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Traditional Chinese medicine — Computerized tongue image analysis system —

Part 5: Method of acquisition and expression of tongue colour and tongue coating colour

Médecine traditionnelle chinoise — Système d'analyse d'images numérisées de la langue —

Partie 5: Méthode d'acquistion et expression de la couleur de la langue et du revêtement de la langue

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 249, *Traditional Chinese medicine*.

This corrected version of ISO/TR 20498-5:2019 incorporates the following corrections:

— The upper and lower limits of some domains in A.2 have been reversed to correct editorial errors.

A list of all the parts in the ISO 20498 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

As one of the most distinctive traditional Chinese medicine diagnosis methods, tongue diagnosis is a method of inspecting the patient's tongue and its coating to determine his or her disease or syndrome. With growing global demand for traditional Chinese medicine, there is an increasing demand for international medicine and academic exchanges on tongue diagnosis as well as tongue-related devices. Traditional tongue diagnosis, mainly dependent on the practitioner's visual observation and text description, often varies with the practitioner's experience, environmental changes and other factors, which makes it difficult to make an accurate diagnosis and archive the tongue image. Therefore, it is necessary to quantify and digitize the tongue manifestation.

With modern scientific knowledge and technology, the practitioner's subjective judgement about tongue manifestation has gradually developed into an objective determination by computerized tongue image analysis system (CTIS) with a standard calculation method. According to statistics, more and more traditional Chinese medicine practitioners have come into contact with and used a device for tongue diagnosis, which undoubtedly plays a leading role in the promotion of tongue-related products worldwide. Thus, it is of the utmost urgency to standardize the CTIS, which will bring benefits to companies involved in the trade of tongue-related devices and to people assisting with CTIS.

Therefore, as one of the five parts of the ISO 20498 series, this document intends to quantify and digitize the tongue manifestation used in the CTIS, which is of great importance to the international trade and service of CTIS, thus increasing business profit.

Traditional Chinese medicine — Computerized tongue image analysis system —

Part 5: Method of acquisition and expression of tongue colour and tongue coating colour

1 Scope

This document describes a method of acquisition of tongue image and expression of tongue colour and coating colour by computerized tongue image analysis system (CTIS).

This document does not cover the clinical tongue diagnosis result.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
tongue body
muscles and vessels of the tongue

3.2
tongue coating
layer of fur-like substance stuck on the tongue

3.3
tongue colour
colour of the tongue body

3.4
coating colour
colour of the tongue coating

3.5
tongue image
digital image acquired by the device

3.6
L*a*b* colour space
three-dimensional, approximately uniform colour space, produced by plotting, in rectangular coordinates *L**, *a**, *b**

Note 1 to entry: The quantity *L** is a measure of the lightness, where *L** = 0 corresponds to black and *L** = 100 corresponds to the perfect reflecting diffuser. Visually, the quantities *a** and *b** represent respectively the red-green and yellow-blue axes in colour space, such that:

— +*a** is a measure of the degree of redness;

— −*a** is a measure of the degree of greenness;

— +*b** is a measure of the degree of yellowness;

— −*b** is a measure of the degree of blueness.

If both *a** and *b** are equal to zero, the test piece is grey.

[SOURCE: CIE 17.4, 845-03-56, ISO 5631-2:2015, 3.6, modified — "of the test piece" has been removed and "achromatic" has been replaced with "grey".]

3.7
standard colour chart
apparatus consisting of 24 single colour patches used for the evaluation of colour calibration of CTIS

Note 1 to entry: The colour chart in this document is supplied by Pantone. It can be replaced when a new special colour chart made for tongue colour is available.

4 Colour calibration of the acquisition device

4.1 Choice of colour space

With the help of L*a*b* colour space's special features, white balance calibration can be done by setting the white balance parameter on the camera before taking the photo or adjusting during post-processing. This is because *L** represents lightness, which is completely independent of *a** and *b** (represented colour), and thus the adjustment of the *L** does not affect image colour data.

In view of image compatibility, the parameter ranges of various tongue colour and tongue coating colour calculated in L*a*b* colour space can be converted to any other colour space by conversion formulas.

4.2 Calibration of the acquisition device

4.2.1 General

In order to reflect realistic tongue colour information in the tongue image, chromatic aberration resulting from the acquisition device itself should be adjusted. Therefore, the prerequisite procedure for tongue image analysis is to calibrate the device hardware characteristics. The calibration is made in two steps. The first is whiteboard calibration, and then colour calibration.

4.2.2 Whiteboard calibration

As one of the factors affecting colour calibration, the determination of the camera's shooting mode is an important part of tongue image acquisition, which has a close association with whether the collected data are real or not. Once fixed in a certain mode (except AUTO mode), the system error of colour is relatively constant. Therefore, once colour distortion is determined under the current mode, the adjustment value is also determined.

Tongue colour analysis needs high-quality images, so it is necessary to check if the auto white balance by the camera is valid enough for our research. Most commercial cameras can adjust the white balance automatically by the software installed in them. A method named whiteboard calibration is offered in this document to meet users' needs for colour high-fidelity images. This method is also useful for those cameras that cannot adjust the white balance automatically.

Whiteboard calibration is carried out using the following steps:

1) Take pictures of a standard whiteboard with the device.

2) Select 24 points that are distributed evenly and calculate colour deviation Δe_i for each using Formula (1) and average deviation ΔE using Formula (2).

3) Adjust the white balance value according to the average deviation value.

4) Repeat steps 1), 2) and 3) until the colour deviation value is less than 5.

Single deviation:

$$\text{L*a*b* colour space: } \Delta e_i = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \tag{1}$$

Average deviation:

$$\Delta E = \frac{1}{24} \sum \Delta e_i \tag{2}$$

The suggested sample points are positioned in Figure 1:

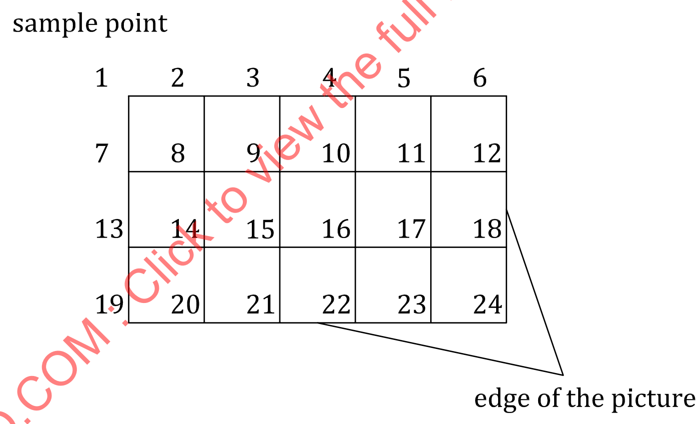

Figure 1 — Position of sample points for whiteboard calibration

4.2.3 Colour calibration

Colour calibration in L*a*b* colour space is carried out using the following steps:

1) Take pictures of 24 kinds of colour on a standard colour chart with the device.

2) Calculate the real L*a*b* value for the tongue image by linear interpolation. Take L^* component as an example. For each pixel in a tongue image, its real L value (L_r) will be calculated using Formula (3).

$$\frac{L_g - L_{g0}}{L_r - L_{r0}} = \frac{L_{g1} - L_{g0}}{L_{r1} - L_{r0}} \tag{3}$$

In Formula (3), L_g represents the raw L^* value from the image. L_g comes from a certain pixel of tongue image. L_{g0} and L_{g1} are calibration points coming from the image of the colour chart. L_{r0} and L_{r1} represent the value of the colour chart. For any L^* value from any pixel in the tongue image, the two closest calibration points are found and the L_r will be calculated.

A sketch is shown in Figure 2. Point X and Y are the reference points on the colour chart. L_{r0} and L_{r1} are respectively the L*value of Point X and Y according to colour chart (here subscript r refers to real value). L_{g0} and L_{g1} are raw L* value coming from the photo of reference point on the colour chart (here subscript g refers to acquired value).

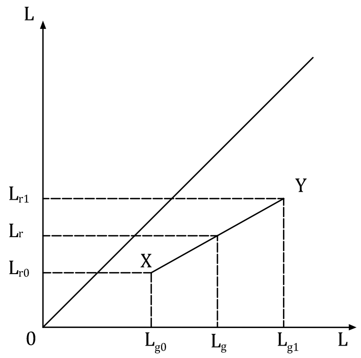

Figure 2 — A sketch of linear interpolation

Here linear interpolation is used for the calibration of the acquisition device since the referenced colour chart can only supply 24 kinds of colour. For pixels which drop between two calibration points, there should be a method to calculate deviation for correcting image. In this case, linear interpolation is a simple and accurate method to do the work. Annex A provides an example of linear interpolation for certain CTIS.

Because of the short distance between the device and the tongue, the collected image geometric distortion is very small, so geometric correction is excluded.

5 Methods of digital representation of tongue colour and coating colour

5.1 Clustering method

The clustering method can be used for tongue colour representation. k-means clustering is a method of vector quantization, originally from signal processing, which is popular for cluster analysis in data mining. k-means clustering aims to partition n observations into k clusters in which each observation belongs to a cluster with the nearest mean, serving as a prototype of the cluster.

Digital data of tongue colour or coating colour is clustered into certain numbers of classes by k-means and then the colour value of central point of the cluster with most sample points is represented as the colour value of tongue colour or coating colour.

The cluster centres resulting from k-means reflect the space distribution of the pixels in L*a*b* colour space. The result may differ from the mean value result, but it can reflect more information of the space distribution in colour space while mean value can only reflect the distribution on one axis.

5.2 Histogram method

A histogram bar plot is used to show the distribution of tongue image in L*a*b* colour space. A histogram is an accurate graphical representation of the distribution of numerical data. To construct a histogram, the first step is to "bin" the range of values – that is, divide the entire range of values into a series of intervals using Formula (4) – and then count how many values fall into each interval using Formula (5). In this document, data of the images in the same catalogue is sorted into 20 equally spaced bins between min and max value, and the L*a*b* values of every pixel on the sample are counted.

$$w_b = \left(w_{\max} - w_{\min}\right)/20 \tag{4}$$

$$h_b = \text{total pixel number which } L^* \left(\text{or } a^*, b^*\right) \text{ value fall in the range of certain bin} \quad (5)$$

5.3 Mean value method

This document also uses the mean value method to represent colour, that is, to get the average pixel value on the examples using Formula (6). And an expression formula of "mean ± standard deviation" is used to indicate the colour range of tongue colour and coating colour under every colour category.

$$L_{\text{ave}} = \frac{1}{n} \sum L_{i,j} \quad (6)$$

where

L_{ave} is the mean value of all the L value of the sample picture;

n is the total number of pixels of the sample picture;

i is the row number of a certain pixel;

j is the column number of a certain pixel.

Annex B presents an example for different methods of digital representation of tongue colour and coating colour by tongue images within a certain database.

Annex A
(informative)

Validity of tongue image acquisition and analysis

A.1 Tongue image acquisition

In this document, testing equipment was used to acquire tongue image. This tongue diagnostic instrument meets the requirements of ISO 20498-1 and ISO 20498-2.

The parameter settings of the testing equipment are as follows:

1) colour rendering index: 92,7 %;

2) colour depth: 24 bits;

3) shooting mode: M;

4) shutter speed: 1/200 s;

5) aperture: 5,6;

6) ISO sensitivity: 400;

7) data format: Jpeg + Raw;

8) colour space: L*a*b*.

A.2 Calibration formula of the device

Colour deviation tests are done in the L*a*b* colour space. The L*a*b* values of the selected colour chart and the original collected are as follows. Table A.1 shows the difference between colour chart and acquisition image, which means the calibration of cameras is needed.

Table A.1 — Colour deviation data in L*a*b*

No.	Colour Chart L_r*	Colour Chart a_r*	Colour Chart b_r*	The Image L_g*	The Image a_g*	The Image b_g*
1	65,367 6	7,356 7	10,080 2	63,961 5	−1,245 8	18,968 1
2	82,874 6	6,541 1	9,351 5	85,561 4	1,366 1	13,528 6
3	74,082 2	−1,297	−13,048 5	76,556	−9,232 5	−11,598 1
4	69,069 6	−11,891 3	15,558 7	70,986 8	−32,309 5	40,914 6
5	77,280 8	6,828 9	−14,179 4	80,679 2	−1,165 1	−9,703 1
6	85,203 8	−19,083 1	−0,531 2	87,157 9	−21,844 1	3,817
7	78,712	9,413 7	42,635	79,565 5	1,752 2	62,319 3
8	67,195 5	7,942 6	−26,436 4	67,464 8	0,612 4	−31,297
9	72,321 4	25,187 3	6,040 8	71,597 9	26,238	13,572 3
10	59,638 1	19,105 9	−17,189 4	57,929 7	6,748 2	−12,100 7
11	85,821 4	−19,006 6	40,095 5	89,475 5	−33,762 4	62,065 7
12	84,842	−0,231 8	49,057 3	85,406 9	−16,29 3	74,814 2
13	58,059 3	14,361 3	−35,525 8	54,540 9	5,973 8	−42,928

Table A.1 *(continued)*

No.	Colour Chart L_r*	Colour Chart a_r*	Colour Chart b_r*	The Image L_g*	The Image a_g*	The Image b_g*
14	75,706 5	−29,411 6	21,564 4	80,123 6	−42,938 3	37,108
15	62,875 4	35,1	11,577 5	61,705 2	33,058 3	25,17
16	89,837 7	−10,185 7	64,050 7	90,842 9	−22,397 1	68,004 7
17	72,183	31,054	−12,803 2	74,061 7	25,054 6	−11,994 3
18	71,230 9	−30,582	−19,099 6	76,117 8	−21,388 4	−18,715 4
19	98,139 8	−0,079 4	0,216 4	96,991	−6,064 8	4,208 9
20	90,976 4	0	0	92,537 7	−8,241 6	5,976 7
21	83,308 1	0	0	85,326 6	−8,273 1	5,358 1
22	74,708	−0,125 8	0,343 1	77,313 3	−8,856 8	5,931 4
23	64,429 9	0	0	63,177	−8,262 2	4,947 3
24	52,277 7	0	0	44,125 1	−7,341	4,739

Using Table A.1, the calibration formulas can be calculated by linear interpolation. Calibration formulas of L* are shown as below:

$$52{,}277\,7 + 0{,}555\,08\,(L_{g} - 44{,}125\,1) = L_r \qquad 44{,}125\,1 < L_g < 54{,}540\,9$$

$$58{,}059\,3 + 0{,}465\,888\,(L_{g} - 54{,}540\,9) = L_r \qquad 54{,}540\,9 < L_g < 57{,}929\,7$$

$$59{,}638\,1 + 0{,}857\,449\,(L_{g} - 57{,}929\,7) = L_r \qquad 57{,}929\,7 < L_g < 61{,}705\,2$$

$$62{,}875\,4 + 1{,}056\,19\,(L_{g} - 61{,}705\,2) = L_r \qquad 61{,}705\,2 < L_g < 63{,}177$$

$$64{,}429\,9 + 1{,}195\,284\,(L_{g} - 63{,}177) = L_r \qquad 63{,}177 < L_g < 63{,}961\,5$$

$$65{,}367\,6 + 0{,}521\,765\,(L_{g} - 63{,}961\,5) = L_r \qquad 63{,}961\,5 < L_g < 67{,}464\,8$$

$$67{,}195\,5 + 0{,}532\,112\,(L_{g} - 67{,}464\,8) = L_r \qquad 67{,}464\,8 < L_g < 70{,}986\,8$$

$$69{,}069\,6 + 0{,}421\,224\,(L_{g} - 70{,}986\,8) = L_r \qquad 70{,}986\,8 < L_g < 76{,}117\,8$$

$$71{,}230\,9 + -0{,}463\,06\,(L_{g} - 76{,}117\,8) = L_r \qquad 74{,}061\,7 < L_g < 76{,}117\,8$$

$$72{,}183 + -0{,}056\,17\,(L_{g} - 74{,}061\,7) = L_r \qquad 71{,}597\,9 < L_g < 74{,}061\,7$$

$$72{,}321\,4 + 0{,}355\,136\,(L_{g} - 71{,}597\,9) = L_r \qquad 71{,}597\,9 < L_g < 76{,}556$$

$$74{,}082\,2 + 0{,}826\,357\,(L_{g} - 76{,}556) = L_r \qquad 76{,}556 < L_g < 77{,}313\,3$$

$$74{,}708 + 0{,}355\,3\,(L_{g} - 77{,}313\,3) = L_r \qquad 77{,}313\,3 < L_g < 80{,}123\,6$$

$$75{,}706\,5 + 2{,}833\,513\,(L_{g} - 80{,}123\,6) = L_r \qquad 80{,}123\,6 < L_g < 80{,}679\,2$$

$$77{,}280\,8 + -1{,}285\,09\,(L_{g} - 80{,}679\,2) = L_r \qquad 79{,}565\,5 < L_g < 80{,}679\,2$$

$$78{,}712 + 0{,}694\,241\,(L_{g} - 79{,}565\,5) = L_r \qquad 79{,}565\,5 < L_g < 85{,}561\,4$$

$$82{,}874\,6 + -1{,}846\,25\,(L_{g} - 85{,}561\,4) = L_r \qquad 85{,}326\,6 < L_g < 85{,}561\,4$$

$$83{,}308\,1 + 19{,}102\,12\,(L_{g} - 85{,}326\,6) = L_r \qquad 85{,}326\,6 < L_g < 85{,}406\,9$$

$$84{,}842 + 0{,}206\,625\,(L_{g} - 85{,}406\,9) = L_r \qquad 85{,}406\,9 < L_g < 87{,}157\,9$$

$$85{,}203\,8 + 0{,}266\,483\,(L_{g} - 87{,}157\,9) = L_r \qquad 87{,}157\,9 < L_g < 89{,}475\,5$$

85,821 4	+	2,937 18	(L_{g-}	89,475 5	) = L_r	89,475 5	< L_g <	90,842 9
89,837 7	+	0,671 879	(L_{g-}	90,842 9	) = L_r	90,842 9	< L_g <	92,537 7
90,976 4	+	1,608 56	(L_{g-}	92,537 7	) = L_r	92,537 7	< L_g <	96,991

Calibration formulas of a* are shown below:

−30,582	+	−0,054 31	(a_{g-}	−21,388 4	) = a_r	−42,938 3	< a_g <	−21,388 4
−29,411 6	+	0,489 637	(a_{g-}	−42,938 3	) = a_r	−42,938 3	< a_g <	−21,844 1
−19,083 1	+	−0,006 42	(a_{g-}	−21,844 1	) = a_r	−33,762 4	< a_g <	−21,844 1
−19,006 6	+	4,897 309	(a_{g-}	−33,762 4	) = a_r	−33,762 4	< a_g <	−32,309 5
−11,891 3	+	0,172 067	(a_{g-}	−32,309 5	) = a_r	−32,309 5	< a_g <	−22,397 1
−10,185 7	+	0,675 197	(a_{g-}	−22,397 1	) = a_r	−22,397 1	< a_g <	−9,232 5
−1,297	+	−0,150 87	(a_{g-}	−9,232 5	) = a_r	−16,293	< a_g <	−9,232 5
−0,231 8	+	0,014 255	(a_{g-}	−16,293	) = a_r	−16,293	< a_g <	−8,856 8
−0,125 8	+	0,016 619	(a_{g-}	−8,856 8	) = a_r	−8,856 8	< a_g <	−6,064 8
−0,079 4	+	−0,036 48	(a_{g-}	−6,064 8	) = a_r	−8,241 6	< a_g <	−6,064 8
0	+	0	(a_{g-}	−8,241 6	) = a_r	−8,273 1	< a_g <	−8,241 6
0	+	0	(a_{g-}	−8,273 1	) = a_r	−8,273 1	< a_g <	−8,262 2
0	+	0	(a_{g-}	−8,262 2	) = a_r	−8,262 2	< a_g <	−7,341
0	+	0,751 237	(a_{g-}	−7,341	) = a_r	−7,341	< a_g <	1,366 1
6,541 1	+	−0,113 7	(a_{g-}	1,366 1	) = a_r	−1,165 1	< a_g <	1,366 1
6,828 9	+	−6,540 27	(a_{g-}	−1,165 1	) = a_r	−1,245 8	< a_g <	−1,165 1
7,356 7	+	0,315 305	(a_{g-}	−1,245 8	) = a_r	−1,245 8	< a_g <	0,612 4
7,942 6	+	1,290 665	(a_{g-}	0,612 4	) = a_r	0,612 4	< a_g <	1,752 2
9,413 7	+	1,171 973	(a_{g-}	1,752 2	) = a_r	1,752 2	< a_g <	5,973 8
14,361 3	+	6,126 808	(a_{g-}	5,973 8	) = a_r	5,973 8	< a_g <	6,748 2
19,105 9	+	0,312 03	(a_{g-}	6,748 2	) = a_r	6,748 2	< a_g <	26,238
25,187 3	+	−4,957 5	(a_{g-}	26,238	) = a_r	25,054 6	< a_g <	26,238
31,054	+	0,505 516	(a_{g-}	25,054 6	) = a_r	25,054 6	< a_g <	33,058 3

Calibration formulas of b^* are shown as below:

−35,525 8	+	−0,421 78	(b_{g}−	−42,928	) = b_r	−42,928	< b_g <	−31,297
26,436 4	+	0,347 811	(b_{g}−	−31,297	) = b_r	−31,297	< b_g <	−18,715 4
−19,099 6	+	−0,160 27	(b_{g}−	−18,715 4	) = b_r	−18,715 4	< b_g <	−12,100 7
−17,189 4	+	2,071 719	(b_{g}−	−12,100 7	) = b_r	−12,100 7	< b_g <	−9,703 1
−14,179 4	+	0,114 089	(b_{g}−	−9,703 1	) = b_r	−11,598 1	< b_g <	−9,703 1
−13,048 5	+	0,018 633	(b_{g}−	−11,598 1	) = b_r	−11,994 3	< b_g <	−11,598 1
−12,803 2	+	−1,738 12	(b_{g}−	−11,994 3	) = b_r	−11,994 3	< b_g <	3,817
−0,531 2	+	0,071 434	(b_{g}−	3,817	) = b_r	3,817	< b_g <	5,976 7
0	+	0	(b_{g}−	5,976 7	) = b_r	5,358 1	< b_g <	5,976 7
0	+	0	(b_{g}−	5,358 1	) = b_r	4,947 3	< b_g <	5,358 1
0	+	0	(b_{g}−	4,947 3	) = b_r	4,739	< b_g <	4,947 3
0	+	19,853 21	(b_{g}−	4,739	) = b_r	4,208 9	< b_g <	4,739
0,216 4	+	0,137 538	(b_{g}−	4,208 9	) = b_r	4,208 9	< b_g <	5,931 4
0,343 1	+	0,654 374	(b_{g}−	5,931 4	) = b_r	5,931 4	< b_g <	13,572 3
6,040 8	+	−1,307 96	(b_{g}−	13,572 3	) = b_r	13,528 6	< b_g <	13,572 3
9,351 5	+	−9,029 74	(b_{g}−	13,528 6	) = b_r	13,528 6	< b_g <	18,968 1
10,080 2	+	0,805 78	(b_{g}−	18,968 1	) = b_r	18,968 1	< b_g <	25,17
11,577 5	+	3,492 893	(b_{g}−	25,17	) = b_r	25,17	< b_g <	40,914 6
15,558 7	+	1,422 612	(b_{g}−	40,914 6	) = b_r	37,108	< b_g <	40,914 6
21,564 4	+	23,929 62	(b_{g}−	37,108	) = b_r	37,108	< b_g <	62,065 7
40,095 5	+	0,130 299	(b_{g}−	62,065 7	) = b_r	62,065 7	< b_g <	62,319 3
42,635	+	−5,426 99	(b_{g}−	62,319 3	) = b_r	62,319 3	< b_g <	74,814 2
49,057 3	+	1,873 309	(b_{g}−	74,814 2	) = b_r	68,004 7	< b_g <	74,814 2

Annex B
(informative)

Example for representation of tongue colour and coating colour

B.1 General

This annex uses an example to introduce the method for digital representation of tongue colour, and the data and results in the example cannot be used as a guideline for clinical classification. The acquisition procedure of the tongue images used in this document meets the requirements of ISO 20498-1 and ISO 20498-2. A.1 shows the details of acquisition environment and the device.

B.2 Sampling from tongue image

Tongue colour and coating colour are calculated using samples taken from a large number of tongue images. Those parts which can reflect tongue colour and coating colour will be taken out by a 50*50 pix window. Figure B.1 shows the process.

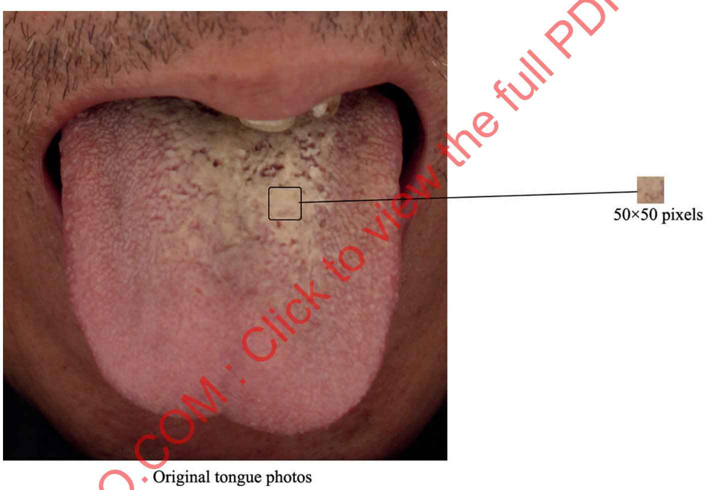

Figure B.1 — Sampling from tongue image

B.3 Cluster and distribution of tongue colour and coating colour

B.3.1 Cluster of tongue colour

Figure B.2 shows the space distribution of tongue colour in L*a*b* space, and every point maps an example of the tongue image.

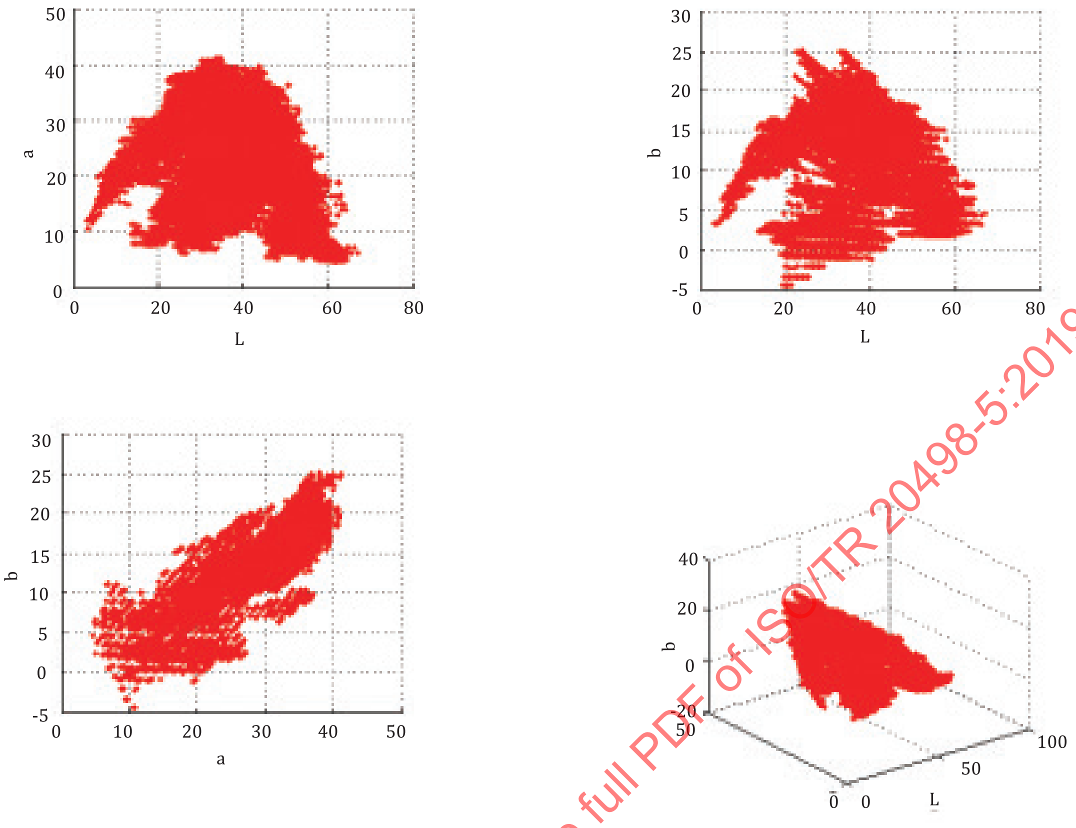

Figure B.2 — Distribution of tongue colour in L*a*b* space

According to the classical theory of traditional Chinese medicine, tongue colour is commonly divided into five classes: pale white, pale red, red, dark-red, purple. Therefore, the cluster number is set to 5. These samples are clustered by k-means to five classes. The results are shown in Figure B.3.

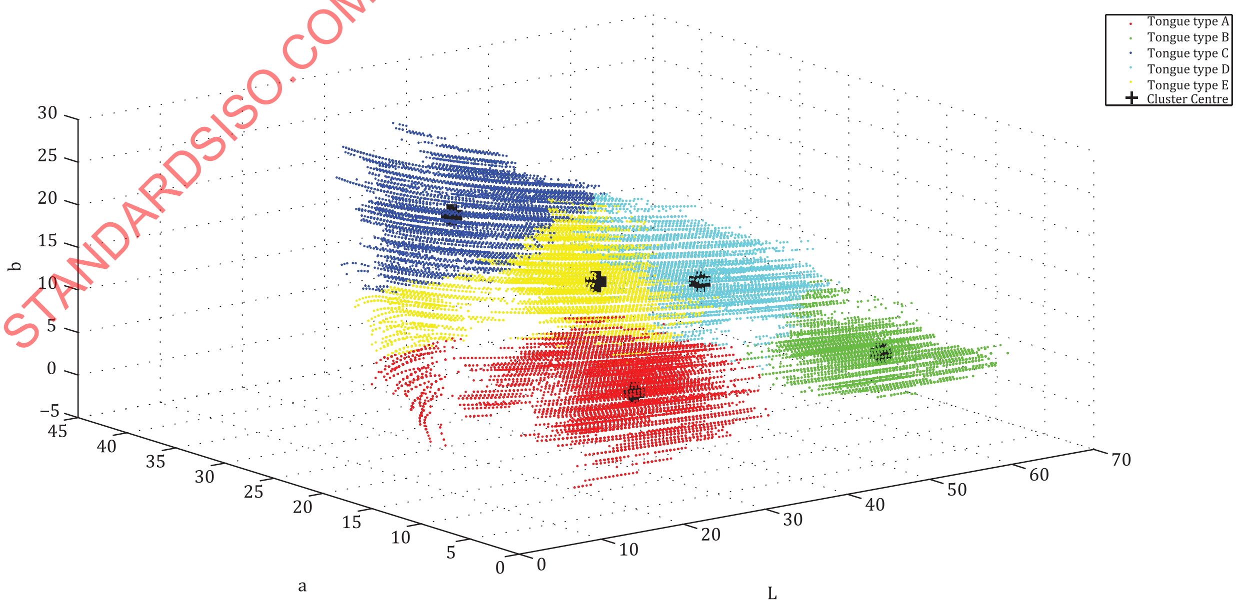

Figure B.3 — k-means cluster in L*a*b* space

The colour values of cluster centres in L*a*b* space is calculated by the cluster method as follows:

1) tongue colour type A

   *L**: 33,980 6; *a**: 16,766 9; *b**: 2,018 6;

2) tongue colour type B

   *L**: 54,853 3; *a**: 9,032 5; *b**: 5,690 7;

3) tongue colour type C

   *L**: 33,196 1; *a**: 34,693 6; *b**: 16,624 6;

4) tongue colour type D

   *L**: 48,093 0; *a**: 21,857 2; *b**: 10,797 1;

5) tongue colour type E

   *L**: 39,331 5; *a**: 25,129 1; *b**: 11,123 2.

B.3.2 Distribution of tongue colour

For each category, the frequency histograms of tongue colour in L*a*b* space are shown in Figure B.4.

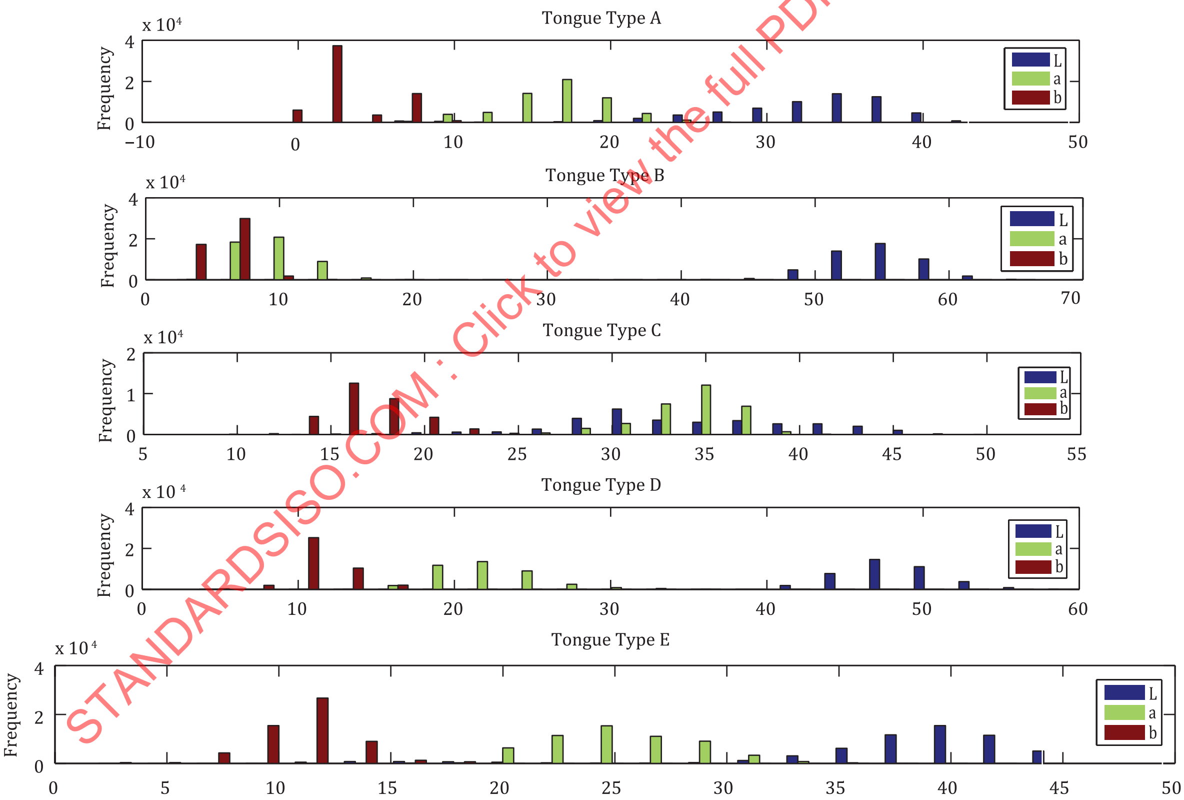

Figure B.4 — Frequency histograms of tongue colour in L*a*b* space

B.3.3 Cluster of tongue coating colour

Figure B.5 shows the distribution of tongue coating colour in L*a*b* space. Every point maps an example from the tongue image.

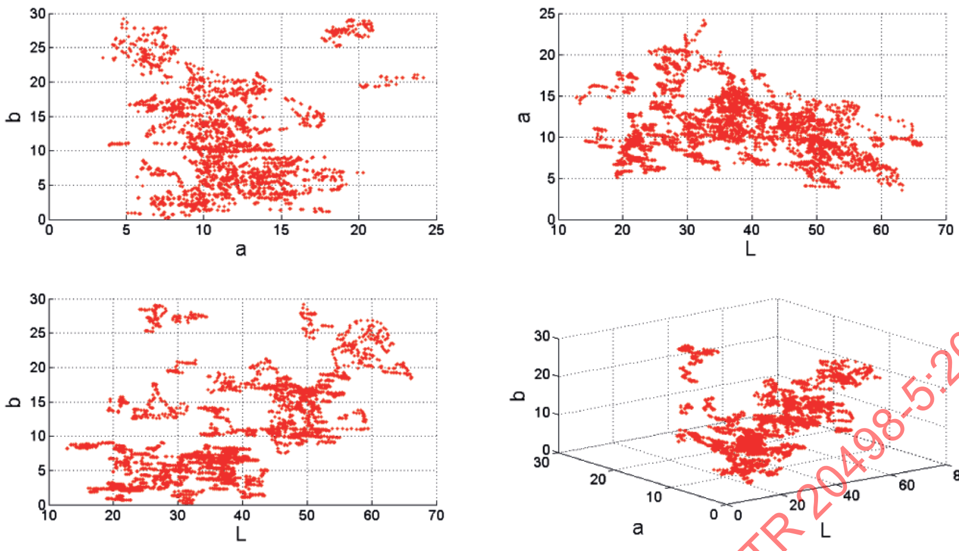

Figure B.5 — Distribution of tongue coating colour in L*a*b* space

According to the classical theory of traditional Chinese medicine, coating colours are commonly divided into three classes: white, yellow and grey-black. Therefore, the cluster number is set to 3. These samples are clustered by k-means into three classes. The results are shown in Figure B.6.

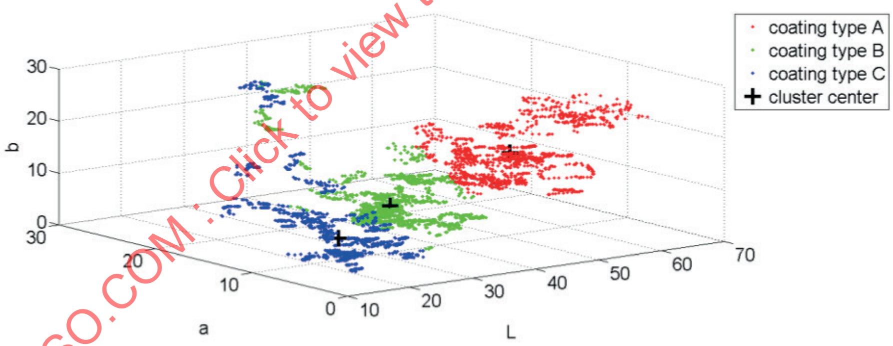

Figure B.6 — k-means cluster in L*a*b*

The colour values of cluster centres in L*a*b* space is calculated by the cluster method as follows:

1) coating colour type A

   *L**:36,515 5; *a**:12,835 1; *b**:6,835 9;

2) coating colour type B

   *L**:50,304 3; *a**:9,439 6; *b**:16,296 2;

3) coating colour type C

   *L**: 24,026 1; *a**:10,110 7; *b**:4,097 6.