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# Wobble Strings: Spatially divided stroboscopic effect for augmenting wobbly motion of string instruments

Shogo Fukushima *, Takeshi Naemura

*The University of Tokyo, Tokyo, Japan*

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ABSTRACT

Visual stimuli in the form of special lighting effects are often used to provide additional entertainment when musicians perform. Many technologies have been developed to synchronize visual and audio effects; for example, a CMOS camera can be used to capture the motions of the strings of string instruments as a visual medium. However, because a CMOS sensor scans video line-by-line in sequence, fast moving objects are distorted during the scanning sequence. This morphing and distortion are known as the rolling-shutter effect, which is considered an artistic photographic technique such as strip photography and slit-scan photography. This effect can only be seen in a camera viewfinder or on a PC screen and is usually not perceived by the naked eye. We aimed to overcome this problem by developing a system to allow the rolling-shutter effect to be observed in real time using spatially divided stroboscopic projection. The system produces a wobbly slow-motion effect by animating the sweep lines. Our system also alters the color and texture of strings using a projection of the color and texture sweep lines. Furthermore, it can also change the shape of strings to arbitrary two-dimensional shapes such as geometric patterns or patterns consisting of characters.



## 1. Introduction

Strings playing and artistic performance are common entertainment activities, and a vast number of instruments and technologies have been studied to augment the experience. In particular, lighting and on-stage visual effects that are synchronized with the musical sound being produced are popular methods to amuse the player and the audience. Most of these systems control the light pattern in accordance with the rhythm of the music. Apart from this synchronization of the order of several tens of hertz, we succeeded in achieving a highly synchronized effect of the order of several kilohertz, which means the lighting pattern can be changed several tens of times while the instrument is acting as a source of vibration. By achieving this high degree of synchronization, we make the assumption that vibration of the vibrating source can be used as visual medium for providing entertainment.

As an example of utilizing a vibrating source as visual medium, we focus on morphing and the distortion effect of the periodic motion of the string of a string instrument. The motion resulting from the string distortion is used as visual medium in music videos [1,2]. For example, when we use a CMOS camera with a specific frame rate and shutter speed to capture strings being played, the strings seem to vibrate in a wobbly slow motion pattern. Because a CMOS sensor scans one line of video in sequence, fast moving objects are distorted during the scanning sequence. The morphing and distorting produced in this way are known as the rolling-shutter effect, which is considered to be an artistic photographic technique similar to strip photography [3] and slit-scan photography [4]. However, the effect can only be seen on a camera finder or a PC screen and the settings of the camera have to be carefully adjusted in accordance with the pitch of the instruments and the brightness of the environment; therefore, the guitar player and audience are quite unlikely to notice it with the naked eye.

We addressed this limitation by developing Wobble Strings, a system that allows the rolling-shutter effect to be observed by the naked eye in real time using spatially divided stroboscopic projection (Fig. 1(A)). The stroboscopic effect is a temporal aliasing effect that is created with a spatially uniform flashing light, and it can create stop-motion and slow-motion effects. On the other hand, we opened up a novel spatially divided stroboscopic system capable of accepting feedback from musical instruments. The system can produce a wobbly rolling-shutter effect in real time by generating the animation of sweep lines using a projector in accordance with the pitch of strings. Our system can also alter the color and texture of strings using a projection of the color and texture

* Corresponding author.
*E-mail address:* shogo@nae-lab.org (S. Fukushima).

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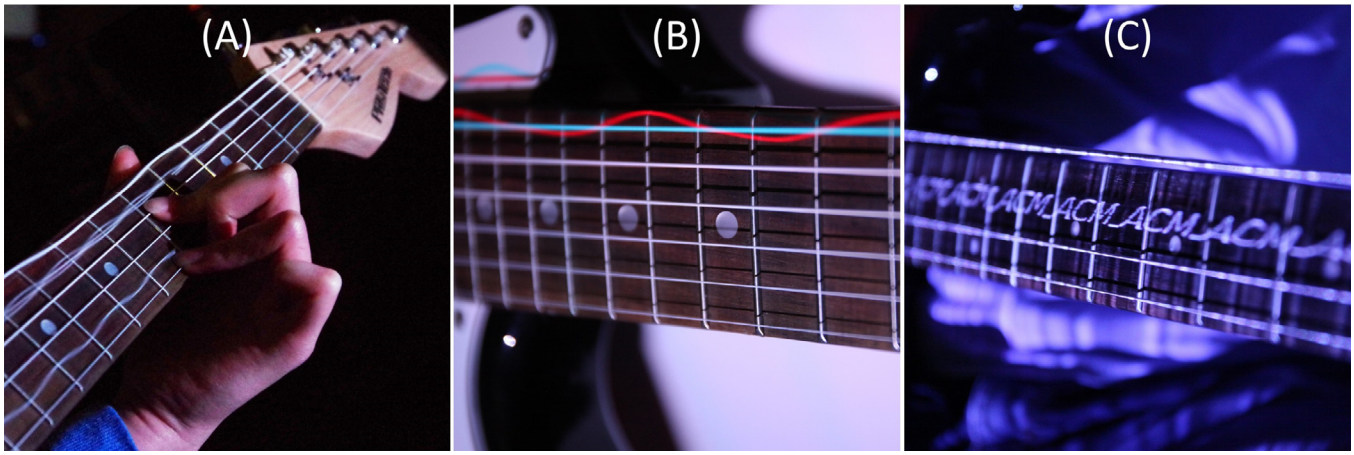


**Fig. 1.** Representative images generated by Wobble Strings. (A) A wobbly motion result in the case of simple animation of the sweep lines. (B) A color-coated wobbly motion result generated by color sweep lines. (C) A shape deformation result generated by special lines pattern.

sweep lines (Fig. 1(B)). Furthermore, it can also change the shape of strings to arbitrary two-dimensional shapes such as geometric patterns and patterns made up of characters (Fig. 1(C)). Our system enables a guitar player to monitor the string oscillations and allows the audience to experience an artistic visual effect accompanying the guitar sound.

The contributions of this paper are:

- We constructed a new projection system that enables the rolling-shutter effect to be observed by the naked eye in real time using spatially divided stroboscopic projection, and evaluate the latency of the system without disrupting the experience created by the guitar being played.
- We propose a flicker-free wave number control method, and evaluate the efficacy through a psychological experiment. The wave number is increased in reverse proportion to the frequency of the sweep line; hence, the flicker-free method is necessary to maintain a stable projection.
- We realize a novel visual effect that is difficult for spatially uniform stroboscopes to generate by using spatially divided stroboscopic projection such as the color and texture coated effects and shape deformation effect.

## 2. Related work

### 2.1. Stroboscope

A stroboscope is an instrument that produces brief repetitive flashes of light similar to a flash lamp or a high-brightness LED. When the frequency at which the light flashes is adjusted to the frequency of a moving object, the moving object appears to be stationary or slow-moving. Thus, the instrument is employed as a timing light for various measuring instruments such as the diagnosis of vocal cords [5], the measurement of the rotation speed of motors [6], and as a stroboscopic guitar tuner [7].

The beautiful visual effect created by a stroboscope is also used for pre-film animations and art works. Zoetrope [8] and Phenakistoscope [9] are the pioneering systems that utilize the visual effect of the stroboscope for creating 2D picture animation. The visual expression produced by Zoetrope has been extended to 3D sculpture animation [10–12]. Kinetic light sculptor [13] is an art work based on a stroboscope and comprises a quickly rotating rope stretched from ceiling to floor and a high-brightness LED. The user can change the stretch of the rope to create various visual patterns. In addition to these light systems, a special goggle-type stroboscopic device was proposed [14]. The goggle device is equipped with a high-speed shutter; hence, it allows users to perceive the same stroboscopic effects in daylight environments. Because this stroboscopic system produces a spatially uniform flashing light, it can create stop-motion and slow-motion effects of an object; however, it cannot easily create morphing and distorting effects of the object.

The use of a stroboscope to create morphing and distorting effects was realized by Fukaya who proposed a spatially divided stroboscope system named MorphoVision [15]. The system comprises a rotating 3D solid object, a projector that produces the image that serves as the slit lighting, and a polygon mirror for sequential scanning. The system provides 16 different slit lighting patterns, enabling the user to select the pattern and observe the distortion result. However, the user can neither directly operate the distortion object nor can they freely change the rotation frequency; hence, the interaction between the user and the system is limited. Furthermore, the developer did not consider a system involving musical instruments and musical applications.

### 2.2. Musical instruments augmented with a light system

Lighting and stage effects are popular methods that are used to augment musical performances. Well-known methods are the projection of graphics onto wall screens and the use of laser lighting together with the release of smoke into the air. Kimura et al. created an augmented violin system [16] that generates interactive graphics in response to the sound of the violin in real time. However, these systems do not utilize the surface of the musical instrument as a projected screen; thus, reproducing the motion distorting and morphing effects of the instrument are difficult.

A system that utilizes musical instruments as a visual display has been emerging in recent years. A variety of commercially available products as well as research systems exist. Augmented systems, which brighten the body of the instruments for staging with embedded LEDs [17] and learning codes with a pocket projector [18], were proposed. However, these systems require musicians to remake their instruments or to buy a special instrument system. Projection-based augmented systems, of which there are mainly two types, i.e., a mobile projector mounted on the instrument and floor-mounted projectors, were proposed. Although these systems do not require instruments to be reconstructed and are able to project rich visual information on the strings and body of the