RETHINKING THE NOTATION DESIGN SPACE

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ABSTRACT

Previous work has demonstrated how the analysis and creation of musical notation can be seen within the context of information visualisation. In this case, graphical and musical features are broken down into primary categories which can then be linked to one another, allowing for the visualisation of notation mapping schemes. The space for mapping these elements is known as the Notation Design Space (NDS). While the NDS has the potential to be a powerful tool for analysing and creating new notations, the current model does not provide adequate support for notations which depict the actions of the performer. This paper proposes changes to the current NDS to include the mapping of sound-producing and -facilitating gestures, followed by a theoretical analysis of the similarities between notation and digital musical instrument mapping. The inclusion of musical gesture within the NDS serves a dual purpose; it allows for a more nuanced reading of prescriptive-based notation focusing more on the actions of the performer, while also aligning the development of new notations with interaction design processes.

1. INTRODUCTION

The process of designing new music notation can be seen as an area of constant innovation, experimentation, and compositional creativity. Aided by advancements in music technology, novel notation designs and modes of representation offer countless opportunities for interacting with musical concepts, ranging from animated or screen-based scores [1], live coding [2], and three-dimensional/virtual scores [3].

While there are numerous avenues for compositional exploration in developing and working with new notations, there are equally many design-based decisions to be made, each with their own trade-offs. In such cases, notation systems balance the structural complexity of their design with the cognitive bandwidth of the user, giving importance to the transparency of when and where these designbased decisions are made [4]. For example, animated notations often have a fixed reading in relation to the time domain, while interactive augmented/virtual reality notations require a certain degree of freedom-of-movement from the reader, which necessitates access to the necessary technology. Even simple graphic constructs such as line thickness and proximity can collaboratively produce additional entities and unintended visual clutter [5]. As such, any notation design choice has the potential to affect the creative pathways of a given work's development, as well as the reader's ability to engage with the score.

The complexity of designing a new notation framework helps explain why some have turned to the field of information visualisation as a resource for better understanding the notation development process. Information visualisation can be defined as the graphical representation of data and/or concepts [6]. For example, a map may employ several techniques in representing the elevation of a specific location, ranging from specific use of colour, shading, texture, and saturation. Previous work has shown that musical notation can share many similarities with cartography, allowing for detailed readings of notation based on instrumental topologies as well as bridging notation with the many information layering techniques found in map making [7]. Other works have investigated the perception of colour within notation [8], and the inclusion of information design principles for notational clarity [9]. When looking closer into human computer interaction (HCI) research, music notation has been used as an example for demonstrating cognitive analysis methods of information structures [10] as well as perceptual clarity in relating to information layering [11].

To aid the process of developing new notations, the Notation Design Space (NDS) was introduced to specifically bridge information visualisation analysis methods to this interdisciplinary practice [12]. By doing so, the NDS provides a method for exploring new notation mapping strategies, as well as analysing the designs of existing notations. But as this paper suggests, the current organisational structure of musical features in the NDS does not provide adequate support for many musical notations which depict the actions of the performer.

2. THE NOTATION DESIGN SPACE

The Notation Design Space can primarily be seen as a tool for tracing the mappings of visual channels to musical features. By viewing notation through the lens of information visualisation, the exact design features of a system can be examined. Thus, any notation mapping scheme can be broken down into its constituent parts, allowing for more helpful critique of specific design choices while also allowing for the consideration of new design opportunities through

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the exploitation of unused visual/musical pathways. The NDS differs from other research on information visualisation in music, as it focuses strictly on the design of notation itself (i.e. performer-centric), rather than the general visualisation of musical data for analysis or information retrieval purposes [13].

2.1 Notation Design Space Organisation

In developing the NDS, Miller et al. turned to some of the primary organizing principles of graphic design, visual perception, and musical composition. On the visual side, the NDS is broken down into various visual channels initially developed by Bertin [14] and furthered by Munzner [15], as well as Gestalt Laws for image patterns and groupings, and finally the use of text within the semantic channel. Therefore we have the following primary visual groupings seen in Figure 1 accompanied by examples.



Figure 1. The original visual categories found within the Notation Design Space by [12] on the left, with specific visual examples of *tilt*, *luminance*, *hue/shape*, and *motion/proximity* on the right.

Each of the major visual meta-categories are separated by their perceptual characteristics and semantic function. The *Identity* (what or where) and *Magnitude* (how much) channels are two fundamental sensory modalities of human perception, while *Gestalt Laws* pertain to perceived patterns and spatial relationships between entities. The *Semantic Channel* relates to the real-world meaning of information and its underlying cultural references.

Within the musical fields of the NDS, the authors have generated a list of musical meta-features based on their own analysis and research. These features are broken down in accordance with their prevalence and use within traditional music notation, or as referred to by the original authors as Common Music Notation (CMN) with regards to the NDS. As such, the musical side of the NDS has four major groups seen in Figure 2.

The original design of the NDS included *duration* within the harmony meta-category due to the influence of note duration on harmonic progression. While this conclusion could be debated from a categorical standpoint, it does not affect the overall functionality of the NDS, as duration could easily be moved to the rhythm section without



Figure 2. This list contains the original musical categories found within the Notation Design Space by [12].

significantly affecting the overview of a given mapping scheme. As a whole, the initial version of the NDS was designed particularly with the CMN framework in mind, which prioritises the features of traditional western musical aesthetics (e.g. quantised pitch and duration values). This will be further elaborated upon in the following sections of this paper. Due to this association, notations which seek to engage with musical concepts which go beyond the CMN structure are not as easily supported. This has led to critiques of the impact CMN has had on both the performance-based constraints and analytical capabilities of the evolving aesthetics in new music, much of which is influenced by music technology [16].

2.2 Current Limitations

In terms of its design, Common Music Notation can be seen as a visual structure for the representation of western musical concepts. The cultural foundations behind this system are strong enough that expert musicians are able to internally hear how a given piece of music sounds by reading the score itself [17]. Therefore it is not uncommon to find CMN referred to as the representation of the intended sound of a piece of music, while action-oriented methodologies focus on the sound-producing actions of the performer [18]. In its present form, the NDS contains underdeveloped room for incorporating notations which do not rely on the primary pitch and duration features of CMN. The instruction meta-category of the NDS is where gestural actions should be more accurately described, but the current features of finger, baseline/clef, arrangement, and most importantly timbre, unnecessarily compress the notated actions found in pieces employing prescriptive notation strategies.

Since many new compositions contain highly complex mappings of specific actions between the performer and their instrument, expanding the *instructions* meta-section could significantly increase both the analytical and creative utility of the NDS. By reviewing approaches to complex timbral interaction in contemporary music, and adopting techniques for representing gesture in digital musical instrument design, more precise analytical categories relating to music performance can be added to the NDS, thereby allowing more nuanced and specific readings of current notation design schemes and potential openings for new ones.

3. TIMBRE AND ACTION

Timbre itself has an almost notorious reputation when it comes to defining its meaning, much less representing it visually [19]. When considering the direct visual depiction of timbre to represent an intended sound, cross-modal sound-form symbols show an apparent link between auditory and visual perception [20], but there remains much to be discovered in this area. Within the context of instrumental notation, visually representing timbre can be seen as somewhat of an issue from a design perspective, as its assignment to any feature of a devised system runs the risk of embracing unintentional ambiguity. Common Music Notation is able to visually encode complex musical ideas because it is structured around historical musical criteria (e.g. quantised pitch, rhythm) which in turn possesses wide-spread cultural understanding. This makes the encoding and visual representation of newer musical criteria difficult to achieve, especially those advanced by electronically produced or altered sound. In the following section, we will examine the structure of CMN from a visual design standpoint. From this position, the functional grounding of notation from a prescriptive and descriptive perspective may shed light on techniques for representing timbre.



Figure 3. A schematic representation of the lattice structure of Common Music Notation as described by Trevor Wishart in [21]. Timbre is shaped by layering instrumental parts. Dynamics are not a primary component of the lattice.

The Lattice Structure

Music theorist and composer Trevor Wishart presents an analytical strategy which may help us understand the representational challenges faced by Common Music Notation [21]. Through his analysis of western notation, we find that CMN can be described by the musical concepts which it prioritises in depicting. In turn, we can reduce its structure to a lattice of specifically quantised pitch and duration values seen in Figure 3. The lattice structure was not designed to support the notation of complex shifting timbres due to its historical development. For the majority of CMN's existence, musical instruments and the sounds they produced were intrinsically linked, but this is challenged by the advent of electronic musical instruments which introduces interfaces, synthesis engines, and mapping into the compositional sphere. While electronic musical instruments can completely change their sonic characteristics with the push of a button (e.g. morphing from the sound of a clarinet to the voice), the lattice-based CMN assumes fixed instrumentation. In other words, acoustic instruments cannot completely adopt new sonic properties beyond their physical limitations.

Wishart goes on to claim that the support structure of the CMN lattice has influenced which kinds of musical practices have succeeded within the academy itself, namely, forms of music which conform to the measurable and analytical values of CMN, thus excluding more improvisatory traditions. Overall, CMN enforces a specific historical set of musical values based on western tuning, scales, harmony, and rhythm, thus rendering itself more difficult to use when exploring techniques and concepts which fall outside their scope.

3.1 Descriptive and Prescriptive Notation

Understanding the nature of what the reader is being asked to interpret can help us contextualise the functional aspects of a given music notation system. Works which explore complex timbral development as part of their compositional grammar (which usually lie outside the traditional pitch/rhythm paradigm of CMN) can access those sounds through the depiction of the gestures/actions which produce them. Notation strategies which represent instructions of this kind can be referred to as *prescriptive* notation, while notations (commonly CMN-based) which depict the intended sound of a composition can be referred to as *descriptive* notation [23].

For example, when examining the score of Peter Swendsen's Nothing that is not there and the nothing that is (2009) [22] in Figure 4, the prescriptive/descriptive framework allows us to unpack the graphic components of the notation. The score displays a series of actions taken upon the surface membrane of a concert bass drum, where explicit visual-graphical channels are mapped to sound producing gestures. The notation itself can be seen as a set of instructions for the performer to interpret, resulting in a realisation of the piece. In other words, the score represents the methods for producing the sounds of the piece. Furthermore, one can also observe various visual channels as seen in Figure 1 directly mapped to musical parameters. In this case, combinations of motion, luminance, and curvature indicate gestural movements as being either smooth, rough, chaotic, or symmetric in nature. For the electronic accompaniment (which includes live processing), graphical texture is mapped to articulation profile and dynamic envelope so that the performer may keep their place in the score. Lastly, text-based semantic channel information is presented above each segment, providing the performer with technical descriptions regarding mallet choice, tempo, and further phrasing instruction.

When considering prescriptive and descriptive notations,



Figure 4. An excerpt from Peter Swendsen's *Nothing that is not there and the nothing that is* (2009) [22] demonstrating detailed prescriptive notation for a percussionist and electronics.

it should be stressed that this distinction is not purely dichotomous; many CMN scores contain both prescriptive and descriptive elements including fingering positions on string instruments, or mallet changes for a percussionist. Rather, the difference between prescriptive and descriptive notations helps us evaluate the economy of graphical space employed, including mappings between visual and musical features. In contemporary music, prescriptive notation has been a useful strategy for engaging with new extended techniques, music technology, and choreographed movement. These are complex forms of interaction which can stretch the utility of CMN, but ones which prescriptiveoriented designs handle well, and which stand to benefit from being incorporated into the Notation Design Space.

4. RE-EVALUATING THE NOTATION DESIGN SPACE

Given the complexity of mapping timbre to graphical features in a notation scheme, the field of instrument design and gestural analysis offers insight as to how the actions of the performer could be integrated for prescriptive designs. Digital Musical Instrument (DMI) research has provided those interested in designing interaction within music with a wide range of tools for understanding how meaningful experiences are created, mapped, and analysed [24]. The research within the fields of HCI and DMI face similar issues, especially in light of third-paradigm HCI research, which promotes the values of contextual use and creating spaces for making meaning [25]. The goals of the NDS have much in common with DMI research as well, especially in conceptualizing interaction mapping as a design process.

4.1 Performance Gestures

Digital Musical Instrument research has long been focused on developing meaningful musical interactions with technology via artificially mapped connections, lending special importance to the topic of gestural analysis. Jensenius et al. [26] offer a resource for breaking down musical performances on a gestural level, revealing the many layers of expressive and performative actions which arise out of playing a musical instrument. In their analysis, each action of the performer can be evaluated contextually, allowing one to observe gestures related to those which directly produce sound, those which facilitate the sound, and those which accompany musical expression elicited by the performer. These main categories of gestural interaction can been seen in Table 1.

With this inclusion, we have a well articulated set of gestural behaviours which tie directly to musical interaction, and thus could be adapted for performance analysis and de-

Visual Channels



Figure 5. A new instantiation of the Notation Design Space which includes performance gestures and more semantic channel categories. These additions are marked with an *. The mapping space is where musical features are assigned to visual constructs in a given notation.

Producing	Facilitating	Communicative
Modification	Entrained	Expressive
Excitation	Support Phrasing	Theatrical

Table 1. Performance gestures as seen in Jensenius et al.[26].

signing notation mapping schemes. It should be noted that not all of these gestural categories are assumed to be directly mappable in an interactive sense. Sound-producing gestures offer the most direct route to mapping, as they relate to specific aspects of controlling the sound of an instrument. Most communicative gestures are generally thought of as artefacts of emotive behaviour. Sound-facilitating gestures lie perhaps somewhere in between where phrasing and supportive gestures lend themselves to being mapped as a feature of shaping the sound of a performance, while entrained gestures (e.g. foot tapping) are less so.

Embodied cognition research may also prove to be fertile ground for the analysis of gestural mapping within the context of notation. A possible downside of visually-based analyses of gestural interaction is that they run the risk of compressing the multivariate nature of dynamic human movement in ways which could be problematic regarding the corporal agency of the performer [27]. Such notions are outside the scope of this paper, but warrant consideration for further NDS analysis.

4.2 Gesture within the Notation Design Space

By adopting gestural analysis methods from DMI/HCI research, we can integrate the relevant categories into the NDS, thus providing a more inclusive space for prescriptive notation design. By specifically adding the features of sound-producing gestures, we begin to have a much more inclusive space for notation mapping analysis. Some sound-facilitating gestures may also be possible for a given mapping, as could a theatrically-oriented communicative gesture. Therefore, a newly developed instructions segment of the NDS can be seen in Figure 5.

The inclusion of gestural categories into the instruction section of the NDS allows for the *timbre/instrument* category to be removed, as it is assumed that these gestural descriptors will offer a more precise reference of *what kind* of instrument-related action is taking place. In addition, the category of finger position can be incorporated into the *sound excitation/modification* gestural category.

With more appropriate descriptions of gesture within the NDS, compositions of prescriptive notation such as *Guero* (1969) by Helmut Lachenmann [28] or *2nd String Quartet* (2010) by Aaron Cassidy can be analysed with a higher level of transparency in their graphical mapping schemes. Cassidy's technique in this example makes explicit use of the various visual channels mapped to sound-producing or modifying actions [29]. Other pieces, such as *Shiver Lung* (2019) by Ashley Fure [30] or *Nothing that is not there and the nothing that is* (2009) by Peter Swendsen [22] in Figure 4, employ combinations of pictograms and other visual

channels as a prescriptive notation due to the complexity of electronically-driven elements found within the piece.

Descriptive-based scores also stand to benefit from the inclusion of gestural action-based elements within the NDS, as these two main categories of score design are not mutually exclusive. Descriptive scores may contain within themselves prescriptive elements and vice versa [31]. A more developed NDS offers a larger analytical space for these schemes, which opens the door for new mappings. As the original authors of the NDS have stated, there remain many unexplored avenues when considering notation mapping schemes, many of which may have to do with the innate perceptual affordances and drawbacks of a graphical entity's ability to represent musical information. In this regard, a connection to perceptual graphics may offer useful insight for further study [6].

4.3 Expanding the Semantic Channel

By including gesture within the NDS, we can see how the semantic channel of the original design could also be extended to contain elements beyond just text. Many notation mapping schemes found in contemporary music employ the use of various glyphs, which can be seen more broadly as bundled collections of visual channels used to produce a visual sign [32]. Fragmenting glyphs into their various graphical parts makes understanding their contextual role within a score more difficult. Therefore, the inclusion of *numbers, symbols/ideograms, signs/icons* groups, and *iso-types* [33] into the semantic channel of the NDS could provide for a richer mapping space as well.

5. MAPPING INTERACTION AND NOTATION

Within the field of DMI design, interaction mapping is a core area of study, fostering further connections to HCI research. In research focusing on embodied cognition in music performance, scores and notation can even be seen as having instrumental properties, serving as intermediaries by which expressive musical interactions take place [34]. By further developing a process of analysis which connects notation to mapping, a framework of study exploring how particular mappings are successful in relation to their intended goals can also be developed. Through the lessons of DMI research, music notation design can be linked as a kind of parallel process to the interactive mapping of musical instruments.

5.1 Leveraging Familiarity

Borrowing interactive mappings from other contexts when designing a new instrument provides the player with an instantly familiar set of performance actions, leading to instant music making and performance feedback [35]. For instance, one can conceive of a musical instrument which uses the QWERTY keyboard as its interface. Most people would quickly be able to navigate this instrument with a well developed set of gestures stemming from their previous experiences with the interface [36]. A similar process of borrowing from familiar graphical schemes found in other contexts could be explored in notation design as well. For example, colour mapping schemes from cartography manage to successfully convey detailed information mappings to the reader. The bivariate choropleth allows for multiple complex readings of diverging or sequential values [37]. Such colour mapping schemes could be adapted and applied in the context of notation, offering a tried and true visual mapping strategy for colour which is demonstrated in Figure 6.



Figure 6. Two examples of bivariate choropleth colour mappings. Image a as seen in [37]. Image b by the author, employing the same colour scheme remapped to audio parameters as seen in an étude [38].

Mapping design tools from DMI research could also be reviewed for their potential use in analysing the mappings of new notations. Interfaces for tools such as Libmapper can be studied with regards to their ability to visualise mapping connections, thus aiding the work-flow in developing new designs [39]. In contemporary music, notation design is a highly interdisciplinary act guided by a wide array of influences specific to the experiences and interests of each composer. As of yet, this process does not have comparable mapping tools to those found in DMI research. When specifically considering prescriptive notation as a form of instruction, the link between interaction design and notation has the potential to spur further research in both creative and empirical contexts.

5.2 Layering and Separation

With a more developed design space for notation, the design choices of any system can be viewed with regards to their visual channels, thus leading to a more directed use of visual elements and bringing the process of notation design closer to the realm of information graphics. The layering of information is a delicate but essential process in the design of any information display [11]. How visual channels are employed can be difficult to manage, thus highlighting how the NDS could be used creatively. Through an expanded NDS, composers of both traditional and experimental styles can determine which visual channels are free and which ones are used, allowing for a critique of a given graphic layering scheme. Information layering carries with it both aesthetic and scientific implications, making the careful and considered use of any visual channel important for both the composition and the performer.

6. CONCLUSIONS

As an analysis tool, the Notation Design Space can help us understand mappings which work, those which do not, and those which are unexplored. The primary issue with its current form is the primary focus on historic musical features guided by Common Music Notation. Today, many new pieces found in contemporary music engage with diverse range of graphical elements to communicate performance gestures with the performer, thus speaking to the need for relevant analytical design tools. The expansions to the NDS suggested in this paper also aim to provide stronger links between notation design, digital musical instrument research, and information graphics. Gestural interaction can be seen as a core focus of many new works today. Therefore, offering a more inclusive design space could be beneficial both in terms of ideation and analysis.

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