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Non-invasive optical intravenous monitoring system

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ABSTRACT

This paper emphasizes Intravenous Fluid Bottle monitoring in hospitals using an innovative non-invasive optical approach. For good patient care in hospitals, the management of fluid and electrolyte bottles is the most fundamental thing required. In all hospitals, an assistant/nurse is responsible for monitoring the bottle's electrolyte level. But unfortunately, most of the time the observer may forget to change the bottle at the correct time due to a busy schedule which can lead to fatal conditions like air embolism due to air bubbles in IV pipe when the bottle gets empty. To overcome this critical situation, an intravenous optical sensor system is proposed to measure the liquid level from outside the bottle. The device is designed such that it can be easily replaced from one bottle to another. This device can avoid any fatal condition and ease the workload of nurses.

Keywords— *Intravenous, IV bottle, drip, non-invasive, optical*

1. INTRODUCTION

The main problem faced while implementing such solutions is the method used to measure the liquid level. We cannot use level detectors or gauge sensors as it needs to be placed inside the bottle to measure the liquid. This compromises the solution as the body of the sensor might contaminate the solution. Another issue with such a system is its cost. This is because each IV bottle will need to have the sensor and can't be reused. So, the only option is to use an external method of measurement. One can use a load sensor but again it comes to the economic feasibility, as load sensors cost a lot. Therefore, we need to think of an alternative approach.

The solution we found for this is an optical approach. All this is based on the concept of refraction. When light rays are passed from rarer to denser medium then the ray deviates towards the normal of the plane of the common plane of the two mediums. Lasers are used to create these rays and Light Dependent Resistors (LDR) to detect these laser rays when it hits the LDR. The laser rays hit the LDR when the liquid level goes below the LDR and if the liquid is above the LDR then the ray will refract from the original path and miss the LDR. There will be a column of these Lasers to measure the liquid level at equal distance intervals throughout the bottle length.

This method does not contaminate the liquid inside the bottle as it is a non-contact approach. As these low power lasers and LDRs are cheap the overall cost decreases. And the device can be easily changed from one bottle to another.

1.1 Material used

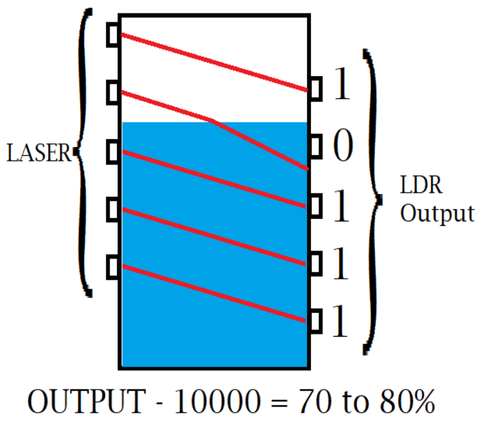

Fig. 1: Arrangement of lasers and LDR's

The device consists of the outer cover or shell structure of the bottle which is designed such that it can be easily replaced from one bottle to another. The shell has two sides one of which has a column of lasers fixed in a specific angle and the other side has a column of LDR's that is one laser for each LDR. The lasers are placed such that the rays coming out of the laser get refracted by the liquid inside the bottle, and hit the other side but not on the LDR. The LDRs are in series with 100 kΩ resistor to act as a voltage divider and the output is taken between the LDR and resistor.

1.2 Method

The lasers are placed in a column with an angle of 30 to 45 degrees which is suitable for considerable refraction of laser rays and avoids total internal reflection with equal spacing. The opposite side of this laser array is the LDR array to detect the laser. The LDR is one for each laser placed such that when the ray does not go through refraction, the ray will hit the LDR. The laser detected in LDR is treated as logic "1" and when no laser detected it is treated as logic "0".

When the liquid is full the output is "0". As the liquid level decreases below the first LDR the ray from the first laser hits the respective first LDR and gives the output as a "1". This "1" is treated as the most significant bit as it is at the highest point. The significance of these bits decreases from top to bottom and accordingly mapped to the liquid level.

This gives discrete value with wide gaps between then. To overcome this problem, we used Kalman Filter to estimate the liquid level in between the discrete output from the laser.

2. RESULTS AND DISCUSSION

To detect only when the laser hits the LDR and not the lights from the surrounding as the surrounding light may change from time to time but the laser source won't. For this we only consider the resistance of LDR when the Laser hits it. The resistance found to be 100 kΩ to 200 kΩ which gives the voltage between the LDR and resistor to be 4V to 4.5V respectively as they are connected in series across 5V. Anything below this voltage is considered to be "0" and the one above this voltage is considered as "1". As we are using five lasers we get five bits as output and are treated as the bit from the highest laser as the most significant bit and the lowest one as the least significant bit.

If "0" comes after "1" then the bit after "0" are ignored as they are below the liquid level and ray from another laser is hitting it after refraction. So, for example, if the output is "10110" then the last three bits are also considered as "0" and the output will become "10000" which is then mapped in percentage as 80%. Similarly, "0000", "11000", "11100", "11110", "11111" are mapped as 100%, 60%, 40%, 20%, 0% respectively.

Using this data, the Kalman Filter calculates the actual liquid level at any time instant. One such result is show below to compare the measurement from lasers, Discrete Kalman Filter Prediction using data from the measurement from lasers and the ideal readings. Equation used for prediction using Discrete Kalman Filter

$$\hat{x}^-_k = A\hat{x}_{k-1} + Bu_k$$

$$P^-_k = AP_{k-1}A^T + Q$$

$$K_k = P^-_k H^T (HP^-_k H^T + R)^{-1}$$

$$\hat{x}_k = \hat{x}^-_k + K_k(z_k - H\hat{x}^-_k$$

$$P_k = (I - K_k H)P^-_k$$

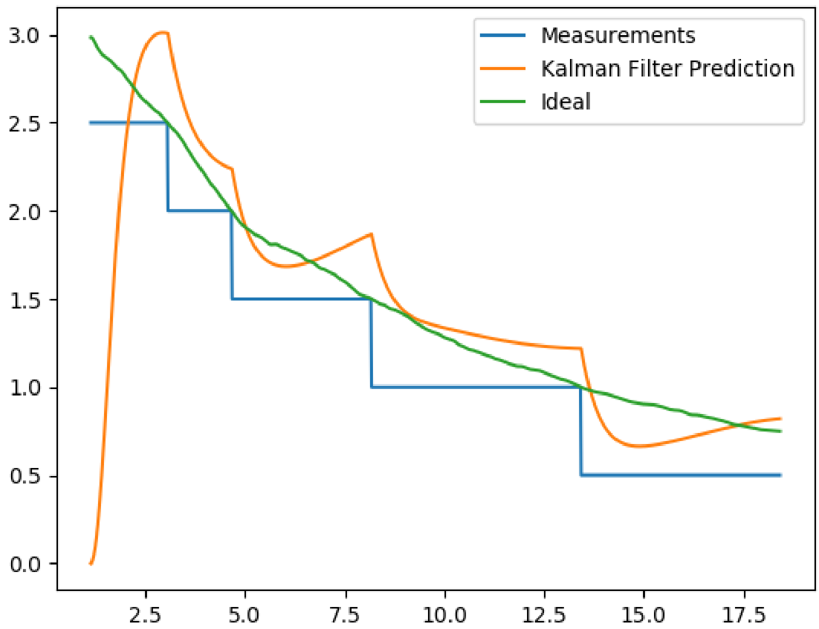

Fig. 1: Liquid level vs. Time

To calculate the theoretical prediction (ideal) we used an equation derived from Bernoulli's equation

$$h(t) = [\sqrt{H} - A/(2a\_t)\,\sqrt{2g}\,t]\hat{}2$$

Where, g is gravity

h(t) is the height of the fluid in the tank at any time

A is the area of the hole

α_t is the area at any time

3. CONCLUSION

This is a low-cost method to measure the liquid level in the drip bottles used in hospitals. The use of Kalman Filter improved the overall accuracy of measurement. The above method when integrated with IoT, then a whole system can be made for hospitals to monitor each patients' IV bottles in real time and get alerts when any bottle in about to finish and there will be no need to check each patients' IV bottles from time to time.

In summary, this non-invasive optical method of fluid measurement was tested and analyzed for saline liquids. This increases the safety of the IV and possibility of hazards due to unattended IV bottles when bottles get empty. This reduces a significant amount of load from the supervising nurses.

4. REFERENCES

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