Non-Invasive Volume Measurement

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JABULLS!!!!!!!!!!!!

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Problem Statement

In medical environments, continuous monitoring of fluid administration is critical to ensure proper treatment. Reducing the time spent on active IV fluid monitoring could improve the workflow of healthcare professionals in intensive medical situations, like sepsis treatment. This project aims to develop a non-invasive method for detecting and estimating the volume of liquid in flexible, non-conductive containers, specifically vacuum-sealed IV bags.

Design Approach/ Methodology

Two time-of-flight (ToF) sensors create a 3D map of the flexible container. The 3D map and a Robot Operating System 2 (ROS2) based software architecture and is used to calculate the volume of the bag using the RP1 I/O controller. The volume estimation is transmitted to a user interface via Wi-Fi. The ToF sensors are controlled using stepper motors placed in a 3D printed chassis. The system obtains feedback of the stepper motor position using switches and a 3D-printed throne for the sensors.

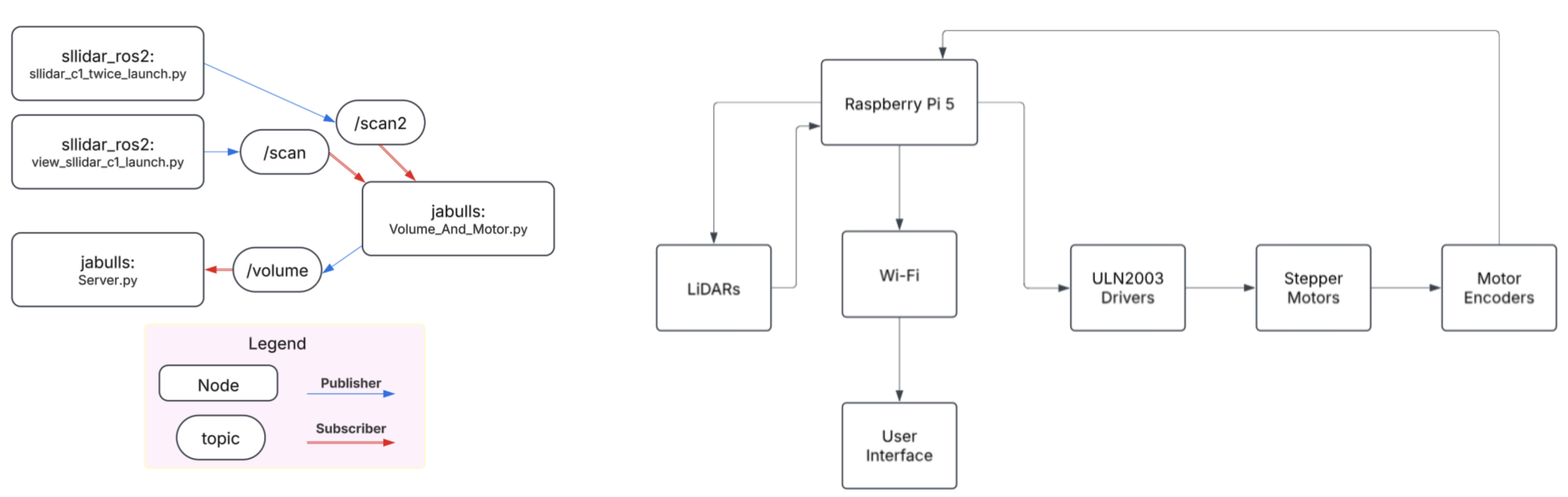


Figure 1: Software architecture (left) and system block diagram (right)

Testing

Table 1: Measurements of a full 500-mL IV bag with water at different distances from the device.

Bag distance from scanner	25 cm	30 cm	35 cm
Avg Vol (mL)	670.8 ± 43.4	441.4 ± 17.1	437.5 ± 12.5
Error (%)	34.1 ± 8.7	11.7 ± 3.4	12.5 ± 2.4

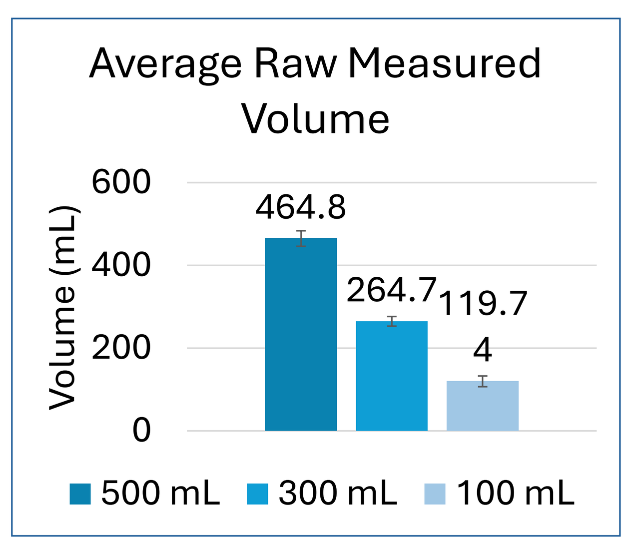


Figure 2: Comparison of raw data averages with 95% Confidence Intervals visualized as error bars

Requirements & Specifications

Need statement: *A way to **reduce the time** spent on **active IV fluid monitoring** by health professionals to **improve the workflow** during sepsis management in **emergency settings.***

Requirements:

- ✓ **Non-invasive:** Does not interact withinside of bag or the liquid
- ✓ **Accuracy:** The volume estimation have 10% or less percentage error in a 1-L bag
- ✓ **Continuous Monitoring:** Takes multiple measurements without additional input
- ✓ **Remote Monitoring:** Data streamed to separate device in UI
- ✓ **Prevent interference:** Identifies bag from other objects
- ✓ **Lightweight:** Below 5 lbs
- ✓ **Inexpensive:** Below $400
- ✓ **Proximity with IV bag**: Can scan a bag 40 cm away or closer

Prototyping

Early protypes used only one scanner and Poisson's reconstruction algorithm to obtain a mesh of a 3D object wherein: The boundaries of the point cloud are filled with missing points. Assuming symmetry within the measured object, the volume of the measured splice is doubled to find the total estimated volume

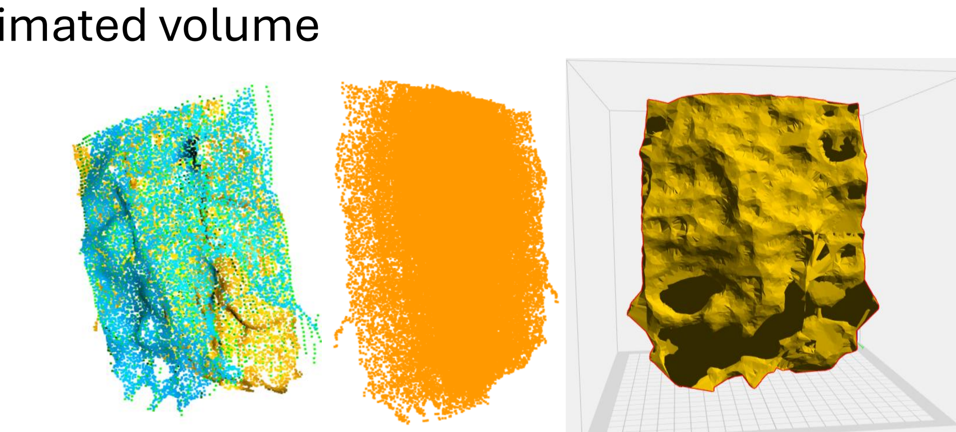
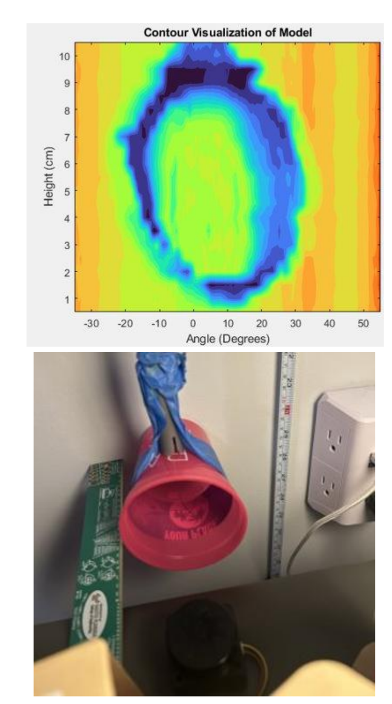


Figure 3: Point cloud and Mesh reconstruction of IV bag in early prototypes

Figure 4: Testing Depth Scan accuracy of LiDAR



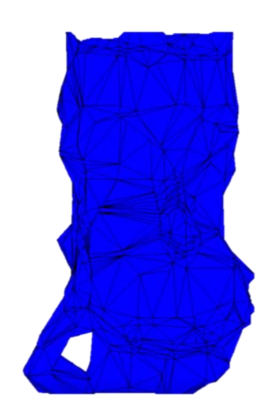


Figure 5: Convex shape generated in later protypes

The final prototype's algorithm uses Kabsch Algorithm to align the datasets obtained, hierarchical clustering to identify the points that represent the bag, polynomial regression and convex hull to create a mesh of the bag.

Proof of Concept (Motivation)

We utilized one LiDAR moved by a stepper motor controlled with a Raspberry Pi 5 to visualize opaque and translucent object to approximate the volume of each shape.

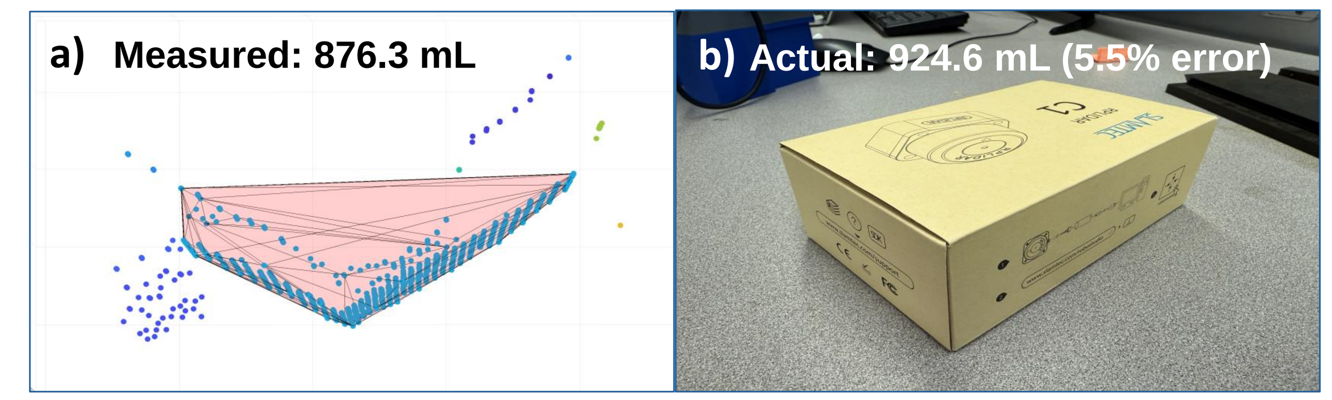


Figure 6: Testing Volume Measurement on opaque box

Analysis of Results

Tests conducted returned a volume within **±12%** accuracy: bags measured at closer distance to the systems (25cm) obtained larger error than those measured 5cm and 10cm away from the bag. Highest accuracy was obtained with a 500mL bag 30cm away from the system. Moreover, each scan takes around one minute to complete, allowing for continuous monitoring.

Conclusion

The system operates within the driving requirements and aids with **IV bag management.** Future improvements can be made to reduce system dimensions as well as increase volume precision, through self manufacturing of PCBs and LiDARs, and additional algorithms and data processing approaches.

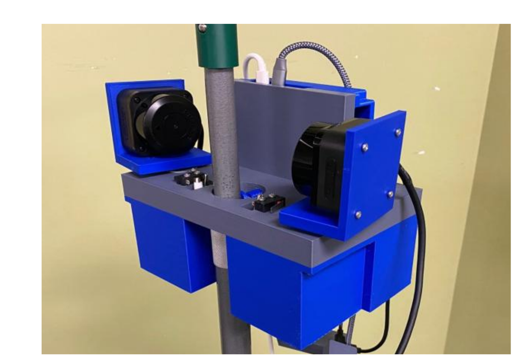


Figure 7: Final Prototype

References

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