Influencing the Perceived Emotions of Music with Intent

Steven R. Livingstone

School of Information
Technology and Electrical
Engineering, The University
of Queensland and
The Australasian CRC for
Interaction Design
srl@itee.uq.edu.au

Andrew R. Brown

Creative Industries Faculty:
Music & Sound, Queensland
University of Technology and
The Australasian CRC for
Interaction Design
a.brown@qut.edu.au

Ralf Muhlberger

School of Information
Technology and Electrical
Engineering, The University
of Queensland

ralf@itee.uq.edu.au

1. Abstract

Music is an immensely powerful affective medium that pervades our everyday life. With ever advancing technology, the reproduction and application of music for emotive and information transfer purposes has never been more prevalent. In this paper we introduce a rule-based engine for influencing the perceived emotions of music. Based on empirical music psychology, we attempt to formalise the relationship between musical elements and their perceived emotion. We examine the modification to structural aspects of music to allow for a graduated transition between perceived emotive states. This engine is intended to provide music reproduction systems with a finer grained control over this affective medium; where perceived musical emotion can be influenced with intent. This intent comes from both an external application and the audience. Using a series of affective computing technologies, an audience's response metrics and attitudes can be incorporated to model this intent. A generative feedback loop is set up between the external application, the influencing process and the audience's response to this, which together shape the modification of musical structure. The effectiveness of our rule system for influencing perceived musical emotion was examined in earlier work, with a small test study providing generally encouraging results.

2. Introduction

No one is sure for what end music came about, be it a biological urge [1], an offshoot of our evolving language faculty [2] or simply another mechanism for the expression of self brought about by mankind's cultural explosion some 100,000 odd years ago [3]. Few however would argue that it is our intense and diverse emotional capacity that allows us to create *music*; the at times transcendental inexplicable. Given this deep emotional connection, and the ease with which sound can be reproduced with modern technology, music is now a pervasive medium found throughout everyday life. It is used in almost every form of human communication and can be heard at the cinema, on television, on radio, in commercials, at the ballet, in shopping centres, on public and private transport, in waiting rooms and restaurants, to name but a few. One study found that within any waking 2 hour period, a person had on average a 44% chance of experiencing a musical event [4]. Considering music's emotional power and diversity, any means of influencing this aspect could provide a powerful affective tool with a wide range of applications. We believe that computers are well placed to grapple with this task. In this paper we will discuss a rule system for influencing the perceived emotions of music.

The system employs a series of structural modification rules that attempt to influence the perceived emotional content of music. These rules have been sourced from the diverse field of empirical music psychology, with studies dating back to the turn of the 20th century. Modification of a musical work's structural properties allows for a greater degree of control, where shaping between perceived emotional states can be planned, revised and graduated over long time scales, like those that occur naturally in music. The ability to influence the perceived emotional aspects of music can be employed by a wide variety of applications, with computer games being the chief target. Traditionally computer games use a series of discrete music tracks which are loaded with each new scene or triggered by in-game events. This is a coarse-grained approach, with the pre-composed music unable to respond dynamically to events happening at the intra-scene level [5]. With the engine described in this paper, the pre-composed tracks are rendered in real-time, where modifications to structural aspects of music can better reflect in-game events. Through the use of recent affective computing technologies, an audience's response to musical emotion can also be captured for use by the engine. Metrics such as mouse movement, keystroke rate, ocular movement patterns and game performance can be used to determine how an audience is responding.

Before the relationship between musical elements and their perceived emotion can be formalised, it is necessary to first understand what is meant by perceived musical emotion, how we can represent emotion and how it can be assessed. This knowledge is then applied in the conglomeration and testing of music emotion structural rules for use in the rule system, discussed in section 4. The engine architecture, into which the rule system fits, is discussed in section 5. The paper concludes with some thoughts for the future.

3. Emotional Considerations

Before one can attempt to influence the perceived emotions of music, a thoughtful consideration of what emotion is and how it can be influenced is required.

3.1 Perceived Versus Induced Emotion

Perhaps the most challenging question one can ask is how can we describe musical emotion in concrete, measurable and implemental terms? How can we hope to influence musical emotion to be "happier", or "sadder", as surely this is an intimate and uniquely personal event? An important distinction to be made at this point is that between perceived and induced emotion. Perceived emotion is the act of sensing the emotional content of the stimuli, or an emotional concept projected. Induced emotion is that felt by the receiver after being subjected to the stimuli. As an example, consider the photograph of figure 1. When we look at this image perhaps the first thing we see is an angry woman. That is, we perceive the emotional state of this woman to be angry, or that she is expressing anger. However, what emotion is induced in us as a result of viewing this stimulus could be completely different, and is dependant upon three emotive response mechanisms. Firstly, that brought about by the threat assessment reactionary mechanism, commonly referred to as the *fight-or-flight* mechanism. Controlled by the amygdala, hypothalamus and hippocampus

[6, 7], fear, anger or other such preparatory emotions could be induced. The second response mechanism is that of an empathic response "*that stems from the apprehension or comprehension of another's emotional state and that is identical or very similar to what the other person is feeling or would be expected to feel*" [8]; in the case of figure 1 this might be anger. The final response mechanism is that brought about by any prior emotional conditioning.

Fig.1: Perception of Anger

Gabrielsson and Juslin were perhaps the first to make the distinction between measuring induced and perceived emotions in music [9]. While it is preferable to measure induced emotion, doing so is a complicated and error-fraught business. Indeed, as Levenson describes, "*[i]t is ironic that humans have emotions all of the time in their everyday lives, yet getting participants to experience a particular emotion at a particular time in the laboratory can be very difficult*" [10]. Similarly, at one time a subject can listen to a Schubert piano sonata and experience a deep emotional connection, while on another occasion they may feel almost nothing. Compounding this problem is the issue of emotion verification. Even if an emotion is induced we have no way of identifying what that emotion is, further, if that emotion is a result of the stimulus or simply brought about by one of the many random thoughts or physiological quirks that go on in the body every second.

The process of capturing induced emotion is also difficult: two available methods include user reporting and the tabulation of sensed physiological metrics. User reporting suffers from the problem that respondents generally cannot describe their induced emotions beyond happy, angry, sad or any other such variant, like a dimensional representation. While physiological capture methods do not suffer from this problem they possess their own set of detracting features. Foremost, physiological methods tend only to be able to detect the arousal dimension of emotion (level of activity), while ignoring valence (e.g. happy/sad) [11]. Further, that the ability to repeatedly distinguish an emotion purely from an autonomic body response pattern is still hotly debated. As Leveson discusses though, it may be possible to detect a small subset of basic emotions from physiological patterns alone [10]. However, inducing basic emotions using multiple forms of media is a vastly simplified process to that of when using music alone. Inducement techniques with mimetic media could include: showing a horrifying image, suddenly confronting the person in a violent manner, showing a baby photo or demeaning the person publicly. Music is generally unable to induce such strong emotions with repeated ease, due in part to a higher level of emotional abstraction.

Recording perceived emotion does not suffer from either emotion verification or measurement issues. It is repeatable, describable and capable of capturing both arousal and valence. Korhonen outlines three similar points as to why the measurement of perceived emotions in music is a more viable path than that of induced emotion [12]. Interestingly, Korhonen argues that studying perceived emotion is really the investigation of emotion communication. Logically, we would expect evolution to produce a simple, repeatable and accurate mechanism for the communication of emotion. This is precisely what was found in studies investigating the communication of universal "basic" emotions in Ekman's *facial affect programs* and further work by Levenson et alia investigating autonomic nervous system responses [13]. Lastly, the bulk of music psychology work cataloguing music-emotion rules, to be discussed in section 4, are based largely on measuring perceived emotion, not induced. Ignoring this enormous resource would be unwise.

3.2 Dimensional Representation of Emotion

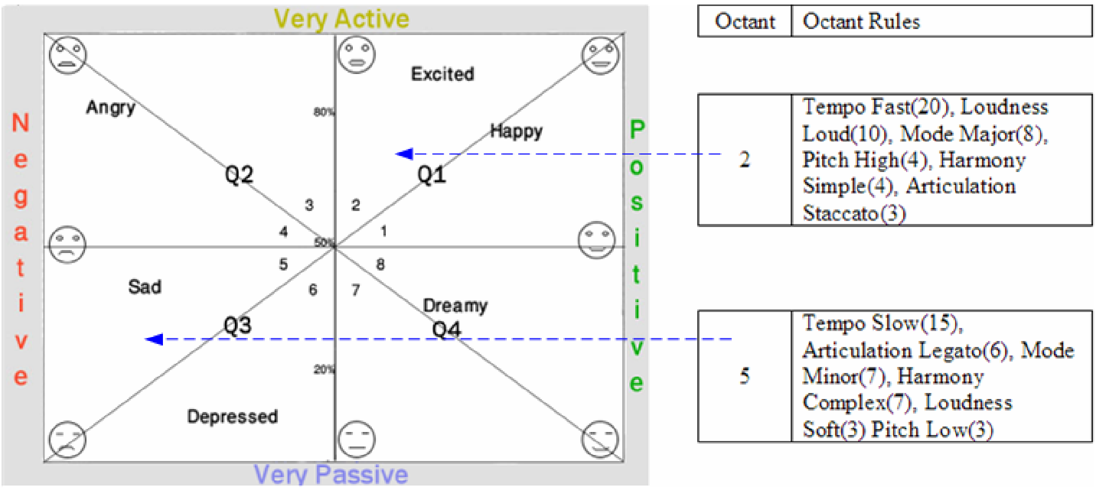
The measurement of perceived emotion requires both a user-response capture technique and an appropriate representation of emotion. The representation and capture method must also meet a number of criteria. One of the quirks of musical emotion that makes it such a difficult entity to study is its time-based nature. While the impact of a photo or painting is largely instantaneous, with a non-linear exposure of information over time (rapid gaze flicking), music and its communication of emotion is a continuous phenomenon that unfolds progressively over time. While music passages can simply be described as "happy", this is a very course-grained approach, suitable for teasing out only the basic elements in music. Thus, the first requirement is a continuous method of emotion capture, to allow for the analysis of the emotional ebb and flow of music. Our second requirement is a continuous representation of emotion. While a music passage can simply be described as "happy", this is a quantised evaluation and gives little indication as to the intensity or makeup of the emotion. Lastly, the means to compare and contrast the collected results is needed; this requires a consistent method of emotion representation. Table 1 outlines the four major emotion capture and representation techniques previously used in the empirical study of music and emotion, all of which are examined in Schubert's authoritative work [14]. Under continuous capture, table cells containing both yes and no refer to differing subtypes of the emotion capture method.

Type	Continuous Capture	Continuous Representation	Consistent
Open-Ended	Yes & No	Partial	No
Checklist	Yes & No	No	Yes
Ranking & Matching	Yes & No	No	No
Rating Scale	Partial	Yes	Partial

Tab.1: Traditional Emotion Capture Methods

As table 1 outlines, none of the traditional emotion reporting methods meet all the requirements for detecting the perceived emotions of music. The last method of user-response testing is known as the dimensional approach. Originally proposed by Wilhelm Wundt in the late 19th century, the dimensional representation of emotion was at the time an innovative approach that sparked a great deal of research. Wundt believed that emotion could be described with a tridimensional representation with axes labelled pleasantness/unpleasantness, tension/release and excitement/relaxation. While today there is still debate over the number and type of dimensions, it is generally agreed that a 2-dimensional approach consisting of arousal (excitement) and valence (pleasantness) for user reporting offers an appropriate balance between richness of representation and ease of user response.

The dimensional representation has received support from a number of prominent psychologists [14], however it was the work of Russell in 1989 that provided the strongest evidence to date in favour of the 2-dimensional circumplex model [15]. Schubert [14, 16] with the 2 Dimensional Emotions Space, or *2DES*, and Cowie et alia [17] with *Feeltrace* provided the first computational implementation allowing for the continuous capture of response data. The 2DES representation of emotion is illustrated in figure 2a.



Octant	Octant Rules
2	Tempo Fast(20), Loudness Loud(10), Mode Major(8), Pitch High(4), Harmony Simple(4), Articulation Staccato(3)
5	Tempo Slow(15), Articulation Legato(6), Mode Minor(7), Harmony Complex(7), Loudness Soft(3) Pitch Low(3)

Fig.2: (a) 2 Dimensional Emotion Space, and (b) Corresponding Music Emotion Rules for Octants 2 & 5

The dimensional approach also has a number of pragmatic advantages. First, its continuous numerical form is well suited to a computational implementation. A numerical rating allows for a greater degree of control in the application of music-emotion rules where, for example, “fast tempo” can be given a variable range ↔ emotion influence value. This property is later discussed in section 5. Second, the widely used Hevner adjective circle response measure used throughout empirical music psychology translates well into the 2DES system.

4. Rule System for Influencing Perceived Musical Emotion

The historical nature of empirical music and emotion studies provides us with an invaluable resource, however, the direct application of this knowledge is complicated by the heterogenous capture techniques that have used over this period (see table 1). In order to effectively leverage this resource a consistent method of representation must be used to index the studies. The 2 Dimensional Emotion Space representation discussed in section 3.2 acts an effective metric for indexing the structural music emotion rules. Using this metric, recent work by Livingstone et alia [5] collated a series of exhaustive works on the empirical study of structural music emotion rules [14, 18-20]. From this a number of recurrent rules were identified, constituting a set of *primary music-emotion structural rules* [5]. These rules were grouped into emotional octants, based on those in the 2DES representation. An example of the indexing between music emotion rules and 2DES octants can be seen figure 2b. The number of studies which yielded a particular result (e.g. tempo fast → happy) is contained in parenthesis beside each of the rules. For a complete rule listing, the reader is referred to [5].

To gauge the effectiveness of the system in influencing perceived emotion, a prototype of the rule system was developed [5]. The prototype implemented the following structural rules: mode [major, minor], tempo [faster, slower], loudness [louder, softer], articulation [more staccato, more legato], pitch [raise, lower], harmony [simplify (partially)]. The application of these rules to music structure was simplified given the prototype operated on MIDI input. The prototype was designed such that at any time the operator could select an appropriate octant, at which time the corresponding octant's rules were applied. Thus, the prototype could effectively "push" the perceived emotion of the current music work towards that octant. For example, selecting octant 2 would increase the tempo by 10 BPM, raise the dynamic by 5, decrease note length by 18% etc., to make the music sound "happier". At present, structural changes are applied wholly at the moment of request; however future revisions will incorporate graduation, as described in section 5.

An experiment was conducted to gauge the effectiveness of the prototype in influencing the perceived emotions of music. As the primary application of this work is the computer gaming field, a secondary aim was to determine if the music emotions rules, sourced predominantly from the study of Western Classical music, could also be applied to the diverse field of computer gaming music. Listeners were asked to rate how the application of octant-specific rules to a musical work shifted its perceived emotion. The listener was first played the original unaltered work, followed by an altered version in which a particular octant's rules had been applied to the musical work. The listener was then asked to mark on a 2DES diagram how they perceived the overall emotion of the work to have shifted. For example, one altered version may have had octant 2 rules applied, in an attempt to make the work sound "happier". Consisting of eleven participants, each listener was played six altered versions of two musical works; one classical, the other a fragment from a popular computer game [21]. A breakdown of quadrant accuracy rates can be seen in table 2.

Quadrant	Accuracy	Guess Accuracy
1	81%	25%
2	26%	25%
3	71%	25%
4	50%	25%

Tab.2: Accuracy Rates of Rule System for Influencing the Perceived Emotions of Music

The system was found to be generally successful in influencing the perceived emotion towards quadrants 1, 3 and 4 ("happier, sadder and dreamier"). The system also exhibited comparable effectiveness for influencing the perceived emotion of Western Classical music and traditional gaming music. While the results are encouraging, future studies will aim to resolve the following factors: small sample size, implement all six of the primary music-emotion structural rules (this adversely affected quadrant 2), and testing methodology.

5. Engine Architecture

Building on the results of [5], we are now in a position to describe an architecture for a rule-based engine to influence the perceived emotions of music. In this section we will discuss the engine architecture and how the rule system described in section 4 fits into this context. Figure 3a depicts a high level design of the engine's architecture. The engine is broken down largely into three major elements: the engine internals containing the rule system and emotive algorithms, the musical score input (MIDI) and the intentional data coming from the application and audience. As discussed in sections 3.2 and 4, the rule system uses a dimensional representation of emotion. One particular advantage of this form allows for perceived emotion to be readily described by numerical coordinates; the arousal-valence pair $[\mathrm{A}, \mathrm{V}]$. This emotion representation is used by both the audience and external application for emotion data input, to be discussed in the following subsections. Succeeding this is a walkthrough of the engine architecture in section 5.4.

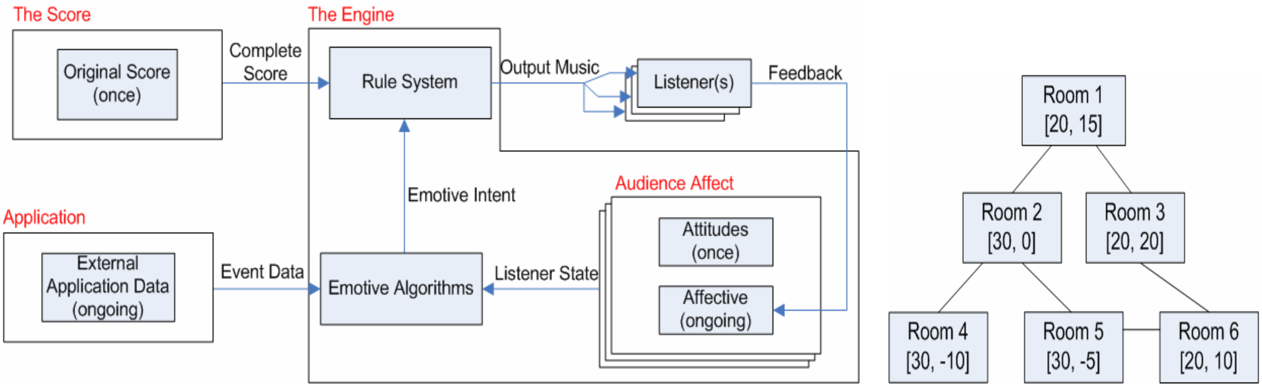


Fig.3: (a) Engine Architecture, and (b) Arousal, Valence values for music of virtual computer game rooms

5.1 Application Intent

There are a wide variety of applications that could integrate with such an engine; computer games are a particularly interesting class of application due to their non-linear and interactive nature. An intense focus on the individual, coupled with a strong emphasis on the emotional narrative that is explicit in the game story makes for a powerful example of application intent and engine adaptation.

The majority of computer game music is delineated at the inter-scene level, where distinct music tracks are grouped based on individuals rooms [5]. At this level of granularity each music track can be described by a summative emotion baseline: $[-50,-50] \leq [\mathrm{A}_{\mathrm{base}}, \mathrm{V}_{\mathrm{base}}] \leq [50,50]$, where values are bounded by the 2DES axes with a ±50 maxima and minima (arbitrary). For example, a particularly negative room which may injure the character could be accompanied by music expressed with the coordinates [40, -30], equating roughly to angry music, while another room which is slower in pace and non-threatening by [20, 5].

Naturally the freedom of movement a user has in a computer game world allows for the switching between a discrete subset of available music tracks. This limiting information can be used to graduate the shift between emotion baselines more effectively. This permissible movement structure can be illustrated in tree form, depicted in figure 3b. From this structure, music track transition information can be encoded as an *AV Vector*, described in equation 1.

$$\text{Inter - Scene}(R_x, R_y) = [A_{base1}, V_{base1}, A_{base2}, V_{base2}, A_{timeStart}, A_{timeEnd}, V_{timeStart}, V_{timeEnd}]$$

Eq. 1. AV Vector Equation for Influencing Inter-Scene Music Emotion Transition

This data allows us to calculate individual affect gradients for both arousal and valence. In effect, how quickly we shift from one emotional state to the next. Computer games have a second form of emotional intent, that occurring at the intra-scene level. This form is a more fine-grained, continuous flow of event data. However the event *AV Vector* takes a form similar to that of inter-scene data; this game event vector is represented in equation 2.

$$\text{Intra}-\text{Scene}(E_X) = [A_\Delta, V_\Delta, A_{timeStart}, A_{timeEnd}, V_{timeStart}, V_{timeEnd}]$$

Eq. 2. AV Vector Equation for Influencing Intra-Scene Music Emotion

Game event data occurs relatively separate from the underlying music track, thus only the change in affect with each event is passed. This desired influence overlays the music track emotion, shifting the baseline in particular directions over time.

5.2 Audience Sensing and Intent

The capacity to influence the perceived emotions of music also provides an opportunity to incorporate an aspect of music performance which has up until now not been accessible to computer mediated music. In a traditional music performance an audience's response provides a wealth of feedback data to the performer. This information is often used by a performer to modulate their performance, to better match the mood of the audience. For example, in a particular live music concert the performer may begin with 20 minutes of high-energy music; through audience feedback the performer determines that the listeners may be growing tired sooner than anticipated. As a result, the performer may slow the pace of the performance as a reaction to the emotional state of the listeners.

Audience feedback data comes in two forms, continuously-sensed audience response data and that from a listener's set of musical attitudes collected prior to the performance. Attitudes are a commonly overlooked factor in the music life cycle, yet they remain critical to musical enjoyment [22]. The importance of attitudes in musical enjoyment was perhaps first articulated by Meyer, first referred to as a belief; "*The mind may suspend judgment, so to speak, trusting that what follows will clarify the meaning of the unexpected consequent*" [23]. This concept of "suspension of belief" was later extended with "*a positive belief in the competence … of the artist … because it is a necessary condition for the empathy on which perceptual engagement and affect response depends*" [24]. Here, the suspension of judgement is a decision based on a belief, that is, the listener's attitude towards the composer and or performer. The effect of attitudes on biasing the evaluation of a performance or composition is well known [25].

Attitudes can also be used to specify emotional bounds on music, where perceived emotional intensity can be "toned down", or shifted depending on the listeners current state (e.g. they may not feel like being exposed to angry music right now). An example of where such controls would have been beneficial was in the recent computer game "Doom 3" [26]. Characterised as one of the most atmospheric games to date, a survey of user experiences [27] found many reported the game to be frightening. Indeed, so powerful was the experience that one player commented "*the only thing I did to make sure I [was] still safe [in real life], was to sometimes turn my head towards the door and check it*". While some users found this level of realism enhanced the gaming experience, others noted that they could only play the game for short periods due to the sustained physical stress that resulted. In this instance users could have specified an upper limit on how scary the music could become during game play: $Quadrant(x) = [A_{\max 1}, V_{\max 2}]$. This bounded value can also be shifted during game play, depending on the audience's current state; for example, if the audience is playing during the daytime, or if they just feel like a good scare.

The rapidly developing field of affective computing is opening up new possibilities for the sensing of audience affect. Measures such as keystroke and mouse response movement rates can be used as tension/relaxation measures, gaze tracking and skin conductivity for interest and arousal levels, which also acts as a strong predictor for memory and attention [28]. Lastly, new facial recognition technology with identification rates comparable to that of a human [28] can be used for the identification of basic emotions. Importantly though, affective computing is a measure of an audience's induced emotional state. As was discussed earlier in section 3.1, we cannot control induced emotion; we can only influence perceived emotions and respond to what emotions are induced as a result of this.

5.3 Emotive Algorithm

This component acts largely as an equalising unit for event data coming from the audience and application. Storing audience attitudes, it couples the music emotion baseline and game event data with user responses, making an executive summary on the $[\mathrm{A}, \mathrm{V}]$ vectors which are continuously sent to the rule system. The following scenario outlines one possible decision the emotive algorithm may make. The present user attitude has the upper bound: $Quadrant(2) = [40,-25]$, while the game music for the current room may be $[32,-18]$. Suddenly the player is surprised by a group of enemies, with the AV vector sent: $[+10,-15,0s,0s,3s,5s]$ (see equation 2) by the external application. The emotive algorithm would cap the AV vector so as not to exceed the quadrant(2) bounds, and may graduate the transition over a longer timescale given the proximity to the quadrant bounds. The final AV vector sent to the rule system might be: $[+8,-7,0s,0s,5s,9s]$.

5.4 Engine Architecture Walkthrough

The engine is initialised by passing in the set of available music scores, along with any collected audience attitudes. When instructed, the engine begins to output the desired musical track. At this point the external application begins to send event data to the emotive algorithm, instructing the rule system to influence the perceived musical emotion in particular directions. Concomitantly, audience feedback data sensed in response to the game and music is passed to the emotive algorithm for processing. As discussed, the emotive algorithm calculates a summative AV vector which is then passed to the rule system. The rule system then applies the structural emotion rules of the octant to which the AV vector corresponds. For example, if the AV vector endpoint falls within octant 2, then octant structural rules 2 are applied. The intensity of the applied rules (e.g. large or small tempo increase) is dependant upon the vector's endpoint coordinates within the octant. From this walkthrough we can see how a generative feedback loop can be setup between the external application, the engine and the audience's response.

6. Conclusion

In this paper we outlined our engine architecture for influencing the perceived emotions of music with intent. Using a rule system for the modification of musical structure, it was illustrated how such a mechanism could be integrated with an external application and audience for use in a practical environment. By employing a dimensional representation of emotion, it was illustrated how emotional data could be encoded in the form of an AV vector. In future work we plan to broaden the rule system's structural rules, along with an expansion of the subsequent testing population. "*The work reported in this paper has been funded in part by the Cooperative Research Centre Programme through the Australian Government's Department of Education, Science and Training.*"

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