Choirs of the Future?

A look at technology, voice(s) & “cyber choirs (of many forms)

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Computer Science (also Music)
also Sonic Mule
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SLEO Workshop
Baton Rouge, LA
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• Fundamental differences between orchestras and choirs, or, more basically, players vs. singers
• Pose and posture, pedagogy, practice, memorization, unions, attire, ...
• Cantabile, other “singing” score markings
• Opera, Recit/Aria, Lieder, Art Songs
• Storytelling: The “Song”, Oratorio, Theater, Emotion
• Audience/Public Expectations
• Gear: Speakers/mics/monitors/etc.

Orchestra(s) of the Future?

PLOrk, SLOrk,
and now many other *Lork(ses)

• History of voices/choirs + technology
• Voice processing (DSP, acoustic)
• Computer analysis of vocal signals (DSP)
• Singer “instrumentation” (measurements, sensors, pose, posture, other physics, & bio signals)
• Voice synthesis, many models (DSP, mechanical)
• Instruments (interfaces) for controlling vocal models (singing machines, computers)
• Voice as controller for “instruments” or other
• Amplification (mic/speaker) issues

Major Topics:

• History of voices/choirs + technology
• Voice processing (DSP, acoustic)
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Pre-History:
Vocal Imitation

• Imitating birds, animal howls, nature
• Language acquisition itself is/was imitative
• Storytelling, song, music (tonal speech)
• Shamanism, healing, magic, control (social)
• Sternomancy, Ventral Fatilouquency, Gastromancy, Voix et l’ombilique, Engrastrimyth, Bauchrednung (Ventriloquism)
• Spirits, divination, séances
• “Spirit Trumpets,” “Spirit Telegraphs,” etc.

Voice: Animal Cries, Magic, Expression, Spiritualism, Coercion
Architecture (delay)
Naturally interesting: Canyons, caves
Regular structures
Design of space:
Theaters
Arenas
Churches
Concert Halls

Primitive Voice TeQ
C cupped Hands
Hollow Logs
Megaphones

Voice as Instrument
• Vocalize (songs without words)
• Humming
• Whistling
• Diddling, Nonsense Vocal Rhythms
• “Reso-Head”
• Clucking, Popping, Other Mouth Sounds
• Ancient and Modern Mouth “interfaces” (seashells, didgeridoo, jaw harp, etc.)

Notated (and Instrumental) Voice
Kodaly

Tabla Bolis

Voice-specific Notations
Instrument-linked
Vocal/Visual/Gestural
Hand-based Notations
Conducting

Clix, other sync.

Spectral Models (perceptual models)

Early “Synth” History:
Speaking Machines

“We represent and imitate all articulate sounds and letters, and the voices and notes of beasts and birds”

Francis Bacon (1561-1626)
from “The New Atlantis,” 1626
Mechanical Voices

- Ancient Speaking Statues
- Other Voices from (pre-formal) History
- Acoustic Tubes
  - Kratzenstein
  - Page
  - Marage
  - von Kempelen
  - Faber
  - Riesz
  - Wheatstone
  - the Bell Family
- Spectral Models (Helmholtz, Koenig)
- Waveform Models (Koenig, Preece and Stroh (Phonautograph too))

Early Speaking Machines

- Kratzenstein's (1779) (vox humana)
- Speaking Tubes
- Abbot Mical's (1783) Speaking Heads
- Von Kempelen's (1791) Speaking Machine

More Speaking Machines (-1937)

- Faber's Euphonia (1840)
- Marage's Vocal Tracts (1900)
- Riesz's Vocal Tract (1937)

Speaking Machines: Into The Electrical Era

- Bell: Helping the deaf communicate,
- Dogs, Cadaver heads, the Telephone,
- Harp Telephone (Harmonic Telegraph)
- Edison
- Helmholtz
- Konig
- Stewart (1922)

Dudley's Voder

- 1939 World's Fair
- Operators (female) manipulate console

Voder: Source/Filter Model

- Noise/Pulse (wrist bar)
- Pitch control (foot pedal)
- Resonances (10 finger sliders)
- Consonant/Stop Presets (thumb buttons)
Dudley’s Voice Coder (VoCoder)

• Subband decomposition of voice signal
• Voiced/unvoiced source detection/modeling

• Immediately CLASSIFIED by US Government

Making Instruments Talk

Making Instruments Talk

• The “Talk Box”
  Sound source excites vocal tract
  Sound source => Hose => Mouth => Mic
• 1976 Frampton Comes Alive, right? Nope...
• 1940 The SonoVox
  Kay Kaiser, others
• Alvino Rey (1939)
• Pete Drake’s “Amazing Steel Guitar” (1964)
• Then Frampton, right? Nope!
• Then, the “VoxWah” pedal (1966, Brad Plunkett, Electronics) demoed by Del Casher

The Cross-Synthesizing Vocoder

• Vocoder, but alternate audio source
• Subbands
• Optional /s/
• Optional fuzz
• Optional Harald Bode

and Wendy Carlos
“Switched On Bach” (1968)
(Clockwork Orange 1971)

Speaking/Singing Machines and Synthesizers (cont.)

• Acoustic Tubes (von Kamele, Kelly-Lochbaum)
• Vocoders/Voders (Dudley, Bode/Carlos)
• Variable Filter-based Models (Klatt, Sundberg)
• Linear Prediction (Atal, Dodge, Lansky)
• Formant Wave Functions (FOFs) (Rohet, Jaffe)
• Sinusoidal Models (McAulay/Quaterri Serra/Smith)
• Frequency Modulation (Chowning)
• Acoustic Tubes (Kelly-Lochbaum, Cook, Carre, Liu, Kim)
• Template-based models (Lomax, George, UPF)
Acoustic Tubes

- Mechanical
- Analog
  - Electronic
- Digital
  - Articulatory
  - Ladder Filter

Bell Labs 1961
(Kelly, Lochbaum & Mathews)

Acoustic Tubes (improved)

- Acoustic Tubes (Cook, Carne, Liu, Kim)
- Nasal Tract
- Throat Radiation
- Lots of Real-Time Control
- Shape/Spectrum Feedback
- Articulation Tracking
- Inertial Articulation Modeling

Great Sheila
Daisy Duet

Source/Filter Models

- Linear Prediction (Atal, Dodge, Lansky)
- Formant Filter Models (Fant, Rabiner, Klatt, Sundberg)

Formant Wave Functions

- Formant Wave Functions (FOFs) (Rodet)

Formants in the time domain

Impossible Animals (Jaffe)
Gesualdo
(Rodet/Bennett)

Linear Predictive Coding (Atal, 1970)

- Waveform: next sample = linear combination of previous samples
- Spectral: best predictor coefficients are least-squares spectral filter
- Perceptual: formant peaks
- Physical: source + ladder filter
- Cross-synthesis
- Music composition (Lansky, Dodge, Moorer, Peterson, others 1980’s)
- Speak&Spell, other TI products
- Coders of all types, LPC10, etc.
- to eventually, VCELP (Cell phones)

Spectral Models

- Helmholtz, Konig
- Haskens Labs PAT (1949)
- Sinusoidal Models (McAulay/Quatieri 1986)
- Sinusoidal Models + Residual (Serra/Smith 1989)
- Sines, Residual + Transients (Verma/Meng 1998)
And.....
We can’t talk about voice, technology, and synthesized singing these days without...

Autotune™!

• Antares Inc. (1997)
  – Detect pitch
  – Pitch-shift to steer toward target pitch
  – Retune speed [0.0,1.0] sets speed at which correct pitch is approached (0.0 = “Cher”)
• Best selling plug in for last couple of years
• Dirty secret: everyone uses it (not set to 0.0)
• T-Pain and others proudly set it to 0.0
• Newest dirty secret: increasingly used live

Autotune Pre-History

• Rotating head pitch/time shifting (1965) (motivates cheap digital pitch shifter)
• Eventide Harmonizer (overlap-add, 1976)
• De-glitched Harmonizer (PSOLA, 1977)
• Smart Harmonizer (real/tonal shift, 1980’s)
  AHA! Factor/Agnello et al invented AutoTune?
• Formant correction: Digitech (Studio) Vocalist

Autotune History

• Cher “Believe” (1998)
• Eiffel 65 “Blue (Da Ba Dee)” (1999)
• Soon, countless others
• Soon, everyone (Chicks, Avril, …)
• Soon, many using it live (Reba, Garth, …)
• T-Pain
• then.... the backlash:
  Jay Z “DOA (Death of Autotune)”
  Grammy Blue Ribbon Campaign
Social Commentary

- "Autotune the News"
  Michael and Andrew Gregory

  Take great (and not so great) speeches, moments in history, stupid news, etc.

  Run them through Autotune

  Add music, effects, make videos, put on YouTube, go viral, get famous.

Yea!

AutoTune for the Masses?

T-Pain + Sonic Mule (Smule) + Antares

= “I Am T-Pain”
AutoTune™ for the iPhone

OK, Enough AutoTune

Let’s talk about how mobile and ubiquitous technologies have been, and can be used for choral purposes

SMule: Social Music

Glee!

- Pitch Correction and Harmonies
- Songs from the Show
- Other (non show) songs
- Share via Facebook, Smule, Email
- Global “Glee Clubs”
- Ad Hoc Groups
- Earn “Gleeks” Comments

People who know each other, but geographically separated, singing together
Strangers making ensembles

- Bicycle Built for Two Thousand (2009)
  (Aaron Koblin and Daniel Massey)
  uses Amazon Mechanical Turk
  - Present a audio token “snip”
  - User records imitation of that
  - Do this to cover the whole
    song multiple times
  - Collect and mix all
  - Animate with “piano-roll”
    style display

Massive (3000 and growing)

- Lux Arumque, Eric Whitacre (2010)
  - YouTube call
  - YouTube submissions
  - Assemble video/audio
  - Make cool “world choir” video

Liberteria, Sabrina Peña Young (2013)

- Virtual Animated Opera
- Casting calls via Facebook, other
- Auditions by submitted recordings
- Click/backing tracks on BandCamp
- Vocal parts submitted by email/upload
- Editing/mixing by distributed team
- Multiple singers per role, for morphing
- Animation by distributed team
- Sound/Score driven facial animation
- Many cast/composer have never met
- Screen in 100+ locations in 2013

Speaking of Animation, and Video...

- Video unrelated to performers
- Performers controlling video
- Video tracking (faces, bodies)
- Display to performers (scores, other)
- Remote (Telematic) performances
Messa di Voce (Levin 2003)

- Camera tracking +
- Voice Analysis +
- Real-time Animation

000000swan

- Kinect tracking
- Sensors, mics, instruments (cello)
- Video display
- Goth/tribal costumes
- Wekinator
- Video(s)

Mouth/Face tracking (body too)

- Very Nervous System
- EyesWeb (VACHorale movie)
- Processing Video Demo
- Jitter
- FaceOSC
- MAGE (vid)
- Mouthesizer

The Mouthesizer (Lyons, ATR, 2001)

“Boom” Camera + Image Processing

Voice-Controlled Synthesis and Processing (2005, UPF)

Voice-controlled Bass and Synth

WahWactor: Voice-controlled WahWah

Controlling vocal synthesis

Mouthesizer

- Very Nervous System
- EyesWeb (VACHorale movie)
- Processing Video Demo
- Jitter
- FaceOSC
- MAGE (vid)
- Mouthesizer
Controlling Vocal Synthesis
• Real time, so possible
• But many, many parameters
• Not a natural “fit”

Uh....
Huh?
60+ parameters!

Few-to-Many Controls (’93)
Tract/Glot, Linear, F1F2, Arbitrary 2D

GloveTalk (Fels and Hinton, 1990+)
• Data gloves and 3D position to control speech synthesizer
• Left Hand “Macros” for Consonants
• Pitch height
• Vowel Space

SqueezeVox (with Colby Leider 2001)
• Voice Control Issues:
  • Pitch
  • Breathing
  • Articulation
  • etc.
  • Fix: Accordiae?

The COWE
Controller, One With Everything
“Bagpipe” with Tilt Sensors, Linear FSR, Buttons, and more

A New One-to-Many Map:
SCurviA (2011)
Singing(Synthesis) Curve for Interpolation of Articulation
“Rainbow” vowels and liquid consonants arranged along a single line
2004: More Voice Control

Voice Oriented Melodica Interface Device
Blowing, Keyboard, Linear FSR, 3xTilt, Joystick, Buttons, Knobs, Sliders, ...

Re-Design: Maggie 2009
Lots o’ buttons, sliders (more buttons)
Bellows pressure AND! Wireless
GUI dashboard and Proxy
And yes, Batteries

Others
Phonodeon (2005) (Anastasia Georgaki)
HandSketch (2009) (Nicolas d’Alessandro)

Sounds in Hands
Talking and Singing Robot (Kagawa University)

GRASSP/DIVA (UBC)
• Gesturally-Realized Audio, Speech and Song Performance
• Digital Ventriloquized Actors
• Extension of GloveTalk Projects

Choir Mob (Astrinaki and d’Alessandro 2011)
• iPhone Singing Synthesis App
• “Intertwine” by Aura Pon, for Choir Mob and Vuzik

Choirs of the Future?
• Players/Dancers/Actors Controlling Digital/Mechanical Vocal Models?
• Robots? Androids? Cyborgs? DIVAs? Toys?
• Computers Singing to Other Computers?
• Vocaloids Judging AutoTuned Humans? (CyberIdol™ on FOX!)
• Hey! How About Augmenting Singers?
(perhaps the optimal vocal controller…)
• draw experience from…
Orchestra(s) of the Future!

Future (past, now) “Cyber” Singers
- Ursula Dudziak 1970’s+
- Laurie Anderson 1980’s+ (video)
- Pamela Z. 1990’s+
- Amy X. Neuburg 1990’s+
- Bjork! (rhymes with PLOrk)
- Many others
  what about choirs??
- Many works for “choir and tape” (70’s)
  Stockhausen, Tavener, Pinkham, Schafer, Kemner, Winsor, Adams, . . .

Choirs of the Future
- Effects added to singer voices
  (controlled by singers)
- Synthesis via controllers
  (controlled by singers dancers, audience?)
- Integrating this + more

Courses: TeQWire: Voice Technology Seminars
Two-Sided Plays (with Laurie Anderson)

Choirs of the Future: TeQ
Singer signals, and sensors to measure:
  – Pose, Posture, Joint Angles
  – Head, Face, Mouth
  – Bio Signals
  – Pitch, Loudness, Timbre, other acoustic
DSP to do:
  – Processing of live singing, canned singing, pre-recorded sounds
  – Feature Extraction and Machine Learning

Bio Signals and Sensors
- Breathing (events, depth, rate)
  (mask, hot-wire, fan, diaphragm, bernoulli, chest band, cond/resistive fabric)
- EGG (Ω between vocal folds, neck band electrodes)
- EMG (electrical muscle signals, skin electrodes)
- EKG (heart EMG, electrodes !CAUTION!! pulse, audio)
- EOG (electrical/magnetic eye direction, coils)
- EEG (brain: α, β, ..., electrodes, coils, squid, IR)
- GSR (skin resistance, electrodes, pennies ©)
- Pulse (heart rate, EKG, electrodes, pulse oximeter)
- Blood gases (O₂, N₂, CO₂, ..., IR, other)

Physical (Pose) Sensors
- Tilt (head, hands, torso, foot/feet, ..., accelerometers, video)
- Absolute spatial positions/orientations (6DOF)
  (body in room, head, hands, feet, etc., RF, polhemus, video, IR, tethers) (DEMO)
- Joint angles (arms, wrists, neck, fingers, hands knees, ankles, torso, cuffs, bendies, gloves, video)
- Facial: orientation(s), mouth/lips, eyebrows, eyes, gaze/focus, video, IR with markers (VAC vide)

Recent solutions for some of these: Kinect! (Phone! DEMO)
DSP Things To Do

- Delay, loops, chorus, flanging, ...
- Pitch shift (correct), harmony
- Spatial processing
- Gender/character (accent?) modification
- Sinusoidal resynthesis (with modification)
- LPC/Vocoder modification/cross-synthesis
- Playback of pre-recorded (contributed) audio
- Gating of audio (captured or pre-recorded)
- Scrubbing of audio (captured or pre-recorded)

Audio Features to Extract
(and things to do with them)

- Time Domain:
  - Loudness (peaks, power)
  - Zero Crossings (Noisiness)
  - LPC coefficients (cepstrum)
- Frequency Domain:
  - Spectral Flux, Centroid, Tilt, Rolloff(s), Sub-band energies, Formants, Harmonicity, Harmonics to Noise Ratio (HNR), Pitch, Multi-pitch
- Classification/MIR/Machine Learning:
  - Vowel/Consonant, Phoneme, Gender, Singer ID, ...
- SMIRK, CLAM, Weka, Wekinator

Microphones/Amplification

- Mic Stand(s)
  - (Freddie, Korn, Emic (NIME), grunge (2mics))
  - How about sensors on/in mic stand?
- Microphone in/on music stand concealed in folder, or in the laptop?
- Sensors in/on music stand, or in folder
- Head(set) microphones
  - Countryman, Shure, Sennheiser, Audio Technica
- Wireless mics, mic/instr. packs, in-ear monitors
- Wireless sensor systems (MIDI(Tron, Spark, Arduino)
- Speakers: House sound? Monitors? Local?
  - Wearable? (remember precedence)

Haptics, Robots, ???

Haptics (display to singers, audience?)
Robots (with singers, as singers)
Exoskeletons, prostheses, ...
Waisvisz (the Hands), BugMudra, Stelarc
Karmetik Machine Orchestra

The Virtual Augmented Chorale (with Ben Knapp, 2005-2009)
Part of the “Integral Music Controller”

Signals/Inputs:
- Physical/Gestural (pressure, tilt, etc.)
- Bio (EMG, EKG, EEG, $O_2$)
  - VACHorale music stand)
- Video: Face, Body
- Emotion (inferred from bio signals listed above)
- Other

SSSS: Singer’s Sensor Speaker Stand

Breathing => Launch phrases
Arm up/down => Ringers
Left grip => scrub mode
Right tilt => rate
Some Recent CyberVoice Pieces I’ve Done

• Credo (solo – trio) (2010)

• I Want (solo) (2012)

• LOrX Aeterna (PLOrk, April 7, 2012)

Conclusions

• Our voices are primal
• Humans perceive the world through (nearly) hard-wired linguistic “lenses”
• Singing is synonymous with “beauty”
• Synthesis methods abound
• Sensors for new controllers abound
• DSP and machine algorithms abound
• Much research remains to put them together
• Figuring out what to do is the hard part
• Magic (aesthetic transcendence?) is possible
• Goal: Make Art!!
• Cantibile (perform in a singing-like manner)

Open Questions, Vexing Problems

• The Curse of Causality
• “Grey Paint”
• “What the hell are they doing?” (a common issue)
• Robustness (or at least less fragility)
• Repeatability, reliability, flexibility
• Persistence (of “instruments”, pieces)
• Feedback!!!

Things I Ain’t Seen (much of) Yet

• Audience involvement
• Masks (Greek, dance/theater, puppets, but little in the way of cool EFX in masks)
• Features and Machine Learning on whole choirs (bio signals, acoustic signals)
• Singer/Choir-specific speakers
• Integrated wireless systems (mic, and sensors, and in-ear monitors)
• Actual dedicated cyber-choral ensembles
• Vocoder choir, sonovox choir, speaking machine choir...
• Theremin-like instruments, ensembles, audience theremin
• Tradition: pedagogy, practice, repertoire, (yea, sure)

Resources

• Gear (sensors, electronics):
  – ElectroTap
  – Infusion Systems
  – Sparkfun, AdaFruit, Parallax, Arduino.cc, AllCorp, Jameco, DigiKey, others.
• Speakers: ElectroTap, Isobel, Bluetooth, ???
• Software:
  – Max/MSP, PD, Processing, SuperCollider, Aura/Nyquist, C* (monkeys), STK, Chuck, Java
• This talk: vocebella.org
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NIME, PLOrk, TeQWire, LAP, Colby Leider, Dan Trueman, Ajay Kapur, Ben Knapp, Curtis Bahn, Ge Wang, Rebecca Fiebrink, and the Princeton CS and Music Graduate Students.

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4 The Visual Voice  Emotion in facial expression, lip reading, visualizations of the vocal organ, and of vocal sound. Spectograms, hand signs, other visual speech tools.
5 The Singing Voice  Singing vs. speech. The basic voice parts. Research and lore about singing. Vibrato, Singers Formant, etc.

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9 The Notated Voice  Speech vs. written language. Musical notation systems, Guidonian hand notation/conducting, Kodaly hand signs.
10 The Broadcast Voice  From smoke signals to drums to wireless telegraph to telephone to radio to television to the interwebs.
11 The Microphonic Voice  Microphone types, technologies, and pickup patterns. The “Perfect Mic?” Microphones for effect. Mic, stand, and cable as instrument and fetish.
12 The Recorded Voice  Sound recording in myth, lore, and pre-history. Music boxes, player pianos, mechanical, electrical, digital recording. The “Record Biz.” Studio is musical instrument.

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15 The Silent Voice  The most powerful “speech.” Vows of silence, spaces and pauses in poetry and music.
16 The Anonymous Voice  Paging (air, bus, pilot), Authority, Anonymity, Radio DJs, Commercial announcing, other voices without faces.
17 The Instrumental Voice  Vocalise (songs without words). Voice as percussion instrument. Vocal-tablature (notation) for Indian, African drumming. Voice interaction with other instruments (brass, other winds). Controlling vocal models in real time, controllers for doing that.
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Cook TeQWire SLEO 2012