Instrumental Geography: Illuminating Relationships through a Spatial Interface

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Abstract. This paper presents a three-dimensional mapping of the double bass in-progress. The project is designed to illuminate spatial and intervallic relationships between different pitch planes or “layers” of the instrument, in order to facilitate composition and improvisation within a composite pitch system. After contextualizing the work within the instrumental field, early versions of the mapping will be shown and discussed, as well as some of the coding structures used to render digital visualizations.

Keywords: double bass, visualization, harmonics, geography, choreography

The MAP is the interface

The fingerboard of the bass spans 480 square cm of blank playing surface – for reference, that’s almost twice the area of the cello’s, four times that of a violin, and just 10 cm shy of the length of a piano keyboard. With no frets or inlays, and few physical anchor points for the hand, it’s almost entirely lacking in visual or tactile landmarks. Nor is it standardized, with wildly different spacings from instrument to instrument. Floating in its self-contained universe to the player’s left, stretching from below the hips to above one’s head, this unwieldy instrument is a wilderness that takes decades to tame. Even the most fundamental musical functions rely upon a precise, comprehensive internal map.

This map – the bassist’s indispensible interface – manifests in two ways. First formed in the mind’s eye, it structures the fingerboard’s blank space into visual collections of points and relationships – a *geography*. Then, translated into the body, the visualized map guides the design of intricate *choreography*, training the left hand, arm, and whole body to reflexively recall and perform exact spaces. Mind and body dance through anchors, intersections, angles, points, developing settings, spacings, territories, patterns and pathways and, with time and practice, creating a kinaesthetic version of the map.

The map is assembled from one basic unit: a set of coordinates, or a *node*. Defined as “a point in a network or diagram at which lines or pathways intersect or branch”, in instrument-specific lingo a node marks a point on the string, where one presses or touches to sound a musical note.

When I envision the fingerboard, I see collections of nodes arranged in space, forming shapes and patterns that guide the shape and movement of the left hand. It resembles a constellation – not the flat diagrams of astronomy books, but more as if one could step inside the constellation, to realize the full dimensionality of points and relationships in living space. I perceive three dimensions because, in addition to the intuitively understood dimensions of length (length of string) and width (repetition of strings side-by-side), there is a dimension of height, or elevation, from the fingerboard created by two[1] contrasting “planes” or “levels” of playability on each string. The stopped note (fully depressing the string against the fingerboard) is the lower level. Natural harmonics (sounded by lightly touching, but not depressing, the string to activate its vibration in equal divisions) are the upper level. Both contain nodes spread ubiquitously throughout the full length of each string, and the shapes and connections created between them now have depth and perspective.

[1] One could make the case for up to 6 pitch systems, “classes” or “layers”, such as false harmonics, subharmonics, composite

The distinction between these planes is something the player feels and experiences, rather than something that can be visually observed from the outside. In the absence of visually structured information, it is easy for a bassist – myself included – to rely upon previous tactile familiarity with nodal locations and to fall back on these old routes in improvisation and performance. My desire to visually model these concurrent pitch planes is driven by the same needs behind any other "map" or position chart – to objectively examine, experiment with, and internalize what notes are there and how they relate to each other, and to design choreographies and practice strategies to perform them.

The aesthetic vision behind this mapping is to more thoroughly highlight the polyphonic, chordal possibilities of the bowed double bass, and to venture beyond diatonic use of these two pitch systems together by illuminating the full extent of their intervallic relationships.

This paper presents an in-process version of the mapping, beginning with half-scale technical drawings, followed by digital renderings built with VPython coding language. In its current state, this mapping is intended as a reference and internalization tool, an interface between my personal musical language and the full capabilities of the bass. I hope to ultimately create a more interactive version, and to compose new pieces for bowed bass and voice using the new relationships it reveals.

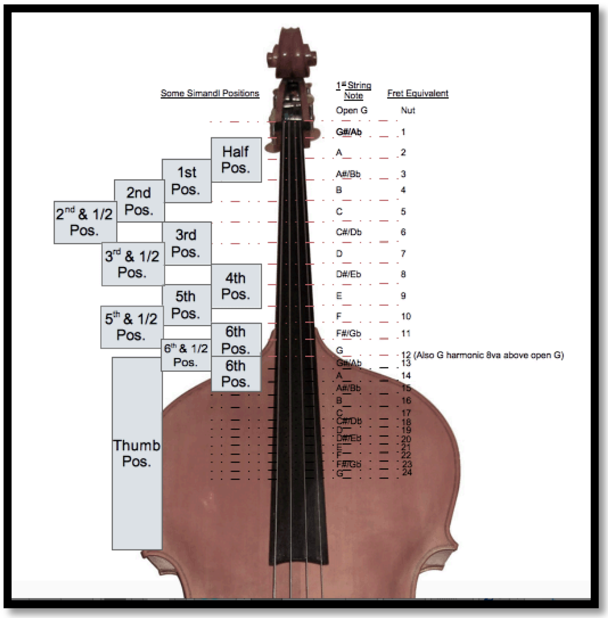
Future versions will also integrate data sets (pitch, partial #, hz, handsetting) in preparation for applications that I have only begun to imagine. Could it be used as a graphic mediator or interface between the acoustic presence of the bass and its amplified/electronic equivalent? Could this have implications in live processing, or help to design customized EQ for these complex resonances? How, and under what circumstances, could it impact mine or other's compositional approach to this instrument? Could there be automated compositional applications of this interface?

This project is intended as a practical tool, rather than objective research or scholarship on acoustic properties. It acts as a foundational project-within-a-project, and will help to structure several years of my work at NTNU. I invite dialogue around the research process and creative possibilities during this performance.

Some background: tradition, purpose and limitations in a collective interface

With such large spaces to traverse and much room for error, it's no wonder that so much pedagogical emphasis is placed on *how* one visualizes, maps and choreographs the fingerboard of the bass. Questions of "how" are answered by "for what purpose" – in what genre or style are we working, with which aesthetic priorities? Bass may support music as divergent as bluegrass and baroque, Stravinsky and Count Basie, free jazz, rockabilly or the romantic symphony orchestra. In recent decades, it has also begun to shine as a solo instrument. Composers have broadened and enriched the repertoire. Trailblazing improvisers have vastly expanded the instrument's timbral and harmonic palette. Due to advancements in technique and a rapidly globalizing pedagogical network, the collective level of playing keeps rising, expanding notions of what the bass can do. These many variable roles have called for variable geographies and choreographies, each deeply correlated to the purpose at hand.

At the time of writing, two main methods are most widely taught. From 1881, Franz Simandl's approach is still used to develop orchestral technique, demarcating twelve distinct positions in the first octave of the string for precision and strength in low registers. Alternately, François Rabbath's streamlined, soloistic fingerboard organization marks fewer, larger positions for more rapid vertical movement along the entire length of the string, with left-hand choreography designed to preserve resonance and a "singing" continuity for the bow. First published in 1977, Rabbath's positions were likely the first to be intentionally constructed around locations of natural harmonic nodes on the string (their sounding pitches are shown on the right in Fig. 2).



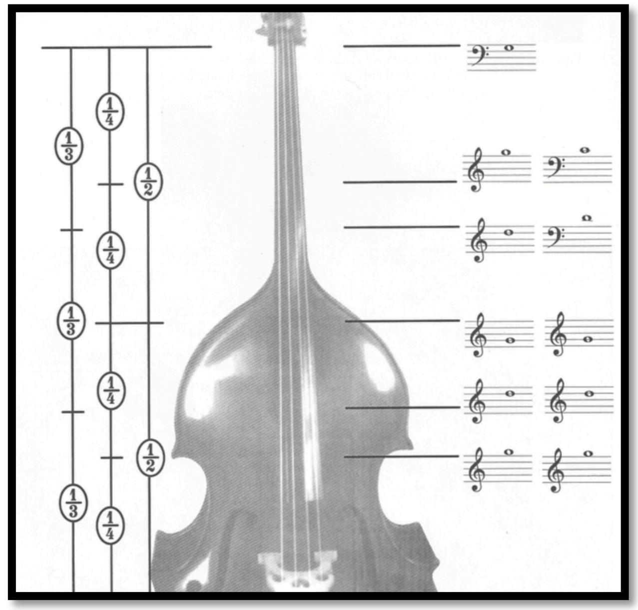


Figure 1. a Simandl position chart (Christopher-j.net)

Figure 2. Rabbath position chart (Vance, page 5)

Modernizing musical languages and pedagogical practices continue to synthesize and augment these two fundamental mappings, with increasing reference to the natural harmonic series. For example, David Allen Moore's system of *Fractal Fingering* (2019) condenses mappings of Simandl and Rabbath, presenting detailed codes of movement within a hierarchy of hand positions. Accessing principles of fractal geometry, Moore divides the string into 6 equal parts (or harmonic "partials") demonstrating that, repeated, the same physical distance will contain stopped-note intervals of a m3rd, M3rd, P4, P5, and P8, respectively (see Fig.3 for a rough sketch of this phenomenon). *Fractal Fingering* methodically decodes some of the advanced, idiosyncratic left-hand techniques of bass virtuoso Edgar Meyer, and builds processes to replicate them – an interface geared toward precision and virtuosity in soloistic, stopped-note playing.

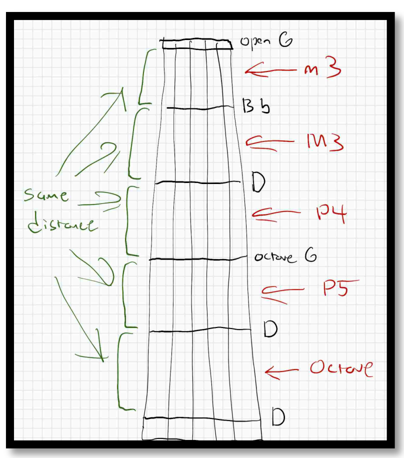


Figure 3. Diagram of the principle behind *Fractal Fingering* (provided by Jason Heath, doublebassblog.org)

Another video-documented mapping, Mark Dresser's *Guts* (2010), applies similar harmonic principles to very different effect. Dresser breaks open the Pandora's box of harmonic techniques, sounds, and systems on the bass and demystifies their acoustic premise, nodal locations and musical potential. Natural harmonics serve as a primer to artificial harmonics, subharmonics, multiphonics, and flautando harmonics. Dresser asserts that an understanding of the natural phenomena of string vibration, or natural harmonic series, is central to his process of exploring sound on the contrabass.

The comprehensive information on *Guts* clarifies and extends the research of his predecessor at the University of California San Diego. In 1989, Bertram Turetzky overviewed how classical and contemporary repertoire used harmonics in *The Contemporary Contrabass*, and mapped them along a single axis indexed to staff-notation (Fig.4). Turetzky mapped as far as the 10th division of the string, which is a fairly high partial. Dresser dared up to the 19th (see Fig 5).

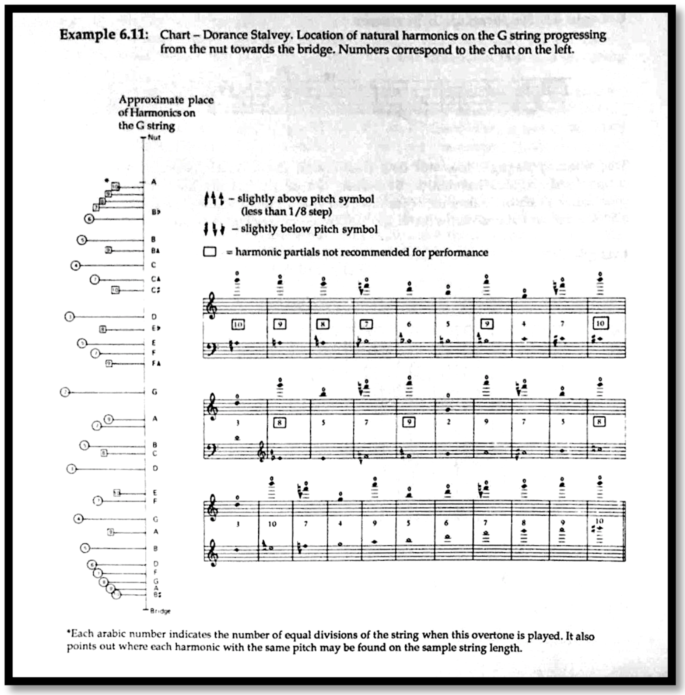


Figure 4. The Contemporary Contrabass (Turetzky) pg 109

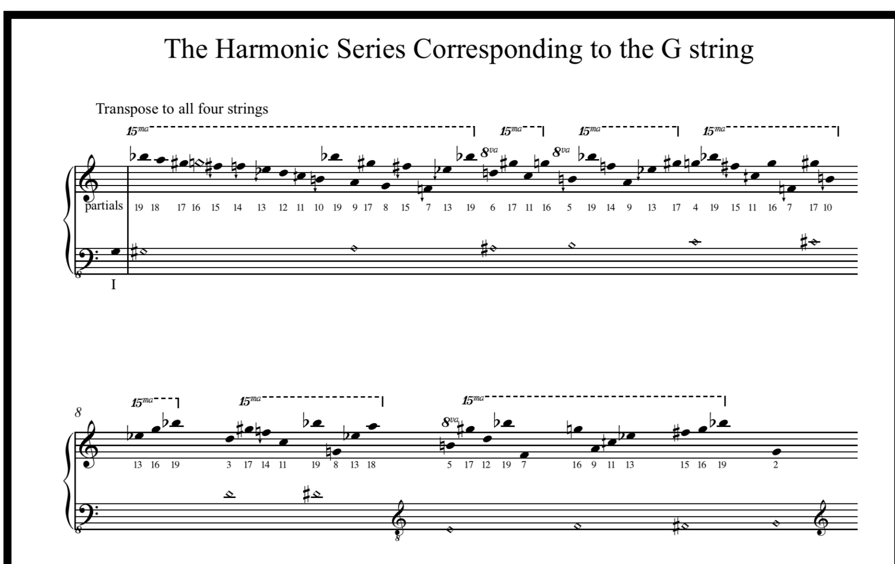


Figure 5. Excerpt from Mark Dresser's document "Harmonic Correspondence – G string" accompanying video footage of *Guts*

Dresser's research was driven by his creative voice. *Guts* elucidates the technical innards of this voice, while also revealing that of Håkon Thelin, Joelle Léandre and the late Stefano Scodanibbio – all bassists, composers and improvisers dealing intimately with the instrument's harmonic properties. Dresser's mappings prepare for the rigors of contemporary experimental music, or give similarly adventurous instrumentalists the tools to strike out into uncharted technical territory.

This is an overview and far from comprehensive, meant to demonstrate a diversity of approach and intention in the bass community. No mapping need exclude the use of another, as their reciprocal influence renders them complimentary angles of a collective interface. Indeed, the modern bassist is fortunate to inherit a rich, diverse, multigenerational set of mappings, variably expressed through each player's singular physicality and musicianship.

The documentation of a mapping may not always manifest as a "map", instead ranging from drawings, tablature and staff notation to video demonstration or live teaching traditions.[2] But a glance under the hood of any approach reveals the pervasive need for spatial and visual awareness. We should take care to document in a way most aligned with the information in-practice.

If the fingerboard is a "wilderness" without pre-installed points or pathways, I propose that a spatial or geographic representation becomes non-negotiable. Plotting the terrain quickly orients us, settling spatial knowledge from theoretical to functional. How much easier is it to glance at a street map than to remember and follow written or verbal directions? At least I benefit immensely from a *literal* map, or position chart, that non-verbally communicates practical routes from here to there on the bass. The myriad versions of such a chart may attest to a widespread preference and need for this amongst my fellow bassists.

Existing charts are two-dimensional, which is sufficient to map linear musical lines of stopped notes – the vast majority of bass playing. However, our collective interface seems to increasingly orient itself around a second, omnipresent pitch layer of natural harmonics, containing no less than *forty-six* nodes per string.[3] These nodes have attracted much exploration and study, as contemporary musical languages capitalize on the bass's proclivity for harmonics. Many good resources are available to understand their pitch content, approximate locations, correspondence to stopped notes directly under them on the same string, etc.[4]

But our mapping of harmonics remains incomplete in a few important ways. First, they are often catalogued with staff notation, but rarely visually or spatially mapped. If and when they are mapped, it tends to be linearly along one string, with loose or approximated scaling despite the exacting mathematical nature of their nodal locations. Most significantly, they tend to be studied and used in overwhelming isolation from stopped notes. Except for their anchoring properties (ie. the nodes that a lower-partial harmonic shares with a stopped note) they are understood linearly and self-referentially, rather than locally or laterally in deep spatial and intervallic dialogue with the correlating and surrounding stopped notes.

It's the complexity and pervasiveness of these relationships I am most interested in, and seek to illuminate with a composite mapping. Bertram Turetzky, writing in 1989, observed that:

> "One seldom-used technique with extensive potential is the double-stop combination of natural harmonics and stopped notes. The sound is unique, often not having primarily the character of two notes, but rather something fused, almost "electronic"…… the technique releases the contrabass from being merely a "one line" instrument.

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[2] The act of teaching may be considered living documentation, passing down choreography in-person

[3] I am counting distinct and reasonably playable expressions of harmonics up to the 8th partial, on the top string of the bass. Theoretically, it is possible to activate up to the the 16th partial, commonly using 9ths-11ths in practice. On lower strings fewer harmonics may be playable, due to the thickness of the string.

There are somewhere between one and three hundred such possible combinations, depending on the size of the performer's left hand and the extent of his or her proficiency with higher partials." (Turetzky, 137-138)

So these two pitch systems, in reality fused into a composite system, are rarely integrated in the mind or methods of the player. Yet there are fascinating sonic and polyphonic qualities waiting for us in this combination, easily unleashed by adding a third dimension to our mental map, and subsequently our practice techniques and conception of the instrument. Indeed, the whole purpose of the bass could evolve yet again if we step inside its many constellations.

Toward dimensionality – rulers, calculators, and code, people

I began mapping this instrument with a tape measure and a sudden understanding that I had forgotten how to deal with all fractional mathematics. Harmonic nodes live at equal divisions of the string. To calculate their exact positions for early drawings of this interface, I would have to do math, specifically division, and we may all sense that a bass player and math make for an unlikely romance. The string length of my double bass is approximately 101 cm, an un-fun number to divide. Also, the biggest paper I could find was 80 cm wide. That is the story of how I ended up with a string length of 60 cm for this modelling, a measurement which followed me off the paper and into the digital realm.

The first objective was to map the manner in which the pitch systems of harmonics and stopped notes relate to each other on *one string* – and to do so in a way that was immediately grasped by the eye, rather than the intellect.

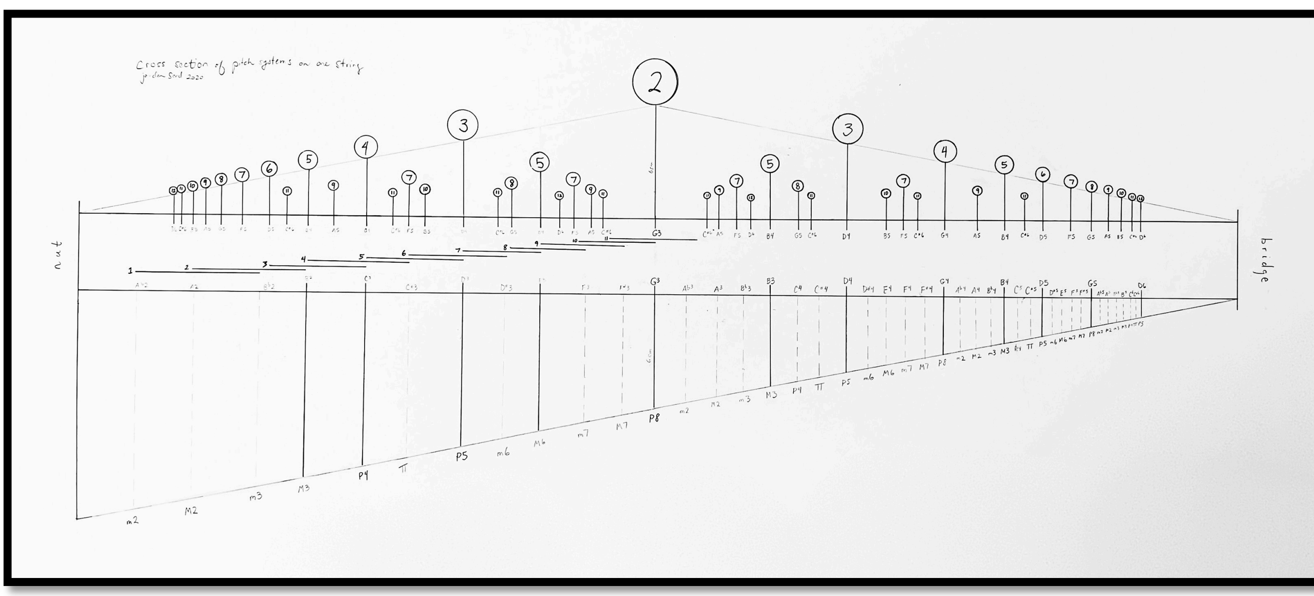

Figure 6. Cross section of pitch systems on one string

The two horizontal lines, at 60 cm long, represent stopped note (lower) and harmonic (upper) planes of the string. The vertical lines extending above and below these planes cross the string at exact nodal locations, or divisions, of the string Their length is proportional to sounding pitch. The longer the line, the deeper the note. From this way of visually representing pitch, we may get quick impressions of where unisons or wider intervals may occur. At the halfway point of the string (the second partial) the sounding pitch of both the harmonic and the stopped note is G3. It is evident that similar unisons continue to occur the higher up the string that we go (or farther right, in this diagram). However, in the first half of the string the disparity between sounding pitch is much more pronounced. It is in this area where I've chosen to focus on the beginnings of an intervallic mapping.

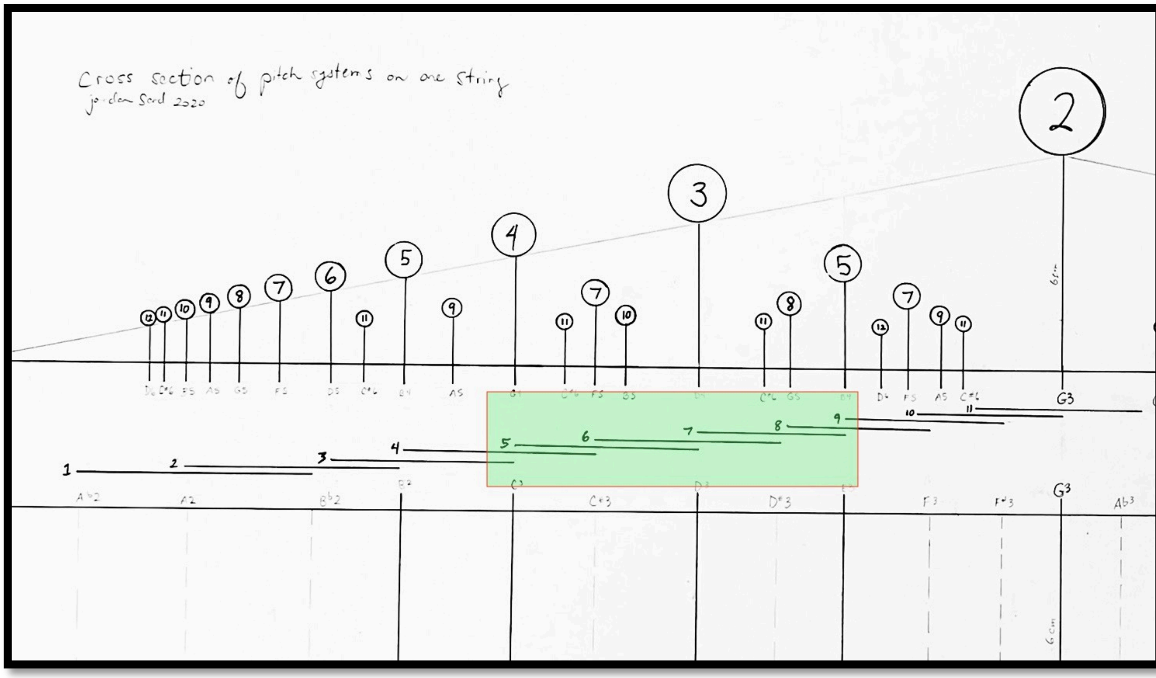

Figure 8. showing the range of hand positions 1-11 with staggered horizontal lines, placed between the two planes

A closer look reveals how we might begin to choreograph the use of these pitch systems together. The staggered horizontal lines represent the range of distinct hand settings in the lower half of the string. (11 distinct positions draws from the Simandl approach, wherein displacing the hand by even one half step constitutes a new position.) If I place my hand in the 3rd position, for example, I can reach every note that falls within its range on both planes without moving or shifting my arm. Positions 5, 6 and 7, highlighted in Fig. 7, are especially interesting to me, because they fall right around where the neck meets the body of the bass ("block position") a tactile anchor of great important to bassists. Although I plan to do this for every position of the bass eventually, and across two and three strings, I chose to begin connecting the dots in these three positions on one string to get an impression of just how many intervallic relationships are living in each small territory, as demonstrated in Fig. 8.

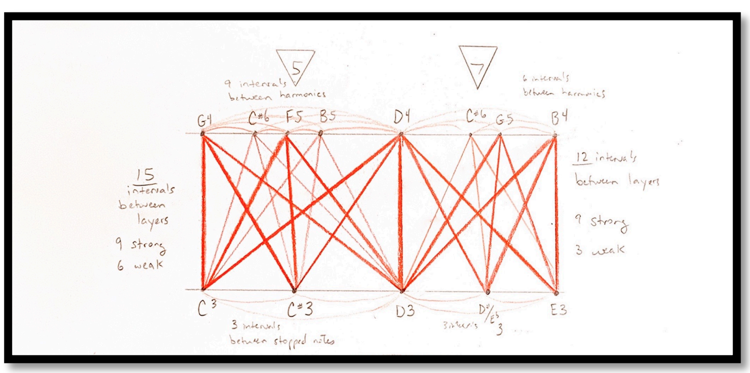

Figure 9. On one string – all possible intervallic combinations between planes within each hand setting

Of course intervals existing on one string, although they have melodic potential, can't be played together as a dyad. The logical next step was to take these connections and explore their workings between two adjacent strings. How many different dyads can be sounded within one hand setting across two strings? Again I am most interested in those dyads occurring between planes (position 5 in Fig. 10), but there are also dyads created harmonic to harmonic (shown in position 7 in Fig. 10) and stopped note to stopped note.

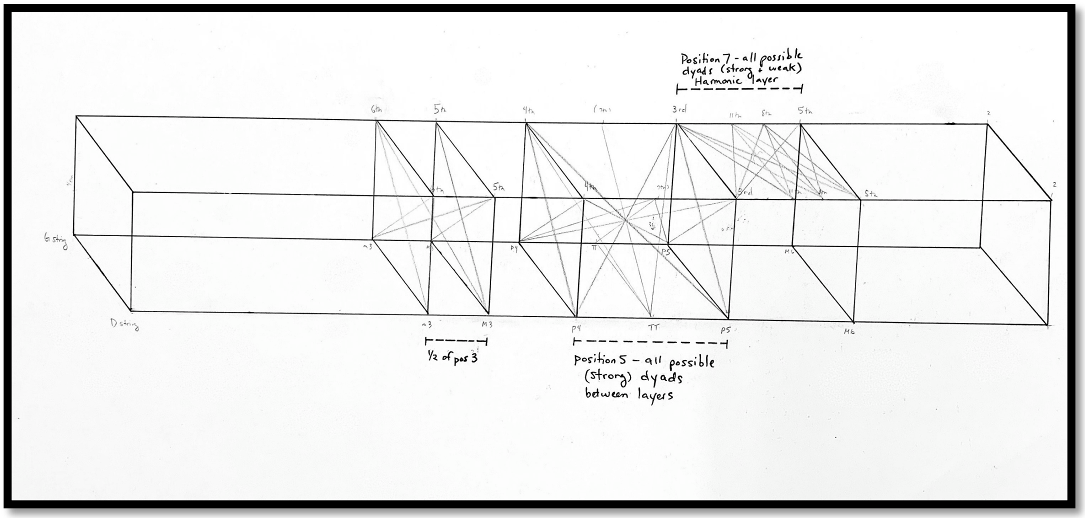

Figure 10. Beginning of a 3-dimensional look at how these pitch materials relate to each other

A static drawing of these relationships across strings quickly becomes a visual mess. It needed to be interactive, in moveable space somehow. I briefly considered making an actual physical 3-d model of it, like middle school science fair. But before I busted out the playdough and pipe cleaners, my supervisor pointed me toward an online visualization tool that would require a bit of coding – a horrifying prospect that turned out to be a lot of fun, and generated new ideas about the possibilities for this interface.

Beginning anew in Glowscript, I took his suggestion to plot the center of the string, or 2nd partial, as 0 on the x-axis, with the open string (or nut) at -30 and the bridge at 30. Because the harmonic series is expressed in a mirror-image of itself from the half-way point of the string, this would generate data sets that were flexible and easy to keep track of when plotting harmonic nodes.

```
partials = [
    [0],
    [-10, 10],
    [-15, 15],
    [-18, -6, 6, 18],
    [-20, 20],
    [-21.4286, -12.86, -4,286, 4.286, 12.86, 21.4286],
    [-22.5, -7.5, 7.5, 22.5],
    [-23.334, -16.667, -3.334, 3.334, 16.667, 23.333],
    [-24, -12, 12, 24],
    [-24.545, -19.091, -13.6364, -8.1818, -2.7273, 2.7273, 8.1818, 13.6364,
19.091, 24.545],
    [-25, -5, 5, 25],
```

Lists with a list in VPython, plotting the locations of partials 2-12 along the length of the string (x axis, from -30 to 30)

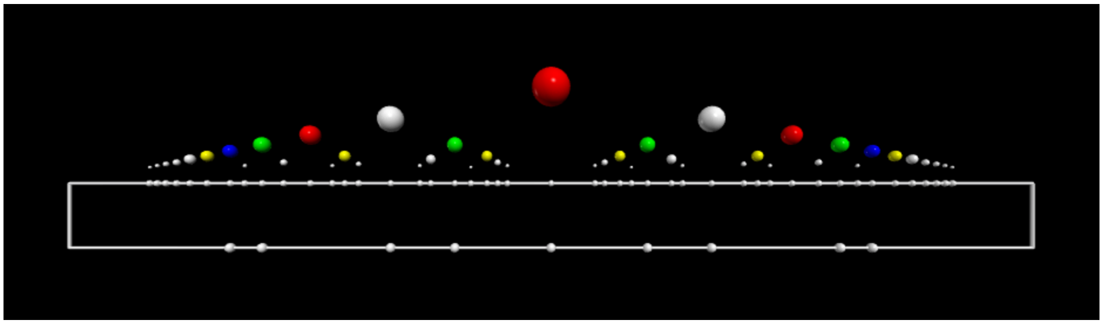

Figure 11. first digital rendering of two pitch planes, one string

Nodal locations on both planes were represented with small sphere objects directly on the string on both planes, rather than as vertical lines that intersected the string as in previous drawings. The larger spheres connected to the harmonic nodes, with sizes and heights proportional to the sounding pitch, were retained for visual tracking purposes. Handsettings were delineated with the color of the curve objects connecting these nodes, rather than separate visual objects. Fig 12 below shows all connections on one string within positions 3, 5 and 7.

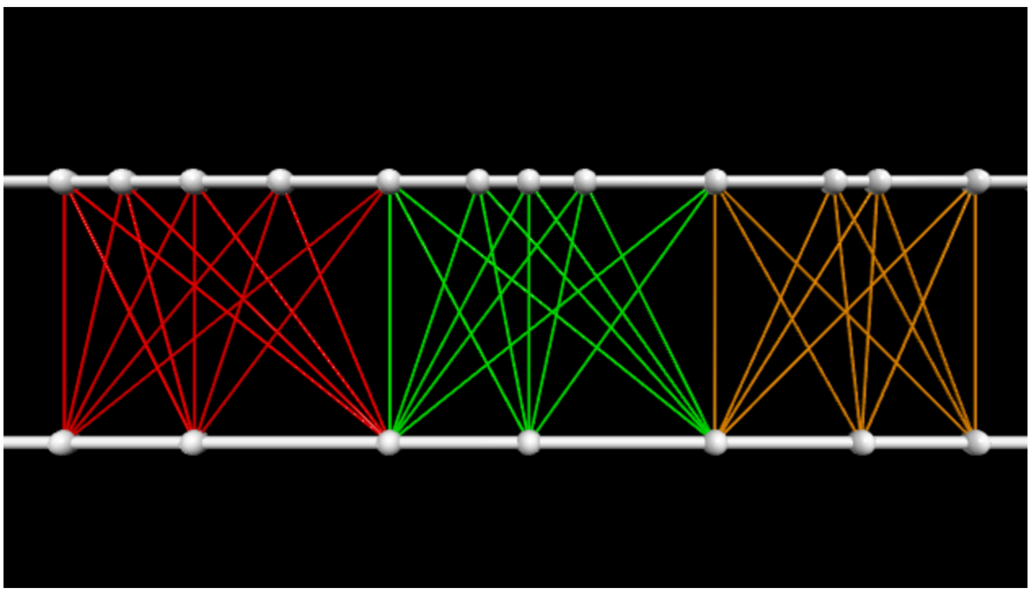

Figure 12. showing relationships

It is noticeable by now that many complex kaleidoscope-like shapes are being drawn to represent intervals, but no intervals have been qualified as of yet – "that line is a minor 10th, this a major 7th plus an octave" etc. That is because this information is something I would like this interface to automatically compute for me, because I am lazy, and because there are literally hundreds of these intervals to discover, catalogue, and create with. I quickly realized that my primitive coding skills, barely one week old, would get me far enough to create a visually acceptable digital representation of this interface. But I did not have the chops to design code that could be easily worked with later, that was flexible and powerful enough to handle the integration of layers of information and allow me to arrange and rearrange it in the future as the concepts behind this interface progressed. What if I wanted the interface to show all the minor 9ths on the bass between layers? What if I wanted to reveal only intervallic connections used in a specific piece to study their spatial relationships carefully? How about filtering connections based on register, partial number, or playability?

So I got out the big guns and called my little brother, who is a computer programmer with a much bigger brain than me, exhibit A:

Figure 13. Little brother, big brain

Over approximately 8 cumulative hours working together on Teamviewer, we were able to build a tool kit that would both render the desired 3-D visualized outcome and set up a "3D" data structure, wherein every partial node is connected or points to the partial series via a series of classes and the objects manifested through them. For the time being, only attributes meant to be rendered visually (such as height, radius, color, points, partial number) are contained within the PartialSeries class. Future drafts of this project can delineate and assign more attributes, such as sounding Hz, calculated according to a flexible fundamental pitch and the partial number, or pitch name and class.

```
class PartialSeries(object):
    '''
    Contains static configuration data for a partial series
    '''
    def __init__(self, number, height, radius, conrad, color, points):
        self.number = number
        self.height = height
        self.radius = radius
        self.conrad = conrad
        self.color = color
        self.points = points


class PartialNode(BaseNode):
    '''
```

```
    Represents a single harmonic node and
    reference to the partial series that contains it
    '''
    def __init__(self, series, position, level, string):
        super(PartialNode, self).__init__(position, level, string)
        self.series = series
```

Excerpt of more recent code behind digital rendering of interface

Visually connecting clear pitch information to nodal location, in addition to being a prerequisite for automating intervallic calculations, can fill another notable gap in our collective knowledge-in-practice. Although the sounding pitch of bass harmonics has been much documented and notated, it is usually only vaguely understood in practice due to a system of tablature-ish staff notation that references only the playing location, not the sounding pitch, of the note (also convoluted by the fact that bass is a transposing instrument.) We should be able to spatially observe nodal locations of harmonics, together with information about their sounding pitch, in order to have working clarity about the real range of this instrument, which is insane. For example, I know now that the 7th partial of the G string is an F5 – my highest vocal note.

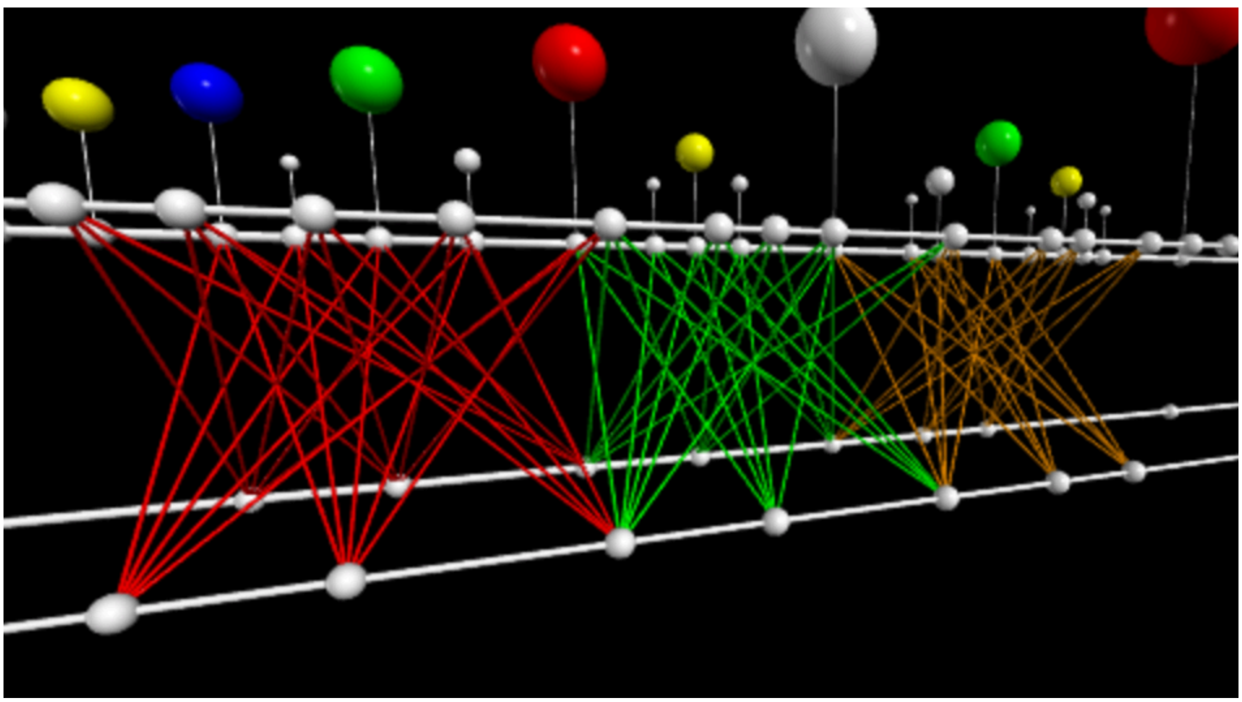

Figure 14. hand positions 3, 5 and 7

An interesting perspective that Austin contributed was the removal of the fixed plane for the harmonic level along the y axis. What if the stopped note level remained constant, but the harmonics floated in space according to their partial number, and the connections were drawn accordingly, as in Figure 15? It was interesting to experiment with the impact that different visual organizations of the information could have on my relationship to these hand positions, when looking at different versions of the diagram with bass in hand.

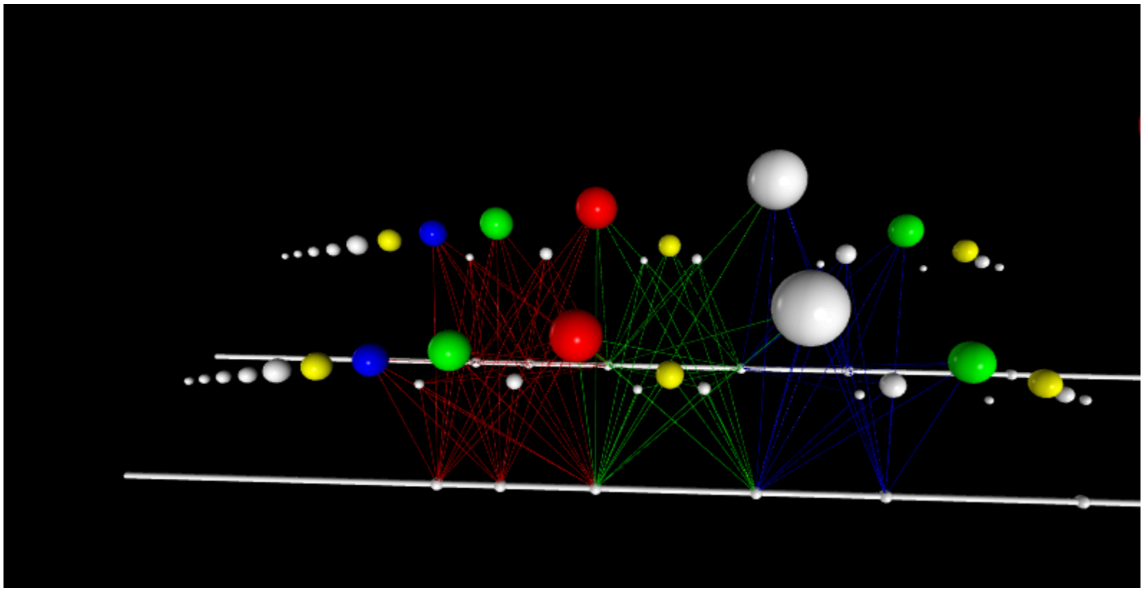

Figure 15. A variable height to visualize nodal locations and relationships, no fixed “harmonic plane”

Surely all these lollipops don’t have anything to do with actually playing the bass? What is this good for? The answer is, almost nothing without the further integration of pitch information, extreme flexibility in examining and filtering information, and, most importantly, lots of energy spent translating newly revealed spatial realities into the body and instrument in real time and space. Precise choreographies must be developed – not just of the left hand, in fact, but of the bow as well. Harmonics and stopped notes require very different bow speed, placement and pressure. One needs an extremely nuanced and accurate approach in order to simultaneously sound such disparate beasts across many octaves. Existing left hand positions, designed primarily for stopped note playing, may only go so far to express and control a composite pitch system. Many upper partial harmonics exist in smaller, more irregular spacings that our hands are not used to in lower positions, and must be practiced with hand settings developed specifically for them. In my playing, these choreographies have been partially developed through intuitive, obsessed stubbornness, but there is much deeper, more organized work to do regarding the development and documentation of methods to internalize the interface. This phase of the project will kick in shortly after the ICLI 2020 conference.

There are many pipe-dream applications of this interface that I will enumerate in a later version of this paper, but they basically come down to two categories: How could this project develop into an actual electronic interface, mediating the acoustic signal of the bass with an amplified or live-processed realm? And what potential could it have to automate or randomize playable compositional frameworks with these pitch materials – in other words, in addition to showing what’s there, helping the mere mortal to imagine what could be created with it?

Double bass: the organ of the string family

This instrument is designed to ring. There’s much debate about its family lineage, but at least some of the basses we play today are old instruments that retained design influences from the viol family of the baroque era – or, in the case of my instrument, they are new instruments designed and built to capture those same resonant qualities. Of course some of that ringiness comes from its low voice. I’ll never forget when my high school orchestra teacher asked me to bow an open string during rehearsal, and we all sat there and silently counted how long the note resounded, even in that dry acoustic room.

It’s because this instrument is both the cathedral and the organ. It is a resonant, multi-layered polyphonic voice with a huge pitch range and it is it’s own house to ring in.

I grew up attending a big empty church with a giant pipe organ. It would completely engulf us, a small congregation singing hymns haphazardly in the wake of that rumbling soaring crashing breathing wave of an instrument. I must never have gotten that sound out of my head, because the imprint followed me to the bass. Or more likely, I followed the imprint and chose the bass, drawn to a familiar voice. I began to sing with it eventually, and compose so I could sing more, not because I was much good at it, but because it seemed like the most natural thing to do in the presence of this sound.

Harmonics are also designed to ring. It's in the name, the harmony of vibration that makes them possible also makes them want to ring, to linger, to sympathise with each other along the length of the string. On the bass we have the perfect storm for their use. No other member of the modern string family has a low enough fundamental or a broad enough fingerboard to access these harmonics as ubiquitously, nor as deep a desire to resonate. It's my nerdiest of missions to dig out all of their possibilities and relationships, and to make my favourite kind of space with them – an engulfing one.

Acknowledgements. I must say thanks for the patient guidance of Øyvind Brandtsegg and patient and spirited collaborations from my brother, Austin Morton.

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