AIMS: Air Injection Measurement System

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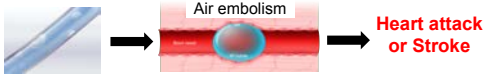
INTRODUCTION

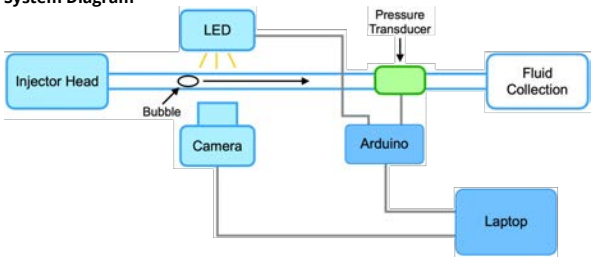
Bayer MEDRAD® Mark 7 Arterion® Injection System

- **Contrast Power Injectors** are used in radiology procedures to diagnose and treat disease [1]
- Risk of causing **air embolisms**, or bubbles in blood vessels [2]
  - May block blood flow and cause adverse effects **including death** in patient [3]
  - May make the collected medical images unusable [4]
- There is need for a system that can **reliably measure the volumes of air bubbles** that pass through the injection tubing



PROPOSED SOLUTION: DEVICE STRUCTURE

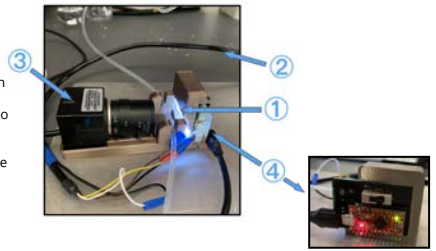
System Diagram



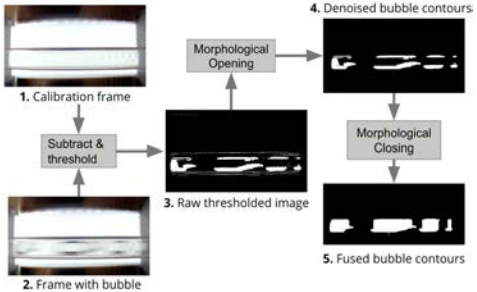
Our proposed system diagram uses a camera and pressure transducer to detect, measure, and quantify the volume of air of a passing bubble. This system will be coordinated by an arduino and commanded by the user via a laptop.

Physical Components

1. Slot for injector **tubing**
   - Fluid with bubbles pass in front of camera
2. **Pressure Transducer** connection
   - Analog reading that is converted to digital by arduino
3. Space for **camera**
   - Video feed goes to our volume calculation algorithm
4. Space in back for **PCB**
   - On/off switch for LED
   - Pressure transducer terminal
   - Houses Arduino which sends measured pressure to laptop



PROPOSED SOLUTION: SOFTWARE ALGORITHM



Algorithm first takes a calibration picture **(fig. 1)**

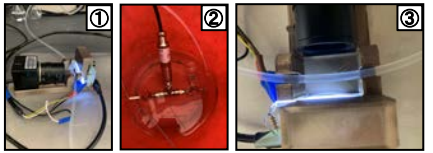
For each frame in the video captured **(fig. 2),** we subtract from calibration picture **(fig. 3)**

We then use morphological opening to reduce noise **(fig. 4)**

We finally use morphological closing to find complete bubble contours **(fig. 5)**

PERFORMANCE TESTING

Goal of testing: The goal of our testing was to characterize the performance of our device.



Testing Setup

① View of the full device setup
- PCB connects to a laptop
- Tubing is fed from injector, through pressure transducer, to device

② Pressure Transducer
- Air is injected through the hand syringe

③ Top view of device setup

Variable Testing Parameters
- Injected bubble volume (mL): *0.05, 0.1, 0.3, 0.5, 0.7*
- Flow rate (mL/s): *0.3, 0.5, 1*

Constant Testing Parameters
- Catheter size: *4 French (1.33cm outer diameter)*
- Injected fluid: *water*

TESTING RESULTS

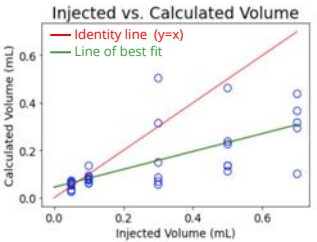


Figure 1. Injected volume (ground truth) vs. volume calculated by our software algorithm. The identity line marks optimal performance.

Line of best fit:
R^2 = 0.456 | Slope = 0.376, Intercept = 0.0448

OBSERVATIONS AND ANALYSIS

High volume bubbles (0.3, 0.5, 0.7mL)
- Most points fall below identity line
  ⇒ algorithm often *underestimates* bubble volumes
- All videos contain at least one "multi-frame bubble" that is longer than one camera frame
- **Why:** Multi-frame bubbles are seen by the algorithm as stationary while both bubble ends are out-of-frame ⇒ their volumes are underestimated

Low volume bubbles (0.05, 0.1mL)
- Calculated volumes fall near identity line and are have a more even split of under- and overestimations
- Calculated volumes are more consistent than for the higher-volume bubbles
- Few videos contain multi-frame bubbles, and in those that do the bubble barely over 1 frame long

MARKET ANALYSIS, MANUFACTURING COST

While devices exist which detect air bubbles, none currently exist which measure the bubble volume, as our device does.

Line Item	Cost / Unit	Upfront Cost
Arduino Micro	$19.99	0
Pressure Transducer	$450	0
PCB	$0.02	$250
Switch	$1.20	0
JST Cable + Connector	$5.89	0
High Speed Camera	$79.10	0
Injection Molded Plastic Exterior	$0.25	$2500
Total	**$556.45**	**$2750**

CONCLUSIONS AND FUTURE STEPS

Our algorithm currently underestimates volume more often in videos with multi-frame bubbles than in videos without them.

There are steps we can take to improve our algorithm's performance:

Changes
- Use a high-speed camera so that bubbles can be captured at higher flow rates, and consequently at higher pressures
- Use of higher viscosity fluids to test the same flow speeds at higher pressures

Benefits
- Enabling higher pressure testing will allow the user to inject greater volumes of air, as the bubbles will be compressed under the higher pressures
- The compression of bubbles at these higher pressures will also avoid multi-frame bubbles

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[2] "Venous Air Emboli and Automatic Contrast Media Injectors." *PA PSRS Patient Safety Advisory*, Dec 2004, http://patientsafety.pa.gov/ADVISORIES/Pages/200412_13.aspx#. Accessed 9 Oct 2020.
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