Digitl Protocol: Enabling Precise Multichannel Digital Audio Transmission for X-Y Matrix Interfaces

ABSTRACT

This paper introduces the Digitl Protocol, a framework designed to enhance the interaction between performers and multichannel digital audio processors in order to achieve precise synchronization between them.

Central to this protocol is a novel approach to digital audio channel management, where each channel is dynamically assigned to the most recent sonic actions of the instrumentalist of an X-Y matrix interface.

This architecture makes possible multiple mapping possibilities, linking actions on the X-Y interface to an unlimited set of pitches and timbres.

The Digitl Protocol thereby significantly enhances the expressive capabilities of digital musical interfaces, offering musicians unprecedented control and variety in sound generation and diffusion.

Author Keywords

Musical Action, Digital Audio Transmission, X-Y Interface

CCS Concepts

• **Applied computing → Sound and music computing**; Performing arts;

1. INTRODUCTION

In the digital era, the evolution of musical expression has been significantly influenced by advancements in data transmission technologies and protocols.

Music data protocols, such as MIDI (Musical Instrument Digital Interface) [1] and OSC (Open Sound Control) [2], or the more recent O2 [3], are engineered to facilitate the exchange of control data and performance information between electronic devices. These protocols do not carry the audio signals themselves but rather instructions on how these signals should be generated, manipulated, or interpreted. For instance, MIDI can communicate key presses from a keyboard, control changes like volume adjustments, or program changes to switch between different instrument sounds, all without transmitting any actual sound data.

In contrast, digital audio transmission protocols, notably Dante/AES67 (Digital Audio Network Through Ethernet), and AVB (Audio Video Bridging), specialize in the high-fidelity distribution of audio signals over networks. These technologies are designed to ensure that audio content is transmitted with minimal latency and maximum quality. Unlike MIDI or OSC, which deal with performance metadata, Dante/AES67 and AVB handle the actual sound, preserving its quality and integrity.

The X-Y Matrix Interface, in the context of digital musical expression, is a specialized control surface designed for precise musical input and interaction. This interface has usually a grid-like layout [4] .

The Digitl Protocol represents an innovative approach to integrating the functionalities of both, music data and digital audio transmission protocols, into an unified system that defines the cyclical channel allocation and the metadata association of the musical actions performed in an X-Y Matrix Interface.

The Digitl Protocol framework enables musicians to assign specific and independent digital processes to the audio signal of every X-Y position that is actioned. The protocol is an ingredient of a platform for distributed musical application, with conceptual similarities with KO2, that merges the messaging protocol O2 with the signal processing language Kronos [5].

2. THE DIGITL PROTOCOL: CONCEPT AND DESIGN

The Digitl Protocol stands at the vanguard of digital music technology, introducing a framework designed to bridge the gap between the tactile expressiveness of musicians and the vast possibilities of digital audio processing.

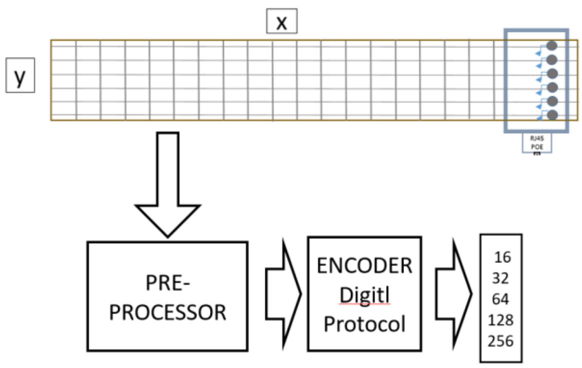

Figure 1. X-Y Interface Actions to Encoder

2.1 Detailed Explanation of the Digitl Protocol

The essence of the Digitl Protocol lies in its ability to transform raw musical actions captured from an X-Y matrix interface into a structured digital format, ready for processing. This transformation is achieved through a sequence of stages, beginning with the pre-processor analysis of incoming audio signals, followed by the packaging of the encoder (see Figure 1), and culminating in the routing of signals to a Multichannel Processor by the decoder.

The cyclical channel allocation algorithm dynamically manages the allocation of audio data from musical actions [6] [7] to a fixed number of channels in a sequential process. It ensures that the system can handle a continuous stream of input by overwriting the oldest audio data with the newest, thereby maintaining a real-time reflection of the

NIME'24, September 4–6, 2024, Utrecht, The Netherlands

most recent musical expressions. This part of the protocol is crucial for managing the parallel transmission of multiple audio signals, allowing for real-time processing and interaction.

Alongside the audio data, metadata specific to each action's audio content is transmitted. This metadata may include information such as the X-Y position of the action; the initial pitch of the note; the intensity and other relevant details that can be used for advanced audio processing, like in Keith McMillen's Acoustic Instrument Message (AIM) protocol [8]. The association of metadata with each audio channel enhances the depth and expressiveness of the music, enabling more sophisticated sound manipulation and processing based on the characteristics of each musical action.

2.2 The Role of PreProcessor

Positioned at the entry point of the protocol's processing chain, the preprocessor analyzes raw audio signals to extract data, including the X-Y positions of musical actions and their corresponding pitches. This component also establishes an action counter, which plays a crucial role in maintaining the sequence of musical events for processing.

2.3 Encoder Functionality

The encoder translates the analyzed data into a digital format and manage the transmission of this data across digital channels. It operates based on foundational parameters, such as the matrix dimensions and the number of digital channels, to ensure that the audio signals are accurately represented and transmitted for processing.

2.4 Decoder Operations and Signal Routing

Upon receiving the encoded data, the decoder routes each audio signal to the appropriate processing pathway within the Multichannel Processor engine. This routing is determined by the X-Y position metadata, allowing for the application of specific digital processes to each musical action (see Figure 2).

Figure 2. Pathway within the Multichannel Processor

3. IMPLEMENTATION

3.1 Establishing Connection between Hosts

In order to establish an effective connection and communicate accurately between hosts, certain foundational data elements must be clearly defined and exchanged. These elements ensure that both ends of the protocol understand the configuration of the system, how data is structured, and how it should be processed.

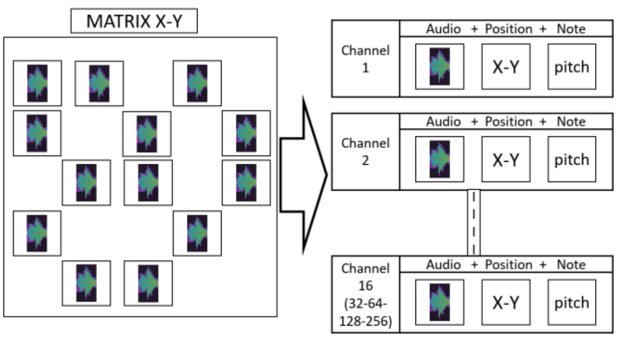

Figure 3. Sound Actions to Digital Audio Channels

3.1.1 Matrix Dimensions (X-Y)

It's the size of the X-Y matrix interface. This information is basic to map the physical actions on the interface to the corresponding digital representations.

The dimensions include the total number of rows (X) and columns (Y) available on the matrix interface. For example, an interface might have a 10x10 matrix, indicating 10 rows and 10 columns.

3.1.2 Number of Digital Channels

It's the total number of digital audio channels that the system can handle concurrently. This parameter determines the capacity for simultaneous audio signal transmission and is essential for managing the cyclical channel allocation.

The configuration can vary (16, 32, 64, 128, 256), and both the encoder and decoder must agree on the number to ensure proper channel management and audio data routing (see Figure 3).

3.1.3 Action Counter

It's a sequential identifier for each musical action captured by the system. The action counter is vital for tracking the order of actions and ensuring that the most recent actions are correctly processed.

It's a numerical value that increments with each action detected on the X-Y matrix interface. This counter helps manage the cyclical allocation of actions to the available digital channels.

3.1.4 X-Y Position of every Action

It's the specific location on the X-Y matrix interface where each action occurred. This data is critical for applying the appropriate digital processing to each audio signal based on its origin.

The X-Y position is represented by two numbers corresponding to its row (X) and column (Y) on the matrix, allowing for precise spatial identification within the digital processing framework.

3.1.5 Establishing Connection and Communication

Upon establishing a connection, the encoder and decoder exchange this foundational data to synchronize their configurations. This setup phase ensures both hosts are aligned in terms of the matrix dimensions, channel capacity, and operational parameters.

As the system operates, the encoder continuously sends updated data packets containing the latest actions audio data, X-Y positions, and action counter. The decoder uses this information to route the audio signals accordingly.

3.2 Cyclical Channel Allocation Algorithm

The cyclical channel allocation algorithm is a key component of the Digitl Protocol, designed to efficiently manage and allocate a finite number of digital audio channels for processing musical actions.

3.2.1 Principles

Fixed Number of Channels: The algorithm operates with a predefined number of digital channels (e.g., 16, 32, 64, 128, 256), which represent the number of simultaneous audio signals that are transmitted.

Sequential Allocation: Each new musical action detected by the system is assigned to the next available channel in a sequential manner.

Position X-Y: The row and column is assigned to every action (see Figure 4).

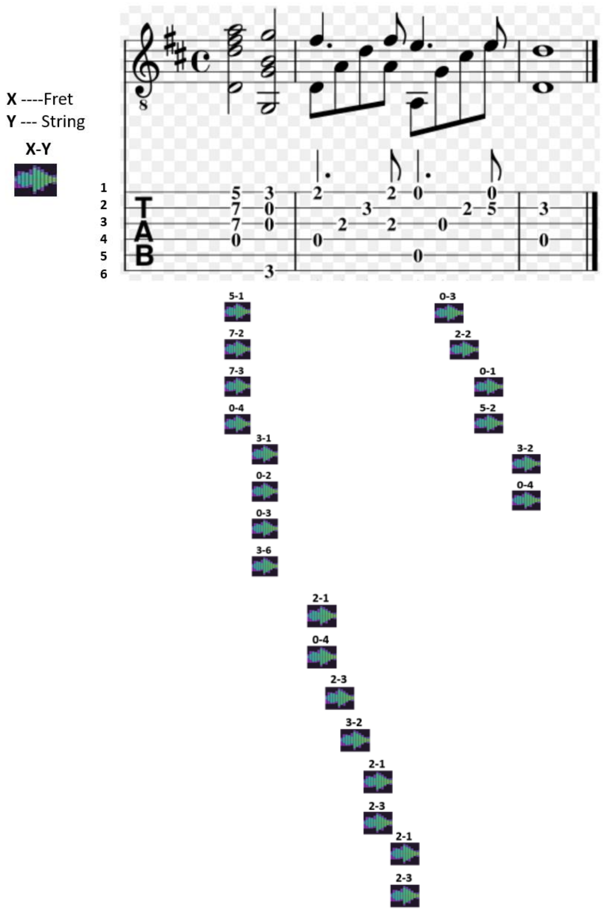

Figure 4. Musical Actions to 16 Digital Audio Channels

3.2.2 *Operational Workflow*

Action Detection: When a new musical action occurs (e.g., a note is played on the X-Y matrix interface), its audio signal is prepared for allocation.

Channel Allocation: The algorithm assigns the audio signal to the channel indicated by the internal counter

Cyclical Overwrite: When the counter reaches the end of the channel list, it loops back to the first channel, continuing the process in a cyclical manner. This mechanism guarantees that the system dynamically updates with the most recent musical actions.

Metadata Association: Alongside the audio signal, metadata such as the action's X-Y position and possibly its pitch are also associated with each channel, informing subsequent processing steps.

3.2.3 *Significance and Applications*

Real-Time Processing: This algorithm is important for instrumental systems where real-time multichannel audio processing is necessary. The Multichannel Processor is conceptually a dedicated and specialized unit, but is an integral part of the instrument itself, and defines the digital nature of the physical instrument. The protocol ensures that the digital representation of the performance is always present.

Flexibility: The algorithm's design allows multiple processing capabilities by simply adjusting the number of channels it manages. A parallel or serial architecture of Multichannel Processors is a possibility.

4. MULTICHANNEL PROCESSOR

4.1 The Heart of Digital Instrumentation

While the Digitl Protocol provides the innovative framework for capturing and transmitting musical actions and their associated data, the Multichannel Processor emerges as the keystone of digital music creation and performance. It is here, within this dedicated processing unit, that the essence of a distributed digital instrument is defined and realized.

The Multichannel Processor is the primary application platform for the Digitl Protocol. However, it isn't a part of the protocol's core architecture. It acts as the creative engine, where the raw digital signals are crafted into rich, complex musical expressions.

4.1.1 *Capabilities and Functionality*

Complex Processing Chains: Each channel received from the Digitl Protocol can undergo a series of processing steps. These chains are configurable and can include effects such as pitch shifting, reverb, delay, modulation, dynamic processing, and more.

Serial and Parallel Processing: The processor has the flexibility to apply effects in serial for individual channels or in parallel, allowing multiple processes to occur simultaneously for different sonic actions.

Global Processing and Mixing: Beyond individual channel processing, the Multichannel Processor integrates a global processing layer. This layer applies overarching effects and mixing controls to the aggregate audio output, ensuring a balanced, harmonious final product that aligns with the artist's vision.

Collectively represents the modern concept of Digital Lutherie [9] .

4.2 Expanding Expressive Potential through Pitch Mapping

A standout feature of the Multichannel Processor within the Digitl ecosystem is its ability to dynamically map musical actions to a diverse array of pitch sets. This capability not only enhances the tonal versatility of the digital instrument but also enhances musicians to explore musical landscapes.

The Multichannel Processor is engineered to interpret the initial actions detected by the Digitl Protocol and assign them to specific pitches. This process goes beyond traditional fixed-note mappings, allowing for the creation of custom scales or the application of unique tonal transformations that reflect the musician's artistic intent.

Instrumentalists have the option to alter these mappings in real-time using data controllers integrated within the instrument. This immediate responsiveness encourages experimental performances and compositions, as artists can shift between tonalities or scales on the fly, responding to the evolving dynamics of their music.

5. FUTURE DEVELOPMENTS

As we look toward the horizon of digital music technology, the aspiration to materialize the Digitl Protocol into tangible hardware becomes not just a possibility, but also an imminent reality.

The digital age has experimented a rapid evolution of processing technologies. GPUs are emerging as powerhouses capable of handling complex computations across multiple cores simultaneously. The application of this technology to audio processing, particularly in the context of the Digitl Protocol, opens up a new world of possibilities. A dedicated hardware unit, designed specifically for audio and leveraging the parallel processing strength of GPUs, promises to achieve minimal latency, a critical factor in live performance and high-fidelity audio production.

The primary goal for this device is to enable real-time processing of digital audio signals with unprecedented speed and efficiency, ensuring that the expressive nuances of musical performance are captured and enhanced.

By incorporating the functionality of the Digitl Protocol, the device will offer musicians a vast array of sound manipulation tools, from dynamic pitch mapping to intricate effects chains, all customizable in real-time and with minimal latency.

The materialization of the Digitl Protocol into a dedicated hardware device represents a significant leap toward the future of digital music. As this technology moves from concept to reality, it promises to unlock new creative potentials and redefine the boundaries of musical expression. The future developments in this area not only hold the promise of enhanced musical experiences but also signal a new era of innovation in digital music technology, where the power of parallel processing and the creativity of musicians converge to create the soundscapes of tomorrow.

6. CONCLUSION

As we reach the culmination of our exploration into the Digitl Protocol and its symbiotic relationship with the Multichannel Processor, it becomes clear that we are stepping up in a transformative era in digital music creation and performance.

Meanwhile, the Multichannel Processor emerges as the essential tool for realizing the artistic potential facilitated by the Digitl Protocol. Its capability to apply specific digital processes to audio signals based on their original X-Y positions, gives to the musicians endless possibilities for sound manipulation and creation.

The journey of discovery is just beginning, and the future of digital music, enriched by technologies like the Digitl Protocol and the Multichannel Processor, is unlimited like our imagination.

7. ACKNOWLEDGMENTS

Thanks to the (artistic) efforts and developments from the past.

8. ETHICAL STANDARDS

No conflicts of interest has been found.

9. REFERENCES

[1] J. Rothstein, "MIDI: A Comprehensive Introduction", A-R Editions, 2nd edition 1995

[2] M. Wright, A. Freed, and A. Momeni, "Open Sound Control: state of the art ", Proceedings of the 2003 Conference on New Interfaces for Musical Expression (NIME-03), pp. Montreal, Canada

[3] Dannenberg, Roger. (2019). O2: A Network Protocol for Music Systems. Wireless Communications and Mobile Computing. 2019. 1-12. 10.1155/2019/8424381.

[4] Rossmy, B., & Wiethoff, A. (2021). Musical Grid Interfaces: Past, Present, and Future Directions. NIME 2021. https://doi.org/10.21428/92fbeb44.6a2451e6

[5] Norilo, Vesa & Dannenberg, Roger. (2018). "KO2 - Distributed Music Systems with O2 and Kronos" Sound and Music Computing Conference, Limassol, Cyprus.

[6] A. R. Jensenius. Action–Sound : Developing Methods and Tools to Study Music-Related Bodily Movement. PhD thesis, University of Oslo, 2007

[7] Jensenius, Alexander & Wanderley, Marcelo & Godøy, Rolf & Leman, Marc. (2009). Musical Gestures: concepts and methods in research. *Musical Gestures: Sound, Movement, and Meaning.* 10.4324/9780203863411.

[8] https://www.keithmcmillen.com/wp-content/uploads/2015/11/The_Acoustic_Instrument_Message_Specification_0.4.pdf

[9] Jordà, Sergi. (2004). Instruments and Players: Some Thoughts on Digital Lutherie. Journal of New Music Research. 33. 10.1080/0929821042000317886.