Shimmer IMU sensors

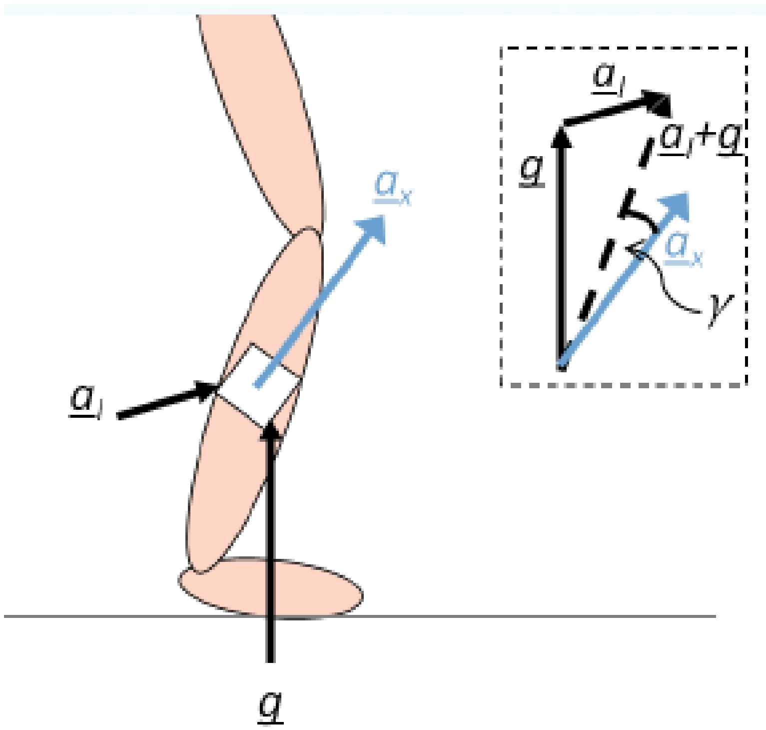
Ευαγγελία Αθανασακη

HARDWARE

- ACCELEROMETER (3D): measures the change in velocity
- GYROSCOPE (3D): measures the angular velocity
- MAGNETOMETER (3D): measures the strength of the magnetic field

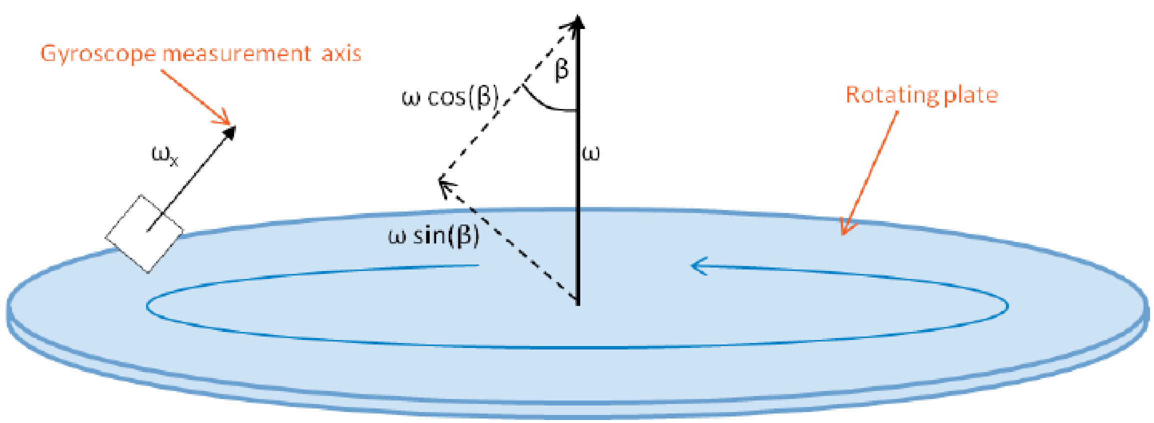
HARDWARE
ACCELEROMETER

$$\underline{a} = \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix} = \begin{bmatrix} a_I \cos(\theta_x) + g \cos(\varphi_x) \\ a_I \cos(\theta_y) + g \cos(\varphi_y) \\ a_I \cos(\theta_z) + g \cos(\varphi_z) \end{bmatrix},$$



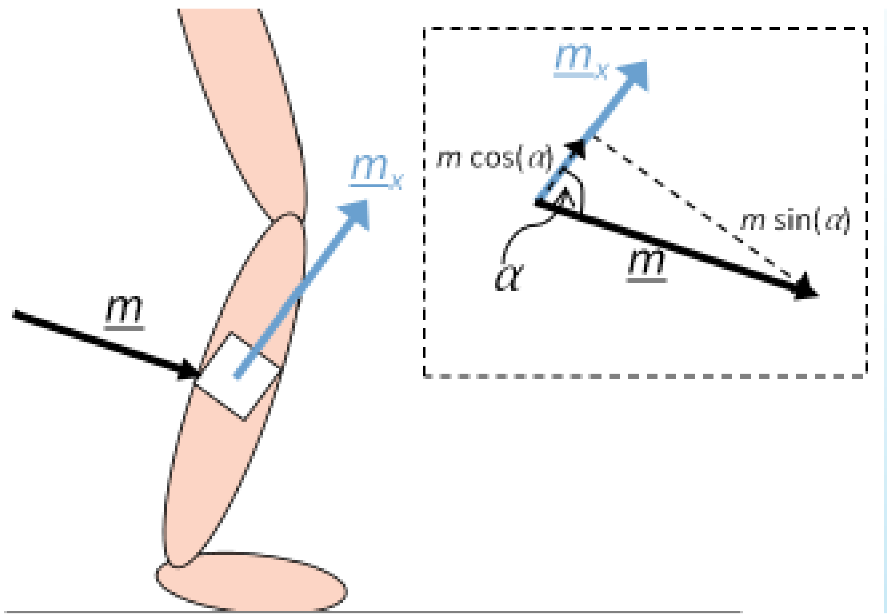
HARDWARE
GYROSCOPE

$$\underline{\omega} = \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix} = \begin{bmatrix} \omega \cos(\beta_x) \\ \omega \cos(\beta_y) \\ \omega \cos(\beta_z) \end{bmatrix},$$



HARDWARE
MAGNETOMETER

$$\underline{m} = \begin{bmatrix} m_x \\ m_y \\ m_z \end{bmatrix} = \begin{bmatrix} m\cos(\alpha_x) \\ m\cos(\alpha_y) \\ m\cos(\alpha_z) \end{bmatrix}$$



SOFTWARE

Data we actually get from each device have this format

ACCELEROMETER			GYROSCOPE			MAGNETOMETER		
X axes	Y axes	Z axes	X axes	Y axes	Z axes	X axes	Y axes	Z axes
-0.6381260517 -0.6380077624 -0.5673273650 ⋮ 0.21909503347 0.23075359958 0.27738063488	-0.85463565892 -0.81825331906 -0.79494647771 ⋮ 4.72064493121 4.72026912372 4.79104052609	9.99691863372 10.0087475664 9.93393015842 ⋮ 8.81426530854 8.78964565140 8.69044442106	-1.30603847151 -1.06992021997 -0.83719184135 ⋮ 1.24207108972 1.79285476800 0.98309672126	0.77993576999 0.84110720293 0.91757149411 ⋮ 1.66692154763 1.03991435999 0.55054289646	-1.71018442341 -1.11508475673 -0.85897238112 ⋮ 1.24207108972 1.79285476800 0.98309672126	0.61133603238 0.61133603238 0.61133603238 ⋮ 0.61740890688 0.61740890688 0.61740890688	-0.64372469635 -0.64372469635 -0.62348178137 ⋮ 0.02834008097 0.02834008097 0.02834008097	0.72 0.72 0.72 ⋮ 0.81500000000 0.815000000001 0.81500000000

They are calibrated so we get them in known SI metrics

SOFTWARE

The output is described by:

$$\underline{Y} = Kr\underline{u} + \underline{b} + \underline{n}$$

$$\underline{Y} = \begin{bmatrix} Y_x \\ Y_y \\ Y_z \end{bmatrix}, \quad \underline{v} = \begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix}, \quad K = \begin{bmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & k_z \end{bmatrix}, \quad R = \begin{bmatrix} r_{x'x} & r_{x'y} & r_{x'z} \\ r_{y'x} & r_{y'y} & r_{y'z} \\ r_{z'x} & r_{z'y} & r_{z'z} \end{bmatrix}, \quad \underline{b} = \begin{bmatrix} b_x \\ b_y \\ b_z \end{bmatrix} \quad \text{and} \quad \underline{n} = \begin{bmatrix} n_x \\ n_y \\ n_z \end{bmatrix}$$

K	Sensor’s scale factor
r	is the rotation matrix which defines the actual sensor axes
u	value of the sensed phenomenon
b	is the offset bias vector
n	is the noise vector

THIS PROJECT

What we do

Characterizing four hand movements using all three 3D sensors

1. up
2. Down
3. Right
4. Left

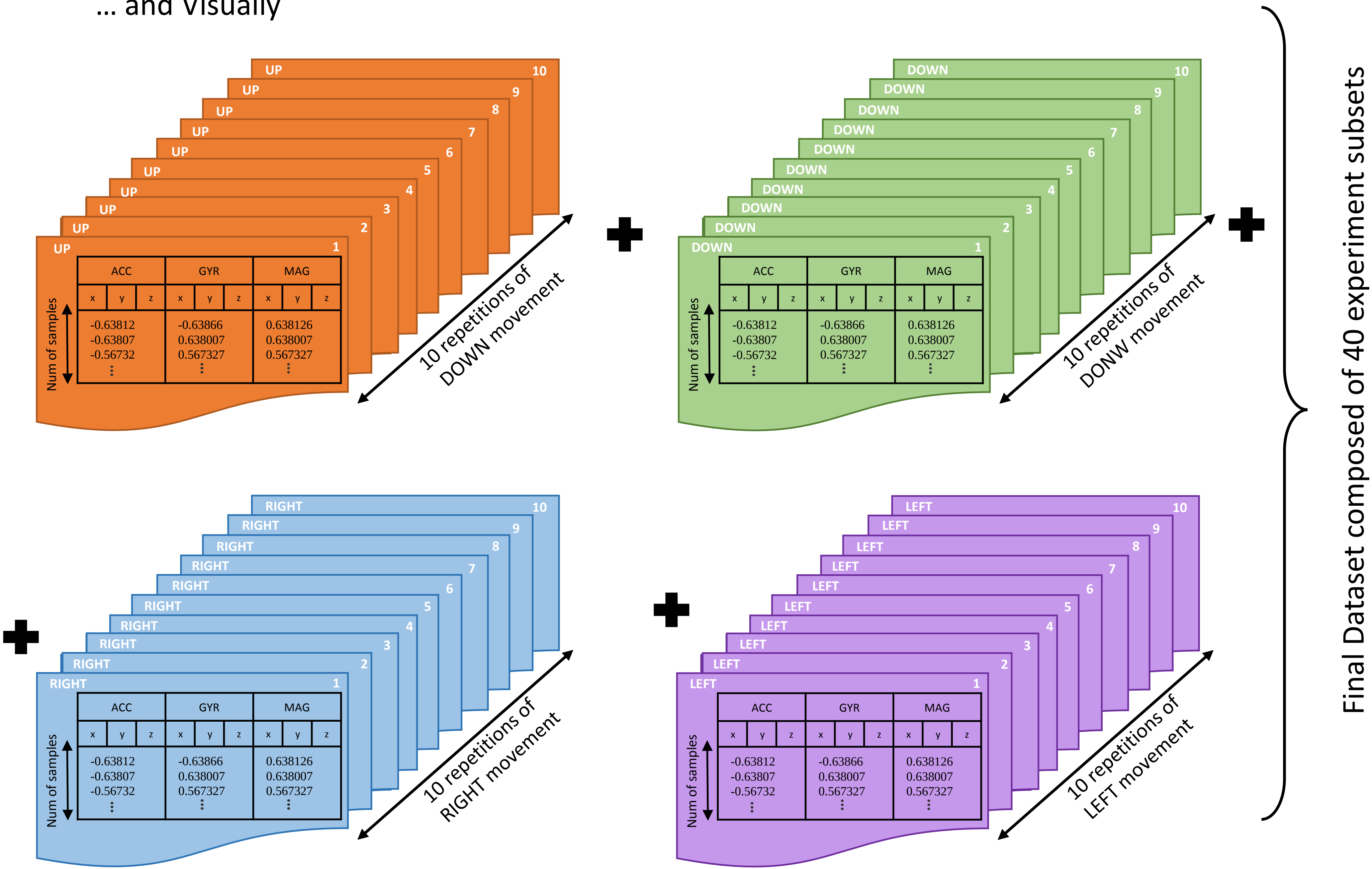
How we do it

- gather measurements (samples) from all sensors for each movement
- Repeat each movement 10 times

…so actually we got 40 experiment sets from samples

THIS PROJECT

… and Visually



DATA ANALYSIS
METHODOLOGY

Training phase

- Choose 7/10 experiment sets of each movement and elaborate them at the same time so we end up with 28 training sets

- From each training set we extract the values below, to use them as features in clustering
  Mean / Rms /Std/ Median

- Using features above to separate into cluster our dataset expecting to get four clusters each labeled as one from our movements

Testing phase

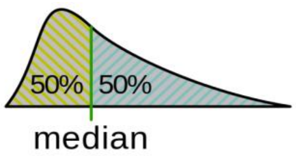
- Take the 3/10 experiment sets that left from each movement total sets (12 testing sets)
- Extract Mean / Rms /Std/ Median values from each set
- Run clustering with the above
- Check the correctness of the results

Mean: average of all numbers

sample $x_1, x_2, \ldots, x_n$

$$\bar{x} = \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right) = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

Median: the middle number in a set of data



Rms (root mean square): the square root of the mean square

n values $\{x_1, x_2, \ldots, x_n\}$

$$x_{\text{rms}} = \sqrt{\frac{1}{n}\left(x_1^2 + x_2^2 + \cdots + x_n^2\right)}$$

Std (standard deviation): quantifies the amount of variation or dispersion of a set of data values

$\{x_1, x_2, \ldots, x_N\}$ are the observed values of the sample items,

$$s = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x})^2}{N-1}}.$$

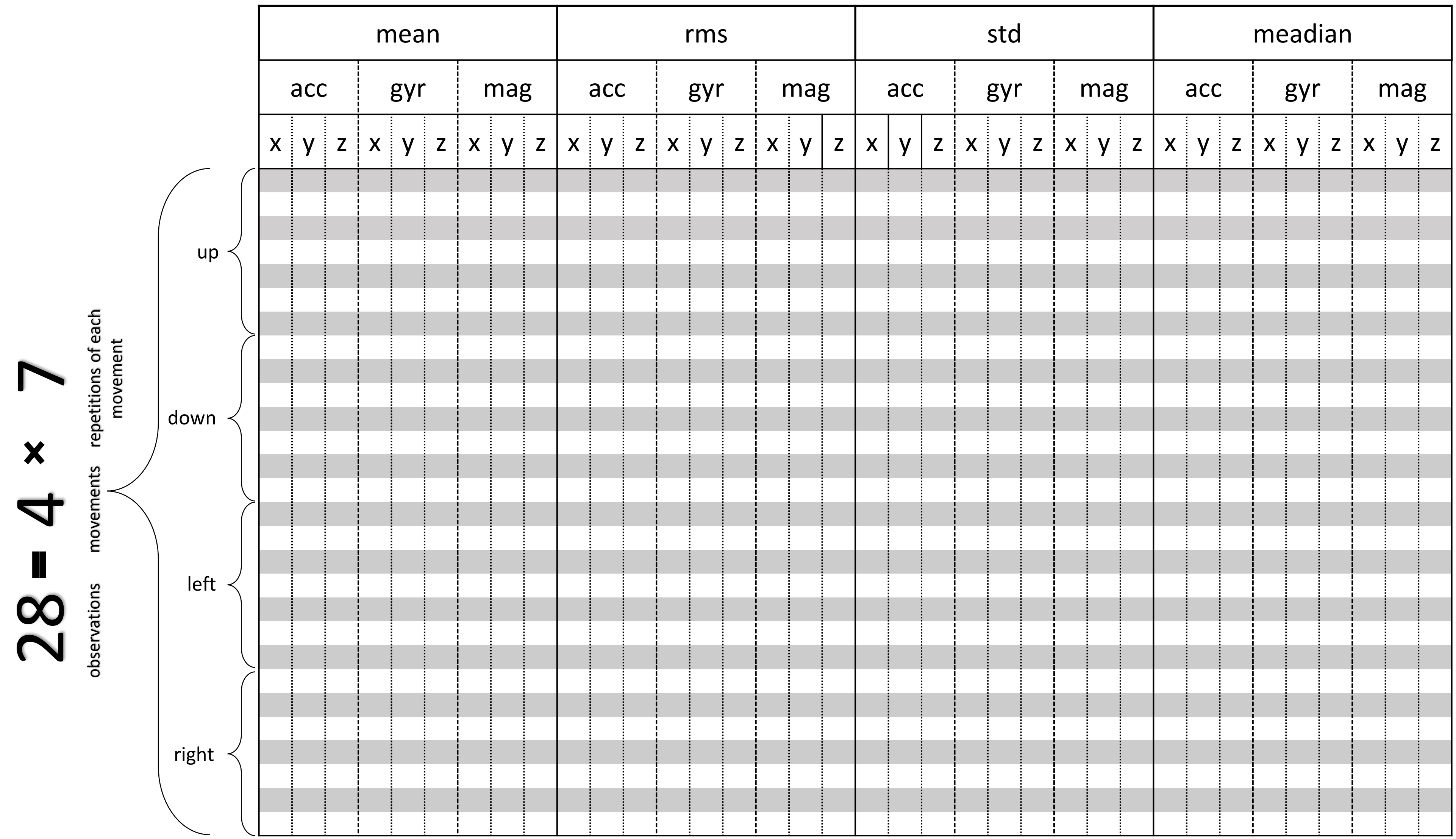
$\overline{x}$ is the mean value

Data we actually analyze

n-by-p data matrix

n: number of observations (28 = $4_{\text{movements}}$ * $7_{\text{experiments}}$)

p: features used (4 from each device → 36 features)



CLUSTER ANALYSIS METHOD

Kmeans

Parameters

- Dataset: 28*36 matrix
- k=4
- Distance metric: cityblock

<u>Why Cityblock?</u>

- Is a metric (36-dimensional)
- Is better in calculating distances in more than two dimensions
- Defined on $\mathbb{R}^n$

$$d(a,b) = \sum_{i=1}^{n} |b_i - a_i|$$

a and b are vectors in $\mathbb{R}^n$ with $a = (a_1, \ldots, a_n)$ and $b = (b_1, \ldots, b_n)$.

RESULTS