Analysis and Design of Adulteration Dairy Milk System

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Abstract. Detection of milk adulteration can be done in several ways. The simplest and fastest one can be done without any tools, but the accuracy is limited since each milk cow produces is different in color. Furthermore, obtaining effective results requires a lot of effort and time; also, the observed milk cannot be reused for other analysis processes. Another approach to detecting milk adulteration is to consider several factors, such as pH, electrical conductivity (EC), and temperature. Research has been conducted using macroscopic observation utilizing IoT devices such as e-nose, e-tongue, pH, EC, NIR, and temperature sensors. Observation can also be done microscopically, but it takes a long time. To answer those problems, we used Framework for the Application of System Thinking (FAST) methodology. In this study, we tried to speed up the detection time for fake dairy milk using a digital microscope and smartphone. This research will discuss the design and architecture of a milk detection system. Microscopic images are taken by connecting a digital microscope to a smartphone as the first step in system design. The system is created using digital images captured by a microscope and processed using machine learning using a smartphone. This research begins with requirement analysis, business process design, and system architecture design and ends with prototype design.

Keywords: dairy milk, dairy milk system, FAST technology.

INTRODUCTION

Food is one of the basic human needs, and milk is one of them. Milk contains various nutrients such as protein, fat, carbohydrates, vitamins, and minerals that can be absorbed easily by the human body at all ages [1]. Milk is recommended as an essential element in a healthy and balanced diet since it contains various nutrients [2]. The increase in the human population also increases the demand for milk. This led some milk manufacturers to immoral practices known as milk adulteration to reduce the gap between milk's demand and supply [3].

Milk adulteration is carried out intentionally or unintentionally by mixing certain ingredients or substances. The reasons vary, such as reducing the gap between demand and supply, the economic motive to gain greater profits, weak regulation, and so on [4]. It leads to a decrease in quality and loss of certain nutrients and, to some extent, can pose a danger to the human body, even leading to death [5]. Differentiating between pure and adulterated milk, to most human beings' naked eyes, is highly difficult since there is almost no difference. There needs to be a mechanism and technology to make it easier to distinguish pure milk from adulterated one.

With the rapid advancement in various fields, heavy laboratory equipment in the past is now available in relatively small and cheap and can even be bought online on many e-commerce websites. One of them is the digital microscope equipped with a USB cable. This led to various research that utilized them to propose many things that previously could only be accessed in the lab. In [6], an integrated system utilizing digital microscopes is designed to capture and transfer the microbial structure in petri dish to a computer via Wi-Fi. The digital microscope can also be used to construct a portable spectrophotometric system [7]. In [8], the effectiveness of digital microscope is investigated in determining the diagnostic and prognostic values of connective tissue disease (CTD). In [9], the digital microscope is used as a tool for quick morphological characterization.

Research related to milk adulteration detection has been carried out using various methods and perspectives. In [10], IoT devices are used to monitor milk conditions based on UV, visible, and IR imaging spectrum, and milk purity is determined using machine learning in real-time by connecting to the internet, and the result can be accessed via a website. A similar approach also has been done using lab-based quantification of spectroscopic techniques [11]. Another technique utilizes metal oxide semiconductor sensors as e-nose to identify milk sources and to estimate the

I. H. Agustin (ed.), *Proceedings of the 2nd International Conference on Neural Networks and Machine Learning 2023 (ICNNML 2023)*, Advances in Intelligent Systems Research 183,
https://doi.org/10.2991/978-94-6463-445-7_20

estimate the content of milk fat and protein [12]. In [13], an electronic tongue was built to recognize five basic taste standards, with high sensibility to acid, salty, and umami taste substances and lower performance to bitter and sweet tastes, and afterward used to detect the adulteration of goat milk with bovine milk.

In this research, a design and architecture of a system for detecting milk purity is proposed. The proposed design utilizes a digital microscope, smartphone, and machine learning to determine whether a milk is pure or adulterated. A convolutional neural network model is trained using sample images from various milk, and then the model is deployed to mobile application. To work properly, a digital microscope is connected to the smartphone via a USB cable, and then the mobile application uses the digital microscope as a camera source. Then, the mobile application captures the milk sample on petri dish and then classifies it based on the trained model. To assist the development process, Framework for the Application of System Thinking (FAST) methodology is used.

METHOD

Framework for the Application of System Thinking (FAST)

Framework for the Application of System Thinking (FAST) is a structured methodology for developing and maintaining information systems. FAST is suitable for small and simple to large and complex projects since it is flexible and easy to adapt. It is based on the principles of system thinking, that is an understanding the world as a complex network of interconnected parts. It helps to identify the root causes of the problems and see the big picture. The solutions it produces are sustainable and comprehensive. The FAST methodology consists of five steps: planning, analysis, design, implementation, and maintenance. The planning phase defines scopes, objectives, deliverables, who is the stakeholder and what stakeholders need. The analysis phase defines the condition of the current system and the strengths and weaknesses of the current system. The design phase is defining the design of the new system that satisfies the requirements of the stakeholders and the prototype of the system. Implementation phases are implementing the new system, training users, and providing support. Maintenance phases are providing updates and enhancements as needed.

Data Acquisition

Several bottles of pure milk with the same source and type were collected. The milk is then split into 5 containers. To all containers, a quantity of water was added: 0% of water was added to the 1st container, 10% of water was added to 2nd container, and so on until 40% of water was added to 5th container. From each container, 10 images of milk samples of petri dishes were taken using a digital microscope with resolution of 1600x1200 pixels, and all images were saved to a computer storage. The images are then renamed based on its milk purity and its sequence in which it's taken; for example, 10_1.jpg is an image of a milk sample that contains 10% of water, and it is sample number one.

Data Pre-processing

The name of each image file contains two segments: the first serves as the purity of the milk, and the second serves as the sequence of the sample. The first segment is later used as the label for that image. All of the images were then resized to 64x32 pixels.

The images were then processed using Compass Local Binary Pattern (CoLBP). CoLBP is an extension of Local Binary Pattern (LBP) extraction method. CoLBP uses 8 matrix kernels from Kirsch Compass Mask. The output of this step is 8 new images from each single image that represents an edge with a different angle. The 8 new images then get calculated to obtain histogram values for each image. The histogram value of each image is then used as the feature in the model. The number of features in each image sample is 2048. All the histogram values and labels are then saved and tabulated in the form of a CSV file.

Model Training and Testing

Artificial Neural Network (ANN) algorithm is used in this research. The ANN used the CSV file as input, three hidden layers with each layer consisting of 100, 150, and 50 neurons for respected layer and two output layers. The two output layers are ‘pure’ and ‘adulterated’. The number of images used as the dataset is 50 items. The ratio of datasets used data training and data testing is 90:10.

Mobile Application Implementation

Flutter framework was used to build the mobile application. The mobile application was constructed after the planning, analysis, and design steps in FAST had been done. The mobile application serves as the product that can be used by the stakeholders. The mobile application works as follows: the user clicks a button, and the user captures the image of milk that has already been put on a petri dish using a digital microscope connected via a USB port; after that, the application pre-processes the image and classifies the milk image using ANN with the trained model. The classification results are then displayed on the same screen. The configuration of the digital microscope and phone is shown in Figure 1.

FIGURE 1. Hardware configuration for mobile application.

RESULT AND DISCUSSION

Project Planning

The scope of the proposed system is final system is in the form of a mobile application running on the Android platform; the application utilizes an additional camera module in the form of a digital microscope that connected to the phone via a USB cable, and the application able to classify image taken from digital microscope using the trained model. The objective is a system in the form of a mobile application that can classify milk samples. The stakeholders are the milk producer/manufacturer and the public.

System Analysis

The current system of detection of milk adulteration is not available in a sense that is easily accessible by the public since the detection of milk purity can only be done in a laboratory with complex equipment. What the stakeholders need is a simple method that can detect milk purity that is easily accessible and not expensive. The functional requirements of the system are it has a simple user interface, can capture images of milk samples by utilizing a digital microscope connected via a USB cable, and can output detection results in a short time.

System Design

The system architecture design is the system in the form of a standalone mobile application. It means the mobile application doesn’t need to use other services outside of the mobile application itself. To achieve this, the mobile application utilizes a classification model that has been trained before. On UI/UX design, the mobile application needs to have a clean and minimalist UI, and the UI needs to be designed to minimize user frustration. The user flow diagram is made as simple as possible; that is, it consists of three steps: the user opens the application, the user clicks a button to capture the image of the milk on the petri dish, and last, after the image has been taken, the application will classify the image and display the classification result on the screen of the phone.

System Implementation

The image dataset of milk samples is split into data training and data testing with a ratio 90:10. Artificial Neural Network (ANN) is used as the algorithm for machine learning. The number of hidden layers used 3 with 100, 150, and 50 neurons for respected layer. The model is trained with 90% of the image dataset, and then the model performance is measured by performing a classification test on 10% of the image dataset. The result is shown in Figure 2.

```
[[12  0  0  0  0]
 [ 0  4  0  0  0]
 [ 0  0  6  0  0]
 [ 0  0  0  6  0]
 [ 0  0  0  0 11]]
```

FIGURE. 2. Confusion matrix of the model

As shown by the confusion matrix in Figure 1, there are 5 labels of the image dataset. In the first row of the confusion matrix, there are 12 images of class ‘0’ and all 12 images get predicted correctly as class ‘0’. In the second row of the confusion matrix, there are 4 images of class ‘1’ and all 4 images get predicted correctly as class ‘1’. In the third row of the confusion matrix, there are 6 images of class ‘2’ and all 6 images get predicted correctly as class ‘2’. In the fourth row of the confusion matrix, there are 6 images of class ‘3’ and all 6 images get predicted correctly as class ‘3’. And the last, the fifth row of the confusion matrix, there are 11 images of class ‘4’, and all 11 images get predicted correctly as class ‘4’. In this case, class ‘0’ is pure milk, and class ‘1’, ‘2’, ‘3’, and ‘4’ are adulterated milk with 10%, 20%, 30% and 40% of its content is water. Based on this result, the model can classify the testing dataset with 100% accuracy, i.e., 12 images of the testing dataset are pure milk, and 27 images of the testing dataset are adulterated milk.

The model obtained is then exported as a file and deployed to the mobile application. The mobile application is developed using Flutter framework and targeted for Android platform. The result of the developed application is shown in Figure 3. It has a simple user interface, clean and minimalist, designed to minimize user frustration.

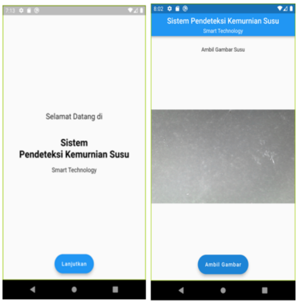

FIGURE 3. User interface of the mobile application

CONCLUSION

The prototype of system for milk adulteration detection has been successfully developed. It employs a simple user interface, clean and minimalist, that minimizes user frustration. The system is in the form of a mobile application that runs on the smartphone of Android platform, is connected to a digital microscope via USB cable, and can classify milk images utilizing the trained model. The model performance has an accuracy of 100%.

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