30.123: Healthcare Product Development (AY2023 Term 7)

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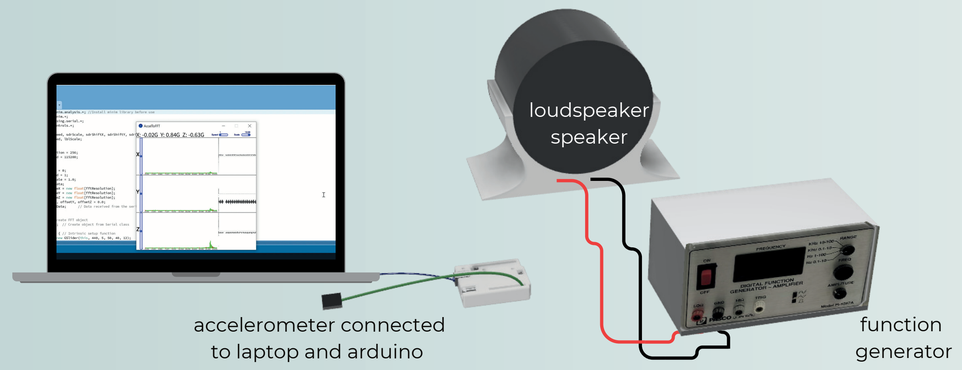
UroSound

NOVEL NON-INVASIVE URODYNAMIC DEVICE

A low cost device to continuously measure the pressure inside the bladder using sound waves with more privacy, no pain, and no risk of infection.



IDENTIFY

CLINICAL NEED

Traditional urodynamic testing:

Invasive, hence **painful, uncomfortable, anxiety inducing and risk of infection**	Catheters inserted in urethra and rectum
Bulky and Expensive	Equipment
Lack of privacy	Void in presence of nurse
2 to 3 months waiting time	Only available in hospitals

CLINICAL SIGNIFICANCE

250,000 individuals → worldwide need UDS test annually

Invasive nature → deters patients

Denying UDS → Long term consequences:
- Kidney failure
- Need of long term catheter to pass urine

No proper treatment

MARKET

The urodynamic study market in developed countries is around **250 million SGD yearly** and expanding. Experts agree: a non-invasive approach for UDS studies is the preferred choice among doctors.[1]

$ 250 million

How might we enable doctors to execute the urodynamic procedure **non-invasively** so that they can **increase patient compliance** and **treat patients effectively**?

IDEATE

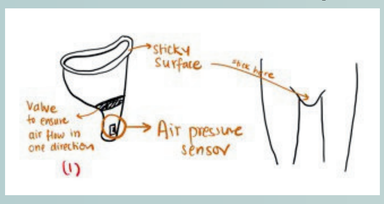
PERSONA

- Peter, 64 years old, in treatment for bladder function abnormalities
- Needs to take a urodynamic test at the hospital
- Thinks about not taking the test because of the invasive procedure

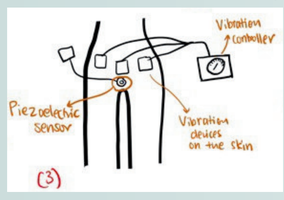
CONCEPT GENERATION

As there is currently no state of the art for a non-invasive bladder pressure measurement device we took **inspiration** from **other biomedical devices and other industries** for concept generation

Inspiration: The go girl, Idea: to make a peeing device that can measure bladder pressure



Inspiration: Wearable ultrasound patch to track heart rate and blood pressure[2]



Inspiration: Piezoelectric sensor based

Inspiration: Pressure measurement in petrochemical industry[3]

PROTOTYPE

Stage 1

Wearable ultrasound patch

- Uses m-mode ultrasound and advanced machine learning models
- Too technical and advanced for the duration term 7

Challenges: Ultrasound sensor for medical application is difficult to develop and exceeds our budget if we try to buy

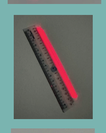
Feedback from prof: Explore possible solutions in the **lower frequency range**

Final idea: Using acoustic waves to measure bladder pressure

Stage 2

Working Principle: Measure the **resonance frequency** of the balloon as a function of pressure inside water-filled balloon bladder phantom

Laser Spot oscillation



Results:

As volume of water in balloon increases the resonant frequency of the balloon decreases.

Amount of water in balloon should be related to water pressure.

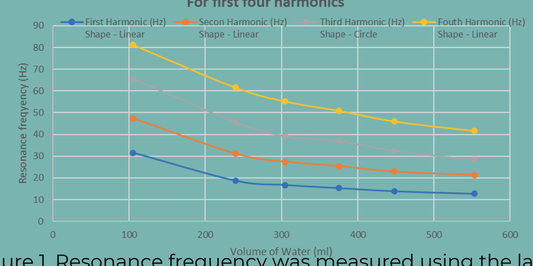


Figure 1. Resonance frequency was measured using the laser spot size amplification (optical method) at resonance condition

Stage 3

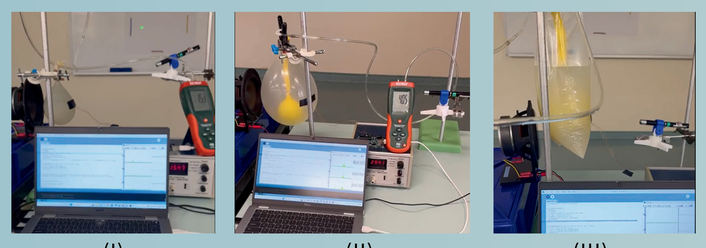
Challenges
- Screen needs to be place approximately 8-10 meters away to view change in laser profile clearly
- Set up takes long time
- For complex vibration at resonance frequency complex vibrations were observed indicating the presence of multiple harmonics, but difficult to make sense of

Accelerometer sensor to detect resonance frequency

Allows collection and recording of resonance condition data in electrical signal - using accelerometer, Arduino and computer
Real time FFT could be performed to obtain the information about different harmonics presence in complex vibration motion

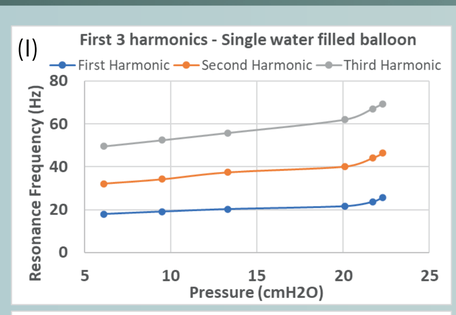
OUR SOLUTION

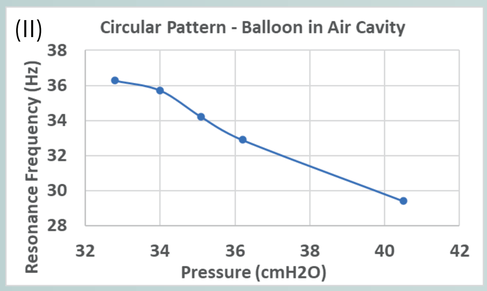
RESULTS

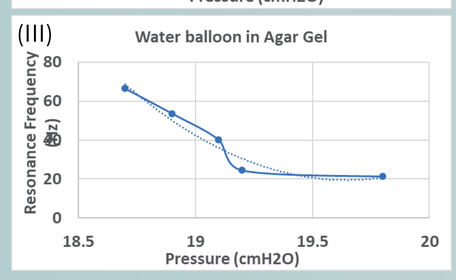


(I) (II) (III)

Resonance Frequency changes with the change in bladder (balloon) pressure for all three experiments (i) Bladder (balloon) alone, (ii) bladder in air-cavity, and (iii) bladder in Agar-gel







CONCLUSION

Change in the water pressure of the balloon changes the resonance frequency and thus can be calibrated.

FUTURE IMPROVEMENTS

Improved accuracy

Application specific tailored sensors and equipment will provide more consistent and more accurate measurements.

Volume - pressure correlation

By better defining how bladder pressure changes in relation to bladder volume, wider measurement scale can be achieved.

Human testing

Testing the setup in real environment can provide valuable information for the practical improvements.

Laser Spot Oscillation

This can be improved to very high resolution, like atomic force microscope, using 2-dimension photodiode array to electrically record the signal.

Machine Learning based Improvement

For application in complex human body situation, ML algorithm probably can be trained using other calibrated measurement technique data together with the data obtained from UROSOUND (either laser spot oscillation data using photodiode array or accelerometer-Arduino data).

FEATURES

Measures bladder pressure

Using sound waves to vibrate the bladder until the resonance frequency is found. The resonance frequency can than be used to estimate the bladder pressure.

Improved user privacy

Due to the increased privacy through the non-invasive nature of UroSound the user feels more comfortable during the procedure.

Real time continuous monitoring

Low Cost

Designed using loudspeaker, accelerometer and Arduino

Designed for everyone

UroSound is not only designed for the user but also the needs of the doctor are considered through ease of use and easiness of implemention.

Accurate bladder pressure measurement

Once, calibrated the device can measure bladder pressure accurately.

Replaceable sensor

The accelerometer vibration sensor can be replaced when damaged

References

[1]https://www.terveystalo.com/fi/palvelut/virtsarakon-tahystys-kystoskopia
[2]https://www.nature.com/articles/s41587-023-01800-0#Sec1
[3]https://www.johnhcarter.com/industries/oil-gas/midstream-oil-and-gas/natural-gas-compression/vibration-condition-monitoring/