A MOTION-REACTIVE STAGE LIGHT SYSTEM CONTROLLED BY THE AUDIENCE'S SMARTPHONES

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ABSTRACT

In the last decades, new ways of interaction between artist and audience at musical events to improve the performance experience have been investigated and put into practice. Our work fits right into this context, as we propose a mapping between the movement of the audience and LED light patterns on stage. The aim is for the attendants to feel empowered and deeply involved directly, changing the performance in a controlled way that does not compromise its own artisticity.

The system suggested in this report is commissioned by the annual musical event FestiValle and will be put into effect during this summer's edition of the festival.

A key aspect of this project is to propose a sophisticated system with technology of daily use. With the sole employment of smartphone sensors we managed to define a metric that describes the movement of the crowd which drives the whole structure.

We also provide results of an experiment we made to link the audience motion metric to musical characteristics of the songs listened by attendants. The outcomes of our study can be used to meaningfully map the light effects associated to a certain amount of movement. Finally we will go through different possible strategies and future expansions of this model.

***Index Terms*—** Stage lighting control, Movement, Smartphone Sensors, Technology-Mediated Audience Participation

1. INTRODUCTION

In recent times the use of technology in the context of live performances is increasingly investigated. [1-11] The purpose of these studies is often to find a way to enhance the experience and bring novelty creating new possibilities of direct interaction. The audience is of course one of the main targets for exploring new strategies of participation, in these cases we talk about Technology-Mediated Audience Participation (TMAP).[1] [2] [4]

In this paper we discuss our proposal for an interaction design system having the crowd controlling the stage lighting through its collective motion. Our system will find a real context of use during the DJ-sets at FestiValle festival which will take place in August 2022 and is designed according to the specifications and the characteristics of the event. Indeed, being an open air setting with different stages and suffering from light conditions, lead us away from more sophisticated methodologies to trace the audience movement like for example motion tracking with cameras. We find interesting to explore the use of mobile phones for interaction since they are a technology already available to everybody that provides with high degree of connectivity and several information thanks to its sensors. Moreover we try to keep the interaction smooth and not intrusive so that the experience is reinforced and not compromised. In addition, we made an experiment of use of our system helpful for trying to correlate the audience motion to some high-level musical features and to examine a possible mapping for the lights.

In the next section we talk about the overall system architecture going through some of the implementation details and describing the instruments we used. After that, we analyze more specifically how we applied the information we retrieved from the audience in order to have a clear description of its movement. Following, we discuss about the experiment setup and our analysis on the retrieved data. At last, before concluding we examined possible expansions of our work that can take place in the future.

2. SYSTEM ARCHITECTURE

Figure 1 describes the proposed system to make the audience control the lights on the stage. Nowadays is very common for the people to carry and make use of their smartphones at concert venues, therefore our idea is to employ them to make the audience feel as an active part of the show.

2.1. Sensors and Web Application

A first step of our architecture is to retrieve each smartphone's sensors data. To achieve that we create a Web Application which is a convenient choice to have access to gyroscope and accelerometer data. We prefer this solution in comparison with a standard application since it is easy-to-use, OS-independent and most importantly less invasive for the audience.[9]

The Web App has the simple duty to take each user's movement data, elaborate them and send the information related to the movement to a Web server via web socket. To accomplish this task we use event-based Web API[1] which capture sensors' outputs in real time(a message every 16 ms). A relevant detail is that is necessary to establish a HTTPS secure connection in order to manipulate and have access to the smartphone's data.

2.2. Server and communication protocols

To collect all the information coming from the audience we designed a Python Web server. It starts a web socket secure connection with all the smartphones logged on the Web Application which act as clients.

[1]Documentation available at https://developer.mozilla.org/en-US/docs/Web/API/DeviceMotionEvent/DeviceMotionEvent

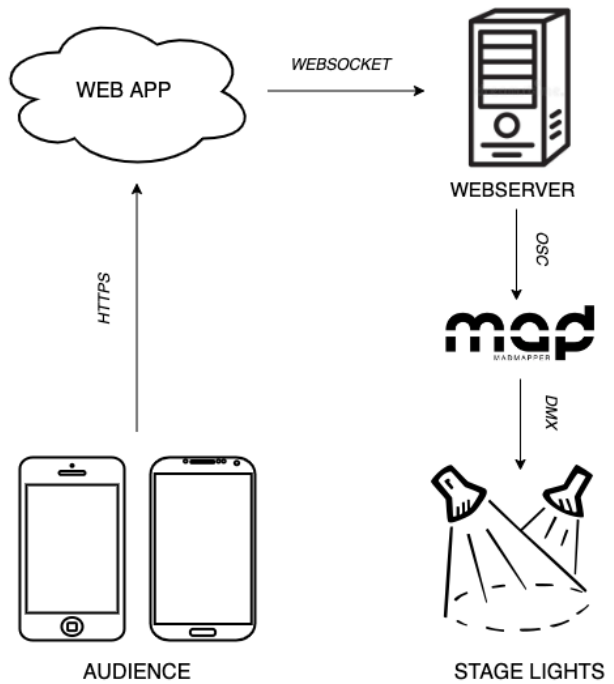

Figure 1: General System Architecture

Its main role is to gather into a buffer all the data in order to average them out and obtain a single measure representing the overall motion of the crowd.

Moreover the server has also the task of controlling the LED lights on stage according to what it receives. This is been carried out by making use of an Open Sound Control(OSC) client hosted on the server. It sends a different OSC message according to the previously calculated movement related values to MadMapper that acts correspondingly. In particular, different patterns and light effects are triggered in compliance with the amount of motion of the audience.

MadMapper is the software that handles the DMX protocol communication with the lights to control directly the LEDs. Exact details on this part relative to the actual context of FestiValle are not ready to be specified yet.

3. NUMERICAL CHOICES AND METRICS

After defining the tools of our work, further action is to clarify how to employ them in order to describe appropriately our context of use.

3.1. Describing motion

We analyzed the kind of data which we can retrieve from our sensors in the interest of synthesizing and describing the overall movement of a person in a single numerical value.

We concur on the fact that accelerometer data are more representative than the gyroscope ones in relation to our aim. Many previous works focus on representing the motion activity of a person just using the acceleration.[10] [12] [13] Alternatively we opt for a combination of two different types of data. This of course is an attempt to be effective in the description of motion we are interested to classify. We came up with this definition also after an empirical tuning and considering numerous complexities due to the specific final setting of a festival.

Moreover are taken into consideration also some of the reflections done by [4][1] regarding TMAP in contexts having an artistic intent.

We prefer to keep the acceleration value as the one leading our metrics, but since in our opinion it is not enough descriptive in all possible situations, it is weighted by a quantity driven by the Rotation Rate (RR). It is a value expressing the rate of change of the device's orientation along the three axis in degrees per seconds.

Our final choice is to describe the movement metrics m as follows:

$$m = acceleration_{tot} * RotationRate \tag{1}$$

The term $acceleration_{tot}$ is the result of the calculation of the magnitude of the acceleration which is given by the sensors as the contribution on a single axis:

$$acceleration_{tot} = \sqrt{a_x^2 + a_y^2 + a_z^2} \tag{2}$$

Regarding the value of RR we choose to rescale its value so that it can influence only partly the acceleration data:

$$RR = \frac{(|RR_\alpha| + |RR_\beta| + |RR_\gamma|) * (MaxMul - 1)}{MaxRot} + 1 \tag{3}$$

$MaxMul$ and $MaxRot$ specific values refer respectively to the maximum weight for the acceleration and the non-scaled value of RR corresponding to it. Both of them come as a result of tuning and of the considerations done in light of the experiment which will be discussed more in the details in the following section.

3.2. MadMapper Thresholds

To simulate the real context of the actual Festival, we include a MadMapper file containing different scenes to be triggered by the audience. Our choice is to assign each pattern to one of three categories: the first one corresponds to a low quantity of movement, the second to a moderate amount, and the last one being the one related to the most active scenario. To distinguish between these areas of operation we calibrate two thresholds according to the data coming from the experiment. In particular we evaluate the whole range of information at our disposal and tuned the corresponding thresholds.

$$\begin{cases} LowMovement < 30\% * DataRange \\ ModerateMovement < 60\% * DataRange \\ HighMovement > 60\% * DataRange \end{cases}$$

4. EXPERIMENT

We put our system into practice in a home-made experiment. Our goal is to get sensor data in response to songs with different musical features. From the obtained values, we can, after the experiment, understand which features impact the most on movement and whether they trigger low, medium or high amount of activity. We acknowledge that these investigations can only be done in a tendencial and probabilistic sense, without expecting to precisely link the behaviour of the audience to the music they hear.

The results of this experiment can deliver possible ideas for a creative feature related choice of the light and visual patterns.

Besides this, with the experiment we obtained a numerical and concrete feedback that made possible a mapping of the stage lights according to the thresholds specified in the previous section.

4.1. Setup

Our choice of songs classification was the use of the Spotify APIs. In fact with this tool we managed to measure in a 0 to 1 range high level information of musical pieces, which we regarded as a good way to define numerically and precisely semantic aspects of the songs. Values near to 0 evidence the absence or the shortage of a peculiar characteristic in a song, while values near to 1 indicate the strong or total presence of that characteristic in the track. In particular, these are the features we decided to use:

• **Tempo** – overall estimated tempo in beats per minute (BPM)

• **Danceability** – how suitable a track is for dancing based on a combination of musical elements including tempo, rhythm stability, beat strength, and overall regularity

• **Energy** – a perceptual measure of intensity and activity based on dynamic range, perceived loudness, timbre, onset rate, and general entropy

• **Acousticness** – whether the track is acoustic

• **Liveness** – indicates presence of an audience in the recording (greater than 0.8 provides strong likelihood that the track is live)

• **Valence** – describes the musical positiveness conveyed (higher valence sounds more positive, e.g. happy, cheerful)[2]

We compute these features for each of several songs and build an heterogeneous playlist. We carefully select the songs to include to have values for each feature as uniformly distributed as possible between the set of songs. Furthermore, we consider in the playlist songs with different combinations of feature values so to analyze features independently.

Once satisfied with the pool of selected tracks, we organize the experiment inviting a few people to participate. The event takes place in a outdoor terrace with enough space for the participants to move freely, as we expect an audience would do in a real case of application of our system. We set up a couple of speakers playing our playlist and a PC acting as the Web server, collecting and saving the data sent during the process in a file.

Participants are asked to connect to our Web App with their smartphones and after that to enjoy the music and dance in the most natural and genuine way.

4.2. Plots and results

To read our results, plotted in Figure 2, it must be taken in consideration that highly precise data curves can not be obtained, due to the context, and are not in our interest. What we are searching for are tendencies, represented by the trend lines in our plots. On the x-axis we have the specific feature in consideration, on the y-axis the averaged amount of motion. Points are representative of each song in the dataset.

According to the results of our experiment, the feature that impact in the clearest way on the movement of the audience is the energy, with a strong direct proportionality relation with movement. Energy measures the intensity and activity of the track and is the most important among the defining dimensions of arousal, which

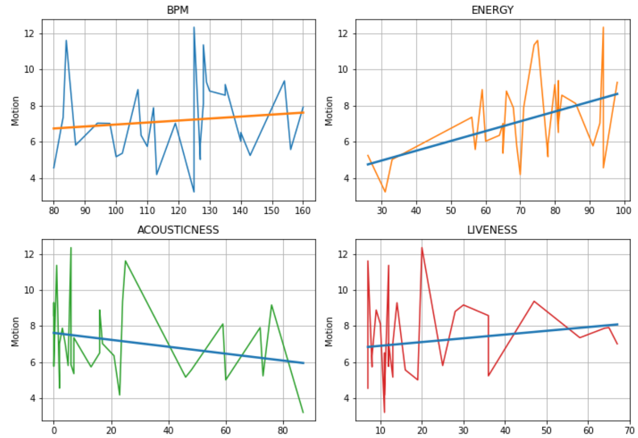

Figure 2: Plots for BPM, Energy, Acousticness and Liveness

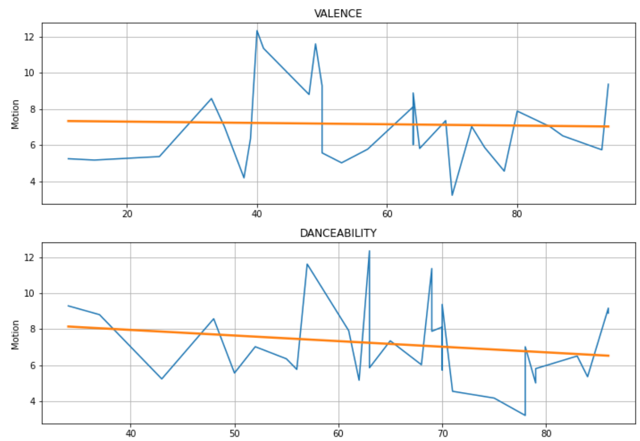

Figure 3: Plots for Valence and Danceability

is a subjective state of feeling that measures the excitement and involvement of an average listener. Therefore, the greater amount of movement on high energy tracks is expectable. [16]

Then, as tempo and liveness rise, in a slighter way than the energy case, movement increases while acousticness is inversely proportional with respect to movement. These results are interesting and similar to what we could expect from an empirical point of view.

As BPM grow, the audience tends to move more. Tempo is another dimension of arousal and therefore faster BPM are connected to a higher crowd involvement.[15]. The major relevance of energy with respect to tempo appears evident from the plot and comes as a possible consequence of previous statements.[16]. Tempo is the only feature not normalized in a 0 to 1 range for clear reasons according to its definition.

On the contrary, in more acoustic songs we expect people to move less. This is confirmed by a inverse correlation between acousticness and energy. [14]. As an example, it is possible to notice that several metal or hard rock songs, which are generally characterized by high energy, have low acousticness.

Furthermore, people appear to feel more involved when they

[2] Definitions according to: https://developer.spotify.com/documentation/web-api/reference/operations/get-several-audio-features

hear live elements, like crowd effects, in songs. In our data set live recordings, so songs with liveness over 0.8, are not present since they are unlikely to be played in the context of use of our system at FestiValle.

Finally, as we can see in Figure 3, danceability and valence appear to have a very irregular behaviour. At first sight this might sound like a contradiction as we could expect a direct proportionality between movement and how a track is suitable for dancing or its conveyed positiveness. However, there are some further considerations that need to be done.

The so called ”Valence-Arousal model of mood” by Russell,[18] a 2D model to rate emotions in reaction to music, show us that songs with high valence, so happy and cheerful tracks, could or could not be linked to big arousal values.

Concerning danceability, our data seem not to be robust enough to underline a convincing relation between this feature and the motion.

As a result, it is hard to predict an evident relation between danceability [14] or valence[15] and movement.

4.3. Discussion on results

We regard as appropriate to do some considerations on the results. Firstly, it is clear that these measurements cannot forecast completely and precisely the behavior of a generic audience subject to a specific musical piece. As a matter of fact, there are a lot of further complexities to be taken into account and so the system can be tuned accordingly. As an example, one pivotal aspect is that each person can deliberately keep his or her phone in the hands or in the pocket. This can have an influence on the range of values of the accelerometer data.

Furthermore, our choice of considering two thresholds and therefore three areas of operation is calibrated on a heterogeneous data set. With our considerations on the relation between feature and motion in mind, it is possible to look at the event playlist (if available in advance), compute the features of the tracks and opt for different solutions. As an example, if most of the songs have high energy, thresholds could be lowered and another high one could be added to avoid stagnation into the ”high motion” scenario for most of the performance.

On the other hand, the movement of the participants depends also on more qualitative and music-independent factors. The temperature, tiredness and personal attitude for example, can lead to a different range of results and so to a description of a different scenario.

Finally, individual musical taste has for sure a role in determining the quantity of movement. We experience this behavior in our experiment: the emotional involvement of specific individuals in the audience can change when the more heartfelt or popular tracks are played. This of course leads to a different result with respect to what we could expect on the basis of the features of that song.

5. FUTURE WORKS

In all our project we considered how the movement of the audience maps different patterns of lights suitable to the current activity. Certainly, features can be used in this sense to convey a particular mood in the light effect, linked to the predicted characteristics of the song played.

A possible future implementation is to study how instead the mapped lights could impact on the behaviour in terms of both movement and emotional response of the audience. This would certainly increase the accuracy of the system and could be useful in a even more movement-related choice of the light patterns. Obviously we are going to take this in consideration when attending FestiValle.

Furthermore, we could evolve our system in two different directions: asking users to give us more data through their smartphones or using more sophisticated technology. In the first scenario, we could ask for additional information that might be helpful to make the server behave distinctively in case of different users. This can be used to do a distinction in the crowd between who keeps the smartphone inside or outside the pocket, so to consider their ranges separately and improve the functionality of the system. Also the GPS position could be sent to have contributions relative to the individual position, of course this can be more effective for larger venues. With the use of this data, the attendants could be divided into groups according to their positions and lights could be mapped in such a way to respond somehow also to the various parts of the audience. This could lead to would increased individual power in influencing the performance. For sure the organizers or the artist should decide the point up to which accept the intrusiveness of the audience into the performance.

Moreover, the use of more sophisticated technology could be integrated into this system to improve it making possible to better capture the audience movement.

6. CONCLUSIONS

In this paper we presented a possible solution for a light control system reactive to motion. Our choices are motivated by the trade off between the reliability of the information we can retrieve from each user and the portability and simplicity of the technology. This is made also to match the requests of the festival and overcome difficulties due to the context of use.

We show how it is possible to capture a representative quantity to describe the amount of movement of all the attendants and how it is connected to some musical characteristics. We opt for a collective representation of the crowd as a whole to reflect in the lights the shared feeling among the people. During our studies, we discovered how energy is important in defining the amount of activity of the audience. We get interesting results also about tempo, acousticness and liveness, which are linked to movement. On the contrary we are not able to clearly correlate features like valence or danceabilty to the behaviour of the audience. This can be both for a not sufficient robustness of our model and for an intrinsic complication in determining a link between these quantities. In fact during our research we encountered similar systems running into akin considerations.

We validate our system in an experimental simulation that confirmed the viability of the model and helped us reflect on how to map the lights to motion carrying also musical information. We considered the possibility to implement motion adaptive or feature-reactive thresholds, but then we come to the conclusion that they will give unfitting results and lead us away from the main focus of the project, the motion as the unique driver of the system.

We are going to examine further details after putting our system in practice in a real concert scenario at FestiValle and expect to get helpful considerations that will be used in the evolution of what we have in hand now for future works.

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