Colour Feature Extraction for Computer-Aided Art Therapy

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***Abstract* - Computer analysis of handwritten pastel drawings to extract colour features for use in mental therapy is studied. A measure for evaluating the psychological properties of a colour is defined as the distance to psychological primary colours in a uniform colour space. A colour clustering method suited for representing a drawing region is also described. An experiment was conducted with drawings and mental state values collected in the actual field of clinical therapy. Also, a classifier for predicting mental states from the colour feature vectors was built using a neural network model. After trained with the limited experimental dataset, the classifier proved some effectiveness of the proposed colour features.**

Keywords - pastel drawings, psychological primary colours, uniform colour space, colour clustering, neural network

I. INTRODUCTION

Creative activities such as painting, drawing, sculpturing and so on have therapeutic effects on mental clients. In drawing therapy, which is a clinical practice of art therapy [1], a client is treated through the activity of making drawings, which are pictures made using tools and materials easy to use, such as pastels and crayons rather than paints. Deducing the client's mental state from drawings they make, their therapist can properly help them to get better through the therapy. Thus, drawing therapy is currently recognized as a practical and effective way of treating clients for some kinds of mental problems [2].

It is assumed that drawings a client makes contain psychological information about a wide variety of their emotions. Not only what the drawing represents but also how it is made, for example, where it is depicted on the drawing sheet, how the drawing tools and materials are used to depict it, how it is made coloured, and so on, can express different kinds of human emotions. Observing the drawing, a therapist interprets it in psychological terms to understand the client's emotions and then, diagnoses their mental symptom.

Different therapists often make different interpretations of the same drawing because pictures are usually viewed from different viewpoints by different people. Besides, the amount of clinical experience of a therapist may affect their interpretation result. Thus, drawing therapy is apt to involve subjective treatment by each therapist.

To reduce the difference in the interpretation of a drawing due to subjective views, objective features of the drawing are effective. A way to obtain such features is to analyse the drawing by image processing techniques with a computer [3]. The analyses are obtained in a numerical form and thus, they can be used in further computer processing. Accordingly, such computer-aided analysis of a drawing is expected to help a therapist to make a consistent and detailed interpretation of the drawing so as to give a proper treatment to the client. It is also helpful to therapists who have only short-term experience. The effectiveness of such quantitative analysis has been reported in the field of painting arts [4].

In the present study we focus on colour features of coloured drawings. It is known in colour psychology that some colours, which are called psychological primary colours, relate strongly to human mind [5]. For each psychological primary colour, the emotions which it often represents have been investigated [6]. The psychological viewpoint indicates that colours used in a drawing express the emotions, especially unconscious ones of a person who depicts it. Thus, colour features are particularly important in the drawing therapy where coloured drawings are used in diagnosis. In this paper, we describe analysis of a drawing for the psychological primary colours so that a therapist can diagnose the client's mental state from the drawing in terms of psychology.

On the other hand, there is a way to measure a mental state in cognitive behavioral therapy. A therapist there talks with a client about their behaviours so that they can change their mind. The therapist also can guess their emotions and evaluate the degree of the mind change. Although the evaluated values are just ones determined subjectively by the therapist, they can be used as numerical data which represent the client's mental state. Thus, by giving both drawing therapy and cognitive behavioral therapy to a client at the same time, the sets of both a drawing and a numerical value that represent their mental state at every clinical time are obtained during their therapy period.

Such a dataset that was collected in the actual field of clinical therapy is used in this study. The collected drawings are handwritten colour pastel ones. We define colour features that can express human emotions in terms of psychology. We also examine the colour features for the effectiveness by applying them to the mental state data: A neural network model that can predict a mental state from the colour features is built using the dataset. From this point of view, this study is a kind of feature engineering for machine learning. We deal with these clinical data as static, though they are

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obviously considered time-series data. Time-series analysis is beyond the scope of this paper.

The rest of this paper is organized as follows. Section II describes the scheme of computer-aided drawing therapy. First, drawing therapy for collecting drawings from a client is explained. Second, cognitive behavioral therapy for evaluating mental states is mentioned. Then, the whole of computer system which uses the drawings and the mental state values to generate information helpful in conducting mental therapy is outlined. In Sec. III, a scheme for making a psychological analysis of a drawing region is described in detail. First, the method previously proposed for extracting the drawing region from a pastel drawing is mentioned. Second, to determine a colour that can represent the whole or a part of the extracted drawing region, a method for reducing the number of colours used in the region is described. Third, to give a psychological interpretation to a colour, a degree of a psychological primary colour is defined. In Sec. IV, an experiment of the proposed analysis scheme is conducted with a clinical dataset of pastel drawings and mental state values. Also, a classifier for determining the mental state class of a colour feature vector is built. Sec. V concludes the paper.

II. A SCHEME OF COMPUTER-AIDED DRAWING THERAPY

A. Drawing Therapy

In drawing therapy, a client is allowed to draw whatever comes into their mind in such a manner as they like with given drawing tools and materials. Thereby various types of self-expression easily appear in such drawings while the client may have been unconscious of their own mental state in drawing. From visible features in the drawing, a therapist deduces the client's emotions. Thus, the drawings can reveal the client's unconscious emotions and also, serve as a link between the therapist and the client.

In terms of colour, a drawing can be evaluated using the psychological properties of colours. The psychological properties of a colour are the emotions which it is usually associated with. It is well known that a single colour has two conflicting mental aspects: a positive one and a negative one. In addition, a colour provokes three kinds of mental responses. Combining these factors, each colour has various psychological properties that affect human mental activities. In the psychological primary colours there are four foremost ones: red, green, blue and yellow. For example, yellow one expresses confidence as one of the positive properties, and depression as one of the negative properties [7]. Expressing such psychologically complicated properties of a colour numerically is necessary for colour analysis.

B. Evaluation of Mental States

Mental problems are considered the result of a bad way of thinking in cognitive psychology. In cognitive behavioral therapy, a therapist helps a client to change their wrong way of thinking to a healthy one. This allows them to change their behavior as a result. Because a human brain deals with information which is gathered by the five senses, human behavior can be analysed by having a client involved in various mental tasks prescribed in cognitive psychology. Through the process, the client can understand their feelings better than before and accordingly, turn the way of thinking into their behavior.

A cognitive behavioral therapist also evaluates a client's mental state by discussing their psychological problems with them. A way of how to evaluate a mental state numerically is as follows: Assume that a client at first thinks in a negative way and may be angry after they were scolded by their boss, for example. At this time, they are considered to be 100 percent angry in such a terrible feeling. Let us suppose next that they can later afford to think in a more reasonable way and their feelings of anger decrease gradually. For example, understanding that their boss was only trying to help them, they may change their way of thinking. By talking with the client, the therapist estimates the degree to which their feelings of anger have dropped to be, say, 50 percent.

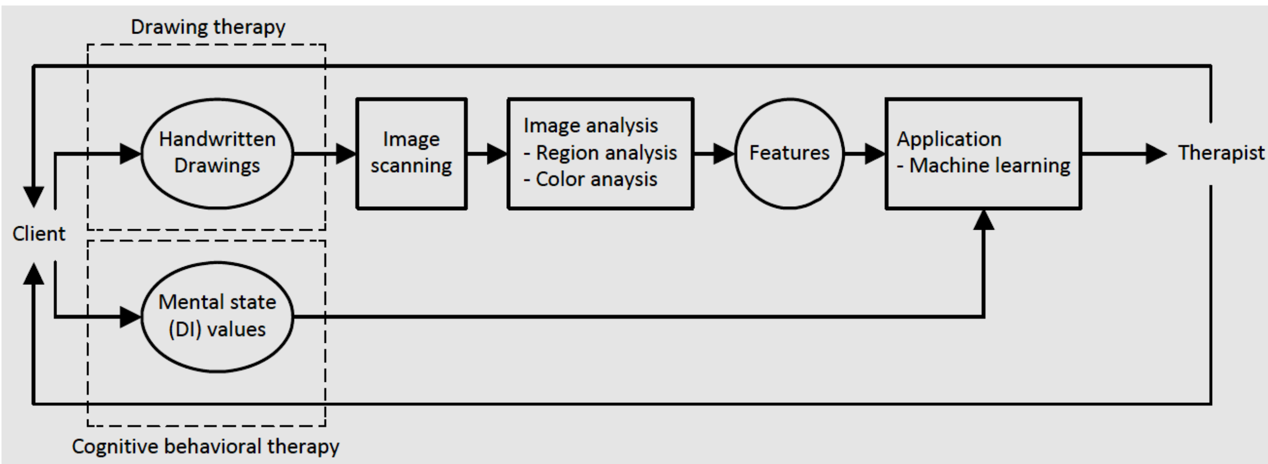

Figure 1. Computer-aided drawing therapy system.

This estimate indicates that the client has made a 50-point improvement in their way of thinking. We refer to the value as the degree of improvement (DI). Although a DI value shows a subjective assessment of the relative change in emotions, it can represent the client's mental state in a numerical way. A series of DI values for a client is collected over their therapy period.

C. Computer-Aided Therapy System

Fig. 1 illustrates a scheme of computer-aided drawing therapy. A client makes drawings by hand following their therapist in drawing therapy. Each drawing is entered as a digital full-colour image to a computer with an image scanner. Image processing techniques are applied to the image to extract and analyse the drawing region, as which we refer to the part actually representing a picture on the sheet. Especially, the way how colours are used there is examined. Then, those features which make psychological sense are extracted in a numerical form from the analysis results. Some other features such as what the drawing represents, where and how it is located on the sheet, how large it is depicted, are also useful to the client's therapist in psychological diagnosis. The features are further analysed in applications such as machine learning.

Cognitive behavioral therapy is conducted to the client simultaneously. The therapist has a discussion with the client regularly during therapy to evaluate their mental state in a numerical form. The evaluated mental state values are used in the applications together with the extracted features of the drawings. Because the drawings and the mental state values correspond to each other, it is most preferable that at the time when the client finishes each drawing, they have the discussion with the therapist in the cognitive behavioral therapy process.

Using the application results, the therapist can understand the client's symptoms in diagnosis, and give them further treatment in accordance with their mental state. The feedback process lasts during the therapy period.

III. COLOUR FEATURE EXTRACTION FROM PASTEL DRAWINGS

A. Extraction of Drawing Regions

An outstanding characteristic of pastel drawings is how pastels are painted on paper. The pastel materials are often attached coarsely on the sheet, especially by drawing with a light touch because of the properties of the materials, and also probably, owing to the granular properties of the paper. After digitized, the drawing region is full of holes in terms of digital geometry. Accordingly, the appearance of the drawing region is made up of both the colour of pastel materials and the paper colour of the holes. Hence, the whole region with internal small holes must be extracted as the drawing region which seems to have been depicted intentionally.

The whole region with internal holes is difficult to extract from an image by simply using a thresholding scheme. A method to extract such regions from a pastel drawing has been developed [8]. The algorithm of the method is based on mathematical morphology. In the algorithm, whether an internal hole is included in the whole region or not is determined by its size. The method performs well for actual pastel drawings as demonstrated later in the experiment in Sec. IV.

B. Colour Analysis of Drawing Regions

We consider representing a full-colour drawing region in a small number of colours. To reduce the number of colours used in the region, the k-means algorithm [9], more precisely, k-means++ algorithm is used in the present work. The k-means algorithm deals with data as points in space. Starting with k initial centroid points in the space, the algorithm repeats two steps: (i) dividing all the points into k clusters by using the given centroids and (ii) recalculating the centroids of each resulting cluster, until a termination condition is satisfied. Choosing an appropriate number for k is usually the primary problem of the algorithm.

To find adequate colours to describe the drawing region approximately in terms of colours, the k-means algorithm is applied to the region repeatedly by increasing the value of k one by one. Let a region mean a set of pixels in the 2-d image plane, and a cluster a set of points in the 3-d colour space. Let $Clr(pel)$ be the colour point corresponding to a pixel pel. Also, let $err(Clr_1, Clr_2)$ be the squared Euclidean distance between two points Clr_1 and Clr_2 in the 3-d colour space, and $Ct(R)$ be the centroid colour of the cluster corresponding to a region R. Let R_0 denote the whole of the drawing region.

At first, let Rt same as R_0, and k be 1. The algorithm is as follows:

Step 1: Divide Rt into two regions, Rt_1 and Rt_2, by the 2-means algorithm. Also, increment k by one.

Step 2: Divide the whole region into k regions based on the given k centroid colours including $Ct(Rt_1)$ and $Ct(Rt_2)$. Let the resulting regions be denoted by $\{R_1, R_2, ..., R_k\}$.

Step 3: Evaluate the approximation error E_i of R_i for i=1, 2, ..., k by:

$$E_i = \sum_{pel \in R_i} err(Clr(pel), Ct(R_i)) . \qquad (1)$$

Using $\{E_i\}_{i=1}^{k}$, evaluate the mean error e_i of R_i for i=1, 2, ..., k and e_0 of R_0, defined by

$$e_i = \frac{E_i}{|R_i|} \quad \text{and} \quad e_0 = \frac{1}{|R_0|}\sum_{i=1}^{k} E_i , \qquad (2)$$

respectively, where |*R*| denotes the number of pixels in a region *R*, that is, the area of *R*.

Step 4: If e_0 is small enough, the algorithm is terminated here.

Step 5: Find R_j that has the maximum of $\{e_i\}_{i=1}^{k}$ and let R_t point to R_j. Then, go back to *Step 1*.

From the above clustering result, a colour averaged over a part, for example, 50% of the drawing region can be evaluated in the following way. First, $\{R_i\}_{i=1}^{k}$ are arranged in the descending order of area, and let the resultant ordered regions be denoted by $\{R_i\}_{i=1}^{k}$ again. Let Ru_j be the union of regions $\bigcup_{i=1}^{j} R_i$ and $Ru_0 = \phi$. The averaging function $Cu(r)$ for an area ratio r ($0 < r \le 1$) is defined by:

$$Cu(r) = Ct(Ru_j) \tag{3}$$

where *j* satisfies

$$\frac{|Ru_{j-1}|}{|R_0|} < r \le \frac{|Ru_j|}{|R_0|}. \tag{4}$$

$Cu(r)$ indicates the primary colour that covers *r* of the drawing region.

C. Psychological Colour Measure

To evaluate colours in terms of psychology, a degree of a psychological primary colour *P* that a colour *c* has, denoted by $a(c, P)$, is defined by using colour distances in the following way. Let $d(c_1, c_2)$ denote the Euclidean distance between two colours c_1 and c_2. Here, the distance is measured in a uniform colour space, where the dimension of colour difference is expressed by the distance on the coordinates, instead of the RGB colour space. For two colour points in the L*a*b* uniform colour space, $c_1(l_1^*, a_1^*, b_1^*)$ and $c_2(l_2^*, a_2^*, b_2^*)$,

$$d(c_1, c_2) = \sqrt{(l_1^* - l_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2}. \tag{5}$$

$a(c, P)$ is defined in the L*a*b* space by

$$a(c, P) = \begin{cases} 1 - \dfrac{d(P, c)}{d(P, P_0)} & \text{if } d(P, c) < d(P, P_0) \\ 0 & \text{if } d(P, c) \ge d(P, P_0) \end{cases} \tag{6}$$

where P_0 is *a psychological basic colour* that can be assumed to be nonemotional, such as a colour like raven black. Thus, $0 \le a(c, P) \le 1$. If *c* is inside the sphere which has its centre at *P* and a radius of $d(P, P_0)$ in the 3-d colour space, $a(c, P)$ is larger as *c* is closer to *P*, and $a(c, P) = 1$ only if *c* matches with *P*. In contrast, *c* differs so much from *P* that *c* is outside the sphere, $a(c, P) = 0$, which means that *c* has no mental effects of *P*.

IV. EXPERIMENT AND RESULTS

A. Experimental Data

Experimental data are based on an actual clinical therapy given to a client who was suffering from a mental problem. How the data were obtained in the therapy is described briefly below.

The client was a male in his 50's. He was experiencing some difficulties at work, and was feeling pretty depressed. However, he had held a will to live and, what was more important, he wanted to be cured of his mental problems. Cognitive behavioral therapy ordinarily works well with intelligent and serious clients, because they are required to write in their diaries and also to work on changing their negative behavior. The client in the case was well-educated and serious-minded, so he had well adapted to this kind of therapy. He also liked the fine arts, so he had chosen art therapy by making pastel drawings in the process of cognitive behavioral therapy. He had received the therapy for about four years at a mental health clinic.

The clinical data were collected in the following way: The client was asked to make a pastel drawing whenever he wanted to every month during his therapy period. He came for counseling once a month bringing both his diary and his pastel drawing he made last month. Then, the therapist had a discussion on the basis of his diary, and evaluated his mental state by a DI value. Thus, a total of 47 sets of a pastel drawing and a mental state value at the time of monthly clinical treatment was obtained. The collected mental state values are shown as a time sequence in Fig. 2.

B. Results of Colour Analysis

The colour analysis of each handwritten pastel drawing *D* is carried out in the following procedure.

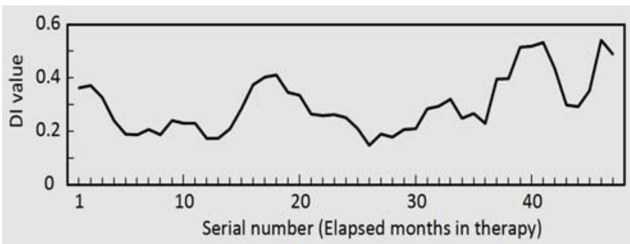

Figure 2. Mental state (DI) values for experiment.

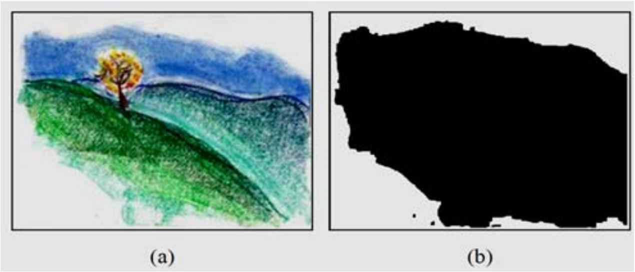

Figure 3. An example of: (a) a source pastel drawing (ser. 33)
And: (b) the map of the extracted drawing region.

(i) D is digitized with an optical scanner to a 24-bit RGB colour image D'.

(ii) Because D' often consists of too many pixels for the following processing, D' is reduced to a small image D", for example, a size of around 500×400 pixels.

(iii) The drawing region R0 is extracted from D" by the method described in Sec. III.A. Unnecessary parts due to, for example, a stain on a blank area in D can be removed if exist by image processing or by using a painting software. Fig. 3 shows an example of a source pastel drawing and the map of the extracted drawing region.

(iv) The number of colours used in R0 is reduced by the clustering algorithm described in Sec. III.B. From the resulting clusters, averaged colours Cu(r) for an area ratio r are evaluated by using Eqs. (3) and (4). As an example, the colours of the region R0 of Fig. 3(b) are reduced to 29 colours by this algorithm. The colour bar of Cu(r) generated from these colours is shown in Fig. 4(a). The partial region corresponding to Cu(0.5) and that to Cu(1) are also shown in Figs. 4(b) and 4(c), respectively.

(v) A single colour that can represent the colours of R0 is determined. Let Ci denote the representative colour of the ith source drawing. In this experiment, simply the averaged colour over the whole R_0 is used as C_i, that is, $C_i = Cu(1)$.

(vi) For C_i, the degree of each psychological primary colour: red, green, blue and yellow, which are denoted by P_r, P_g, P_b and P_y, respectively, is evaluated by using (6). Here, the nonemotional colour P_0 is assumed to be (0, 0, 0) in RGB. P_r, P_g, P_b and P_y are also assumed to be (1, 0, 0), (0, 1, 0), (0, 0, 1) and (1, 1, 0) in RGB colour, respectively. Let $a^r{}_i$, $a^g{}_i$, $a^b{}_i$ and $a^y{}_i$ be the abbreviations of $a(C_i, P_r)$, $a(C_i, P_g)$, $a(C_i, P_b)$ and $a(C_i, P_y)$, respectively. Also, let $\boldsymbol{a}_i$ be the 4-d vector $(a_i^r, a_i^g, a_i^b, a_i^y)$ for later use. Thus, $\{a_i^r, a_i^g, a_i^b, a_i^y\}$ for C_i (i=1, 2, ..., 47) were obtained. In Fig. 5, each value is plotted as the sequence of i, which indicates the elapsed months in the client's therapy period.

C. Mental State Classifier

We consider a model for predicting a client's mental state from the drawings. First, the mental state (DI) values s are classified into, as an instance, three classes: 0 ('bad'), 1 ('fair') and 2 ('good'), using a function $Class(s)$ defined by:

$$Class(s) = \begin{cases} 0, & \text{if } s < 0.25 \\ 1, & \text{if } 0.25 \le s < 0.35 \\ 2, & \text{if } 0.35 \le s \end{cases}, \qquad (7)$$

where the boundaries of s are determined roughly within the range where the value actually varies in Fig. 2.

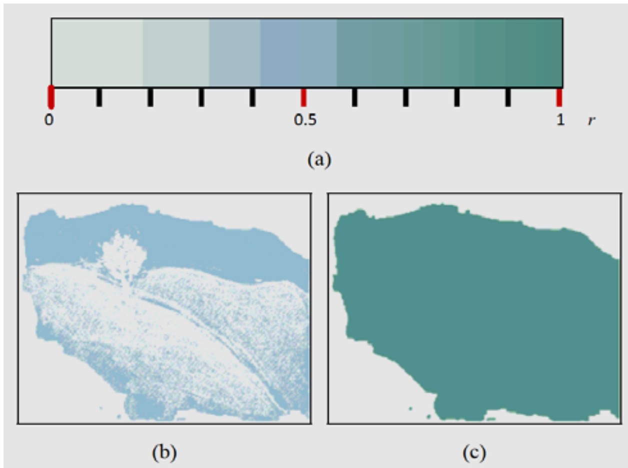

Figure 4. Averaged colours in the drawing region of Fig. 3:
(a) averaged colour bar Cu(r) for area ratio r, (b) primary five clusters of Cu(0.5) (56% area) and (c) the whole 29 clusters of Cu(1) (100% area).

Let S_i denote $Class(s_i)$ for each s_i for i=1, 2, ..., 47. S_i's are determined as shown in Fig. 6. Then, a classifier can be built by machine learning using $\{S_i\}_i$ as the 3-class targets and $\{\boldsymbol{a}_i\}_i$ as the feature vectors. To achieve the classifier, a neural network model is examined. Its network architecture and hyper parameters are listed in Table I. The dataset of $\{\boldsymbol{a}_i, S_i\}_i$ are split into two sets: Ten data are randomly chosen as the testing set, and the rest is kept as the training set. The latter is use to learn the model, and the former is used to evaluate the resulting model.

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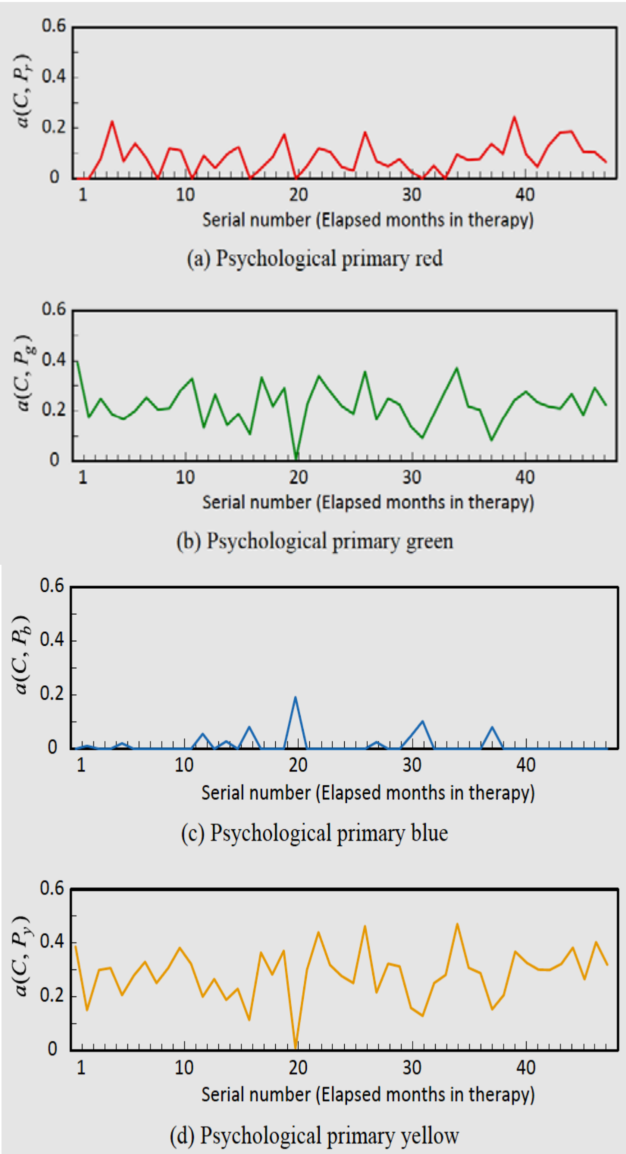

Figure 5. Degree of a psychological primary colour evaluated from drawings.

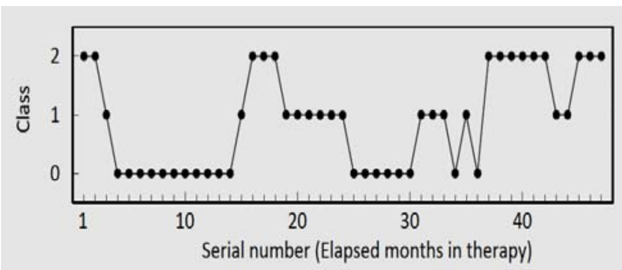

Figure 6. Mental state classes for the classifier.

TABLE I. NEURAL NETWORK MODEL

(a) Network Architecture

Layer	Configuration		
	Number of units	***Activation function***	***Dropout rate***
Input	4	relu	0.5
Hidden #1	200	relu	0.5
Hidden #2	200	relu	0.5
Hidden #3	200	relu	0.5
Output	3	softmax	-

(b) Hyper parameters

Item	Definition
Optimizer	Adam with learning rate=0.0005
Number of training epochs	20,000
Batch size	37

The performance is measured by classification accuracy. As a result, an accuracy for the training set reached 1.0, and that for the testing set 0.7 by the classifier.

V. CONCLUSIONS

The colour features proposed in this study are reasonable from the psychological viewpoint. In the definition, however, the followings are still assumed:

- The psychological basic colour P_0: In the experiment, P_0 is assumed black. Other possible values are white, and the ground colour of drawing paper.
- The numerical value of each psychological primary colour P_r, P_g, P_b and P_y

Although the training and testing dataset used in the experiment were insufficient for learning the neural network model, the resulting classifier proved some effectiveness of the colour features. Further feature engineering could be developed to put the system to practical use in the field of mental therapy with much more clinical data.

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