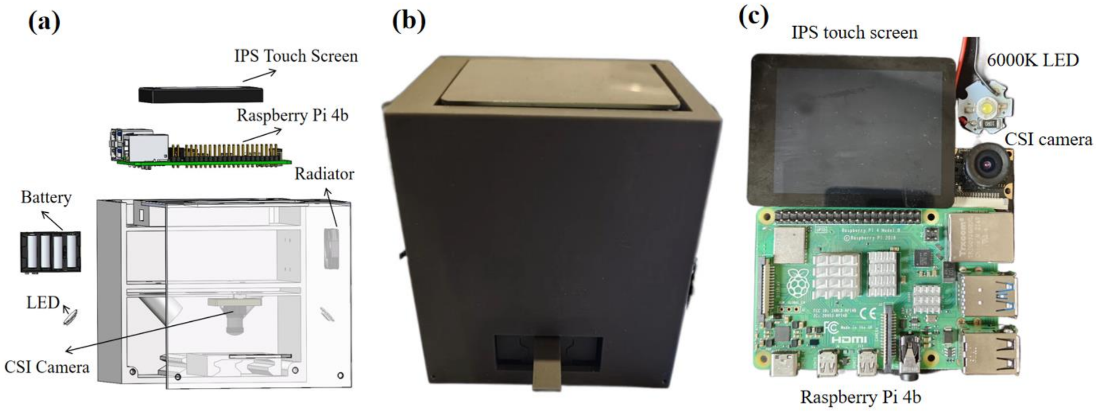

Figure S1 Structure of the optical device. (a) Expanded views of the device designed using SolidWorks software; (b) physical map of the POCT device; (c) the major components of the device.

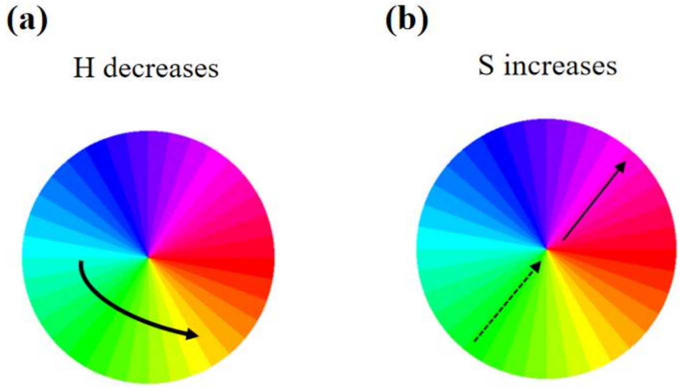

Figure S2 HSV color space matches well with spectroscopic change. (a) A decrease in the H parameter is accompanied by an increase in wavelength. (b) An increase in the S parameter is accompanied by an increase in intensity.

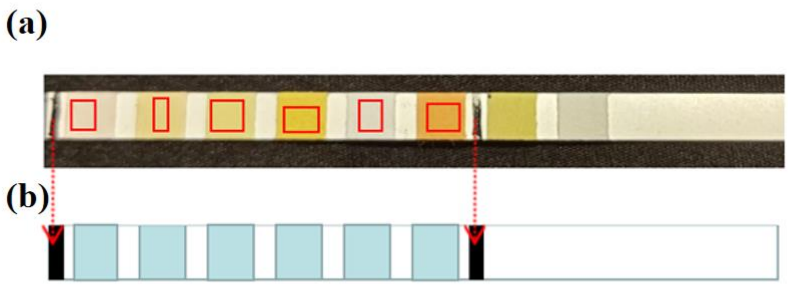

Figure S3 Template used for automatic recognition. (a) Image of a urine test strip consisting of eight paper-based sensors in an array; (b) mono-color template on the image to determine the position of the strip.

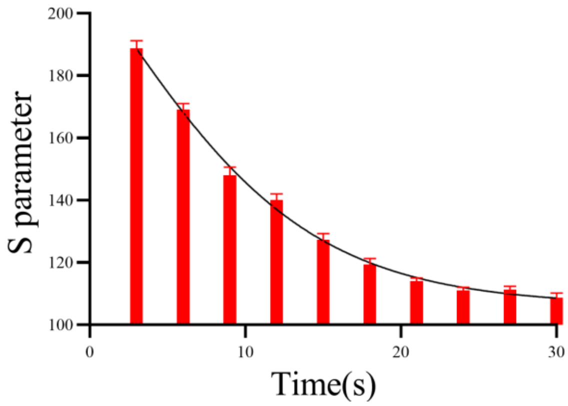

Figure S4 S vs. time plot showing a kinetic response of a glucose sensor using colorimetry.

Input: Image $X_{1\text{-}t}$ of size m×n

Output: Image Y of the same size as X

Initialize $DIFF$, N_1, N_2

for i = 2 to t -1 **do**

for j = 1 to m **do**

for k = 1 to n **do**

if $|\text{Pixel}_i(j,k) - \text{Pixel}_{i+1}(j,k)| \geq DIFF$

$N_1 = N_1 + 1$

if $|\text{Pixel}_{i-1}(j,k) - \text{Pixel}_i(j,k)| \geq DIFF$

$N_2 = N_2 + 1$

end for

end for

$Ni = N_1 + N_2$

end for

$Y = X_{i \to \min Ni}$

Figure S5 Pseudocode of the algorithm to determine detection time.

```
Input: Image X of size m×n, kernal radius r
Output: Image Y of the same size as X
  Initialize kernal histogram H
  for i = 1 to m do
    for j = 1 to n do
      for k = -r to r do
        Remove X_{i+k,j-r-1} from H
        Add X_{i+k,j+r} to H
      end for
      Y_{i,j} ← median (H)
    end for
  end for
```

Figure S6 Pseudocode of the fast two-dimensional median-filtering algorithm with a time complexity of o(r).

```
Randomly initialize K cluster centroids μ1, μ2, . . . . , μk ∈ R^n
Repeat {
        for i = 1 to m
            c^(i) = index (from 1 to K) of cluster centroid
                closest to x^(i)
        for k = 1 to K
            μk = average (mean) of points assigned to cluster k
        }
```

Figure S7 Pseudocode of the K-means segmentation algorithm.

Input: Image *X* of size m×n

Output: Image *Y* of the same size as *X*

Initialize *GLINT*

for *i* = 1 to m **do**

for *j* = 1 to n **do**

if $R_x(i,j) \geq GLINT$ or $G_x(i,j) \geq GLINT$ or $B_x(i,j) \geq GLINT$

Y(i,j) = 0

else

$Y(i,j) = Grey\ (R_x(i,j), G_x(i,j), B_x(i,j))$

end for

end for

Y = cvtcolor (*Y*,GRAY2BGR)

Figure S8 Pseudocode of the flashing–filtering algorithm.

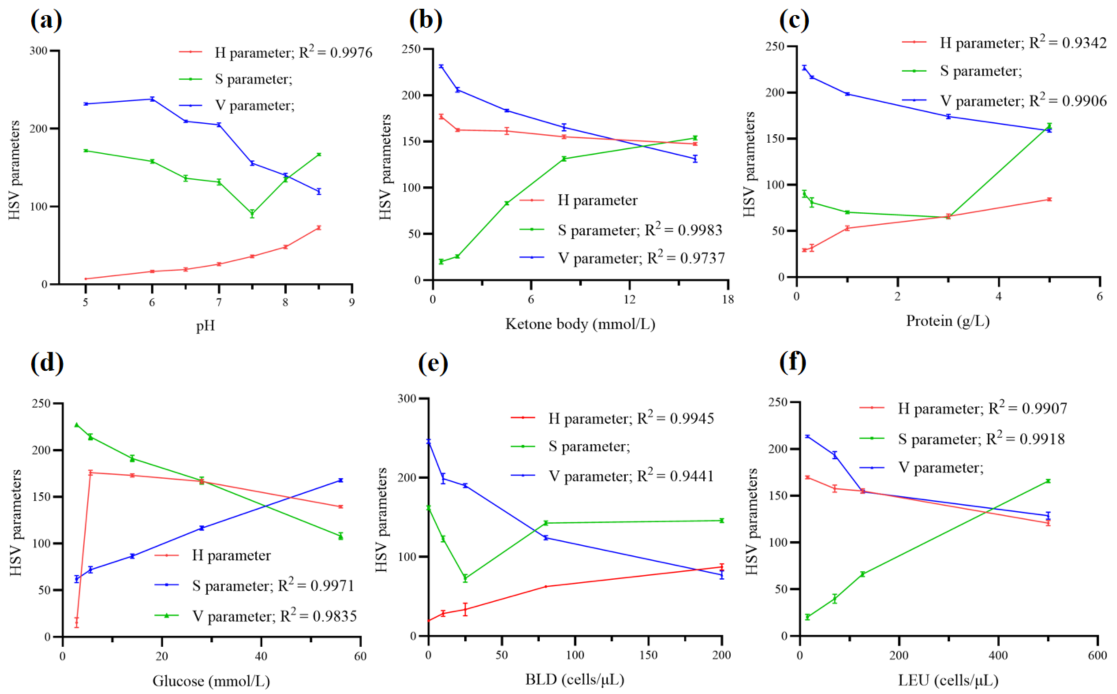

Figure S9 HSV parameters vs. analyte concentrations after image processing under the optimal sensing condition, for (a) pH, (b) ketone bodies, (c) protein, (d) glucose, (e) occult blood, and (f) leukocytes.

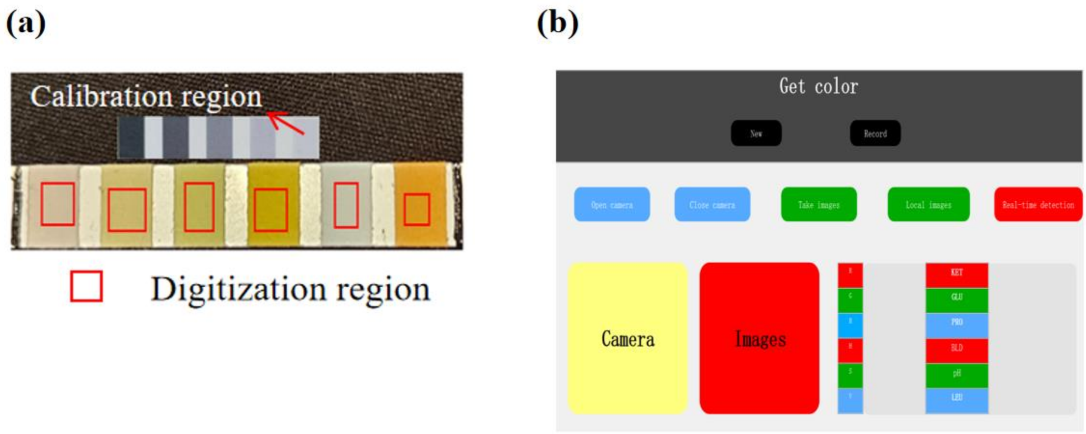

Figure S10 The Graphical User Interface (GUI) of the software. (a) Real-time detection of a urine sample; (b) Getcolor software installed on Raspberry Pi written in Python with the Opencv and PYQT5 support libraries.

Table S1 Detailed information for negative responses and positive responses of each analyte.

Analyte	Negative	Positive				Unit
		Level 1+	Level 2+	Level 3+	Level 4+	
KET	0 - 0.5	1.5	4.0	8.0	16	mM
GLU	0 - 0.55	5.6	14	28	56	mM
PRO	0 - 0.1	0.3	1.0	3.0	5.0	g/L
BLD	0	5-10	25	80	200	cells/μL
pH	5 - 8.5	-				-
LEU	0	15	75	125	500	cells/μL

Table S2 Results of real urine sample analysis generated by the proposed colorimetric urinalysis and a hospital instrument.

Analyte / Sample	KTT*	GLU*	PRO*	BLD*	PH*	LEU*	KET	GLU	PRO	BLD	PH	LEU
1	-	2+	-	-	5.0	-	-	2+	-	-	5.34	-
2	-	-	-	-	5.0	-	-	-	1+	-	5.27	1+
3	-	-	1+	-	5.5	93	1+	-	1+	-	5.94	2+
4	-	-	-	1+	6.0	37	-	-	-	1+	6.23	1+
5	-	-	1+	3+	6.0	-	-	-	1+	3+	6.46	-
6	-	-	-	2+	5.0	-	-	-	-	2+	5.34	-

7	-	4+	-	-	7.5	-	1+	4+	1+	-	7.23	-
8	-	-	-	3+	5.0	81	-	-	-	3+	6.45	2+
9	-	-	1+	-	5.5	-	-	-	1+	-	5.38	-
10	-	-	-	2+	5.5	-	-	-	-	2+	6.34	-
11	-	2+	1+	1+	5.0	189	-	1+	1+	1+	5.29	2+
12	-	-	-	1+	6.0	-	-	-	-	1+	6.39	-
13	1+	-	-	-	5.5	-	1+	-	-	1+	5.25	-
14	-	-	-	2+	6.6	-	-	-	1+	2+	6.64	1+
15	-	-	1+	2+	5.5	-	-	2+	1+	2+	5.57	-
16	-	-	1+	2+	6.0	-	-	-	1+	2+	5.23	-
17	1+	-	-	-	5.0	30	1+	-	-	-	4.79	1+
18	-	-	-	2+	5.0	-	-	-	-	3+	5.36	-
19	1+	-	1+	2+	6.5	-	2+	-	1+	2+	6.23	-
20	1+	-	2+	2+	5.0	-	1+	-	3+	2+	4.79	-
21	-	-	1+	-	5.5	37	-	-	1+	-	5.23	-
22	1+	-	-	2+	7.5	35	1+	-	-	2+	7.23	1+
23	1+	3+	-	2+	5.5	67	-	4+	-	3+	5.27	1+
24	-	3+	-	3+	6.0	91	-	3+	-	3+	7.23	2+
25	-	1+	-	-	5.0	-	-	1+	1+	-	5.48	-
26	-	-	-	-	7.0	-	-	1+	-	-	7.29	-
27	-	-	1+	1+	5.5	500	-	-	-	1+	5.29	4+
28	1+	1+	-	-	5.0	-	1+	2+	-	-	5.37	1+
29	-	4+	1+	2+	6.0	-	-	4+	1+	2+	6.46	-
30	-	1+	-	-	6.5	-	-	1+	-	-	6.57	-
31	-	3+	2+	-	5.0	169	-	3+	2+	-	4.1	3+
32	-	-	1+	3+	5.0	-	-	-	-	3+	5.29	-
33	1+	2+	-	-	5.5	60	2+	2+	-	-	5.38	2+
34	-	2+	1+	1+	6.0	-	-	2+	1+	1+	6.25	-
35	-	-	1+	1+	7.5	-	-	-	-	1+	7.12	-
36	1+	3+	2+	1+	5.5	93	1+	3+	2+	2+	5.38	2+
37	-	-	2+	1+	6.0	-	-	-	2+	1+	7.2	-
38	-	3+	1+	-	6.5	269	-	3+	1+	-	6.23	3+
39	1+	2+	-	-	5.0	50	1+	2+	-	-	5.73	2+
40	1+	3+	-	-	5.5	36	1+	3+	-	-	5.45	1+
41	-	-	3+	-	7.0	-	-	-	3+	-	7.36	1+
42	-	3+	-	1+	6.5	-	-	2+	-	1+	6.98	-

43	-	3+	-	1+	5.0	-	2+	3+	-	++	5.47	-
44	-	-	1+	2+	6.5	155	-	-	1+	2+	6.88	3+
45	-	-	-	1+	5.5	-	-	-	1+	1+	5.63	-
46	-	4+	3+	-	6.0	-	-	4+	3+	-	6.74	-
47	-	4+	-	-	7.0	-	-	4+	-	-	7.12	1+
48	1+	-	-	-	5.0	-	1+	-	-	-	5.03	-
49	1+	1+	3+	2+	5.5	250	1+	1+	3+	2+	5.56	3+
50	1+	3+	-	-	5.5	-	1+	3+	-	-	6.23	-
51	-	4+	-	-	5.0	34	-	2+	-	-	5.45	-
52	-	3+	-	-	5.0	-	1+	3+	-	-	5.47	-
53	-	3+	2+	-	5.0	-	-	3+	2+	-	5.34	-
54	-	-	-	-	7.5	62	-	-	1+	-	7.59	2+
55	-	-	-	1+	5.0	81	-	-	-	1+	5.34	2+
56	-	-	1+	-	6.0	155	-	1+	-	2+	5.54	3+
57	-	-	-	-	7.5	31	-	-	-	-	7.52	1+
58	-	1+	-	-	6.0	-	-	1+	-	-	7	-
59	-	3+	2+	1+	6.5	-	1+	3+	2+	1+	6.65	-
60	-	-	-	2+	5.5	-	-	-	-	2+	6.65	-
61	-	-	1+	-	6.0	-	-	-	1+	-	6.17	-
62	-	-	-	1+	5.0	56	-	2+	-	1+	6.82	1+
63	-	-	1+	3+	5.0	30	-	-	1+	3+	5.34	1+
64	-	2+	-	-	5.0	-	-	2+	-	-	5.42	-
65	-	-	-	2+	5.0	42	-	-	1+	2+	5.48	2+
66	-	4+	-	-	5.5	-	-	4+	-	-	5.73	-
67	-	-	2+	1+	5.0	61	-	-	2+	1+	5.31	2+
68	-	-	1+	2+	5.0	210	-	-	1+	2+	5.29	3+
69	-	-	1+	-	5.0	36	-	-	1+	2+	5.21	1+
70	-	2+	1+	1+	5.5	-	-	2+	1+	1+	5.59	-
71	-	1+	1+	-	5.0	122	1+	1+	1+	-	5.39	2+
72	-	-	2+	-	5.0	-	-	-	3+	-	6.68	-
73	-	-	2+	2+	5.5	43	-	-	2+	2+	5.68	2+
74	-	-	1+	3+	6.0	-	1+	1+	1+	3+	6.37	-
75	-	-	-	-	6.5	49	-	-	1+	-	7.16	1+
76	-	-	-	3+	6.0	70	-	-	-	3+	6.21	2+
77	-	-	3+	-	5.0	-	-	-	2+	-	5.32	-
78	1+	-	-	-	5.5	-	1+	-	-	-	5.76	-

79	-	-	2+	-	6.0	-	2+	-	-	2+	6.46	-
80	-	1+	1+	1+	5.5	67	-	1+	1+	1+	5.56	2+
81	-	-	2+	-	5.0	74	-	-	2+	-	5.32	2+
82	-	-	-	2+	6.0	-	-	-	-	3+	6.49	-
83	-	-	1+	3+	5.0	128	-	-	1+	3+	5.32	3+
84	-	2+	1+	-	5.0	-	-	2+	-	-	5.18	-
85	-	-	-	-	7.0	269	-	-	-	-	7.34	3+
86	-	-	3+	-	6.0	615	-	-	3+	-	6.46	4+
87	-	-	-	1+	6.5	-	1+	-	-	1+	6.97	1+
88	-	-	-	1+	6.5	-	-	-	-	-	6.63	-
89	-	-	2+	3+	6.5	113	-	1+	2+	2+	6.34	3+
90	-	-	1+	-	6.5	-	-	-	2+	-	6.05	2+
91	-	-	-	-	5.5	42	-	-	-	-	6.29	2+
92	-	-	-	1+	6.5	87	-	-	-	3+	7.02	2+
93	-	-	-	1+	6.0	33	-	-	-	1+	6.46	1+
94	-	-	1+	-	6.0	-	-	-	1+	-	6.32	-
95	-	-	-	1+	5.0	32	1+	-	-	1+	5.42	1+
96	-	-	-	1+	6.5	-	-	-	1+	1+	6.97	-
97	-	-	-	1+	5.0	-	-	-	-	1+	5.49	-
98	-	-	-	1+	7.0	-	-	-	-	1+	7.29	2+
99	-	-	1+	-	5.0	-	-	-	1+	-	5.44	-
100	-	-	-	2+	5.5	-	-	3+	-	2+	5.87	-

* represents the hospital result. “-, 1+, 2+, 3+, 4+” represent “negative, level1+, level2+, level3+, level4+”, respectively. Red results indicate that data do not match with the hospital instrument.

Table S3 Comparison between our method and conventional methods for urine detection.

Analytical method	Detection range	Detection time	Automation	Reference
HSV color space	Neg, level1-3	-	Manual photography	[17]
Spectrometry	pH 5-7.5	-	Manual photography	[19]
Paper-based Hybrid LOC device	glucose 0-350 mg/dl	240 s	Low degree	[20]

	protein 0-2000 mg/dl			
CIE lab color space	pH 5.25-7.5 glucose 2-19 mM protein 0.2-1.7 g/L	120 s	Manual photography	[21]
HSV color space	pH 5-9.5 Neg, level1-4	60 s	Operated by a touch screen	Our work

Highlights

An optical POCT device was achieved with (1) a programmed Raspberry Pi with a CSI camera, which can achieve quantitative analysis with satisfactory accuracy for detection of ketone bodies, glucose, protein, occult blood, pH, and leukocytes in human urine samples. (2) The optical POCT device has a pocket size with dimensions of 85 × 60 × 65 mm (length × width × height), representing a portable and stable application for home health monitoring of patients. (3) A black box with an independent internal lighting system was designed to eliminate the influence of ambient light, which can considerably enhance the accuracy and sensitivity of POCT using colorimetric detection.