Movement to emotions to music: using whole body emotional expression as an interaction for electronic music generation

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ABSTRACT

The augmented ballet project aims at gathering research from several fields and directing them towards a same application case: adding virtual elements (visual and acoustic) to a dance live performance, and allowing the dancer to interact with them. In this paper, we describe a novel interaction that we used in the frame of this project: using the dancer's movements to recognize the emotions he expresses, and use these emotions to generate musical audio flows evolving in real-time. The originality of this interaction is threefold. First, it covers the whole interaction cycle from the input (the dancer's movements) to the output (the generated music). Second, this interaction isn't direct but goes through a high level of abstraction: dancer's emotional expression is recognized and is the source of music generation. Third, this interaction has been designed and validated through constant collaboration with a choreographer, culminating in an augmented ballet performance in front of a live audience.

Keywords

Interactive sonification, motion, gesture and music, interaction, live performance, musical human-computer interaction

1. INTRODUCTION

The augmented ballet project gathers research in various fields around a single applicative goal: to augment a live dance show by adding virtual elements (visual ones as well as audio ones) to the stage and give performers new ways of interacting with those virtual elements. In this paper, we present a specific interaction paradigm: using movement for recognizing a dancer's emotions, and using the recognized emotions to generate musical phrases. The flow of information carried by the dancer's movement is captured, processed to recognize the expressed emotion which is in turn used as a seed for music generation: movements to emotion to music. The dancer may then use this generated music as a root for improvisation, thus completing the cycle. In addition to this original interaction, we also used some movement characteristics for generating a second layer of sounds. The resulting music generation hence goes through two layers of abstraction: an upper-level layer where sounds are produced from emotions, and a lower-level layer where sounds are directly generated from movement. In this paper, we will however put the emphasis on the music generation from recognized emotions.

The contribution presented in this paper is the result of the collaboration of researchers from three different areas: human-computer interaction, sound and music modeling, and arts. In human-computer interaction, we have a special interest in movement-based interaction, and especially in movement-based emotion recognition. Through analysis of the dancer's movement, and basing ourselves on knowledge and studies from psychology, we built a system able to recognize the emotions a person expresses through his movements, in real time. We consider emotion recognition to be an interaction: the recognized emotion must trigger a change in the system's behavior. This change should be perceptible to the user. In music modeling, our interest was to define a set of high-level perceptive parameters that could easily be mapped to emotional concepts and then drive a real-time generative music system from emotions recognition. For artists, combining those two fields unveiled a brand new field of exploration for improvisation in dance, where the dancer could manipulate the sound and use it for improvisation at the same time.

We will first review some related works to highlight the originality of our work: the interaction cycle goes from movement capture (input) to music generation (output) through a high level of abstraction (recognition of the emotions expressed by the dancer). We will then present in detail the technical system used for this interaction. It is based on two independent systems called eMotion and MuZICO as shown in Figure 1.

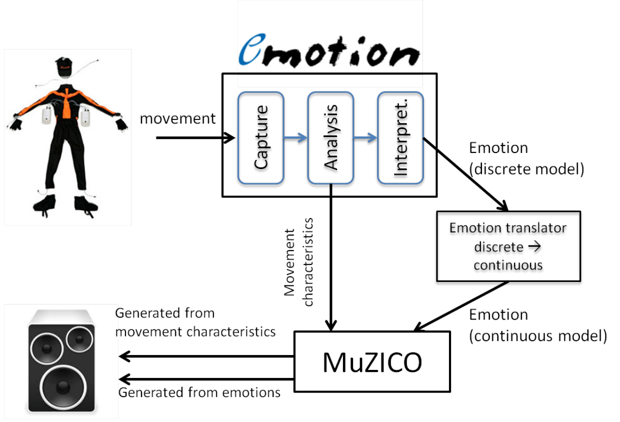

Figure 1 : Overview of the interaction system

The two remaining sections describe how this interaction was put in practice in a live augmented performance, in front of a real audience, and present a validation of our work through the analysis of feedback from both the dancer/choreographer and the audience.

2. RELATED WORKS

The field of affective computing [11] seeks to give computers the ability to decode a user's emotions (the sub-field of emotion recognition) and to express emotional content (the sub-field of emotion synthesis). The work presented here covers both of those fields. We first recognize the expressed emotions of a dancer from his movement, as well as some characteristics of movement. We then use this emotion to automatically generate an emotional piece of music (e.g., a sad or happy sentence).

2.1 Affective computing

Affective computing involves decoding emotions expressed or felt by a user (emotion recognition) and generating emotional feedback to the user, for example through animating virtual characters or generating emotional pieces of music. Both fields must rely on a theoretical background on emotions. There are many definition and representations of emotions in the field of psychology, but few of them are actually used in computer science. The two systems that permit the interaction described here rely on the two preponderant representations. Our emotion recognition system, called eMotion, was built around Ekman's six basic emotions [7]. The music generation system, called MuZICO, relies on a two-dimensional plane of emotions [12]: emotions are then characterized by their valence (pleasant – unpleasant) and their arousal (high – low), those two characteristics being the axes of the 2D plane. As such, a translation from discrete representation to continuous representation was developed to successfully connect both systems.

2.2 Emotion recognition from body movement

Emotion recognition can be divided in three consecutive steps: monitoring the subject (through his facial expression, voice, movements or physiological reactions), extract cues of emotional expression (e.g. a smile, a raise of the eyebrows) to finally infer an emotion. There is a large literature about bodily expression of emotions. In psychology, humanly-perceived cues are identified and validated as conveying emotional information. For instance, De Meijer [4] adopted a top-down approach to identify and validate, through human evaluations of actor performances, affect-expressive movement cues such as trunk curvature, position of hands or velocity of a movement. Wallbott [17] conducted a bottom-up study to identify typical movement characteristics for the following emotions: elated joy, happiness, sadness, despair, fear, terror, cold anger, hot anger, disgust, contempt, shame, guilt, pride, and boredom. Coulson [2] worked on affective cues in static body postures. In computer science, the Infomus lab created systems able to recognize emotions from movements. Using video-analysis techniques, they identified a set of movement characteristics to be extracted from video sequences. Their work was applied in particular to dance; the system could classify dance sequences into four emotions [16][1]. In our system, music is generated from the two upper level of emotion recognition: one layer of sound is generated from the movement characteristics that our system extracts for recognizing emotions; a second layer is generated from the recognized emotions.

2.3 Music generation from gesture and from emotions

Generating music directly from gestures or from emotions are two different problems. Some systems are instrument-oriented whereas others are more generative. In our approach we use an instrument-oriented paradigm to process movement characteristics, and generative paradigm to generate the musical flows from emotions. In the instrument-oriented paradigm, various works can be cited about gestural control of electronic music: for example, A. Tanaka [14] exploited muscular signals thanks to B. Knapp's Bio-muse system [19] to play music in real-time. Serge de Laubier proposed the meta-instrument [3], a general-purpose gestural controler that involves the full body and can be used as a real musical instrument. In the generative paradigm, a famous example of music generator is Omax [6], an IRCAM software using Markov chains to generate melodies (which has become a standard technique in generative music), allowing the interaction with a performer. Eduardo R. Miranda [10] set up a brain-computer interface for generating music, which is not far from emotion analysis.

It is established that composed musical structures, as well as actual performance, influence the perceived emotions [8]. Several empirical studies have focused on which emotions can be expressed by music and which musical factors contribute to the perceived emotional expression. Most of these studies focused especially on Western classical music. A review of articles about analysis of music features and their effects on the perceived emotion has been published in [9], providing rules related both to composition and performance for eliciting a particular emotion. Similar experiments in music generation led by emotion have been conducted before [18]. Our contribution regarding these articles is the real-time performance aspect of our implementation, and the refinement of the modeling of musical complexity (relative to the valence, which is the dimension of the pleasure in the emotional space) and the combination of the two sources gesture and emotions.

3. THE SYSTEM BEHIND THE INTERACTION

The proposed interaction covers the whole interaction cycle from the input (the dancer's movements) to the output (the generated music). This interaction isn't direct but goes through a high level of abstraction: dancer's emotional expression is recognized and is at the source of music generation. This interaction has been designed and validated through constant collaboration with a choreographer, culminating in an augmented ballet performance in front of a live audience, as presented in the next section.

The overall interaction system (see figure 1) is as follow. Firstly, the eMotion system, divided into three modules (Capture, Analysis and Interpretation) can interpret and send the emotions and the movement characteristics of a user on the network as UDP packets using the OSC protocol. Secondly, the MuZICO system is able to generate musical phrases according to an emotion label given in input. MuZICO is also able to take movement characteristics values as input parameters to generate a second layer of sounds. Connecting the two systems together allowed us to perform music generation from the dancer’s emotions, recognized from his movements.

3.1 The eMotion system

As introduced above, our computer-based gestural emotion recognition system relies on 3 modules. The Capture module has the role of acquiring data, the Analysis module has the role of extracting gestural and postural emotional cues, and the Interpretation module has the role of interpreting them as an emotion. From an architecture point of view, the eMotion software is a component-based system; each atomic operation (data acquisition from a sensor, extraction of a feature, interpretation from a set of feature) is embedded in a pluggable/unpluggable communicative component which allows easy modifications of the system. We did not focus on identifying new expressive movement cues for emotion recognition but instead considered characteristics proposed by de Meijer [7]. eMotion was developed in C++/Qt, and is fully described in [20].

The dancer wears an XSens MVN motion capture suit [22]. The suit decomposes the dancer into a 23 segments skeleton. The coordinates of each of these segments are refreshed and sent through the network at a frequency of 10 Hz.

From the flow of coordinates, the eMotion software computes trunk and arm movement, vertical and sagittal directions, and velocity. The interpretation is then performed by choosing the maximum weighted sum of each cue over each of the six basic emotions defined by Ekman [7]: joy, fear, anger, sadness, disgust, and surprise. We focused on these emotion categories as their bodily expressions are already documented in the literature. Specifically, the movement characteristics computed in eMotion and their respective weights used in inferring each emotion were taken from [4]. At each frame, the eMotion software delivers an emotion label through the network as well as movement characteristics such as the speed vectors of the basin, hands and feet.

3.2 Music generation with MuZICO

The music generation was performed with the goal of highlighting the emotions expressed by the dancer, and reinforcing the impact of those emotions on the audience. We were led to the creation of such software by former research by Jean-Louis Di-Santo [5] towards the formalization of perceptual parameters describing electroacoustic music. The model that arose from this study mainly described sonic properties rather than musical ones, but the interesting part was the perceptual point of view. When we started generating more tonal music, we needed this perceptual approach to be able to control the generator intuitively. The field of emotions was the best start we could find to work at a higher level than tonality, rhythmic signature and other purely musical concepts.

The music generator was developed as a set of pureData patches. PureData was chosen as it already has most of the features we need built-in as integrated libraries, and it is easily expandable by creating libraries of abstractions and/or writing new external objects in C or C++. The audio part of the software was designed to be as versatile as possible, including beatboxes, chords players, melodies players, texture generators, soundscapes players and audio effects.

The software can be decomposed in three sets of modules. The two first sets (sample players modules and audio synthesis and effect modules) are gathered in the following paragraph as sound producing modules. The last set contains the modules for musical rules generation.

3.2.1 Sound-producing modules

Sample player modules produce sound by relying on a database of sound samples, called sampleDB. The benefit of this database is that sound samples can be tagged into categories (e.g. "wood", "metal", "synthetic"). This system is completed by the use of perceptive sound descriptors (peak amplitude, spectral descriptors, regularity, granularity). Sounds can then be selected upon their perceptive attributes. Sample players can then access the database using such attributes and tags. Simple sample players play a sound on a trigger event, with continuous control over the pitch, panning and volume of the sound. Granular sample players generate a texture from any sound by splitting it into small grains. It offers real-time control over a larger set of parameters, such as the grain size, the position of the sound file to read, the pitch, panning, volume, etc. Finally, the soundscape player is a basic reader for large files used as audio background (e.g. nature ambiences, human activities).

Audio synthesis modules generate sounds from a set of parameters than can be changed in real time and easily translatable from perceptive parameters. This allows a greater control over the generated sounds but cannot cover a variety as wide as what can be achieved with the sample database.

3.2.2 Modules for musical rules generation

The last set of modules is composed of the 6 modules used for musical rules generation. The overall architecture is presented in figure 2. The music generator software relies on a set of musical rules that will be used to generate rhythmic patterns, harmonic trajectories (melodies), bass lines, chords grids and other music description concepts that will in turn be used to play the sounds. The transport module defines the rhythmic signature (duple or triple meter) of the music to be generated, its tempo, and the position in a pattern. This module gives the tempo to every module which needs it. The rhythmic pattern generator creates several linear rhythms that stick to a pulse, each rhythm being defined by its time density and an offset from the first pulse. Those rhythms are then superposed by a logical « OR » operation, the result being the finally generated rhythm. Complexity of a rhythm is a parameter for emotional generation and is evaluated with the help of a weight pattern based upon the actual rhythmic signature, and obtained with Toussaint's measure [15] or other rhythmic complexity evaluation techniques. The musical scale generator takes as arguments a fundamental frequency and a number of notes to generate starting from that frequency. The scale is generated by the sequence $U_{n+1} = U_n * oct^{(cycle/div)}$, where *oct* is the octave ratio, *cycle* the interval used to generate the scale, and *div* the number of divisions of the octave. We state that the harmonic complexity of a scale depends on the values of these three parameters and on the number of iterations that produce the scale. The simplest examples for an occidental ear are (considering $oct=2$, $cycle=7$, $div=12$) the pentatonic scale (5 iterations), the diatonic scale (7 iterations), and the chromatic scale (12 iterations).

The melody generator takes as input the current scale and asks the rhythmic pattern generator for a new pattern. Each note in the scale has a weight, as every division of the rhythmic pattern. For every onset in this pattern, a note is chosen randomly in the scale according to a Gaussian probability density varying in function of the onset's weight. This gives us a “seed melody” that can be developed musically by various algorithms, such as a probabilistic suffix tree. The resulting melody's complexity mostly depends on the Gaussian probability densities and the parameters configuring the PST.

The chord grids generator is based on a generative grammar and outputs chords sequences according to harmony rules. The complexity of the generated grids depends on the complexity of each chord (ex : triad = simple, seventh chord = complex), the complexity of the articulations between chords (ex : cadence = simple), and the number of distinct chords in a sequence.

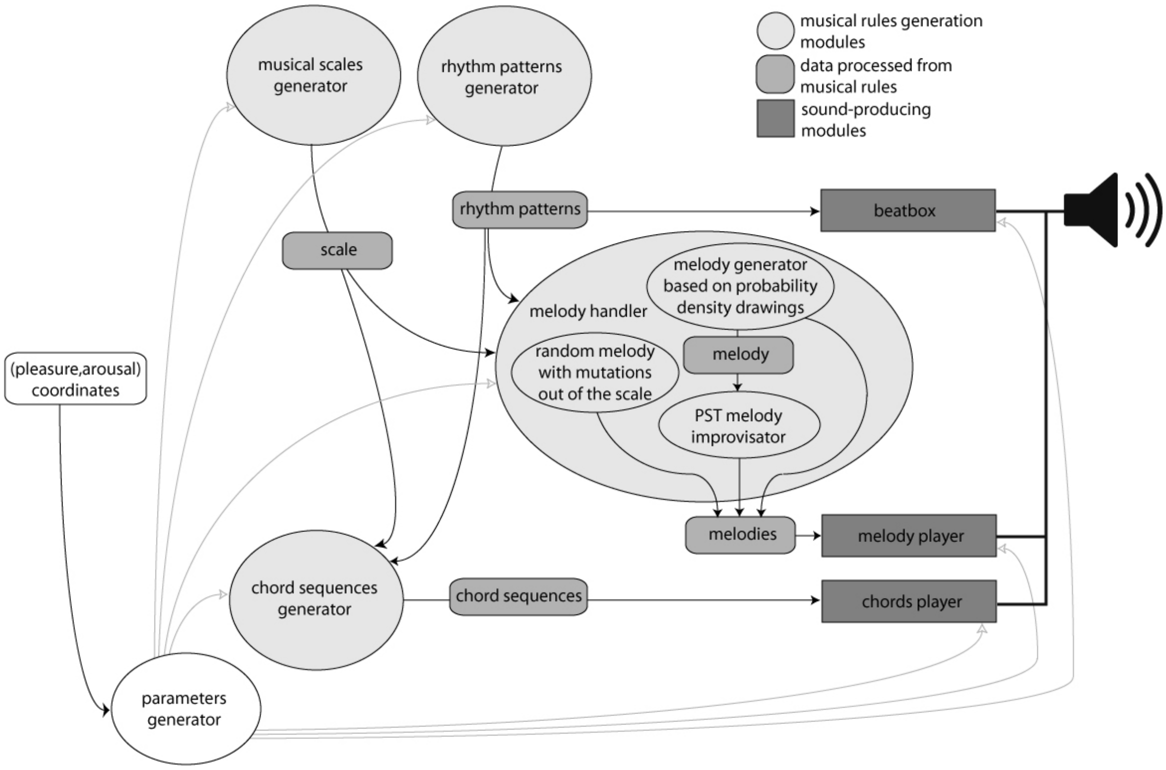

Figure 2: Musical rules generation modules: MuZICO

3.2.3 Producing emotional pieces

To generate music, a parameter generator takes care of generating the musical rules, i.e. the parameters of the musical sentence (tempo, pitch of each notes, etc…) those parameters are then fed to the sound generators. The generated sounds are then assembled to produce the musical sentence. The goal of the music generator is to generate emotional pieces of music corresponding to an emotion. In MuZICO, emotions are represented in the 2D Pleasure-Arousal plane. Parameters qualifying pleasure and arousal were taken from the literature [9]. Those parameters may have discrete or continuous values defined by adjectives (e.g., timbre can be muted/ bright) or scalars, and were mapped to sets of bounded parameters that are then sent to our different modules. Arousal-related parameters are the tempo, the timbre (muted for low arousal, to bright for high arousal), the notes attack time, the notes pitch, the naturalness of the instrumental sounds (natural to synthetic), the nature of the sounds (sustained to percussive), the number of instruments and the notes onset. Tempo is handled by the transport module. Timbre, attack time, pitch, naturalness and nature of the sounds can all be modified either by manipulating sample files (using sample players modules) or by directly generating the appropriate sound with a sound generation module. Pleasure-related parameters are of a more structural nature: the perceptive parameters that vary according to pleasure are tonalities and cadences (minor for low pleasure, major for high pleasure), chords (extensions – 13th to 11th to 9th to 7th chords, to triads), chord grids (complex to simple), the scales (from twelve-tone to diminished, harmonic, diatonic, to pentatonic), the rhythm complexity (complex to simple) and the complexity of the structure of the melody (complex structure to lullabies). Using the valence coordinate to generate emotional sentences is the main originality of our music generation system [21].

3.3 Bridging both systems

The emotion recognition system, eMotion, and the music generation system, MuZICO, were developed independently and connected. As they do not share the same representation of emotions nor the same time scale, an interface between both systems was developed in order to transform the emotion labels delivered by the emotion system into coordinates in the continuous pleasure arousal plane. eMotion delivers through the network, at a rate of 10 Hz, an emotion among Ekman's basic emotions such as "joy" or "anger" as described above. Those emotions are scattered among the 2D plane used by the music generator. When the music generator receives en emotion, it first translates it into pleasure-arousal coordinates. The generative music software is driven by a 2D cursor which travels through the emotional space. To smooth transitions, each time eMotion sends an emotion label, the 2D cursor makes a step towards the pleasure-arousal position related to this emotion. In MuZICO, the coordinates shifting of the travelling cursor in the 2D emotional plane triggers the change of musical parameters values corresponding to either arousal or valence. eMotion also sends, for each time an emotion is recognized, the value of the emotional characteristics of movement. A simple mapping is then done to use those input parameters for sound generation.

4. VALIDATION: FEEDBACK FROM THE EXPERIMENTAL BALLET

In March 2011, we presented at the Casino de Biarritz (South-West of France) an augmented dance show titled "*the CARE project, staging of a research process*." A movie about this show is available at [23]. The aim of this show was to conclude the CARE project [24], a research project funded by the French National Research Agency (ANR). This project proposed to apply Augmented Reality techniques to the cultural domain, bringing together 7 partners whose goal was to integrate, adapt and develop tools to enhance interactive systems devoted to cultural experiences. These enhancements are based on Augmented Reality and Emotions.

Two representations of the show were given on 2011, march 4th. The first one was for VIP, about 30 peoples, elected officials, funders, professionals, etc. The second one was given in front of an audience of roughly 120 invited people (the show was free). The show featured various visual augmentations of the stage, as well as the musical interaction system on which we focus in this paper. Acoustically, the sounds and music reflected the dancer's expression. The main idea was to highlight the emotions that the dancer was expressing.

4.1 Choosing the parameters for the show

The musical generation was performed with the goal of reinforcing the impact of dancer-expressed emotions on the audience. As presented before, on a general point of view, for the scope of the show, we chose to generate sounds and music on two different layers. First, the recognized emotions were used to generate a musical layer. Second, the movement characteristics used to recognize an emotion were grabbed by and triggered the generation of the second layer of sounds. Those two layers of sound were not always played simultaneously. The "scenario" of the ballet involved a dive from the real and organic world to the virtual and synthetic world as the show was going on, before brutally reversing to reality at the end of the show. For this specific show and scenario, we hence defined a musical line where instruments were added along the show and were sound gradually translated from organic sounds to more synthetic ones. We then had to choose specific parameters as shown in following paragraphs.

As rhythmic thread we used Nyabinghi, an afrocarribean music played at groundation ceremonies in rasta culture that symbolizes a heartbeat rhythm. We hence mapped sounds emulating a traditional drum kit (bass-drum/snare/tom), according to the desired environment: respectively heartbeat/ breath/ bones-cracking for organic ambience or crystal and hydrophonic recorded glass sounds for synthetic moods.

The first part of the show only involved sonification of the dancer's emotional movement characteristics. Sonification acts as a catalyzer of the audience's attention and their comprehension of what's going on stage. The muscular, kinetic energy of the dancer is directly translated into sonic energy, thus becoming audible and creating a synaesthesia phenomenon. Concretely, we used four parameters, of two distinct types. Firstly we analyzed the raw positions of the right hand and the left leg sent in parallel by eMotion and computed their speed. We mapped these speed values to the volume control on two corresponding granular synthesis modules (kinetic energy to sonic energy). Secondly we analyzed more skeleton points' positions and defined thresholds on the distance between two of them. When crossing one of these thresholds, a sound was trigged with a volume proportional to the velocity at the moment of the crossing (kinetic energy to sonic energy).

In the second part of the show, we mixed this layer of sounds generated by gesture with a musical layer generated from the dancer's recognized emotions. We used an artistic approach to choose the sound samples to be played for a particular emotion. The artistic proposal was to determine the sounds that the body would make during the experience of a specific emotion. By using piezoelectric microphones, three sets of sounds were recorded following three methods of acquisition. The first set was recorded by volunteers who were elicited some emotions. For the second set, one of the authors, proficient in dance, recorded the sounds produced during two minutes-long improvised dance sequences expressing the basic emotions. The third and last set of sounds is the result of a two-days continuous recording to obtain more spontaneous emotions from the same person. The choice of each sound was done according to its length, quality, and adequacy with the considered emotion. The retained sounds consisted in bone cracking for anger, heart beat rhythms for surprise, breath for fear, swallowing sounds for sadness, and sounds of skin energically rubbing for joy. Emotions triggered the computation of specific parameters for the different modules in MuZICO. This triggered the choice of the corresponding body sound samples for each emotion, thus validating our recordings.

4.2 Feedback from the audience

The second representation of the show was presented in front of an audience of about 120 people. Upon their arrival we distributed them questionnaires for collecting feedback about the show. We collected 97 questionnaires (i.e. roughly an 80% return rate). For a non-researcher, it is quite difficult to apprehend the scientific world. The show presented the CARE project scientific results in a both artistic and playful way; scientists were directly in front of the audience, which the audience appreciated. 90% of the people who gave a feedback cited the innovative or even magical aspects of the show as its best asset. However, the audience found, that the generated music expressed too frankly the emotion being portrayed (75% of the audience). We deduce from this feedback that the music should have taken more distance with the expressed emotions, and leave more interpretation from the spectator. This criticism is interesting as it validates the parameters we chose for music generation, but pinpoint the fact that more artistic choices could have been favored. Finally, when asked about the potential improvements that could be made, 98% of the people stated that they wished to witness the evolution of the show, should it be in the scientific content, the choreography, the sound generation and/or the graphical choices. The audience hence had a very strong interest in following this collaboration between art and science; this interest went further, as it sparkled reaction from medias in the form of articles and an interview on local television.

4.3 Feedback from the dancer and choreographer

The artist with whom we collaborated during this project is both a choreographer and the dancer that performed during the show. As a long-term user of the technologies we developed, his feedback is highly relevant from a qualitative aspect. The performer was asked several questions about the interaction, both from a dancer and a choreographer point of view, and answered for each of them on a scale from 1 to 10. As the show was improvised, the choreography was quite high-level and mainly consisted in cutting the show into several parts, and defining improvisation guidelines for each part. As the performer highly contributed to the development of the eMotion software and its use over time, no question was asked on this part of the system.

As a choreographer, the technology set on stage (motion capture suit, emotion recognition, music generation and visual augmentations) did not restrain creativity but rather oriented it by setting a set of constraints, which could be played with. Music generation was not really a decisive point for the choreography; it was more important from the dancer's point of view, as a support for improvisation.

As a dancer, the performer was asked questions about the physical setup and the music generation system. It appeared that even if the motion capture suit was indeed a disturbance (7/10, 10 being "extremely disturbing"), the constraints it gave also acted as original guidelines for improvisation, which then leant towards expressing the relationship between dance and technologies. As such the dancer saw the suit rather as a source for improvisation than as a disturbance (7/10, 10 being "really helps the creativity in improvisation"). The performer felt he had only an imprecise control over the generated sounds and music (6/10, 10 being "complete control"). However, he heavily used it as a basis for improvisation (9/10, 10 being "extensive use of the generated music for improvisation"). Immobility was particularly interesting, as it triggered silence, and allowed creating subtle sounds with subtle movements. The generated sounds were a feedback of which emotion was recognized by the system, giving the performer cues about his interaction with the emotion recognition system. The performer could identify which sounds were related to his gestures and which sounds were related to the emotion he was portraying, allowing him to play on both sides.

5. CONCLUSION: DISCUSSION AND FUTURE WORKS

In this paper, we presented an innovative interaction: movement to emotion to music, where a dancer's emotions are recognized from his movement, and music and sounds are generated from the recognized emotion. Technically, the system is composed of two subsystems that recognize emotions from movements and that generate music from emotions. The interaction was tested in an augmented show, in front of an audience of about 150 people. The movement to emotions to music generation, presented in this paper, gathered positive reviews. Feedback from the dancer and choreographer was extremely positive. The generated music and sounds had three roles. It was a feedback for the emotional recognition of the dancer's expression; a new channel for improvisation that the dancer could experiment with the sounds by using his body; and a basis for the movement. This last point completed the interaction cycle, from movement to emotions to music to movement again.

This very positive feedback validates our system as an interaction cycle, where the generated music acts as a basis for new movement. The main criticism that arose from the audience during the show is that musical augmentations would too frankly re-express the emotion expressed by the dancer. Although this validates the choice of our parameters for music generation, this has led us to realize that producing an augmented show raises the difficulty of staging the technologies: the audience must be given the freedom to interpret what is rendered on stage, should it be visual or audio.

Current and future works concern both the emotion recognition system and the music generation system. Work is currently in progress to rebuild the emotion recognition system using Scherer's componential model of emotions [13], which should provide much smoother transition and much more subtleties in the recognized emotions while still allowing real-time recognition. As for MuZICO, various new experiments are currently in progress with a set of physiological sensors. Our goal is to focus on the analysis of felt emotions rather than expressed emotions, in order to study the interaction loop between felt emotions and music generated from these perceived emotions. Other augmented shows are also in preparation; the preparation of such shows motivates the finalization of research results for a use in real situations. It also helps the artists to familiarize with the technologies we develop, both for designing a show and for performing it.

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