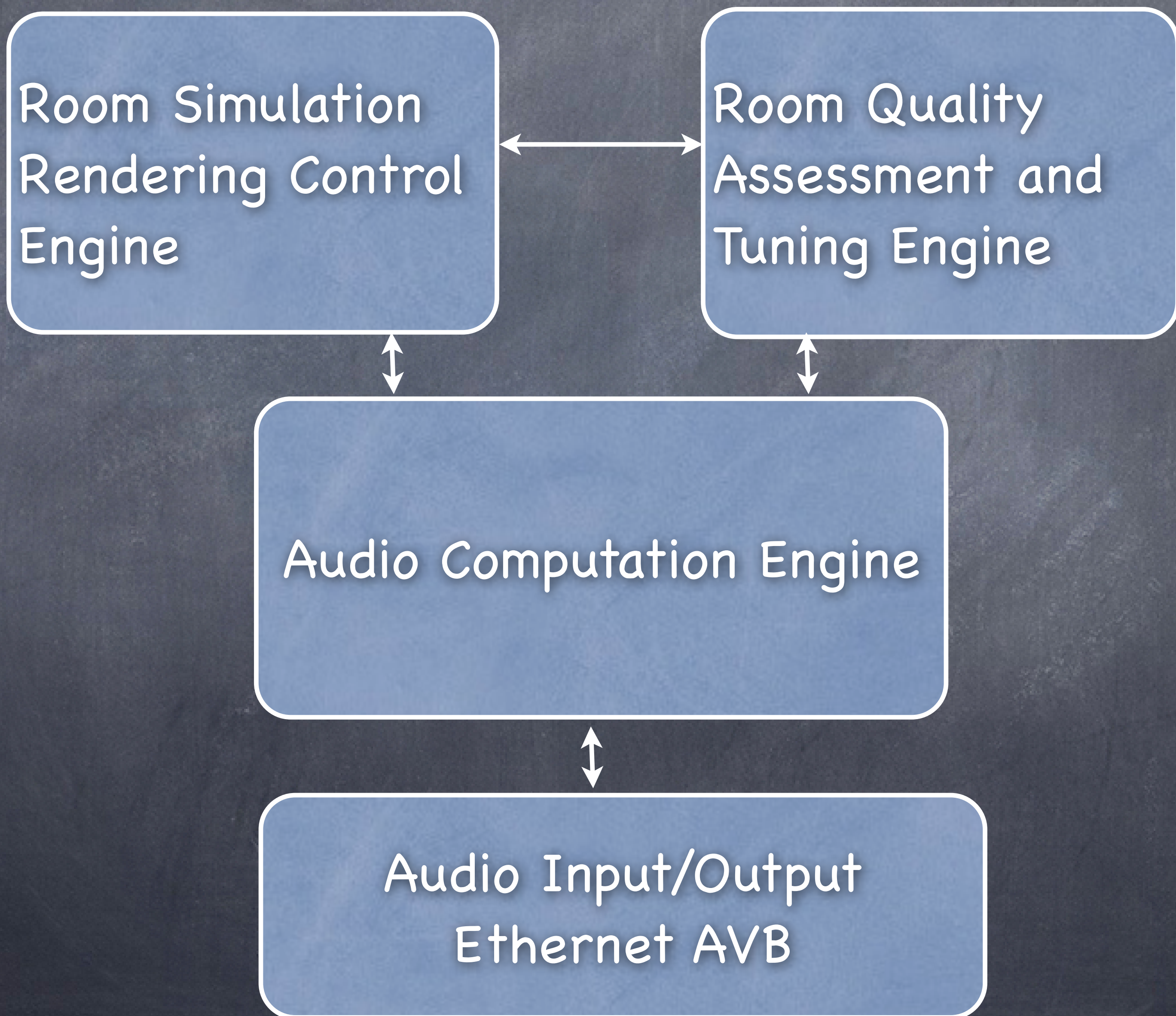
Many-Channel Audio Systems

Arrays of speakers and microphones
Huge number of independent channels (Already 100s)
Bandwidth requirements; Gigabit and beyond
Low input to output latency
Non-trivial computational requirements

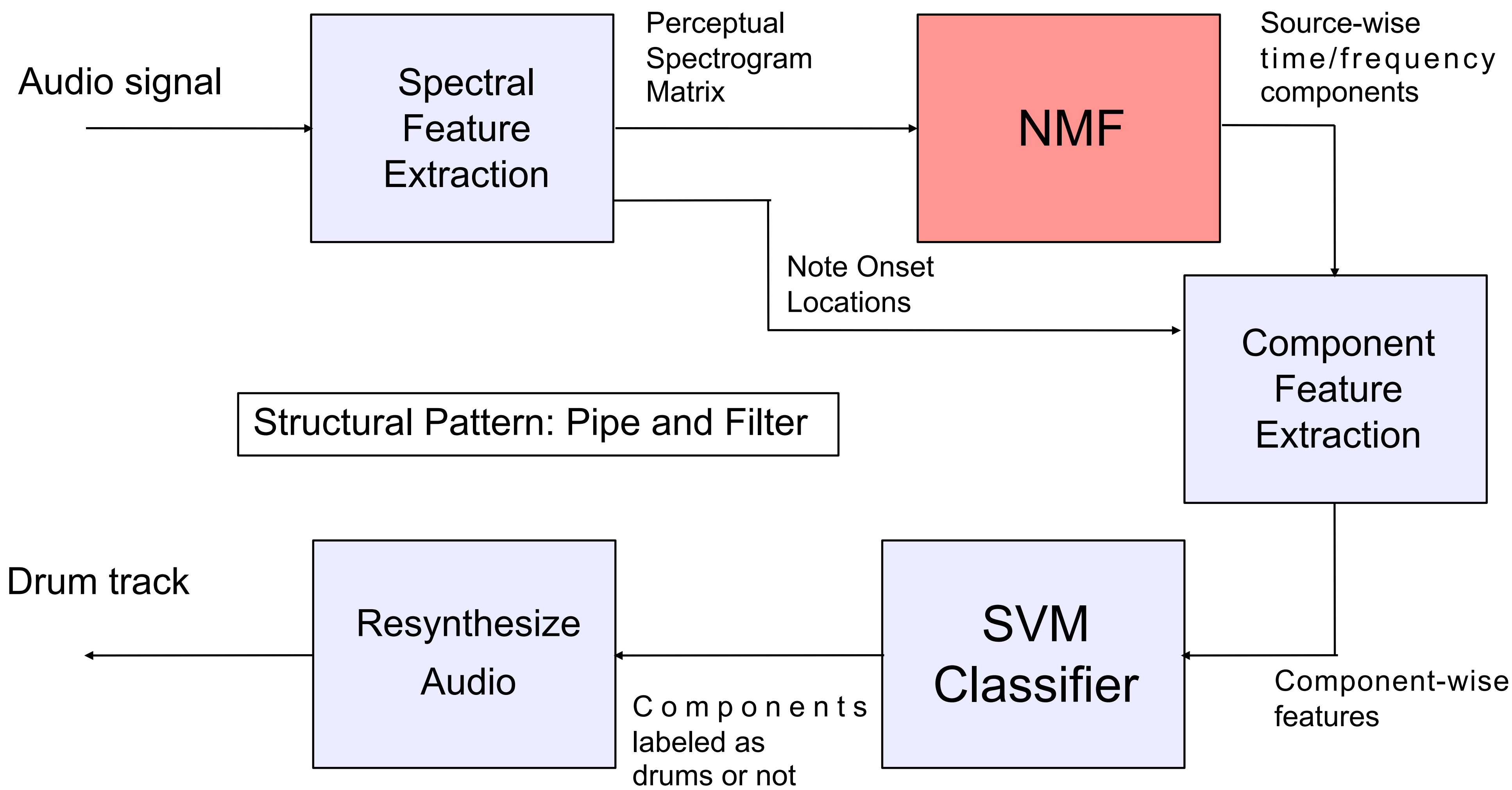




An i7 (Nehalem) Based Audio Diffusion System

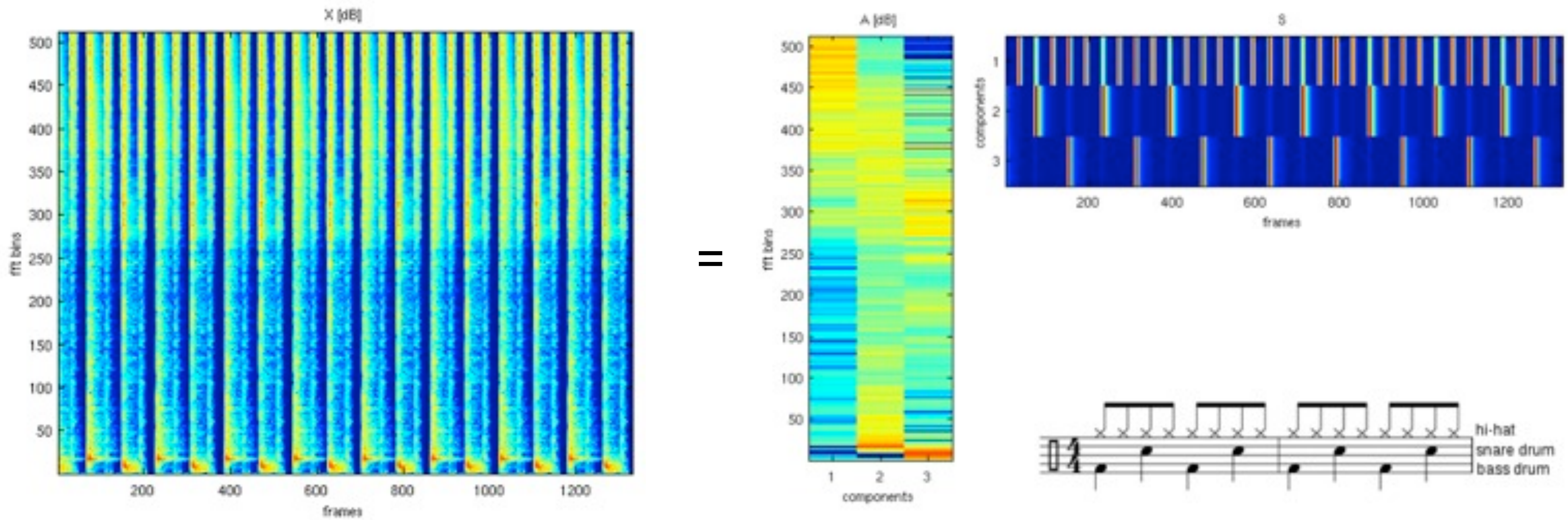


Drum Track Extraction



Non-negative Matrix Factorization

- NMF source separation is accomplished using an iterative gradient-based solver
  - Our aim is to factorize a positive matrix X (MxN) into two positive matrices A (MxK) and S (KxN), where K is much smaller than M and N
  - For source separation on a spectrogram matrix: M is the number of frequency components, N is the number of frames (in time), and K is the number of sources



Pattern Mining Overview

	Spectral Feature Extraction	NMF	Component Feature Extraction	SVM Classifier	Audio Resynthesis
Structural Pattern	Pipe-and-Filter	Bulk Iterative, Pipe-and-Filter	Pipe-and-Filter	Pipe-and-Filter	Pipe-and-Filter
Computational Pattern	FFT, Sparse Linear Algebra, Structured Grid	Dense Linear Algebra, Graph Algorithms	FFT, Structured Grid	Dense Linear Algebra	FFT, Dense Linear Algebra
Algorithm Pattern	Data Parallelism, Geometric Decomposition	Data Parallelism, Geometric Decomposition, Recursive Splitting	Data Parallelism, Geometric Decomposition	Data Parallel, Geometric Decomposition	Data Parallelism, Geometric Decomposition
Implementation Pattern	Strict Data Parallel, SPMD	Strict Data Parallel, Distributed Array, SPMD	Strict Data Parallel, SPMD	SPMD, Distributed Array	Strict Data Parallel, Distributed Array
Execution Pattern	SIMD	SIMD, Collective Synchronization	SIMD	SIMD	SIMD, Collective Synchronization

Special Thanks

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Rimas Avizienis and Adrian Freed for their work on the slab and connectivity processing.

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Eric Battenberg for the OpenMP and CUDA implementations of Non-negtive Matrix Factorization

Resources

For Max/MSP/Jitter:

http://www.cycling74.com/downloads/max5

For video demo of SLABS in action:

http://www.youtube.com/watch?v=q_mtCZqN0Ms

http://www.youtube.com/watch?v=S1R8h_CU7xQ&feature=related

For Open Sound Control (OSC) 1.1

http://cnmat.berkeley.edu/user/adrian_freed/blog/2008/10/06/open_sound_control_1_1_specification

Thanks for your attention

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