

A Forest of Pipes: Presenting the 37-pipe *Sheng* from the Inside

Une forêt de tuyaux : présenter le *sheng* à 37 tuyaux de l'intérieur

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Volume 32, numéro 1, 2022

L'orgue à bouche entre Extrême-Orient et Occident : l'invention d'un répertoire contemporain

URI : <https://id.erudit.org/iderudit/1088782ar>

DOI : <https://doi.org/10.7202/1088782ar>

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Éditeur(s)

Circuit, musiques contemporaines

ISSN

1183-1693 (imprimé)

1488-9692 (numérique)

[Découvrir la revue](#)

Citer cet article

Baskind, A. & Wei, W. (2022). A Forest of Pipes: Presenting the 37-pipe *Sheng* from the Inside. *Circuit*, 32(1), 37–51. <https://doi.org/10.7202/1088782ar>

Résumé de l'article

Dans la grande majorité des productions existantes en studio et en direct, le *sheng* est représenté comme un objet sonore externe, c'est-à-dire une source sonore (typiquement positionnée à l'avant) selon une distance et une largeur déterminées et placée dans un espace réel ou virtuel, comme cela est couramment fait pour d'autres instruments vedettes dans la production musicale. La recherche empirique présentée ici renverse la perspective d'écoute. Elle développe des méthodes permettant de placer métaphoriquement l'auditeur à l'intérieur du *sheng*, entouré de ses tuyaux, à l'image de la « forêt de tuyaux » à laquelle on fait parfois référence à propos de l'orgue d'église. Cette idée, qui dans le cas de l'orgue d'église est peut-être techniquement plus aisée (bien que complexe) à appliquer, pose des difficultés significatives pour le *sheng* en raison de la taille de l'instrument et des propriétés de rayonnement de ses tuyaux (principalement dirigés vers l'extérieur). Des méthodes alternatives pour la conception du système de microphones doivent donc être recherchées pour surmonter cet obstacle.

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Inside the 37-pipe *sheng*

The aesthetic goal of this project is to metaphorically set the listener within the 37-pipe *sheng*, surrounded by its pipes. This research has been intrinsically motivated and relates to performance and composition issues. Consequently, the empirical research method adopted here describes multiple situations: recording sessions in a studio (where the focus is primarily on sonic rather than musical considerations), experiments in production conditions (*i.e.*, during creation and composition residencies), and concerts.¹ The goal of this project is to enable a clear perspective reversal and may contradict our understanding of the objective acoustical radiation of the instrument. However, this approach does not aim to achieve realism as the very notion of realism in music production is highly questionable.

a) Realism in music production

A common aesthetic perspective for studio or live production of any kind of instrument is to consider the instrument an external sound source for the listener, mostly presented in front of them (mono and stereo) or, if using surround channels, to convey additional room information through electronics. This perspective, which can be considered an *imitation of a “real” situation*, is the most common one for the *sheng* and other mouth organs. Although there is nothing is wrong with this approach, we must bear in mind that there is no true “realism” in music production, which, even when it aims to create an *illusion* of realism, implies an artificial (re)construction of timbres and audio space.

1. The web supplement to this article (<https://www.revuecircuit.ca/web>) presents excerpts of those three situations.

2. There are also numerous pieces of contemporary music where the musicians are positioned to surround the audience.
3. A famous early example is Karlheinz Stockhausen's *Mikrophonie I* (1967), where the tam-tam is projected around the audience.
4. The second Glenn Gould recording of Bach's *Goldberg Variations* (Bach, 1982) is a good example, except that the left hand is presented on the right side of the stereo image and vice versa (*listener's perspective*).
5. The aforementioned *Mikrophonie I* (1967) by Karlheinz Stockhausen, as well as *Where is Pannonica?* (2009), a contemporary Jazz album by Andy Milne and Benoît Delbecq, provide very good examples of the same approach, the latter allowing a real immersive listening experience thanks to the surround format.
6. See the article by René Caussé, Véronique de Lavenère et François Picard in this issue for more information about the history of mouth organs.
7. The history of the so-called "Jew's harp" (*guimbard*), a free-reed instrument probably coming from Southeast Asia as well, may be even older.
8. Thrasher, 1996.
9. Ben, 1998.
10. Thrasher, 1996.
11. See for instance Raz, 2020.
12. *Ibid.*, as well as Blench, 2020.

Furthermore, the *situation* intends to convey a traditional concert, with the listener directly in front of the soloist. Not only is this situation far from the only one possible with purely acoustic instruments,² but the use of electronics has completely changed the rules, allowing audiences to virtually stand *inside* electroacoustic instruments, as acoustic sources are extended by the whole electroacoustic chain from microphoning to diffusion.³ Indeed, there is no real reason to assume that the listener's perspective must reflect an audience member's position during a concert. Numerous productions in many genres employ completely different standpoints: that of the conductor in an orchestral piece, or of the player,⁴ or a "non-realistic" presentation,⁵ which is especially common in popular music.

The point of this article is not to discuss the aesthetic relevance of placing the listener's perspective inside an instrument, since this objective will be closely related to the piece of music being performed and produced. There is no "good" or "bad" way to capture and reproduce the sound of an instrument, as the aesthetic goal is always context-dependent, and there are tools and methods to achieve it. Being surrounded by the pipes of a *sheng* may not correspond to the physical situation of a listener watching a *sheng* as an audience member, but it may be close to the inner representation of the instrument by the same listener closing their eyes, or of the musician playing the piece.

b) The 37-pipe *sheng*, a bridge between tradition and modernity⁶

The *sheng* is not a single instrument, but a family of instruments, some of the world's oldest free-reed instruments.⁷ The *sheng* has a history of over 3,000 years: its ancestors (*he* and *yu*) were recorded in oracle bone scripts in the 15th century BC⁸ as well as in classifications of Chinese instruments in historical records from the West Zhou Dynasty (c. 1100–771 BC).⁹ The *sheng* as such was first mentioned in the 7th century BC.¹⁰ It has played an important role in the development of Chinese music culture, and in the whole of Southeastern Asia. Its Korean version, the *saenghwang* (쟁황), is still used to play court music from the Song dynasty. It was introduced in Japan through the Korean peninsula in the 7th century (its Japanese name is *shō*—笙), and is used to play *gagaku* music and court music from the Tang dynasty.

The first evidence of the Chinese *sheng* in Europe dates back to the second half of the 18th century (through the writing of the German scientist Christian Gottlieb Kratzenstein, upon his visit to Saint-Petersburg).¹¹ It was not the first Asian instrument to be found in the West; mention of the Laotian/Thai *Khaen* was made by Marsenne in *Harmonie Universelle* in 1636.¹² However, it was influential. The principle of free-reed instruments

spread rapidly among European instrument makers. Beginning in 1780, it led to the invention and development of the harmonium (pump organ), the accordion, and harmonicas, among others. Until recently, the history of this cultural and technological heritage was not properly acknowledged; many publications and patents omitted it. Researchers cite this failure as a typical case of cultural appropriation.¹³

Meanwhile, in Southeast Asia, the development of mouth organs continued and, especially in China during the 20th century, ran parallel to the evolution of a musical language that was increasingly polyphonic, employing more polytonality and atonality.¹⁴ This led to the invention of many new types of *sheng*, some built on quite different acoustical principles than traditional instruments (using different materials for the pipes and the reed, or based on pipes closed when not being played), which made many of them inadequate for performing traditional music.

The so-called 37-pipe *sheng*, the instrument on which the present article focusses, was conceived with the explicit aim of bringing tradition and modernity together. As will be further explained, its design and fingering draw from several traditional mouth organs (especially the Hebei *sheng* and the Japanese *shō*), extending it to a full chromatic instrument with a 3-octave range, making it now equally suitable for traditional Chinese music,¹⁵ Japanese *gagaku* music, and contemporary repertoire.¹⁶

c) Milestones in this research

This empirical research does not pretend to present a unique microphone system that perfectly fits any situation or project. First, there are often multiple ways to achieve a goal, and second, as stated above, aesthetic choices depend on context, including the acoustics of the room, the instrument, and, most of all, musical content. The purpose of this article is to discuss issues that should be considered.

- **Tradition as a starting point.** As mentioned before, the *sheng* is not one instrument, but a family of instruments with a very long, rich history of parallel development. The 37-pipe *sheng* is a modern instrument with strong ties to its history. This history should be taken into account, especially when it comes to acoustics and fingering. This means asking how to embrace not only the contemporary, but also the traditional, repertoire, and different ways to present them.
- **Square the circle of acoustics.** As will be developed in the next section, there is an inherent mismatch to be solved between the aesthetic goal

13. Raz, 2020.

14. See Chaoming, 1997; Chaoming, 2014; Shanli, 2004.

15. Listen for instance Chaoming, 2002; Zhenfa *et al.*, 1993; Zhenfa, 2006.

16. Listen for instance Chin, 2014.

(a “forest of pipes” surrounding the listener) and the actual design of the *sheng*, which has pipes close together, mostly radiating outward.

- **Compatibility with existing microphoning systems (“technical tradition”).** As with the need to reconcile musical and organological traditions, the technical requirements can be stated as follows: the new microphone system should be compatible with, or used in conjunction with, existing microphone systems. As will be discussed later, efforts have been made to extend existing close-microphone techniques (for instance Wu Wei’s setup, which will be described below) that can be employed along with microphone pairs or overheads. These techniques shape the listener’s perspective in a scalable way.
- **Compromise between the ideal and the feasible.** Just as a forest is made of many trees, we may think at first that our “forest of pipes” requires many microphones to represent all 37 of them. Yet, the compact size of the instrument and the need for playability (the musician cannot play within a “jungle of cables”), the drawbacks related to microphones being close to the pipes and, last but not least, economic constraints, call for a compromise to be made.
- **From capturing the source to shaping a space.** A sonic space is much more than a bunch of sources with reverberation. Shaping it requires special attention, much of which is beyond the scope of this article. To use a culinary analogy, this text describes how to select the right ingredients, but not how to cook the dish.

Anatomy of the 37-pipe *sheng*

a) Pipe design

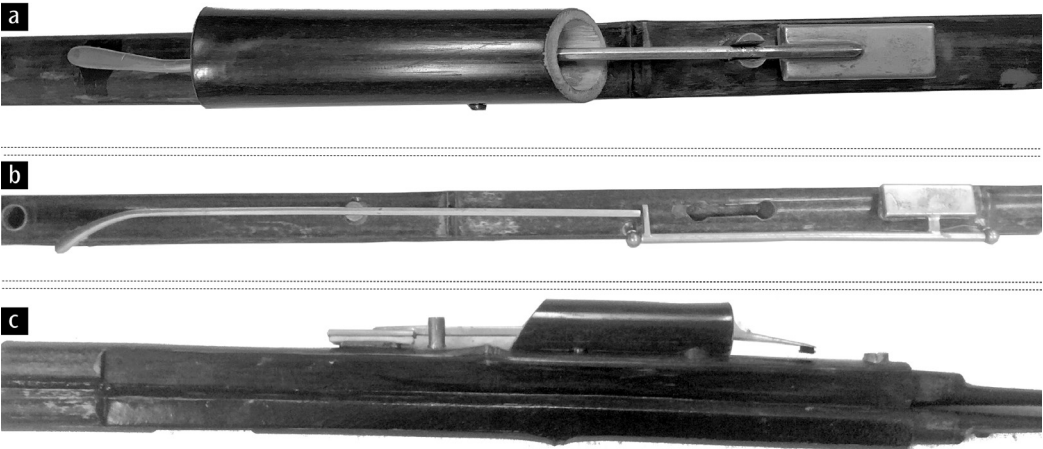
The 37-pipe *sheng* is a modernized redesign of formal traditional versions and was first architected by Weng Zhenfa and Mo Shanping in 1985. Its most prominent difference from traditional instruments is its chromatic design (37 notes from G₃ to G₆, *i.e.*, 3 full octaves). The need to pack additional pipes in a portable and playable instrument (Figure 1) was one of the greatest challenges in its design.

Leverage keys have been added to some pipes in order to access all notes comfortably. Two kinds of keys are present, depending on the position of the sound hole (Figures 2a and 2b). This leads to two fundamentally different kinds of pipes: twenty of them (“open-hole pipes”) are of traditional design, *i.e.*, single pipes without levers. The sound hole is open by default, and, when closed (directly by a finger), the tube length matches the resonance frequency of the reed and a tone is produced. Among them, the 13 pipes for the highest

FIGURE 1 These two photos show how compact the 37-pipe *sheng* is, despite its complex engineering.



FIGURE 2 **a)** One pipe with a straight lever giving direct access to the cup covering the sound hole. Note the bamboo tube used for amplification. **b)** One pipe with an angled lever, allowing control of the cup covering the sound hole via a lateral pivot system. **c)** One double pipe (C#6 on top, C#4 below) with a lever for the hidden pipe (below). The second pipe (C#4), being much longer for the lower note, is buckled back to reduce height. Note here again the bamboo tube used to amplify the higher note.



17. The choice of bamboo as the material for the amplification tubes, rather than metal, as is used on other types of modern *sheng*, is motivated by sound aesthetic considerations (matching the tone color of traditional *sheng*).

18. See Zhao *et al.*, 2008, for an analysis of the physical sound power level of traditional *sheng*.

19. See Kuang *et al.*, 2015, for measures on a 24-pipe *sheng*, one of the very few published studies on the topic.

octave (G₅ to G₆) are fitted with acoustic amplifiers made of short tubes, either bamboo¹⁷ or metal, and open at both ends (Figures 2a and 2c). On top of that, seventeen (“key-operated pipes”) use key/lever mechanisms where, by default, a cup covers the sound hole. When the key is pressed, the hole opens, letting the air out of the pipe, which produces the tone.

Therefore, more than half of the 37 pipes are of traditional design, allowing for a very dynamic responsive instrument, that can reach significant loudness.¹⁸ The drawback, however, is that the open pipes, when not being played, allow air to pass through. Consequently, the 37-pipe *sheng* offers little resistance to the air flow produced by the musician, requiring of them significant physical training to have the capacity to provide the necessary air volume for even soft dynamics. To keep the instrument size as compact as possible, double pipes are incorporated in the design, one behind the other, which must remain accessible from the outside (Figure 2c). This applies to 12 of the 14 lower notes (from G₃ to G[#]₄, with only D₄ and G₄ as single key-operated pipes).

b) Radiation pattern

A crucial point of our research was to investigate the instrument’s sound radiation pattern. First, we must remember that most of the sound holes are directed outwards. This may seem to create an obvious obstacle to the goal of having the sound image of the *sheng* surrounding the listener and directed inwards, and makes the idea of placing microphones between the pipes obsolete. Yet, the actual radiation pattern is quite complex and cannot be modeled by a circle of directional sound sources turned outwards. There are at least three reasons for this:

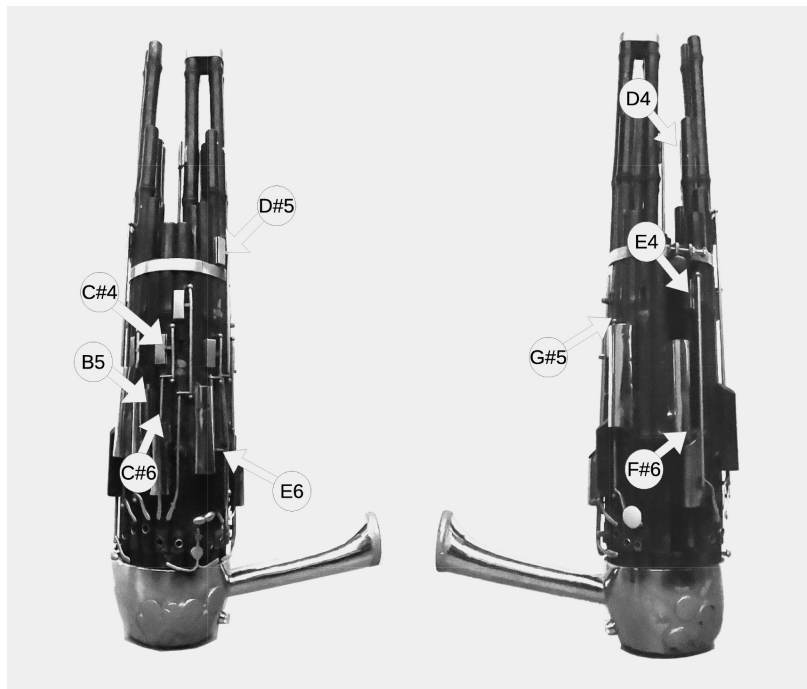
- The sound sources (the sound holes of each pipe) are at different heights (Figure 3).
- The body of the instrument and the presence of the other pipes interferes with the radiation pattern any single pipe.
- There are clear indications that the pipes interact with each other in a non-linear way.¹⁹ Similarly, we can assume that the radiation pattern of a chord differs from the radiation of the single notes it comprises.

c) Fingering

The fingering of the 37-pipe *sheng* does not obey a chromatic logic (Figure 4). It is, above all, guided by the need for compatibility with the fingering of several traditional Chinese and Japanese mouth organs. As Thrasher points out,²⁰ there is no unified pitch position and fingering for all of the traditional

20. Thrasher, 1996.

FIGURE 3 Position of some of the sound holes on a 37-pipe *sheng*, showing the disparate heights of the sound sources.



sheng, and, in any case, the position of the pipes is determined by maximal finger convenience for the music being played.²¹ This can differ significantly depending on geographic region and era. As an example, Figure 5 compares the fingering of the modern 37-pipe *sheng* with one of the traditional 17-pipe *sheng* from the Hebei region (one of its closest traditional ancestors), and the Japanese *shō*, which is used in *gagaku* music. The kinship is obvious.

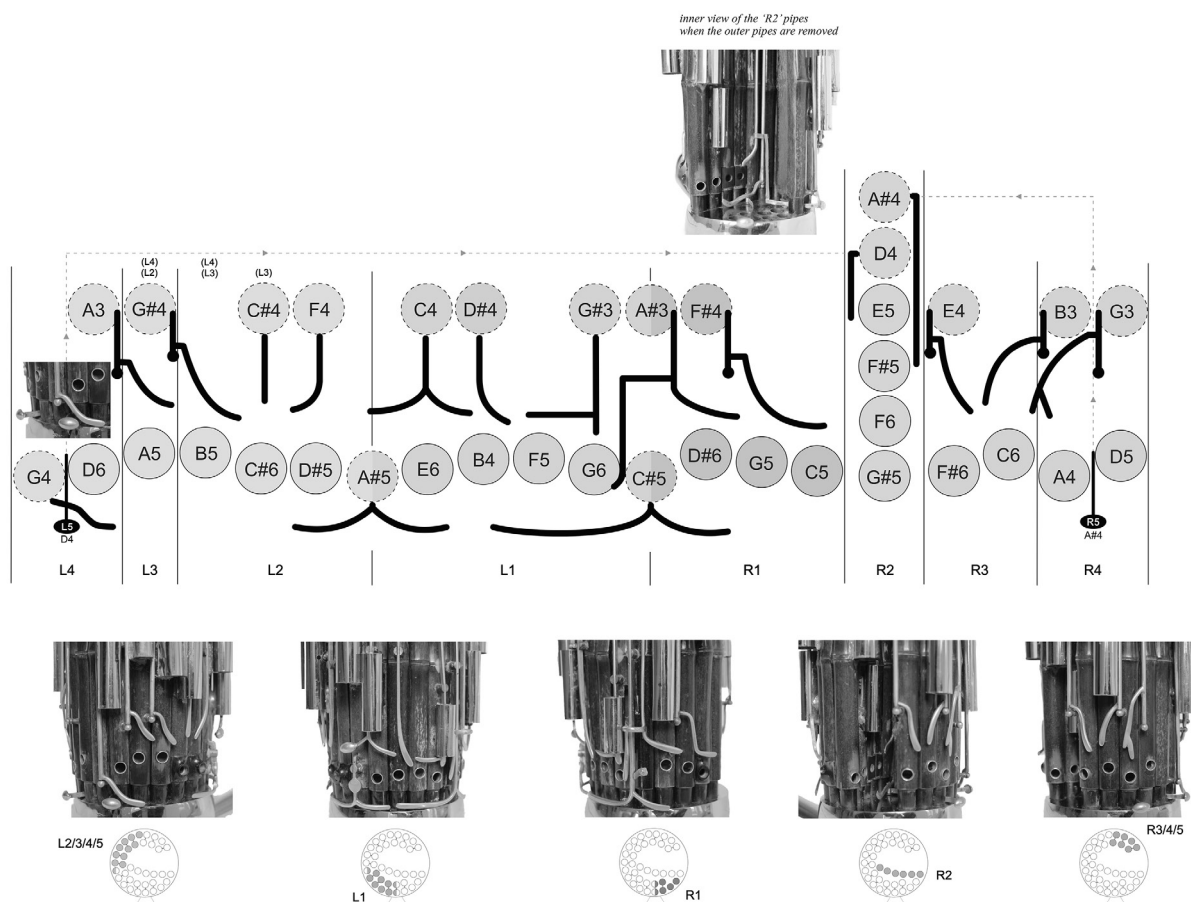
21. Chaoming, 1991.

Designing a specific microphone system

a) Usual microphone systems for the *sheng*

A common method for capturing the *sheng* consists of setting one or two overhead microphones over the top front of the instrument, about 1 meter apart (Figure 6a). This provides a good overall sound image and a well-defined high register. However, the lower register is often weak, despite the closeness of the microphones to the longer pipes. This system requires good acoustics to capture the sound emitted from the back and sides of the

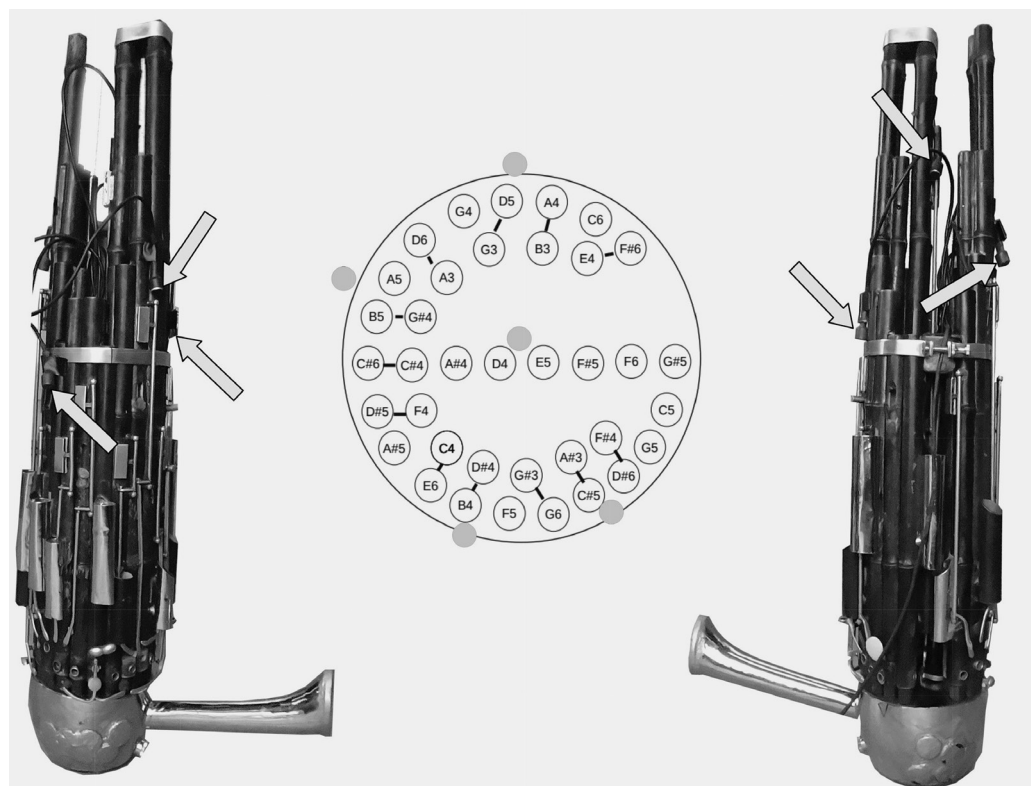
FIGURE 4 Unrolled schematic view of the 37-pipe *sheng* (designed by Wu Wei and Yushun Pei) showing each pipe type (solid circles = open-hole, dotted circles = key-operated) as well as the hand (“L” or “R”) and the finger used to play it (from index = 1 to little finger = 4). The 12 pipes of the topmost line (A₃, G#₄, C#₄, F₄, C₄, D#₄, G#₃, A#₃, F#₄, E₄, B₃, G₃) are parts of double pipes.



instrument (because it must reflect back to the microphone positions). Using a traditional pair of stereo microphones, for instance ORTF, leads to a similar conclusion: such systems work only in conjunction with good room acoustics, which is problematic if we aim to shape an artificial space.

As a workaround, to enhance the lowest register, a single close microphone attached to the top of the instrument is sometimes used in addition to a set of overhead microphones. Sometimes this single close microphone is used alone (Figure 6b), but this proves unsatisfactory, as it captures the sound for a very limited number of pipes (typically D₄ and A#₄). This solution should, however, be kept in mind.

FIGURE 7 Wu Wei's usual live pickup system based on 5 electret microphones. The central diagram is a schematic top view of the instrument, showing the position of the microphones. This may be misleading, since their vertical position cannot be represented. For clarification, the arrows on the left and right views show all microphones on the instrument.



the instrument without proximity effect, therefore retaining a relatively good balance between neighboring pipes. These microphones are mounted higher on the longer pipes (corresponding to the lower notes) which boosts the lower register. The higher notes, being more shrill, carry better and are naturally perceived more loudly without amplification.

b) Towards a new microphone system

On the basis of the above considerations and the previous sections, it becomes clear that an appropriate microphone system must be positioned around the instrument and close to it. This aims to minimize the influence of the room, the possibility of feedback with the public address system, and to provide good

The selection of microphones, especially taking their directivity into account, is of major importance. A good starting point consists of Wu Wei's omnidirectional based live-microphoning system, as has been extensively used by him and presented here. This system is not perfect; its main drawback (apart from delivering a mono signal) lies in its unsatisfactory rejection of leakage and feedback. For this reason, we have conducted research to conceive a similar system with directional microphones, in our case DPA 4099 supercardioids. However, directional microphones require distance from the instrument: first, to avoid focusing on only one or two pipes per channel, and secondly, to control the bass boost due to the so-called proximity effect.

To summarize, the solution presented here (which is not the only one) consists of four supercardioid miniature microphones (DPA 4099) positioned around the instrument with small but sufficient distances between them (5–10 cm), and a fifth omnidirectional miniature microphone (AKG C417) on the top to capture the sound emitted by the highest, central, pipes (Figure 8).

c) Optimizing microphone positions

As stated in the introduction, it does not make sense to aim for “the” perfect position of the microphones, since context is so important. However, some variables can be kept in mind, as well as methods for managing them. Assuming that directivity is fixed (four supercardioids and an omnidirectional microphone), the main variables are as follows: position (circular, height) of each microphone, angling, and distance to the instrument. The main questions to be addressed are:

- How is the balance between all 37 notes (which requires knowing which pipes each microphone picks up)?
- Does the sound (tone color, dynamics, presence, etc.) match what we're looking for?
- How do the microphones mix?

To address these questions (balance and tone color), a simple but efficient test can be used. This consists of playing all notes chromatically, keeping overall dynamics as constant as possible, and listening to the result. If played on a multichannel setup (for instance a quadraphonic system), the notes should be spatially split, but overall dynamics (especially loudness) and presence should remain constant, with tone color matching our requirement of consistency over the whole register. If presented in mono (all five channels summed together), the question of mixing and possibly induced tone color distortion is easier to identify. In fact, if the sound of any given pipe is cap-

tured by more than one microphone (which is invariably the case), interferences may occur. When the microphones are not more or less equidistant to the source, unwanted effects on tone color can arise.²⁴

In practice it's not possible to completely avoid these negative interferences for all 37 pipes; but it may not be a problem if the mixing works well for the most critical cases (*i.e.*, for the pipes that are most distant from the microphones and therefore picked up by two or more of them). This issue also depends a great deal on the playback system, which determines if and how the five channels are mixed together, the most critical case being the mono downmix.²⁵ The ideal situation is a direct assignment of each microphone to a dedicated speaker in a multichannel system (implying no mixing between channels at all).

Several of the technical and aesthetic issues discussed here are illustrated in audiovisual examples in the web supplement to this article. There we present chromatic scales for slightly different microphone positions. We show downmixes for mono as well as for headphones with binaural processing. We also offer practical musical examples.

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This article presents some intermediate results of an ongoing empirical research on a new microphoning technique for the 37-pipe *sheng* in live performance and studio recording. The goal is to put the listener metaphorically in the heart of the mouth organ. The methods developed for this purpose can also be applied to instruments other than the *sheng*, for projects requiring microphone setups for spatial separation of the registers.

The musical implications of the perspective reversal proposed here are far from limited to sound aesthetics and the creation of a spatial effect. For instance, dispersing the different regions of the *sheng* around the listener has, among other things, a major influence on the clarity and balance of the different voices, particularly in the case of polyphonic writing (as shown in the excerpt of Wu Wei's piece "Fragrance of the Cherry Blossoms" in the web supplement). This has potentially far-reaching implications for composition.

On a more sonic/technical level, the next steps are to:

- Address the question raised in the introduction on shaping a space (the "forest") out of raw information (the "trees").
- Proceed with further tests in larger rooms/reverberant spaces, using amplification to address not only possible technical issues (feedback) but also aesthetic ones: how should our virtual space be shaped to coexist with

24. In technical terms: if the *phases* between the signals received by each microphone are not equal.

25. The issue of the "mono compatibility" is a classic in sound engineering, as it is almost mandatory in many cases to ensure that a mono sum of all channels of a mix (especially stereo, and especially for radio and vinyl media) is not too strongly distorted in terms of balance and tone color.

a real space with a mostly fixed acoustical fingerprint? How can musicians be aware of this space, even as they are in the middle of it, when so close to their instrument?

- Begin research on putting an extra microphone/sensor close to the source of energy (the breath), *i.e.*, probably inside the wind chest of the instrument. The goal would be twofold: first, to capture more low-frequency information (which is lacking in the radiation of an instrument that has as its lowest note G₃—ca. 200 Hz) that the musician feels; and, secondly, to better capture the huge amount of energy that the musician provides, of which only a small portion reaches the listener.

The examples presented here and in the web supplement do not claim to provide a definitive microphone setup for this purpose, since this goal is context-dependent, the requirements for achieving it necessarily changing with the music being played. More relevant here are the considerations and methods used to reach this goal.

Acknowledgments

The authors would like to thank Paul Cameron and Brian Smith for proof-reading this article.

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