Technical Report on a Short Live-action Film whose Story with Soundtrack is selected in Real-time based on Audience Arousal during Performance

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ABSTRACT

'many worlds' is a short narrative live-action film written and directed so as to provide four optional linear routes through the plot and four endings. At two points during the fifteen minute film, decisions are made based on audience biosignals as to which plot route to take. The use of biosignals is to allow the audience to remain immersed in the film, rather than explicitly selecting plot direction, as done in most interactive films. Four audience members have a bio-signal measured, one sensor for each person: ECG (heart rate), EMG (muscle tension), EEG ("brain waves") and Galvanic Skin Response (perspiration). The four are interpreted into a single average of emotional arousal. This is used to decide which route to select at each of the two plot selection points. The film starts with a binaural soundscape composed to relax the audience, and depending on which clip is selected at the decision points, a different soundtrack is played under the visual action as well. 'many worlds' is the first live action linear plotted film to be screened in a cinema in front of the general public which utilizes the above reactive approach.

1. INTRODUCTION

This paper documents the design and implementation of an engine for real-time detection of biosignal responses from an audience which can drive live editing of a film and its soundtrack. This generates streaming video for the purpose of audience affective manipulation whist they watch the narrative of an algorithmic short film written and directed by Alexis Kirke: 'many worlds'. A key vision behind the film is that at fixed points in the plot the audience's arousal level will be sampled and if is below a pre-determined threshold, a more intense version of the next scene will be selected.

There has been much previous work in algorithmic live action film, mostly database cinema [1]. There has also been a lot of work in interactive cinema [2, 3], in which the audience select plot lines. However most of this work has involved the audience consciously selecting film behaviour. This has the effect of destroying the immersion in the story [4]. [4] has begun to attempt to address this in a simple computer-generated graphical drama using single viewers at a workstation. A brain-influenced film installation has been developed which was displayed in a museum [5], also leading to further research in cinema and neuroscience [6]. [7] measured peoples' biosignals while they sat in a cinema to see if their emotional reactions could be detected. The result indicated that the detection was possible. [8] attempted to detect audience interest during movies scenes using various bio-signals but could not quantify the precise nature of "interest". A related study is found in [9] which attempted to detect "boredom" in people playing a video game. The power of such approaches is that not only can they maintain peoples' immersion, but can potentially increase it, by reactively manipulating them using plot, edit or soundtrack elements which respond to the audience dynamically.

1.1 Metering affect

The various models of emotion proposed by affective sciences offer complex, and still evolving, representations which can be used to map musical features to mood and vice versa. The dimensional approach to specifying emotion utilizes an n-dimensional space made up of emotion "factors". Any emotion can be plotted as some combination of these factors. The 2-Dimensional 'circumplex' model of affect [10], with emotion comprised of valence and arousal, is often utilized in emotional evaluation for music [11, 12, 13, 14]. In many emotional music creation systems [15] these dimensions are used. In this model, emotions are plotted on a graph with the first dimension being how positive or negative the emotion is (valence), and the second dimension being how physically excited the emotion is (arousal). For example "Happy" is high valence high arousal affective state, and "Stressed" is low valence high arousal state.

Self-reporting arousal on such a model [16,17] presents problems for the presentation and development of responsive, immersive music — and particularly as in this case, responsive immersive cinema — in that they force the interruption of any narrative. The use of a range of biosensors to meter affective responses [18, 19] from the cinema audience and respond accordingly presents the opportunity to bypass self-reporting or self-selection of material (for example, in the feature film world when DVD audiences can select alternative endings by a root level navigation menu) in favour of an affectively driven, emotion-synchronous model.

'many worlds' attempts this with a pilot system that does not currently utilize valence, focusing on the measurement of arousal as a time-based vector. Important factors of the movie experience (beside emotions) fall outside of what such a system can take into account. Aspects of the viewers' cognitive processes, of aesthetic dimensions, evaluative reactions, etc. – which are central parts of the movie experience – fly under the radar of the system. However arousal was chosen for this initial implementation because most biosensor research in the past has been more successful in detecting emotional arousal than emotional valence [20], and there are no current forms of measurement available for the other elements of the cinema-going experience such as those mentioned.

As has been mentioned, in emotional measurement, arousal is what distinguishes Happy from Relaxed, and Angry from Depressed. It measures the physical activity of the emotion. So if a watcher is feeling positive about a film, an arousal-maximizing strategy will make them feel Happy rather than Relaxed, or Angry rather than Depressed. This is obviously a fairly blunt instrument but provides a first in-road into implementing emotion-control strategies.

The arousal vector is involved in a constant feedback loop, as ongoing arousal is continuously 'pinged' in real-time within the limits of a preset buffer. This vector is evaluated at various time values, mapping the arousal and time value to a video selection, creating a range of possible narrative routes through the film for the audience. The entities involved in this process are time and a high-level arousal estimate (at a lower level, raw biosignal data), with the relationship between these entities determined by the director in order to sustain or increase audience arousal whilst watching the film.

This pilot system has possible applications in affective algorithmic soundtrack selection for film and television, as well as affective metering for standalone computer music or film.

2. SYSTEM OVERVIEW

Four sensors are used to monitor participating audience members physiological reactions in real-time. These responses are combined in an affective estimation algorithm to give a moving average value for audience arousal, which is compared with an arousal threshold at various decision points in the narrative to give control data that maps the next part of the narrative the audience will watch, seamlessly creating an edit 'on-the-fly'. Previous computer music research has made use of similarly collected biosignal data as control inputs for music with emotional correlations. Such affective correlations to the selected biosignals are well documented in literature [21, 22]. A flow-chart illustrating the complete signal flow is given in Figure 1 (at the end of this paper). The system broadly comprises three sections: Biosignal metering, Arousal estimation, and Video editing (arousal synchronous narrative selection). These sections are explained in more detail below.

Four biosensors were utilized, all of which have implicated in detecting affective arousal:

1. Electrocardiograph (EKG), indicating mean heart rate from the participant above calibration threshold, averaged over 2-10 beats [22]
2. Electromyograph (EMG), indicating muscle tension from the right forearm of the participant, as a mean within each buffer(n) [23]
3. Electroencephalograph (EEG), using three electrodes to indicate frontal brain activity, filtered to give only the alpha region using a band-pass 8-12kHz two-pole filter [24]. As in [24] the natural logarithm of the alpha data was calculated and multiplied by -1
4. Galvanic skin response (GSR), giving a normalized value for perspiration on the left wrist and forefinger of the participant [22]

2.1 Bio-signal metering

Sensor responses are digitized and passed to Max/MSP as raw data in real-time. Each data stream is calibrated to remove background noise using adjustable maximum and minimum input level outliers with EEG and GSR responses, and a simple noise-gating threshold for EKG and EMG responses. The responses from each sensor were then passed to an affective estimation routine to determine an instantaneous audience arousal value with which to carry out video selection.

2.2 Arousal estimation routine

Affective arousal is estimated from the four biosensors as a moving average. The output from each sensor is normalized before being summed across a nominal buffer, as shown in Equation 1, where A(n) = estimated arousal for buffer (n):

$$A(n) = \frac{\Sigma\, EEG(n)+EKG(n)+EMG(n)+GSR(n)}{n} \qquad (1)$$

Results from the arousal estimation algorithm are compared with a pre-determined arousal threshold (AT) in order to generate a control message for selection of video playback in the video mapping portion of the code.

2.3 Video editing: arousal-synchronous narrative selection

The first iteration of the Jitter-based video playback engine was designed in order to switch between three different narratives 'on-the-fly' by direct comparison of arousal values with the pre-determined arousal threshold (AT). In the finished system, video timecode is also used as a mapping entity such that time and arousal are mapped to video selection and playback, creating an arousal-synchronous method of video narrative selection. 7 clips in total are used in this system, as illustrated in Figure 2.

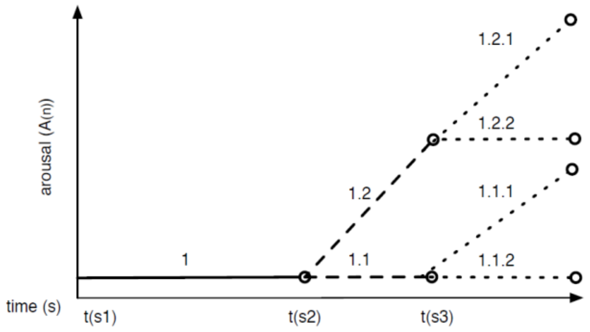


Figure 2. Illustrating arousal threshold and ‘split’ points – editing decisions are made at predetermined timecodes by comparing the estimated audience arousal from the four biosensors to an arousal threshold and selecting a bipolar route through to four separate narratives.

Table 1 and Figure 2 shows that the 7 clips present four possible ‘routes’ for the audience, through two branches or ‘split’ points based on timecode values, t(s2) and t(s3) respectively. The arousal buffer, (n), is reset after each of the split points as part of the affective estimation algorithm. This real-time detection of arousal allows the filmmaker to select narrative according, and in direct response to, the audience’s arousal. This allows the film to adapt to the audience, and the filmmaker to discretely target the induction of arousal in the audience, maintaining or increasing arousal through the narrative. The choice of trying to increase audience arousal was an artistic decision by the filmmaker (writer / director). Other strategies that could have been chosen include minimizing arousal or creating a certain arousal trajectory.

The marking-up of video clips as to which expressed higher or lower arousal, was done by the filmmaker. This was a subjective process and part of the artistic decision making, as there are no agreed methodologies for measuring such “plot arousal”. The story involves three lead characters, and takes place in two locations: one outside and one inside in a single room. Clips 1.1 and 1.2 in Figure 2 are differentiated by action taking place with one or with two people respectively. The two-person clip was considered to have a higher arousal due to their interactions. Clip 1.2.1 was considered to be higher arousal than Clip 1.2.2 for reasons which will not be documented here, so as not to reveal the endings: the writer / director judged Clip 1.2.1 to be higher arousal for dramatic reasons. Similarly with the decision that Clip 1.1.1 was higher arousal than Clip 1.1.2.

Four modifier values were applied to ensure correct clip selection at the pre-determined split point timecode values:

[beginning of film +1]
[first clip reached timecode +1]
[reached first split point +2]
[reached second split point +3]

Pathway	Clips Played	Arousal <> Arousal Threshold
1	1, 1.2, 1.2.1	Low arousal, Low arousal
2	1, 1.2, 1.2.2	Low arousal, High arousal
3	1, 1.1, 1.2.1	High arousal, Low arousal
4	1, 1.1, 1.2.2	High arousal, High arousal

Table 1. Showing four possible routes through seven video clips, with corresponding arousal estimations

which, combined with a modifier value for arousal (determined by comparing the moving average arousal with the selected arousal threshold):

[arousal >= arousal threshold +1]
[arousal < arousal threshold +0]

generate a unique reference number for each of the decision points. This unique reference is used as a control message to select the relevant clip and begin playback in the Jitter video engine.

clip URN 1 = +1 (beginning of film, no arousal)
clip URN 2 = +1 (beginning of film) +1 (first clip reached timecode)
clip URN 3 = +1 (beginning of film) +1 (first clip reached timecode) +1 (arousal>threshold)
clip URN 4 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point)
clip URN 5 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point) +1 (arousal>threshold)
clip URN 6 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point) +3 (reached second split point)
clip URN 7 = +1 (beginning of film) +1 (first clip reached timecode) +2 (reached first split point) +3 (reached second split point) +1 (arousal>threshold)

3. SOUNDTRACK GENERATION

A soundtrack was composed by the writer / director for each of the film clips had been marked up for arousal. The electronic composition was generated with binaural beats. These involve two pure tones with frequencies that are slightly different. This creates the psychoacoustic effect of a beating slowly modulating their frequencies. The apparent frequency of modulation increases as the difference in pure tone frequencies increases. Although there has been work suggesting that binaural beats can affect mood [25], they are used here as an aesthetic choice by the composer, not with any scientific claims of mood manipulation. The use of such an abstract soundtrack is not so unusual. One key example of how audiences are becoming more used to such soundtracks is the sparse sub-bass soundtrack found in the mainstream feature film Paranormal Activity 2.

The composition for ‘many worlds’ was done intuitively based on scene drama, not based on the arousal markups. However an interesting structure emerged, as shown in Figure. Given that Clip 1.2.1 was marked up as having a higher arousal than Clip 1.2.2, it was found in post-analysis that the soundtrack had a maximum higher energy peak for the clip whose arousal was marked up as being higher (i.e. Peak 0.105 > Peak 0.052). Similarly with Clip 1.1.1 being marked up as higher arousal than Clip 1.1.2, the peak energy of the soundtrack turned out to have a higher energy in the higher arousal-marked clip (i.e. Peak 0.0975 > Peak 0.0920).

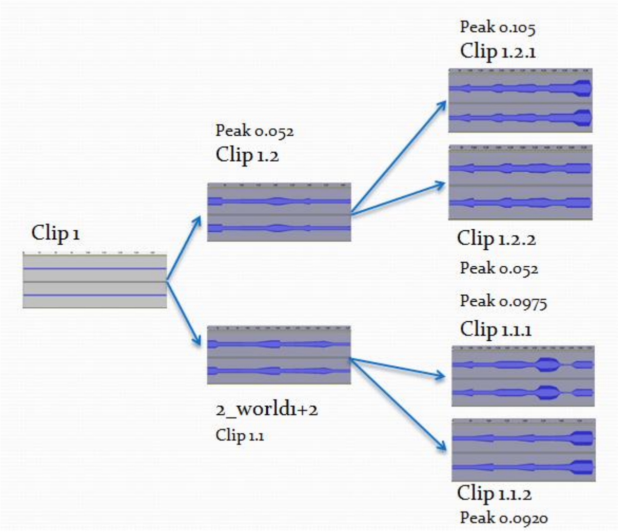
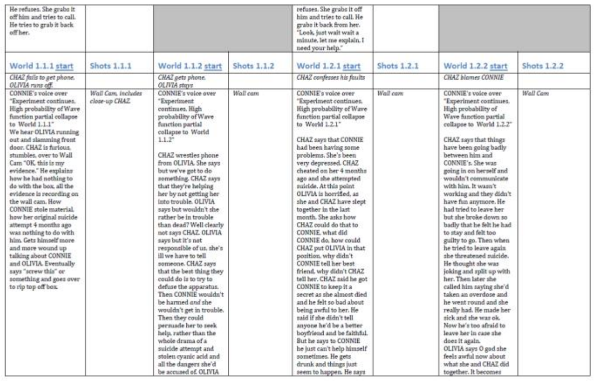


Figure 3. Parallel soundtrack structure using binaural beats sounds. Peaks indicate the maximum sample peak in the soundtrack in a clip.

4. SCRIPT

Little is mentioned here about the script, as it is desired to not reveal key storyline elements except when the film is viewed. The actual script was provided to the actors in a branching form, with all four routes in one script, as shown in Figure 4. (The figure is deliberately unreadable so as not to give away key story elements.) In summary: two students Charlie and Olivia arrive at the apartment of their friend to try and cheer her up on her 19th birthday. They find Connie, a physics student, has sealed herself in a coffin-sized box with a cyanide gas-capsule connected to a Geiger counter. At any time a large enough burst of cosmic rays in the atmosphere could trigger the cyanide and kill Connie; in fact it could already have happened. Charlie – also a physics student – realises Connie is performing a twisted version of a famous quantum physics experiment about the nature of reality, but one that was never meant to be performed in real-life. Over the next 10 minutes – through clips from their phones and a mysterious camera observing the room – the audience learn the true reason for the experiment.

A key inspiration for the film’s creator was that the story refers to unresolved philosophical issues in quantum mechanics concerning how the observer effects the observed in physics experiments. This is paralleled by the audience sample affecting the observed story as they watch the film. Thus the mode of presentation of the story (live biosignal based editing) parallels the story content itself.



He refuses. She grabs it off him and tries to call. He tries to grab it back off her.				refuses. She grabs it off him and tries to call. He grabs it back from her. “Look, just wait wait a minute, let me explain. I need your help.”			
World 1.1.1 start	Shots 1.1.1	World 1.1.2 start	Shots 1.1.2	World 1.2.1 start	Shots 1.2.1	World 1.2.2 start	Shots 1.2.2
CHAZ fails to get phone. OLIVIA runs off.		*CHAZ gets phone. OLIVIA stays*		*CHAZ confesses his faults*		*CHAZ blames CONNIE*	
CONNIE's voice over “Experiment continues. High probability of Wave function partial collapse to World 1.1.1” We hear OLIVIA running out and slamming front door. CHAZ is furious, stumbles, over to Wall Cam “OK, this is my evidence.” He explains how he had nothing to do with the box, all the evidence is recording on the wall cam. How CONNIE stole material, how her original suicide attempt 4 months ago was nothing to do with him. Gets himself more and more wound up talking about CONNIE and OLIVIA. Eventually says “screw this” or something and goes over to rip top off box.	*Wall Cam, includes close-up CHAZ.*	CONNIE's voice over “Experiment continues. High probability of Wave function partial collapse to World 1.1.2” CHAZ wrestles phone from OLIVIA. She says but we've got to do something. CHAZ says that they're helping her by not getting her into trouble. OLIVIA says but wouldn't she rather be in trouble than dead? Well clearly not says CHAZ. OLIVIA says but it's not responsible of us, she's ill we have to tell someone. CHAZ says that the best thing they could do is to try to defuse the apparatus. Then CONNIE wouldn't be harmed and she wouldn't get in trouble. Then they could persuade her to seek help, rather than the whole drama of a suicide attempt and stolen cyanic acid and all the dangers she'd be accused of. OLIVIA	*Wall cam*	CONNIE's voice over “Experiment continues. High probability of Wave function partial collapse to World 1.2.1” CHAZ says that CONNIE had been having some problems. She's been very depressed. CHAZ cheated on her 4 months ago and she attempted suicide. At this point OLIVIA is horrified, as she and CHAZ have slept together in the last month. She asks how CHAZ could do that to CONNIE, what did CONNIE do, how could CHAZ put OLIVIA in that position, why didn't CONNIE tell her best friend, why didn't CHAZ tell her. CHAZ said he got CONNIE to keep it a secret as she almost died and he felt so bad about being awful to her. He said if she didn't tell anyone he'd be a better boyfriend and be faithful. But he says to CONNIE he just can't help himself sometimes. He gets drunk and things just seem to happen. He says	*Wall cam*	CONNIE's voice over “Experiment continues. High probability of Wave function partial collapse to World 1.2.2” CHAZ says that things have been going badly between him and CONNIE's. She was going in on herself and wouldn't communicate with him. It wasn't working and they didn't have fun anymore. He had tried to leave her but she broke down so badly that he felt he had to stay and felt too guilty to go. Then when he tried to leave again she threatened suicide. He thought she was joking and split up with her. Then later she called him saying she'd taken an overdose and he went round and she really had. He made her sick and she was ok. Now he's too afraid to leave her in case she does it again. OLIVIA says O god she feels awful now about what she and CHAZ did together. It becomes	*Wall Cam*

Figure 4. Section of script used by actors; near the top of this page the two possible paths each split into two again.

5. DISCUSSION

The system allows time-synchronous mapping of biosignal responses from four sensors to audio and video material, for the purpose of ‘editing’ a short film on the fly in direct response to a simple real-time metric of the participating audience’s arousal. Four narrative structures are implemented, though many more are possible with the appropriate processing power — a version making use of distributed processing has been developed using User Datagram Protocol to send and receive control data and trigger video playback via a local area network. Larger numbers of sensors might reasonably be implemented by similar means.

In terms of sensor usage in the cinema environment, some people found the EEG headset uncomfortable, and one person found the muscle tension monitor uncomfortable. The sensors most amenable to calibration were heart rate, and also the muscle tension monitor, as the audience member could be asked to directly flex the area of muscle involved. EEG was the most difficult to calibrate because of the noisiness of the data and its artifacts, in fact a key addition to the system in future would be an artifact removal algorithm. GSR was also difficult to calibrate quickly because it was such a slow moving signal. The GSR also contributed the least to story pathway selection because of its slow-moving nature. The heart rate sensor, as well as being simple to calibrate, was the simplest to use. The downside was there was sometimes a false triggering of a heartbeat, so a suitably long averaging window needed to be used to filter these out.

The system might provide a useful platform for further work evaluating audience arousal through different narrative structures, (i.e., for emotional metering of real-world test material), or adapted to soundtrack-only manipulation, building on existing research into the affective changes which sound-tracking can induce [26, 27]. There remains a significant window for further work devising a method for incorporating valence metering to the affective estimation algorithm, applicable both to the real-time affective video system described here, and more widely to affective composition, music psychology, and emotional performance algorithms in computer music.

6. CONCLUSIONS

Affective mapping of arousal and timecode to video and sound selection, by means of a moving average estimation from four biosignal sensors (EKG, EEG, GSR, and EMG) allows the filmmaker to meter and respond to audience arousal in real-time with this system. The system described is capable of playing back full HD video and synchronous audio whilst monitoring and calculating the arousal estimate in real-time and was demoed to a live cinema audience at the Peninsula Arts Contemporary Music Festival, UK, on February 23rd 2013. Footage from the premier can be seen here: **http://www.bbc.co.uk/news/technology-22436014**

Acknowledgments

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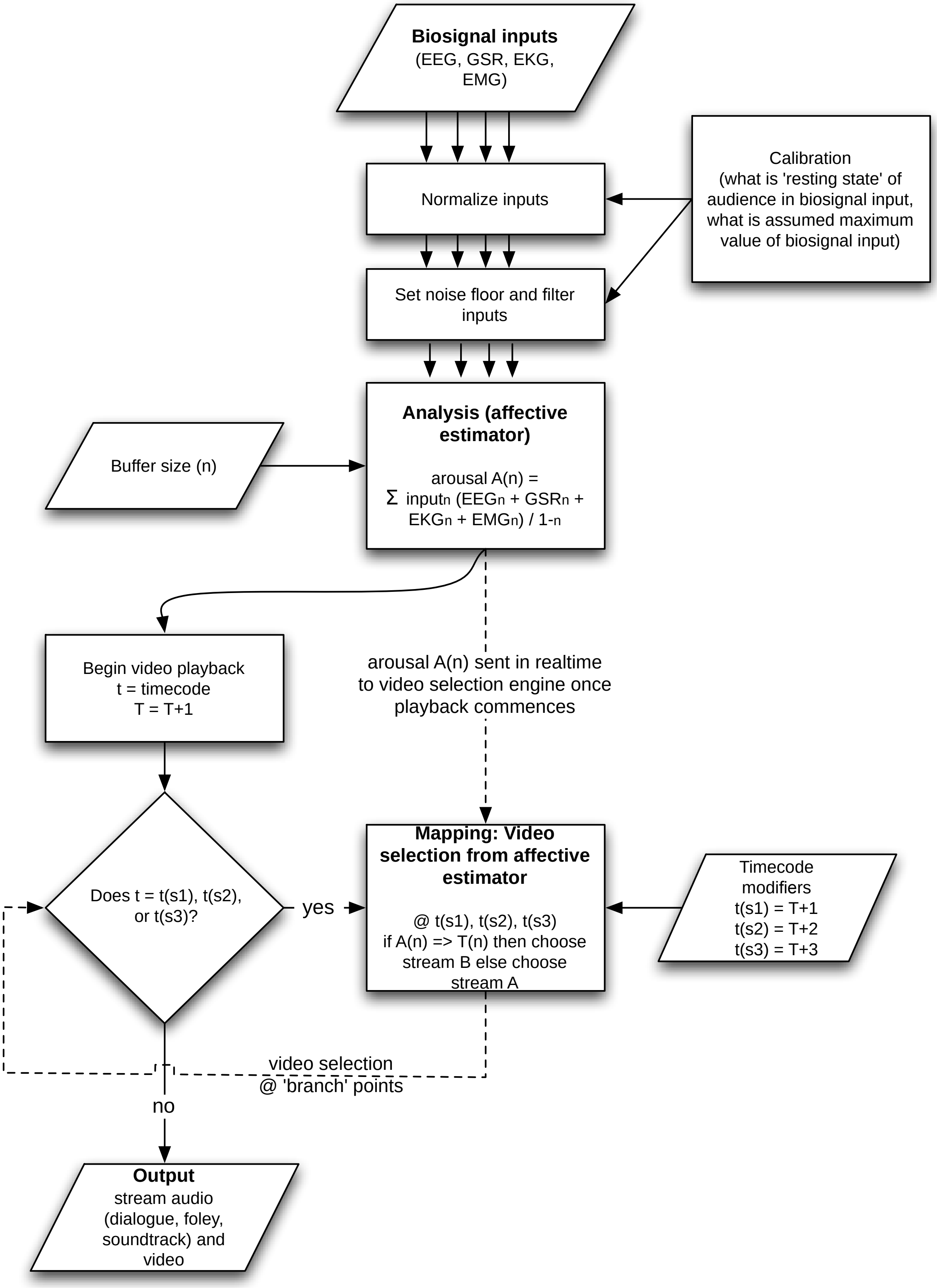

Figure 1. Flow chart overview of system: Biosignal inputs are calibrated, normalized, and averaged to determine values for synchronously selecting video outputs