1. INTRODUCTION

Historically, electronic musical interfaces have appropriated existing hardware in unexpected but expressive ways. By exploring interactive elements on traditional musical instruments and imagining their possible analogues on commodity hardware, we can take advantage of existing musical gestures and potentially recontextualize them. Designing for widely-available computing devices benefits from a low barrier to entry (in terms of cost and experience) and familiarity to the user, as well as new aesthetic and expressive possibilities. These motivations led to the Laptop Accordion (LA), which takes advantage of the simple opening-and-closing action of nearly every modern laptop, utilizing its front-facing camera as a primary input to the interface. The interactions associated with the traditional instrument are transferred to the digital artifact, combining a recognizable instrument with an everyday computing device and resulting in a whimsical, unconventional musical interface.

Given the simplicity of the idea, the ubiquitousness of laptops, the proliferation of laptop orchestras, and the physical similarity of opening and closing a laptop to that of an ac-
Ocarina.

existing instruments suggest new controllers. Further-
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and UI challenges. Discussions of new musical interfaces of-
ence," rather than the typical one-screen-one-user paradigm)
gests new forms of interaction (particularly with an "audi-
der" on its side. The LA asks its user to rotate the laptop
90 degrees, face the screen away, hold it in a specific manner,
and engage with it on uncannily familiar physical terms. As
such, the laptop is recast into something else: a strange-yet-
familiar, whimsical musical interface.

Facing the screen and keyboard away from the user sug-
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and UI challenges. Discussions of new musical interfaces of-
ten question the traditional laptop-based performance setup
where a performer faces the audience with a laptop in front of
them, engrossed in the information on the screen. A
time-honored complaint about this performance aesthetic is
that the performer looks as though they "might as well be
checking their email" rather than actively participating in
music creation. Furthermore, traditional DAW-based pro-
duction environments have become so ubiquitous that the
notion of a laptop as a physical instrument rather than a
software interface, sequencer, synthesizer, or processor of
musical data can be difficult to conceive. This nearly un-
shakable stereotypical role of the laptop is what renders the
LA a compelling exercise in interaction design.

2. RELATED WORK

The design for the LA was inspired by previous notable
reappropriations of the physical laptop for musical ex-
pression. The Small Musically Expressive Laptop Toolkit
(SMELT), for instance, provides tools for developers to use
the physical interfaces of the laptop as controllers, including
the keyboard, microphone, and for those laptops with sud-
den motion sensors, the accelerometer. In this work,
Fiebrink et al. articulated an ethos of co-opting laptop
hardware to transform the laptop into physical musical in-
terfaces ("don’t forget the laptop"!), and directly influenced
the use of a laptop hinge as a physical vehicle of expression.
In a less physical sense, live coding has re-examined
the aesthetics of live laptop performance.

The iPhone “Ocarina” was designed almost purely by
working backwards from the available sensors and capabil-
ities on a smartphone, leveraging multitouch, accelerome-
ters, microphone, graphics, sound synthesis, and even net-
working and global positioning to craft a coherent musical
artifact. It made for an uncanny computer-mediated re-
envisioning of a real-world instrument.

As an augmented musical interface, Cook and Lieder’s
SqueezeVox provided additional context for an
Accordion-style music controller. This notable set of
computer-mediated controllers didn’t so much co-opt
the laptop, but the accordion itself by augmenting it with
various sensors mapped to synthesis parameters. The
SqueezeVox project featured multiple instruments (named
Bart, Lisa, Maggie, and Santa’s Little Helper) that explored
using the physical accordion interactions as a controller for
singing synthesis.

The game modes of the LA, meanwhile, took direct
inspiration from the expressive and proactive interaction
paradigms in music games like Smule’s “Magic Piano” and
, to a lesser extent, from the more reaction-based map-
dings of video games like Guitar Hero and Rock Band.
The ability to play a complex song with one’s own
pacing (such as in Magic Piano) is a design goal that was
factored into the LA, where different difficulty levels afford
a low barrier of entry as well as a high skill ceiling.
Finally, the laptop orchestra paradigm has further pro-
liferated the design of laptop-based musical interfaces, and
provides an ecosystem for continued development and
performance with the laptop.

3. DESIGN

The core mechanic at the center of the LA is the use of
the laptop hinge to simulate bellow movement, and the key-
board as a stand-in for the right-hand manual. The opening
and closing of the laptop screen is tracked in real-time by
computer vision analysis and motivated many design deci-
sions in creating the instrument. A primary goal was to
map the user’s notion for the action of an accordion
(whether based on prior experience with the instrument or
a passing familiarity) to minimize the learning curve.

A user familiar with the interaction of an accordion can
use the same gestures on the LA and expect a similar re-
sult. For users with no conception of an accordion, a brief
experimentation with the keys and screen rotation provides
an understanding of how to control its main musical param-
eters, dynamics and pitch, as well as the expressive and me-
chanical capabilities of the instrument, including polyphony
and the keys or bellows to create different articula-
tions, staccato or legato, just as would be the case with a
traditional acoustic accordion. Since the physicality is pre-
served, one can experiment with LA in the same manner as
the “real thing”.

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Figure 2: The Laptop Accordion (LA) tracks the opening and closing of the laptop screen as a physical metaphor for the stretching and compression of accordion bellows and the keyboard as a buttonboard. These inputs are mapped to real-time generated audio.
Upon beginning the program, the laptop screen renders a skeuomorphic representation of accordion bellows that stretch and compress when the screen rotates or there is movement in front of the camera. In this context, skeuomorphism refers to design cues that imitate the original instrument, but are no longer “necessary” to perform the task of sound production—whereas bellows are mechanically fundamental in acoustic accordions, the LA simply utilizes the image of bellows to refer to the original functionality of the instrument and as a vehicle for visual communication. The immediate feedback provided by this skeuomorphic system clues the user into the usage of the instrument without explicit directions, leaving them to explore the accordion on their own terms.

As a tool for encouraging user engagement with the program, skeuomorphism ties the virtual and the real accordions together, creating a meaningful metaphor for beginners without being explicit about the intended method of playing the instrument. Secondly, the orientation of the bellows on the screen (stretching and compressing along the height) suggests a particular orientation of the laptop which is more consistent with how one would hold an actual accordion, rather than sitting on a table or lap.

A second visual style was created as an experimental, non-skeuomorphic alternative to the accordion bellows, while still retaining the graphical motion cues from before. In particular, the graphics are comprised of a field of particles on a dark background that stretch and compress at the same rate as the skeuomorphic accordion bellows. The intention of this mode was to provide similar feedback for the motion of the instrument without harkening back to the original instrument, allowing for a different relationship between the synthesis of accordion sounds and the associations these alternative visuals might suggest.

Furthermore, an overlay interface gives visual feedback of the keys being pressed (the basis for various game modes) and allows selection of various musical parameters such as scale, key, and pitch bend, as well as program parameters, such as graphical style, fullscreen toggling, game mode switching, and the pitch mapping layout.
4. IMPLEMENTATION

As with an acoustic accordion, sound production is primarily contingent on two parameters: volume is controlled by the rate at which the bellows are stretched and compressed, and pitch is controlled by the buttonboard. These both have corresponding mappings to the laptop itself, where bellows rate is congruent with screen rotation rate and the buttonboard is functionally identical to a keyboard.

Keeping with our interactive design goals, the sound output of the instrument is a synthesized accordion, implemented with SoundFont synthesis and MIDI controls using the Fluidsynth library. The use of SoundFonts provided acceptable real-time timbres while abstracting away many complexities in sound production, allowing us to focus on playability.

The main technical challenge of the LA is calculating a good measure of screen rotation, which is accomplished using the front-facing camera. The application is built within the OpenFrameworks library, and utilizes a built-in OpenCV (computer vision) add-on as well as a user-created add-on, OfxCv. Together, these implement feature extraction and the tracking of an input image to calculate its optical flow, or the movement of image pixels between two frames.

The OfxCv add-on utilizes an implementation of the Lucas-Kanade algorithm for estimating optical flow [15]. Using a recursively-built pyramidal representation of two successive images, the algorithm approximates vector displacements between tracked feature points, whose average is a good predictor of motion in front of the camera, or, in the LA case, the movement of the camera itself. Using optical flow for musical input can be traced to projects such as SoFA [17, 18], which used optical flow to detect facial movement. Useful overviews of these algorithms can be found in [17, 18].

As a brief technical note, the feature extraction step is not strictly necessary, and algorithms [19] exist to compute the so-called “dense optical flow,” taking into account the movement of all pixels between images. Considering all points has the potential to offer more accurate estimates of camera motion, but in practice we found these procedures to be insufficiently performant on many laptops, while the chosen algorithm, which considers only extracted feature points, seems to offer a good blend of performance and accuracy.

The calculated velocity vector (with some conditioning) controls the MIDI channel velocity, which is congruent to the compression rate of an accordion’s bellows. Given the goal of utilizing only sensors found on a typical laptop, this calculation does not rely upon any external or non-standard components.

5. EVALUATION

The LA can be evaluated just as any new musical instrument, since at its core it is a translation of an actual accordion. Since squeezebox-style instruments are already well-defined, the success of the LA can be gauged by its emulation of the intrinsic musical affordances of those instruments, as well as the presence of any new expressive affordances. As with a typical musical controller, qualities of a useful invention include versatility, expressiveness, learnability, and the intangible traits that result from the idiosyncrasy of the instrument.

Since the target platform for the LA is unspecified consumer hardware, its responsiveness is subject to hardware specifications, the calculation of optical flow, and operating system latency, all of which may vary across systems. Two specific metrics we found to be important were keyboard latency and any bounds on simultaneous keypresses. Overcoming these limitations would be a primary step in developing virtuosity on the instrument. Furthermore, while the physical keyboard layout is fixed and optimized for typing, it is trivial to arbitrarily program keys to with respect to scales, keys, or other novel pitch mappings.

Using optical flow to track the opening and closing of the laptop introduces some latency, which we estimate to be in the 100 to 200 millisecond range. Fortunately, the latency of this component, with proper filtering, is less impactful than the keyboard latency, which accounts for the primary point of articulation in the sound and is far more responsive (as a matter of hardware and software design).

Optical flow, in essence, controls the volume envelope: when the laptop screen is in motion, the user would still need to press a key to begin the sound. The envelope value at the point of articulation controls a note’s velocity, and subsequently provides continuous control to further modulate the volume, making a variety of nuanced possible. In our informal user trials, participants report the main button-and-buttonboard interaction to be natural and responsive.

The physical resistance of the screen hinge emulates the feedback from air compression in traditional accordion bellows, and presents an interesting opportunity to enhance the perceived embodiment of the instrument. At the same time, a practical question remains on structural wear-and-tear of the laptop screen hinge under the stress of repeated opening and closing. While this hasn’t caused issues in our experiments, one should be mindful of the possibility.

Our existing repertoire of LA music includes The Star-Spangled Banner, Auld Lang Syne, Étude Satie’s Gymnopédies, Bach’s C Major Cello Suite, Vittorio Monti’s Csardas, Claude Debussy’s Clair de Lune, Nikolai Rimsky-Korsakov’s Scheherazade, Mozart’s Rondo Alla Turca (the “Turkish March”), and the ever-popular Twinkle Twinkle Little Star. The flexibility of the instrument means that the sky is the limit when it comes to play through mode—all any tune that lends itself to arrangement on the accordion can be translated into a MIDI file and played with ease.

Performance with the LA is a largely unexplored arena, but the possibility of novel performance practices was apparent during the development of the instrument. In particular, since the camera tracks whatever features it sees, waving a hand in front of the camera can be congruous to opening and closing the laptop lid. Other actions, such as moving in space or rotating one’s body provide similar input, opening up a multitude of performance opportunities, as well as suggesting the LA equivalent of a “palm mute” gesture, where the camera is purposefully covered to prevent unwanted motion detection.

Finally, the LA seems to be accessible for new users, while providing a significant skill ceiling for those who wish to
practice its various modes; a series of carefully-designed visual cues, for instance, teaches the instrument’s mechanics. This range of difficulty can be adjusted between simplicity for novices on the one hand, and on the other, sensitivity for users advanced enough to exploit it. Above all, perhaps, there is inherent charm in watching a performer hold a laptop sideways and play a tune with it.

6. FUTURE WORK

Moving forward, there are several avenues for exploration and improvement. The Laptop Accordion can benefit from more accurate simulation of the accordion sound, and experimentation with abstract (non-accordion) sounds that lend themselves to the interaction. In both cases, the instrument could become a professional tool or a more fully realized objet d’art. Options for improved synthesis veracity include physical modeling of the acoustic instrument or reproduction of samples from a variety of real-life instruments (such as concertinas or accordions from different time periods).

User studies would be extremely useful in determining the capabilities of the LA with respect to skeuomorphic feedback and the possibility of virtuosity. Interesting topics for study would be the preference of performers and audiences for various interfaces (skeuomorphic or not), as well as the system performance requirements to enable a virtuoso player in pushing the instrument to its limits.

Cross-platform compatibility and modularity is another distinct goal for the future, enabling more types of users to experience and iterate on the software. While the initial artifact was intended as an exercise in design, future projects could use the LA paradigm as a generalized controller for other sounds (e.g. singing synthesis, like the SqueezeVox). Options for increased modularity—in tandem with the goals for sound production—include interchangeable synthesis modules, as well as frameworks for driving other engines (e.g. via MIDI or OpenSoundControl).

On a more mechanical level, the calculation of the average optical flow is a relatively complex and expensive operation, and therefore is not very well suited to slower devices. Research into algorithms that provide good tracking with lower computational cost (and possibly lower latency), or even modifications to the current system, might extend usability to older or low-cost devices, enabling a larger user-base and the possibility of inexpensive musicianship. In addition, modification of the synthesis system (as mentioned above) could result in speed gains while lending additional flexibility in implementation.

Finally, while a range of music is currently being played on the LA, the possibilities afforded by instrument-specific works are broad and of significant interest. Considerations such as networking and ensemble play are rich for exploration, as is the use of the screen for the display of work-specific artistic content. As previously noted, laptop orchestras like Stanford’s SLOrk provide an excellent incubator for the vast possibilities of the instrument. We look forward to creating dedicated works for the LA in exploring the possibilities of various ensembles.

7. CONCLUSIONS

We designed, implemented, and evaluated an accordion-like instrument based on the core components of a traditional laptop. Our efforts made use of off-the-shelf image processing algorithms to track the motion of a laptop’s screen, serving as an analogue to the compression of accordion bellows, which is in turn mapped to the volume of the synthesized sound. The net result was a piece of software we found to be accessible yet nuanced for musical expression.

Moreover, by prioritizing user experience and aesthetic satisfaction in designing the Laptop Accordion, we developed an artifact that is functionally pleasing to use, and aesthetically quirky. We believe that more potential for musical expression exists in the tasteful, creative repurposing of existing technology, and we look to continuing this line of design inquiry for future work.

8. ACKNOWLEDGMENTS

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9. REFERENCES


