Automatic Fish Feeder System for Aquaponics using Wi-Fi Based WSN

Linet Rose A. S., Thomas Mohan, Vinodkumar Jacob

Abstract: Aquaponics is a farming method, which is the combination of aquaculture and hydroponics, which grows fish and plants together in one integrated system. The fish waste provides an organic food source for the plants, and the plants naturally filter the water for the fish. The purpose of this project is to build an automatic fish feeder system for aquaponics using image processing technique with the help of Wireless Sensor Network (WSN). This helps the farmers to reduce manual effort and safeguard a balanced food delivery. The number of fish in the pond may vary over time, so the amount of fish feed provided need to be changed. As there will be a large number of fish moving randomly in a pond, the manual tracking and counting of fish is very difficult. It is a time consuming and erroneous process. This work focuses on developing a system that tracks and counts the fish in the pond for aquaponics. This automatic fish identification system processes the video of the entire pond and makes it easier to estimate the count of fish. The frames from the video are processed using Raspberry-Pi board and the count of fish is transmitted through Wi-Fi. Such a system would assist to feed the fish accordingly. Based on the count transferred, a fish feeder mechanism is controlled using NodeMCU at the other end of the Wi-Fi. The amount of fish feed remaining in the feeding box is informed to the user through mobile application.

Index Terms: Aquaponics, Automation, Fish Detect, Image Processing, WiFi, Wireless Sensor Network

I. INTRODUCTION

Aquaponics is a symbiotic combination of aquaculture and hydroponics. Aquaculture means raising fish and other aquatic animals whereas hydroponics is farming plants without soil. In this system, aquatic animal's discharge and waste are fed to the plants and in return, the plant bed cleans the water that goes back to the tank. The nutrition for the plants is obtained from the water and microbes also play an important role.

These beneficial bacteria convert the fish waste and the solids into substances the plants can use to grow. This is a high profit farming method, and it requires only little care, once the initial setup is done. The fish feeding in aquaponics is done either manually or automatically by providing a fixed amount of feed in regular intervals. Currently, marine biologists manually analyses underwater videos to find useful information. This procedure requires a lot of time and human concentration to get correct number if fish in the pond.

The over-feeding issues associated with improper feeding include accumulation of unprocessed feed and will lead to much smellier and messy conditions that enhance the growth dangerous fungus that could affect the system. Also when the fish are overfed, sudden spikes in the Ammonia levels, especially when temperature conditions are higher than normal, can affect the lives of fish very easily. Above all, the wastage of feed is a loss for the farmer. Under-feeding is also a serious issue when fresh water with small volume of water is used. The lack of nutrients can affect the growth of fish. Since the number of fish in the pond is not constant, the requirement of fish feed vary over time. So for the proper feeding, the number of fish in the pond should be known in advance. An automatic aquaponics system would require fish-feeding system, according to the requirement by the fish.

The water may have varying degrees of clearness and cleanness. Moreover, unlike a normal fish tank in a lab, open pond videos will consist of "non-fish" moving objects – which require additional handling to eliminate. In addition, as algae grow rapidly in waters and on camera lens, it affects the quality of the videos taken. Consequently, different degrees of greenish and bluish videos are produced. In order to decrease the algae, frequent and manual cleaning of the lens is required. Since the aquaponics system automatically recycles water, minimum required visibility can be assured.

This automatic feeding system finds the number of fish in the pond by image processing technique. For that, images of the entire pond is captured and saved in a server. Each frame is processed and detection of fish is done. After detection, counting operation is performed. The result of counting is transmitted to the fish feeder operating system through Wi-Fi. The fish feeder is operated according to the count obtained. This system can avoid the over-feeding and under-feeding of fish, which is a serious issue that causes threat to the lives of fish.

II. RELATED WORKS

The paper [1], presents an approach by using an automated Video Processing (VP) system that analyses videos to identify interesting features.

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The algorithm chosen was the Adaptive Gaussian Mixture Model, which was reliable enough for removing the false positives and fast enough. This system use a combination of two algorithms for tracking: the first one is based on the matching of blob shape features and the second one based on the histogram matching. The process of tracking is performed by applying CamShift algorithm. In [2], fish detection is carried out using background subtraction which is based on GMM, classification is performed using Pyramid Histogram Of visualWords (PHOW) features with SVM

classifier and finally identified fishes are tracked using Kalman Filter. In Covariance Based Tracking Algorithm, tracked object is used to represent a unique fish and contains information about the fish appearance history and its current covariance model. Covariance Based Tracking Algorithm is also used for tracking to analyze huge amount of underwater video data.

Automated fish counting using image processing implemented in [3] uses edge detection to identify the fish. The maximum number of true edges is obtained by using canny edge detector. Once filtering of noise and background objects are completed, the remaining blobs correspond to the fish. Now to count the fish the standard area for one fish has to be estimated. The paper [4], propose a computer vision method, based on background subtraction, to estimate the number of zebrafish inside a tank. Optical flow is highly related to pixel motion and its variability between frames. Furthermore, it gives a reliable estimation of displacement between different frames. Background subtraction is especially relevant when, for example, the need for isolating moving regions in a sequence of images arises.

In paper [5] establishing a WSN under the water for communication. Underwater communication research is primarily focused. One among the major issues in the field of underwater communications is the low data rate available due to the use of low frequencies. Also there exist many problems which are inherent to the medium. This includes reflection, refraction, energy dispersion, etc., that greatly degrade communication between device.

III. PROPOSED SYSTEM

The proposed system block diagram is shown in Fig 1. The video processing unit captures the images of the entire pond and finds the number of fish. Wi-Fi communication is established between video processing system and feeder system. The count obtained is updated in a local web server. The feeder system takes the count value from the local web server and feed the fish accordingly. It also send notification to the mobile phone regarding insufficiency of fish feed in the feeder box.

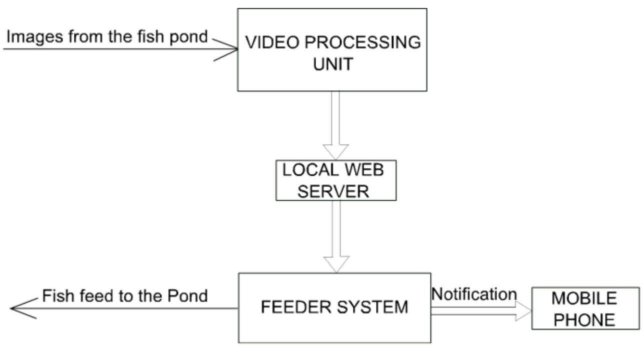

Fig 1: Block Diagram of the Proposed System

A. Video Processing Unit

Entire system is powered by a 12V battery. The Pi Camera is connected to Raspberry Pi processing system. It captures the images of the entire pond by rotating the camera. Raspberry Pi operates stand-alone with a 5V supply from the powering circuitry. The whole system is placed under the water in a sealed transparent glass box. It is placed at the center of the pond and rotated 360^{o} by DC Gear Motor in order to capture the entire image of the pond.

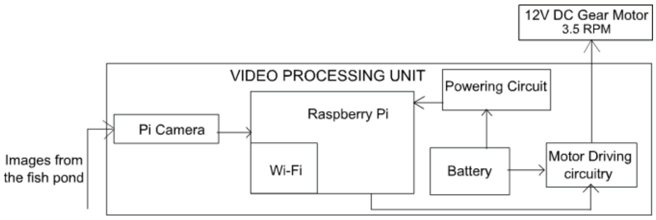

Fig 2: Video Processing Unit

The Motor operation is controlled by motor driving circuitry and the signals are provided from Raspberry Pi. The Raspberry Pi processor evaluates each frame of the captured images using the image processing technique, detects the fish in it. After the detection, counting is carried out to get the total number of fish in the pond. The fish count is updated in a local web server through Wi-Fi.

B. Feeder System

The NodeMCU controls the feeder system. Entire feeder unit is powered from the 12V battery. NodeMCU works with 5V supply from the powering circuitry. The feed for the fish is given by rotating a 100RPM DC Gear Motor in anti-clockwise direction. The control signals for motor rotation are given by NodeMCU through the motor driving circuitry. The fish count is obtained from the local web server through Wi-Fi. The fish feeder system is operated by the micro-controller according to the number obtained. From the 'fish count' information, the time required to operate the Motor is found out.

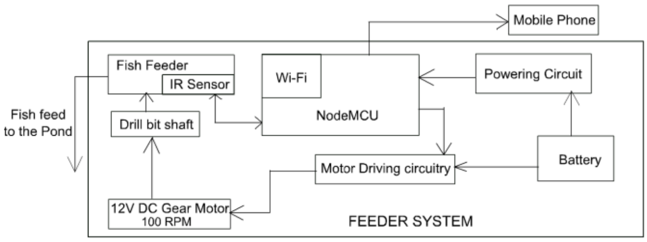

Fig 3: Feeder System

The feeder box is filled with fish feed and replaced manually when empty. IR Sensing Circuit checks whether the feed in the box is below a threshold value. Also the information regarding insufficiency of fish feed in the feeder box is sent to the user through mobile application. Thus the owner can replace the fish feed when the box become empty.

IV. IMPLEMENTATION

A. Video Processing Unit

A glass box of 15x15x50 cm is used for setting up the Video Processing Unit. Raspberry Pi, powering circuit, Motor driving circuit and Battery are placed on a plastic sheet.

It is kept on a bearing for easy rotation. The entire unit is connected to the DC motor with a metal rod. The entire image of the pond taken using Pi Camera by rotating the Video Processing Unit, which is placed inside a transparent glass box. The set-up for Video Processing Unit is shown in Fig 4. Since the Field of View of the camera is 72.4 degrees, 5 frames can cover the entire pond. The rotation, capturing and processing are done by Raspberry Pi. The algorithm for Video Processing Unit is given below.

Step 1: Write the count as zero in the html file
Step 2: Capture the image by Pi camera
Step 3: Rotate the Video Processing Unit for 1.2sec
Step 4: Repeat step2 & step3 four times
Step 5: Rotate the video processing unit in opposite direction for 4.8sec
Step 6: Run the Object Detector with trained data
Step 7: Detect the fish in each frame one after the other
Step 8: Obtain the count by taking no.of boxes around each detected fish
Step 9: Sum up the count from all 7 frames
Step 10: Update the html file with obtained 'Count'
Step 11: The value in the local web server updated

Fig 4: Set up for Video Processing Unit

B. Fish Detection

Since we need to detect objects of particular types (here fish), we trained our detector with the objects we want to detect. And for that, the objects in images are annotated. The steps to build an object detector at very high level includes (i)Collecting training images, (ii)Annotating object locations in the training images, (iii)Training the Object Detector with the object regions and (iv)Saving & testing the trained detector.

Initially training images of fish are collected. Large number of images of fish in different orientation is collected from the pond. The sample images collected are shown in Fig 5. And images are saved as dataset folder in Raspberry Pi. Each image is considered and the object (fish) locations are annotated by drawing rectangle around the object. Then annotation and image path are collected and appended to files. At last, the annotation and image path are converted to numpy array and saved in the disk.

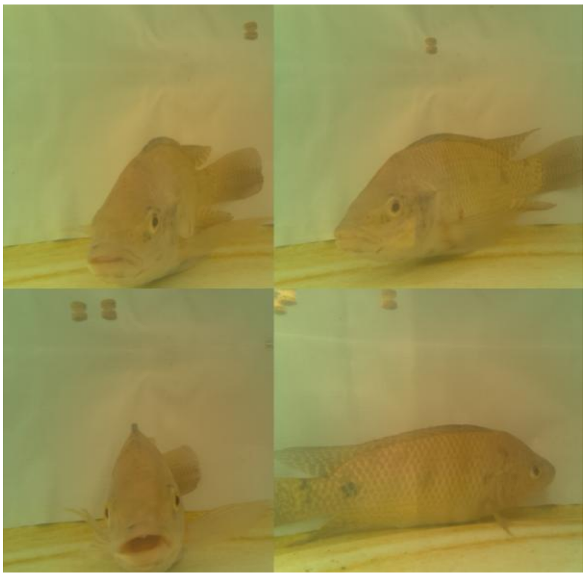

Fig 5: Sample images from the pond

In order to train the images, initially HOG(Histogram of Gradient) descriptor is created. A HOG feature descriptor is a representation of an image or an image patch. And it simplifies the image by extracting useful information & throwing away extraneous information. In the HOG feature descriptor, the distributions (histograms) of directions of gradients (oriented gradients) are used as features. The magnitude of gradients is large around edges and corners (regions of abrupt intensity changes) also the edges and corners pack in a lot more information about object shape than flat regions. Therefore gradients (x and y derivatives) of an image are useful. A linear SVM (Support Vector Machine) model is created and trained on the extracted HOG feature.

In order to test the detection, average window size is estimated. Scale down or up the image for several levels up to a certain termination and build an image pyramid. The window is slid through each image in an image pyramid and HOG features are extracted from each location. The probability of trained SVM model is estimated with current HOG feature. This matching probability is used to determine whether the object present or not. If it is more than certain threshold then it contains the object, otherwise not. Then the boundaries of box are predicted and rectangle is drawn around the object. The detection example is shown in Fig 6.

Fig 6: Fish Detection Example

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C. Feeder System

A rectangular box of 25x15x6 cm is attached to the system to store the fish feed. And a drill bit is attached to motor shaft via a coupler to drop the fish feed into the tank at required instances. The coupler for connecting drill bit and shaft of Motor is 3D printed.

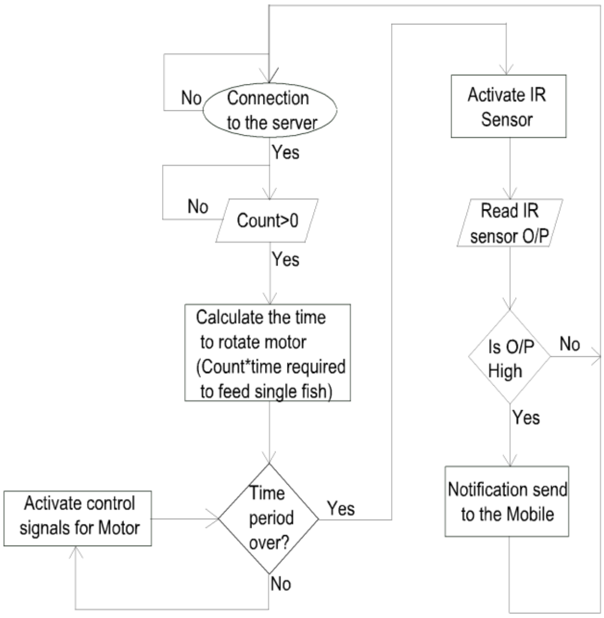

Fig 7: Flow chart of Feeder System working

The feeding is done by activating the motor so that the shaft rotates in anti-clockwise direction moving the feed through the grooves in the drill bit. The control signal for activating motor is provided by NodeMCU five times a day. The motor activation period is calculated depending on the fish count. The flow chart of working of the Feeder System is shown in Fig 7.

D. Push Notification from ESP8266 to Android Mobile

The notification is sent to the mobile device whenever the feed in the feeder box goes below a threshold value. For that the IR Sensing Circuitry is installed inside the feeder box. When the feed goes below the threshold, there is no object between IR emitter and receiver then it produce a High output. Then NodeMCU sends a notification to the linked Mobile device. The notification is sent to the mobile device through 'Pushbullet' android application. For that, initially setup the Pushbullet service. Pushbullet is an internet service which for SMS sending, notification management for your mobile device. Next set up PushingBox, the IoT notification center. It is a cloud that can send notification, emails, tweets based on API calls in real time.

V. RESULT

The complete Video Processing Unit was kept inside the pond in order to capture the images of pond. The Fig 8 shows the set-up for fish counting, placed inside the pond. Five frames will cover the entire pond. Testing was done in a water tank having 120cm diameter and 60cm height. And counting was tested with 10 Tilapia fishes inside the tank.

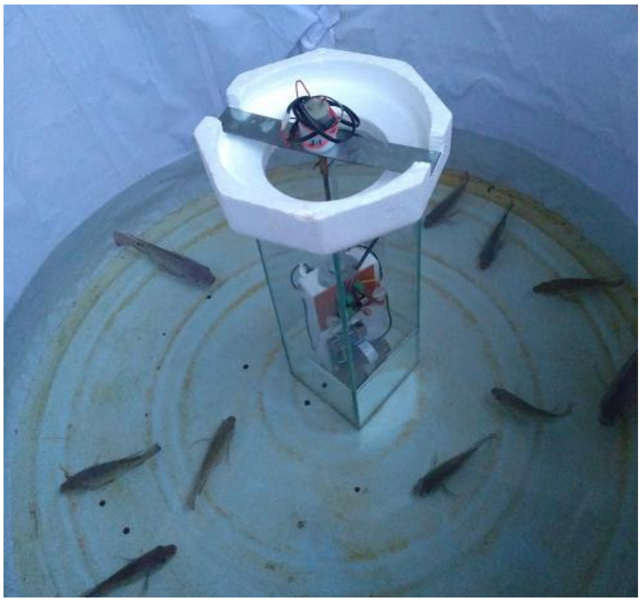

Fig 8: Complete Set-up for counting the fish

In order to obtain the number of fish, the counting system was implemented with 10RPM, so that the delay between capturing the frames reduced. Only 5 frames are captured at regular intervals from the pond, which is sufficient to cover the entire pond. The screenshot of Raspberry Pi's python shell is shown in Fig 9 and the count obtained as 9. This count is updated in the local wed server which can be accessed by the ip address 192.168.43.155. The screenshot of this local web server is shown in Fig 10.

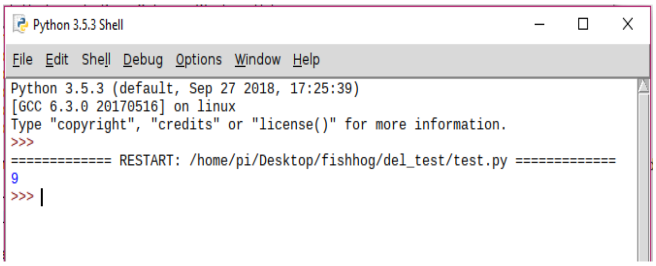

Fig 9: Count obtained after Image Processing

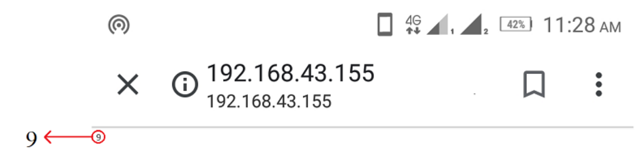

Fig 10: Count from local web server to NodeMCU

The performance of the system is satisfactory which detected 9 fishes out of 10. The 10% error is due to the random movement of fish and this can be tolerated. In order to get more accurate result, the counting is performed several times and the average of those can be written as final count in the local web server.

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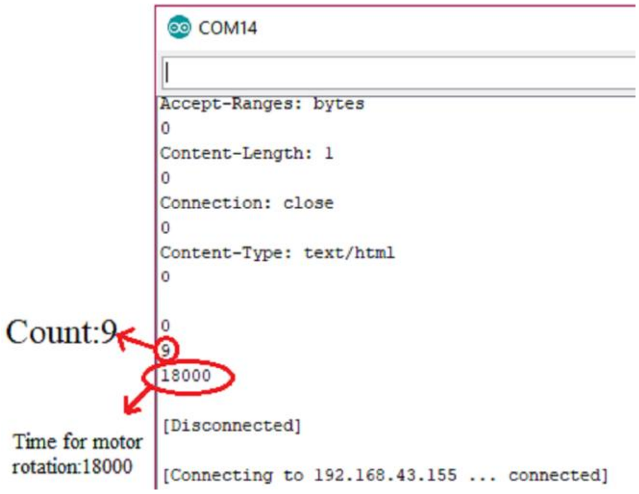

Fig 11: Arduino serial monitor for NodeMCU

The final count is retrieved from the local web server by NodeMCU. The controller then calculates the time to rotate the motor. When the motor is activated, the drill bit also rotated. Thus the feed is pushed out of the feeder box. The Arduino serial monitor which shows both these values is shown in Fig 11. The fish count from local web server is 9. This is multiplied with a constant value, which is the time required to rotate the motor for a single fish.

The feeder is operated according to the count obtained. Complete feeder set up is shown in Fig 12. Average fish weight assumed to 250gm. A single Tilapia fish eats about 5% of its body weight in a day. The feeder is activated five times in a day

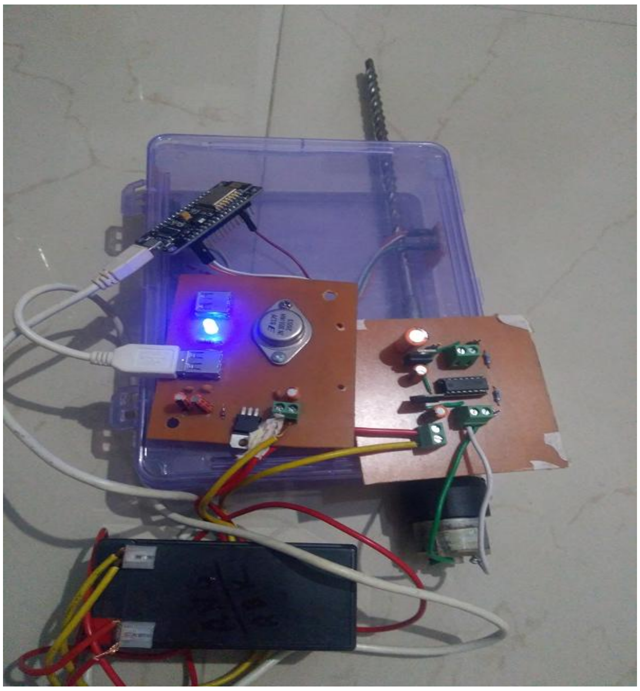

Fig 12: Feeder System

After the feeding, IR sensor .is activated which checks the feed amount remaining in the feeder box is below the threshold or not. If it is below the threshold, the NodeMCU send a notification to the connected mobile device. The screenshot of mobile notification is shown in Fig 13. The farmer need to fill the fish feed in the feeder box manually when the notification is received.

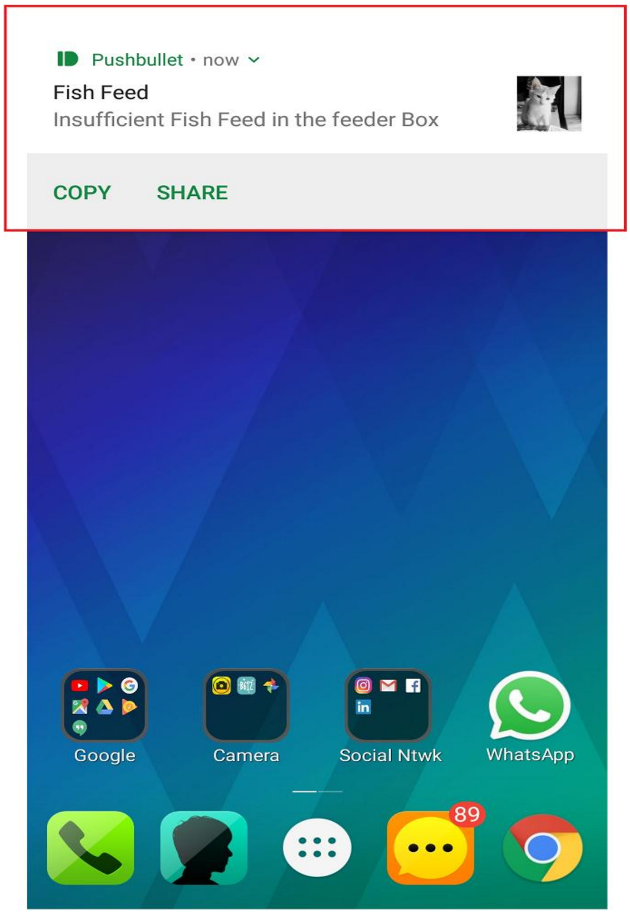

Fig 13: Screenshot of Notification send from ESP8266 to Mobile

VI. CONCLUSION

The automatic fish feeder system will be very helpful for the fish farms. It can reduce manual effort of visiting the pond multiple times in a day for feeding the fish. This system is capable of feeding the fish according to the requirement. This can avoid the over-feeding and under-feeding issues that can affect the lives of fish. The system effectively finds the number of fish in the pond using image processing techniques. The images of the pond are captured by Pi camera which is connected to Raspberry Pi, and detection, & counting carried out by the processor. The video processing system is separated from fish feeder system and Wi-Fi communication established between them. Fish feeder can be operated by NodeMCU. Also the information regarding insufficiency of feed is provided to user through mobile application, so that refilling can be done.

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