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Accessibility in Pure Data for visually impaired musicians: a real-time soundscape strategy

Accesibilidad en Pure Data para músicos con discapacidad visual: una estrategia de paisaje sonoro en tiempo real

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Abstract
Background: Pure Data (Pd) is a predominantly visual programming language widely used by musicians in the process of composition and musical performance that involves sound synthesis. This visual characteristic implies poor accessibility for a visually impaired musician (VIM) because screen readers do not allow recognition and/or manipulation of language elements. Objectives: This work aims to present an inclusive strategy that enables VIM to interact with other musicians in real-time during performances. Methods: A sighted musician programmed a Pd script consisting of five patches. Switches and potentiometers of a MIDI controller matched elements of the script, activating and modulating parameters of sound clips. The VIM uses the screen reader to access Pd, open the programmed code, configure the MIDI controller, and enable audio output. The performance is executed by the VIM. Results: The result of the elaborate composition was a live soundscape performance that had similarity in the manipulation of the MIDI controller with that of the sighted musician. Conclusion: These strategies enabled a VIM to perform autonomously in real time using Pd patches, fostering interaction with sighted musicians and expanding accessibility.

Keywords: Accessibility; Visually impaired musicians; Pure Data; MIDI controller; Free improvisation.

Resumen
Introducción: Pure Data (Pd) es un lenguaje de programación predominantemente visual ampliamente utilizado por músicos en los procesos de composiciones e interpretaciones musicales que implican síntesis sonora. Esta característica visual implica una accesibilidad deficiente para un músico con discapacidad visual (MDV), ya que los lectores de pantalla no permiten reconocer y/o manipular los elementos del lenguaje. Objetivos: Este trabajo pretende presentar una estrategia inclusiva que permita a los MDV interactuar con otros músicos en actuaciones en directo. Métodos: Un músico vidente programó un guión de Pd compuesto por cinco parches. Los interruptores y potenciómetros de un controlador MIDI se ajustaban a los elementos del guión, activando y modulando los parámetros de los clips de sonido. El MDV utiliza el lector de pantalla para acceder a Pd, abrir el código programado, configurar el controlador MIDI y habilitar la salida de audio. El MDV ejecuta la actuación. Resultados: El resultado fue una actuación de paisaje sonoro en directo que presentaba similitudes en la manipulación del controlador MIDI con la del músico vidente. Conclusión: Estas estrategias permitieron a un MDV actuar de autónomamente en tiempo real utilizando parches de Pd, favoreciendo la interacción con músicos videntes y ampliando la accesibilidad.

Palabras clave: Accesibilidad; Músicos con discapacidad visual; Pure Data; Controlador MIDI; Libre improvisación.

Introduction
Pure Data (Pd) is an open-source, free-to-use, visual programming language [1] that focuses on the production of computational, electro-acoustic, and/or interactive music and multimedia works, thereby promoting real-time interaction among audio, MIDI, graphics, and video [2]. These characteristics confer efficiency, versatility, and robustness, making Pd a widely used tool by musicians and researchers [3-5]. A notable advantage is the active community of contributors [6], which benefits those who want to produce multimedia. Collaboration can be a crucial tool for boosting creativity in audio production, especially when a community of collaborators is available.
A recent study found that audio producers must constantly make judgments based on audio and visual evidence, using complex production tools [7]. Therefore, there is a challenge for audio producers who are either blind or have low vision. In this paper, subjects from both impairment categories are referred to as visually impaired (VI) musicians. The problem of audio equalisation was tackled by researchers who developed the HaptEQ system. It is one of the approaches to increase accessibility of digital audio production

tools for VI producers. It consists of a physical setup that uses passive tactile elements as surrogates for virtual controllers on the screen [8]. However, live digital audio synthesis remains problematic for contemporary music VI performers.

Musicians can develop Pd projects to produce audio through live presentations or live performances [9, 10]. However, despite its performance and versatility, not everything in Pd is accessible, especially for VI users. The most striking feature of this system is the systematic use of the mouse as a device that allows changing the code and providing visual feedback [9]. The creation and maintenance of source code are based on systematising small boxes (objects) that use parameters configured by numbers and letters. These objects are interconnected by virtual lines, forming a 'set of objects' (a.k.a. patch) to produce the sound result [11]. Figure 1 presents an example Pd patch. A simple analysis reveals that this fact makes it impossible for a VI musician to exploit its resources.

Assistive Technology (AT) solutions enable VI users to access digital technologies. AT is a set of resources and services that enable or enhance the functional abilities of people with disabilities and promote autonomy and inclusion [12]. Screen readers (e.g., NonVisual Desktop Access – NVDA [13]) are the primary resources used for digital inclusion. In principle, these ATs guarantee accessibility to VI users, enabling Internet browsing and the operation of various software. It expands and enhances processes related to education, communication, work, socialisation, art, entertainment, and other activities.

NVDA is one of the most widely used screen readers today, ensuring accessibility and autonomy for more than 100,000 people with visual impairment in more than 150 countries [14]. Also noteworthy is its gratuity and updates from voluntary contributions from developers, making it an attractive alternative for users and contributing to digital inclusion. However, previous studies have shown that not all graphical elements on a screen can be accessed by screen readers [15]. Relying solely on a conventional screen reader for media editing and production may not be sufficient. Lazar et al. [16] investigated its use when browsing web pages and identified many inconsistencies. The Pd use case is an excellent example of a software platform that presents difficulties to VI musicians using only a screen reader. Screen readers are ineffective at interpreting images and graphics, such as those used to manipulate Pd visual programming objects, because they do not provide adequate feedback from the interface [17].

The visual elements in the Pd canvas cannot be converted to audio feedback [15]. This limitation prevents VI musicians from fully exploiting its features and capabilities. Therefore, a VI musician cannot access Pd, which compromises the perspectives on editing, musical creation, and interaction with other musicians on this platform. Therefore, it would be of particular interest to develop an alternative mode for the operation of these elements of Pd. Thus, the objective of this work, as a preliminary study, is to promote accessibility through hardware for a visually impaired musician, allowing him to generate soundscapes in real time and autonomously, overcoming the inaccessibility of Pure Data's graphical user interface.

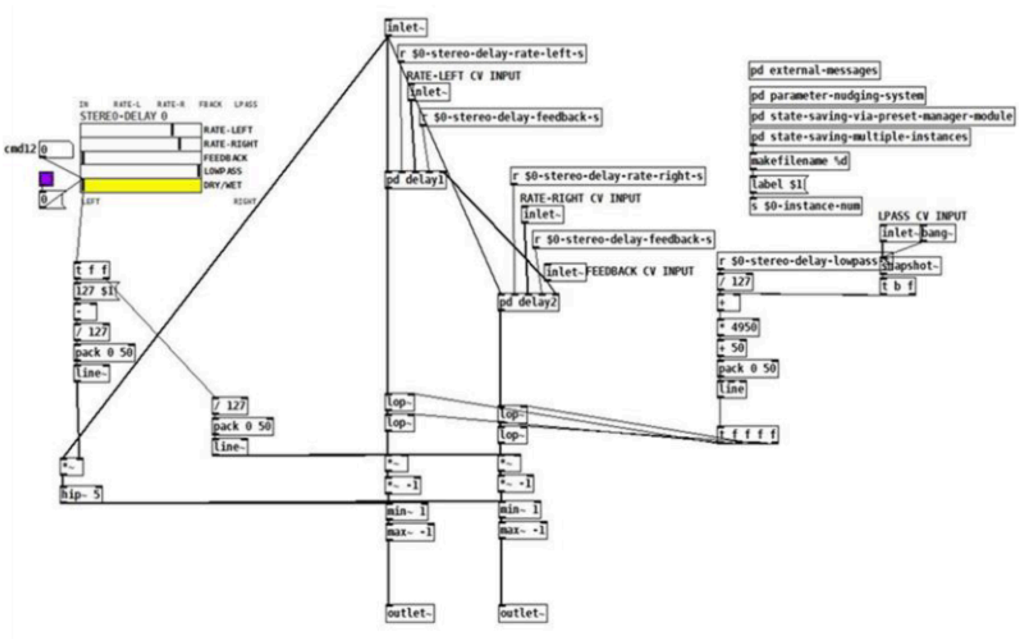

Figure 1. Example Pd patch (Source: authors).

Materials and Methods

The following subsections present the resources used by a VI musician in the approach performed and explain the method.

Computer

The solution in this work involves using a computer as the central element of the devices, with the sound synthesis software installed. The operating system (OS), hardware, and connectivity characteristics may determine the audio performance and quality. The system must have sufficient RAM space and processing power to run the patches, and the OS and screen reader must not negatively impact sound quality or synchronisation. In addition, the computer must provide internet connectivity (for remote performances) and at least one USB port.

In the present work, we used an Avel laptop (model A70 MOB) equipped with an Intel Core TM i7-11800H processor (2.3 GHz), with a 24 MB cache, 32 GB Dual Channel RAM, 1 TB SSD M.2 NVME hard drive, and GeForce RTX 3060 (6 GB GDDR6) video card running Windows 11 Server. All OS updates for November 2022 have been installed. The laptop had three USB 3.0 ports and one Realtek Audio sound card. DELL USB speakers were connected to the USB port and provided audio feedback to the VI musician.

Pure Data

In the proposed approach, Pure Data was used in its stable Vanilla 0.51.4 version. No additional external was incorporated into the installation.

MIDI Controller

This device consists of pushbuttons, knobs, and sliders, which enable the handling and control of resources, such as functions and commands in music production programs [18], replacing the computer mouse for manipulating objects in Pd. Thus, the difficulty of operating the virtual elements is minimised.

The CR-9 controller (KFX, China) was used (Figure 2), consisting of 20 pushbuttons, nine knobs (red box), nine vertical sliders (green box), and one horizontal slider (yellow box). All pushbuttons are programmable, but the ones used in this work are highlighted in the white box.

Figure 2. The CR-9 (KFX, China) MIDI controller used for the desired performance (Source: authors).

In this model, when triggered, each physical control (pushbutton, knob, or slider) sends the computer a unique number that identifies it, which can be programmed and reprogrammed, thereby modifying the original mapping of the controls. This mapping can be called a keymap. Another way to alter the keymap in real time is to use so-called banks, of which the CR-9 controller has 4. Banks are selected, and the entire keymap is modified. Only a single bank was used in the performance described in this text. However, the original keymap of the controller must be changed to match the patch objects.

Screen Reader

The screen reader used in this study was NVDA 2021.2, a free, open-source software with a large developer community. It has stable integration with the Windows OS and third-party software. An important feature is that NVDA does not use a video interception driver to avoid possible conflicts between hardware and software.

Assistive strategy

The intended strategy is divided into three stages:

a) A sighted musician

i. Creates a patch from scratch or employs other ready-made patches.

ii. Creates sound samples for use in live performances.

iii. Selects the MIDI controller.

iv. Configures keymap mapping the MIDI controller's knobs, sliders, and pushbuttons to access the objects in the new patch. It has a function that is analogous to that of the mouse.

b) Preparing to perform, a VI musician

i. Connects the MIDI controller to the computer USB port.

ii. Uses a screen reader (e.g., NVDA) to browse the OS and open the Pd patch file.

iii. Accesses the Pd menus to perform basic settings, such as enabling the MIDI controller and selecting audio inputs and outputs.

c) Free improvisation execution

i. Can be performed autonomously by a VI musician.

The Pd programming in this project consisted of five patches (Figure 3) to produce the audio in the output (dac~): two for sound oscillators, two for effects (reverb and delay), and one for controlling 17 audio samples. The configuration of the Pd objects on the MIDI controller occurred as follows: The first oscillator (osc1) had its volume, height, time, and random note parameters set individually on the MIDI controller sliders, and a delay effect was added to the output (pd delay 2). The volume control is set up on another slider. The second oscillator (osc 2) had the same parameters as osc1, configured individually in the MIDI controller knobs. Additionally, a reverb effect was added to the output of osc2 (pd starlight), and its volume was set up in another knob.

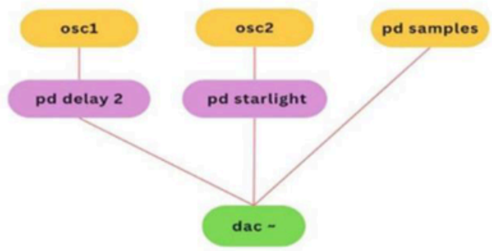

Figure 3. Block diagram exemplifying the functional links of patches (Source: authors).

The samples were programmed in the patch "pd samples" and divided into two groups. The first group (gp1) comprised samples in continuous execution (loop), and the second group (gp2) comprised short samples with durations up to 30 s. The gp1 consisted of four samples, and each sample's volume control was configured individually in sliders. The second group (gp2) consisted of 9 samples, each of which was activated separately by triggering pushbuttons. These buttons fire the samples without the volume control programmed in gp1. All channels were stereophonic. To explore the effects of sound spatialization, a sample of flying flies was configured on the MIDI controller's horizontal slider, allowing the sound to move from right to left and back again. Table 1 lists the continuous execution samples, whereas Table 2 lists short samples used in the performance.

Table 1. Description of continuous samples and mapping in the MIDI controller.

Samples	Audio description	Mapping (see Figure 2)
Pad A	Synthesiser timbre formed by overlapping several notes of A in different octaves	Slider 1
Pad B	Synthesiser timbre formed by overlapping several notes of A in different octaves	Slider 2
Didgeridoo	Australian Aboriginal musical instrument	Slider 3
Nigerian	Percussion of a cultural manifestation of a Nigerian group	Slider 4
Waters	Running water	Knob 1
Birds	Flock of birds in a forest	Knob 2
Wolf	Overlap of several howling wolves	Knob 3
Flies	Several flies flying	Horizontal slider AB

Table 2. Description of short samples and mapping in the MIDI controller.

Samples	Audio description	Mapping (see Figure 2)
Light 1	Short excerpt from the intro to the song "In the Light" by Led Zeppelin	Pushbutton 1
Light 2	Short excerpt from the intro to the song "In the Light" by Led Zeppelin	Pushbutton 2
Winds 1	Wind blowing	Pushbutton 3
Winds 2	Wind blowing and sea waves	Pushbutton 4
Whale	Song of two whales	Pushbutton 5
Ant	Sounds emitted by ants	Pushbutton 6
Frog	Various croaking frogs	Pushbutton 7
Eagle 1	Squeaks of a type of eagle	Pushbutton 8
Eagle 2	Squeaks of another type of eagle	Pushbutton V

Considerations for this Preliminary Study

Because this preliminary study is a proof-of-concept to test whether the patch-programmed system enables VI musicians to access a visual-programming sound-synthesis software, no submission to the ethics committee for research with human beings was required. One of the co-authors is a blind musician, a professor of contemporary music, and a member of research groups on accessibility for VI musicians. Even though no solid experience with sound synthesis is demanded to operate the patch, for better effectiveness and satisfaction, it is interesting that the VI musician know in advance all sounds, modulations, delays, and other effects available and which controls of the MIDI controller trigger them and are mapped by the Pd patch, as well as have knowledge of computer operation using screen readers.

The VI musician opened the Pd patch and used a standard computer input to connect to and enable the MIDI controller. Then, the VI musician selected the laptop speaker as the audio output using a screen reader to navigate the options.

The intended performance was individual and had no audience. It should be noted that the proposed methods did not include aesthetic analysis, as compositional procedures are not the focus of this study. Also, sound quality analysis was not conducted in this work.

Results

The idea of this work is to enable a VI musician to produce sounds, especially timbres, using Pure Data, within an aesthetic of "free improvisation" which, according to Derek Bailey, "… has no stylistic or idiomatic commitment. It has no prescribed idiomatic sound" [19].

The results of the first part of the method were obtained by a sighted musician with approximately one year of experience in sound synthesis using Pd. It took him about 25 days to get the finished version. Sound samples were created and added to the patch within 5 days. Keymapping and MIDI controller selection took 11 days.

The proposed strategy requires the VI musician to connect the MIDI controller to the computer, access the OS, and open the Pd patch. This task is elementary and can be completed quickly. However, for the execution of the third part of the strategy, the VI musician took 4 days to feel safe operating all the available sound variations in this patch.

The programmed Pd patch was named “Forest Night”. This patch was used in the recorded free improvisation video, in which the initial sensation refers to a forest at night, in a ghostly and suspenseful environment that was initially created by the superposition of continuous samples (Pad sounds), a synthesiser timbre formed by the sum of several A notes of different octaves, and the sound of an Australian Aboriginal instrument. Then, the combination of different inserted sounds resembles the environment of running water in a cave and the sounds of birds, which are emphasised by the reverberation effect. Other sounds, such as those of ants, eagles, and whales, as well as percussive sounds, are added to the performance.

The “Forest Night” patch was operated and performed by a blind musician, and the video shows the hand movements on the controller and the spatial location at the performance time.

The result of the elaborate proof of concept was a free improvisation performance also entitled “Forest Night,” performed by a blind musician [20], which was not presented to an audience and was later recorded and reproduced. Figure 4 illustrates a pose of the performed dynamics, which can be followed on YouTube.

Table 3 shows the instant (in seconds) at which each sample is first committed in the recorded performance, for better description and understanding of the sounds. However, because there is no correct manner or proper sequence to activate the knobs and slides provided, the free-interpretation nature in this context means that different VI musicians could use as many effects as they want and activate all or a few of the knobs and slides available in the patch.

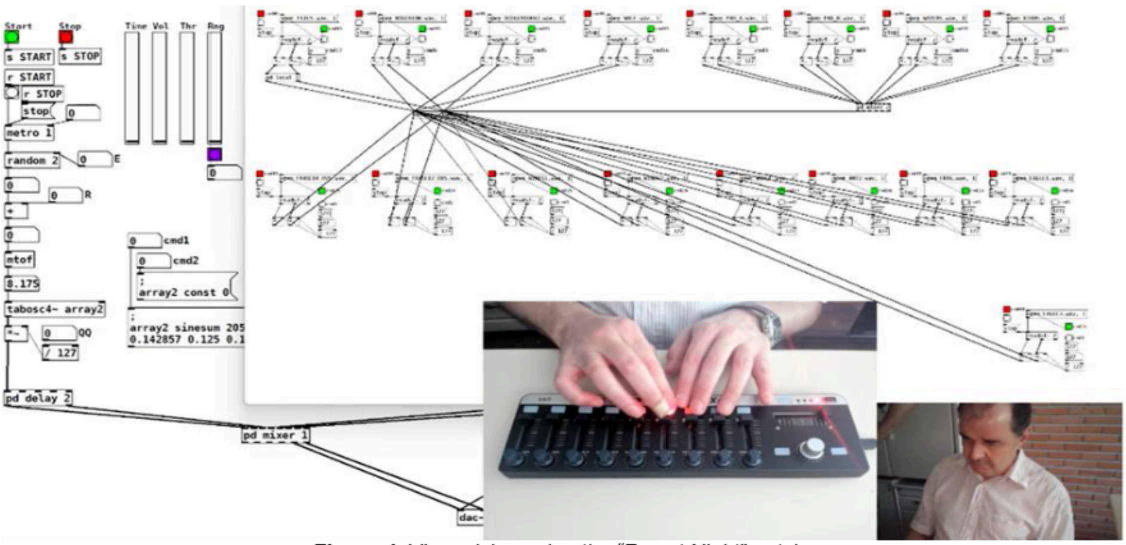

Figure 4. VI musician using the “Forest Night” patch.

Table 3. Samples and the moment of occurrence in performance.

Sample	Occurrence(s)	Control
ANT2	9	Pushbutton 6
BIRDS	60	Knob 2
DIGERIDOO2	60	Slider 3
EAGLE1	31	Pushbutton 8
EAGLE3	32	Pushbutton 9
FLIES	60	Knob 4
FRASE 2	6	Pushbutton 2
FRASE 4	6	Pushbutton 1
FROG	10	Pushbutton 7
NIGERIAN	60	Slider 4
PAD A	60	Slider 1
PAD B	63	Slider 2
WATERS	63	Knob 1
WHALE	18	Pushbutton 5
WINDS1	48	Pushbutton 3
WINGS 2	30	Pushbutton 4
WOLF	78	Knob 3

Discussion

This preliminary study aimed to overcome the inaccessibility of Pure Data's graphical user interface, enabling a VI musician to generate soundscapes in real time and autonomously. Although one could question the need for a VI musician to choose Pure Data as software for sound synthesis (since it is not the most accessible) to the detriment of other more viable alternatives, Saha and Piper [21] have already observed that the audio production industry requires an understanding that accessibility in the sound production industry is currently limited but critical for professional success. Other researchers also value strategy proposals that promote inclusive practices and preserve availability [22]. This can justify the need to develop strategies for visually impaired musicians to perform using audio synthesis software, as collaboration with other (visually impaired or sighted) musicians is compromised by the caveats posed by the software's accessibility limitations [23].

In the context of accessibility to music production software, efforts have been made to enable visually impaired musicians to access various patch features, actions, and commands that are adequately programmed by sighted musicians. HaptEQ was used as a feasible solution to increase audio production accessibility [8]. However, it focuses primarily on audio equalisation in the audio processing stages, and its applications during live performances should be tested. AirSticks focused on inclusive music improvisation and created a percussive Accessible Digital Musical Instrument (ADMI) that uses a Razer Hydra gaming controller to convert motion into sound [24]. Moving the gaming controller can adjust the sound pitch and tempo, while accounting for the need to calibrate the user's movement amplitude. This mapping was executed by Custom AirSticks MIDI Software [25]. If virtual zones are triggered, the controller can be moved to add reverb or distortion. This type of strategy could also be set to operate with multiple combinations to trigger audio samples and modulate pitch and frequency in a soundscape scenario, such as the one performed in this study. However, more work is required to change features, especially when they are not modulating together in the same virtual zone. As an advantage, strategies based on motion capture allow for various performance possibilities, as can be seen in the YouTube videos [24].

As observed in the video results, a VI musician can perform the PD patch using the controller rather than the mouse. An advantage of the proposed strategy is that the controller can be configured to the Pd without the user installing a driver. It was sufficient for the VI musician to connect it to the computer via a USB cable and enable it to access the software's MIDI input and output ports. The model was considered effective because it provided sufficient resources for free improvisation in electronic music and, for the first time, allowed this VI musician to complete the task (accessing Pd patches and producing sound synthesis) autonomously. The disadvantage could be that, compared to other alternatives, such as [24], the present strategy does not require performance in wide-body movements, which could give the interface an even more artistic aspect, although it does not reduce its functionality.

Other musicians have already been practising soundscapes [26]. Fornari *et al*. asserted the importance of broadening the notion of composition and performance using bioinspired adaptive computational systems. In this sense, the present work demonstrates a form of performance expansion for VI people. However, it should be noted that this study does not solve the issue of a VI musician building patches using Pd, given that the proposed assistive strategy does not allow or facilitate changing the interconnection of graphic elements. Such a solution is nearing completion, therefore not yet published, and it is another patch under development by the authors that explores the idea of the autonomy of blind musicians, not only in their performance but also in the construction and editing of patches by a VI musician, according to their preferences.

Another aspect of soundscape performance is that each performance is interpreted differently (free improvisation). For example, performance using the "Forest Night" patch has already been performed by a sighted musician [27]. At the time, the computer system consisted of an Easycontrol 9 (Worlde, China) MIDI controller and a Vaio notebook (model NRE4407), equipped with an Intel(R) Core i5-1035G1 CPU @ 1.00GHz, 8 GB RAM, 1 TB of storage, Windows 10 64-bit OS, version 21H1 with all updates, 3 USB ports available, a Realtek sound card model RTL8168/8111, and a Tobias Erichsen MIDI control unit model teVirtualMIDI. Empirical and observational analyses of both execution videos reveal a similarity in the manipulation of software and hardware. However, due to the free improvisation, the performance varied. This indicates that the VI musician's autonomy in interpreting the soundscape was enabled, thereby guaranteeing equality [28].

Although the performance with the "Forest Night" patch was successful, preliminary results revealed some difficulties. A problem was the Pd update stages. Version 0.51.4 was used because its most recent version (at that time, 0.52.1) presented problems during patch execution, a problem that may be related to the computer setup.

For free improvisation performance, only one controller bank was sufficient. However, for performances that require a greater number of audio samples, effects, and oscillators that employ more than one bank, a controller with a larger number of channels than the model used in this study (CR-9, KFX, China) may be necessary.

The main disadvantage of the proposed method is related to hardware limitations. The mechanics to actuate on knobs and slides are fixed, and, mainly, the movements involve only two degrees of freedom (up/down or right/left). MIDI hardware models do not have sensors, so they do not sense changes in light, distance, movement, pressure, etc.

Even though the focus of this work is the investigation of the feasibility of employing this strategy for the free improvisation of VI musicians, the interaction with sighted musicians was not addressed in this study. However, given that the result obtained was considered effective, it is believed that interaction with other musicians using this technique is possible, and its efficiency will be investigated in future work.

Conclusion

In this paper, we have presented an accessibility strategy that enabled a visually impaired musician to perform autonomously using Pure Data. The MIDI controller enabled the functionality of a Pure Data patch, so visually impaired musicians did not experience difficulty controlling the Pure Data objects.

It is hoped that the alternative accessibility paths found with the use of the NVDA screen reader and MIDI controller can contribute positively to the community of visually impaired musicians regarding the use of Pure Data, collaborating with digital and social inclusion, knowledge, and technological improvement of people with visual impairment, resulting in an increase in the qualification of their professional curriculum.

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