Stitch: a Knitting-powered Musical Interface using Computer Vision

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ABSTRACT

This paper describes a new instrument for musical expression that makes music from knitting. This interface uses only knitting needles, yarn, and a computer as hardware. The webcam input on a laptop captures the player knitting in real-time, and a bespoke MaxMSP patch processes the incoming data stream. Movements are detected using computer vision principles to identify shapes, lines, and the motions of the performer's stitches. Gestures the performer uses are then mapped to a synthesizer that produces music according to how the player moves, while they knit and purl. Each performance varies due to the speed at which the performer knits, the technical knitting style of the performer, the kinds of stitches cast on the needles, the color and texture of yarn used during performance, and the size of the knitting project.

Author Keywords

NIME, Sound and Music Computing, fiber arts, knitting, computer vision, Max MSP

CCS Concepts

•Applied computing → **Sound and music computing; •Human-centered computing** → *Gestural input;*

1. INTRODUCTION

Knitting has a centuries old, storied tradition among women in Scandinavia. Originating from Arabia and travelling to Europe on trade routes [9], it was originally a craft performed primarily by tradesmen's guilds. As yarn became increasingly affordable and available, many middle and upper class European women started to knit too. As a result of this change, men began to reject the craft as a feminine pursuit [8]. As time progressed, women began to knit as a means to demonstrate ability to provide for a husband, and later as a means of protest in feminist movements [17], [2]. Today, knitting is still most common amongst women and girls, with as many as 99 percent of respondents in some studies involving knitting identifying as women [19]. Additionally, knitting has been shown to be a pastime that reduces stress, and can be done at home as a solo activity, contributing to its recent resurgence as a hobby catalyzed by the COVID-19 pandemic [20][10][3][4]. All of this is relevant and interesting to the first author, who happens to be a woman living in Scandinavia who has recently learned to knit.

Within the NIME community, and within the broader electronics and sound communities, interest in knit materials for interaction has been rising in recent years. E-textiles are used for flexible, tight fitting sensor data acquisition systems [18]. In the musical instrument domain, projects such as FabricKeyboard [21], KittedKeyboard [22] and Singing Knit [15] were sources of inspiration for this project, because of their use of knitted materials. Where this project departs from such inspiration is in how knitted fabric is used. The aforementioned works use pre-knitted materials as sensors to either replicate existing instruments (KnittedKeyboard) or augment acoustic instruments (Singing Knit). Stitch aims to turn the act of knitting yarn together into what makes the music as process in and of itself. Placing a performer with knitting needles and yarn in front of a webcam running the Stitch software is the only thing needed for this work.

The concept for Stitch is to investigate how to build a NIME that creates music while also incorporating a component of visual art. While such approaches are not new, e.g., projects capturing dancing with sensors on clothing or using a webcam to map movements to sonic gestures [16], but there has been relatively little done in the area of using fiber arts to create music. With Stitch, the design of the knit informs the composition of the piece being played, and vice versa. Similar to how there are infinite ways of knitting a sweater, scarf, or hat by changing the pattern of the stitches and yarn, Stitch's compositions have infinite possibilities. It can be used by beginner knitters or experienced knitters at home to compose music while making a project, or it can be used by musicians who want to learn some knitting technique. This would be especially useful for them, according to a study showing that amateur knitters are significantly happier than amateur musicians [6]. There can also be more of a performative aspect to Stitch by placing the artist on stage with accompanying musicians. Stitch can be a collaborative instrument, for instance in knitting circles if each member of the circle has their own webcam and accompanying software setup. Stitch can also be a solo instrument, included in an avant-garde music performance or enjoyed in the privacy of ones home while knitting on the couch. The gesture mapping and synthesizers used for Stitch can also be changed depending on the composer's artistic needs.

The remainder of this paper gives an overview of the

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work related to inspiring and informing Stitch, describes its design goals and current sound mappings, and details the implementation of the computer vision concepts, packages, and synthesizers used in the MaxMSP software developed for Stitch. Finally, we put forth some discussion about the outcomes of this initial exploration of Stitch, and where future work on the project could lead.

2. ETHICAL STATEMENT

This project was created in earnest as a way for people to make music regardless or gender, ethnicity, or socioeconomic status. No data was collected from individuals outside the creators of the project. Knitting needles and yarn are available at low costs in second hand stores, and can be reused. Most libraries have computers that can be used to download and run software on a free license of MaxMSP.

While the authors strove for an inclusive system, of course there are shortcomings. Those who have limited or no mobility in their hands will struggle to use the instrument. Additionally, while those who are visually impaired can still knit using their tactile senses, they may encounter difficulty when operating the software.

3. RELATED WORK

The following projects include work that was surveyed when preparing Stitch. These projects were considered for their use of textiles to make musical interfaces:

- FabricKeybord/KnittedKeyboard: The KnittedKeyboard is a project that emerged from MIT's Media Lab, which is a keyboard made from conductive, thermochromic, and polyester yarns knit together by an industrial machine [22]. There are additional sensors embedded into the fabric piano for further gestural control. The FabricKeyboard is an earlier iteration of the same knitted keyboard interface. The nature of this keyboard allows for stretching, twisting, folding, and compacting the fabric to make sounds [21].

- Singing Knit: The Singing Knit is a wearable knit collar for measuring a singer's vocal interactions through surface electromyography (EMG) made by a group at Queen Mary University of London [15]. It uses EMG sensors to augment vocal performance by using knit fabrics, something that humans are used to wearing around their necks instead of dealing with the discomfort and irritation that comes with applying and wearing electrodes, as is customary for EMG augmented instruments.

- Buffer: Made by artist Nicola Woodham, Buffer is an e-textile made of a jacket and companion headpiece with sensors placed inside both. The sensors both trigger sound samples and adjust filter parameters in a performance setting [1].

These projects were considered for their use of computer vision through a laptop's built-in webcam.

- Hand Motion-Controlled Audio Mixing Interface: A touch-free music mixer using computer vision on either the LeapMotion or the Microsoft Kinect. The user moves objects around within the cameras view to control musical parameters such as volume and panning [14].

- Handmate: A browser-based hand gesture controller for Web Audio. It was built in the web environment so that its users could access computer vision technology without requiring specialized hardware or software. It uses a webcam to track hand gestures. There are two modes – one for making effects with hand gestures on a microphone sound input, and one mode for MIDI, which maps the hand gestures to MIDI output[7].

4. DESIGN

After surveying the available literature, the ideal outcome for the Stitch system would be a musical interface that requires no special equipment beyond what would be in a typical home of a musician or a knitter, and creates beautiful music based on thoughtful mappings from gesture to sound output. The ideal outcome of Stitch would also be a system that allows the audience to walk away from a Stitch performance feeling like they saw something powerful and novel, and allows the performer to walk away from a performance with a piece of art (or at least the start of one) and a calm demeanor, as is typical after a long knitting session.

Something that all of the e-textile NIMEs surveyed in the literature have in common is sensors and conductive threads embedded into their bodies, either through the use of conductive thread embedded into the yarn or sensors attached to the yarn making the body of the instrument. This is the nature of an e-textile [18]. For Stitch, it would not be appropriate to attach sensors to the yarn or the needles, as this would inhibit the movement of the performer and the construction of the knit. The most logical solution was therefore to use a camera to track the movements and shapes made by the knitter and the fabric.

With the concept fleshed out and main hardware selected, it was time to consider how to design the system. Figure 2 shows a block diagram of the whole system, from the knitter, through the sound processing done in MaxMSP, to the final sound output at the end. A knitter sits in front of a webcam captured in MaxMSP, and as they move their hands, knit, purl, stretch, and pull the yarn these gestures are tracked by various objects from the cv.jit (v.2.02) package available in the MaxMSP package manager [13]. It was decided to use this package because it comes with a multitude of image processing techniques and feature detection objects, along with extensive documentation. There are some native objects in MaxMSP that process video as well, but more advanced are available in the cv.jit package. The details of this implementation will be described later.

Knitting items by hand is a "slow-living," offline, relaxing process that people to do slow down and give a lot of attention to something they love. This idea is at the heart of Stitch, and was especially in the designer's mind when considering how to map gestural input to sound output. It is important that the mappings can feel organic, straightforward, and natural [12], and not like one is fighting the computer to have control of the music. Three of the most obvious visual features that could be picked up by a camera and mapped are:

- The orientation of the knitting needles. Are they pointing up? Is one needle pointing to the side? Are they both pointing at a 45 degree angle?

- The amount of already-knit yarn is in the frame of the camera. Is the project a bright pink almost-finished scarf cascading down the performers lap? Are there only two rows of stitches that are the same color as the performers shirt? Are the individual stitches being

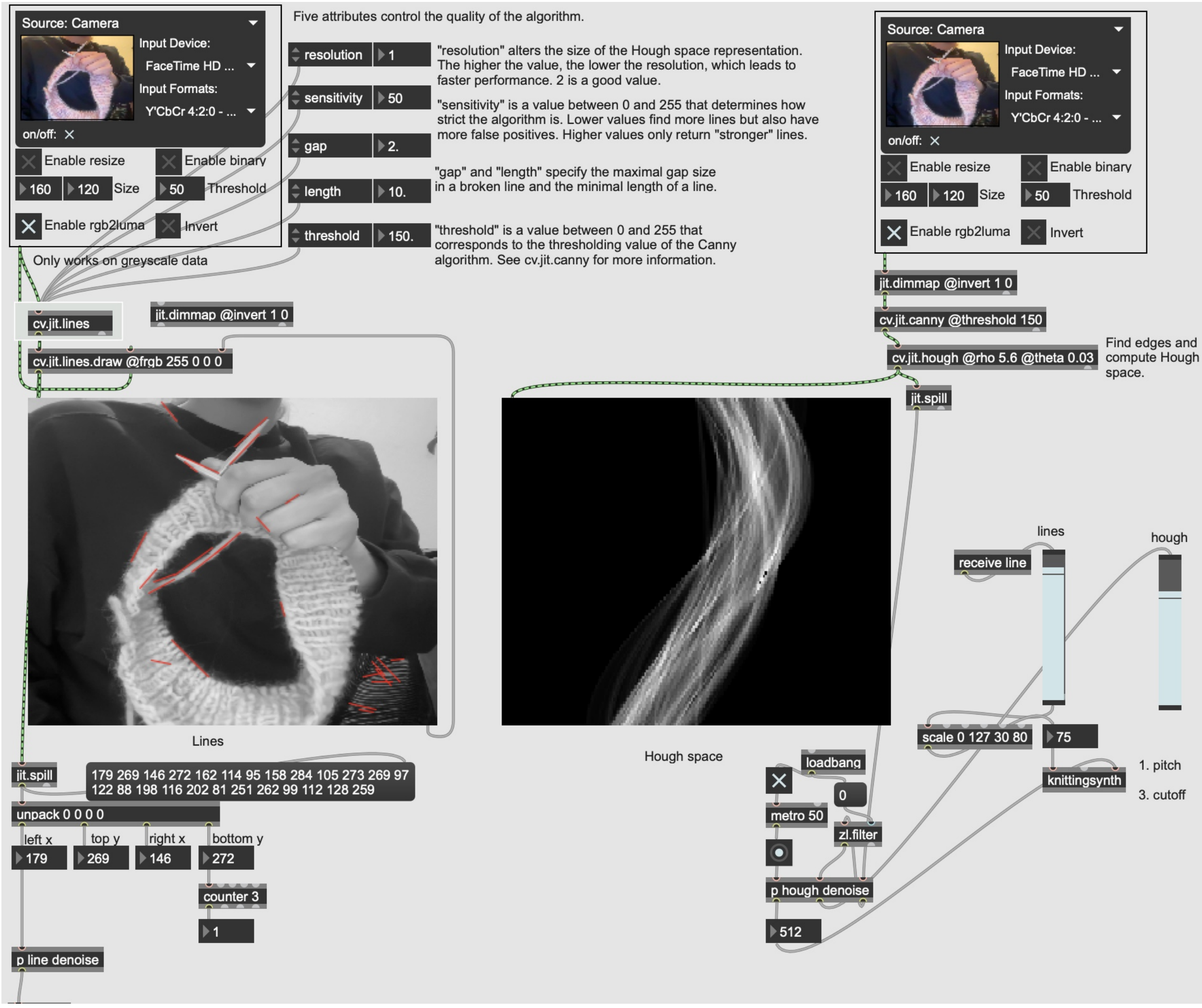

Figure 1: A screenshot of the main maxpatch

stretched out for the knitter to read their work? Are the stitches scrunched together?

- The amount of movement the performer is making. Are they making small, slow movements with the stitches? Or are their elbows flying and is there smoke flying from the needles because they are knitting so fast?

The gestural inputs described above were mapped to two parameters of a synthesizer: the fundamental frequency of the synthesizer and the center frequency of a bandpass filter applied to the synthesizer. The sound design vision for Stitch is somewhat modular, because it is fairly simple to change the synthesizer being used at the end of the data stream, once it has been processed and de-noised. For this first iteration of the project, a drone sound was chosen. In some meditation practices, it is common to have drone sounds played over long periods of time that create strong overtones. Since knitting is a relaxing way to pass the time [4], it seemed fitting that the sonic design theme was meditation.

5. IMPLEMENTATION

The software environment chosen to implement the Stitch system design was MaxMSP 8. It is a rapid, robust prototyping software that has both built-in video and audio processing capability as well as a plethora of user-made software packages with ample documentation. This specific patcher makes use of the jitter objects that come with Max and the objects in the aforementioned cv.jit package made by Jean-Marc Pelletier [13]. This package contains a collection of external objects that use various computer vision concepts such as facial recognition, blob detection, and overlaying graphics that give visual feedback for the patterns that the objects detect. The following objects were leaned on most heavily for image detection in Stitch:

- cv.jit.hough: This object computes the Hough transform of the live webcam stream once it has been turned into a binary image. For every pixel in the binary input that contains a 1, every line passing through that point is represented in a Hough space image output by its distance and angle from the origin. The result is that for every 1-pixel a sinusoid is created. See the black box in the middle of Figure 1 for a view of how the Hough space looks in the patch's visualizer.

- cv.jit.lines: Figure 3 shows the camera input connected to this object. There are red lines superimposed on the image where it has detected lines on the knitting needles. cv.jit.lines uses the Hough space mentioned above to find straight lines in a greyscale image.

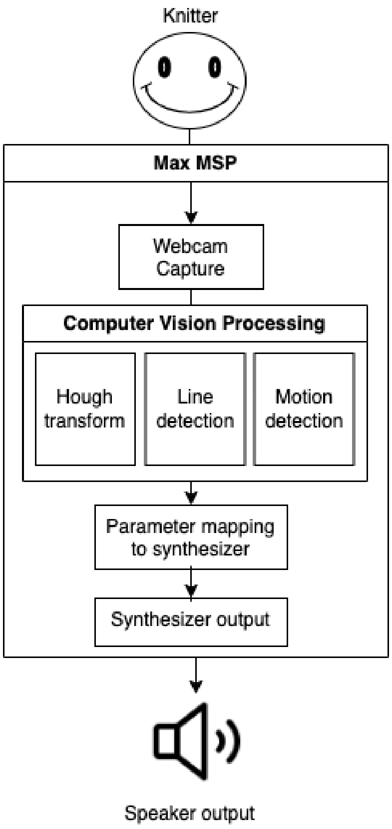

Figure 2: High level overview of the the entire Stitch system.

Figure 3: Line capture visualizer from the cv.jit.lines object

Once each of the webcam streams are passed through their respective computer vision processing objects, they output data in the form of Cartesian or polar coordinates. Each of the raw data stream outputs are incredibly noisy, and for that reason needs to be processed to make more manageable data streams, that can be controlled in simple one-to-one mappings using gestures of the knitter. This was done by taking the running median each of data stream and smoothing it out so that it was a bit more manageable to map parameters to.

After the data streams are smoothed, they are mapped to the parameters of a synthesizer. The synthesizer used in this patch is a simple monophonic synthesizer overlayed with a bandpass filter. The line detection algorithm's output was mapped to the pitch of the synthesizer, and the output of the hough space calculation was mapped to the center frequency of the bandpass filter. The line detection algorithm fed the frequency of the synthesizer because of the way that the cv.jit.lines object works: One of its outputs is the left most x coordinate of a line, and it seemed intuitive that the position of the lines on the screen should be mapped linearly to pitch. The Hough space output was mapped to the center frequency of a cutoff filter because that is another effect that was desired in the sound design, because it was in the creator's mind that there should be noticeable overtones in the music created because they create a meditative effect that compliments the already soothing nature of knitting.

Please see Figures 1 and 4 for a view of the entire max patch, and the synthesizer subpatch, respectively. A video of Stitch can be found at the Youtube link in the footnotes. [1]

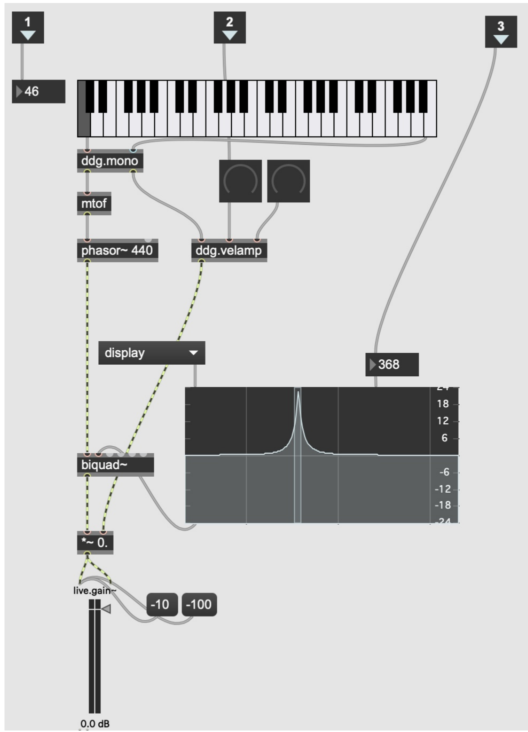

Figure 4: A screenshot of the synthesizer subpatch (called knitting synth, bottom right of the main patch)

6. DISCUSSION

This paper is an initial exploration for the concept of Stitch. Its development included an autobiographical design (ABD) from the first author of this paper, who designed and created the system. ABD research shows that human-computer interface experts often use this process when developing new systems [11] [5]. It has been shown to be extremely valuable for designers to get early stage feedback on their system, and it facilitates major tinkering and faster iteration than having to wait to recruit a panel or participants for a generalized usability test [11]. These are relevant considerations for Stitch, which is a novel instrument by a designer with the necessary skill set of the intended end-user. One result from this ABD is that there is most obvious room for improvement by reducing the amount of latency caused by the denoising process, and having more granular control over the sonic output of the system. It would demonstrate true control over the mappings process if one could hear the difference between each individual stitch being cast onto the needle in soothing synthetic polyphony.

[1]https://youtu.be/iZujUEqWma0

7. CONCLUSIONS

In this paper, the concept, design, implementation, and potential use cases for a knitting instrument were described. Stitch is an instrument that is inspired by e-textiles but takes the concept in a different direction. It is a knitting musical interface that uses computer vision from a webcam in MaxMSP to make music while also participating in making fiber arts. There was consideration in how to map the movements in a way that feels natural for the performer and also fits the vibe of knitting, which is a calming and meditative time for most knitters.

The authors acknowledge that the scope of Stitch in its current iteration is limited, as this was an initial investigation of its concept. There is always room for future work in any project, and Stitch is no exception. Obvious first steps toward the future could include a more generalized perceptual evaluation of the system from both musicians and knitters to see what they make of the interface and the sound design.

Other future work that would be of interest to the authors would be to weave conductive fibers into a ball of yarn, so that Stitch becomes more of a classic e-textile. It would also be very interesting to test different software mappings and synthesizers, to evoke different sonic themes. For instance, if there were conductive fibers woven into the yarn the knitter could create an “electric blanket” that makes cozy ambient electric sounds as they knit.

The authors look forward to any opportunity for forthcoming research and development on Stitch, and spreading awareness of the exciting fields of e-textile instruments, knitting, and where those two intersect.

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