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A NOVEL APPROACH TO AUTOMATIC ROTAMETER READING USING OPENCV

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Abstract— *Computerized sensors and automation helps industry to get better accuracy and throughput. Aim of this proposed system is digitization of fluid flow rate measuring device called Rotameter. In market for different fluids different rotameters are available and this system is able to support them independent of its fluid. It uses BeagleBone Black (BBBlack) or ORANGEPI 2G-IOT a tiny computer for all its computation needs and a camera device as an eye of the computerized sensor to read the rotameter. Application code is entirely written in C++ with Qt for GUI and OpenCV for camera handling. This system gives real-time measurement and it is more accurate than human measuring. It requires one time calibration to detect rotameter. This system is highly modular and scalable. Currently system is designed to consider one rotameter at a time but with little modification system can be easily extended to centralized system with multiple rotameters and cameras.*

Keywords— *Rotameter, BeagleBone Black, OrangePi 2G-IOT Embedded, Sensor, Camera, C++, OpenCV, Qt, and Linux.*

I. INTRODUCTION

Rotameter is a fluid flow rate measuring device. Since different fluids having different flow properties, individual rotameter is built to measure specific fluid. Rotameter has two ends; one for fluid input and other for output. A needle inside the closed tube indicates the flow rate value. Needle is created with its proper weight, shape and material to measure particular fluid flow rate.[1]

To know the flow rate, human sees the needle position and its associated flow rate value written on rotameter.[7] By digitizing the system, we are replacing the human by a tiny computer which sees the needle from camera and will map its height to sensor table to retrieve flow rate value. This will add more accuracy than human measuring and also monitoring fluid flow became automated. The tiny computer we used is BeagleBone Black or ORANGEPI 2G-IOT. Flow rate value is displayed on local application along with real-time photograph of the rotameter. Currently system is showing flow rate value locally.[5]

Fig. 1. Rotameter Front View

Fig. 2. Rotameter Side View

II. SYSTEM DESIGN

A. *Rotameter Calibration Point*

To detect rotameter position, we pasted four yellow colored calibration points on rotameter as shown in fig. 3. It is assumed that rotameter is placed vertically in right angle wrt. Camera.

Fig. 3.Rotameter with Calibration Point

This calibration point's boundary should adjacent to minimum and maximum flow rate line to detect them in system. If rotameter is transparent then its sides except front side should cover with white paper to avoid external luminous noise.

B. *Hardware Setup*

Current hardware setup is for single rotameter system. But system with little modification can be extended to centralized system with support to multiple cameras and rotameters. Hardware setup is shown in fig. 4. A computer application is developed for digitizing the system. BBBlack a tiny computer with GNU/Linux installed is required to run application. Monitor is required to display application. Mouse used for interacting with application. Keyboard is used to start application. If application is auto-started on boot then keyboard is not required. Camera is needed to fetch photograph of rotameter. Active USB Hub to connect Camera, Mouse, Keyboard to BBBlack, because BBBlack is having only one USB port.

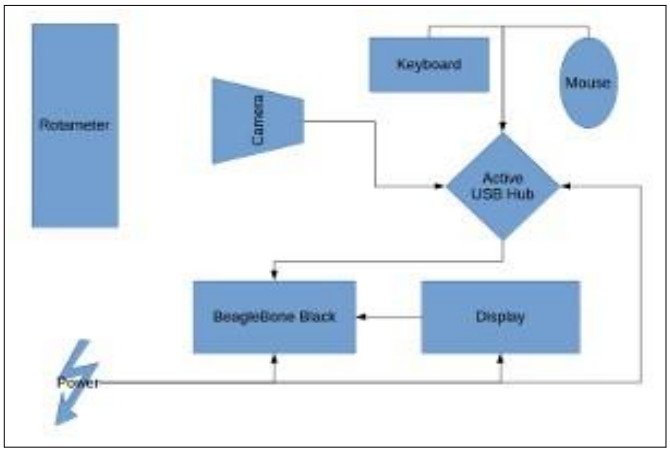

Fig. 4. Hardware Setup

Camera placed in front of rotameter vertically with clear view of needle and calibration points.

C. *Software Design*

Multiple fluid rotameters need to support by this single computer application; so Rotameter Specification File is introduced. This file contains distance between minimum and maximum line and sensor table mapping distance to flow rate value. User can select particular specification file at calibration time. Filename of this file is visible to user at the time of calibration.


```
ROTAMETER_SPECIFICATION_START

VAR DISTANCE_MM = 102

TABLE SENSOR_DATA
# Distance in MM  -->  Value
0                   0
1                   2
2                   5
MAX                 Y_MAX
TABLE_END

ROTAMETER_SPECIFICATION_END
```

Fig. 5. Rotameter Specification File

Needle can be of any color and shape. We used two techniques to detect needle. First one is *chromatically* and other is *nonchromatically.*

In chromatic needle detection all the hue, saturation and value components of needle are checked with specified tolerance. In nonchromatic needle detection only value component is checked with given tolerance. Nonchromatic detection is suitable for any color needle. Needle detection method and tolerance value can be altered by user at runtime also.

A computer application designed to display flow rate value along with real-time photograph of rotameter with one horizontal line over photograph showing the position of the needle. This horizontal line will be helpful in calibration and configuration of rotameter.

III. IMPLEMENTATION

BBBlack's operating system updated with LXQt supported firmware to support Qt runtime for GUI and updated firmware had preinstalled Video4Linux (V4L) library used by OpenCV. BBBlack is the ARM device; System development done on x86 desktop computer with cross-compilation to ARM target. Development toolchain on host x86 system contains cross-platform ARM libraries of Qt and OpenCV. A single BASH script is created to install the development toolchain.

Application code is written in C++. GNU C++ compiler is used for compilation and GDB for debugging. Threading is widely used to distribute multiple tasks. Different modules in application shown in fig. 6.

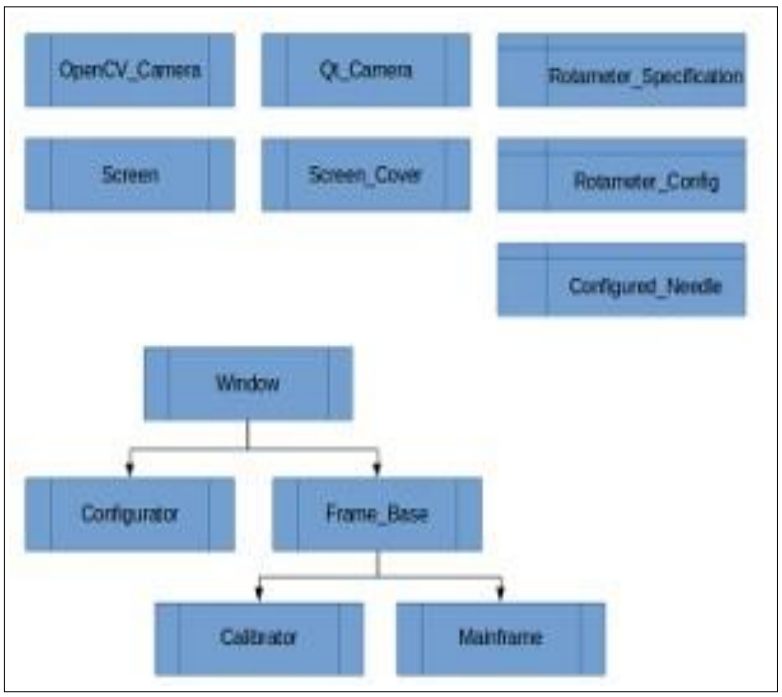

Fig. 6. Modules in Application Code

Modules in application code are,

1. OpenCV_Camera :
Fetches photograph with help of V4L library.

2. Qt_Camera :
Fetches photograph from OpenCV camera in and convert it to QImage-RGB24 format.

3. Screen :
Takes photograph from camera on specific interval and displays it as a widget.

4. Screen Cover :
Layer above screen for highlighting objects.

5. Rotameter Specification :
Represents rotameter and stores its properties. This structure is read by application.

6. Rotameter_Config :
Application settings to detect needle. This structure is read by application.

7. Configured_Needle :
Needle properties, for its detection.

8. Window :
This is base window class for GUI of this application.

9. Configurator :
Place where configuration is to make.
It's a GUI Window class. Currently not used directly but used as a widget in other window classes like *Calibrator* and *Mainframe* for configuration.

10. Frame_Base :
Base window with needle detection capability.

11. Calibrator :
Place where calibration is to done. It's a GUI Window class. Contains *Configurator* instance.

12. Mainframe :
Place where needle reading is to take. It's a GUI Window class. Contains *Configurator* instance
.

IV. EXPERIMENTS AND RESULTS

Cross-compiled on x86 host computer and executable copied to BBBlack device with Rotameter Specification Files. In first run calibration should be done. For calibration application should execute with -s or –set-calibration parameter. In calibration needed to select Rotameter Specification File to specify rotameter in use. file.

Fig. 7. Selecting Rotameter.

Next step is to select calibration points to detect location of rotameter. Select them in anticlockwise direction starting from Top-Left point. Make sure rotameter is placed in right angle wrt. Camera.
After rotameter location is detected, needle detection method need to select.

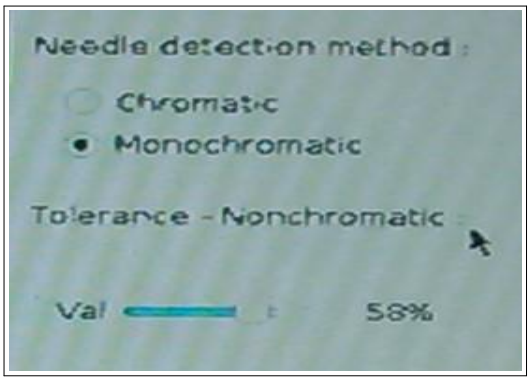

Fig. 8. Needle detection method selection.

Two types of needle detection methods are introduced.

a. Chromatic:

Uses Hue, Saturation and Value components of needle color to detect needle. Useful for unicolor needle like red, green but not efficient in variable light intensity.

b. Monochromatic (default):

Uses only Value component of needle color to detect needle. Useful for any color needle and also works good in variable light intensity.

We recommended to use Monochromatic method as it is resulted more reliable in test. After selecting needle detection method, set its tolerance value.

A yellow horizontal line will appear to indicate the needle position according to selected method and tolerance. Please set method and tolerance accordingly to detect more accurate needle position.
Next to set Refresh interval time.

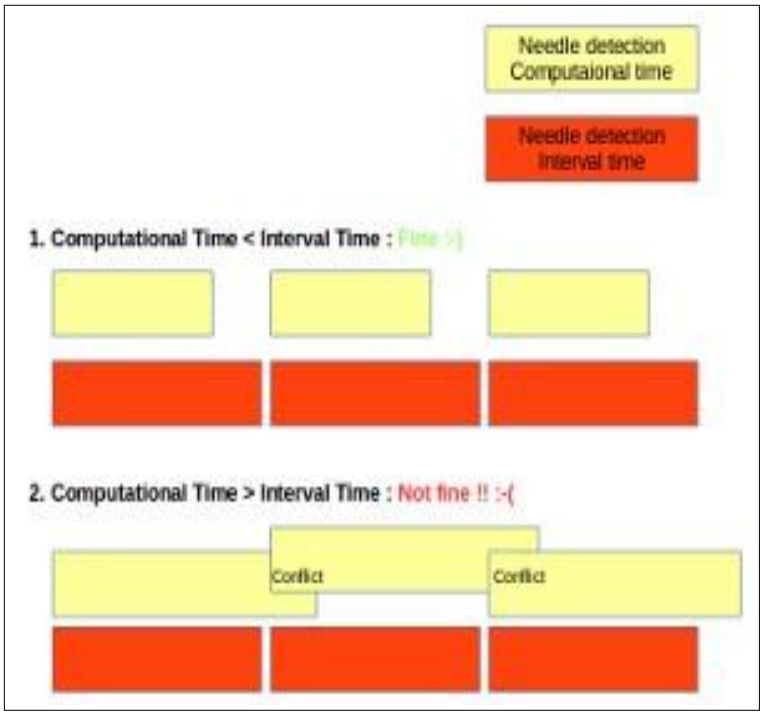

Fig. 9. Refresh interval and conflict.

Misconfiguring refresh interval can lead to conflict as shown in fig. 8. Due to conflict, application may respond irregularly or stalled. If at run-time such symptoms occurred then increase the time to decrease refresh rate.

BeagleBone Black works well on 2000 milliseconds refresh rate value.
After finishing calibration application terminates itself. To perform regular measuring application should be started without any parameter. Flow rate value is shown on top right corner and yellow horizontal line on real-time photograph to indicate needle position.

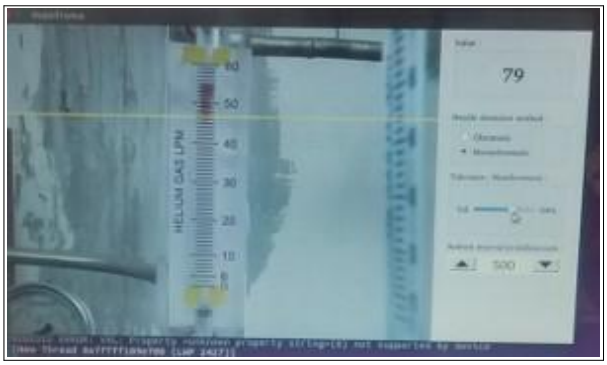

Fig. 10 Reading flow rate

TABLEI. The following table relates the position of the float with the flow as measured by the webcam and as measured visually

Actual flow rate (in LPH)	Rotameter-float position (cm)	Pattern co-ordinates (X, Y)	Calculated flow (in LPH)	Error (in LPH)
50	4	(218,202)	50.04	0.04
75	6	(218,304)	75.10	0.10
100	8	(220,401)	100.02	0.02
125	10	(221,505)	125.14	0.14
150	12	(219,603)	150.08	0.08
175	14	(221,702)	175.06	0.06
200	16	(220,804)	200.10	0.10

V. CONCLUTION

We tested application with three different fluid rotameters which having different needle colors and different shape. For bright colored needle Chromatic needle detection found more reliable while for silver color needle Nonchromatic needle detection method found more reliable. Refresh interval for BBBlack found 2000 milliseconds good to execute application without any conflict. Application gives reliable measurement of flow rate. Current system will reduce the human work and monitoring gas flow became automated. This work is mainly focus on to detecting needle of meter and extract the position of the needle and send the needle position to the display unit.

The processing time of monitoring the gas flow will decrease from 50sec to 30sec and the Camera distance from rotameter to device is also reduced for capturing images.

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