Project 1: Musical Variation Engines

Engine A. CantoVario Musical Variation Engine: Variations of Multiple Pitched and Non-pitched MIDI Instruments. During the NSF I-Corps Teams program, 27 aspiring musician-producers were asked, "Do you ever make versions of your songs?" 22/27 make versions of their songs, suggesting an openness to variation. They were also asked to define "version." Responses ranged from "different varieties" and "modification", to the "the soul stays the same, despite changes." CantoVario was designed to make variations of music according to the style of the musical input. The creator of that input can then decide whether to produce variations close to the original or farther away. If desired, the variations can mutate, producing a completely different song, far removed from the original. Finally, CantoVario creates a virtually infinite set of variations, which can be both blessing and curse. Several interviewees spoke of being "overwhelmed" by the sheer number of options offered by music production software. As a result, CantoVario will likely offer two Musical Variation Engine options: 'lite' and 'full.' (cantovario.com provides a short explanatory video on its home page, the first part of which demonstrates a CantoVario-generated variation which alters the pitch and rhythm of a Gershwin Prelude. More variations available on request.)

Evidence: Engine A has been implemented as both a standalone application and a demo web app that is currently available at: http://cantovario.com/summer2019/ for beta testing. A 2017 Olin Summer Innovation and Research Grant funded an Olin student (Justin Kunimune '19) to code this web app (updated Summer 2019), as well as a CantoVario MIDI Standalone App that would incorporate all my algorithms that vary MIDI songs (as specified in my 2016 patents). His work was excellent. The summers were incredibly productive—and fun! CantoVario proposals were also awarded funds for a student programmer in 2015-2016. These summer research grants enabled me to move forward with implementing CantoVario MIDI and audio algorithms 2006-09 and 2014 – 2017.

Engine B. CantoVario Variation Engine: Audio Mashup/Hybridization of Songs. Increasingly today, artists are collaborating on songs, e.g., "Drop it Like it's Hot" (2004) was an early example. CantoVario proposes moving the needle farther on collaboration by offering artists a platform to deliberately commingle their songs or blend an array of different ideas. This technology (disclosed in a 2017 provisional and 2018 utility patent, pending) harnesses chaos theory as a 'behind the scenes' actor to introduce more contrapuntal complexity in today's songs, including the element of surprise. The concept of "expectation and surprise" is a time-honored tradition in classical music where the great composers led an audience forward with expected guide posts, only to turn the tables on their expectation with surprise. A simple, but effective, example is the deceptive cadence: here the audience is set up to expect the authentic cadence, i.e., dominant to tonic chords (V – I), but hears instead the deceptive V – VI cadence. Examples abound in Haydn piano sonatas. Significantly, as a result of interviewing listeners as part of the NSF I-Corps program, I found that they value musical surprise over predictability. One telling piece of evidence is their preference for shuffle mode when listening to personal playlists.

Professional musician-producers lamented during interviews that streaming services are reducing listeners' attention spans, while acknowledging that the services have the clout to do so. The streaming revenue model encourages single song listening, not album listening. The emotional hook (the part of the song people remember best) or the chorus (the repeated section that captures the song's message) are now coming earlier. Thus in order

to capture and sustain a listener's attention, artists feel the need to address the musical point more quickly.[13] "It's survival-of-the-fittest: Songs that manage to grab and sustain listeners' attention get played and others get skipped. There's always another song. If people can skip so easily and at no cost, you have to do something to grab their attention."[14]

CantoVario is meeting this challenge with technology that helps artists collaborate and produce songs that offer something unexpected: musical variation that invites attentive listening.

Evidence: An example mashup variation ("Evacuate the Dance Floor" by Cascada mashed with "Set Fire to the Rain" by Adele) can be heard at http://test.cantovario.com/listen?mu_id=59070a37155185139b24a0a5.
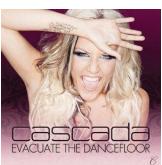

Figure 18. Album art for "Evacuate the Dance Floor", "Set Fire to the Rain", and the CantoVario mashup.

More demo mashup variations, in fact 160 of them, are at www.cantovario.com

Project 2: *Music via Chaos Theory* Exhibit for a science museum. CantoVario not only seeks to create positive change in the music industry through its engineering technology, it also seeks to scientifically motivate kids, teens, and their families through an exhibit that unites music and engineering. A quick 1-minute video description can be found at https://www.youtube.com/watch?v=kU5Mx9mY02Y CantoVario Science Museum Demo

Additional evidence for the viability of a chaos/music science museum exhibit came from a CantoVario keynote given for the 2018 Academy of Applied Science Northeast Regional Young Inventors' Program Convention. The Academy of Applied Science's Young Inventors' Program (YIP) is a K-12 project-based learning program that provides hands-on STEAM (Science, Technology, Engineering, Arts, Math) educational enrichment opportunities to budding youth inventors. The Young Inventors' Program delivers YIP Kits, i.e., invention kits for classrooms, to help schools introduce a fun invention curriculum to their students in the form of a teachable unit, or via a club or afterschool program, that culminates in a school Invention Convention event.

I presented an interactive demo for 700 attendees (K-12 students, teachers, and families) at Southern New Hampshire University in March 2018. The interactive CantoVario Mashup demo received 416 plays in 10-minutes; 304 of the plays were rated 4 or 5 stars out of 5. According to Google Analytics, there were 204 users. These

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[13] Hubert Léveillé Gauvin, Doctoral Dissertation, The Ohio State University, 2018: On popular music and media: Analyzing changes in compositional practices and music listening choice behavior using attention economy principles. Dissertation Committee: David Huron, Advisor Eugenia Costa-Giomi Robert Bond.

[14] [Ohio State News: Misti Crane]. (Apr 4, 2017). "Has music streaming killed the instrumental intro?" [Text File]. Retrieved from https://phys.org/news/2017-04-music-streaming-instrumental-intro.htm . June 30, 2019.

results gave us significant data from a large sample size in which none of the participants had prior exposure to CantoVario, thus providing additional support for a CantoVario chaos/music science museum exhibit.

The Museum of Science and Industry (MSI) in Chicago would like to work with CantoVario and Brown Innovations (CantoVario's industry partner) by providing guidance and feedback to inform the project. The Director of Science Exhibitions and Partnerships at MSI wrote that the chaos/music museum prototype "aligns well with our mission (to inspire the inventive genius in everyone) since the core technologies behind the project are current inventions that could inspire others." Her conclusion: "we enthusiastically support development of the Music/Chaos Exhibit Prototype and would like to see it grow into an exhibit at MSI, space permitting, as well as contribute to its export to other museums of science." MSI is the largest science center in the Western Hemisphere.

Since the exhibit has an audible component, sound-focusing technology is necessary to direct the audio to different listeners, so that each listener has a set of controls to make their own song variations. To ensure focused audio, CantoVario plans to work with Brown Innovations, whose founder, president, and chief engineer is Kevin Brown. Brown Innovations has provided revolutionary sound focusing technologies since 1993, ranging from museum displays at the Rock and Roll Hall of Fame to audio installations at Sao Paolo's Art Biennial; from outdoor information kiosks in Helsinki to quiet library and gallery settings.

Project 3: A Concert of "Variations and Shadows." As an outgrowth of the musical variations project, a Variation Concert prototype presents a new kind of live performance: seat location determines which variation path the audience hears through a given piece. During the past year, performances occurred at two different venues. The first occurred in July 2018 as a beta test. In November 2018, we presented a variation concert at Houghton Chapel as part of the Wellesley College Concert Series for a large audience.

Evidence: The Variation Concert piece produced for the Wellesley College Concert Series (*Parallel Lives—Distant Mirrors*) can be experienced in the final movement of https://www.youtube.com/watch?v=xSqE22X4I8U .

Parallel Lives—Distant Mirrors explores parallel universes in Iraq and the United States over a period of five movements: Ignition, The Last Minutes of Baghdad TV, An Iraqi Mother's Lament, Quranic Verses 16:111-114, and Catharsis. The culminating movement (Catharsis) includes a soundtrack composed of Associated Press recordings from the 2003 bombardment of Iraq, the last minutes of Iraqi TV, and recorded American and Iraqi voices, among others. Movements 2, 3, and 4, each focus on one of the Arabic voice recordings heard in the soundtrack, but in translation.

Scored for solo piano + soundtrack, Catharsis offers the audience a new listening experience, a "Variation Concert" where **seat location determines which variation path one hears through the soundtrack.** Everyone hears the live piano, but the Left side of the audience hears one path through the soundtrack, while the Right side hears a different path. Midway through the piece, the paths switch: much of the material heard by the Left side during the first half of the piece is now heard by the Right side, and vice versa. A sung Introduction opens the movement, followed by a 3-part structure comprising Mashup, Macchina (Machine), and Tristezza (Sadness) that repeats but with variations. The Introduction and Coda are each heard by the entire audience. The soundtrack comprises the following audio material:

Soundtrack for the **Left Side** of the Audience	Soundtrack for the **Right Side** of the Audience
Introduction: Verses 16:111-114 of the Quran sung by Ahmed Burhan Mohamed	
1. **Mashup**: Day 3, the Bombardment of Iraq, recorded by an Associated Press reporter, 2003	1. **Mashup**: The last minutes of Baghdad TV before its transmitter was destroyed, 2003
2. **Macchina**: A soldiers' footsteps	2. **Macchina**: Apache helicopter starting up
3. **Tristezza**: An American mother remembering her son, who became a soldier	3. **Tristezza**: An Iraqi mother remembering her son, a translator for the American Army
4. **Mashup'**: The last minutes of Baghdad TV before its transmitter was destroyed, 2003	4. **Mashup'**: Day 3, the Bombardment of Iraq, recorded by an Associated Press reporter, 2003
5. **Macchina'**: A military robot	5. **Macchina'**: A soldier's footsteps
6. **Tristezza'**: An Iraqi mother remembering her son, a translator for the American Army	6. **Tristezza'**: An American mother remembering her son, who became a soldier
Coda: A duet of thrushes, songbirds common to both the Middle East and the Americas	

I've talked about a "variation concert" since the 1994 inception of my musical variations project, both in public lectures and informal conversations. A fellow MIT alum, Kevin Brown, built a company (Brown Innovations) around sound-focusing technology. Over the years, we discussed producing a variation concert. *Parallel Lives— Distant Mirrors* was the first one.