Differential and Integration of Sensation and its Application

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Abstract

Our sense can be seen as a dynamical system in multi-dimensional sensory space, where each dimension corresponds to the sort of sense such as visual, audio, tactile, and so on. Our sensory systems are composed of differentiators and we perceive sensory stimulations through differentiating sensory stimulations. In order to calculate differentiation of sense, we have to set measurable quantity of the sense, we can use not only quantity measure such as brightness of picture, loudness of sound but also can use quality measure such as value of Semantic Differential (SD) method for measuring impressions or emotion such as beautiful, fear, happy. We propose a method of Differential and Integration of sensation and we show the case when transforming a drawing of *Piet Mondrian's "1921"* into a music piece by using this method.

Keywords: Computational Aesthetics, Tactile Communication, Tactile Score, Kansei Computing

1. Introduction

To see shapeless or unseen things and to hear unheard things have been challenges in Arts and Sciences. Visualizing shapeless things such as light, air, emotions, etc. or unseen things such as concepts, atmosphere, etc. have been challenges in visual Art and Science. For example, Leonard da Vinci, who is an artist, engineer, biologist and a pioneer of data science, drawn a normalized human anatomical chart based on dissecting many human dead bodies.

Tactile sense directly makes an appeal to the deep feeling without language or words [3]. Tactile sense has a language however the way of using the language is obscure. If we could have full command of the language of tactile sense, and express the feeling and tell it by using the language, cold media would be changing into intimate organic ones.

Visual media are systematized with colors and their combinational principles such as color circles, and music [1] in auditory media is systematized with combinational principles of theories of harmonics [2, 5]. On the other hand, there is no such a combinational principle for tactile sense.

We communicate through tactile sense in the form of shaking hands to express your trust, hugging a grieving friend instead of speaking to him or her, and stroking cute dogs and cats. These communications directly make an appeal to the sensitivity and feeling, and we tactilely grasp the innermost truth of who someone is from the way of using the language and behavior.

Tactile sense has been of interest to basic science, such as psychology, psychophysics, cognitive science, and recently it has also been of interest to engineering and design. In engineering, technologies of tactile sense have been developed in virtual reality, e.g., robotics and ergonomics. One of the main issues they have addressed is "how to regenerate the tactile sense mechanically" and the necessary and desirable applications of such technologies have been explored. Reviewing the large amount of research on tactile engineering should preferably be included elsewhere, in another book. In the past, tactile engineering has mainly been applied to entertainment, such as the integration of a tactile sensing

device into a video game controller, and to communication technology, such as in mobile phones.

2. Calculus of Senses

Our sense can be seen as a dynamical system in multi-dimensional sensory space, where each dimension corresponds to the sort of sense such as visual, audio, tactile, and so on. Our sensory systems are composed of differentiators and we perceive sensory stimulations through differentiating sensory stimulations.

In order to calculate differentiation of sense, we have to set measurable quantity of the sense, we can use not only quantity measure such as brightness of picture, loudness of sound but also can use quality measure such as value of Semantic Differential, SD method for measuring impressions or emotion such as beautiful, fear, happy. Major headings should be typeset in boldface with the first letter of important words capitalized.

The most important concept of the differentiation of sense is measuring the differences in time or / and space of sense; it shares the concept of differentiation in mathematics but this is not mathematical concept and a mathematical equation of sense is not required; in calculating differentiation of sense, we use differentiable measure. Algorithm of differentiation of sense is as follows;

I. Differentiation of Sense

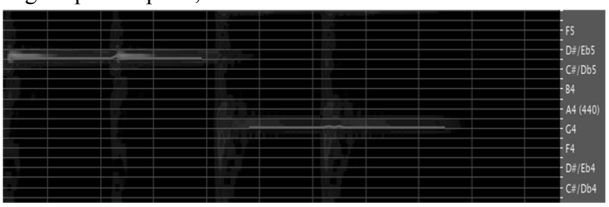
1 select a sense to calculate differentiation,
2 set the width of differentiation,
3 measure the differences by the time width (2.);
  3.1 (if it is required) measure of the differences of 3.

For example, we will differentiate a music piece;

1. a sense to calculate differentiation = the frequencies of sound,
2. the time width of differentiation = 0.5 second,
3. the differences by the time width (2.);

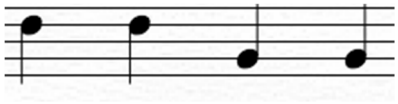
then we differentiation the sound measure and obtain the spectral pitch, which is the amount of vibration at each individual frequency and it corresponds to pitch of music note (Fig. 1).

Fig.1 Spectral pitch, the horizontal axis illustrates time and the



vertical, frequencies that correspond to pitches of music notes. D, D, G, G and duration of each note is the same as 0.5 second.

and by setting the duration of quarter note is 0.5, we obtain the music score of D, D, G, G;



, this differentiation of sound corresponds to drawn the music piece in musical notation.

II. Transform Sense

1. select a differentiated sense and the sense to transform (e.g. the volume of sound into the brightness of movie)
2. transform the sense and reconcile time width each other,

Transform sensory such as audio sensory to visual has been developed well, for example, the sound-on-film recording, which is the most prevalent method of recording analog sound on a film print; in short, transform the volume of sound (audio sense) into brightness (visual sense) of a film and synchronize the sound and film. For example, by using this method we transform a picture into a music score; we differentiate a picture of Piet Mondrian, 1921 and transform into a music score.

1. the differentiated sense = the area of the same color grid square (square centimeter), space width = the area of a grid square
2. the sense to transform = musical pitches, reconcile space width;

we coarse grained the area as more than 90 square centimeters = whole note, between 90 and 45 = half note, between 45 and 22.5 = quarter note, between 22.5 and 11.25 = eighth note, between 11.25 and 5.625 = 16th note, between 5.625 and 2.8125 = 32th note and less than

2.8125 = 64th note, respectively; and we are assigned color and musical pitch as; black as C, blue, D, red E, yellow G and white, A by borrowing Major Pentatonic Scale (Table 1).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
a	1.0	2.9	3.9	2.7	7.8	2.4	6.5	0.9	3.7	2.1	8.2	1.6	1.97	1.4
b	12.4	34	24.3	30.9	89.5	28.1	75.1	10.6	42.2	24.3	93.6	18.2	22.5	16.2
c	1.3	3.6	2.6	3.3	9.6	3.1	8	1.1	4.7	2.4	10.1	1.9	2.4	1.5
d	4.3	12.0	8.6	10.9	31.6	9.9	26.5	3.7	14.7	8.5	33.1	6.4	7.9	5.7
e	9.6	26.5	18.9	24.1	69.8	21.9	58.5	8.3	32.9	18.9	73.0	14.2	17.6	12.6
f	1.1	3.2	2.3	2.9	8.5	2.6	7.1	1.0	4.0	2.3	8.9	1.7	2.1	1.5
g	6.3	17.3	12.4	15.8	45.7	14.3	38.3	5.4	21.5	12.4	47.5	9.3	11.5	8.4
h	4.1	11.3	8.1	10.3	29.8	9.3	25	3.5	14.0	8.1	31.0	6.0	7.5	5.4
i	1.4	3.9	2.8	3.6	10.5	10.5	8.8	1.2	4.1	2.8	10.9	2.1	2.6	1.9
	41.5	114.7	83.9	104.5	302.8	102.1	253.8	35.7	141.8	81.8	316.3	61.4	76.1	54.6

Table 1, Area of grid square of Mondrian 1921, in square centimeter; 8.1 is black, 24.1 and 31.0, red, 58.5 yellow, 93.6 and 47.5 are blue, 1.5 is black and all others are white

III. Integral of Sense

And also once a sense is differentiated we can calculate integral of sense as follows;

1. select the differentiated sense (time width was defined),
2. define the interval of calculating integral.
3. calculate an area of sense at each time width and calculate the sum of areas in the interval.

Then we obtained a music score of Mondrian 1921(Fig.2);

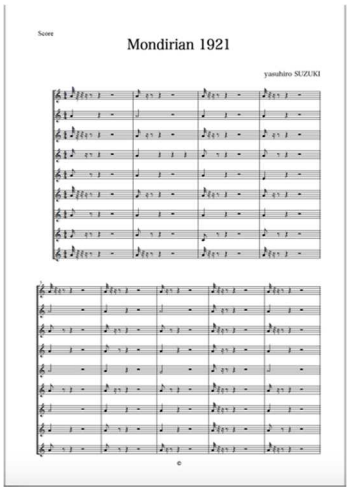


Fig 2. From the music score, which is transformed P.Mondirian's 1921;

3. Tactile Score

Massage, which is composed of various tactile senses of movements of hands on the body, is a form of haptic engineering that we have been developing for more than two thousand years. For this reason, we chose to investigate massage as a way to devise a method of describing the tactile sense [4]. Through our investigations, we found massage to be composed of pressure, an area of contact or touching, and the velocity of the movement of massager's hands. We modeled our tactile description on the musical score (Fig.3). In staff notation of the tactile note, we defined the third line as the basic pressure—the basic pressure with which we might hold a baby or delicate, breakable object. Hence, the basic pressure is not defined absolutely but may change from person to person or for different types of massage.

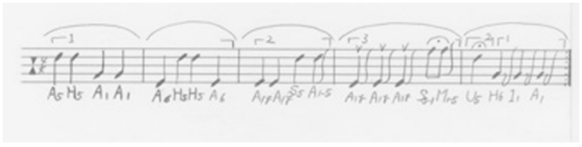


Fig.3: (Top) An example of a tactile score, with special marking above the staff notation. 1 denotes both hands moving the same; 2 indicates a small gap between hands; and 3 indicates a large gap between hands. The slur-like marks illustrate a unit component, a massage phrase; the integral-like marks illustrate releasing pressure; and the breath-like marks correspond to a short pause in massaging, much like a breath in playing music

We also defined the part of the hand used in massage and the kind of stroke used when massaging (see Fig. 4). For example, the fingertip to the first joint is 1, the second joint is 2, the third joint is 3, the upper part of the palm is 4, the center of the palm is 5, and the bottom of the palm is 6. Thus, a flowing motion from a fingertip to the third joint is denoted as "1–3."

For massage strokes, we analyzed the method of massaging in face therapy and the stroking action of the hands' movements. For example, A_5 illustrates drawing a circle on the cheek with the center of the palm.

In the tactile score (Fig.3), at the first count in the beginning part, A5 circles are drawn on both sides of the cheeks using the center of the palm with weaker pressure than the basic pressure; at the second count, the hands are moved to the tails of the eyes and a small circle is drawn using the center of the palm while keeping the same pressure as the first count; and, at the third and fourth counts, the hands are moved to both sides of the cheeks

and circles are drawn using the fingertips with a stronger pressure than the basic pressure.

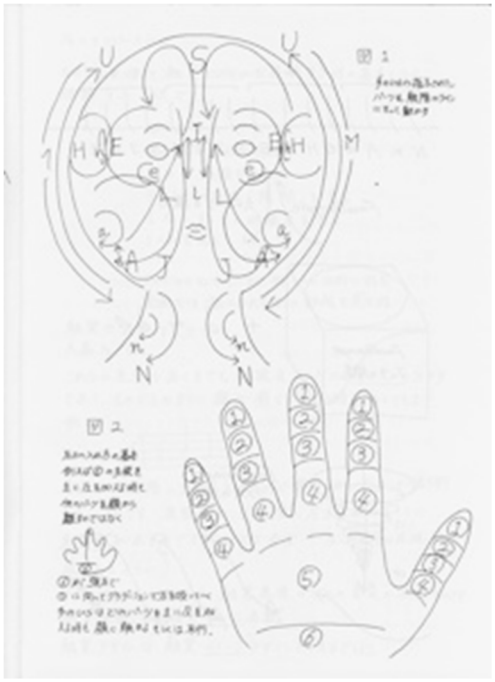


Fig. 3: (Top) Strokes of massaging on a face. These strokes are obtained from massage experiences in beauty shops. Strokes that pass uncomfortable areas have been excluded. (Bottom) Usage of part of the hand.

3.1. *Transform sounds to Tactile Score*

According to the method of differentiate sense in the section 2; we select a sense to calculate differentiation is pressure (step 1), the width of differentiation is the same the range of pressures of sound (step 2) and measuring the differences by the time width is the same as the rhythm of sound (step 3).

Tactile score denotes pressure, contact area and rhythm. In this example, we will denote pressure and rhythm, where the contact area is defined as frequency of sound; we assume that lower frequency has broad contact area and higher frequency has narrow contact area so we take the reciprocals of frequencies and multiply by amplitudes. We show an example when the noise in the cabin of Japanese bullet train (Shin-kan-sen train, Fig.4).

Fig.4. Tactile score, which is transformed from the noise of cabin in Japanese bullet train (Shin-kan-sen train).

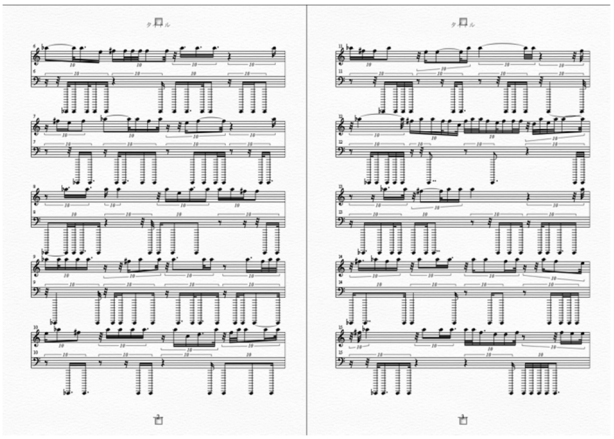


Fig. 4 Tactile score transformed from the noise in a cabin of Japanese bullet train (Shin-kan-sen train).

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