Lecture 13

Adaptive Digital Audio Effects (A-DAFx)

(figures from the DAFx book)

What Is It?

- Audio Effects: signal transformation techniques
- Static Audio Effects: transformation doesn't change over time
  - Pitch/Speed change, reverberation, spatial effects, equalization, etc.
- Adaptive Audio Effects: transformation changes over time, dependent on the input audio
  - Dynamic range control, cross synthesis

Why Adaptive?

- More fun!
  - Creative, intelligent, flexible
- Useful
  - Dynamic range control in car audio systems
  - Voice morphing to hide identity

Perceptual Categorization of Effects

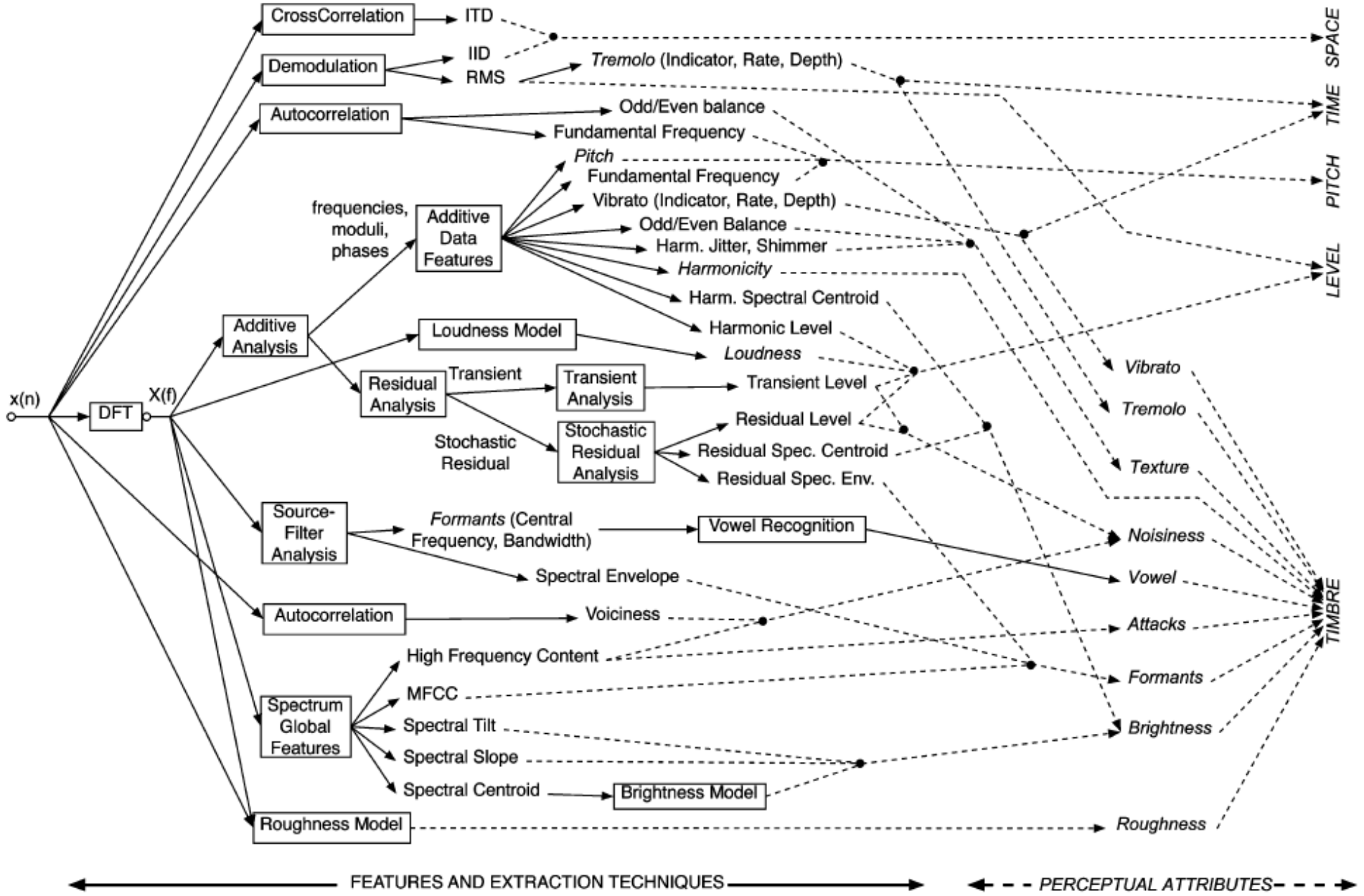
- **Loudness:** sound intensity level, perceived loudness, loudness modulation
- **Time:** modulation, beats, rhythm
- **Pitch:** fundamental frequency (F0), harmonics, harmonicity, pitch-class (chroma)
- **Space:** ITD, IID, HRTF, reverberation, echo, Doppler effect
- **Timbre:** More complicated

Timbre (tone quality, tone color)

"That attribute of auditory sensation in terms of which a subject can judge that two sounds similarly presented and having the same loudness and pitch are dissimilar."

---- ANSI, 1960.

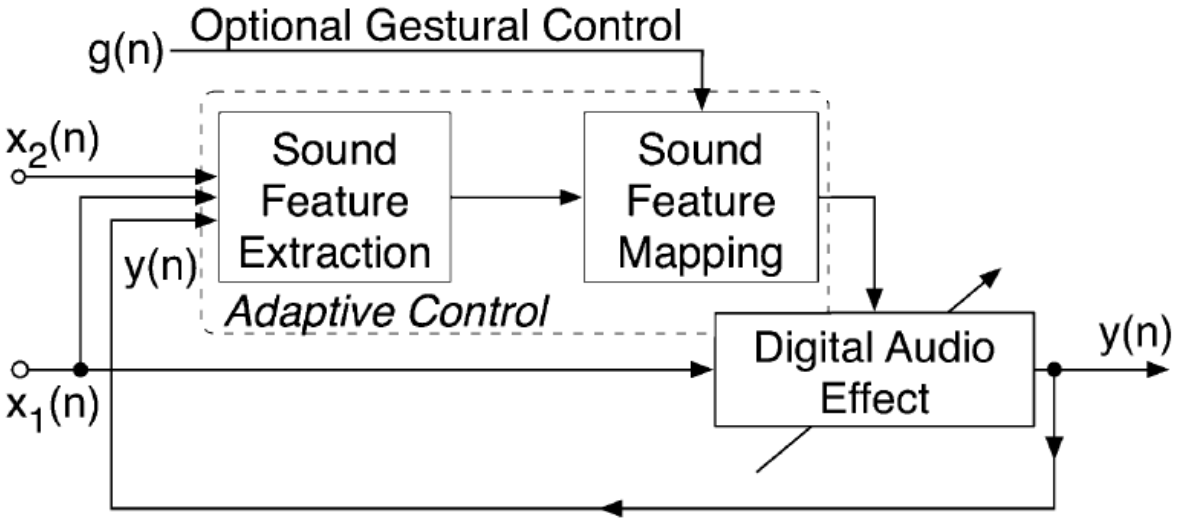
- Many factors
  - Frequency composition
  - Temporal dynamics: attack/sustain/decay
  - Spectral envelope, and evolution over time
  - Phase relationship between harmonics
  - ……


CrossCorrelation
ITD
Demodulation
IID
RMS
Autocorrelation
Odd/Even balance
Fundamental Frequency
Pitch
Fundamental Frequency
Vibrato (Indicator, Rate, Depth)
Odd/Even Balance
Harm. Jitter, Shimmer
Harmonicity
Harm. Spectral Centroid
Harmonic Level
frequencies, moduli, phases
Additive Data Features
Tremolo (Indicator, Rate, Depth)
SPACE
TIME
PITCH
LEVEL
x(n)
DFT
X(f)
Additive Analysis
Loudness Model
Loudness
Residual Analysis
Transient
Transient Analysis
Transient Level
Stochastic Residual
Stochastic Residual Analysis
Residual Level
Residual Spec. Centroid
Residual Spec. Env.
Vibrato
Tremolo
Texture
Source-Filter Analysis
Formants (Central Frequency, Bandwidth)
Vowel Recognition
Spectral Envelope
Noisiness
Vowel
Autocorrelation
Voiciness
Attacks
High Frequency Content
Formants
Spectrum Global Features
MFCC
Spectral Tilt
Spectral Slope
Spectral Centroid
Brightness Model
Brightness
TIMBRE
Roughness Model
Roughness
FEATURES AND EXTRACTION TECHNIQUES
PERCEPTUAL ATTRIBUTES

Common Effects

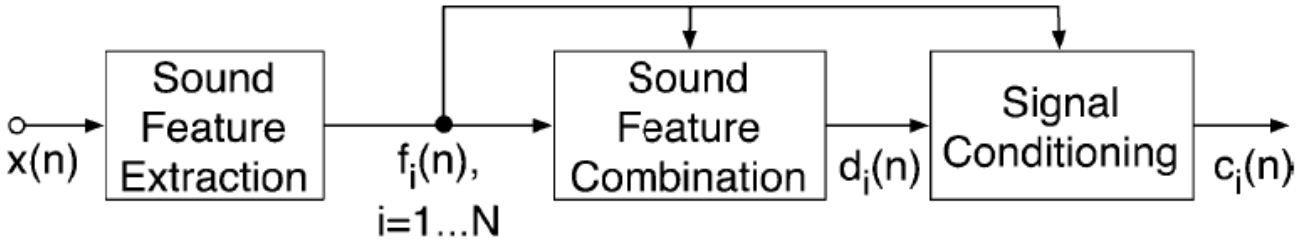
- **Loudness:** volume change, tremolo, dynamic range control
- **Time:** time scaling by resampling, phase vocoder
- **Pitch:** pitch shifting, harmonizer (adding pitch-shifted versions), auto-tuning
- **Space:** room effects, reverberation, 3D audio
- **Timbre:** vibrato, phasing (e.g., chorus, flanging), equalization, spectral envelope modification, whisperization (randomizing magnitude/phase spectrum), transient enhancement/attenuation

Adaptive DAFx



- Auto-adaptive: depends on x1
- External-adaptive: depends on x2
- Feedback-adaptive: depends on y
- Cross-adaptive: depends on x1 and x2

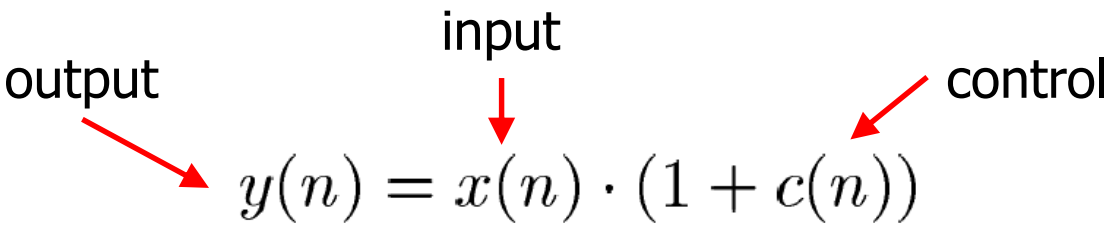
Mapping Features to Control



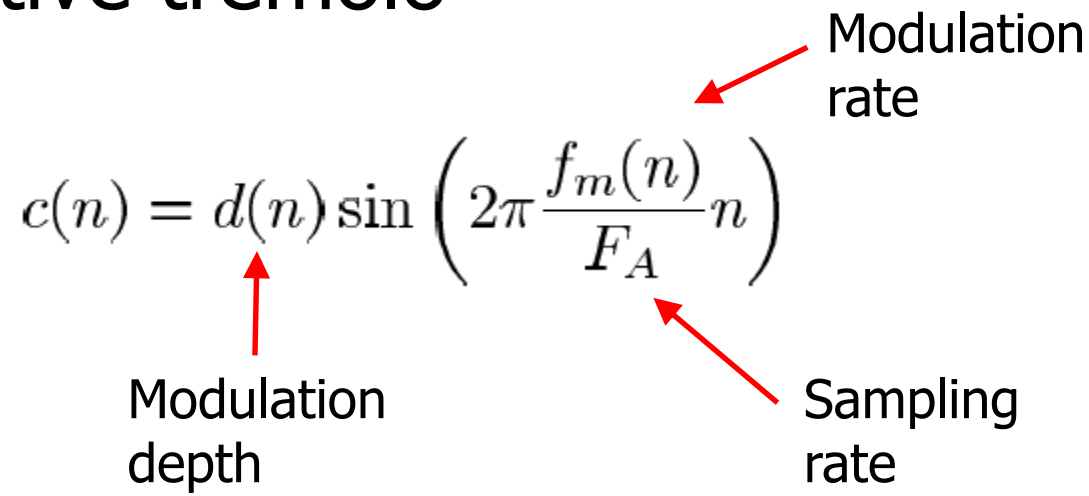
- Sound feature combination: normalization → warping → linear combination → warping

- Signal conditioning: modify signal to fit to the boundaries and variation type of controllers

Adaptive Loudness Effects



- Adaptive tremolo



Adaptive Time Effects

- Adaptive time warping: time-scale audio differently at different times
  - Preserve note attack/transient
  - Time-scaling with vibrato
- Adaptive time warping that preserves signal length
  - Distorting mirror

Adaptive Pitch Effects

- Adaptive Intonation Change
  - Intonation: pitch info contained in prosody of human speech

pitch

macro-intonation

micro-intonation

$$F_{0,\text{in}}(m) = \overline{F_{0,\text{in}}^{\text{loc}}} + \Delta F_{0,\text{in}}(m)$$

$$F_{0,\text{out}}(m) = \gamma \overline{F_{0,\text{in}}} + \alpha \left(\overline{F_{0,\text{in}}^{\text{loc}}} - \overline{F_{0,\text{in}}} \right) + \beta \Delta F_{0,\text{in}}(m)$$

Global mean

Adaptive Timbre Effects

- Adaptive Equalizer
  - Uses an adaptive equalization curve
- Adaptive Panning
  - Azimuth angle changes with sound feature (e.g. brightness)
- Adaptive Spectral Panning
  - Pan different frequencies to different angles

Adaptive Spatial Effects

- Sound moves according to chroma
- Make sound move only during attack/transients
- Make sound move only during steady states