

scoreLight: playing with a human-sized laser pick-up

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ABSTRACT

scoreLight is a playful musical instrument capable of generating sound from the lines of drawings as well as from the edges of three-dimensional objects nearby (including everyday objects, sculptures and architectural details, but also the performer's hands or even the moving silhouettes of dancers). There is no camera nor projector: a laser spot explores shapes as a pick-up head would search for sound over the surface of a vinyl record - with the significant difference that the groove is generated by the contours of the drawing itself.

Keywords

H5.2 [User Interfaces] interaction styles / H.5.5 [Sound and Music Computing] Methodologies and techniques / J.5 [Arts and Humanities] performing arts

1. INTRODUCTION

A previous work called **Sticky Light** [1] called into question the role of light as a passive element when contemplating a painting. Indeed, the quality of the light, its relative position and angle, all fundamentally affect the nature of the perceived image. The installation sought to amplify this by giving light rays new ways of interacting with a painting. **Sticky Light** is basically a “smart” laser scanner/projector: drawings presented to it are augmented by one or more laser spots that follow contours and bounce at the interfaces between colors. The wandering of these light spots naturally catches the viewer attention. As a result, the role of the scanner is somehow inverted: it no longer acquires shapes passively, but *augments* figures by superimposing a dynamic choreography of light. A clear example of this is the **Sticky Light** operating over a logo or a maze (Fig.1): the eyes may get the whole picture, but as we follow the motion of the laser we may gain a deeper, *temporal* understanding of the figure's elements (connected components effectively trap the laser spot, that keeps circulating indefinitely thus creating visual rhythms). When several spots operate at the same time, we also start better appreciating symmetries and compositional equilibriums (Fig.2).

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NIME2010, 15-18th June 2010 Sydney, Australia
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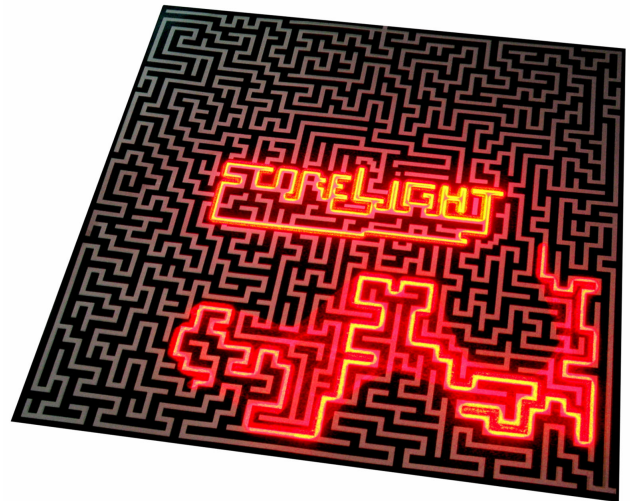


Figure 1: Light is trapped in a maze - and the audience can hear its despair.

2. SONIFICATION OF “STICKY LIGHT”

The installation presented here builds on top of **Sticky Light** by introducing another sensorial modality. Indeed, **scoreLight** not only translates static geometry into motion, but also makes *audible* such features as smoothness or roughness of the artist's stroke, texture and length of the lines, etc. Sound is produced and modulated according to the curvature of the lines, their inclination as well as their color and texture. This means that **scoreLight** implements gesture, shape and color-to-sound artificial synesthesia [5, 8]. Abrupt changes in the direction of the lines trigger discrete sounds (percussion, glitches), thus creating a rhythmic base (the length of a closed path determining the overall tempo). In turn, the generated sound affects both the kinematics and shape of the light spot, therefore forming an audio-visual feedback loop. The result of all this is a spot of light that dances over the surface of the drawing, while decrypting it as a sonic score. In this sense, the installation is an artistic approach to artificial sensory substitution research and artificial synesthesia very much along the lines of Golan Levin's works in the field [9, 10]. In particular, it can be seen as the reverse (in a procedural sense) of the interacting scheme of **Pitchpaint** [9], in which the speed and direction of a curve continuously being drawn on a screen is controlled by the pitch and volume of the sound (usually voice) captured by a microphone nearby. However, the purity of the laser light and the fluidity of the motion make for an unique aesthetic experience that cannot be reproduced by the classic camera/projector setup.

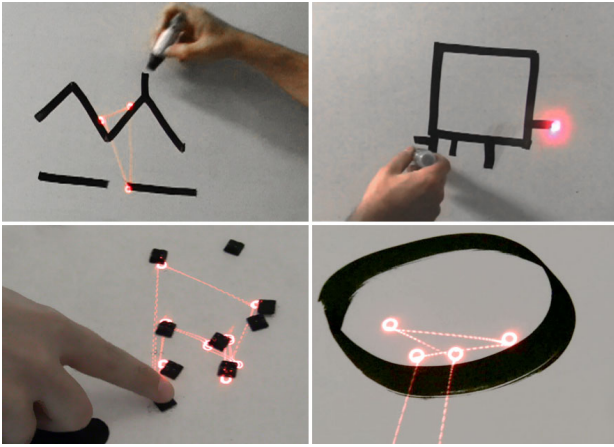


Figure 2: Example of handwritten “light scores”.

2.1 Modes of operation

The simplest mode of operation is *contour following*. In this mode, the drawing as a whole acts as a multi-track sound sequencer (up to six lasers spots can simultaneously scan the surface), each connected component on the drawing representing a particular sound track. Sound can be generated and modulated in the following ways:

- Discrete pitches can be generated by the inclination of the lines (if the figure is composed by curves, their tangent can still be discretized to fit each of the twelve tones of the chromatic scale - or any other scale by the way). In this mode, a closed contour will generate a periodic melody, each note value being proportional to the length of the figure’s (straight) segments. The size of the drawing and the length of the contour will dictate respectively the tempo and overall duration of the melody. (Pitch gliding is possible when the inclination is not discretized.)
- Alternatively, pitch can be continuously modulated as a function of the local radius of curvature of the line being followed. This mode of operation enables one to hear the smoothness of the figure (i.e, reproducing the ‘kiki/bouba’ effect [5]).
- The height of the objects can also be measured by the laser (Fig.11). The (discretized) height can be used to transpose by octaves (up or down). We are now considering the carving of precise three-dimensional structures (resembling a reduced model of a city) that would encode complex musical scores in this way.
- Sound dynamics (volume) can be controlled by the relative position of the spot on the surface. In our last setup, the position of the spot on the performing table controls panning between four speakers encircling the performer (Fig.8).

2.2 Global manipulations

An interesting aspect of the modes described above is that *global manipulations* can be performed on the drawing/score taken as a whole. For instance, rotating the drawing will effectively transpose the melody to a higher/lower pitch when the inclination of the lines code for pitch; changing the direction of the scanning spot will produce a temporal inversion of the melody; flipping the drawing (it can be printed on a transparent slide) along a certain line will

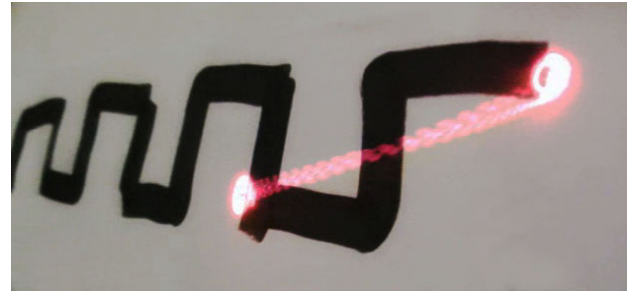


Figure 3: Glitches are produced by a zig-zag.

have a more complex effect (the line’s angles will transform onto their own conjugates, and since the full 360 degrees represents an octave, every interval with respect to the unchanged pitch-line - the flipping line - will be inverted); elevating and slanting a flat drawing can produce interval inversions if height indicates the octave (certain notes will be raised or lowered by octaves). Other suggestive graphical transformations cannot be readily described in musical terms (such as the use of flat mirrors to break the drawing and generate kaleidoscopic-like symmetries or curved mirrors producing complex mappings in 2d, perspective transformations or arbitrary deformations of the surface, etc). Another intriguing possibility consists on drawing on a stretchable supports such as textiles (or the body surface!): stretching along different directions will affect spatial frequencies, thus slowing down or accelerating the speed of the “recording”, very much like in a defective cassette tape. Stretching equally in all directions (i.e., scaling) will affect tempo.

2.3 Other experimental modes

Other modes of operation being explored include:

- Extreme curvature (corners or spikes) can be easily detected and used to trigger pre-recorded samples (percussion, glitches, etc) - Fig.3.
- Bouncing on lines or edges (with or without artificial gravity - Fig.4). This may be useful to create a rhythmic base, or to create instead isolated beeps (very much like in the “Hanenbow” mode in Toshio Iwai’s “Elekroplanton” [3]). In our latest setup, we have included a subwoofer capable of shaking the table as the spot ‘collides’ with figures (rhythms can thus be felt through the hands and body).
- Interaction between spots. Relative distance between the spots can affect the sounds produced by each other (frequencies can become closer with distance, so as to produce audible intermodulation) as well as their dynamics. Moreover, a particular spot can be given attractive ‘mass’ so that the others will tend to revolve around it.
- We are presently experimenting with granular synthesis: parameters of the grains are controlled by large and small scale features of the drawing (these are obtained by computing an FFT of both X and Y positions of the spot taken as a temporal sequence).

Several modes of operation can be combined on a single spot (for instance, spatialization of sound, pitch modulation by the angle of lines, and triggering of pre-recorded samples). Moreover, up to six spots can operate at the same time, each with its own mode of operation. It may

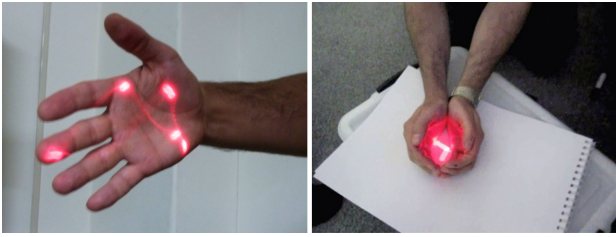


Figure 4: The laser bounces on physical contours.

be playful to “hear” any kind of drawing; however, if one is to use **scoreLight** as a musical instrument, presumably more control can be obtained by creating and reusing interesting drawings and rearranging them on the scanned surface. Recording those scores/patches is inherently a graphical process here; for instance, stickers can be used as the support of sound loops, a technique reminiscent of Oskar Fischinger’s “sound scrolls” or Norman McLaren graphical sound templates. (By the way, precise figures/melodies can be generated and printed by a computer from a MIDI file.) Drawings can also be used as “patches” modulating and controlling the sound material generated by neighboring figures as explained above. For instance, the drawing on a sticker - its shape and orientation - could be used to modulate the volume of the sound produced by another sticker, very much like with the “modular synthesizer widgets” used in the **reactTable** [4]).

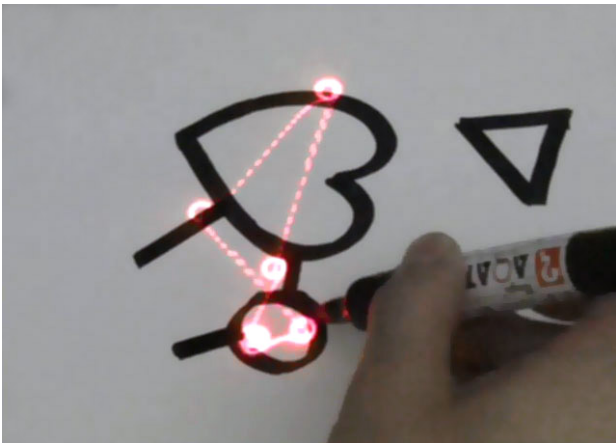


Figure 5: Rhythm is given by the figure perimeter (contour following) or figure area (bouncing mode).

3. TECHNICAL STATEMENT

The hardware is an update of the previous “smart laser scanner” system [2]. The most recent implementation does not use a computer, but an ArduinoMega microcontroller that controls the laser projector, pre-process the acquired data, and sends OSC packets to a synthesizer. Our (custom) laser projector is composed of two laser diodes (red and green) and a couple of galvano mirrors (GSI Lumonics VM500). The sensing mechanism uses a single *non-imaging* photodetector (Hamamatsu APD C5331-13) that measures the backscattered light and whose output feeds a custom Lock-In amplifier. Fig.6 shows a diagram and a picture of the real system (about 30x20x15cm for the main module). The red laser beam (modulatable Premier Laser diode 1mW, 635nm) is used for measuring the surface reflectivity (or for calculating the target distance when the reflectivity is a known parameter), as well as for displaying. Syn-

chronous photodetection is necessary to filter ambient light and other sources of noise. The micro-controller generates a 100KHz square signal that modulates the red laser; this signal also serves as the lock-in amplifier reference laser. The lock-in amplifier acts as a pass-band filter with a very high Q-factor, and usually needs a pair of reference signals (one in phase and another in quadrature) to compute both the phase and the amplitude of the signal. To simplify the hardware, and since the corresponding wavelength of the modulated AM signal is on the range of several hundreds of meters (making the phase shift practically constant), we discarded the quadrature reference and calibrate the phase of the mixing signal once and for all so as to obtain a signal as strong as possible.

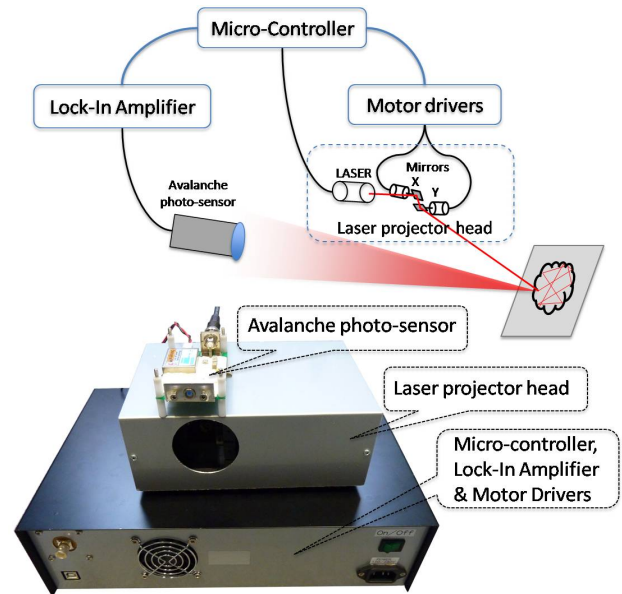


Figure 6: Principle of operation of the SLP using a pair of galvano-mirrors.

3.1 Tracking principle

The microcontroller reads the lock-in amplifier output and an adaptive threshold is used to discriminate between a dark and a bright zone (in fact several gray levels). It also controls the position of the laser spot by generating analog signals driving the X/Y galvano-mirror pair. Tracking and contour following is based upon a technique developed in previous works [2]: the laser beam is capable of detecting, bouncing and following contours in the very same way a blind person uses a white cane to stick to a guidance route on the street. Concretely, instead of continuously scanning over the full field of view, the laser scanner restricts its scanning area to a very narrow window precisely the size of the target. This ‘narrow scanning window’ can be a parametric curve or a raster-scan region. Fig.7 shows the typical circular ‘saccade’ used to track fingers and compute local variations of reflectivity (or depth) when using a scanning curve. The hardware is very unique: since there is no camera nor projector (with pixelated sensors or light sources), tracking can be extremely smooth and fluid. Indeed, the filtered baseband signal extends up to 10kHz, and each exploring ‘saccade’ contain about 20 points, meaning that each saccade can be performed in about 2ms. Several laser spots (up to around six in the present system) can be generated and controlled by a unique scanning head. These produce a wealth of data, arguably large enough for generating inter-

esting and complex sound landscapes (it suffices to equate each spot to a single string in a guitar).

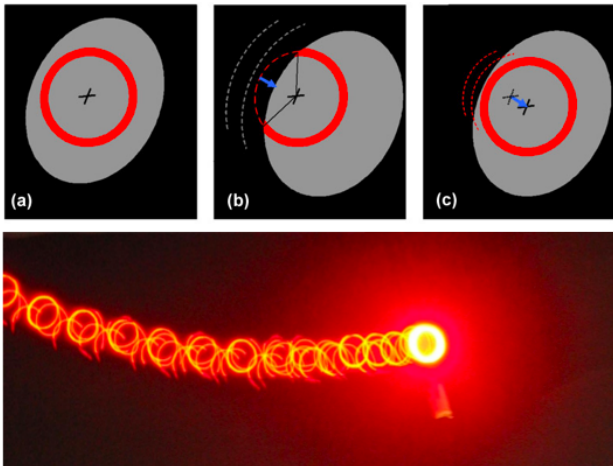


Figure 7: Tracking by local circular scanning.

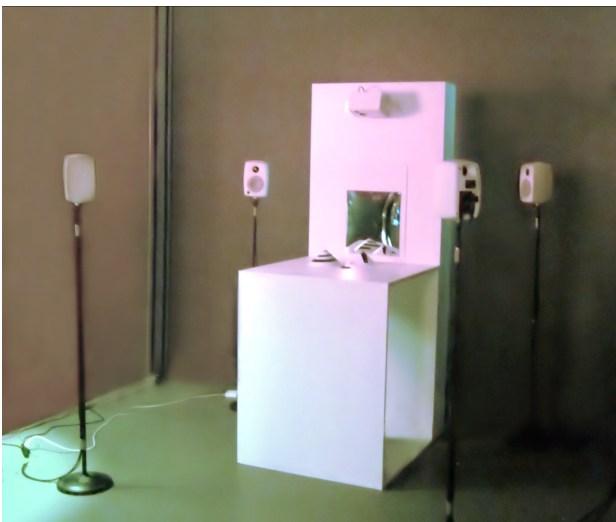


Figure 8: scoreLight in table configuration.

3.2 Sound generation

The scanned material does not need to be black and white nor a flat figure; it can be virtually anything (a colorful tissue, a moving volume). What is needed is that the scanned object presents enough contrast for the spot to know its whereabouts. Presently, the scanner head is fitted with one red and one green laser, but in the near future, we plan to integrate a “white” laser (a laser projector integrating several colors) capable of reproducing the full visible spectrum (it could be interesting to change the wavelength according to the pitch of the sound for instance). Data collected by the scanner is pre-processed on the micro-controller, and immediately used for steering the laser(s) spot(s) over the figure, as dictated by the selected mode of interaction. Simultaneously, both raw and processed data is sent via OSC (every 20ms or less) to a computer running MAX/MSP and Supercollider in charge of generating the sound (with the current protocol used, the maximum sample rate is about 7 to 10ms, but we have noticed a visible slowdown in the agility of the laser spots). For each spot, a data packet is sent containing information about the reflectivity of the surface, the position of the spot in space, its current speed and

acceleration, as well as pre-processed data such as the angle and curvature of the lines being followed by the spot or the presence of extreme spatial frequencies indicating “spikes” in the drawings (see upper part of Fig.9). This information is used to control a bank of filters (LPF, HPF and BPF) as well as pitch, flanger, distortion, granular delay and reverb, or playback speed of a pre-recorded soundfile. The way the control parameters relate to these diverse effects can be easily reconfigured through a MAX matrix (Fig.9, lower).

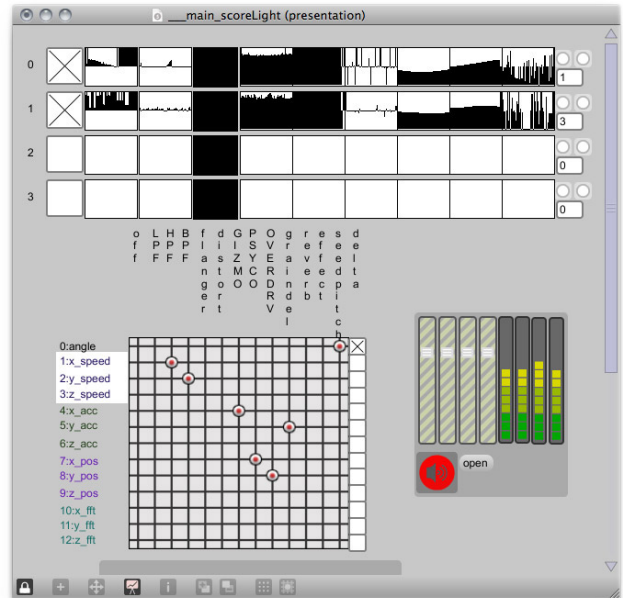


Figure 9: MAX controller window.

Present problems involve the treatment of noisy data, in particular when computing the inclination of the lines that code for (continuous or discretized) pitch. This is easily solved by “debouncing” the data using several consecutive samples (about five), but implies a somehow slower speed of control for the sound modulation. It is interesting to note that the rate at which we can send (preprocessed) data packets is 50Hz or faster (the ultimate limit - that is sending pure raw data - is given by the speed of the mirror’s saccade and tops at about 500Hz). It is also in this respect (and not only for the quality of the light and the fluidity of the motion) that the laser tracking system clearly outperforms the classical camera/projector setup. This is indeed perfect for real-time, fine control of sound generation (involving in particular granular synthesis). Another issue needing this time a lot of patience as well as artistic sensibility involves the precise scaling of “laser data” to continuous audio data parameters (frequency, grain size, distortion overdrive value, etc). Finally, the computer running MAX is also capable of sending commands back to the microcontroller to modify in real time the shape, color, speed and mode of operation of each laser spot independently, as well as to delete spots and/or instantiate new ones depending on the occurrence of precise events or following a pre-decided performing schedule.

3.3 Installation setup

The system can be easily configured on a table accessible from all sides and enabling collaborative play (see Fig.8 and Fig.10), or function on a vertical surface such as a wall or a white/blackboard. Alternatively, the installation can be

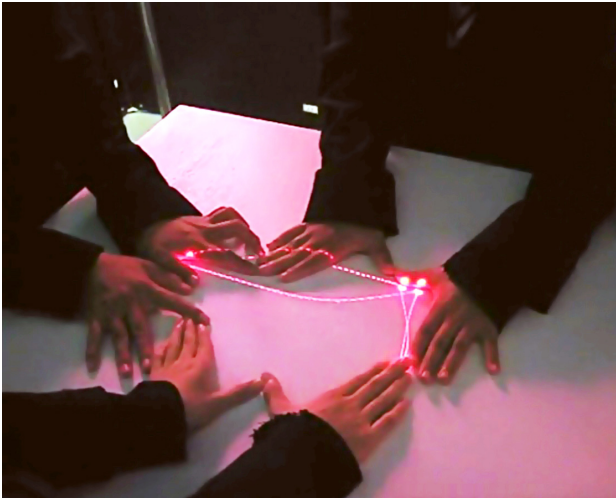


Figure 10: Collaborative play by using bare hands to constrain the motion of the laser spots.

site-specific (and used for real time augmentation of sculptures or architectural landscapes). Also intriguing is the possibility of augmenting stage performances in real time (for instance by projecting the laser over the floor or even over the dancer's clothes or tattooed/painted skin - Fig.12). Since there is no need to perform any camera/projector calibration (by construction the reading beam and the projecting beam are collinear) setup and installation is extremely simple, opening the door for on-the-spot experimentation with stage musicians, choreographers and dancers. When using the system on a table, the laser power is less than half a milliwatt - half the power of a conventional laser pointer. More powerful, multicolored laser sources can be used in order to "augment" (visually and auditorily) facades of buildings tens of meters away - and then enabling the readout of the city landscape as a musical score.

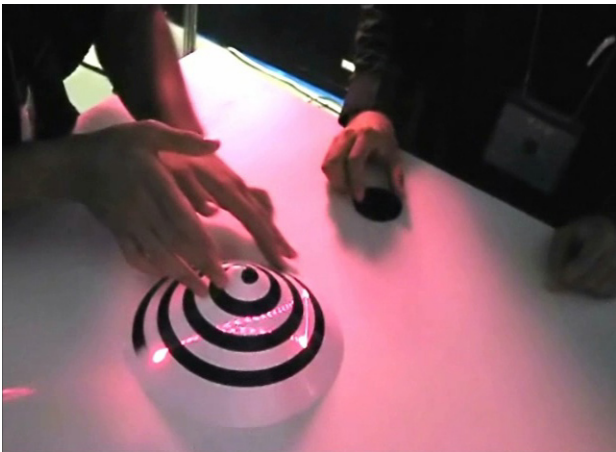


Figure 11: Shapes (flat or three-dimensional) guide the laser beam that turns them into sounds.

4. DISCUSSION

It is important to note that although **scoreLight** looks superficially similar to a "musical table" (i.e, a tabletop interface for musical performance as defined in [4]), this is purely coincidental. In fact, this device is more than a tabletop interface for manipulation of virtual or physical widgets; while certain laser spots could definitely be set to

scan and recognize figures on the table that would work as controllers, in general the table is just one of the possible supports for drawing figures (or for placing and arranging objects). In fact, **scoreLight** better fits the definition of a "painterly interface" [7] and is only a "musical table" to the same extent that Levin's **Scrapple** [6] can be called one. Indeed, **scoreLight** fulfills what Levin considers the preconditions for making an audiovisual instrument of "unparalleled expressivity" (namely, (1) the possibility of creation and performance in real time; (2) inexhaustible and extremely variable results; (3) sonic and visual dimensions commensurately malleable; (4) avoidance of arbitrary conventions and idioms of established visual languages; and last but not least, (5) simplicity and intuitiveness of the operation principles that do not imply a reduction of expressive capabilities [7]).



Figure 12: scoreLight can augment clothes with light and sound

5. CONCLUSION

We have presented here a NIME capable of generating rich sound synchronized with the wanderings of one or more light spots on a drawing. It is still too early to decide if this piece can be effectively used as a musical instrument. This will depend on the way we solve the tension between the unlimited freedom conferred by hand-drawing and the necessity for precise control over a certain number of parameters. However, in its present form, **scoreLight** represents a particularly strong example of the leveraging of painterly interfaces for musical expression. As a consequence, the user does not really know if she is painting, sculpting or composing music. With a few strokes, anyone can produce enjoyable, hypnotic rhythms of light and sound. It is thrilling to imagine that if developed in the right direction, **scoreLight** may be an effective setup for literally sculpting sound. For more information and video demos, check here: www.k2.t.u-tokyo.ac.jp/perception/scoreLight.

6. ACKNOWLEDGEMENTS

The authors would like to thank Stephane Perrin who participated in the early development of the smart laser scanner technology, Benjamin Maus for creating interesting shapes and 3d "sonic sculptures" such as the "musical cones" seen in Fig.11 as well as the anonymous reviewers whose valuable comments helped improving the quality of this paper.

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