Limitations of the e-puck’s accelerometer to detect earthquakes

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Layout

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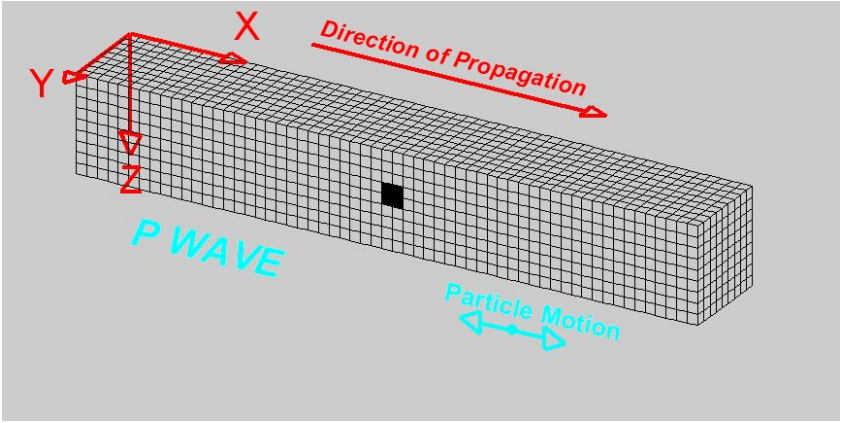
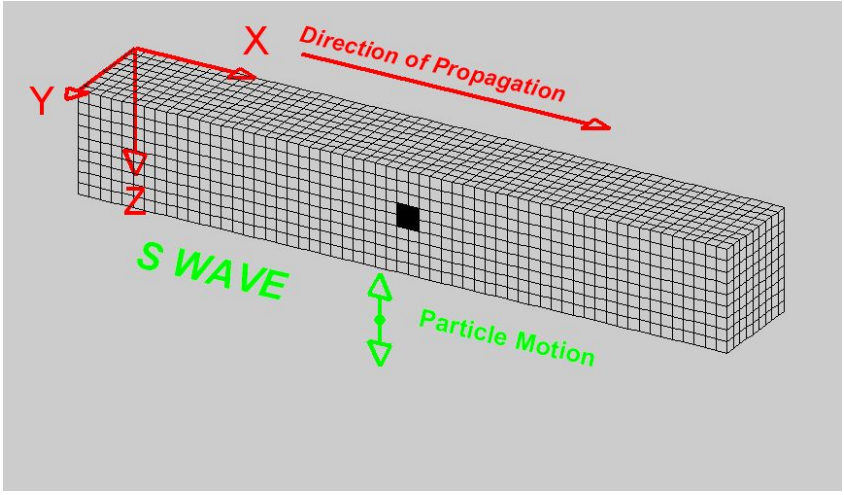
Goals of the project

- Detect an earthquake in real time
  - Find the magnitude of the earthquake
  - Find the frequency of the earthquake
- Distinguish between different kinds of movements
  - Avoid false alert
- Validate the use of e-pucks as small cheap seismograph

Earthquake waves

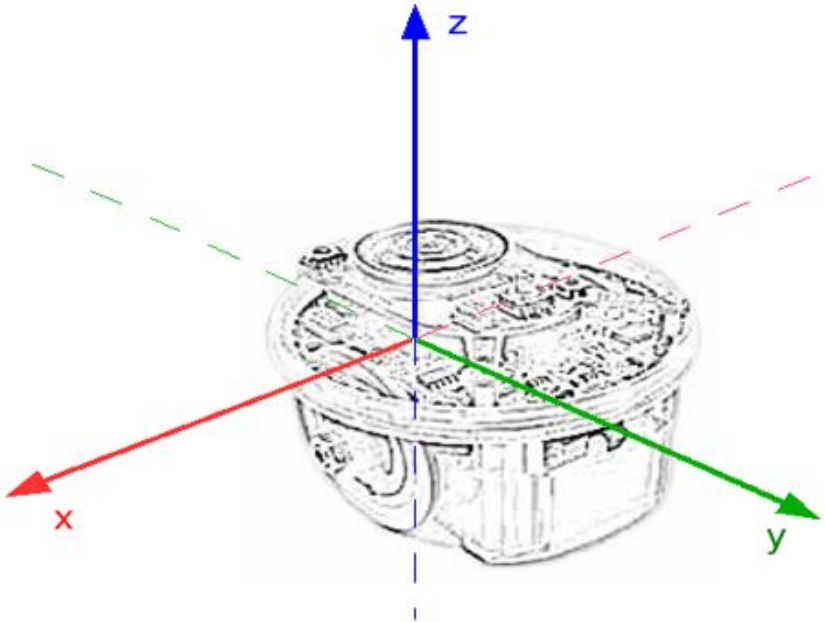
- Two major kinds of waves
  - Primary waves (P-wave)
    - Faster
    - principally in the x-y plane
  - Secondary waves (S-wave)
    - Slower
    - in the z direction
- Range of measured earthquake: [0.1-29.43] m/s^2
- Most common frequency: [0.02-20] Hz





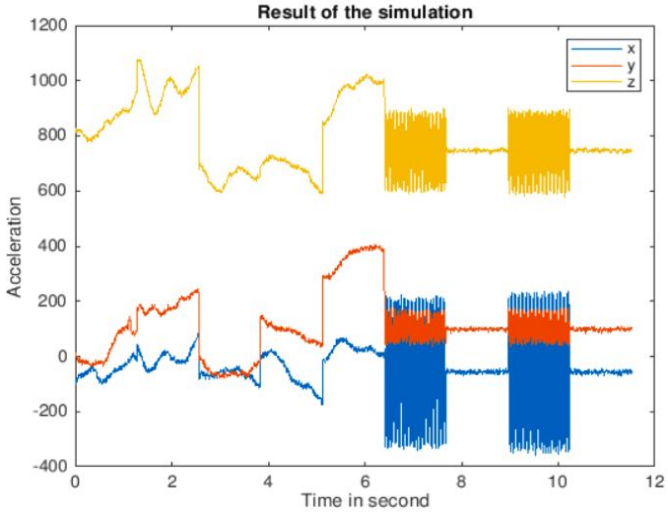
Accelerometer

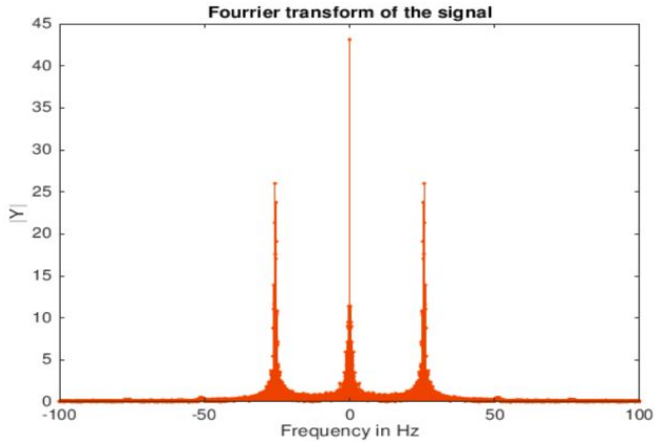
- Low-g Micromachined Accelerometer
- Rate of change of velocity with time
- Range of sensitivity
  - ±1.5g, ±2g, ±4g, ±6g
    - 1g= acceleration of earth
- Min and max amplitude detectable for ±2g
  - 0.0768m/s^2
  - 19.62 m/s^2
- Max sampling frequency is 11kHz
- **Theoretically able to detect earthquakes**



Matlab (1)

- Understand the data
  - rough data
    - simple movement
    - vibrating phone
  - after computing the FFT
    - zero frequency



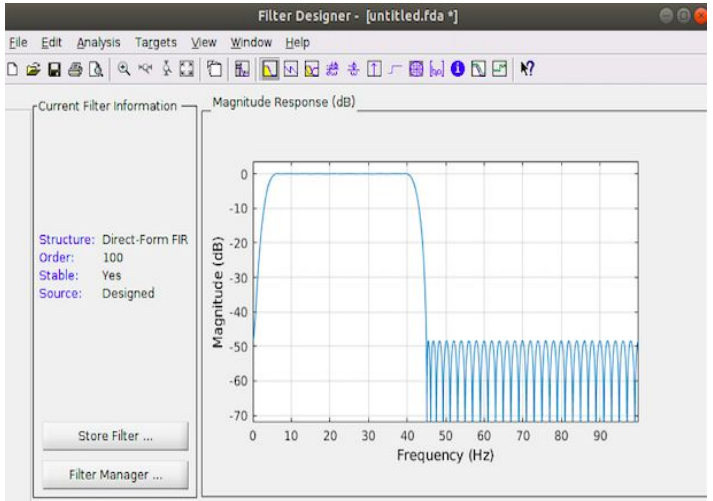


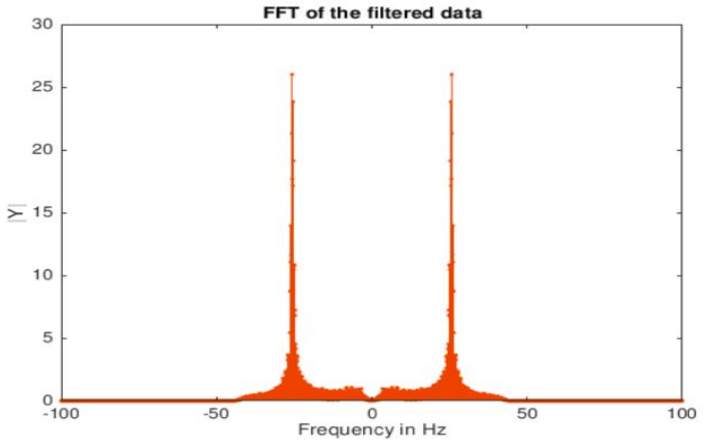
Matlab (2)

- Bandpass Filter
  - magnitude response
  - convolution

$$y[n] = \sum_{k=0}^{M} b_k x[n-k]$$

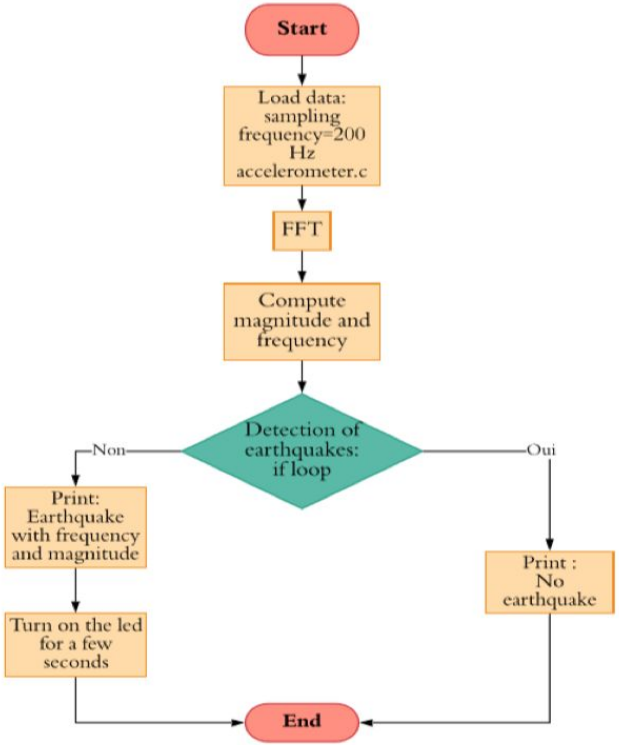
- FFT

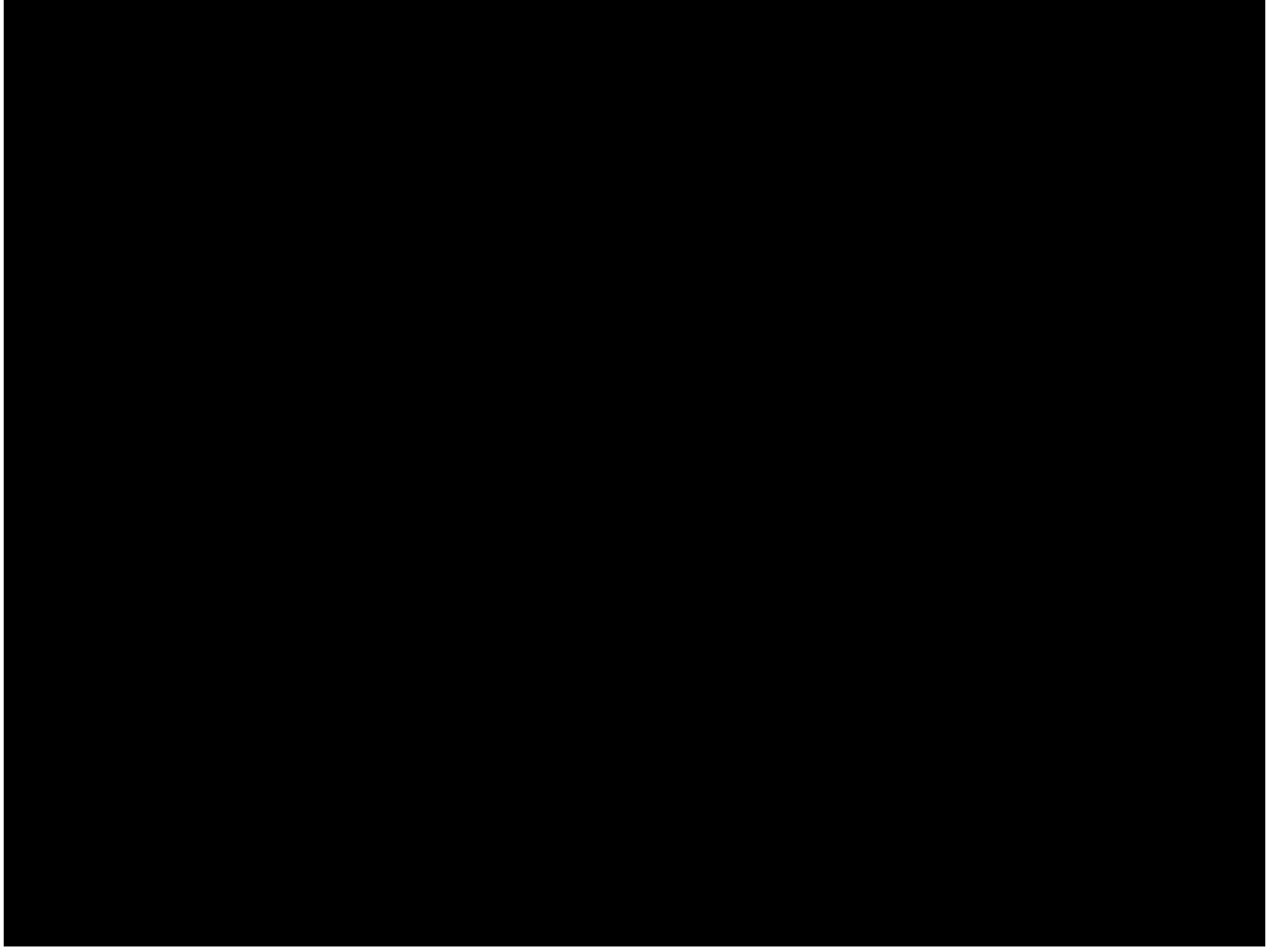




Algorithm used on the E-puck

- No filtering
- 5Hz-80Hz
- Block of 256 data
- Magnitude less than a given threshold
- Extract the frequency with the maximum corresponding magnitude
- Light
- Send a message to the console





Short movie of the e-puck in action

Experiments and results

- 4 experiments with the e-puck
  - Staying still on a table (Test 1)
    - goal: no detection of seism
  - Someone moving the e-puck around (Test 2)
    - goal: not mistake the simple movement with an earthquake
  - Phone on vibration mode to mimic an earthquake (Test 3)
    - goal: detect the vibration
  - A mix of everything above (Test 4)
    - Distinguish between the simple movement and the earthquake
- Binomial law: 1=success & 0=failure

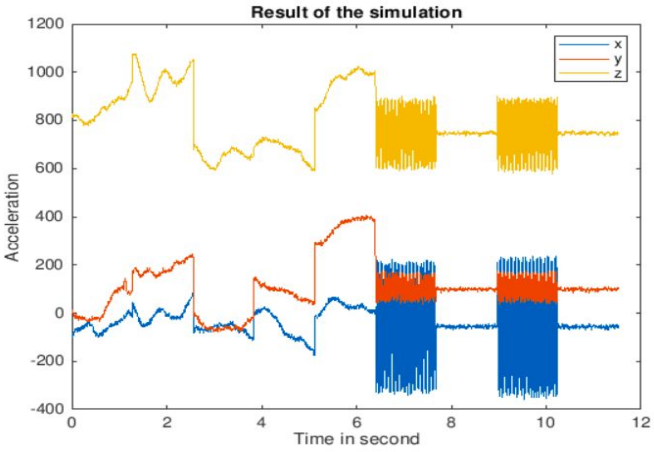
Result of the different scenarios				
	Test 1	Test 2	Test 3	Test 4
Percentage of success	100	60	70	60

! Earthquakes have different characteristics than a smartphone on vibration mode !

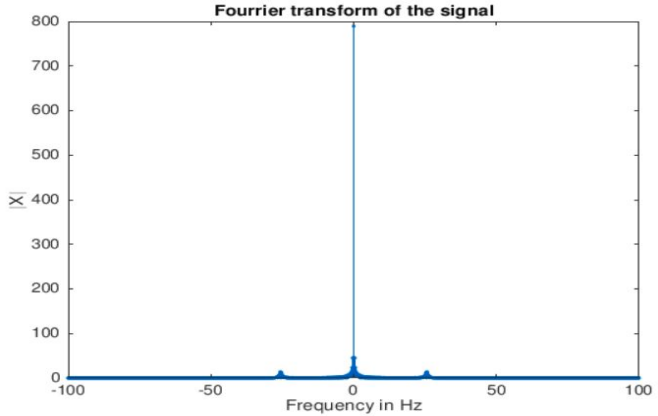
Limitations (1)

- Noise
  - of the sensor
  - 0 frequency
    - below 5 Hz

    → “filter” the frequency
- Physical limitation
  - insulating wheels
  - accelerometer only in 3 direction
- For more precision
  - store the frequency and magnitude in a float
  - not possible with e-puck



Graph showing the acceleration for the three dimensions



Graph showing the amplitude of the FFT of the signal along x-axis

Limitations (2)

- Only detecting one earthquake each ~1.2 s
  - Sampling frequency: 200 Hz
  - FFT done each 256 data

  → extract the maximum magnitude

  => Fs = 2000 Hz + FFT each 256 data → detect earthquake each 1/8 s → more robust
- Delay: always present → deal with it
  - no filtering
  - 40 trails: 1.18 s of delay between the phone starting vibrate and the console printing it

Improvements if more time available

- Detect earthquakes with frequency lower than 5 Hz
- Distinguish a P-wave from a S-wave
- Set a scale of dangerousness by using different colors of led depending on the magnitude

Conclusions

- Distinction of an earthquake and a simple movement under certain conditions
  - type of smartphone
  - way it is moved around
- Biggest difficulty: make the FFT work
- Programming skills improved
- Application of a mathematical tool such as the Fourier Transform to a concrete case
- Interesting and funny

References

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