Low-cost Spirometer

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Problem Definition

Background:

- Spirometry measures respiratory volume and flow rate
- Test results displayed as a spirogram (Figure 1)

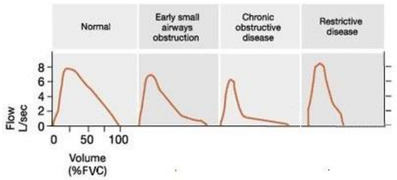

Figure 1: *Examples of spirograms for different respiratory conditions.[1] The shape of the curve is useful in making diagnoses.*

Motivation:

- Common tool for Chronic Obstructive Pulmonary Disease (COPD) and asthma diagnosis
  - ➢COPD is fourth leading cause of death in the world
  - ➢600 million diagnosed worldwide, many lack treatment[2]
- Over 80% of asthma deaths in low and lower-middle income countries[3]

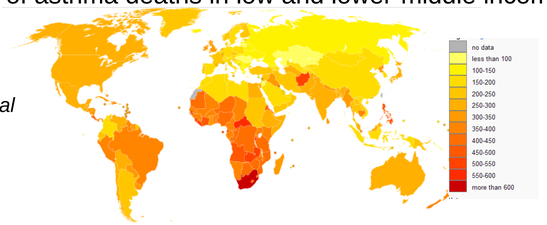

Figure 2: *Map of global asthma distribution[4]*

- Used to monitor drug efficacy, lung growth and aging[5]
- Commercial spirometers cost upwards of $1000
  - ➢ Examples include SDI Diagnostics[6] ($2395) and MicroDirect SpiroUSB[7] ($1419.55)

Design Criteria

- Spirometer connects to computer via USB
- Affordable for use in emerging countries
- Handheld and durable
- Standardized audiovisual coaching for patient
- Easy to operate and disinfect
- Minimize calibration

Budget

Prototype Cost per Unit			
Body		**Circuit**	
PVC	$2.00	Sensor	$7.24
Cardboard mouthpiece	$0.07	Signal conditioner	$2.00
Vinyl tubing	$0.10	PIC18 microcontroller	$1.85
2 Tubing connectors	$3.98	Board Fabrication	$20.00
Cordierite Capillaries	~$30	Accessory circuitry components	~$8.00
Section Total:	$36.15		$39.09
TOTAL			**$75.24**

•Change in capillary material will reduce cost

Abstract

Current spirometers on the market often have retail prices of over $1,000, making them unaffordable to many physicians in emerging nations. We have designed and built a low-cost spirometer model that consistently generates a linear signal output based on air flow. We have implemented software that displays data in real-time and a method for calibration utilizing a 3-L syringe. Post-calibration, volume measurements between our spirometer and a Jones syringe are similar. The mean volume measured by the spirometer for 30 plunges from a 3-L syringe was 3.04 ± 0.26 L. A spirometer capable of preliminary respiratory assessment can be manufactured for under $100 which would make spirometry more accessible to practitioners in low- and middle-income countries.

Final Design

Spirometer Hardware

- •Spirometer body contains capillaries that produce laminar air flow (a Fleisch design).
- Utilizes a differential pressure sensor to measure drop through spirometer (Figure 3).
- Pressure is proportional to flow, air volume obtained by software integration.

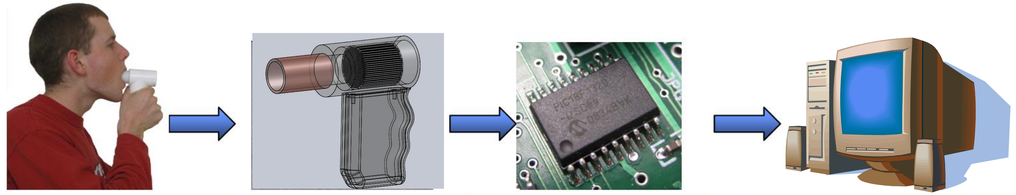

Figure 3: The proposed final layout of the operation of our spirometer.

Software and User Interface

- Open-source application written in Java
- Digital Butterworth filter reduces noise
- Used to calibrate spirometer
- Start and stop with click of button
- Real-time graphing of data
- Sailboat incentive screen

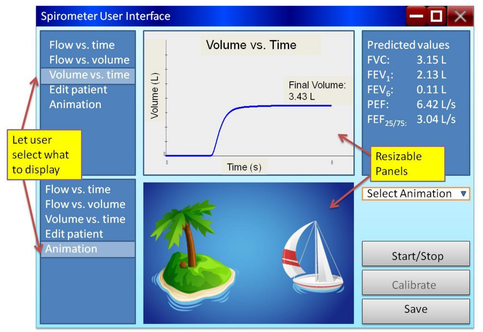

Figure 4: The proposed graphical user interface screen.

Calibration Methods

Volume-based Calibration

- Can be performed with industry standard 3-L syringe
- 3-L syringe plunged 30 times at slow, medium, fast speeds
- Integral of the flow values equates to volume
- Volume for all trials is known
- 3rd order polynomial provides good pressure-flow conversion[8]
- Calculate polynomial coefficients using linear regression

Testing

Testing system

- Jones calibration syringe measures PEF, FEV1, FVC, FEV25, FEV75 and MMEF
- Compare values calculated by spirometer to Jones syringe
- •Mean volume = 3.04 ± 0.26 L

Figure 5: Jones calibration syringe

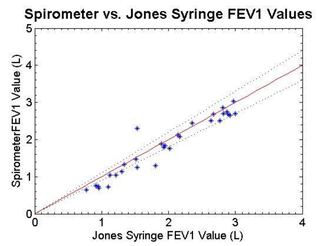

Figure 6: Plot of FEV1 values calculated by our spirometer's calibration vs. the values displayed on the Jones syringe. Dotted lines indicate ±10% of expected values.

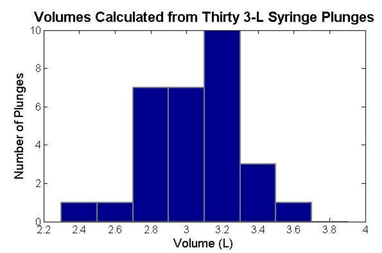

Figure 7: The volumes calculated by our spirometer for 30 plunges of a 3-L syringe.

Future Work

- Perform human subjects testing
- Establish method for low-cost capillary manufacturing
- Print circuit and finalize microcontroller program
- Apply for federal funding for global implementation

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