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Smartphone-based point-of care quantitative urinalysis device for chronic kidney disease patients:

-Quantitative urinalysis of human serum albumin(HAS)\_using AIE nanomaterial bioprobe

normal threshold value of 30 mg/dL microalbuminauria exhibits al\_ levels of more than 30mh/dL

Colorimetric investigation

such as those from Dirui, Cormay, Spinreact, Roche, Siemens, Rayto, PocketChem and Arkray

More recently launched reagent strip devices such as Siemens DCA Vantage Analyzer (DCA Vantage) are capable of producing semi quantitative analysis,

An alternative solution to smartphone-based urinalysis is to image

and automatically analyse assays confined within disposable test tubes

for full-quantitive detection of albumin in urine,

Differences between uTester and Albumin

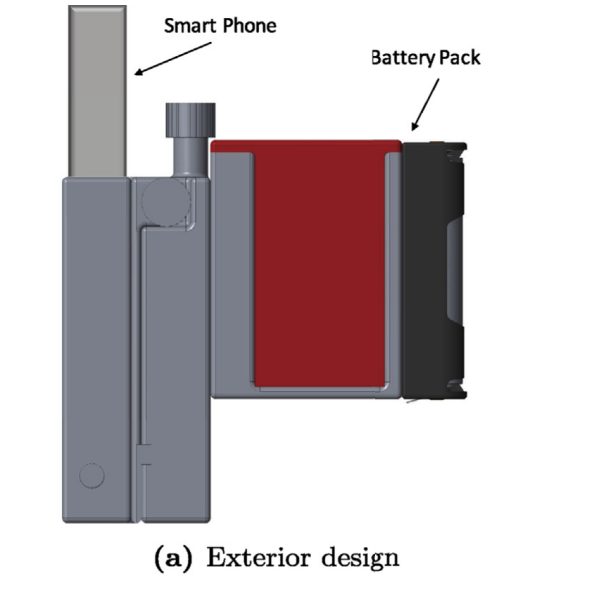
1.uT explores a new reagent BSPOTPE that is based on aggregation-induced nanomaterial bioprobes ,w whereas AT uses a commercial reagent \_Albumin blue 580- from active Motif.

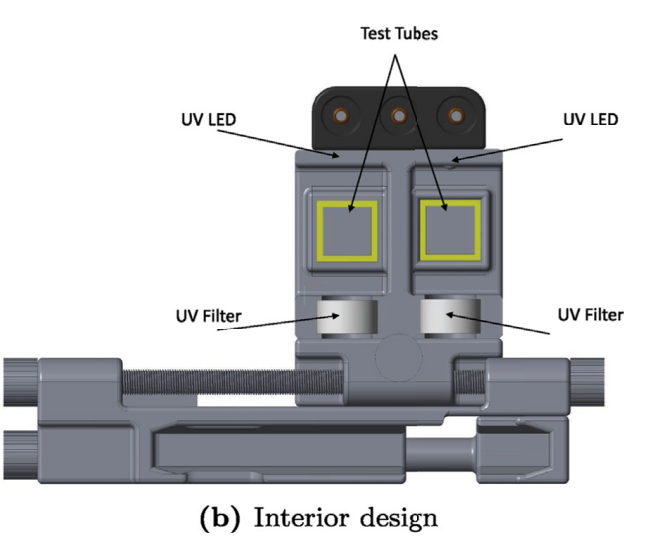
2.uT requires only single tube for test filled with AIE reagent and AT requires two test tubes filled with different reagents for the AIE reagent.

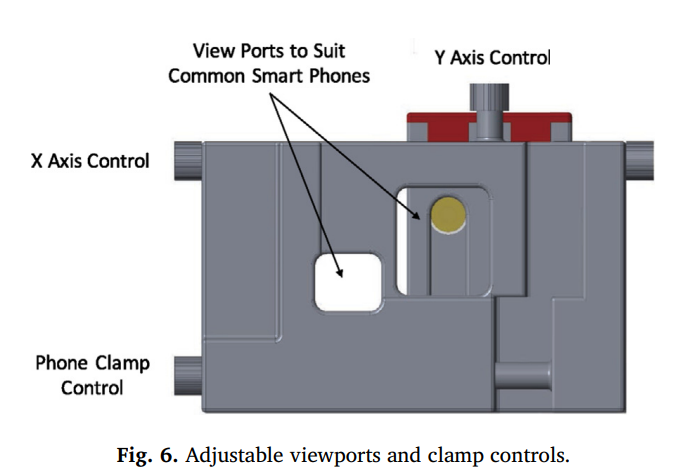
The device consists of five key components: the smartphone, the albumin test reagent BSPOTPE, the imaging housing, the image processing and analysis techniques underpinning the mobile application, and mobile application itself.

Artificial urine which was prepared following Chutipongtanate’s AU-Siriraj protocol (Chutipongtanate and Thongboonkerd, 2010), with pH of 6.8 and gravity of 1.010 g/mL. PBS (Phosphate-buffered saline) was made according to the cold spring harbor laboratory protocol (Cold Spring Harbor Protocols).

Imaging housing and camera calibration







To ensure a consistent imaging condition across different smartphones

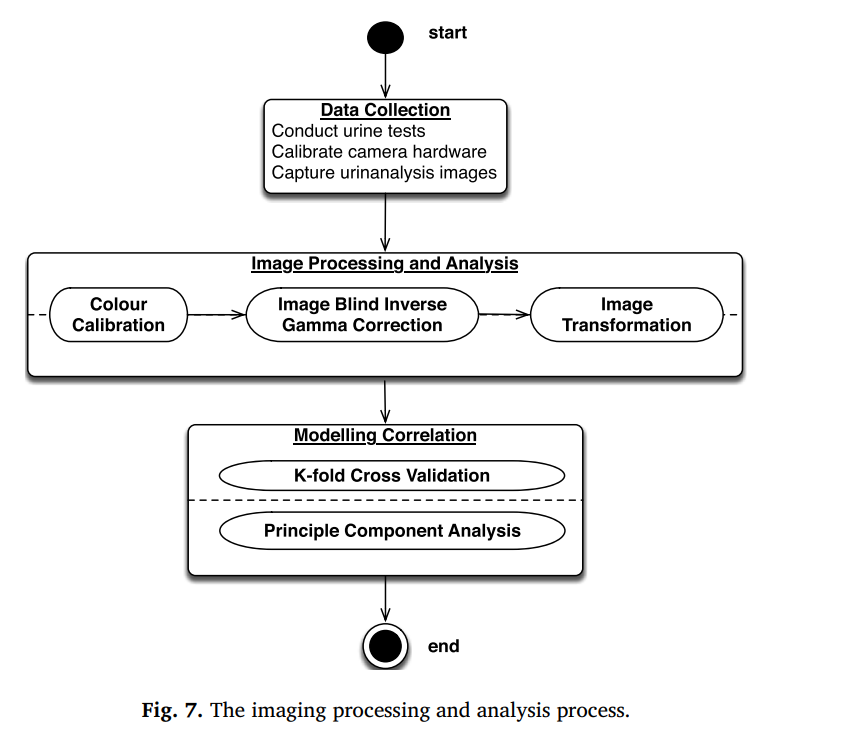
• Setting the image size of 3264 × 2448 (4:3) (8M).

• Choosing a low ISO of 200/100 to avoid noise in order to capture a high quality image under low light conditions (Nour Abura’ed and Khan, 2016). ISO controls the sensitivity of a camera’s sensor.

• Set Auto White Balance (AWB) into Daylight to preserve the colour response as a constant (Tai et al., 2012; Zhang and Batur, 2012). AWB algorithms try to account for changes in human visual sensitivity under different ambient illuminant conditions (Xiao et al., 2003).

• Turning off High Dynamic Range (HDR). HDR is used to increase the span between shadows and highlights in an image (Au and Donn, 2003).

*Image processing and analysis.*



After we obtain images from a smartphone equipped with the housing, we need to deicide which method should be used to transform the visible EM into digital signal. In other words we need to choose the vest model to represent the colour intensity that well responds to the FL intensity.

Human eyes perceives colours by brightness attributes while a computer can describe a colour by using the RGB model

However it is not the best model to perceive as it is psychologically non-intuitive and perceptually non-uniform

A better alternative is HSL model.

Hue:pure spectrum colours and corresponds to the prevailing colour as perceived by a human,

Saturation refers to proportional purity, and luminance refers to the amount of light in a colour we are especially interested in the luminance of a particular colour in the captured image as it corresponds to the FL intensity we need to measure.

The process to get colour luminance value is describes as follows.

1. Identify a region of 32 × 32 with uniform and homogeneous colour within the centre of the image.
2. Transform the RGB colour space of the selected region into the HSL colour space
3. Calculate the mean values of the intensity band of the HSL colour space from the selected region.
4. Retrieve the mean lightness value from the HSL colour space to represent the luminance colour band of the region.

Process starts with data collection by first calibrating camera hardware and then capturing urinalysis images from the urine tests. After capturing a sequence of urinalysis images corresponding to different albumin concentration levels, the process proceeds to image processing and analysis consisting of a series of subprocesses in the order of colour calibration, image blind inverse gamma correction, and image transformation. The final stage of the process is to model a relationship between image luminance values and HSA concentration levels through a modelling technique such as Principle Component Analysis (PCA) or K-fold cross-validation

A more accurate improvement mist be applies to the images captured by the already calibrated cameras. However, the effect of software improvement must be kept to a minimum in order to avoid amplifying noise, clamping and colour space distortion errors, three different post processing methods are found useful to improve the results, including

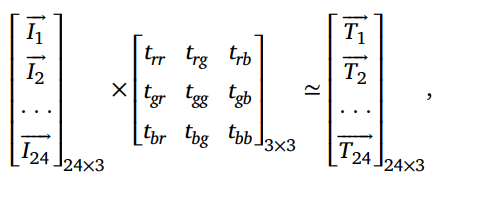
1.linear least square matching,

2.3\*3 RGB to RGB linear transform,

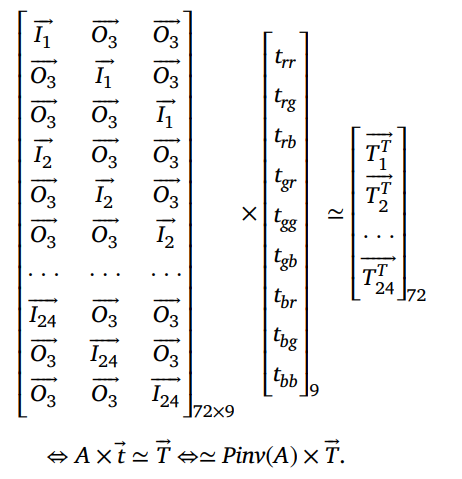
3.General polynomial transform,

2. is one of the common post-processing methods used to account for the inter-channel effects. It transforms the 24 colour samples of a camera image into the parallel colour samples of a target image.

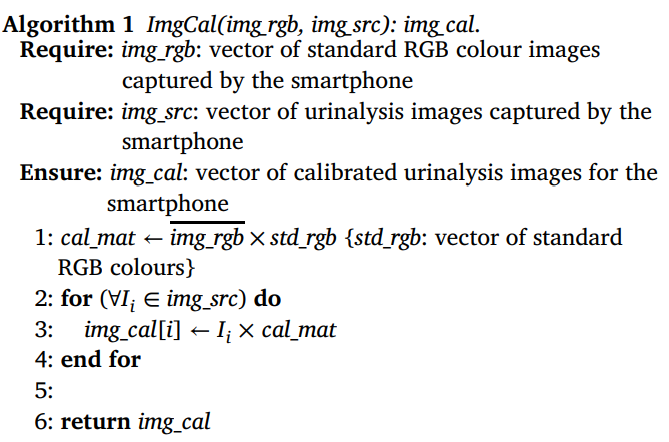
The following matric is the key solution to the over-constrained matrix system:



The following is a linear system below:



* 1. Colour calibration



* 1. Blind inverse gamma correction

