Tian Jinqin’s String-Controlled Instruments: Formalizing and Reimplementing a Ribbon-Based Interaction Design Pattern

Enrique Tomás
enrique.tomas@kunstuni-linz.at
Tangible Music Lab, University of Arts Linz
Austria

Boris Shershenkov
boris.shershenkov@kunstuni-linz.at
Tangible Music Lab, University of Arts Linz
Austria

Figure 1: Left: Tian Jinqin’s *XK-1* instrument. *Radio* Journal (1980), *used with permission.* Right: Tian performing at the annual meeting of *National Electronic Musical Instrument Technology Trade and Promotion Association*, Chengdu, 1987.

Abstract

This paper documents and reconstructs Tian Jinqin’s *string-controlled* electronic instruments from 1970s China, and formalizes their recurrent ribbon-based interaction design pattern. Drawing on ethnographic study in direct collaboration with Tian, we studied the historically situated decisions for creating the *XK* instruments and translated them for proposing a contemporary, modular, and reproducible platform for ribbon controllers. Using a *research-through-practice* approach, we examine the challenges of building expressive and accurate ribbon-based instruments across these dimensions: sensor materials, muscle memory, ergonomics, protocol constraints, and socio-political contexts. Finally, we introduce a modular, open-hardware design solution based on Tian’s patterns, which has proven effective for creating affordable, well-tuned ribbon controllers. By situating this non-Western instrument lineage within NIME discourse, the project shows how reconstruction can inform interface reliability, re-implementability, and long-term use while expanding the historical and cultural foundations of digital musical instrument design.

Keywords

Ribbon Controllers, Interaction Design Patterns, Non-Western, Tian Jinqin

1 Introduction

Tian Jinqin’s (田进勤) contributions to electronic musical instrument design are of particular contemporary interest for diverging from well-known Western-oriented synthesizer paradigms that dominated the second half of the twentieth century. Developed in China from the early 1970s onward, his interface-control design paradigms were conceived to facilitate the expressive nuances of

---

NIME ’26, June 23–26, 2026, London, UK

traditional Chinese music, emphasizing glissandi, vibrato, portamento, and fine melodic articulation. Moving beyond keyboard-centric designs, Tian Jinqin drew inspiration from traditional Chinese string instruments such as the erhu, guzheng, and pipa to develop what would today be referred to as multi-dimensional expressive interfaces based on ribbon controllers.

In 1978, Tian Jinqin denominated them *string-controlled* electronic musical instruments (figures 1-4). A 1980 documentary demonstrating the instrument can be accessed from our website[1].

Tian Jinqin's pioneering instruments resonate with the ongoing challenge of creating expressive and multidimensional digital instruments. While current research has increasingly explored adapting musical interfaces to local and ethnically specific performance practices [2, 12, 14], Tian anticipated this trajectory in the 1970s–80s, proposing design strategies for electronic instruments suited to traditional Chinese styles in two articles [7, 9]. These examples point to the value of studying Tian Jinqin's work and advancing ethnographic research on non-Western projects, a commitment of this NIME conference.

Figure 2: Capture from documentary film *Electronic Organ Dian Zi Qin* ” (电子琴) (1980). Tian Jinqin performing the XK-1 (front).

Despite some emerging academic attention [5, 6, 24], rigorous research on Tian Jinqin remained absent and it has been often inaccurate. In February 2024, we visited the 87-year-old Tian Jinqin in Taiyuan to study his instruments firsthand and to systematically document his work. We worked collaboratively to create an initial index of instruments, publications, and media (Figure 3). Since then, we have maintained online exchange to authenticate, cross-reference, and catalog the expanding corpus of materials. Our findings and analysis—together with verified biographical details and an index of instruments and publications—are presented in a comprehensive article coauthored with Tian's son Fangmeng [19].

In this paper, we first document and formalize the interaction design patterns of Tian Jinqin's principal creation, the *XK* instruments. Second, to better understand the historical design decisions, we present and discuss a modern reconstruction of the *XK* interface, developed in direct communication with him. The outcomes of this process, including the resulting open-hardware and software tools, are detailed in the following sections.

2 Tian Jinqin's *XK* instruments

Tian Jinqin's instruments are rooted in traditional Chinese music, particularly vocal and string traditions. In notebooks from summer 1971, he addressed the problem of performing Chinese music on electronic organs, and the technical challenges of a *singing-controlled* electronic instrument.

> From the prospects, it is possible to develop an electronic instrument that can be played completely with the voice. [. . .] The principle is the same as singing in a low voice, singing a melody with a small volume with the mouth, filtering out the second and higher harmonics with a tracking filter, and using its fundamental wave to control the waveform generator, so that the instrument can emit a sound equal to, multiplied by, or divided by the pitch of the song [8].

The technical difficulties of developing *singing-control* in 1971 led him to abandon its development when he turned his focus to *string-controlled* instruments.

Between 1971 and 1978, while working for the national Taiyuan Radio Factory no.2, Tian Jinqin designed the *XK* (*Xian Kong Qin*, 弦控琴), literally *string-controlled instrument* (xian 'string'; kong 'control'). It is a monophonic electronic instrument with a string/ribbon pitch control interface modeled on the erhu (figures 1-4). In this series of different instruments developed since the mid 1970s, a vertical fingerboard enables continuous and microtonal pitch control with the left hand, while the right hand continuously modulates amplitude and filter envelopes. The instrument was conceived to be easily playable by string performers with minimal adaptation.

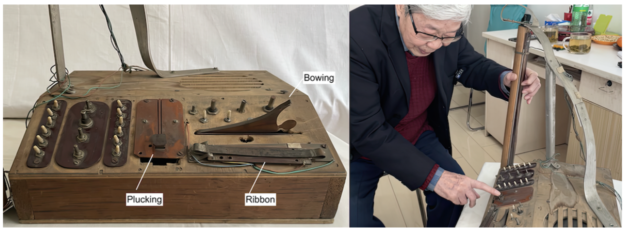


Figure 3: Right: Tian demonstrating the *XK* prototype (1978) in February 2024. Left: three different envelope articulation methods of this instrument.

Tian Jinqin developed the *XK* in three phases, each with different features. First, between 1971 and 1978, Tian designed and built an initial monophonic prototype incorporating one pitch ribbon, three different methods for articulation, and a small set of timbres (Figure 3). Following approval for development and production, the instrument was repurposed as a product featuring four electronic strings, four envelope and filter controls, and a knee-operated modulator (figures 1, 2, 4). It was integrated into a console with numerous knobs and buttons for timbre design and preset management. The instrument was called *XK-1*, and, in 1979, a trial batch of 36 units was manufactured, 21 of which were sold to domestic cultural and artistic organizations.

The project received official recognition and awards, and the instrument was included in several cultural troupes. In 1982, a pre-production *XK-2* model with expanded timbral options and improved electronics was presented, but it did not proceed

---

[1] https://tamlab.kunstuni-linz.at/projects/tian-jinqin/ retrieved 22 April 2026

to production. That year, the state-owned company employing Tian suspended further development of the XK project. Pressure from international investors, combined with the company's lack of experience in managing patents[2], ultimately prevented the instrument from returning to production.

Figure 4: Pitch and articulation controls in the *XK-1* (1979).

Tian Jinqin later balanced his daily job with a sustained interest in more advanced concepts. Notably, many of his subsequent personal inventions continue the interactive design pattern established with the original *XK*, including portable *string-controlled* instruments and gestural metaphors inspired by Chinese instruments such as the guzheng. Unfortunately, Tian could not preserve his *XK-1* instrument, and we failed to find any of the units sold previously. Consequently, a modern reconstruction of the instrument posed not only a research challenge but also a personal motivation for both Tian Jinqin and the authors.

3 A genealogy of *string-controlled* instruments

Tian Jinqin's instruments in the 1970s and early 1980s coincided with a brief revival of ribbon-controlled instruments in the global musical mainstream. To contextualize this moment, we present a brief reverse genealogy of such instruments, tracing back to the 1920s.

Notable cases from this period include, for example, Bob Moog, who developed a ribbon controller as part of his modular system, and made it available for sale beginning in 1965[15]. These ribbon controllers were used in live performances by internationally recognized bands such as *The Beach Boys*, and *Emerson, Lake & Palmer*[13]. In Japan, engineers at *Nippon Gakki* (the predecessor of *Yamaha Corporation*) patented several ribbon-controlled designs inspired by the *Trautonium* and the *Ondes Martenot*[1, 16]. They also experimented incorporating a ribbon for portamento control in organs (*YC series*[26] and *E5-AR*[27]) and in early polyphonic synthesizers between 1970 and 1976 (models *GX-1*[28] and *CS-80*[29]). These ribbons were abandoned in later models. In the UK in the early 1970s, David Vorhaus created the *Kaleidophon*, a four-ribbon electronic string bass for controlling CV synthesizers[20]. It was demonstrated to a wide audience in 1976 on BBC's *Tomorrow's World* and received a prize at the first Ars Electronica Festival in 1979[3]. Later, the *Kaleidophon* was adapted into one of the first ribbon-based MIDI controllers, marking the transition from analog to digital technology[23]. Despite extensive media coverage of these developments, Tian Jinqin remained unaware of them due to the isolation imposed during the Chinese *Cultural Revolution* (1966-1976) and its aftermath.

From our perspective, the *XK* project more closely aligns with, and extends, earlier paradigms of *radiophonic* and *electromusical* instruments with continuous control that dominated the early twentieth century. As with electronic-music pioneers of the 1920s and 1930s, Tian's goal was not to invent entirely new sounds but to enhance acoustic instruments by imitating their timbres and introducing new dimensions of electronic control and expression in live performance. His motivations and solutions were strikingly similar to those of Theremin, who was experimenting with polyphonic electronic fingerboards and multidimensional *singing-controlled* instruments during the same period[18].

According to Tian Jinqin, from the late 1950s until the *Cultural Revolution* in 1966, he accessed American, Soviet, Taiwanese, and Japanese radio magazines reporting advances in electronic circuits[25]. However, as Tian Jinqin noted in our conversations, the Soviet magazine *Radio* had little practical influence on his work. The magazine reached China only in the 1960s and ceased circulation within a few years amid the Sino–Soviet split. Additionally, its circuits were almost entirely transistor-based while Tian could only use vacuum tubes. Japanese and Taiwanese magazines offered richer coverage on instruments, but Tian lacked subscriptions and he could only sporadically access library copies. Additionally, implementation was impeded by expensive transistors costs at the time and a Japanese-language barrier.

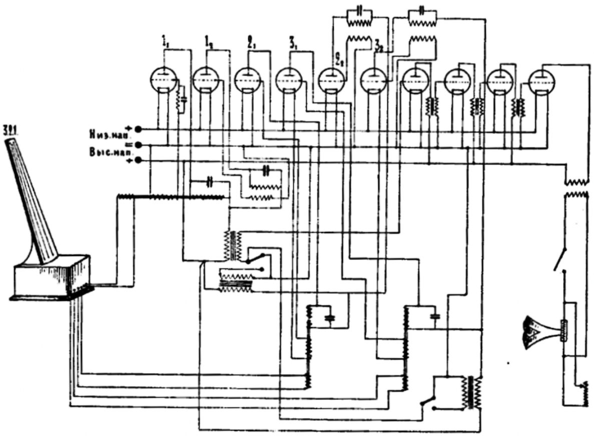


Figure 5: The *Violena*, by Gurov and Volynkin (1922).

In development since 1932, the *Ekvodin* combined a keyboard with a ribbon controller and it become the most advanced electromusical Soviet instrument. The instrument was influenced by copies of the *Volkstrautonium* brought to the USSR in the 1930s by German émigré intellectuals [17] as well as by other expressive instruments devised by Soviet inventors active since the early 1920s [22]. Interestingly, one of the most notable influences identified by Volodin was the first ever documented *string-controlled* instrument, the *Violena* (Figure 5). It was developed in 1921, in parallel to the *Thereminvox*, by radio engineers Vladimir Gurov and Viktor Volynkin and patented in 1922. The *Violena* was inspired by bowed string instruments, and employed a string rheostat, a conductive fingerboard made from resistive material and four metallic strings[21]. In a later monophonic version, the *Neoviolena*, the metallic strings were replaced by a fabric strip with conductive thread[11], thereby constituting the earliest documented implementation of conductive ribbon controllers in the history of electronic music we have identified.

---

[2] The first patent law in China entered into force on April 1985.

4 Interaction design patterns

Our analysis of Tian's instruments reveals a sustained emphasis on a specific interaction mode that he viewed as central to instrument design. We term this recurrent approach his *interactive design pattern*.

A design pattern is a reusable solution to a recurring problem within a specific context[4]. It defines the problem, the conditions under which it appears, and a validated strategy for addressing it, including trade-offs and applicability. A pattern therefore serves as both description and template across situations. For instance, the *Singleton* pattern ensures that a software system creates only one instance of an object with controlled global access. By contrast, a computer mouse is not a design pattern but a device that embodies several interaction patterns, such as point-and-select, drag-and-drop, hover-to-reveal, secondary-click context menus, and scrolling.

Within NIME, terms such as *musical interaction design pattern*, *tangible interaction pattern*, and *control archetype* align more closely with this discourse. Examples of common interaction patterns can be those mapping sonic parameters to hand position (e.g., *Lady's Glove*, *The Hands*), applied pressure (e.g., *The Sponge*), or object placement on tabletop interfaces (e.g., *the Reactable*). In our view, attention to interaction design patterns contributes to clarify instrument and designer lineages, as patterns can be historically traced to practitioners who propose or adopt them. While new patterns emerge, many are inherited or adapted directly or metaphorically from prior acoustic instruments (e.g. ribbon controllers evoking string behavior), mechanisms with proven effectiveness (e.g. knobs, levers, wheels), and previous music controllers (e.g., the *Violena*, the *Theremin*).

4.1 *XK* interaction design pattern and distinctive features

Our pattern analysis draws on the following instruments:

(1) The *XK* prototype (1978) (figure 3). It features a single vertical ribbon pitch controller mounted on a vertical fingerboard and played with the left hand. Three distinct physical techniques for envelope and filter manipulation (plucking, sliding, bowing) are integrated into the console of the instrument and played with the right hand.
(2) The *XK-1* (1978) and *XK-2* (1982) models (figures 1, 2 and 4). They incorporate four vertical and long ribbon controllers for pitch, and four horizontal and short ribbons assigned to envelope and filter control of each string. The interaction follows the prototype, but polyphonically expands the system to additional strings and timbres.
(3) The *Two-Strings Electronic Huqin* (1984), the *Portable XK* (1986) and other electronic ribbon-based guitars from 1989 and 1991 (Figure 6). They introduce, respectively, two and one ribbon(s) per pitch and two ribbons dedicated to envelope and filter control. Interaction remains consistent with earlier models, but Tian redesigned them with portability in mind.

Tian Jinqin's interaction pattern is a bimanual, continuous-control scheme that separates microtonal pitch production from timbral and articulatory shaping. Pitch is generated by the left hand through pressing and sliding a thin metallic wiper along a long, vertical resistive ribbon affording fretless techniques such as vibrato, portamento, and microtonal intonation. Envelope and filtering are controlled continuously and independently by the right hand via shorter horizontal ribbons and dedicated gesture modes (e.g., plucking, sliding, bowing). This per-string mapping and spatial separation of roles recur across his instrument family, regardless of sensor electronics or sound-synthesis technology.

Figure 6: Tian's portable *XK* and *prototype* instruments

The distinctive feature of XK instruments, developed and refined by Tian Jinqin over the decades of his work, is the use of bare-metal strips as the primary interaction element. This solution gives them outstanding tactile and haptic properties, blurring the line between modern-day ribbon controllers and string instruments.

5 Development of a new *XK*: the *XK-S*

Having fully documented each *XK* instrument, the project adopted a *research-through-practice* methodology to reconstruct Tian Jinqin's designs and probe their functional and aesthetic principles. This approach foregrounds tacit knowledge in historical design decisions unreachable through documentation alone—material choices, sensing strategies, ergonomics, and musical affordances. By replicating the original interface with contemporary technologies, we surface practical issues, limitations, and latent potentials, generating new insights into continuous-control musical interface design. Our reconstruction relies on the *XK prototype* (1978), on partial technical documentation, and video and audio recordings. The instrument's intellectual property rights remain with the state-owned company where Tian was employed, and detailed circuit information cannot be publicly disclosed. Tian provided detailed technical accounts of its principal characteristics and extensive information about his interface design. He supplied components from the original fingerboard, most notably the original rod assembled with resistive wire and metallic (copper) bands (figure 9).

The new *XK-S* interface (*XK-Shùzì*, digital) was developed in close consultation with Tian Jinqin, with his explicit agreement and endorsement, and he was informed at each stage of our progress. Our goal was creating an open-hardware research platform, not a commercial product.

5.1 Design goals and controller configuration

For the development of this project we have put these goals:

1. **Fidelity to the original interaction design pattern**: Preserve the XK's core interaction principles, affordances, and control modes so they remain recognizable amid modern fabrication. This fidelity protects interface identity, credits original authorship, and sustains historical performance compatibility.
2. **Musical goals**: Emulate the *XK*'s microtonal, continuous pitch control and polyphonic playability. Preserve the historical focus on acoustic-timbre emulation, yet support broader synthesis by integrating with both digital synthesizers and analog modular systems.
3. **Accessible goals**: Deliver a portable, lightweight, customizable, modular, low cost instrument, and with minimal expertise. Ensure replicability, openness and hackability through transparent construction methods, accessible materials, and public documentation.

The construction of the *XK-S* interface shares the original design solutions of *XK-1*: the usage of multiple ribbon controllers of different types combined in two groups for two different hands. The first group consists of four long (30-40 cm) and thin (3-6 mm) metal ribbon controllers mounted vertically on the *fingerboard* part of the instrument and used for pitch control. The second group consists of four short (8-10 cm) and wide (20 mm) metal ribbon controllers mounted horizontally in the *keyboard* part of the instrument and used for sound modulation.

For the *XK-S*, we decided to implement each of these groups in separate interchangeable modules allowing different rearrangements. First, resembling the *XK-1*, as a tabletop solution. Second, all modules combined in one portable body similar to the Chinese erhu and other bowed instruments. The outcome of this work and its goals is illustrated in figures 7 and 8, which provides the reader with an overview of the final interface.

Figure 7: Two *XK-S* configurations. Experts testing the interface.

5.2 Sensor technology

The original technical solution provided by Tian Jinqin consists of three main parts (figure 9):

1. Sensor: custom-made linear wirewound resistors made out of a core of copper rod, isolated with lacquer; length – 310 mm, diameter 2mm; resistance 15 kOhm.
2. Metal strips: brass alloy strips, thickness 0.1 mm; length – 350 mm; width – 4,5 mm.
3. Tensioners: steel extension springs, diameter – 3 mm, length – 9 mm.

Figure 8: The *XK-S*

A key challenge was identifying accessible sensors with a strong linear position–resistance correlation, less sensitivity to force/pressure, and preserved responsiveness and tangibility. Commercial linear potentiometers (e.g., *Spectra Symbol* softpot[3]) match the *XK* design in resistance and dimensions, but tests showed their required actuation force severely reduces responsiveness, rendering them unsuitable for the fingerboard. They also demand point-contact pressure and are incompatible with metal ribbon configurations.

Hence, we decided to produce the linear potentiometer ourselves. The use of bare metal strips requires robust and wear-resistant surfaces. Because of that, we had to exclude the most widespread materials for ribbon controller making, such as conductive paints, plastic films, and resistive foils. For the ribbon sensor, we evaluated the following:

- **Newly made wirewound resistors**. Although they offer strong response and linearity, the form factors and dimensions of commercially available units for laboratory and power applications are incompatible with project requirements. Custom resistors could be produced to the necessary specifications, but the available resistive wires are fragile, and the winding process requires specialized equipment.
- **Custom linear potentiometer PCBs**. Specialized printed circuit boards integrating resistive films can be fabricated to arbitrary resistance ranges, track lengths, and physical

---

[3] https://www.spectrasymbol.com/linear-position-sensors/thin-form-linear-pots-thinpot retrieved January 4 2026

Figure 9: Original wirewound sensors at *XK* instruments.

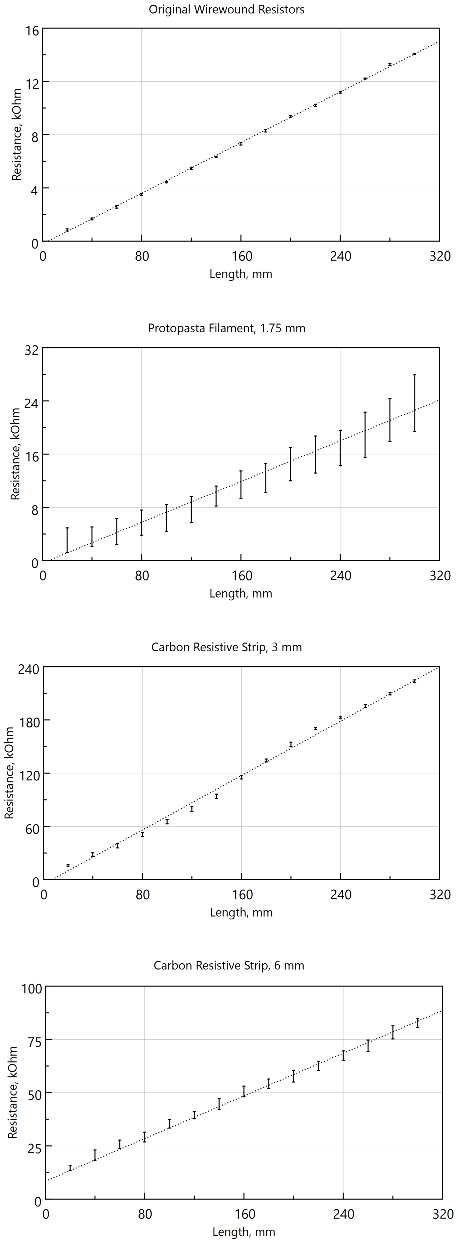
dimensions, meeting project requirements[4]. However, tooling and production costs are substantial and typically only economical at high volumes (e.g., more than 100 units).

- **Conductive 3D-printing filaments**. On paper, electrically conductive composite PLAs such as Protopasta[5] have a typical resistance of 200-350 ohm per cm for a 1.75-mm filament, which is very similar to the electrical properties of the round 2-mm wirewound resistors used by Tian Jinqin. We found that the overall resistance of the filament depends mostly on its surface resistance, making filament resistors more sensitive to pressure between metal contact and filament than to the distance between the two contacts. This behavior, also reported by others in similar contexts [10] produces inconsistent sensor characteristics and pronounced nonlinearity that increases with the number of printed layers, regardless of printing temperature or layer height. Consequently, 3D-printed sensors are unsuitable as linear potentiometers for our application.
- **Carbon heating foils**. Infrared heating films are widely used as heating elements for apartments or cars, and contain a resistive carbon layer similar to the carbon layer used in the linear PCB potentiometers. These films are relatively inexpensive, easy to find and process, and have various dimensions and electrical properties, which makes them a good option for our task.

For the project, we chose *Calorique*[6] infrared carbon heating films, 50 cm wide, with dissipated power 150 W/m^2 at 230 V, as the main resistive material. Each meter of this foil consists of 60 separate carbon strips 460 mm long and 12-14 mm wide, and costs around 25 euro, less than 50 cents per carbon strip.

After removing the protective plastic film, the measured resistance per centimeter of the carbon strips is 1,5 ± 0,3 kOhm / cm. This resistance has consistent linearity but also notable deviations over the length of the strip, which have to be compensated through digital calibration. These strips can be observed in figure 13.

The carbon strips can be easily cut to any length and thickness, changing the linear resistance and response. The optimal size of the carbon strip for our *XK-S* interface was found experimentally to 3 mm wide and 320 mm long, offering a total resistance of 223 ± 21 kOhm, and surface resistanc of 7 ± 1 kOhm. Comparison between different types of resistors is shown in figure 10.



Original Wirewound Resistors

Protopasta Filament, 1.75 mm

Carbon Resistive Strip, 3 mm

Carbon Resistive Strip, 6 mm

Figure 10: Measured linear response and pressure sensitivity for resistive materials

5.3 Microcontroller and ADC

The core of our digital implementation is an *Espressif* ESP32-S2 Mini microcontroller. To mitigate the known nonlinearity of its internal ADC, particularly near its voltage rails, we incorporated a *Texas Instruments* ADS1115[7], a high linear 16-bit ADC. The ADS1115 supports sampling rates up to 860 samples per second and presents a typical input impedance on the order of megohms, compatible with the approximately 200 kOhm source impedance of our sensor. This configuration enables calibration procedures to focus primarily on the intrinsic nonlinearity of the sensor rather than ADC-induced errors.

From an electrical point of view, each ribbon sensor can be seen as a combination of a push-button and a variable resistor. After

---

[4] We explored PANDA PCB http://www.panda-pcb.com/html/Products/Linear-Potentiometer-PCB.html retrieved January 4 2026

[5] https://proto-pasta.com/products/conductive-pla retrieved January 4 2026

[6] https://calorique.info/shopw/?k=267 retrieved February 9 2026

[7] https://www.ti.com/lit/ds/symlink/ads1115.pdf

testing several connection options, the metal strip is connected directly to ground to reduce interference from the performer's body. The resistive carbon film is connected to the ADC input in series with a RC low pass filter, and in parallel with an external pull-up trimmer potentiometer, which compensates resistance variations between different sensors. The schematic diagram of the sensor connection is shown in figure 11.

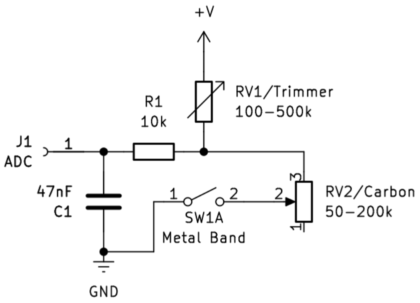


Figure 11: Ribbon Sensor Connection Schematic

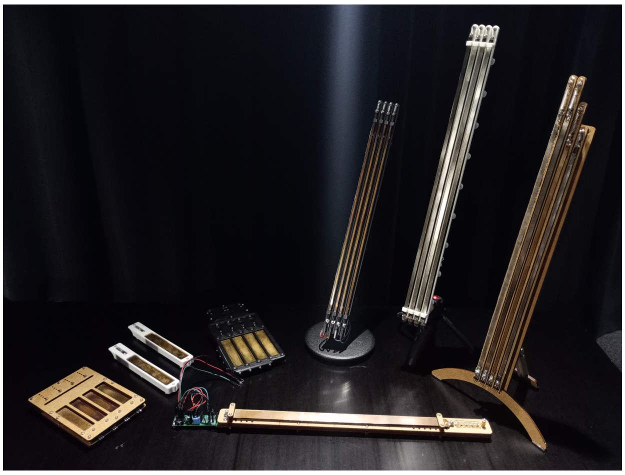


Figure 12: Different iterations of our platform to compare sensors and features

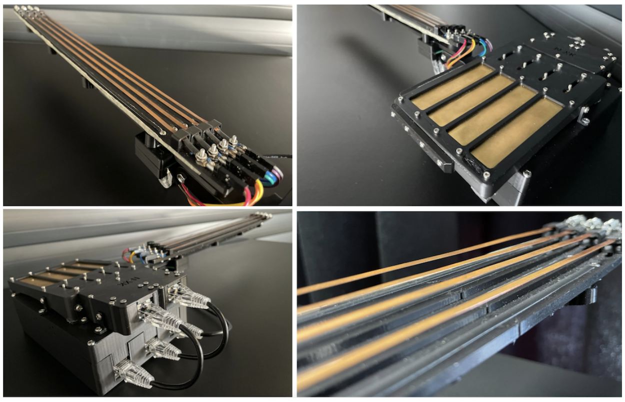


Figure 13: The *XK-S* modules: fingerboard, envelope control, RJ-45 connections, and carbon films.

5.4 Interface body

5.4.1 ***First Iteration: Testing.*** The first prototype version of the *XK-S* interface was made from wooden materials using the laser cutting technology, which allows the production of large monolithic parts with multiple materials, making it easy to integrate different types of sensors, including the original wire-wound resistors. The fingerboard module was designed to be as adjustable as possible to test the relative height of the ribbons and the distance between them (fingerboard profile). It also allowed comparing different types of sensors (original wirewound resistors, 3D-printed resistors, carbon films) and other materials and tensions for the metal bands.

For the keyboard modules, we tested the original bronze band with 0.1 mm thickness, copper bands made from 0.05 and 0.1 mm sheets, and a commercially available 20 mm-wide brass band with 0.1 mm thickness. For different fingerboard modules, we tested original 0.1 mm-thick and 4.5 mm-wide brass strips; 0.1 mm- and 0.15 mm-thick, 5 mm- and 6 mm-wide battery-welding nickel strips; and 0.2 mm-thick and 3 mm- and 6 mm-wide copper strips.

The tests showed that for the keyboard module, the best material in terms of tangibility and resistance to oxidation and deformation was 0.1 mm brass. For the fingerboard module, a 0.15 mm nickel strip showed the best results, but due to its ability to produce various allergic conditions, nickel was replaced with 0.2 mm copper.

After several months of occasional playing with the ribbon controller, there were no signs of wear or noticeable difference in the electrical properties of the carbon resistive strips with any of the metal strips used.

5.4.2 ***Second Iteration: Towards Reproducibility.*** In order to increase its reproducibility, sustainability, and ergonomics, we decided to switch to 3D-printed solutions, which don't require the use of specialized laser equipment and can be produced with any kind of 3D-printing hardware. We decided that the dimensions of all the parts in the design should not exceed 250 mm, which is the standard size of the bed for the most widespread 3D-printers, and all the parts should be printable with standard PLA filaments without supports, reducing production time and plastic waste. To achieve these goals without compromising on the dimensions, stiffness, and bending resistance of the modules' enclosures, a special system of interlocking fixtures was developed and tested on this second prototype with various fingerboard and keyboard profiles.

5.4.3 ***Third Iteration: Towards Performativity.*** The third prototype (figure 13) was informed by prior gained knowledge to implement a closer solution to Tian Jinqin's *XK-1* original instrument. It consists of four fingerboards with 320 mm carbon sensors and 0.2 mm-thick and 3 mm-wide copper strips, combined in one module; and four keys with 80 mm carbon sensors and 0.1 mm-thick and 20 mm-wide brass bands combined in one keyboard module.

After performing with the software instruments, we found the interface lacking switch controls that can be used to change synthesis parameters. For this purpose, 8 additional touch sensors were added to the keyboard module (figure 13 top-right), in positions allowing to be accessed by the performer's thumb. For the connection between interface modules, we chose RJ45 8-core Ethernet cables because of their high prevalence, customizability, and reliability.

The latest version of the *XK-S* interface, including schematics, PCB, and BOM files, STL models, and assembly instructions, is available through our online repository[8].

5.5 Firmware

Our CircuitPython implementation realizes the *XK-S* as an embedded, MIDI-capable controller on a microcontroller. The firmware continuously samples ribbon sensors, applies per-ribbon calibration to linearize measurements, and produces normalized position data for pitch mapping and amplitude (figure 14). A modular codebase separates drivers, signal conditioning, calibration, and musical mapping for extensibility.

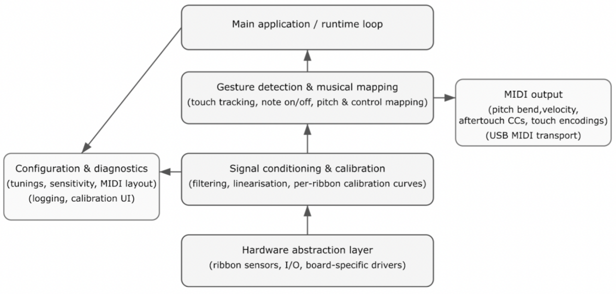


Figure 14: Firmware implementation

A calibration mode captures reference points in fifths along each ribbon to compute piecewise sensor-to-pitch mappings. We found more robust than global fitting. The firmware's calibration mode, capturing five reference points along each ribbon and computing segmented linear maps, proved superior to polynomial fits for stability and interpretability. In practice, local fits handled contact variability and micro-regions affected by manufacturing tolerances. This was the equation to achieve it:

$$p(V) = p_i + (p_{i+1} - p_i)\,\frac{V - V_i}{V_{i+1} - V_i}, \qquad V \in [V_i, V_{i+1}]$$

where V is sensor voltage and p is the mapped pitch coordinate.

A gesture layer extracts envelope onsets, pitch trajectories, and auxiliary controls, which are encoded as MIDI (or MPE-style) with configurable scaling, quantization, and channel assignment.

Mapping assigns left-hand position to MIDI note plus fine pitch-bend, and right-hand position to velocity and a continuous controller (e.g., aftertouch or filter). Polyphony is implemented by dedicating one MIDI channel per string, enabling independent pitch-bend; future versions will add full MPE.

Capacitive touch on the right-hand controller generates discrete MIDI notes. Specific touch events or combinations are interpreted as articulation controls, mapping to MIDI parameters that change the synthesizer's playing mode (e.g., staccato vs. legato, mute vs. sustained), thereby enabling rapid, gesture-driven modification of timbre and phrasing.

Key challenges in this implementation were:

- **High-resolution sensing parallel to significant electrical noise and non-linearity of the ribbons**, requiring the design of filtering and debouncing strategies that reduced jitter without compromising responsiveness or subtle gestural detail.
- **Reliably detecting subtle performance techniques** such as hammer-ons and pull-offs, which manifest as rapid, low-amplitude transients in the ribbon signals. These techniques introduced ambiguity in peak detection and tracking, necessitating robust algorithms to distinguish intentional glissandi, chordal gestures, and inadvertent touches.
- **Sensor scanning scheduling and MIDI message generation** to avoid timing jitter and buffer overflows, while staying within low-latency constraints, and ESP32's memory and performance budget.

5.6 Playability, presentations and expert feedback

Following our developments, we conducted periodic testing sessions with a professional violinist, who learned to play the instrument and helped to test and validate its playability and precise tuning. The violinist's feedback was key in defining the instrument's dimensions, string width, sensor sensitivity, and sound mapping. A video demonstrating the instrument can be accessed from our project website.

The instrument debuted at the *Electronic Lutherie* international symposium[9] on electronic instruments, using a tabletop configuration with separate bimanual controllers. Following a 20-minute keynote on Tian Jinqin's instruments, the first author performed for the audience (figure 15 right), and the instrument was then showcased for three days (figure 7). Twenty-three specialists, performers and instrument makers, provided feedback, most of it concerning the separation and placement of the hand controllers relative to the body. These points are addressed in Section 8 (Ergonomics).

A second evaluation occurred in a concert with the *Postdigital Ensemble* in Linz in January 2026, along with five electronic musicians. In a portable carry setup, the instrument was connected to a modular analog synthesizer and only used the pitch fingerboard (figure 15 left). The *XK-S* control proved effective and well aligned with analog synthesizers.

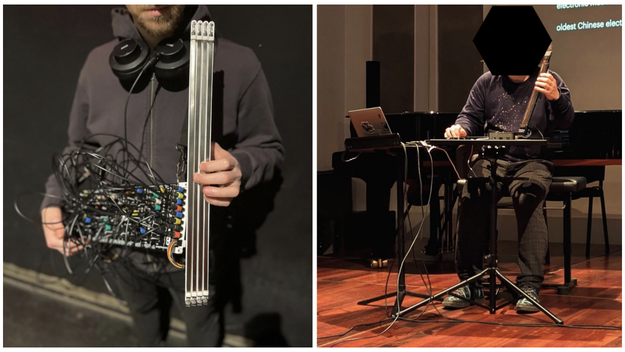


Figure 15: The authors during two public performances

6 Discussion: On the challenges of designing well-tuned string-controlled instruments

Designing well-tuned digital instruments with the pitch accuracy of early analog electronic designs (e.g. Ondes Martenot) remains difficult. Other scholars cite concise reasons: persistent challenges

---

[8] https://tamlab.kunstuni-linz.at/projects/tian-jinqin/ retrieved 22 April 2026

[9] Orpheus Instituut Ghent, January 2026

in precise pitch control (Freed, 2013), lack of suitable commercial components (Gallin and Sirguy, 2009), and soft-potentiometer limitations (Oliveira da Silveira, 2018). These are our considerations after developing and performing the *XK-S*:

6.1 Ribbon sensor constraints

1. **Nonlinearity is sensor-specific, not merely a property of ribbons**. Across multiple commercial solutions and our own hand-built sensors, we observed distinct transfer curves tied to variability in fabrication: material density, and the type of geometry used for the contact with the sensor. This required per-sensor calibration rather than assuming a single factory curve.
2. **Width–force sensitivity trade-off**. Empirically, we observed how ribbons feature high dependence on finger force and contact area while pressing. Wider sensors demanded greater force and produced variable intonation under lateral finger motion. Narrower sensors increased false positives and stiction artifacts. This characteristic strongly affects playability. Our sweet spot of 3–4 mm range minimized this dependency while preserving tuning stability.
3. **Mechanical tension and bridge angle**. Subtle changes in copper band tension and the fingerboard's bridge angle improved contact linearity and reduced intermittent touches under fast slides. We have not found any reference to the importance of micromechanics at the wiper-wire interface. For us, iterative adjustment of these micromechanics was essential to allow stable tuning.
4. **Electrical impedance**. Long ribbon sensors tend to feature relatively high impedance, in the range of hundreds of kilo Ohms, which increases susceptibility to noise and interference and complicates direct interfacing with microcontrollers.
5. **Resistive surface sensitivit**y: instruments for accurate tuning require precise ranges of force to press the string. Soft potentiometers often require greater force to trigger touch events, reducing playability, and the possibility to tune.

6.2 Muscle memory

Only after practising with the *XK-S* interface we discovered that tactile referencing is necessary, not optional. This is a problem present in typical soft potentiometers. Lamb and Robertson [2011] argue that muscle memory requires: (1) activity not dependent on vision; (2) tactile positional feedback; and (3) standardized, consistent interface properties. *XK* instruments meet these needs through their copper band's tactile reference. More broadly, many ribbon interfaces (e.g., *Doepfer*, *Eowave*) offer limited tactile feedback or unstable configurations, making non-visual performance difficult. The result is a system that complicates learning and practice.

6.3 Limits of MIDI Integration

Ribbons pair naturally with analog synthesizers but are hard to incorporate to MIDI instruments. Ribbons can modulate already triggered MIDI notes effectively, like in MIDI pitch bend. However, using ribbons for string-like articulation is more challenging as MIDI provides no straightforward way to distinguish specific performance gestures. For example, a legato gesture (e.g., hammer-on) in MIDI can be mapped either as a pitch bend or as a new note-on event, both of which are problematic. Legato (hammer-on) mapped as pitch bend often alters timbre in sample/wavetable synths, and ignores expression accents in the envelope; mapped as note-on retriggers envelopes, disrupting continuity. These articulations are generally better suited to synthesizers whose timbre remains stable under pitch bend, such as those based on physical modeling or algorithmic synthesis. However, a significant portion of the expressive information is often lost due to the limitations of MIDI integration.

6.4 Ergonomics

An important component of this study was the evaluation of two spatial configurations: tabletop or embedded into one single instrument's body. From our evaluation with specialists (section 5.6.), the tabletop bimanual arrangement was viewed as conceptually compelling but challenging to master in practice. Given the instrument's continuous control characteristics, especially for pitch, many participants recommended anchoring the instrument to the performer's body, analogous to acoustic string instruments (e.g., cello, violin, erhu). Several participants who were also string players noted that, despite accurate tuning, the distance from the body imposed unfamiliar ergonomics. These insights motivated the development of an integrated version in which fingerboard and envelope controller are co-located and optimized for close coupling to the performer's body. This direction is consistent with our experience with the portable version, which emphasizes a more intimate physical relationship with the performer.

6.5 Political, economic, social constraints

Tian Jinqin's designs bear the imprint of China's political economy in the 1960s and 1970s, when instrument development occurred within a state-owned, planned manufacturing system marked by constrained access to imported components, strict hierarchy of projects to support and produce, and limited information on the revolution on musical electronics happening outside China. These conditions radically shaped Tian's processes, encouraging solutions that were suitable to the technical materials available, but also to the political, social and cultural environment where he lived. These struggles could be parallel to the ones of many pioneers such as Theremin, Gurov and Volynkin, for mentioning a few from this paper.

The outcomes of this project underscore the importance of situating historical instruments within their economic and social contexts, not only to assess the technologies available at the time, but also to apprehend the biographical and social positions of their builders, their creative autonomy, economic dependencies, access to information, professional competition, and the personal and emotional dispositions and worldviews that shaped their work.

7 Conclusion

This project contributes an ethnographic study of Tian Jinqin's *string-controlled* instruments that not only formalizes their development, but also seeks to embody the challenges faced in designing well-tuned designs, both historically and in contemporary practice. By directly engaging in sensor fabrication and instrument building, we were able to surface forms of tacit knowledge that remain absent from archival sources. We argue that this hands-on engagement not only retraces lineages of design patterns and authorship, but also opens a path for the NIME community to approach historical reconstruction as a means of enhancing the replicability of our contemporary solutions. Taken together, we hope these outcomes provide a foundation for future work on expressive ribbon-based digital instruments, locally fabricable practices, and more diverse methodological perspectives in NIME.

8 Ethical Standards

This research project was conducted in close collaboration and ongoing consultation with Tian Jinqin, with his explicit agreement regarding our intentions and his full endorsement of the work. Tian was informed regularly—often weekly, and at times daily—about each stage of our progress as well as all plans for public presentation. The project's aims were strictly scholarly: to develop an open-hardware research platform rather than a commercial product. All interactions, design decisions, and representations were carried out with respect for Tian's authorship, expertise, and historical contribution.

Acknowledgments

To Meng Qi and Tian Fangmeng, for helping us in the process of documenting Tian's work.

References

[1] Akira Nakada. 1971. *Playing devices for electronic musical instruments.* Retrieved January 25, 2026 from https://patents.google.com/patent/US3624583A/en?oq=3%2c624%2c583

[2] Nick Bryan-Kinns and Li Zijin. 2020. ReImagining: Cross-cultural Co-Creation of a Chinese Traditional Musical Instrument with Digital Technologies.. In *Proceedings of the International Conference on New Interfaces for Musical Expression.* https://doi.org/10.5281/zenodo.4813428

[3] David Ellis. 1981. David Vorhaus and Kaleidophon Studio. *Electronics Music Maker, no. Jun 1981, pp. 74–76,* (1981).

[4] Erich Gamma, Richard Helm, Ralph Johnson, and John Vlissides. 1995. *Design patterns: elements of reusable object-oriented software.* Addison-Wesley Longman Publishing Co., Inc.75 Arlington Street, Suite 300 Boston, MAUnited States.

[5] Li Han. 2023. Synthesiser Sounds and Phenomena in China. *Frontiers in Art Research, 5(18)* (2023).

[6] Wang Jing. 2021. *Half Sound, Half Philosophy. Aesthetics, Politics, and History of China's Sound Art.* Bloomsbury Academic, 1385 Broadway, New York, NY 10018, USA.

[7] Tian Jinqin. 1974. A Brief Discussion on Electronic Musical Instruments and Their Prospects, Unpublished manuscript, available through anonymized online archive for reviewers. Retrieved February 9 2026. (1974). https://tamlab.kunstuni-linz.at/projects/tian-jinqin/

[8] Tian Jinqin. 1987. Voice-controlled Electronic Instruments, Unpublished manuscript, available through anonymized online archive for reviewers. Retrieved February 9 2026. (1987). https://tamlab.kunstuni-linz.at/projects/tian-jinqin/

[9] Tian Jinqin. March, 1986. On the Issues of Instrumentation and Nationalization of Electronic Music Instruments. *Journal Music and Dance (音乐与舞蹈)* (March, 1986).

[10] Chantelle L. Ko and Lora Oehlberg. 2020. Touch Responsive Augmented Violin Interface System II: Integrating Sensors into a 3D Printed Fingerboard.. In *Proceedings of the International Conference on New Interfaces for Musical Expression.* https://doi.org/10.5281/zenodo.4813300

[11] S. Korsunskiy and I. Simonov. 1957. *Elektromuzykal'nyye instrumenty [Electromusical instruments].* Moscow: Gosenergizdat.

[12] Michaella J Moon, Jim Murphy, Ajay Kapur, and Dale Carnegie. 2024. Overview of NIME Techniques Applied to Traditional Korean Instruments.. In *Proceedings of the International Conference on New Interfaces for Musical Expression.* https://doi.org/10.5281/zenodo.13904820

[13] Trevor Pinch and Frank Trocco. 2002. *Analog days: the invention and impact of the Moog synthesizer.* Harvard University press, Cambridge (Mass.) London.

[14] Hanyu Qu, Francesco Dal Rí, Hao Zou, Hanqing Zhou, and Raul Masu. 2025. O – : An Epistemic DMI for Cross-Cultural Reflection on Time and Music.. In *Proceedings of the International Conference on New Interfaces for Musical Expression.* https://doi.org/10.5281/zenodo.15698936

[15] Robert Moog. 1965. *Ultra-Short Form Catalog of Electronic Music Composition Instruments.* Retrieved January 4, 2026 from https://moogfoundation.org/wp-content/uploads/1965-Ultra-Short-Form-Catalogr.pdf

[16] Shoichi Suzuki and Takatosi Okumura. 1971. *Variable resistor device for electronic musical instruments capable of playing monophonic, chord and portamento performances with resilient contact strips.* Retrieved January 25, 2026 from https://patents.google.com/patent/US3626350A/en?oq=US3626350

[17] E. Simonov. 1936. *Elektrifikatsiya zvuka [Electrification of Sound].* Tekhnika – molodyozhi (8): 13-16.

[18] Leon Theremin. 1966. *Fizika i muzykal'noye iskusstvo [Physics and The Art of Music].* Moscow: Znaniye.

[19] Enrique Tomás, Tian Fangmeng, and Martin Kaltenbrunner. 2026. Sinicization of Electronic Music Instruments: Tian Jinqin's Pioneering Inventions and Designing Ideas. *Leonardo Journal (in press April 2026)* (2026).

[20] Simon Trask. 1986. History of the Future. *Electronics Music Maker, no. Sep 1986, pp. 41–47* (1986).

[21] Vladimir Gurov and Viktor Volynkin. 1922. *Ustroystvo dlya upravleniya vysotoy tona, poluchayemogo v elektromuzykal'nom katodnom pribore" [Device for controlling the pitch obtained in an electronic musical cathode ray tube].* Retrieved January 25, 2026 from https://patents.su/3-1891-ustrojjstvo-dlya-upravleniya-vysotojj-tona-poluchaemogo-v-ehlektromuzykalnom-katodnom-pribore.html

[22] A. Volodin. 1970. *Elektronnyye muzykal'nyye instrumenty [Electronic musical instruments].* Moscow: Energiya.

[23] Paul White. 2002. David Vorhaus, Electronic Music Pioneer. *Sound on Sound, Feb. 2002, Retrieved: Feb. 04, 2026. Available: https://www.soundonsound.com/people/david-vorhaus* (2002).

[24] Jiayue Cecilia Wu. 2022. Today and Yesterday: Two Case Studies of China's NIME Community. In *Proceedings of the 22nd Conference on New Interfaces for Musical Expression (NIME).* https://doi.org/10.21428/92fbeb44.57e41c54

[25] Xu Cheng. 2024. *Zhōngguó diànzǐ yuèqì xiānqū – TiánJìnqín xiānshēng fǎngtán [Interview with Mr. Tian Jinqin, a pioneer of Chinese electronic musical instruments].* Retrieved January 25, 2026 from https://mp.weixin.qq.com/s/RLDul8I0e16zgXxJ86Bnew

[26] Yamaha Corporation. 1970. *Yamaha Combo Organ YC-30 Owner's Manual.* Retrieved January 25, 2026 from https://usa.yamaha.com/files/download/other_assets/6/316086/YC30E.PDF

[27] Yamaha Corporation. 1973. *Getting Aquainted with Your New YAMAHA Electrone, model E-5AR.* Retrieved January 25, 2026 from https://usa.yamaha.com/files/download/other_assets/1/320771/E5ARE.PDF

[28] Yamaha Corporation. 1975. *GX-1: Guide to Your Yamaha Electone.* Retrieved January 25, 2026 from https://usa.yamaha.com/files/download/other_assets/4/320414/GX1E.PDF

[29] Yamaha Corporation. 1976. *CS-80 Polyphonic Synthesizer Instruction Manual.* Retrieved January 25, 2026 from https://usa.yamaha.com/files/download/other_assets/0/311160/CS80E.zip