# TABstaff+: A HYBRID MUSIC NOTATION SYSTEM FOR GRID-BASED TANGIBLE USER INTERFACES (TUIs) AND GRAPHICAL USER INTERFACES (GUIs)

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## ABSTRACT

TABstaff+ is a hybrid music notation developed for grid-based user interfaces. The system builds on notational elements and conventions of tablature, standard five-line staff notation, and chord diagrams. TABstaff+ strives to facilitate teaching and learning, composition and production, and performance using grid-based tangible user interfaces (TUIs) and graphical user interfaces (GUIs). For usability testing, the study involved seven participants, music production and composition students (ages 13 to 19) with prior musical experience. The paper considers the Ableton Push instrument to illustrate the application and adaptability of the TAB+, Staff+, and Charts+ notation systems. These notation systems aim to further the development of postdigital practices by leveraging Human-Computer Interaction (HCI) and pre-digital practices of reading, playing, and teaching music using instruments and notation. TABstaff+ aims to be a transferable music notation system that allows educators and practicing musicians to utilize the pedagogical and creative capabilities of musical grid interfaces.

## 1. INTRODUCTION

Musical Instrument Digital Interface (MIDI) grid instruments and touchscreen graphical user interfaces (GUIs) have changed how music is composed, performed, taught, and learned [1] – [5]. Considering these developments, comprehensive and dedicated notation systems are needed for musical grid interfaces. As Giles [6] points out, 'due to the grid controller's primary association with more popular styles of music, a scoring paradigm for it has not been explored.' Many of the compositions and performances utilizing these types of interfaces, to a large extent, employ un-notated and improvisatory approaches. While many of these works are recorded via audio, MIDI, video, and other means, they tend to be fixed or semi-fixed media. A notation system for musical grid interfaces can enable the education, creation, and live performance of digitally produced works, leading to new educational paradigms, artistic possibilities, and forms of dissemination [7]. As musical instruments with grid interfaces offer 'an utterly unique method of controlling a computer system' [6], a notation system that accounts for grid playing surface topographies can significantly contribute to Human-Computer Interaction (HCI) in digital music practices, as the grid controller is becoming an industry standard and an "object of research in the HCI community" [8].

While digitization of music has enabled new creative and collaborative opportunities, there remains a gap in HCI in terms of reading, learning, teaching, and performing digitally created music [9, 10, 11]. The use of musical grid interfaces, like the Ableton Push, Novation Launchpad, Native Instruments Maschine, Akai MIDI grid controllers, and software applications featuring touchscreen grid GUIs such as Ableton Note, Groovepad, Drum Pad Machine, and others, have been a step forward in human-machine music making, enabling immediate and tactile engagement with digital material. These developments where already underway in the 1960's with "push-button matrices" that "were used in electronic devices (cf. phones) and research and development (US3676607A) created new technologies which influenced the design of later grid interfaces" [12]. In the late 1980's MPC controllers were introduced and quickly adopted by the music industry [13]. Advancements in touch-sensitive technologies have allowed for more expressive control over sound manipulation; parameters like velocity, MIDI Polyphonic Expression (MPE), finger position tracking, and others have empowered musicians to achieve unprecedented nuance and creative expression. These advancements invite new ways for fostering creative reusability and reproducibility (e.g., live performance) of digital musical material [14] – [16]. The challenge lies in translating digital musical information created through Digital Audio Workstations (DAWs) and other technologies into live performance contexts utilizing grid interfaces. Finding ways to bridge the gap between digital and physical environments remains essential for furthering music creation, performance, and education in the postdigital age.

A real-world example of this challenge in education can be a music teacher designing a class activity in which students learn fundamental elements of music by triggering

of loops, controlling parameters of sound, and playing melodies and chords on grid TUIs or GUIs. Effectively communicating musical instructions poses a challenge due to the absence of a recognized notation system that graphically represents playing actions for grid instruments. One option is for the teacher to create their own notation system or set of instructions. While this may work for an isolated case, such a system may be limited in terms of reproducibility in different contexts, with other educators and students needing to 'decipher' the 'new symbolic language' [17, 18]. Furthermore, developing such a notation system is highly demanding for music educators, taking time away from teaching-related activities. While designing a hands-on classroom activity in the DAW may be relatively straightforward, the difficulty lies in finding a way to translate digital material into a human-readable format optimized for learning and playing on grid instruments [19].

Music educators and musicians who work with traditional and non-electronic mediums use various established notation systems. These include the standard five-line staff, tablature, chord diagrams, percussion-specific notation systems, and world music notation systems. These systems enable the clear communication of intricate musical concepts and effectively support activities such as teaching, learning, composing, and performing. Nevertheless, many systems, like tablature and chord diagrams, are often instrument-specific. Even general-purpose systems, like the five-line staff notation, are optimized for traditional instruments such as piano, violin, flute, and others [20]. Although these systems work well in their respective contexts, they are not as effective in representing and communicating musical material created digitally and intended for performance on musical grid interfaces. Graphical representations of musical material in DAWs exist in the form of the piano roll, timeline, MIDI data, and other visualizations. These are helpful for activities such as MIDI programming, sequencing, and automation in composition and production. However, they are not optimal for grid interface-based learning, teaching, and performance. Traditional DAW visualizations like piano rolls or MIDI data are often static and complex, which can be challenging for beginners to understand. Musical content created using MIDI programming in a DAW can be saved as a MIDI file, converted into MusicXML format, and imported into music notation software like Dorico, Finale or MuseScore, allowing for the digital music data to be represented in standard five-line staff notation or tablature for human readability in performance practices. However, traditional notation systems are not optimized for readability and playability on grid TUI and GUI instruments. These challenges can be overcome through the development of new notation systems designed specifically for musical grid interfaces offering intuitive, visual and tactile ways of learning music.

The TABstaff+ notation system introduced in this paper recognizes that 'notation of electronic music' is part of the 'evolutionary lineage' of notation systems and builds on the standard five-line staff, tablature (TAB), and chord chart notation conventions [21]. These established graphical and symbolic representations of music are utilized in developing TABstaff+ due to their widespread familiarity, usability, and transferability across multiple musical styles, genres, and practices. TABstaff+ encompasses three notation subsystems: TAB+, Staff+, and Charts+. These new notation paradigms combine elements from the traditional notation systems, expanding each to account for the unique layout of grid interfaces.

## 2. EDUCATIONAL IMPLICATIONS

National and international music curriculum guidelines underscore the importance of equipping students with the ability to 'use a system, e.g., staff notation or TAB, to learn and perform music appropriate to the instrument and musical style' [22]. Additionally, new teaching and learning frameworks emphasize digital aptitude and literacy in teacher training and at all levels of education [23]. As grid TUIs and touchscreen GUIs are being increasingly integrated into the music classroom [24] – [27], a notation system developed specifically for these types of interfaces can serve as a means of furthering the teaching of music and fostering digital skills. Research acknowledges 'that problems in music reading skills hold back countless students and may be a major cause for them to drop out of music lessons,' a systematic and user-friendly notation for grid-based instruments, already commonly used in many educational settings, has the potential to contribute to the development of musical and digital competencies [28], [29]. From the perspective of the music educator, it has been noted that 'many music teachers tend to abandon music reading instructions in the initial phase of their program or at least try to minimize the emphasis on music literacy' [28], [29]. However, understanding that 'fragmented musical knowledge results if reading is not taught hand-in-hand with playing the instrument' underscores the importance of musical instruments and notation for holistic music education [30] – [32]. As grid user interfaces (UIs) are designed to 'reduce learning' in terms of cognitive dissonance by 'eliminating confusion,' they can streamline the learning process [8], [12]. In this context, 'reduce learning' is viewed positively, as in minimizing the amount of new information or skills that a user must acquire to effectively use a system. For grid UIs, this might mean that the interface is designed in such a way that a user can intuitively navigate and use it without needing extensive instruction or trial and error. Grid interfaces are typically designed for clarity and ease of use: each element's purpose is clear, and there are no ambiguous controls or commands. They are created to match users' expectations and preconceived notions of functionality, which minimizes the likelihood of cognitive dissonance, where a user's experience clashes with their expectations. A comprehensive and user-friendly notation system for grid instruments holds the potential to support the development of musical aptitude and digital proficiencies.

## 3. METHODOLOGY

The development of TABstaff+ hybrid music notation system involved a multi-stage process, including (1) literature

review, (2) Design-Based Research (DBR), and (3) usability testing with seven music students (ages 13–19). The study began by identifying where additional research was needed on musical notation for grid-based TUIs and GUIs. The notation system developed in this study drew on prior research (e.g., [6], [17]) on notation for instruments like Push and comparable grid-based musical interfaces. The literature review shaped the development of the conceptual framework for the TABstaff+ notation system, encompassing (1) adaptability across musical genres, (2) ease of use for educators and students, and (3) compatibility with various grid-based instruments and interfaces. The Design-Based Research (DBR) stage included (1) research of grid-based instruments, (2) analyses of musical notation systems, (3) initial design of TABstaff+, (4) prototyping and iteration, and (5) final TAB+, Staff+, and Charts+ notation systems. The three subsystems of TABstaff+: TAB+, Staff+, and Charts+, underwent multiple iterations for refining of graphical representations, symbols, and usability. To ensure compatibility and transferability of the notation, the prototypes were tested on various grid-based instruments and music applications featuring touchscreen grid GUIs. The usability testing involved seven private music composition and production students, ages 13 to 19, with varying musical abilities. Participant feedback and observations were collected during the testing phase. Students were asked to perform specific musical tasks (playing scales, playing chords, triggering loops, etc.) using TABstaff+ and provide feedback on their experiences. The observations and feedback were used to refine the TABstaff+ notation system and contributed to the development of the final TAB+, Staff+, and Charts+ notation subsystems.

## 4. NOTATING FOR THE PUSH

*"It falls to the educator to [...] cater for as wide a range as possible. And I think there is a portion of students who, upon learning to play the Ableton Push, would greatly benefit from a formal notation system to scaffold and guide their practice. This is not to say that Ableton educators are not aware of this and acting on it daily, but that a notation system would surely add to the variety of methods available to learn the instrument in a guided and supported way"* [17].

The challenge of creating a notation system for the Push and similar musical grid interfaces lies in the numerous layout configurations afforded by MIDI mappings. Initiating the Push in Live, the user is presented with options for setting the topography of the instrument at the *mega*, *macro*, and *micro* level layouts. The layouts exhibit a nested hierarchical structure. The mega layout includes two modes: 'Note' and 'Session.' One can switch between these using buttons with corresponding names and symbols on the Push. Within the 'Note' mode, seven *macro* layouts are available:

- Melodic: 64 Notes
- Melodic: Sequencer
- Melodic: Sequencer + 32 Notes
- Drums: 64 Pads
- Drums: Loop Selector
- Drums: 16 Velocities
- 'Session' Layout

The *macro* layouts contain the following *micro* layouts:

- 4ths 'In Key' Vertical
- 3rd 'In Key' Vertical
- Sequent 'In Key' Vertical
- 4ths 'Chromatic/ Vertical
- 3rd 'Chromatic' Vertical
- Sequent 'Chromatic' Vertical
- 4ths 'In Key' Horizontal
- 3rd 'In Key' Horizontal
- Sequent 'In Key' Horizontal
- 4ths 'Chromatic' Horizontal
- 3rd 'Chromatic' Horizontal
- Sequent 'Chromatic' Horizontal [17, 33, 34].

The micro layouts can be set using the mode, layout, and direction parameters, adjusted using the encoders (knobs) and buttons above and below the display screen. The mode parameter contains two layout options: 'In Key,' in which only the notes that belong to the selected key are lit and accessible on the pads, and 'Chromatic,' in which all chromatic notes are available, with the notes within the scale lit and those outside unlit [33]. The layout parameter contains three options: 4ths, 3rds, and Sequent. In the 4ths view, each pad is positioned a fourth higher from the pad row below; in the 3rds view, each pad is positioned a third higher, and in the sequent view, each pad is positioned an octave above. The direction parameters contain two further layout options: Vertical, in which scales are played from left to right, and Horizontal, in which scales are played from bottom to top.

While the above pertains to the Push, similar complex MIDI mappings are possible on other musical grid interfaces. The variety of layout choices showcases the versatility of grid controllers as dynamic musical instruments. However, it presents a challenge in terms of designing a notation system capable of accommodating diverse playing surface topographies. To facilitate the development of such a notation system, TABstaff+ introduces *nano* layouts that divide grids into smaller units.

## 5. TAB+: A TABLATURE SYSTEM FOR GRID INTERFACES

### 5.1. Single-Line Notation in TAB+

The 64-pad layout of the Push allows for the division of the pads into four 16-pad sets, *nano* layouts, each with a 4×4 matrix. The TAB+ notation introduces four new clefs, **A**, **B**, **α**, and **β** (pronounced as A-clef, B-clef, alpha-clef, and beta-clef), for specifying the nano layouts. The A and B clefs correspond to the two 16-pad nano layouts in the lower half of the instrument, while the α and β clefs correspond to the two nano layouts in the upper part (Fig. 1).

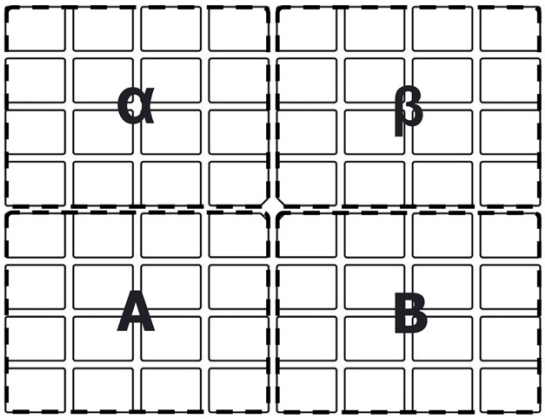


**Figure 1**. The main 64-pad grid playing surface of the Push divided into four 16-pad groups and labeled with TAB+ clefs **A**, **B**, **α**, and **β**.

The 4×4 matrices facilitate the development of the TAB+ four-line tablature system. This notation resembles traditional tablature systems; however, where lines usually indicate strings and numbers indicate frets, in TAB+, lines represent pad rows, and numbers specify pads within rows (Fig. 2). The adoption of elements from traditional tablature systems in the development of the TAB+ allows for the retention of key notational features such as the representation of time, note duration, rhythm, chords, contour, and other musical elements.

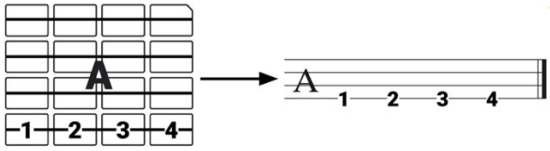


**Figure 2**. Four-line tablature with lines representing pad rows and numbers specifying pads in each row.

The TAB+ system allows musical structures such as melodies and harmonies to be read and played with ease. For example, in the default mode on the Push, an ascending one-octave C major scale (C2–C3) can be notated using the **A** clef. As the clef indicates, the scale is played in the bottom left nano layout (Fig. 3).

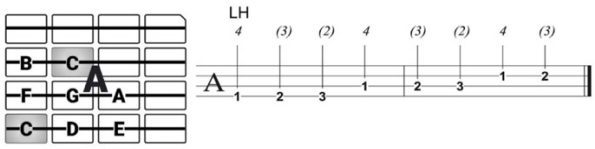


**Figure 3**. An ascending one-octave C major scale (C2–C3) notated in **A** clef for the left hand.

The TAB+ system incorporates note stems and beams for clarity of rhythm; however, it is also possible to use the system without stems and beams. The non-italic numbers on the tablature lines indicate the pads to be played, and the italic numbers above provide fingerings. To play a two-octave scale, the hand must traverse two nano layouts; there are two ways to notate this using the TAB+ system. For example, an ascending two-octave C major scale starting on C2 can be written using A and α clefs (Fig. 4 a) or only the A clef with ledger lines representing the transition into the pad rows of α (Fig. 4 b). Like the function of traditional clefs, the grid-specific alpha and beta clefs (i.e., A, B, α, and β) provide a reference point for interpreting the notes and their ranges. The TAB+ system further incorporates ledger lines as extensions of the tablature, resembling the function of ledger lines in the standard five-line staff notation system. This allows for the notation of musical material that extends beyond a single octave or calls for two or more nano layouts. Traditional tablature systems generally do not use clefs or ledger lines; this is a novel feature of the TAB+ notation system.

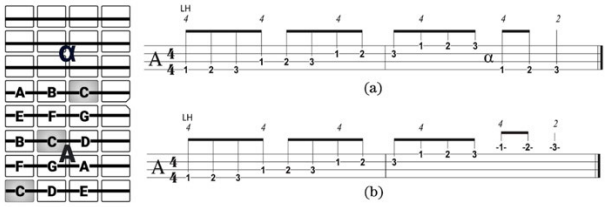


**Figure 4**. (a) An ascending two-octave C major scale (C2–C4) notated in **A** and **α** clefs for the left hand; (b) the same scale notated in **A** clef with ledger lines indicating the transition into the **α** range.

While traditional ledger lines extend the upper and lower range of staves by numerous lines and spaces, the number of ledger lines in TAB+ is limited to the number of pad rows. In the case of the Push, in **A** and **B** clefs, a maximum of four ledger lines above the tablature can be used for denoting upper extensions into the **α** and **β** range. In **α** and **β** clefs, a maximum of four ledger lines below the tablature denote lower extension into the **A** and **B** range. As demonstrated in Figure 5 (a), a two-octave scale can be notated with a clef change or (b) with ledger lines.

The TAB+ additionally includes indications for the parameters: *layout* (e.g., 4ths)*, mode* (e.g., 'In Key')*, key* (e.g., C), and *scale* (e.g., major), ensuring that the notation is read correctly. The italic numbers above the staves specify fingerings and indicate transitions between pad rows (Fig. 4 and 5). Fingering suggestions for the first and last notes of the scale show the correct starting and ending positions.

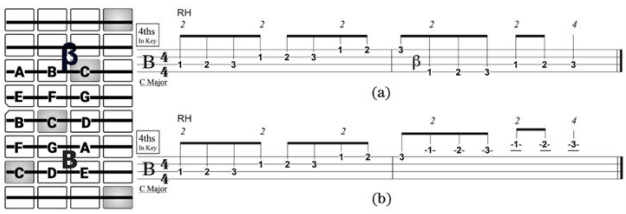


**Figure 5**. (a) An ascending two-octave C major scale (C3–C5) notated in **B** and **β** clefs for the right hand; (b) the same

scale notated in **B** clef with ledger lines indicating the transition into the **β** range.

The TAB+ system further introduces two hybrid clefs; **AB** and **αβ** (pronounced as AB clef and alpha-beta clef). The combination of the **A** and **B** clefs allows for the use of 32-pad layouts. The **AB** and **αβ** hybrid clefs are pertinent to the Sequent layout, for which the notation is more idiomatic using a 32-pad layout due to the arrangement of the pad rows in octaves. As observed in Figure 6, the tablature with hybrid clefs requires additional number indications (e.g., 5, 6, 7, and 8) for the Sequent layout.

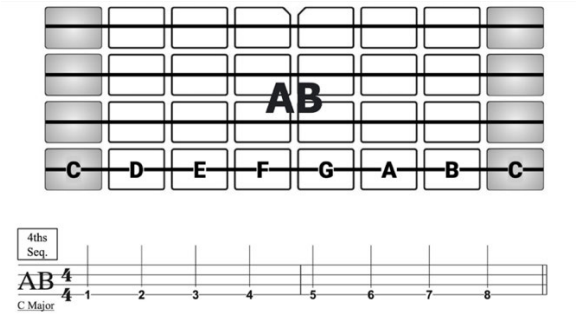


**Figure 6**. An ascending one-octave C major scale (C2–C3) in Sequent layout notated in **AB** clef.

In addition to facilitating notation in the Sequent layout, these hybrid clefs solve the challenges of notating musical material played *on* or *between* two nano layouts. For example, in a two-octave C major scale in thirds played with two hands, the left hand would be notated in **A**, and the right would be notated in **AB** and **αβ** clefs (Fig. 7). The **AB** and **αβ** clefs indicate that the right-hand moves across multiple nano layouts during the scale.

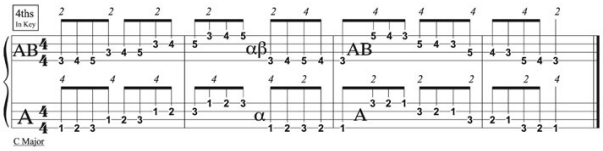


**Figure 7**. An ascending and descending two-octave C major scale in thirds played with two hands: right hand starting on E2 and left hand on C2.

The TAB+ system is transferable to other grid UIs. The number of lines in the tablature system can be adjusted depending on the number of rows of physical pads or graphical grids. Likewise, the numbering of the pads can be changed depending on the layout of the grid interface.

### 5.2. Adaptability of TAB+ in Different Push Layouts

The flexibility of the TAB+ is observed in its capacity to represent musical material in different modes, layouts, and directions. Figure 8 demonstrates how a two-octave C major scale (played by the left hand) can be notated in the 'In Key' mode for the 4ths, 3rds, and Sequent layouts. Figure 9 displays how the same scale can be notated in the 'Chromatic' mode for 4ths, 3rds, and Sequent layouts.

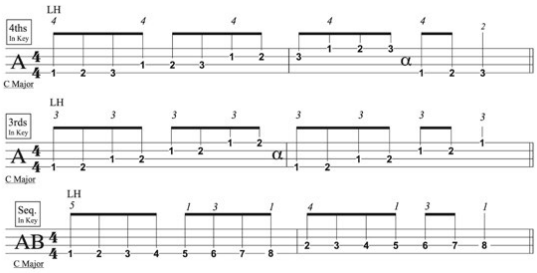


**Figure 8**. An ascending two-octave C major scale (C2–C4) notated for 'In Key' mode in 4ths, 3rds, and Sequent layouts.

The examples in Figure 8 highlight the flexibility of the TAB+ clefs, allowing the same musical material to be notated in three different ways, facilitating the readability and playability depending on various musical contexts. For example, guitarists accustomed to fourths tunings may prefer the 4ths layout, while pianists may find the Sequent layout more familiar. The TAB+ notation can be adapted to various artistic and pedagogical needs.

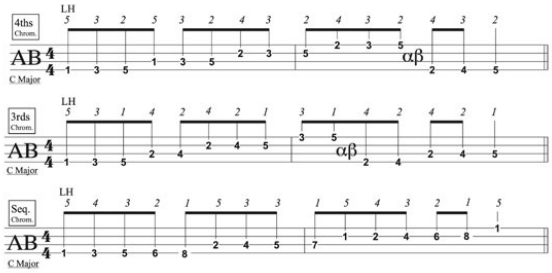


**Figure 9**. An Ascending two-octave C Major scale (C2–C4) notated for 'Chromatic' mode in 4ths, 3rds, and Sequent layouts.

The 'Chromatic' mode examples in Figure 9 further exemplify the functionality of hybrid clefs. These examples show that due to the extended playing range resulting from the addition of chromatic pitches, a 32-pad layout is required to simplify the notation and avoid excessive clef changes.

### 5.3. Harmonic Notation in TAB+

The TAB+ system provides the ability to represent chords. Figure 10 demonstrates root position diatonic triads in the key of C major played with two hands. In contrast to tablature systems used for fretted instruments, which typically use a single number per line to indicate the string and fret position, TAB+ utilizes multiple numbers on a single line to indicate that multiple pads need to be played within a specific row. Furthermore, Figure 10 demonstrates the application of ledger lines in chord notation. The first three diatonic triads notated in **β** clef with ledger lines below the tablature indicate that the notes of the chords are in both **β** and **B** nano layouts.

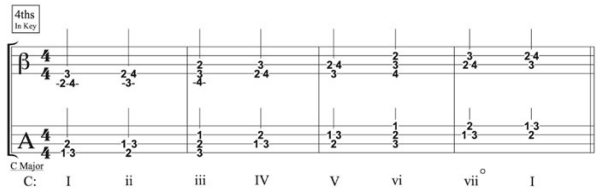


**Figure 10**. Root position diatonic triads in C major.

The examples thus far have demonstrated the use of TAB+ in the Vertical direction of the Push. The same notation principles are transferable to the Horizontal direction and other grid TUIs and GUIs with the capacity for changing the directional layout. Figure 11 illustrates the notation of a one-octave C Major (C2–C3) scale played by the left hand in the Horizontal direction.

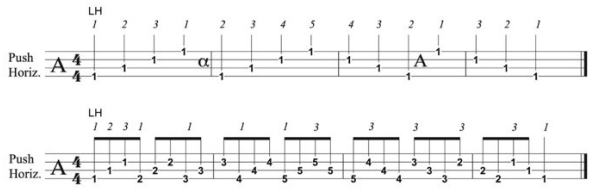


**Figure 11**. A one-octave C major scale (C2–C3) in 4ths Layout, 'In Key' mode, and Horizontal direction.

Indicating the direction parameter (i.e., vertical or horizontal) within a musical score is needed as it affects how the notation is read and realized in teaching, learning, and performance contexts. The TAB+ system incorporates the abbreviations used by Ableton in the Push display for vertical and horizontal, 'Vert.' and 'Horiz.' directions into the score (Fig. 12). This integration not only enhances the accuracy of musical notation but also streamlines musical communication.

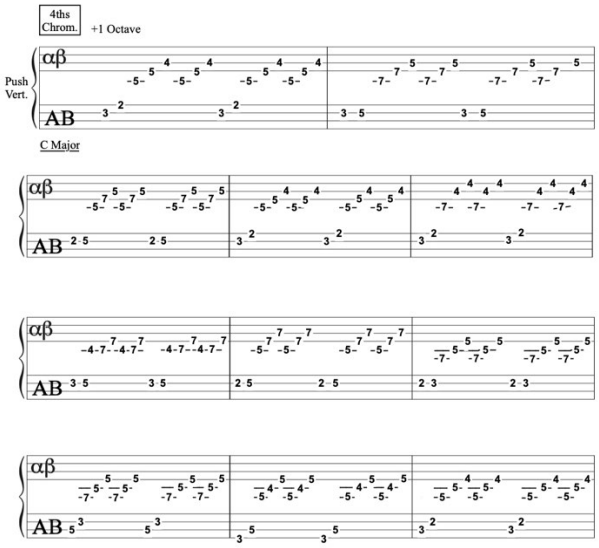


**Figure 12**. J. S. Bach, "Prelude No. 1 in C Major," from *The Well-Tempered Clavier, Book I*, measures 1–11, notated using the TAB+ system.

## 6. STAFF+: TRADITIONAL STAFF NOTATION WITH TAB+ CLEFS AND ROMAN NUMERAL MATRICES

### 6.1. Single-Line Notation in Staff+

The Staff+ subsystem of TABstaff+ is designed with the view that 'regardless of the many varied developments around the fundamental elements of music,' the traditional five-line staff notation offers immense 'flexibility' in terms of notation for electronic music [21]. As such, Staff+ expands on the traditional five-line staff notation system through the incorporation of the **A**, **B**, **α**, and **β** TAB+ clefs (introduced above) and Roman numeral matrices for labeling specific pads. Similar to TAB+, the alpha and beta clefs specify one of the four nano layouts. Unlike in TAB+, which indicates pads using tablature lines for pad rows and Arabic numerals (i.e., one to four and one to eight), the Staff+ system employs Roman numeral pairs (e.g., **(II, ii)**) for specifying individual pads. The uppercase Roman numeral indicates the location of the pad on the x-axis, and the lowercase numeral specifies the location of the pad on the y-axis (Fig. 13). The Staff+ system uses alpha-numeric indicators to clarify pitch and octave for notes on the conventional five-line staff and the corresponding pads on the grid-playing surface. These indicators combine either an alpha or beta clef with a Roman numeral pair (for instance, **B (II, iv)**).

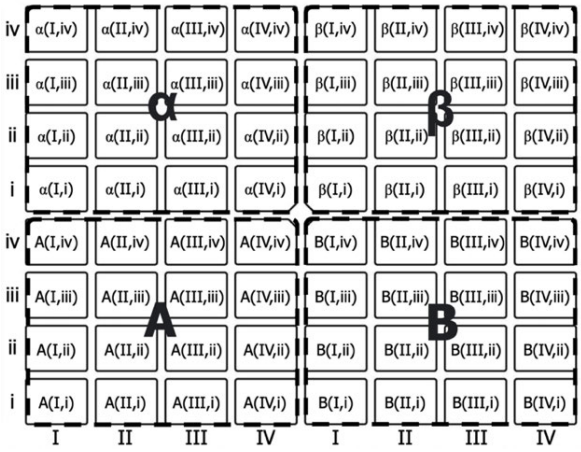


**Figure 13**. TAB+ clefs and Roman numeral matrices specifying 16-pad (4×4) nano layouts and individual pads.

Using alpha-numeric indicators, an ascending and descending two-octave C major scale (C4–C6) would be notated, as shown in Figure 14. The starting pitch (middle C) is labeled **B (II, iv)**. The **B** clef clarifies which nano layout notes are to be played in, and the Roman numeral pairs specify the pads corresponding to the notes. With this information, the user knows to position their right hand over the nano layout **B** in the bottom right of the Push and play the second pad (x-axis: **II**) in the fourth row (y-axis: **iv**). In Staff+, the alpha-numeric markers also serve as points of reference for transitions between different nano layouts. As seen in Figure 14, the **β (II, i)** specifies that with F4,

the hand shifts to and remains in the upper right nano layout until the E4 in the last measure, where **B (IV, iv)** indicates the transition back to the bottom right nano layout. Similar to the TAB+ system, italic Arabic numerals are used for fingerings and transitions between pad rows (Fig. 14).

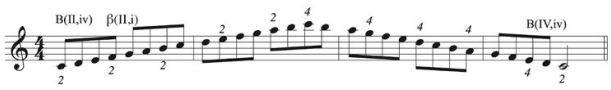


**Figure 14**. An ascending two-octave C major scale in Staff+ notation with TAB+ clefs and Roman numeral pairs indicating transitions between nano layouts.

For two-hand notation, Staff+ employs the conventional grand staff with treble and bass clefs. The use of traditional notation provides 'everything we need to capture the quintessential elements of music: pitch on the vertical, time on the horizontal, and anything else in the margins' [21]. Alpha-numeric indicators are used in both staves to designate notes and their corresponding pads. Figure 15 shows an example of a two-octave C major scale in sixths notated on a grand staff with treble and bass clefs, TAB+ clefs, and Roman numeral pairs, the amalgamation of which defines the Staff+ notation system.

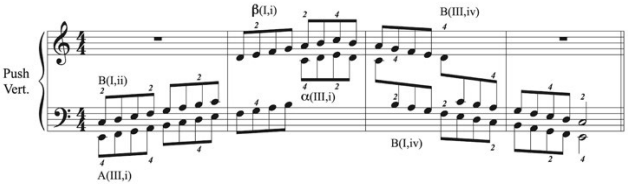


**Figure 15**. An ascending two-octave C major scale (in sixths) in Staff+ with TAB+ clefs and Roman numeral pairs indicating transitions between nano layouts.

In the above example, the right hand (treble clef) begins on pad **B (I, ii)**. As the scale ascends, **β (I, i)** is used to show the transition of the hand into the upper-right nano layout; as the scale descends, **B (III, iv)** designates the transition back to the lower-right nano layout. Similar indicators for the left hand (bass clef) are observed in Figure 15. As the left-hand traverses all four nano layouts during the scale, three TAB+ clefs (**A**, **α**, and **B**) are used to mark transitions between the lower half of the instrument (32-pads **(A, B)**) and the upper half of the instrument (32-pads **(α, β)**).

### 6.2. Harmonic Notation in Staff+

In Staff+, the TAB+ clefs with Roman numeral pairs can be used for notating chords and other harmonic material. As seen in Figure 16, diatonic triads in C major can be notated by indicating the lowest note of the chord. For example, a root position C major triad built on C4 would be notated using the **B** clef and the Roman numeral pair **(II, iv)**. By labeling the root position C major triad alpha-numerically with **B (II, iv)**, the register of the chord and its position on the instrument are made clear.

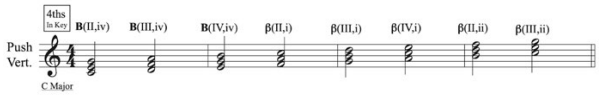


**Figure 16**. Root position diatonic triads in C major with TAB+ clefs specifying nano layouts and Roman numeral pairs indicating the position of the lowest note of each triad on the instrument.

Chord inversions are represented by specifying the position of the lowest note of a given chord. As seen in Figure 17, **B (IV, iv)** indicates a C major triad in the first inversion (lowest note E4), and **β (III, i)** specifies the second inversion (lowest note G4).

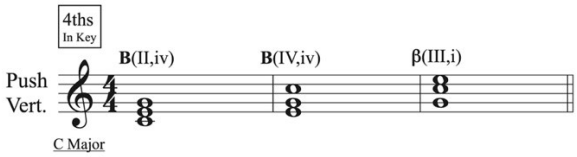


**Figure 17**. Staff+ labeling for inversions.

As demonstrated by the provided examples, Staff+ builds the traditional five-line staff notation by introducing TAB+ clefs and Roman numeral matrices. These elements are designed to aid in reading, learning, teaching, and performing music on the Push, other grid TUIs and GUIs.

## 7. CHARTS+: CHORD DIAGRAMS FOR THE PUSH AND GRID INTERFACES

### 7.1. Chord Diagrams for 'In Key' Mode

Charts+ is the third subsystem of TABstaff+; it utilizes 16, 32, and 64-pad diagrams for graphical representation of chords and playing actions such as the triggering of loops, sequences, formal sections, and other discrete musical elements [35]. The 16 and 32-pad diagrams are used primarily for chords in 'Note' mode on the Push, and 64-pad diagrams are used for specifying the activation and deactivation of loaded clips in 'Session' mode. Indicating chords using 64-pad diagrams is possible (Fig. 18); however, 16-pad and 32-pad diagrams offer the advantage of being easier to read, more space efficient in score formats, and resembling traditional chord diagrams used for instruments like guitar, ukulele, and others.

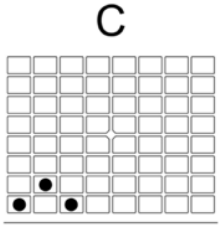


**Figure 18**. A Charts+ 64-pad diagram for a C major triad in root position.

In traditional chord charts, horizontal lines represent frets, and vertical lines represent strings, in Charts+, cell grids are used to represent pads. Similar to traditional chord charts, finger indications are given using black dots, which can be solid or contain numbers for finger indications. Light grey gird cells are used to show the tonic of a given scale (Fig. 19). Additionally, it is possible to specify scale, layout, and mode parameters within the charts.

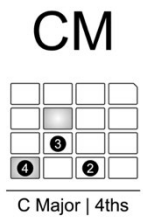


**Figure 19**. A Charts+ 16-pad diagram for a C major triad in root position with finger indications for the left hand.

The Charts+ system can be used in tandem with the Staff+ and TAB+ systems. Figure 20 shows how chord charts can be added above staves to specify finger placements corresponding to the notated triads.

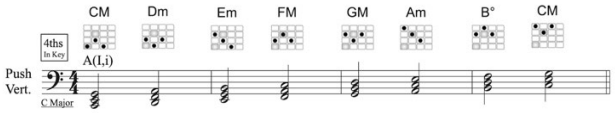


**Figure 20**. Root position diatonic triads in Staff+ with Charts+ diagrams.

Due to the different pad layout possibilities of the Push and similar grid instruments, there are multiple ways to play a given chord. For example, in the 4ths layout, a C major triad can be played with four different finger patterns. As observed in Figure 21, the C major triad can be played on a single row of pads (finger pattern one), two rows with two pads on the lower row and one pad on the upper row (finger pattern two), two rows, with one pad on the lower row and two pads an on the upper row (finger pattern three), and lastly, across three pad rows with a single pad per row (finger pattern four).

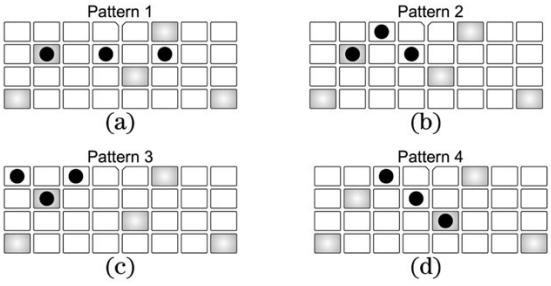


**Figure 21**. 32-pad Charts+ diagrams showing four finger patterns for a C major triad in root position.

Finger patterns two (b), three (c), and four (d) can be notated using 16 or 32-pad diagrams given that these lie on adjacent pad columns (Fig. 21). Finger pattern one (a) requires the use of a 32-pad chart, as it spans five pad columns, extending beyond the 4×4 grid of a 16-pad nano layout. Chords between two different 16-pad nano layouts can be represented graphically using a 32-pad diagram.

As observed in Figure 21, finger patterns one (a) and four (d) have two notes in the bottom left nano layout and one in the bottom right. This necessitates the use of a 32-pad diagram for graphical representation. The versatility of 16 and 32-pad chord diagrams can be observed in specifying extended chords and other complex harmonies. These diagrams enhance the comprehension of intricate chord structures, providing a valuable resource for teachers, students, and practicing musicians.

### 7.2. Chord Diagrams for 'Chromatic' Mode

The notation of chords in the 'Chromatic' mode on the Push requires 32-pad diagrams. As the addition of chromatic pitches makes finger patterns wider, two 16-pad nano layouts are needed for playing chords (Fig. 22). The Chart+ diagrams employ black and white grids to represent unlit and lit pads in 'Chromatic' mode.

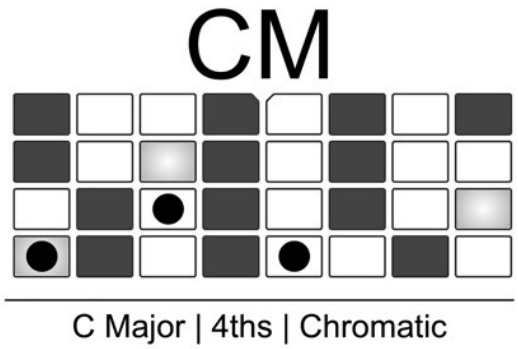


**Figure 22**. Charts+ diagram for a root position C major triad in the 'Chromatic' mode.

Similar to how a chord can be played with different finger patterns using the 'In Key' mode, the same holds in the 'Chromatic' mode. Figure 23 shows three finger patterns for playing the same F major triad. Each pattern offers unique flexibility depending on the musical or pedagogical context.

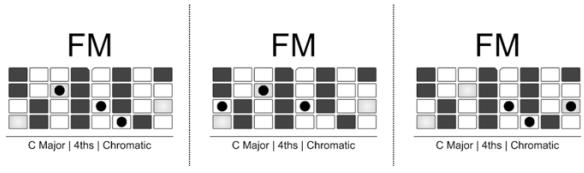


**Figure 23**. Three Charts+ diagrams showing different finger patterns for the same root position F major triad in the 'Chromatic' mode.

Charts+ offers a dynamic and versatile solution for artists and educators, seamlessly integrating notation with diverse TUIs and GUIs.

### 7.3. Diagrams for 'Session' View on the Push

The Charts+ system can be used in the 'Session' mode for indicating the triggering of clips containing musical fragments such as loops, song sections, and other elements at various levels of musical structure. The diagrams for the 'Session' mode use three grayscale colors for specifying empty, loaded, and active clips. Black pads indicate open clip slots, light grey pads specify loaded clips, and white pads show active clips. Black dots are used to indicate which pads should be pressed to launch clips (Fig. 24 a). On the Push, there are two main methods for stopping clips; the first is to press an empty slot within the track (column of pads) that contains the active clip (Fig. 24 b), and the second is to use the 'stop clip' button (Fig. 24 c). The '×' symbol is used to indicate which pads are to be pressed to deactivate clips.

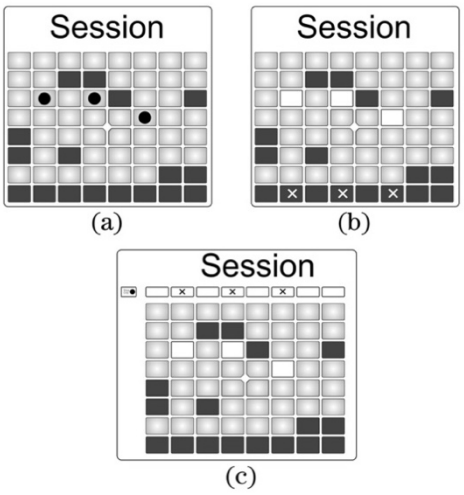


**Figure 24**. Charts+ diagrams for 'Session' view; (a) shows the triggering of clip slots, (b) specifies the stopping of clips using open slots, and (c) shows the stopping of clips using the 'stop clip' button and buttons below the display screen.

Instructions for deactivating clips using the second method are given in the chart (Fig. 24 c) by indicating pressing the 'stop clip' button in combination with the buttons below the display screen corresponding to the track(s) containing active clip(s). These examples illustrate the use of grid cell diagrams of various dimensions for the graphical representation of chords and other discrete musical structures. The diagrams presented above can be adapted to various musical grid interfaces and applied to a wide range of artistic and pedagogical contexts.

## 8. CONCLUSION

The TABstaff+ notation system presented in this paper is designed to provide a robust means of graphically communicating musical structures for musical grid interfaces. The paper emphasized the need for comprehensive notation systems that account for the unique attributes of these instruments. A new notation system, TABstaff+, was introduced as a versatile solution for this challenge. TABstaff+ encompasses three subsystems: TAB+, Staff+, and Charts+. These systems, while building on established notation conventions, consider the specialized layout of musical grid interfaces, allowing musicians and educators to communicate ideas more effectively. The TABstaff+ system leverages HCI and pre-digital practices of reading, playing, and teaching music with instruments and notation. The paper stressed the importance of music literacy, especially in a world where digital technologies are increasingly integrated into music education. TABstaff+ is presented as a means of enhancing pedagogical approaches, making it easier for students to learn, play, and comprehend music on grid-based instruments. The paper provided insights into the adaptability and flexibility of the TABstaff+ notation system across different layouts and modes, showcasing its applicability in various contexts. It highlighted the potential of TABstaff+ to empower musicians, educators, and learners by offering a systematic and user-friendly approach to musical notation that bridges the gap between traditional and digital music education. The implications of TABstaff+ resonate with broader discussions on HCI and the evolving relationship between technology, education, and the arts. As the digital landscape continues to shape the future of music, TABstaff+ aims to contribute to the development of postdigital artistic and pedagogical practices.

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