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Tesseract

Dissertation Completion Fellowship

Statement of Purpose

Foreword:

TESSERACT Continuum, my dissertation piece and research project at the University of Chicago, will be an album-length work for saxophone quartet and fixed media electronics, which I will create in collaboration with the Chicago-based quartet; ~Nois saxophone quartet. In sum, TESSERACT is an attempt to sonically portray the idea of a hypercube, which is a visual representation of what physicists understand to be the fourth dimensional plane. Our three dimensional perspective renders the hypercube essentially inaccessible to us, allowing it to exist only in the realm of possibility. University of Chicago alumnus Carl Sagan popularized the concept on his television show *Cosmos: A Personal Voyage*. His famous dialog about the fourth dimension was sampled and added to the electronics of TESSERACT *Continuum.* The subtitle *Continuum* emerges from the idea of sonically, or rather, physically drawing the imaginary lines of such a cube, leaving the interior untouched. Since the work is designed to actuate inner ear perception, causing a series of psychoacoustic phenomena that will be described below, what happens inside of the TESSERACT will be discovered by whomever ventures into it during the performance/installation.

TESSERACT is an attempt to alter a physical space into an aural space, revealing a sonic reality that may emerge physically or metaphysically. Here, *space* and *silence* have equal weight, allowing physical performance space to become active, and most importantly, malleable. The concept of building such an auditory space is by no means novel, and can be found in the musical traditions of Japanese gagaku and Indonesian gamelan, for example.

The form of the piece, in its current state, is rather direct: to sonically convey the visuals of a square where all sonic material is organized into four imaginary lines. These lines are drawn over time and in the span of four octaves. These octave lines will have their sound projection modified and integrated by the supporting electronic tape music, bringing a meta-quality to acoustically sourced sounds. Later sections of this work will explore other electronic music techniques further in depth, using emerging techniques in signal analysis and decomposition, in order to most faithfully explore theories of sound listed below in this statement.

The electronics you hear in the supporting recording attached with this application were all made at CHIME Studio, located at the University of Chicago Music Department, using the modular analog synthesizer as its primary sound source. My goal with this research is to delve deeply into electronic composition techniques and their numerous forms of interaction with acoustic composition. The current excerpt that I have provided is a 10 minute portion of the larger composition, which will be completed by May 2022.

Auditory Scene Analysis (ASA)

This dissertation project is heavily based on Auditory Scene Analysis (ASA), a term coined by psychologist Alban Bregman. He started with his research into psychoacoustics and perception in the 1960's while at Yale University and his book on ASA was published[1] in 1990 by MIT Press. Auditory Scene Analysis is, very broadly speaking, the study of the perceptual organization of sound, organizing listening into two categories: Analytic and Synthetic.

During the early stages of my research and while analysing how the organization of listening phenomena worked in TESSERACT, I arrived at the following conclusion:

In the **analytic listening** mode one can identify the harmonic spectrum of a pitch. When a single pitch rings, other sympathetic pitches are activated to create the harmonic spectrum. These sympathetic pitches are all proportional to the fundamental frequency of the single pitch. For example: if one of the tones is 1046.50 Hz one's ears can analyze it as the thirty-second partial of 16.35 Hz (C_0). By applying special techniques to the saxophone, or an oscillator to a pure sine tone, the same C_6 is now slightly flattened and could also be associated as a flat seventh partial (in this case the 18th partial) of a hypothetical 18.35 Hz (D_0).

What if the two C_6's are ringing at the same time? What if the result is a "false impression" of a lower frequency emerging from the 2 Hz difference between the two hypothetical fundamentals? What if I then modulate this new pitch by adding noise to its source? With these questions I enter into the holistic characteristics of a tone, which, according to Bregman, is defined as **synthetic listening**.

With this brief introduction to the basic concepts of ASA, I can state that the ultimate goal I have with TESSERACT is a ludic stimulation of the human auditory input, studying and experimenting with the acoustic differences (and the sonic phenomena involved) between two or more auditory messages happening at the same moment. Another concept within ASA is the process in which auditory attention happens, where Bregman divides attention into two categories: voluntary and involuntary.

I have translated these concepts into the following table of compositional ideas:

Voluntary Auditory Attention	Involuntary Auditory Attention
- Pitch	- Beating (Critical Bandwidth)
- Tessiture	- "Busy-ness"of sonic texture
- Volume (Dynamics)	- Psychoacoustics
- Timbral Modulation	- Auditory Masking
- Attention vs. Time	- Attention vs. Time
- Filtering	- Continuity Illusion

According to Bregman, our auditory attention is inversely related to time, thus meaning that the more a sound is iterated or sustained, the less attention our auditory perception will reserve for that stimulus. This simple concept can be

[1] Bregman, Albert S. 2006. *Auditory scene analysis: the perceptual organization of sound.* Cambridge, Mass: MIT Press.

used in interesting ways, such as juxtaposing several layers of sonic material over different scopes of lengths. This creates a structure of "auditory attention dynamics," in the same way that our ears are immediately drawn to louder volumes rather than softer ones.

This idea opens a path to several interesting psychoacoustic properties that can be applied to music, such as the concept of continuity illusion and auditory masking, which are concepts that can be found in the sample of the piece provided in this application.

Continuity illusion is generated when there is the impression that a sound is continuously produced by the same sound source, even though it is actually being produced by a different source. A way to achieve this effect is by applying a transient (attack) and/or a white noise source to the primary source while shifting the “continued” sound to the secondary one, misleading the ear apparatus and thus providing a fake impression of limitless continuity. This idea has much to do with the physical direction of the primary source in the space it inhabits, which can also provoke interesting reactions in the listener's ears.

In this recorded sample of TESSERACT, I conveyed this effect via the juxtaposition of artificial sine tones to the ones produced by the saxophones. When the saxophones fade out, the sine tones continue, coming from a different point in space. This phenomenon, though present on the recording, is better perceived during a live performance of the piece, since listening with headphones collapses and flattens the sonic space.

Before diving into auditory masking I must briefly cover the concept of **Critical Bandwidth**[2] (**C.B.**), coined by American physicist Harvey Fietcher in 1933, also an alumnus of the University of Chicago.

In broader terms, C.B. is the difference in frequency between two sine tones, in which the sensation of roughness disappears and the tones sound "smooth". This "sweet spot" is called the critical band. The byproduct two tones existing within the critical band is **Beating**. The psychoacoustic phenomenon of "roughness", "smoothness"or "beating" happens in the inner ear of the subject, stimulating the basilar membrane.

The basilar membrane, which is located within the cochlea, is thinner and stiffer in its outside edge (closer to the sound source) and it processes higher frequencies. The inner regions of the membrane, the "apex", is more elastic and is activated by lower frequencies. **Beating** happens when the basilar membrane cannot resolve the difference between two inputs. The ability of the ear to process and hear two distinct frequencies is known as frequency selectivity, thus the critical band happens exactly when the brain understands two frequencies as one, where the second tone will interfere with the perception of the first tone. This is what Bregman calls auditory masking.

Auditory Masking occurs right at the boundary of frequency selectivity and in the axis of time, since the original signal needs to exist first in order to "be masked" by a second. This all happens in the auditory filters located within the inner ear. The masking signal (second frequency) should always be louder than the original signal (first frequency). Masking will occur more successfully between two signals of the same frequency. In TESSERACT that first frequency of 1046.50 Hz will be masked by the second one which is slightly flattened, if the second one is higher in volume. Masking here happens because the sine tones are processed in the same region of the basilar membrane.

With this statement of purpose and score (dissertation chapter), the committee is also receiving a ten-minute audio recording of the piece. With that in mind, and to illustrate what was displayed above, I prepared a short selection of five moments in the piece, which are also marked in the score respectively. Apart from its instructional purpose, this selection also allows me to pinpoint where there is compositional potential in the piece to explore the given sonorities for a much more extended period of time.

Tesseract *Continuum*

MARK I 00'20''- Auditory Masking: Continuity Illusion

MARK II 02'30''- Beating

MARK III 04'00''- Timber modulation/transformation: Filtering

MARK V 07'00''/10'00''- Pulsation: Temporal Patterns

MARK V 09'00''- Multiphonics: Spectral Similarity

Electronics:

Synthesizer

The electronics for the recorded sample were created on the modular analog synthesizer, where I produced sine tones of the exact frequency as the tones provided by the sound samples I collected from the saxophone quartet previously. For the piece, I used alternate fingerings for all of the tones, which have a very particular microtonal[3] nature to them. These alternate fingerings, together with the micro inflexions they may or not produce, are all provided in the score:

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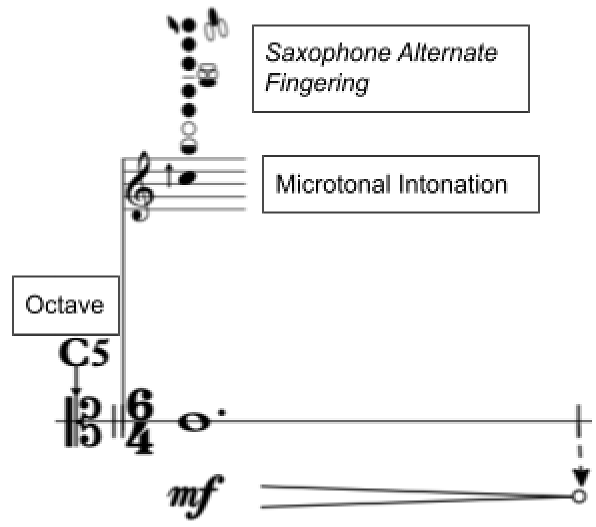
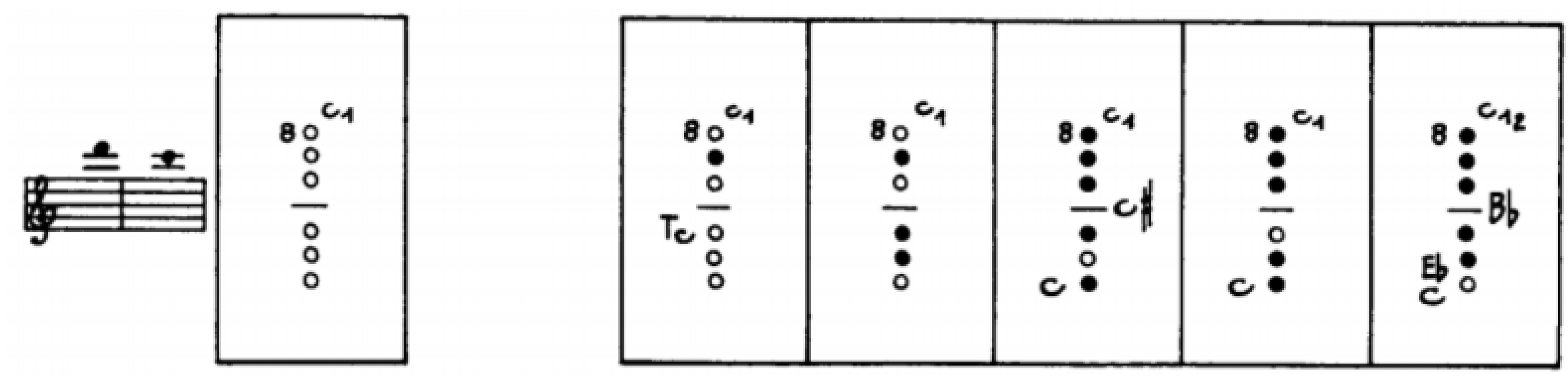
[2] Lin, Jian-Yu. 1996. *Psychoacoustical theory and experiments on human auditory organization of complex sounds and the critical bandwidth*. http://catalog.hathitrust.org/api/volumes/oclc/36451769.html.

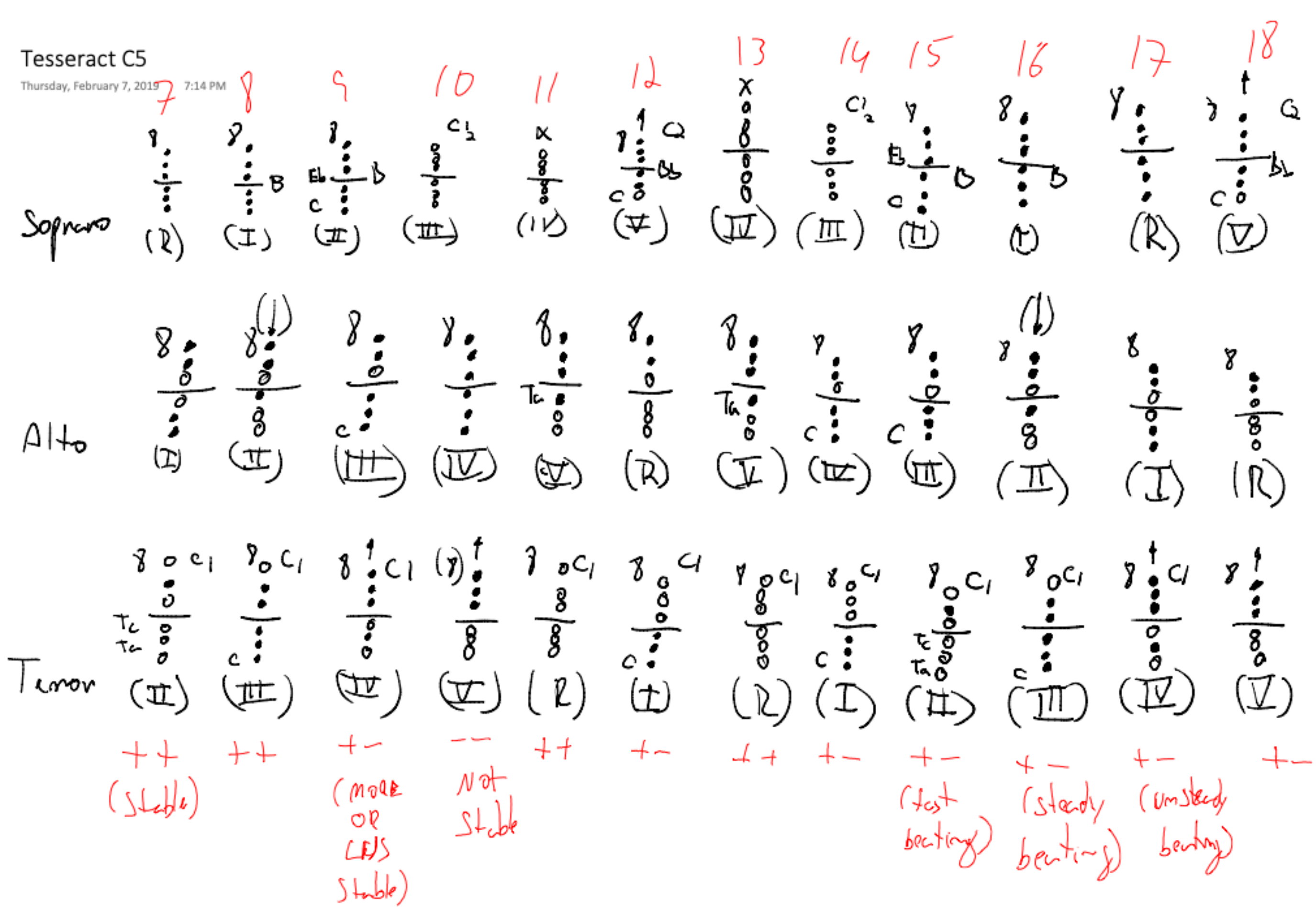
[3] Lesser or larger of a tone in comparison to the equal temperament from the piano keys.



All the fingerings were obtained from Marcus Weiss's book[4] "The Techniques Of Saxophone Playing/Die Spieltechnik Des Saxophons". This is an example of the material extracted from this book:

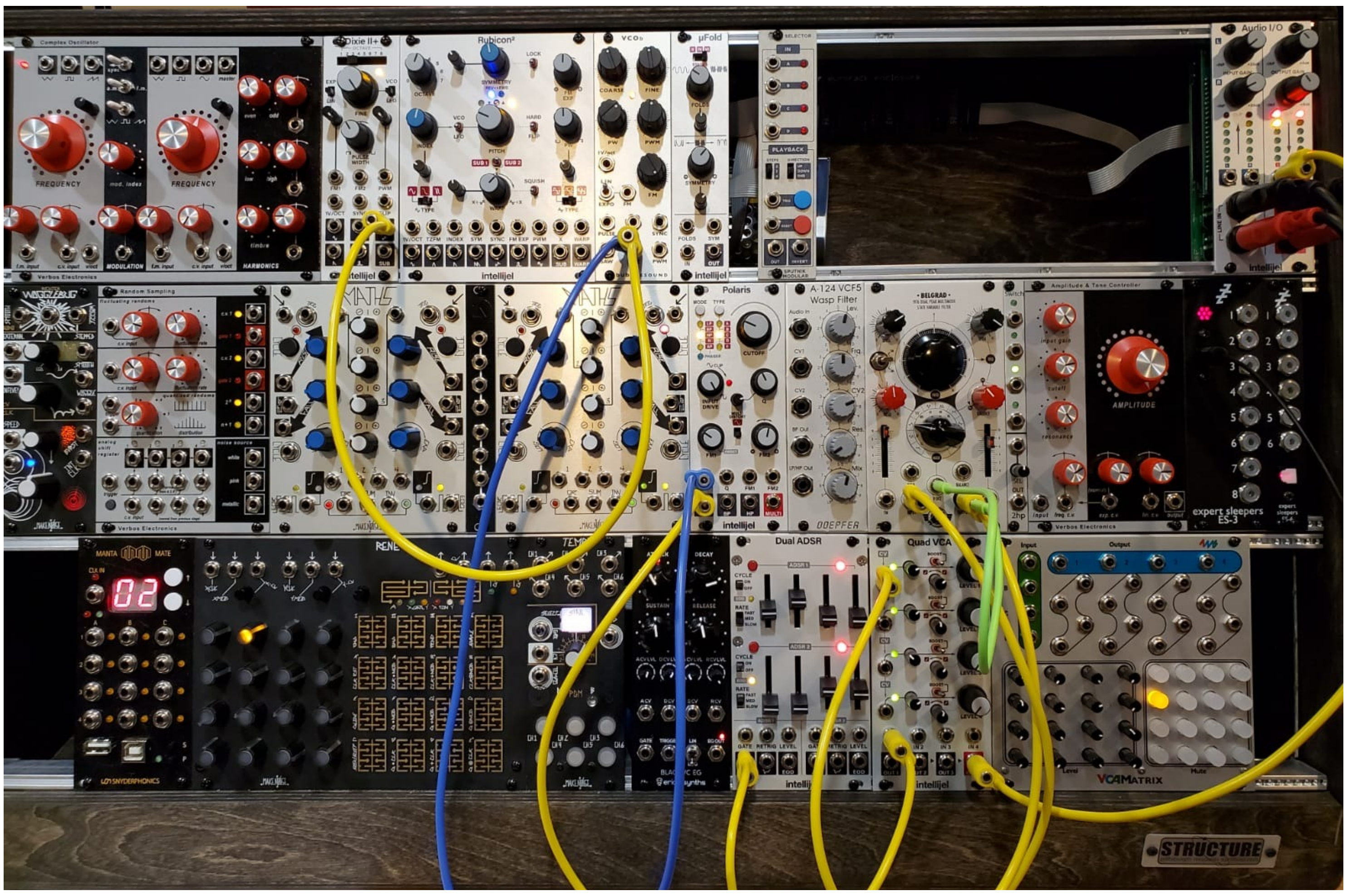


I have also created a system for the cataloging of the newly created fingering charts:



After producing all of the sine tones (C_3 to C_6) on the synthesizer, I apply a series of filters, oscillators and envelope-shapers to create patches and alter these newly collected sounds, aiming to produce all the above discussed sonic phenomena. The photo below shows one of the patches I built during the process at the analog synthesizer in CHIME Studio:

[4] Weiss, Marcus, Giorgio Netti, Marcus Weiss, and Marcus Weiss. 2015. *The techniques of saxophone playing = Die Spieltechnik des Saxophons.*



I have also produced a catalog of qualities for each of the tones from the saxophone, using ASA's synthetic listening concept, looking for the holistic properties of these tones. These are some of my notes taken during the process:

The blue, yellow and red highlights catalog the tones from most to least stable, respectively.

C6

C6 -1: S.U. (fast microtonal beating), overtony
C6- 2: S.U., similar to C6-1 but somewhat darker in timbre
C6-3: U.U., overtony
C6-4: S.U, beautiful extremely fast and controlled beating, less overtony
C6-5: E.U., with a 4th (F) that rings above and a **beautiful** subtone.
C6- 6: U.U, with a (fast beating) that comes and goes.
C6-7: S.U., with an extreme fast beating
C6-8: U.U., nice color
C6-9: U.U., with a strange mid tone

C5

(around C5-1 there is a ring tone at around C4. reproduce that in the electronics)

C5-1: S.U., not stable beating
C5-2: U.U., more stable, gentle beating
C5-3: U.U., almost no beating, a very wide beating
C5-4: E.U., very fast beating
C5-5: U.U., wide steady beating
C5-6: S.U., steady moderate beating (generates C#)
C5-7: U.U., controlled gentle beating
C5-8: S.U., interesting ritard. beating
C5-9: E.U., crazy beatings in different velocities
C5-10: E.U, fast beating, overtones pop up (it could create a bridge to C4)
C5-11: U.U., stable

C4

C4-1: U.U., light beating
C4-2: S.U., fast beating
C4-3: U.U., very stable
C4-4: E.U., beatings that start controlled but behave wild sometime later
C4-5: E.U., beatings that start controlled but behave wild sometime later
C4-6: S.U., nice controlled beating
C4-7: S.U., sweet rhythmic beating
C4-8: S.U., sweet rhythmic beating, somewhat more stable than C4-7

C4-14: E.U., this one is BEAUTIFUL, there is a half-step that emerges (flat C#). The (alt) there is a beating happening.
C4-15: S.U., sweet rhythmic beating (slow)
C4-16: S.U., sweet rhythmic beating (slow), the most unstable of all.

C3

C3-1: U.U., very stable, almost no beating, just color
C3-2: S.U., a subtle, regular beating
C3-3: E.U., beating fast, a overtone multiphonic quality
C3-4: E.U., rhythmic beating, very dark
C3-5: U.U., similar to C3-1
C3-6: U.U., similar, a little bit more overtony

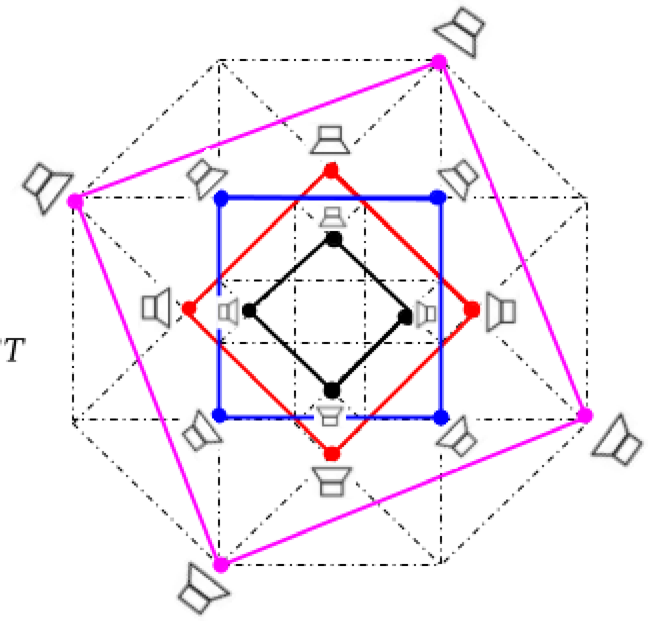
Multiple (4-D) Quadraphonic Systems

The spatialization of the sound is perhaps the most important element in TESSERACT, which I imagine being realized in two ways: a live performance with the quartet being part of the spatialization component (orthogonal projection diagram) and also as a sound installation where the pre-recorded saxophone tracks would be played through an extra set of speakers.

In both ways the quartet is perceived as a set of four equidistant sound sources in space (a sonic square), and together with three more sets of squares formed by additional speakers, I can achieve a set of four quadraphonic systems, not equidistant with one another, being only equidistant among its related pairs, thus portraying in the clearest way possible, a sonic image of a hypercube.

Through an orthogonal projection[5] seen from above, a **quadraphonic system diagram** is generated. The hypothetical hypercube, which exists in a plane superior to ours (represented by P), generates a series of vertices in which the sum of them becomes a bidimensional projection of its source (P'), where P' consists of all the vertices I chose (represented by dots.) These vertices are, in practical terms, where the sound sources will be placed in space (speakers and/or saxophones). The image below represents how I picture such arrangement:

Orthogonal projection of a hypercube set as a speaker arrangement for *TESSERACT - Continuum*



Although I am also working on more feasible solutions to an actual performance of the piece, the ideal place for this setup of speakers would be one that provides a suspended floor, where some of the subwoofers and speakers could sit beneath. With this, a real three dimensional arrangement of sonic sources could be achieved. Such spaces do exist in North America and Europe. I have visited one of these spaces, the semi-anechoic chamber at CCRMA Stanford (Stanford University).

In the diagram, the **black square** is where the saxophone quartet musicians would stand, while the **blue square** is where the speakers that are amplifying the saxophones are placed. These speakers would ideally be set in an array above and below the ground level and pointed at a 45˚angle towards the ground floor, promoting a further and more complex spatialization where auditory masking happens more effectively. The same principle is applied to the electronics track. The **red square** is the set of speakers that will play the electronic track, while the **pink square** is where the subwoofers will be placed. The subwoofers will be suspended from the ground level (to avoid the "coupling effect"-- an unwanted increase in volume) and set below the surface level (within the hollow created by the suspended floor). Since low frequencies travel through the air in a spherical shape, there is no need to point the subwoofers toward a specific point in space. In the case of a sound installation, the saxophones would be replaced by a set of smaller (up to 5") speakers.

Since multiple "sonic hot-spots" can be found within the hypercube, the audience should experience this sitting still in one place for a certain amount of time and then venturing to other points within the complex set of speakers.
Currently in my research on sound spatialization I am studying more in depth the dissertation on **Vector Base Amplitude Panning** (**VBAP**)[6], by Finnish audio researcher Ville T. Pulkki, professor of Aalto University (2015-.) According to his website VBAP "is a method for positioning virtual sources to arbitrary directions using a setup of multiple loudspeakers. In VBAP the number of loudspeakers can be arbitrary, and they can be positioned in an arbitrary 2-D or 3-D setups. VBAP produces virtual sources that are as sharp as is possible with current loudspeaker configuration and amplitude panning methods, since it uses at one time the minimum number of loudspeakers needed, one, two, or three."

Conclusion:

I am working with Sam Pluta, my dissertation advisor, on the multichannel and spatialized systems research as well the other acoustic and electronic music concepts presented in this writing. This fellowship would be extremely important for me in completing this dissertation project. It would grant me the resources and time necessary to accomplish the ongoing research at CHIME Studio and to fully explore my collaboration with the Chicago-based ~Nois saxophone quartet.

This work, when completed, will not just musically expand the horizons of what a saxophone quartet can do in terms of instrumentality, but it will also serve as part of a much larger structure. With this piece I hope to bring creative and innovative solutions to the questions, concepts, and possibilities posed in this proposal, combining theories and concepts from scientific research not usually associated with musical creation. Above all things, my intentions with TESSERACT *Continuum* is to promote an immersive, sensorial, and extremely ludic experience to the interactive audience. The listener will be a living part of the performance experience, shortening the barrier between where the sound is produced and where it is perceived, thus enabling a mode of active listening, where the listener becomes an important element of the work.

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[5] The orthogonal projection can be represented by the equation $(p,v) \rightarrow (p - \langle v,p \rangle)$. In this context, one can interpret the left portion of the equation as the hypothetical hypercube, where the right portion is its bidimensional representation.

[6] Pulkki, Ville & Lokki, Tapio. (2021). Creating auditory displays to multiple loudspeakers using VBAP: A case study with DIVA project.