Study of a smart cup for home monitoring of the arm and hand of stroke patients.

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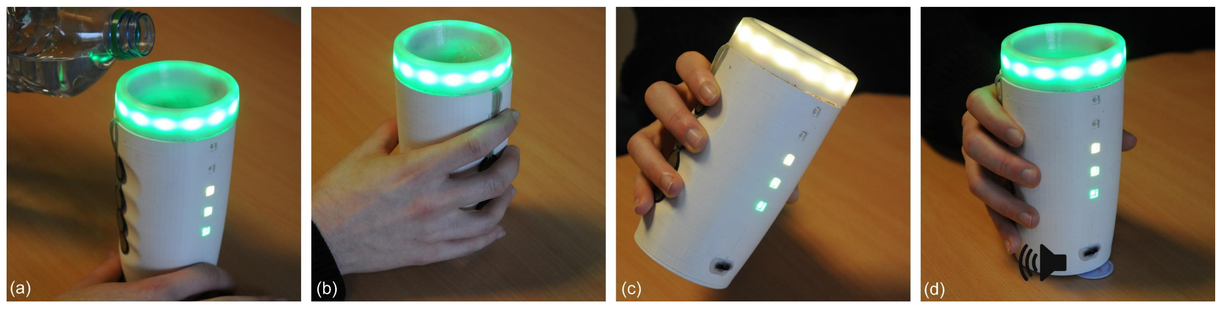
Context

- 15 million people are affected by stroke every year. [1]
- Stroke patients encounter varied cognitive and motor impairments.
- Stroke rehabilitation is very expansive in terms of infrastructures and medical staff. Moreover, patients are left alone at home without monitoring to assess their recovery,
- Activities of the Daily Living (ADLs) can provide relevant data about the patients' recovery.

Objectives

- Continuous monitoring of stroke patients
- Monitoring at home
- Based on Activities of the Daily Living [2]
- Provide guidance during task completion



SyMPATHy cup used during steps: (a) filling, (b) grasping, (c) moving and (d) releasing.

Design Process

Identification

Task to perform

Interview:
2 health professionals working at a stroke rehabilitation center

→ **task of reaching, filling and transporting a cup**.

► Based on different motor sub-tasks (arm movement, hand grasping, etc.) with the upper limb,

► Sub-tasks involved in other usual ADLs (cleaning, take a shower, etc.).

► Simultaneously involves vision, tactile, proprioception and audio sensory feedback.

Features and feedback

► Filling the cup
→ visual feedback (column of LEDs)

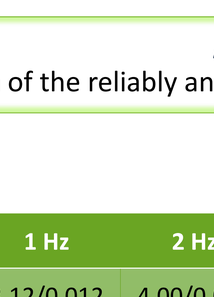
► Grasping the cup
→ no feedback

► Holding and moving the cup
→ visual feedback (circle of LEDs)

► Releasing the cup on the table
→ audio feedback (beep)

Additional monitoring: Tremors

Implementation



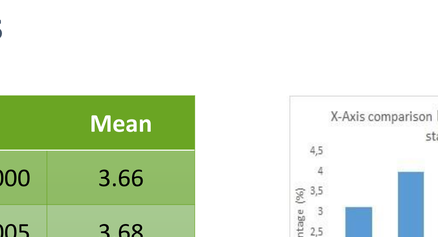
Sensors
- 9-DoF Inertial Movement Unit (Orientation and tremors)
- Custom liquid level sensor based on water conductivity (Liquid Level)
- Near-Field Communication (NFC) board (Relative position of the cup)
- Force Sensing Resistors (FSR) (grasping)

Displays
- Circle of LEDs (Orientation)
- Column of LEDs (Liquid level)
- Speaker (Relative position of the cup)

Data Processing

Fusion Algorithm

RTIMULib from Richards-tech uses RTQF fusion algorithm, a simplified version of a Kalman filter for an effective fusion of data.



Low Pass Filters (LPF) applied for noises suppression.

- 20 Hz cutoff frequency LPF for the gyroscope
- 21Hz cutoff frequency for the accelerometer.

Tremor detection and characterization

Based on a spectral analysis tool Fast Fourier Transform (FFT)

→ highlight the frequency components of a noisy time domain signal.

Method:

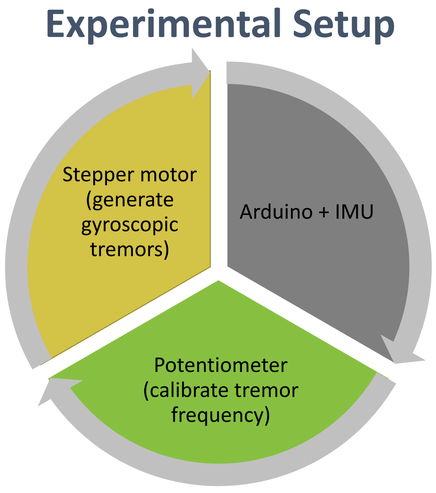
1. FFT for the each axis.
2. Compute the Power Spectral Density (PSD) for each axis.
3. Select the maximum value of PSD corresponds to the fundamental frequency of the signal.

Technological Study

Aim

Evaluation of the reliably and accuracy of the tremor detection.

Experimental Setup



Protocol

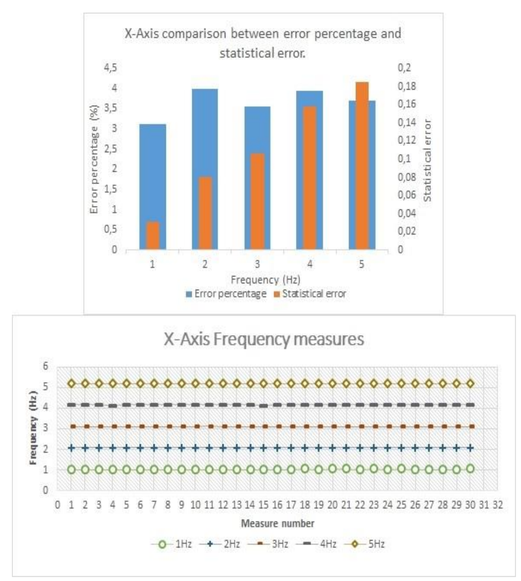
- Axis recorded : X, Y, Z
- Number of measures : 30 per axis
- Tremor frequencies (Hz) : 1, 2, 3, 4, 5

Results

	1 Hz	2 Hz	3 Hz	4 Hz	5 Hz	Mean
X	3.12/0.012	4.00/0.000	3.55/0.005	3.96/0.007	3.71/0.000	3.66
Y	3.32/0.013	4.00/0.000	3.55/0.005	3.86/0.012	3.69/0.005	3.68
Z	2.93/0.010	4.00/0.000	3.61/0.009	3.80/0.005	3.77/0.009	3.66

Error percentage/Standard deviation with a ±3% specified error range.

- Error percentage is independent from the axis and always around 3.6%.
- Standard deviation never exceeds 1% of the measured frequency → good accuracy.
- Statistical error proportionally increases with the frequency.
- Error percentage always around 3.6%.
- Measures with the IMU sensor are repeatable.



Representation of the X-Axis data.

Conclusion & Future Work

Conclusion

- ✓ **Development of SyMPATHy for home monitoring and guiding of stroke patients during ADLs.**
- ✓ **Recording of relevant data about the patient recovery state.**
- ✓ **Technological validation of the reliability and repeatability of the platform.**

Forthcoming Research

- → **Two studies are planned to improve the features of the cup**
- → **Creation of a usable visualization tool for the therapist**
- → **Investigation of the usability of the cup both for patients and therapists.**

Acknowledgments

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References

[1] J. S. Kim. Delayed onset hand tremor caused by cerebral infarction. *Stroke*, 23(2):292-294, 1992.
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