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Optimizing the MFlex monitoring system using Mahalanobis-Taguchi system

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Abstract. Methadone Flexi Dispensing Service (MFlex) has been officially re-branded from Methadone 1Malaysia Service (M1M) since 2nd January 2019. Patients under MFlex are frequently taking their methadone according to a plan provided by pharmacist at public clinic. From the dose monitoring taken annually, pharmacists can predict critical patients based on high monthly dose increases. However, the current monitoring system is written documentation with total doses that cannot accurately measure addiction levels and slow down the distribution process to appropriate incentives as provided by the government. The main objective of this work is to develop a new data monitoring system by evaluating all factors contributed to the addiction level. Mahalanobis-Taguchi System (MTS) is a method of predicting and diagnosing system performance using multivariate data in order to make quantitative decisions with the construction of a multivariate measurement scale using an analytical method. The results show that the minimum Mahalanobis Distance (MD) for healthy data is 0.2245 while the maximum is 2.3380. The minimum and maximum MD of unhealthy data is 0.6077 and 24.5719 respectively. Thus, parameters of blood, bilirubin, nitrite, specific gravity, leukocytes are considered as significant parameters by considering positive value signal-to-noise ratio (SNR) gain. Graphical user interface (GUI) has been developed for analyzing the normal and abnormal patients in detail. Meanwhile, mobile application has been developed as a decision-making tool to classify that the patients is either normal or abnormal.

1. Introduction

Methadone Flexi Dispensing (MFlex) has been widely used to help in rehabilitation of drugs addicts. MFlex patients take their methadone according to a prescription given by the pharmacist at the government clinic. The concentration of the dosage given to the patients is depends on the critical condition of the patient. Even with the help of MFlex, the relapsed cases keep increasing in this four years' period. National Anti-Drugs Agency (NADA) stated that 8,754 relapse case in 2019 per case. Approximately 1000 increment from year before.

In 1936, a notable Indian analyst Prasanta Chandra Mahalanobis built up the MD to recognize individuals from a gathering through qualities by taking the connection structure of a framework which may or not be associated. Then in the 1950s, Taguchi's hearty design was acquainted by Genichi Taguchi with improving the designing quality which can be estimated as far as deviations from the ideal presentation. In this way, Genichi Taguchi incorporated the thought toward MTS for strong designing by giving away to characterize the reference gathering and measure the level of the anomaly of individual perceptions.

These days, with the accelerated progress of creativity, associations have the potential to gather a lot of knowledge needed for the inquiry. However, in the case of a state-of-the-art company, it is more important to handle the enormous amount of knowledge. For example, the retrieval period of significant data from a large knowledge base [1]. According to Cudney et al., [2], MTS is a technique that suggested by Genichi Taguchi for predicting and diagnosing the system performance which used multivariate data to settle on a quantitative choice with the development of a multivariate estimation scale that utilizes an investigative strategy. In a multivariate framework, decision-making is based on examining the data that gives more than one variable. The system is incomplete when the calculation for every variable does not consider the relation of all variables. As described by Cudney et al., [3], in order to create a multidimensional measurement scale, it is necessary to provide a distance measurement dependent on the correlation between the variables and the various patterns. These patterns may be defined and evaluated with respect to the basis or reference point.

MS is a reference group in the MTS is obtained by applying uniform variables of healthy or normal data or target group. Nevertheless, MS can be used to differentiate between normal and abnormal objects or target and off-target group as well. Orthogonal array (OA) or so-called Taguchi design is a method for developing applications that involves a fraction of the complete factor combinations. The orthogonal array ensures that the development is calibrated such that the degree of the factor is evenly weighted. According to [4], each factor can be evaluated by other factors, thus, it does not affect one factor although it is influenced by estimation of another factor. OA and SNR reduce the number of attributes. However, this should not reduce the crucial performance of the system.

The MD concept is applied where the measurement of two parameters is identical to the spatial orientation that is far away [5]. MTS is a multivariate data set that is obtained from a large data size, accompanied by the isolation of healthy or normal data sets from abnormal or unhealthy data sets [6]. By using the healthy data collection and serving as a reference metric, MD can calculate and scale of used and un-used resources. The MD is scaled by dividing by the number of variables. Thus, the average length of the scaled MD is roughly similar to that of the known healthy dataset. Subsequently, for unhealthy dataset, the scaled MD is supposed to be significantly larger than one. When the MTS starts approach a large number of features in each multivariable dataset, the chance for a multivariable dataset to contain an important feature is good. The key features in this case are those features that render the scaled MD wide for unhealthy data. Figure 1 shows the concept of MTS which has four phases according to [7], the MTS concept is ideal for use in various application fields.

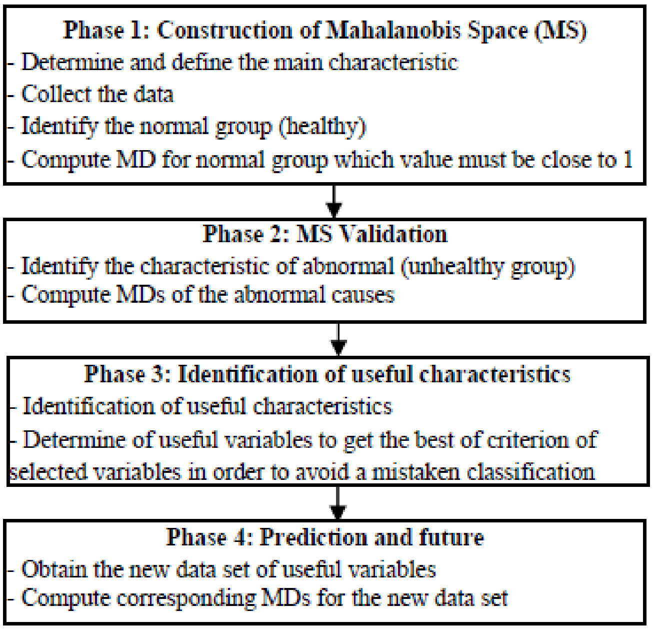


Figure 1. Concept of MTS [7].

A significant feature of MTS is the calculation of the signal-to-noise ratio (SNR) dependent on the Mahalanobis distance of the characteristic variables in the classification process [9]. In false alarm situation, according to international guidelines, there are various types of fire situations. All of these fire situations should be recognized by a fire alarm system. MTS was then used to increase process control and improve the effectiveness of the sensor system by reducing false alarms [10]. In [8], it compares MTS to journal's other methods. The findings show that the MTS is more effective in forecasting a discriminatory analysis or an increasingly discriminatory analysis, independent of the full model or the reduced model. The MT approach uses only simple mathematical principles that are present in many statistical computing systems. Hsiao et al., [11] used MTS as a method of solving class imbalance data by displaying classification templates for MTS which is constructed by identifying a reference base using just one class of samples, as opposed to developing from the dataset, which could have unequal class distribution. It was shown that this intrinsic property is useful to overcome the problem of class inequality.

However, MTS has a downside that it cannot solve the serious problem of correlation between variables [9] [12]. In [13], Reséndiz-Flores and López-Quintero stated that methodologies based on MTS only perform optimal selection of features while Mahalanobis distance is used to build reference space. Production of MTS-based fault detection methods is therefore largely dependent on the previous classification of data into healthy and unhealthy classes. Wang et al., [14] claimed that when MTS is used to identify the fault of the bearing, resulting in an error due to the lack of appropriate variation of the signal-to-noise gain level. The MTS suffers from the lack of a robust systematic procedure to assess the criterion for discrimination between the two groups [15].

There are a variety of published works on MTS. [16] found the positive signal-to-ratio (SNR) gain shows the efficiency of the system still in fine condition from February with 0.1244 to December with 0.4432 after an irrelevant variable has been removed. [17] identified that 4 insignificant and 11 significant parameters in the visual mechanical inspection workstation using the method for optimization. [18] diagnosed the process on production line in electric and electronic industry using MTS and time-driven activity-based costing

(TDABC). [19] proposed of MTS and TDABC in electric and electronic industry to determine the important parameters and establish the time equation and the cost rate of capacity respectively. [20] measured the degree of abnormality with MTS and diagnosed the parameters that affect the system. [21] evaluated the criticality of the end-of-life crankshaft parameters dependent on the Taguchi's orthogonal array and subsequently estimated the cost using traditional cost accounting by considering the critical parameters. [22] defined critical and non-critical variables during the remanufacturing process using MTS and simultaneously estimate costs using the activity-based costing (ABC) system. [23] developed a distinctive pattern of crankshaft and identify the critical and non-critical parameter of crankshaft based on the MTS and subsequently applied ABC as a method of estimation for the remanufacturing cost of crankshaft. [24] classified end-of-life crankshafts for recovery operations dependent on MTS. [25] provided systematic pattern recognition using MTS by creating a scatter diagram that could assist industry decision making in 14 major crankshaft papers, 7 engine models with different sample numbers belong to each other.

Therefore, this work is really important to support the existing literature on the application of MTS in healthcare monitoring system.

2. Methodology

2.1. Construction of Mahalanobis space

First, specify the variables in this phase that determine which cases are considered "healthy" or "normal" and those that are not "normal". Based on table 1, the negative row value shows the healthy data. All parameters in the test area row are determined as the variable.

Table 1. Sensitivity/ limit of detection of test strips for urinalysis (model: sd urocolor).

Test Area	Results	Negative (-)	Trace (±)	Positive +	++++
Blood	Conc. (RBCs/µl)	0		10	
Ascorbic Acid	Conc. (mg/dl)	0		10	
Bilirubin	Conc. (mg/dl)	0		0.5	
Glucose	Conc. (mg/dl)	0	100	250	2000
Ketones	Conc. (mg/dl)	0	5	10	
Leukocytes	Conc. (WBCs/µl)	0		25	
Nitrite	Conc. (mg/dl)	0		>0.5	
pH	pH value	5.0	6.0	6.5	8.0
Urobilinogen	Conc. (mg/dl)	0.1	Normal ↔	1	12
Protein	Conc. (mg/dl)	0	10	30	1000
Specific Gravity	S.G. value	1.000	1.005	1.010	1.025

Then, collect all the data required from all the variables in the data collection. For "healthy" and "unhealthy" cases, a factor analysis method has been applied to the data test set in our method. Before implementing the MT strategy, the training set will be refined. We then standardize the variables values.

$$MD_j = \left(\frac{1}{p}\right) Z_j^T C^{-1} Z_J \quad (1)$$

$$Z_J = \left(\frac{x_{ij} - \bar{x}_l}{s_i^2}\right) \quad (2)$$

$$\bar{X}_i = \frac{\sum_{j=1}^{m} x_{ij}}{m} \quad \text{and} \quad S_i^2 = \sqrt{\frac{\sum_{j=1}^{m}(x_{ij}-\bar{x}_l)^2}{m-1}} \tag{3}$$

Eventually, we only use the inverse of correlation matrix (MTS method) to measure values of Mahalanobis distance (MD) for health circumstances.

2.2. Mahalanobis space validation

For the next stage, measure the MD values for findings which do not relate to a healthy population. In this cases, unhealthy group is in positive row of Table 1. The basic concept behind the MT approach is that abnormal cases will never relate with another group, and every case is special. Therefore, while using the mean and the standard deviations of the corresponding variables of the healthy population, the values of the variables in these abnormal cases are normalized. The correlation matrix (MTS method) referring to the category of healthy findings is used to measure the MD values for abnormal cases. The scale has been verified by a quite simple rule: the MD values for abnormal findings for healthy population findings will be higher on an effective scale. It simply means that they are farther away from the middle of the healthy case population than all of the healthy cases. This is conceptually right, even if they are not, there is no basis to argue that they are irregular based on the measurements taken in the situation.

2.3. Identification of the most useful set of variables

At this point, the key objective is to determine the optimum subset of variables. In other words, we are attempting to eliminate unnecessary factors that do not influence the precision of the measurement scale. Orthogonal arrays (OAs) and signal-to-noise ratios (S/N) are also used, then it is accomplished.

$$\text{S/N} = 10\log_{10}\frac{\frac{1}{r}(s_\beta - v_e)}{v_e} \tag{4}$$

where,

S_T = total sum of squares ($\sum_{i=1}^{t} y_i^2$)

S_β = sum of squares due to slope ($\frac{1}{r}\sum_{i=1}^{t}(M_i y_i)^2$)

r = sum of squares due to the input signal ($2\sum_{i=1}^{t} M_i^2$)

S_e = error sum of squares ($S_T - S_\beta$)

V_e = error variance ($\frac{S_e}{t-1}$)

2.4. Diagnostic and prediction of future observations

In the final step, just the "optimal" subset of variables that have been detected in the previous phase is used to reconstruct the measurement scale. Consequently, for any unknown cases, the restored scale is used to measure the values of the MD to take any corrective action if necessary. By setting an appropriate criterion (for classification problem) or specifically (for prioritizing based on an abnormality scale), the final measuring scale can be used in a possible diagnosis.

The gain for each variable is determined by subtracting the average S/N ratio when the variable was exempted from the average S/N ratio when the variable was included as can be seen in equation. (5).

$$\text{Gain} = (\text{S/N Ratio}_{\text{avg.}})_{\text{variables present}} - (\text{S/N Ratio}_{\text{avg.}})_{\text{variables absent}} \tag{5}$$

3. Results and discussions

The main layout of the GUI is shown in figure 2. The main layout consists of inserting data, choosing data, revealing data, generate data and program execution button.

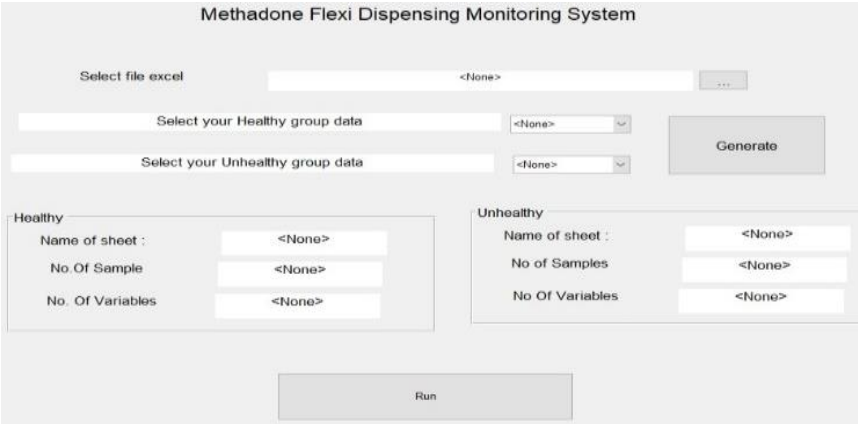
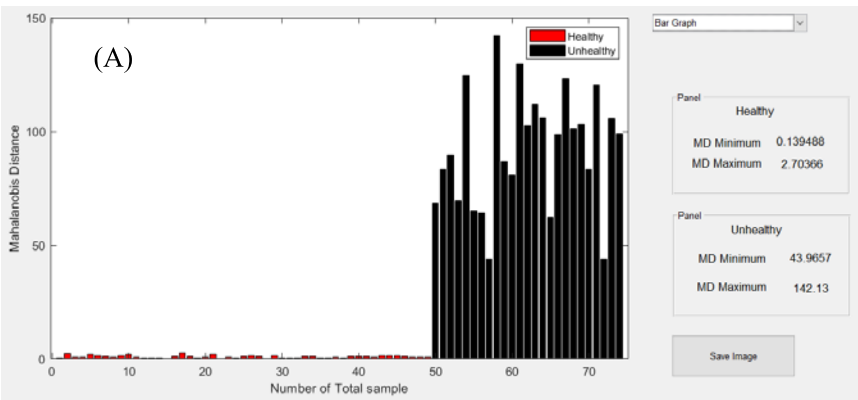


Figure 2. Main layout of Graphical User Interface.

The minimum and maximum data then shown in the graph layout after calculated. The selected valid data in the Excel file will return to the GUI. After that, the total sample and total variables are generated. To run the program successfully, the number of variables for both selected sheets must be the same and the position of each variable must be the same.

3.1. First case: Normal and abnormal within their specification

The first validation test was performed. The system will automatically calculate the MD as a result and plot a graph. This is to test the abnormality of the MD. It contains 49 samples for healthy data and 25 samples for unhealthy data. The result for each variable in healthy data is within the negative outcome of the reference table 1. Meanwhile, unhealthy data surpass the normal range, which means that each sample has a value at each variable within a positive range. The range of MD between healthy data and unhealthy data is out of the range. The minimum and maximum value of MD for healthy data is 0.1395 and 2.7037 respectively. Two types of data can be selected to ease the vision of the user.



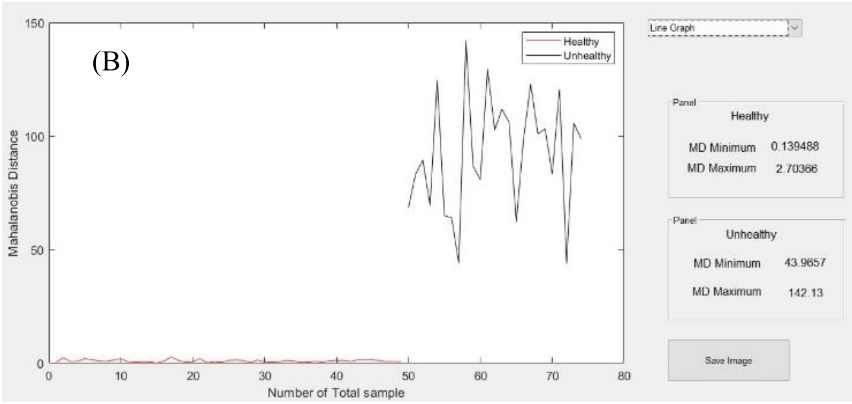


Figure 3. Healthy patient within normal range and unhealthy patient exceed normal range for (A)Bar Graph and (B)Line Graph.

3.2. Second case: Normal within normal specification and abnormal within normal specification

The data consists of 49 samples for healthy data and 25 samples for unhealthy data where the users were in between the normal range. The range of MD between healthy data and unhealthy data is close. This shows that the data for healthy and unhealthy were in range for every variable. In other words, every sample has a value of each data within the range or in a negative row.

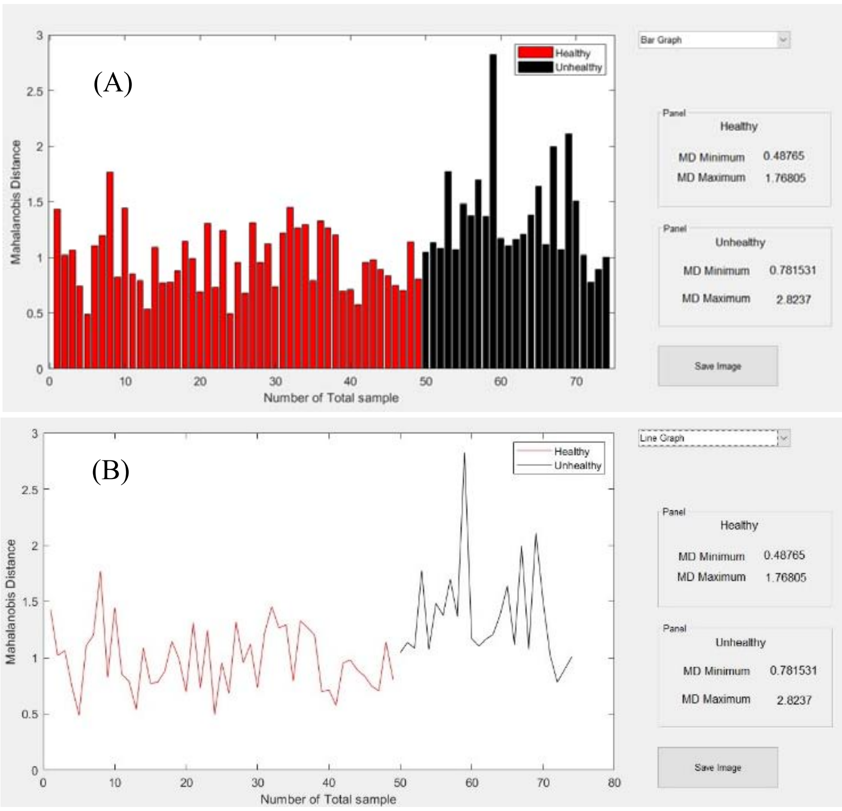


Figure 4. Healthy and unhealthy within normal range for (A)Bar Graph and (B)Line Graph.

3.3. Implication on real patient case

The data were taken from public clinic at Pekan, Pahang. The system generated all the data needed for the calculation of the MD. The range of the MD is shown in figure 5 by graph. Some of the point in unhealthy MD is in range of healthy data. The minimum MD for healthy data is 0.2245 and the maximum MD is 2.3380. The minimum and maximum MD of unhealthy data is 0.6077 and 24.5719 respectively.

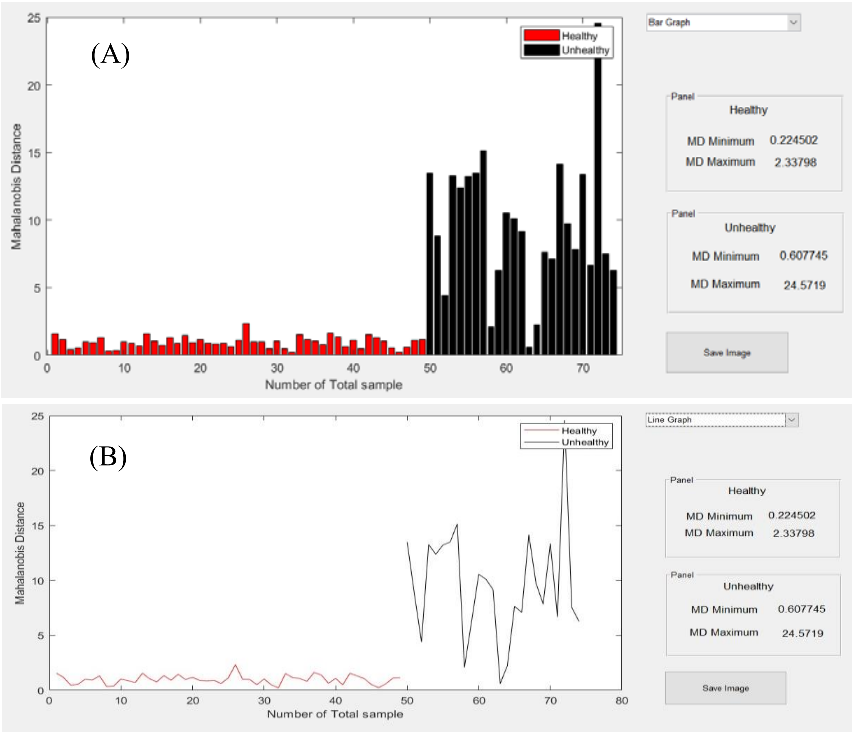


Figure 5. Patient's data for (A)Bar Graph and (B)Line Graph.

3.4. Implication towards optimization

In figure 5, the table shows the gain of the data. The highest value of data is 2.2053 which is the second variable. The lowest value of gain is -0.4447 which is the eleventh variable. Parameter number 1, 2, 6, 9, and 10 (blood, bilirubin, nitrite, specific gravity, and leucocytes) has a positive value while else has a negative value. It does mean that the positive value is a significant variable.

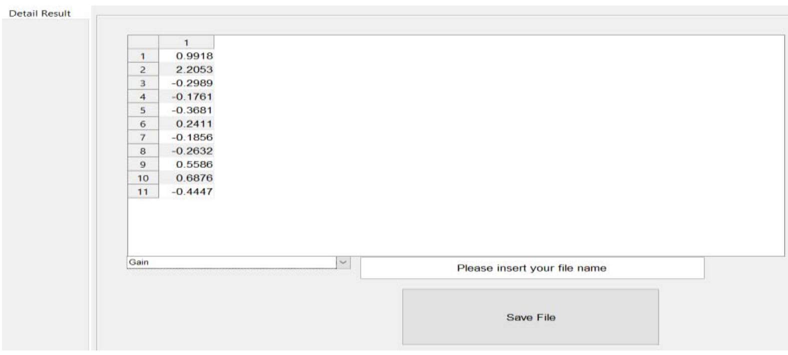


Figure 6. Gain of the data.

3.5. Mobile Application

In mobile application, the user insert required data to generate and store patient's data. The data required is the value of concentration of ascorbic acid, blood, ketones, nitrite, specific gravity, bilirubin, glucose, leukocytes, pH-value, and urobilinogen. A random patient's data was inserted in mobile application. Based on the figure 7, the system detects the patient's as normal patient when the value for each parameter does not surpass the normal value. For the figure 8, the patient was detected as an abnormal patient because some of the value in parameter exceed the normal value. The value for each parameter then will be stored in google sheet to ease the doctor for storing the data of the patient.

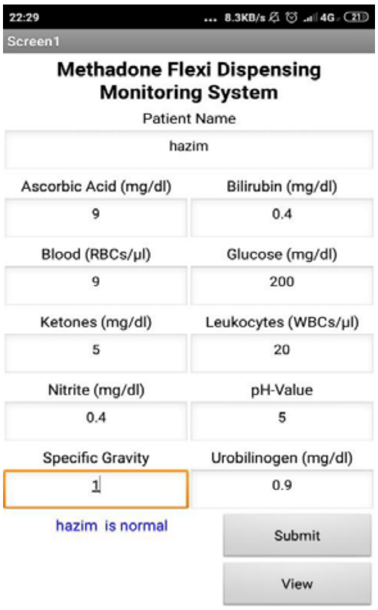


Figure 7. Mobile Application testing healthy.

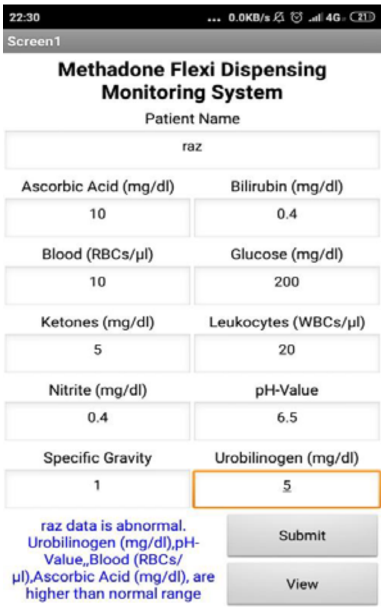


Figure 8. Mobile Application testing unhealthy.

4. Conclusion

In this work, a classification of urine test through Mahalanobis distance is achieved based on the minimum MD for healthy data is 0.2245 and the maximum MD is 2.3380. The minimum and maximum MD of unhealthy data are 0.6077 and 24.5719 respectively. Thus, parameter of blood, bilirubin, nitrite, specific gravity, leucocytes are considered as significant parameter by considering positive value SNR gain. GUI has been developed for analyzing the normal and abnormal patient in detail. Meanwhile, mobile application has been developed as a decision making tool to classify that the patient is either normal or abnormal.

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