Development of a System to Generate Artificial Ambiance based on Entropy

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Abstract: Ambience is an abstract concept of sensory information. If we can control sensory information, then we will be able to somehow provide ambience as needed. We developed a controllable ambience model using the entropy of distribution functions based on this hypothesis. We adapted the model to several sensory modes, such as facial expressions, tones, and unobjective figures written in HTML and JavaScript available on any browser. We introduce these systems in this paper.

1 INTRODUCTION

In human communities, there are concepts or words whose meanings are ambiguous, such as ambience, emotion, mood, and feeling. But despite their ambiguity, we somehow understand them. These words are used on a daily basis but are defined academically in some fields. For example, in psychology, emotion is defined as rapid mental changes based on obvious causes. On the other hand, mood is defined as slow mental changes based on vague causes. Some people may feel that there are differences between the conventional and academic meanings of words. Therefore, engineering systems with these academic meanings may not work well for human communities. To address this problem, we try to define these concepts quantitatively in order to maintain their ambiguity. When the attempt is realized, human-centric applications will have potential for growth. In this paper, we focus "ambience" in particular.

We first discuss ambience from some perspective. Based on these perspectives, we define "ambience" quantitatively and propose a model for creating artificial ambiences. Finally, we demonstrate and discuss applications of the model.

2 DISCUSSION ABOUT AMBIENCE

2.1 What is Ambience

Ambience is a word with an abstract meaning. According the *Oxford Advanced Leaner's Dictionary*, ambience is "the character and atmosphere of a place." Atmosphere is "the feeling or mood that you have in a particular place or situation; a feeling between two people or in a group of people." Feeling is "something that you feel through the mind or through the senses," and mood is "the way a group of people feel about something; the atmosphere in a place or among a group of people." In these sentences, though we can only perceive that an abstract something controls ambience, we understand that ambience is an interhuman something. Thus, ambience can be considered as the degree of coincidence of human conditions.

On the other hand, Japanese critic Yamamoto discussed air (Yamamoto, 1983), which is similar to ambience, compared to water, which is similar to a power of a changing the ambience, during World War II in

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Japan. Members of a community create air. However, when an authority pours cold water on the air, this breaks up the air suddenly and creates new air. In his opinion, we can see that air (ambience) is affected by the degree of coincidence of members' something.

2.2 Ambience of Music

As mentioned above, we discussed ambiences as involving two or more people. Here, let us focus ambience that consists of another medium—music (Lanza, 2004).

In 1934, background music (BGM), referred to as Muzak, was broadcasted to create a mood or ambience. BGM is also called elevator music. In the past, elevators were considered dangerous conveyances similar to airplanes and roller coasters. Therefore, BGM was played in elevators to ease passengers' fears and tension. Music was played not just in elevators but also other environments, such as factories, stores, and so on.

In addition, various musicians created music for specific environments. For example, Erik Satie composed "furniture music" in 1920. He created music that was meant to remain in the background, just like furniture in rooms. Needless to say, the purpose of this task was to create and control ambience.

Brian Eno proposed "ambient music" as a musical genre and composed "Music for Airports" in 1978. This music melts into the background of airports and eases the tension felt by passengers before getting on airplanes.

As shown in the example, there are many challenges in creating and controlling ambience using music. However, there is no well-established methodology for creating ambience with music.

2.3 Ambience as an Aggregate of Senses

Ambience depends on various human perceptions. Ambience is created by both single and multiple modes of perception. In the previous examples, modes that perceive the dispositions of members as well as sounds create ambiences. To give a further example, the ambience of a painting is created by the relationships between colors, compositions of objects in the painting, and/or the artist.

In this study, we define ambience as an aggregate of the various aspects of human perception.

2.4 Ambience as Relativity

Ambience is created by the presence or absence of perception. For example, a situation in which members conform to something creates ambience. If a member opposes this, the situation changes and a new ambience is created. The reason is because "relativity" between agreement and disagreement creates different situations, and members can understand the difference. Humans are sensitive to change, which is evident in their physiology. This phenomenon is observed in electroencephalography (EEG) called mismatch negativity (MMN) (Näätänen et al., 1978). EEG is electrical recorded signals in the brain. An event related potential (ERP) is a particular EEG response to a stimulus event. A listener is kept stimulated by sound (e.g., 400 Hz tone for 1 s), and then abruptly stimulated by another sound (e.g., 600 Hz tone for 1 s). Comparing the ERPs for the two stimuli, we find differences at 300 ms after the onset of the stimulus. This difference, i.e., MMN, shows that humans continuously search for perceptual deviations in the environment at both the conscious and unconscious levels.

Although there is relativity of modes, i.e., between pitches in this example, relativities between modes create ambience. Let us consider two modes: image and music. Multimedia that consists of a sad image and sad music creates a sad ambience because of the consistency between modes. On the other hand, multimedia that consists of a sad image and happy music creates a curious ambience because of the inconsistency between modes. Moreover, the relativity between perceptual modes in music affects ambience (Ohmura et al., 2013). Complexities of perceptions in rhythm and melody may be divided into different musical genres. When both rhythmic and melodic perceptions are simple, the music sounds like a children's song or nursery rhythm. When rhythmic perception is simple and melodic perception is complex, the music sounds like jazz. When both rhythmic and melodic perceptions are complex, the music sounds like contemporary music. As we have mentioned, we consider how changes in perceptual mode affect ambience.

In this study, we consider that humans perceive using various senses and pick up ambience from temporal changes and relativities.

3 COMPUTATIONAL AMBIENCE

3.1 Ambience as Deviation

It is said that deviation is one of the important elements of emotion, from theoretical and empirical points of view. In a musical study, Meyer pointed out that deviations of expectation arouse emotions

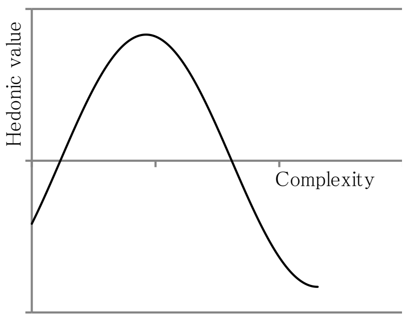

Figure 1: The optimal complexity model (modified from (Berlyne, 1970)).

(Meyer, 1956), based on Dewey's theory that emphasizes the conflict or opposition of tendencies (Dewey, 1894). Continuing Meyer's theory, Narmour defined the relation between expectation and its realization/deviation as the implication-realization theory (Narmour, 1990). Moreover, Huron proposed an extended theory known as ITPRA (Huron, 2006).

Although these findings came from musical study, when emotional states are regarded as ambiences, then ambiences depend on deviations.

3.2 Complexity and Ambience

Deviation from an expectation occurs from disappearing or decreasing patterns which are created by humans. These situations are regarded as increasing uncertainty and complexity. With regard to complexity, Berlyne proposed the optimized complexity model (Berlyne, 1970), which shows the relationship between hedonic emotion and complexity (1). This relationship is expressed by an inverse U function (x-axis: complexity, y-axis: hedonic value).

Putting aside the difference between positive and negative, stimuli that elicit ambiences can be controlled and created by adjusting complexity.

3.3 Entropy and the Information Theory

An environment where deviations from expectations occur frequently is regarded as high uncertainty, and such an environment can be expressed quantitatively using information theory (Shannon and Weaver, 1949). Information theory calculates how communication acts as a function of information.

When an event i occurs, the amount of information I is defined as

$$I = -\log p_i \tag{1}$$

where p_i is the probability of event i. When p_i decreases, I increases. That is, the amount of information increases. When n events occur with the probabilities p_1, p_2, ..., p_n, the expected values are calculated as

$$H = -\sum_{i=1}^{n} p_i \log p_i \tag{2}$$

The value H represents the number of times information is delivered, i.e., the degree of uncertainty and complexity. H is the entropy or average amount of information.

Therefore, by controlling entropy we can create frequency of deviations, i.e., control artificial ambiences.

3.4 Meaning and Ambience

In information theory, there are no meanings of events. For example, given two persons and two situations: in the first situation, one person is happy while the other one is angry; in the second situation, one person is laughing while the other one is smiling. The entropies of these two situations have the same values. That is, information theory dose not distinguish between "laughing," "smiling," and "angry," and regards them as independent events. In ambience, the relationships between events are important because the two examples above are not same ambience. In order to distinguish these, we defined the relationships between events computationally.

Some information on perceptions were defined from psychological considerations or physiological features. For example, the relationship of emotion was proposed as a circumplex model by psychological consideration (Russell, 1980). The relationship of musical notes in music was defined as twelve tones by physiological features.

When the relationships between some events are not defined, the designer of the ambience must define the relationships between them.

In this study, we develop generative artificial ambience systems based on these considerations.

4 GENERATIVE ARTIFICIAL AMBIENCE SYSTEMS

4.1 Method for Artificial Ambience

We propose generative artificial ambience systems using one or more perceptual modes. Basically, we defined quantitative relationships and gave each event a probability using functions. Functions are defined based on the normal distribution for these systems. A number of social and natural phenomena follow normal distributions; thus, we adopted the normal distribution for the system. We can calculate the probabilities of events using the Gaussian function based on the normal distribution. The x-axis represents the relationships between events. The y-axis represents the scale of probabilities. The Gaussian function is represented as

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \tag{3}$$

This equation describes the normal distribution with average μ and variance σ^2. Setting each event to x, each probability is calculated from μ and σ.

Adjusting the variance σ^2 of the Gaussian function, users can control the edge shape of the function. Upon decreasing the variance σ^2, the shape of the function becomes flat, resembling a uniform distribution. In this state, the entropy reaches a maximum that prevents the user from predicting the next event. Upon increasing the variance σ^2, the function peaks. In this state, the entropy reaches a minimum, allowing the user to predict the next event easily. Using Gaussian function, we can treat σ^2 like entropy. We implemented the method using HTML and JavaScript[1].

We describe the details of the systems in the next section

4.2 Generative Ambience System using Simple Facial Expressions

We adopted simple facial expressions for the system. These facial expressions consist of figures of the eyes and mouth. Although the faces are simple, they can express emotions. The relationship between emotions was defined as a circumplex model (Russell, 1980). In this model, emotions were mapped in two-dimensional space with arousal and valence as the positive and negative axis, respectively. We adopted figures of facial expressions as relationships in the two-dimensional emotional space in this system, as shown in figure 2.

In this system (figure 3), when users push the play button, each face in the 7×7 matrix starts to change depending on its probability at arbitrary time intervals. The y-axis of the distribution function means circumplex, and both ends can connect. Arbitrary time intervals are set with Interval slider.

[1] http://sites.google.com/site/hidefumiohmura/home/program/icaart2018

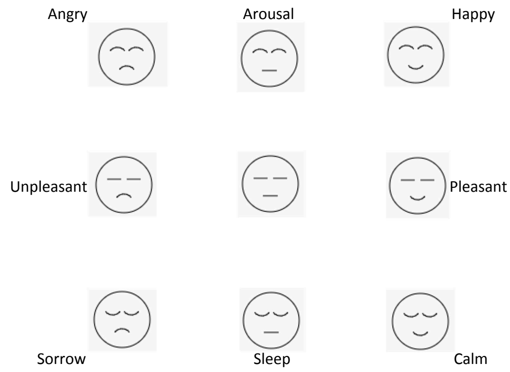

Figure 2: Relationships between simple figures of facial expressions.

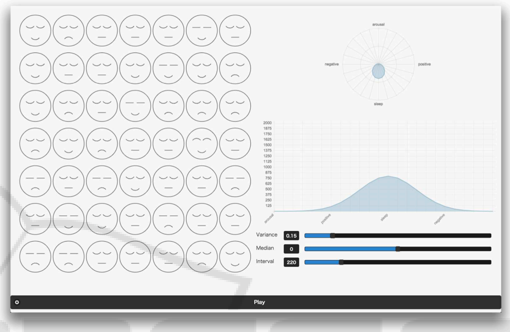

Figure 3: Generative ambience system using simple facial expressions.

4.3 Generative Ambience System using Sounds

We adopted sine waves as tones to the system. We adopted the physical ratio of frequency as the relationship. The relationships of double (2:1) or half (1:2) in frequency are called octaves, the relationships of 3:2 or 3:4 are called the perfect fifth, and the relationships of 4:3 or 2:3 are called the perfect fourth. Using these relationships and ignoring octaves, we can get twelve notes as a circumplex model. The relationship is called the circle of fifths or fourths. Clockwise rotation means $3/2 \times n$, anti-clockwise rotation means $2/3 \times n$, where n is an arbitrary frequency. In this system, the range of frequency is in four octaves.

When a user pushes the play button (see figure 4), the system produces sound that depends on the model at arbitrary time intervals. Arbitrary time intervals are set with Interval slider. Note that the values are set with Value slider.

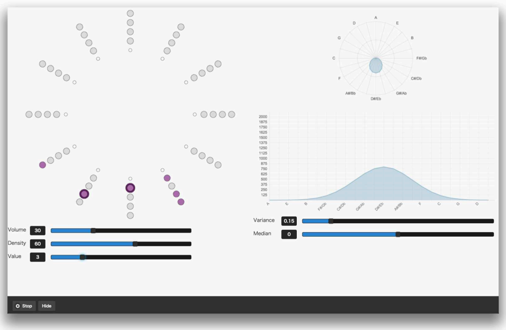

Figure 4: Generative ambience system using sounds.

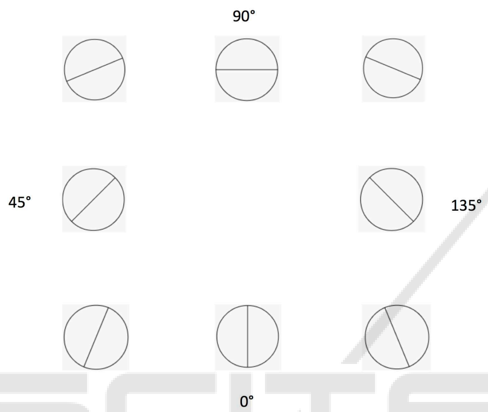

Figure 5: Relationships between abstract figures.

4.4 Generative Ambience System using Abstract Figures

In order to get rid of meaning, we adopted abstract figures to the system (figure 6). Basically, this system is similar to the system using simple facial expressions. However, the figures are lines in circles that do not express meaning. The relationships between these figures are angles (see figure 5).

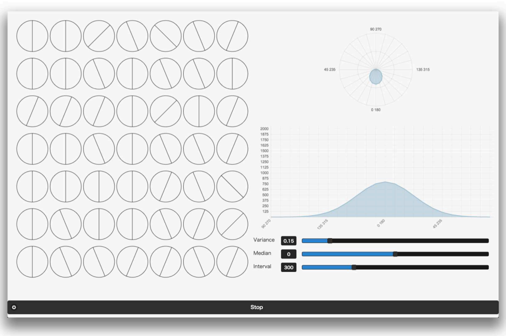

Figure 6: Generative ambience system using abstract figures.

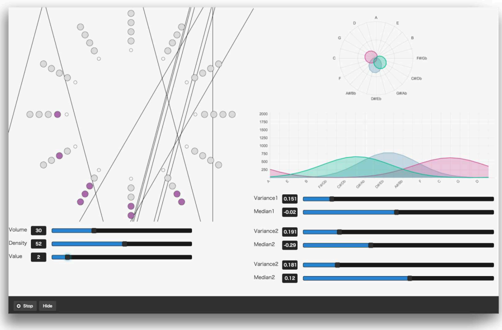

Figure 7: Generative ambience system using sounds and abstract figures.

4.5 Generative Ambience System using Sounds and Abstract Figures

In order to express multiple modes, we adopted both sounds and abstract figures to the system (figure 7). This system creates ambience based on the comparison between entropies of sounds and abstract figures, and generates them synchronously or asynchronously. Abstract figures: lines are controlled by three modes—angle, x-position, and y-position. Sounds: pitches are controlled by a perceptual mode—pitches.

4.6 Discussion

Using each system, we find that ambiences change depending on the entropies. The system using simple facial expressions generates concrete meanings. However, when the entropy is high, we cannot understand the concrete meanings. We really consider that phenomenon as ambience. The other systems do not have concrete meanings. Therefore, in order to understand ambience, we need to compare other outputs. It is not clear how concrete/abstract meanings affect ambience. It will be interesting to determine what kinds of ambience other distribution functions create. We plan to conduct experiments on these in the future.

The elements of these systems, such as sounds and figures, are simple. When we adopt complex elements, such as agents to the system, we may develop a more interesting system. We will try this in future work for a multi-agent system.

5 CONCLUSION

In this study, we defined ambience as an aggregate of various senses of human perception. We developed generative ambience systems using these relationships and a normal distribution based on information entropy. This system created ambience with multimodal perception, such as sound, faces, and figures. We plan to conduct experiments for the various ambiences in the future.

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