Design of a low cost system for determination of fat using IOT and ML

A A H Patil1, E G Jakatdar2, S C Bhadreshwarmath3, V R Kumbhar4, P P Mitragotri5, B B Deshmukh6 and R D Mistry7

1,2,3,4,5,6,7Mechanical Engineering Department, Walchand Institute Of Technology, Solapur, 413006, India.

*Corresponding Author: A A H Patil. Email: patilalifya@gmail.com

Abstract: The husbandry is very important business of Indian farmer. Dairies collect milk from farmer everyday & payments for this milk are done according to the quantity and quality of milk. This rate depends on various quality parameters of the milk. Fat is one of most important component of milk. Due to its higher importance along other quality parameters of milk, it becomes mandatory for the determination of fat percentage especially for the milk vendors, small dairy owners etc. The classical method used to determine the fat percentage in milk is Gerber method. It's a chemical test which is destructive in nature. Due to inclusions of various chemicals it becomes time consuming procedure for determination of fat in milk. Due to this, the number of samples that can be tested is very low in a given period of time. This paper presents the design and development of Milk Fat Analyser. The system is built by interfacing Light Dependent Resistor (LDR) with Raspberry pi Microprocessor. The parameter that is measured is fat percentage. The result obtained is displayed on screen which provides a good interface to the user. This project aims to provide a low cost, fairly accurate and reliable system to the farmers, small dairy shop owners and similar small factories where quality of milk matters while processing it to make other milk products and also for supplying milk consumed by people at large. Experimental results show that the method with Machine learning algorithm can detect fat with fair accuracy.

Keywords: IOT, ML, Raspberry pi, Arduino Uno, Randomforest Algorithm, Milk Fat Measurement

1. Introduction

Milk Analyser available for measurement of the major parameter in milk like fat percentage is really expensive and not affordable to farmers or small dairy owners. The ones which are bought by people range from INR 20K to INR 50K. In order to provide a cheaper milk analyser a system has been proposed in this paper. If milk quality parameters such as Fat percentage, SNF, adulteration mainly water, pH (safe range 6.5 to 6.9), temperature, odour etc. are known then the quality of milk can be determined. So through this project the required parameters will be measured with fair accuracy and the
whole system will be made developed at a cheaper rate. Primarily, the major focus of this paper is on accurate determination of fat percentage as SNF can be determined using fat percentage.

It is important that milk analysers are made cheap so that it is affordable to as many people as possible and the quality of milk being supplied by the farmers to the dairies or any other milk processing factories is known. Knowing milk fat is important for the farmers as they need to sell the milk that their cattle produce. Not just to the dairy owners but also in the big milk processing industries such milk analysers are used to determine the milk’s quality. Adulteration in the milk which is generally in the form of water reduces its quality and is not good enough for consumption and is really very unhealthy. So through such systems where we get results quicker, at low power consumption and at less cost such malpractices can be stopped as every dairy owner or factory owner will be able to get the milk quality tested.

The above mentioned aim can be achieved by interfacing various electronic sensors with the Raspberry pi microprocessor. The parameters that will be displayed on the screen are Fat percentage, Temperature and pH, etc.

2. Literature Review

We have carried out literature review to understand the work that has been done in the area of analyzing quality of milk by the measurement of its parameter. While doing so we came through a lot of techniques used in the market today which helped us understand how important it is to measure the quality of milk as it affects a lot of industries and people at large. Through the process of developing our idea we came across some good work done by people around the globe which has been described below:

An Arduino microcontroller was being employed for developing a less costing milk parameter detecting system[1]. The merits of their system are low power consumption, compact size, low weight, etc. which they offered by using embedded systems. This research paper narrates about the implementation of an Arduino based system that calculates and projects the parameters such as CLR (Corrected Lactometer Reading), pH, SNF (Solid but Not Fat). The CLR and the pH were calculated using pH sensor and lactometer respectively. SNF was calculated using CLR value. The milk parameters were displayed on the LCD panel. To check adulteration of milk low cost alternative is not available for now. The main goal of this research paper was to build a system which costed less and consumed less power.

Irrespective of the scale of the milk industry the testing and the control of quality are the major and required components of a milk processing industry[2]. There is always a risk of adulteration by unfaithful farm workers in the milk as it is made up of 87% water. Under unhygienic production environment and storage at ambient temperatures there is a risk of rapid multiplication of bacteria in the milk because of its high nutritive value.

The reasons behind costly testing as described in the paper were:-

- The Milk Processor:-The producer is paid by the milk processor so he needs to ensure the good quality of milk because it is directly consumed by people or is used for making a variety of products.
- The Consumer:-The consumer directly pays money for milk he/she buys so good quality milk needs to be supplied to the consumer.
- The Milk Producer:-The producer is directly paid the cost of milk so for the person who purchases this milk in huge quantity the quality of milk becomes important. Hence to improve the sensitivity of the system the cost increases.

Ultrasonic milk analyzers are in operation in the existing system and the analysis of milk of buffalo, cow, sheep is made and also accurate analysis of cream 45%, UHT milk and other products is done[3]. The different components of the milk like protein, lactose, added water, fat, SNF, density, temperature of the sample, freezing point, total solids, and salts are calculated by them. The aim of their project was to develop methods and instruments for milk quality analysis and its inspection as well. It is one of the finest work done in the field of electronics showing its power. Using electronic
devices it helps in determining milk density, its conductivity, etc. of milk in labs and in milk industries. Automatic and efficient analysis of milk samples can be done by this system. Here the interfacing of the project with the computer was done and it automatically collected all the data or parameters and stored them for future reference.

The optical scattering principle of light by the fat particles present in homogenized milk provides an alternative method for fat measurement [4]. Large numbers of charge carriers get excited when an adequate amount of light falls on the LDR. Hence, more current starts flowing and the resistance of the LDR decreases. The accurate information about FAT, SNF & CLR content was displayed on the LCD screen. In order to give farmers what they deserve depending on the quality of milk they provide they have carried out this research. The credible and economical technology used in their project improved the delivery system by ensuring immediate payment to the farmers, diffusing their confidence in the dairy industry, and by doing this the risk of accepting unfavourable samples also got reduced.

The work done on measurement of two important constituents which are density and fat content is crucial in the analysis of milk [5]. For determination of density the height of the u-tube manometer type device was used to get the density of milk being measured. The value obtained was divided with the density of water to get the CLR reading which was called Auto CLR reading. This value was more accurate than the CLR reading obtained using the Lactometer. For the measurement of fat content the known scattering principle of light was used. The IR module and phototransistor were used as modules to determine fat content. The transmitter and receiver was separated by a certain distance and a milk sample was placed in between them and measurement was done. Certain band of light got absorbed by the IR module and the light reaching the receiver was the measure of fat content.

The existing milk analyzers work on ultrasonic technology and are pretty expensive so, hence research on producing low cost analyzers is being done [6]. And in order to reduce the machine cost, they have shown how one can go with the embedded systems in which a computer system can be designed to perform a specific task and show output. Since it is compact and requires less power, it reduced the cost of the machine. The proposed method in this paper to determine fat it included use of sensory organs in which Light dependent resistor (LDR) was prime. When light passes through a milk sample, it is intensity reduces due to scattering of light by fat globules was the principle on which they worked. The un-scattered light was detected by LDR. Then, a relationship was developed between the amount of light in-scattered and the fat percentage and with the use of embedded systems they displayed fat percentage as output. The overall performance of the developed system was quite reliable and highly accurate because of the use of microcontrollers. The hardware used was very less that reduces the cost of the system. And they gave a future scope by saying that other milk quality parameters like SNF, Density, CLR etc could also be determined in the same and cheaper way.

The description of the processes of determination of various parameters of milk is given [7]. The parameters discussed in this paper are acidity, density, total dry extract, cryoscopy, non-fat dry extract and fat content. The methods discussed in this paper for measurement of various parameter were:

- Density – Thermolactodensimeter
- Fat content(F) - Gerber’s method
- Total dry extract(TDE) - Using Ackermann’s disc
- Non-fat dry extract(NFDE) - NFDE=TDE-F
- Cryoscopy - Using electronic cryoscope
- Acidity - Using salut acidimeter

Simultaneous measurement of fat and protein as well as elimination of the problem of homogenization of milk which is generally faced during fat measurement is difficult to carry out [8]. The technique of ultraviolet absorption was used here to determine fat and protein. By dissolving milk in acetic acid a clear solution was obtained. The reading of absorbance was taken at 280 μm and protein was determined and then an urea solution was added to obtain turbidity which has nothing to do with size of fat globules and fat turbidity was obtained at 400 μm. Number of readings were taken for various samples of varying fat percentage and a graph of protein against absorbance at 280 μm and
fat against absorbance at 400 nm was taken. In the end they came to a conclusion that this technique could be applied to other food items like beans or eggs but further study is required.

3. Problem Definition

From the above literature review we learnt that a fat measurement system with low cost is not available as usually ultrasonic technique is used for measurement and the low cost system available don’t have fair accuracy. There have been attempts made in the past to produce a cheaper system but the sensor used for example, IR module and phototransistor are comparatively more costlier than LDR which was used by us. Some work has been done using LDR but the proposed system did not measure the fat percentage but only gave an alarm which helped to understand if the milk was consumable or not hence, this makes our system completely different from the ones that exist because we are using Machine Learning Algorithm to generate output. The output generated is fairly good, the system proposed is compact and cheap as well.

For determining the milk fat percentage, development of an IOT and ML based system is the major task to be done so as to precisely measure the fat percentage of any type of milk with a wider range of fat values at any given point of time.

Hence, developing the system at low cost and fair accuracy which is acceptable widely is the major goal to be achieved.

4. Proposed Work

For the measurement of fat the principle of scattering of red light when falling on fat globules present in milk is used. The difference in LDR reading with empty cuvette and with filled cuvette is taken to calibrate the fat percentage and this is fed into the RandomForest regressor to train the regressor for predicting the fat percentage from the difference of LDR reading for an unknown sample.

The outcomes proposed in this research paper are:-

- New method of calculating fat of the milk using a fundamental sensor and machine learning technique (Random Forest).
- Proof for the reproducibility and reliability of the system.
- Cost effectiveness in comparison with currently available milk analyzers.
- Compactness and portability of the system.
- Comparison of two models, one using Arduino which was previously used in other researches and our model which is constructed using Raspberry pi.

5. Methodology

The principle on which the system works is based on scattering of light by the fat globules present in the milk which get scattered when red light falls on the milk sample held in a cuvette. The red light falls on the cuvette from a red light emitting LED which acts as source of light.

![Flowchart showing process of fat measurement](image)

**Figure 1.** Flowchart showing process of fat measurement

The flowchart provided in Fig. 1 we can clearly get an idea about the flow of events carried out one after another for determination of fat percentage.
In Fig. 2 it can be clearly seen that the LDR is placed opposite to the cuvette. The unscattered light falls on the LDR directly and is a measure of the fat present in the milk sample. To minimise errors the cuvette is placed inside a black box which has two opening one for LED and the other one for LDR (Light dependent resistor) to pass through.

The amount of light that gets scattered by the milk sample depends solely on the fat content present in it as fat molecules are big enough to scatter the light falling on the sample. Hence the light that reaches the LDR depends on the fat in milk and the light reaching LDR produces change in resistance and this change in resistance is used to predict the fat percentage.

In order to predict the fat percentage, a dataset was created which consisted of LDR readings (difference between empty cuvette and cuvette with milk sample) for milk samples with known fat values. Then using a machine learning algorithm called RandomForest the dataset was trained and then using Raspberry pi the model was used to predict the fat percentage of unknown samples using the LDR readings obtained from the LDR directly.

The above Fig. 3 depicts the setup for fat determination unit which was placed in a small wooden box which made it handy to use and made it compact as well. As we can see these readings were taken on Arduino which just acts as interface for noting LDR values then the values were processed on Raspberry pi as Predictive Machine Learning programming cannot be done on Arduino and hence from the components used we can clearing understand that the setup was built at low cost.
The development cost of proposed system is less than that of the one available in the market and hence if this product is manufactured in mass production the cost would further lower.

6. Results

6.1. Verification of working principle
For measurement of fat, the LDR module was interfaced with a Raspberry pi microprocessor. Code was written to interface the LDR sensor on Raspberry pi, the cuvette was placed between the LDR and light source and a reading of empty cuvette was taken and the milk was poured in it and the new reading was taken and then the difference was calculated, as the fat of the sample was known. For verifying the working principle a milk sample was taken and water was added and 6 samples were prepared. As the water content increased the light reaching the LDR increased which by our logic we expected to happen because with addition of water the fat percentage was bound to reduce which reflected in the results we obtained which is as shown in Fig. 4.

![Figure 4. Verification of working principle](image)

6.2. Verification of reproducibility of system
After verifying the principle of working we went on to check the reproducibility of the system by taking multiple values for a same sample of milk, for which we took milk having 3.5% of fat in it. We took three readings for the same sample and the difference between the sample for empty cuvette and cuvette with milk sample was almost the same with very little variation in it which is clearly seen in Tab. 1.

| Sample No. | LDR Reading (Empty cuvette) | LDR Reading (Milk sample) |
|------------|-----------------------------|---------------------------|
| 1          | 926                         | 754                       |
| 2          | 925                         | 752                       |
| 3          | 923                         | 753                       |

6.3. Testing results of milk sample

6.3.1. Actual output on the existing machine. In Fig. 5 given below we can see that the fat percentage is 8.1%.
6.3.2. Output using RandomForest algorithm. Using the dataset obtained by collecting samples a model was trained using RandomForest Algorithm and following results were observed:

6.3.3. Output using MATLAB. In the below Fig.7 we can see the results for same sample done by computing the same data set on MATLAB and the output obtained was 8.02%.
6.3.4. **Comparison between results of MATLAB and RandomForest Algorithm.** A comparison between curve fitting using MATLAB on Arduino and RandomForest Algorithm on Raspberry pi:-

From the above figures we can see that the output for LDR reading 169 is 8.02% and the value obtained using RandomForest Algorithm was 8.1% which is equal to the value obtained using the Fat analyzers available in the market which are used by people.

7. **Conclusion**

From the current research is clearly seen that fat percentage was determined using a completely new method which incorporated the usage of Raspberry pi, LDR sensor and a machine learning algorithm which is RandomForest. The comparison between output generated using curve fitting on MATLAB via Arduino clearly depicted that RandomForest Algorithm on Raspberry pi produced better results. It is further concluded that the proposed system is a low cost, has fair reproducibility and reliability, is portable and compact. The use of IOT and ML improves system accuracy and also the measurement technique makes it different from existing techniques.

8. **Reference**

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