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Design and Implement of a Novel Tool Software for Studying on Urine Dry-Chemistry Analysis

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Abstract: Dry-chemistry analysis of urine has been one of the most common and useful assay means in clinic for diagnosing disease, especially urinary system disease because it is very convenient and low cost. One of the most important keys about this analysis is to expediently and efficiently acquire the change relationship between color value about urinalysis reagent piece (URP) of each test item (ETI) and semi-quantitative result (SQR). For getting the relationships easily, a novel tool software is designed in this paper. First, we introduce the idea of this designed software. Second, the implement method of the software is described. Third, several functions and application examples about acquiring color values of test items are narrated. Then, the change relationships among color values and semi-quantitative results (SQRs) about two test items were also shown. From the examples, we could confidently draw a conclusion that it is very convenient and effective to study on the relationships or laws among color variations of urinalysis reagent pieces (URPs) and SQRs for different manufacturers' urinalysis reagent strips (URSs). Therefore, the software can be taken as a useful tool for studying on urine dry-chemistry analysis, especially, for developing application software, which may be installed in some household smart devices with cameras, such as smartphone and iPad, to realize the function of portable point-of-care and household urine analyzer.

Keywords: Semi-Quantitative Result; Dry- Chemistry Analysis; Urinalysis Reagent Piece; Urine Reagent Strip.

1. Introduction

Urine analyses play a major role in clinical assay because it is helpful for screening and diagnosing [1-9] urinary system and other diseases, assessing curative effect, detecting drug safety and evaluating health status roughly [10-14]. Among them, dry-chemistry analysis of urine is one of the most common and significant clinical assays [15, 16], such as urine routine examination, urine special chemical examination [17] and so on. For example, glucose (GLU) and ketone (KET) detection in urine, two of the principal chemical signatures of diabetes, are taken as an effective method of screening diabetes with inexpensive urinalysis test strips [18]. However, it is the basic principle of urine dry-chemical analysis that some characteristics of urine and the quantity of some chemical composition in urine are relative with color changes of URPs about corresponding test item by some specific chemical reactions [19-21]. And a URP corresponds to a defined test item. Therefore, by comparing colors of URPs and relative standard color pieces at given time, SQRs of all test items, such as leukocytes (LEU), urobilinogen (URO), micro-albumin (mALB), protein (PRO), bilirubin (BIL), vitamin C (VC), specific gravity (SG), nitrite (NIT), creatinine (CRE), hydrogen ion concentration (PH), blood (BLO), urinary calcium (UC) and so on, can be acquired. Generally, the SQRs of urine test items correspond to several disperse values of concentration interval about some special biochemical substance or some semi-quantitative levels (SQLs). For example, SQRs of GLU have disperse values of concentration interval, which are negative, 50mg/dL, 100 mg/dL, 250 mg/dL, 500 mg/dL and 1000 mg/dL, 2000 mg/dL, or some SQLs, which are -, ±, 1+, 2+, 3+ and 4+. It is necessary to be point out that the disperse values of concentration interval, such as 100 mg/dL and 200 mg/dL, are not exact value but very rough ranges. Hence, the SQRs only roughly reflect how much tested biochemical substance is in the urine.

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In the early days of the urine dry-chemistry analysis, the SQR of ETI may be gained by directly comparing color of each URP with correlative standard color pieces via our naked eyes [22, 23]. As is known to all, different people have certain differences in subjective judgments of color, so the results of the identical URP may be inconsonant for different peoples. With the development of automation and microprocessor technologies, many kinds of urine dry-chemistry analyzers have been made by different manufacturers for improving test accuracy and efficiency [24]. And the analyzers have already been applied widely in clinical practice [25-31], which can automatically read the color values of each reagent piece and effectually improve test accuracy and efficiency of urine dry-chemistry analysis. However, the core technologies of urine analyzer based on dry-chemistry analysis are the ways of getting color value about each URP and algorithms of SQRs [32]. Whereas, the ways of acquiring color value depend on the hardware and algorithms. Among them, the hardware lies on optical path structures and corresponding photoelectric sensors[32-35], while the algorithms are determined by the relationships or laws among color variations of urinalysis reagent pieces (URPs) and SQRs.

Additionally, the trends of color changes about URP for a same test item among different manufacturers usually are inconsistent. As Figure 1 shown, the standard color pieces and corresponding results of URP about GLU for two manufacturers are displayed. Figure 1(A) is about ACON Biotech (Hangzhou) CO., LTD. of China. Figure 1(B) is for Chongqing Teco Huayi Pharmaceutical CO., LTD. of China. It is very obvious that the trends of color change have big differences between the two kinds of URPs made by those two manufacturers with the increase of GLU concentration. Besides, Figure 1 indicates that the standard colors of each same SQR are inconsistent for different manufacturers. In practice, different URPs were fixed on a urine reagent strip (URS) in individual order by manufacturers. Generally, there are many kinds of URSs, including 10, 11, 12 and 14 URPs. A URP means a test item. In other words, if there are 14 URPs on the URS, it can test defined 14 items in urine. Figure 2 displays a URS of 14 test items, made by ACON Biotech (Hangzhou) CO., LTD. of China. In addition, the sequences of test items on URSs, produced by different manufacturers, may be inconstant. Therefore, for urine dry-chemistry analyzers, the algorithms of acquiring SQRs about ETI are incompatible among these URSs. However, the algorithms must be based on the relationships or laws among color change of URPs and the relative SQRs. That is to say, the relationships are the most the core technologies for urine dry-chemistry analysis except for hardware.

Figure-1. The standard color of urine reagent piece about GLU for two manufacturers:(A) for ACON Biotech (Hangzhou) CO., LTD. of China;(B) for Chongqing Teco Huayi Pharmaceutical CO., LTD. of China.

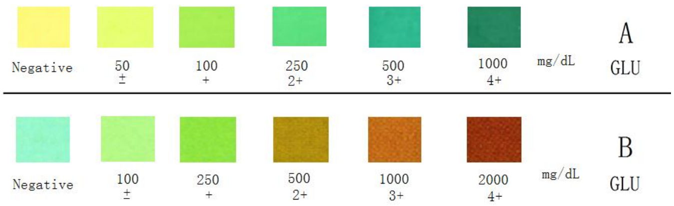


Figure-2. Urinalysis reagent strip for fourteen items

Moreover, with the development of electronic technology, all kinds of household smart devices with camera, such as smartphone and panel personal computer, are becoming more and more popular. Some of them have great potential to become the portable point-of-care and household diagnostic devices [36], including urine analyzer with dry-chemical method. Few studies have reported that the smartphone was taken as urine analyzer of the test in a clinical setting and emergency department [37]. But, the relationships among color change of URPs and the relative SQRs are also their most core technologies.

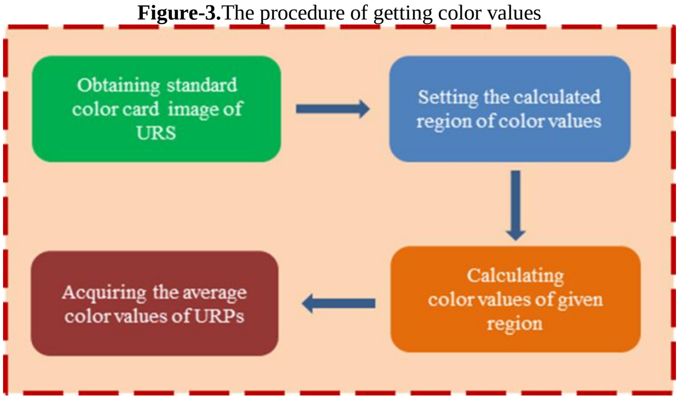
Based on the demand of studying on dry-chemistry analysis for different manufacturers' URSs, we designed a novel tool software to expediently and efficiently acquire the change relationships among color values about URP of ETI and SQRs. The color value includes its red-, green- and blue-component values (RGBCVs). As far as we know, there is no our designed software with analogous functions to be reported. Next, we introduce design and implement of this tool software in detail in this paper.

2. Design and implement

2.1. Design Procedures

This software is written with C++ Builder 6.0, and the design procedures of this software, which include four steps, are shown in Figure 3. The design of each step is expounded below.

Figure-3. The procedure of getting color values

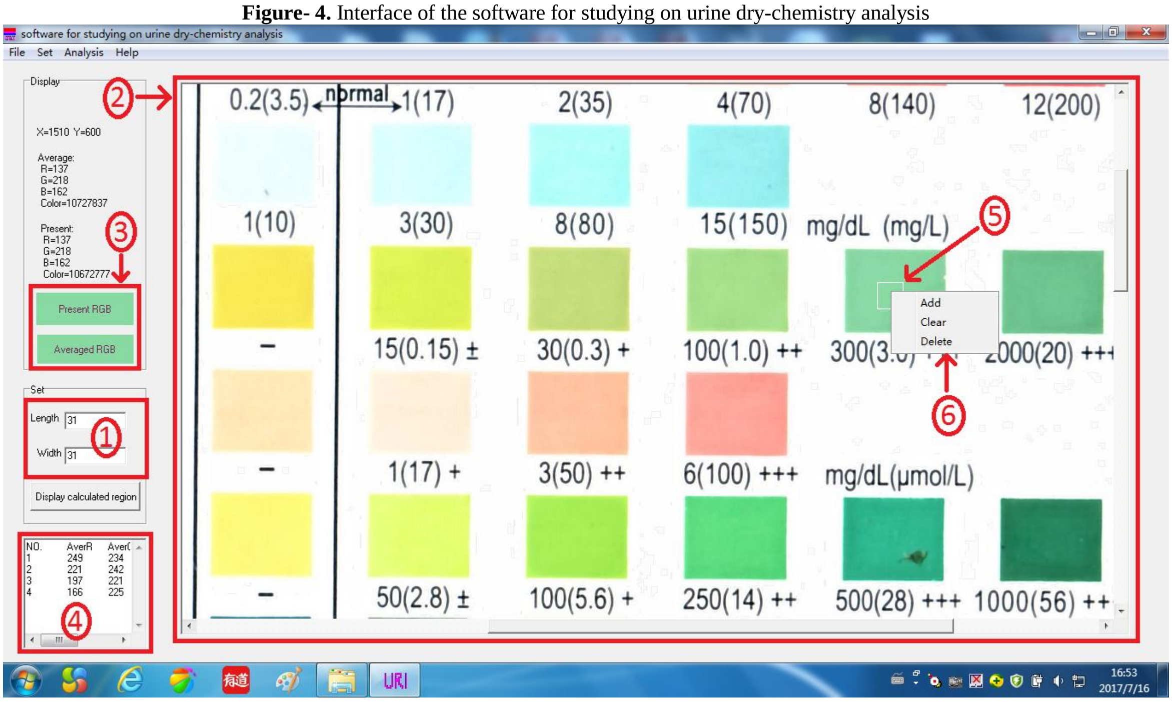


1) The first step is obtaining standard color pieces image of URS. The image must be high fidelity color picture, which may be gained by applying scanner to scan standard color pieces afforded by its manufacturer, or other devices, such high performance camera, smartphone, iPad.
2) Setting the calculated region of color values, the second step, is aimed at letting the user determine the computed rectangle region of the color value according to the actual situation. The rectangular region is defined by given length and width.
3) Calculating color values of given region is the third step, and the goal is respectively computing average values of color and its three components, namely red, green and blue components, in the defined region.
4) The last step, the fourth one, is acquiring the average color values of URPs and standard color pieces for different test items, saving the corresponding data and other disposes.

2.2. Implement of design

To implement design of the software, there are many programing languages, such as Delphi 6.0, Java, C#6.0, Visual C++ 6.0 [38], Visual Basic 6.0, C++ Builder 6.0 [39, 40] and so on.

Figure- 4. Interface of the software for studying on urine dry-chemistry analysis



In practice, we chose our familiar C++ Builder 6.0 to write this software, and its interface is displayed in Figure 4. Then, the main part of specific implementation is descripted in detail below.

2.2.1. Obtaining Standard Color Pieces Image

The image file of standard color pieces afforded by the manufacturer must be gained firstly. In reality, using all kinds of image capture devices, like scanner and high performance camera, the image file can be acquired easily.

2.2.2. Setting the Calculated Region

We defined two pointers of TLabel, a class of C++ builder 6.0, to display “Length” and “Width” of the calculated rectangle region. Meanwhile, two pointers of TEdit, which is also a class of C++ builder 6.0, were used to let user input length and width of the calculated region. The running result of these was marked ① in Figure 4 with red color. Furthermore, length and width of the region defined by user can be obtained by StrToInt function of C++ builder 6.0. In order to show the calculated region visually, we added a TShape pointer to the program, and the effect was labeled as ⑤ in Figure 4.

2.2.3. Calculating Color Values of Given Region

Firstly, we defined a TImage pointer to load the image file gained in the first step by LoadFromFile function of TImage. If the image is loaded, the picture, the content of image, will be display in image box signed ② in Figure 4.

Secondly, when mouse enter the region of image box, the averages of color values and RGBCVs will be acquired by the following GetAverColorValues function program.

```
Void GetAverColorValues(int X, int Y, int XH, int YH)
{
  TColor tempcolor;
  DWORD RSum=0,GSum=0,BSum=0, totaldot;
    int i,j, XW,YH,XW2,YH2;
    long long totalcolor=0;
  totaldot=XW*YH;
  XW2=XW/2;
  YH2=YH/2;
  for(i=0;i<XW;i++)
  {
   for(j=0;j<YH;j++)
   {
   tempcolor=ImageFile->Canvas->Pixels[X-XW2+i][Y- YH2+j];
    RSum+=GetRValue(tempcolor);
    GSum+=GetGValue(tempcolor);
    BSum+=GetBValue(tempcolor);
        totalcolor+=tempcolor;
   }
  }
   AverR=RSum/totaldot;
   AverG=GSum/totaldot;
   AverB=BSum/totaldot;
   PresentColor= tempcolor;
     AverColor=totalcolor/totaldot;
}
```

Among the function, X and Y represent position coordinate of mouse in the image box. XH and YH express width and length of calculated rectangle region respectively. AverR, AverG, AverB are public variables, which indicate averages of RGBCVs in given region. PresentColor and AverColor, two public variables of class TColor, mean the color value of mouse position and the color average of calculated region severally. ImageFile is a pointer of class TImage of C++ builder 6.0. GetRValue, GetGValue and GetBValue are Functions of C++ builder 6.0 for gaining RGBCVs from a variable of class TColor.

Thirdly, for showing the color of mouse position and the average color of calculated region respectively and intuitively, two pointers of class TLabel are designed. The running results were labeled as ③ in Figure 4.

2.2.4. Acquiring the Average Color Values of URPs

To display and save averages of color and its three component values, we added a TMemo control and a PopupMenu to the program. In the PopupMenu, three items, “Add”, “Clear” and “Delete”, were set. And the running effects were marked ④ and ⑥ in Figure 4 respectively.

3. Results and Discussion

The running result of the software was exhibited in Figure 5. To better understand its value, we discussed from two aspects, application process and application examples.

3.1. Application Process

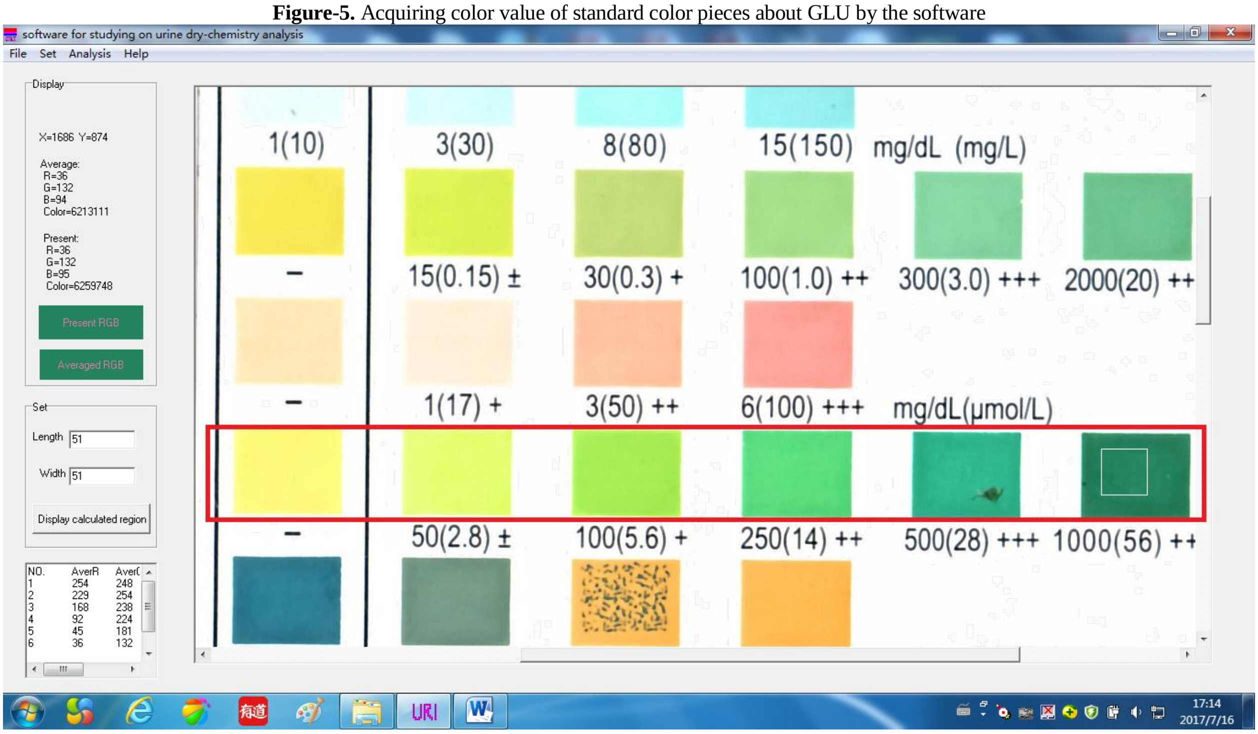
The application process of the software generally consists of the following steps:

1) Apply image capture devices, like scanner and high performance camera, to get image file of standard color pieces afforded by the manufacturer.
2) Click “Open”, the next level menu of “File”, and select the image file that we want to open. Then we can see the picture to be shown in the image box.
3) Input the length and width of the calculated rectangle region.
4) Move mouse to the expected position of standard color piece about needed analytical item, and click right button of mouse. Then a popup menu will appear. We can click “Add” to append the averages of RGBCVs and the color

value about given region to TMemo control. If the error is found, click “Delete” to erase the last time appended values. If you want to clear all data, please click “Clear”.

5) Repeat step 4 until all averages of RGBCVs and color value about standard color piece of each SQR for needed analytical item are acquired.

Figure-5. Acquiring color value of standard color pieces about GLU by the software



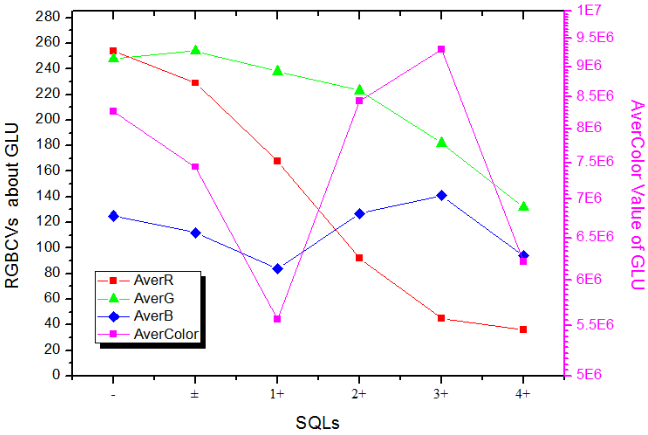
3.2. Application Examples

We only expounded the following two examples of acquiring RGBCVs and color values of standard color pieces. One is for about GLU, and the other is about URO. Firstly, we applied a scanner, CanoScan LiDE25, to scan standard color pieces provided by ACON Biotech (Hangzhou) CO., LTD. of China with resolution of 600 dots per inch (DPI). In this way, our needed image file was gained. Certainly, we can also get image files of standard color pieces produced by other manufacturers with this method. Secondly, we clicked “Open” menu, and chose the gained image file. Then the image file was displayed in image box. Thirdly, both width and length of calculated rectangle region were set 51 pixels displayed in Figure 5. Fourthly, we moved mouse to central position of the first standard color piece of test item GLU, and clicked “Add”. Then the order, its corresponding RGBCVs and color value were added into region labeled as ④ in Figure 4. Fifthly, we moved mouse to central position of the second, third, fourth, fifth and sixth of standard color pieces about GLU in turn, and clicked “Add” to append corresponding values to TMemo control simultaneously. Then the final result is displayed in Figure 5, and the specific RGBVs are displayed in Table 1. In addition, the standard color pieces of GLU were marked with red rectangle in Figure 5. Meanwhile, Figure 6 exhibits the relationships among the RGBCVs and color values of standard color pieces and SQLs about GLU.

Table-1. The relationships among RGBCVs and color values of different SQRs about GLU

NO.	SQRs (mg/dL)	SQLs	AverR	AverG	AverB	AverColor
1	Negative	-	254	248	125	8265745
2	50	±	229	254	112	7439330
3	100	1+	168	238	84	5566317
4	250	2+	92	224	127	8434397
5	500	3+	45	182	141	9305150
6	1000	4+	36	132	94	6216100

Figure-6. The relationships among color values of standard color pieces and SQLs about GLU.



In Table 1, SQRs, SQLs, RGBCVs and color values of standard pieces about GLU were listed. Meanwhile, the change relationships among the RGBCVs of standard color pieces and SQLs about GLU were shown in Figure 6 with left Y and bottom X axes. And the change relationships among their color values and SQLs were displayed in Figure 6 with right Y and bottom X axes. According to Table 1 and Figure 6, it is easy for us to draw the conclusion that the red and green component values in the color of the URPs are closely related to the RSQs and SQLs of GLU. But only the red component value decreases monotonically with the increase of SQRs. Both blue component and color values are not monotonous changes with the increases of SQLs of GLU. Therefore, we can get the SQRs and SQLs of GLU in urine on the basis of the red component value.

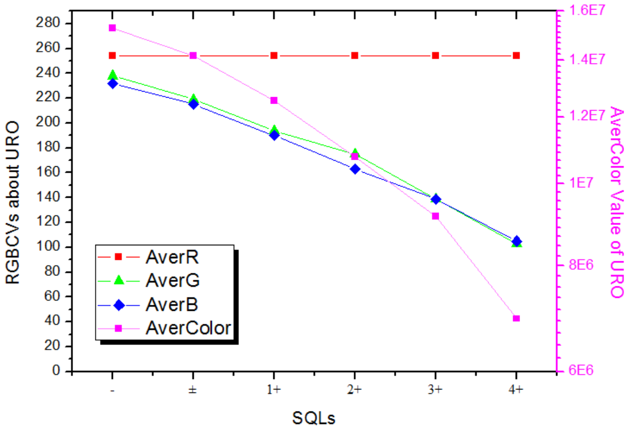
Figure-7. The standard color pieces and SQRs about URO

In order to further clarify the application and significance of this software, we gained the RGBCVs and color values of standard color pieces about URO under the condition that both width and length of calculated rectangle region were also defined as 51 pixels. The Figure 7 exhibits the standard color pieces and SQRs about URO, and Table 2 lists the relationships among RGBCVs and color values of different SQRs about URO. Figure 8 intuitively illustrates their relationships with changing curves.

Table-2. The relationships among RGBCVs and color values of different SQRs about URO

NO.	SQRs (mg/dL)	SQLs	AverR	AverG	AverB	AverColor
1	0.2	-	254	238	232	15277933
2	1	±	254	219	215	14160480
3	2	1+	254	194	190	12538625
4	4	2+	254	175	163	10763806
5	8	3+	254	139	139	9159084
6	12	4+	254	103	105	6930957

Figure-8. The relationships among color values of standard color pieces and SQLs about GLU.



On the basis of Table 2 and Figure 8, it is obvious that the change relationships among color values and SQLs about URO are big differences from that of BLU. The red component values of color about standard color pieces of URO, equaling to 254, are constant. The green and blue component values of color and color values are all monotonous changes with the increases of SQLs of URO. Therefore, the SQRs and SQLs of URO can be acquired according color value and its green or blue components.

Therefore, from the two above mentioned examples, we can make sure that it is easy to expediently and efficiently obtain the change relationships among color values of URP about ETI and SQRs by this designed software.

4. Conclusion

In this paper, design and implement of the novel tool software for studying on urine dry-chemistry analysis was expounded firstly. Then its two application examples were narrated and they have strongly suggested that it is very convenient and effective to get the change relationships among SQRs and color values of standard color pieces about any test items. Similarly, it is clear that this software can be used to easily and efficiently acquire the relationships among SQRs and the color values about standard color pieces and URPs made by any manufacturer. And, the change relationships, which are the most important core technologies of urine dry-chemistry analysis, provide convenience for developing urine analyzer, which may be applied in various strips of the different manufacturers. Furthermore, the acquired change relationships afford the core technology for developing application software, which may be installed in some household smart devices with cameras, such as smartphone and iPad, to realize the function of portable point-of-care and household urine analyzer.

Therefore, we could confidently draw a conclusion that our designed software can be taken as a useful tool for studying on urine dry-chemistry analysis.

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