

# VISUALIZATIONS FOR THE Human Movement Analysis

**Machine Learning approach to the 2-dimensional human  
movement analysis**

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# Aplicaciones del Estudio del Movimiento Humano

- Estudios de Biomecánica Para Rendimiento Deportivo
- Evaluaciones neurológicas clínicas
- Animación
- Realidad aumentada
- Robotica colaborativa
- .... Entre otros



Estudios con LIDAR

Sensores de Inercia (MEMS)

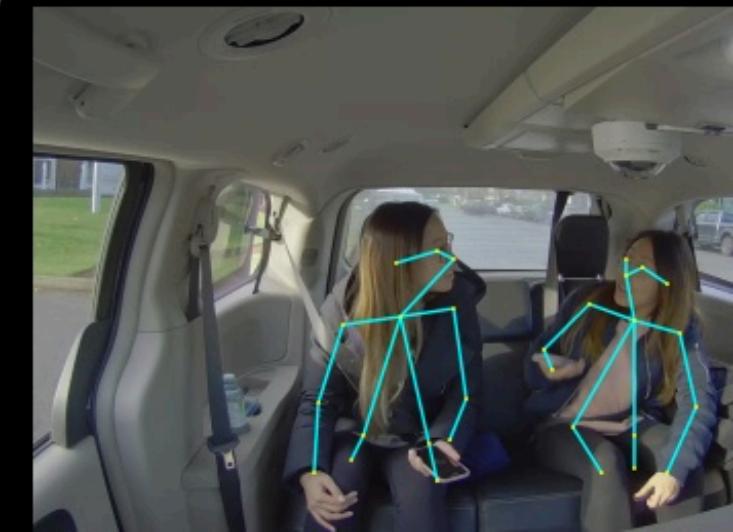
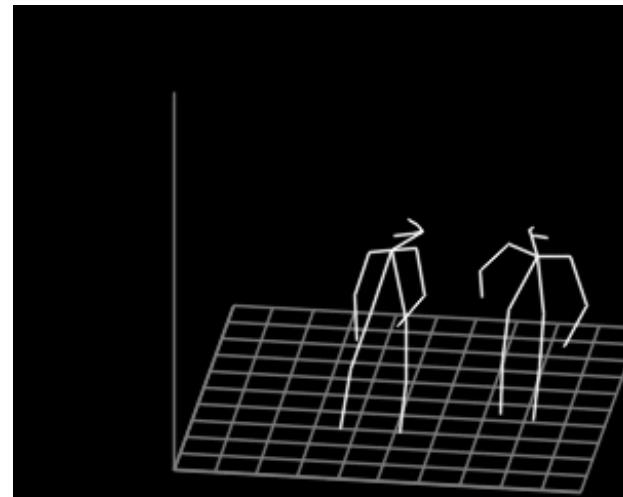
Estudios de Kinesiología por marcadores IR

Análisis por medio de Procesamiento de Imagen

Aplicaciones del Estudio del Movimiento Humano

## Objetivos (ingeniería):

- Obtener posiciones de las articulaciones
- Obtener señales de movimiento
  - Velocidad
  - Aceleración
  - Velocidad Angular
  - Recorridos máximos
- Desplazamientos
- Frecuencias de Movimiento
- Energía consumida
- Trabajo realizado



# Descomposición del Problema

1. Detección

2.1. Señal de ubicación

2.2. Desplazamiento del Cuerpo

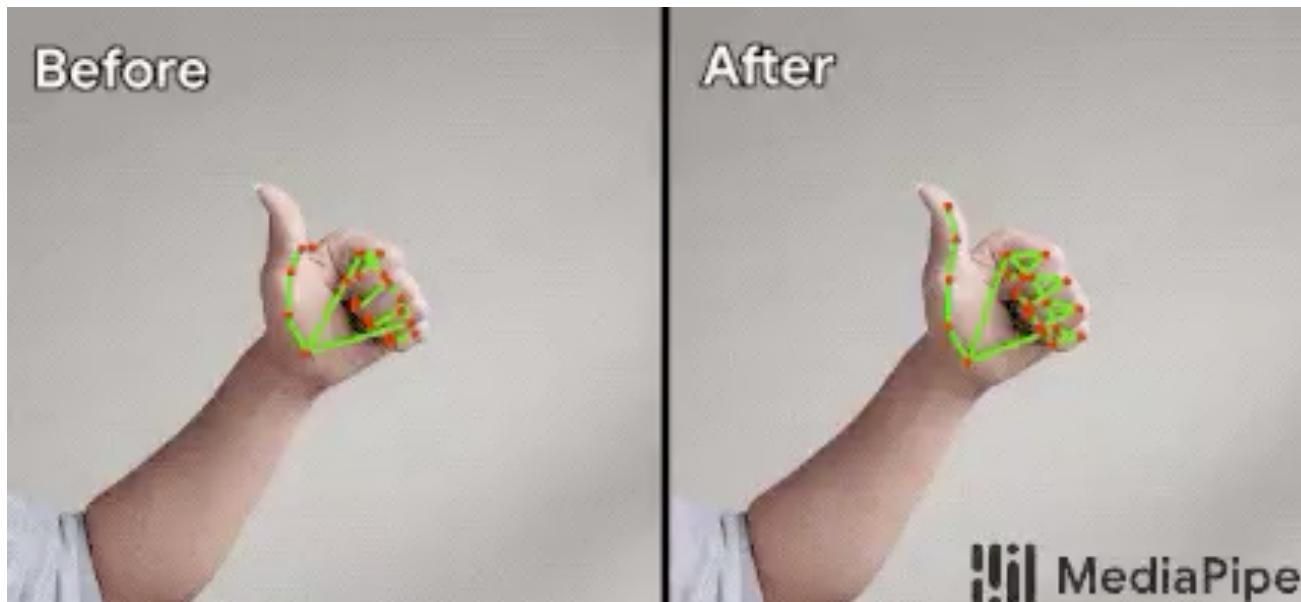
2.3. Velocidad de las Articulaciones

2.4. Indicadores de movimiento agregados

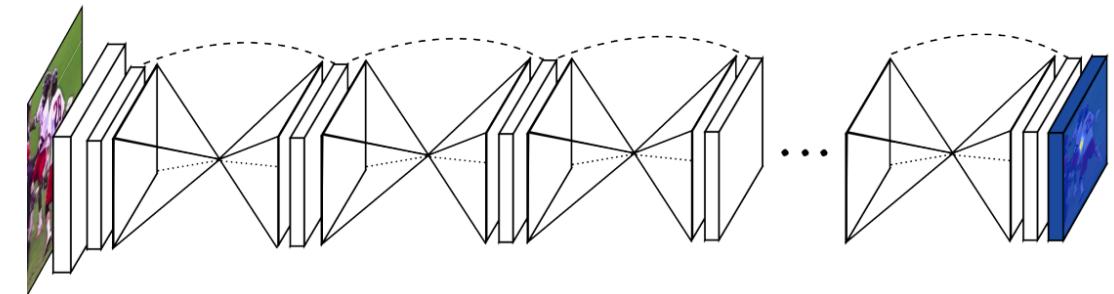
3.1 Calculos de Trabajo

3.1 Análisis Frecuencial

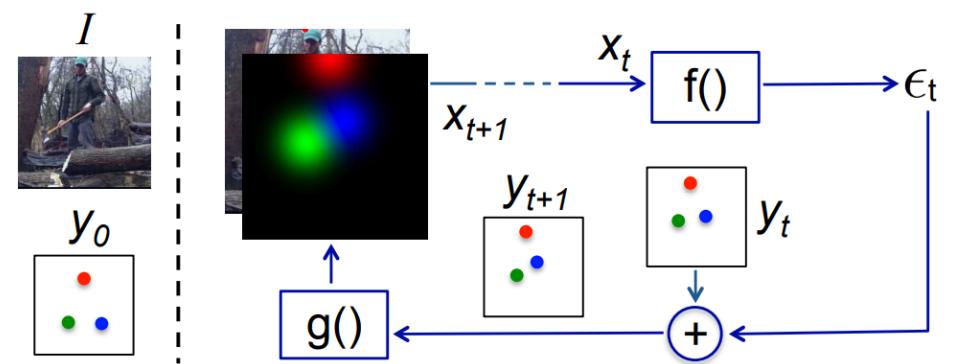
# 1. Detección



<https://mediapipe.page.link/hand>



**Fig. 1.** Our network for pose estimation consists of multiple stacked hourglass modules which allow for repeated bottom-up, top-down inference.



Z. Cao, T. Simon, S. Wei and Y. Sheikh, "Realtime Multi-person 2D Pose Estimation Using Part Affinity Fields," 2017



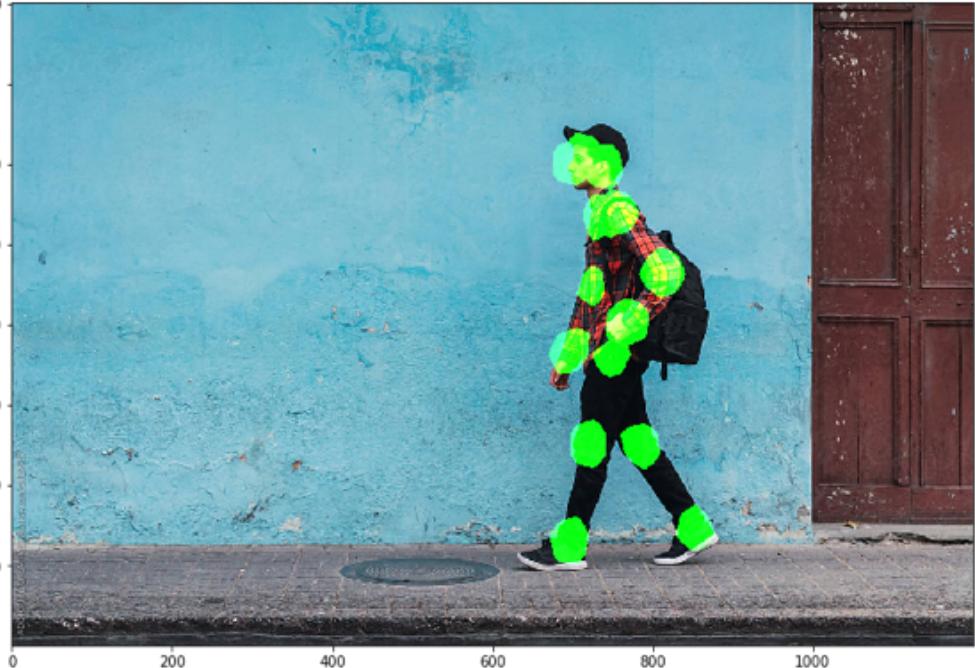
Bottom UP



Context Modules



Osokin, Daniil. (Jun 2019). Global Context for Convolutional Pose Machines, Intel Russia



Segmentación



Mapa de Calor



Hugh Máximos

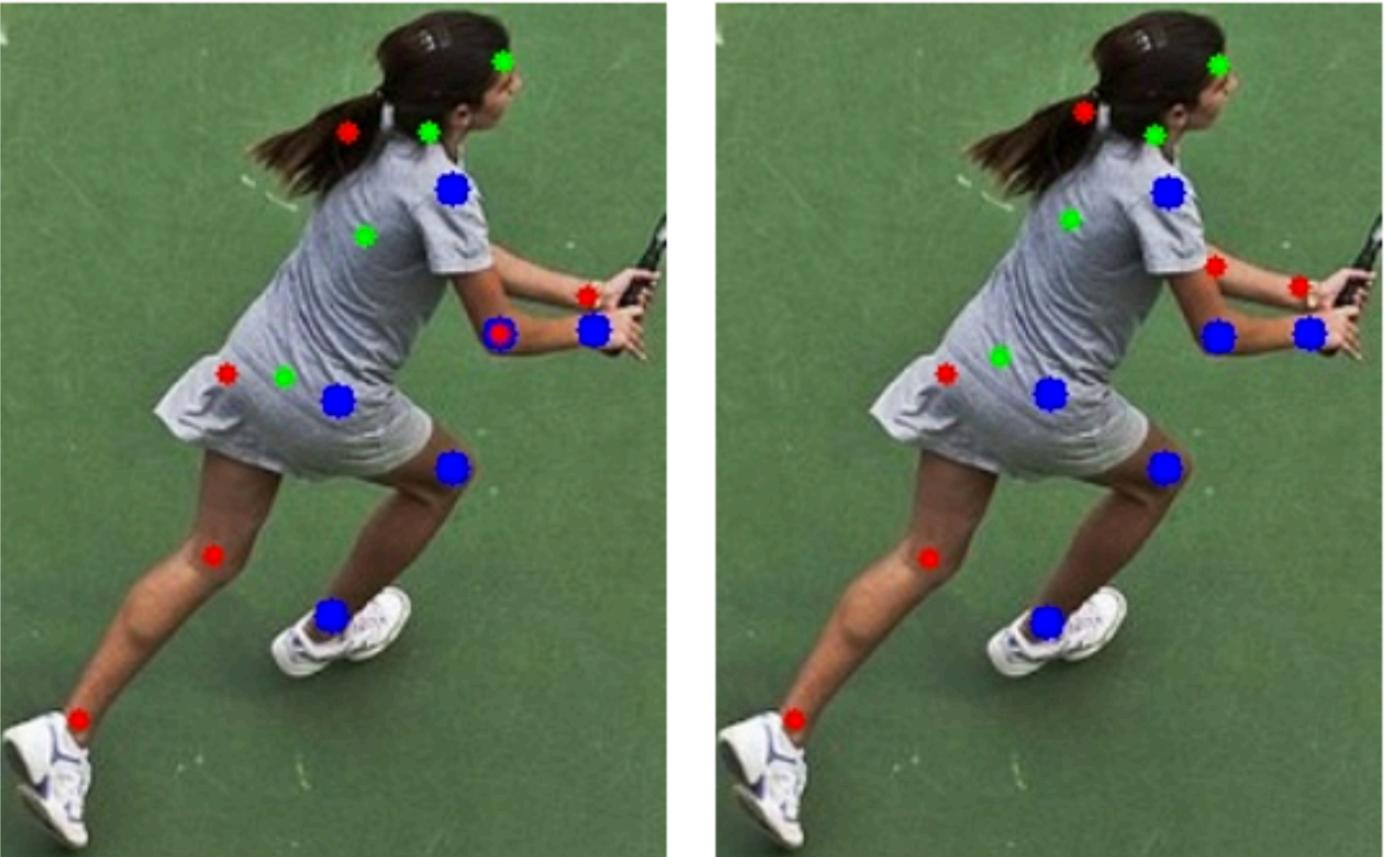


Coordenada

(792, 341)



- Detección de Todas las Articulaciones
- Generación de Skeleton
- Control de Errores

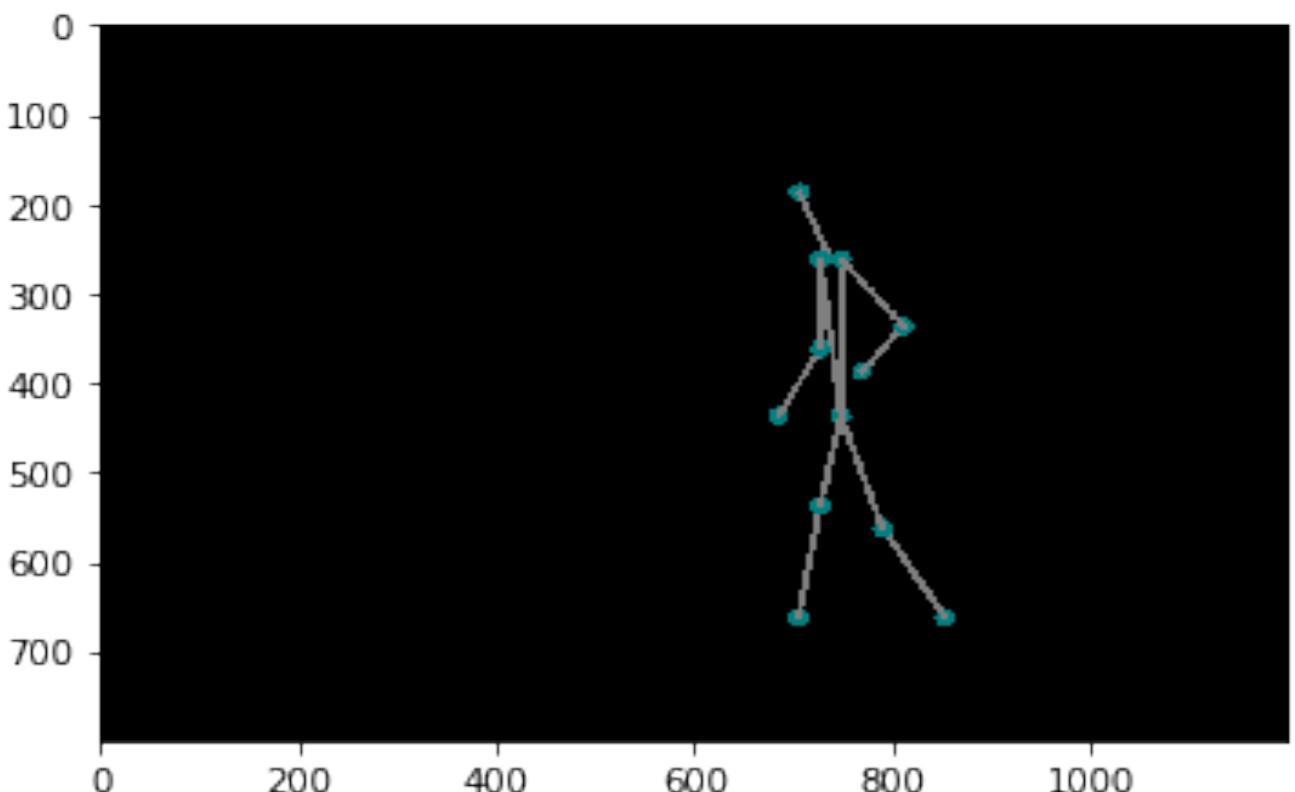




Entrada

Imagen RGB

Salida  
Skeleton  
Coordenadas  
Conexiones



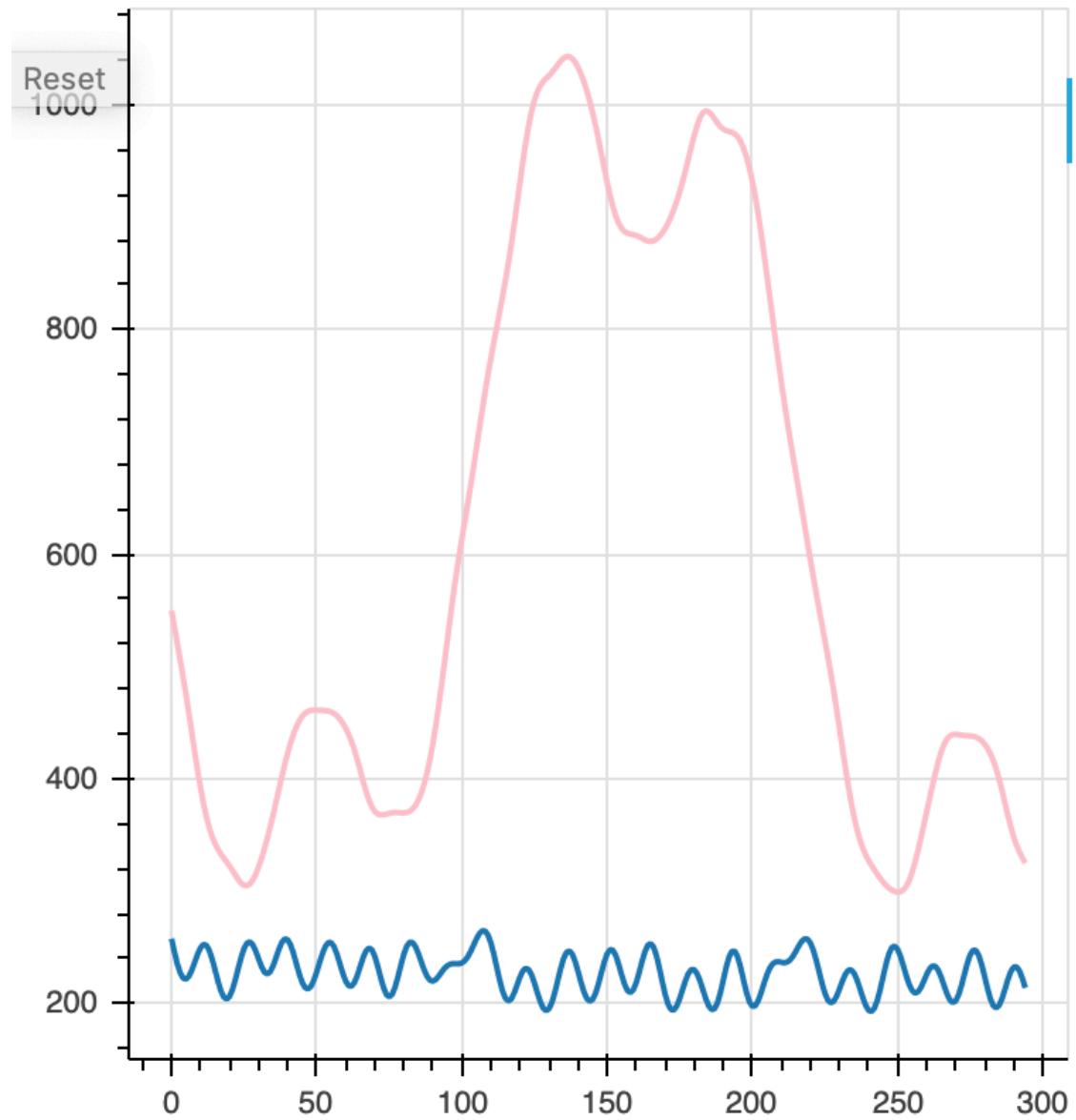
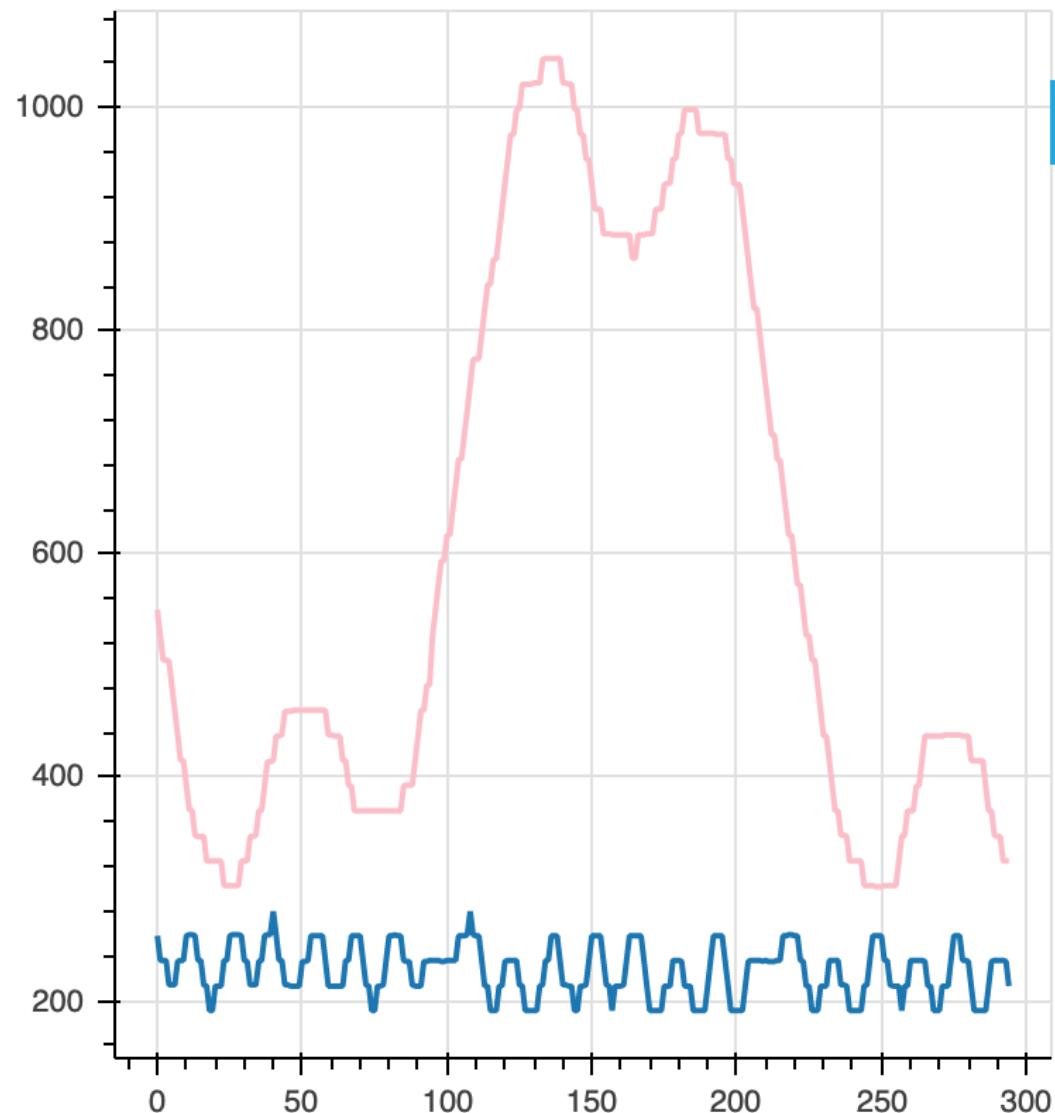
## Modelo Skeleton

	SINGLEPOSE	MULTIPOSE	baseColor	hexColor
<b>head</b>	0	0	(179, 112, 117, 30)	#7570b3
<b>neck</b>	None	1	(179, 112, 117, 30)	#7570b3
<b>right_shoulder</b>	6	2	(2, 95, 217, 30)	#d95f02
<b>right_elbow</b>	8	3	(2, 95, 217, 30)	#d95f02
<b>right_wrist</b>	10	4	(2, 95, 217, 30)	#d95f02
<b>left_shoulder</b>	5	5	(119, 158, 27, 30)	#1b9e77
<b>left_elbow</b>	7	6	(119, 158, 27, 30)	#1b9e77
<b>left_wrist</b>	9	7	(119, 158, 27, 30)	#1b9e77
<b>right_hip</b>	12	8	(30, 166, 102, 30)	#66a61e
<b>right_knee</b>	14	9	(30, 166, 102, 30)	#66a61e
<b>right_foot</b>	16	10	(30, 166, 102, 30)	#66a61e
<b>left_hip</b>	11	11	(138, 41, 231, 30)	#e7298a
<b>left_knee</b>	13	12	(138, 41, 231, 30)	#e7298a
<b>left_foot</b>	15	13	(138, 41, 231, 30)	#e7298a
<b>right_eye</b>	2	14	(2, 95, 217, 30)	#d95f02
<b>left_eye</b>	1	15	(119, 158, 27, 30)	#1b9e77
<b>right_ear</b>	4	16	(2, 95, 217, 30)	#d95f02
<b>left_ear</b>	3	17	(119, 158, 27, 30)	#1b9e77

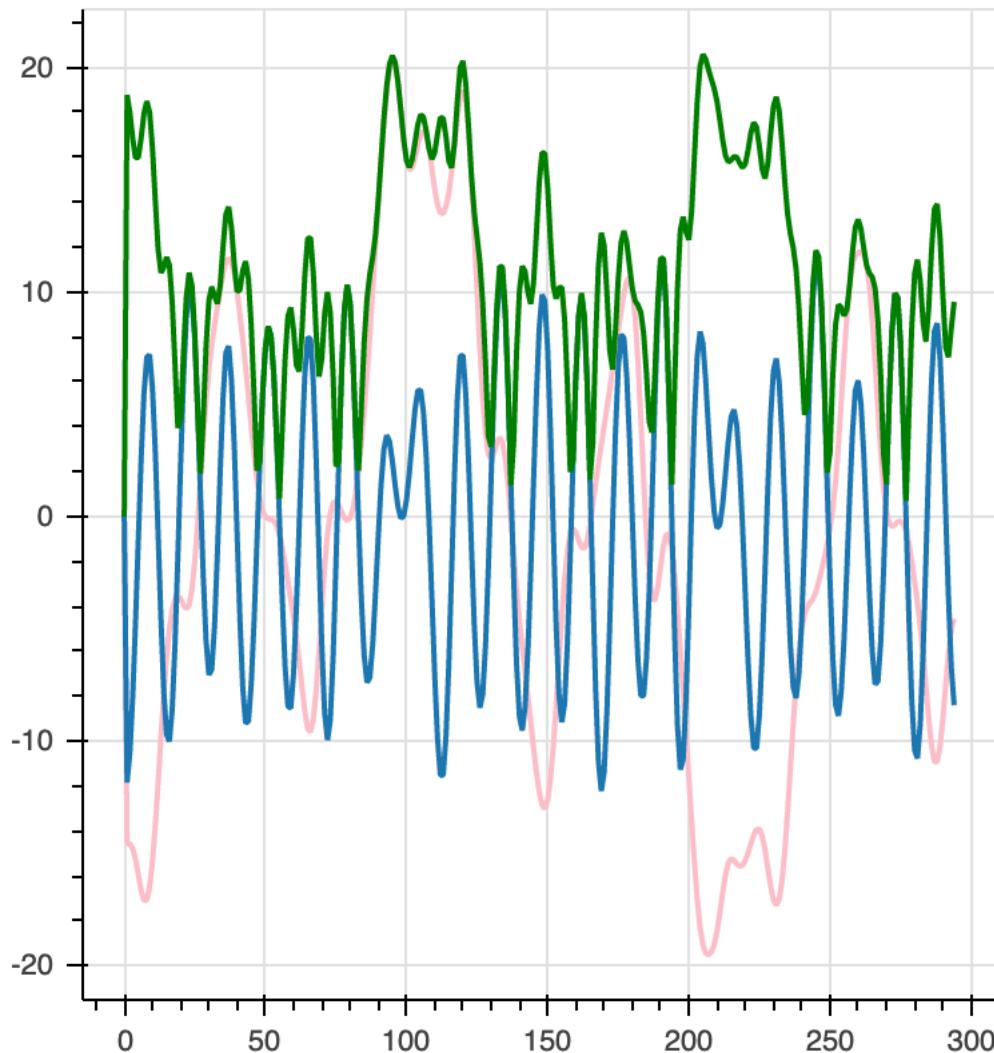
# Modelo Ubicaciones de Video

	head	neck	right_shoulder	right_elbow	right_wrist	left_shoulder	left_elbow	left_wrist	right_hip	right_knee	right_foot	left_hip	left_knee	left_foot	right_knee	right_foot
0	(617, 101)	(684, 123)	(662, 123)	(662, 235)	(639, 258)	(685, 123)	(707, 236)	(639, 281)	(707, 303)	(707, 438)	(707, 573)	(707, 303)	(662, 438)	(662, 574)	(617, 438)	(617, 574)
1	(617, 101)	(684, 124)	(662, 123)	(662, 213)	(639, 258)	(706, 123)	(707, 236)	(639, 281)	(706, 303)	(707, 438)	(729, 574)	(707, 303)	(662, 438)	(640, 595)	(617, 438)	(617, 595)
2	(639, 101)	(684, 124)	(662, 123)	(662, 213)	(639, 258)	(707, 123)	(707, 235)	(639, 281)	(706, 303)	(707, 438)	(729, 574)	(707, 303)	(662, 438)	(640, 574)	(617, 438)	(617, 574)
3	(639, 101)	(684, 124)	(662, 123)	(662, 213)	(639, 258)	(707, 123)	(707, 236)	(640, 281)	(707, 303)	(707, 438)	(729, 574)	(707, 303)	(662, 438)	(640, 573)	(617, 438)	(617, 573)
4	(639, 101)	(684, 124)	(662, 124)	(662, 213)	(640, 258)	(707, 123)	(729, 236)	(640, 281)	(707, 303)	(729, 438)	(751, 573)	(729, 303)	(662, 438)	(640, 573)	(617, 438)	(617, 573)
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
982	(662, 101)	(707, 146)	(729, 146)	(662, 235)	(730, 258)	(707, 146)	(662, 236)	(572, 280)	(685, 326)	(639, 439)	(594, 573)	(707, 325)	(752, 461)	(842, 574)	(640, 461)	(640, 574)
983	(662, 101)	(707, 146)	(707, 146)	(662, 236)	(751, 258)	(707, 146)	(662, 236)	(572, 280)	(684, 326)	(639, 460)	(595, 595)	(707, 326)	(752, 483)	(842, 573)	(640, 483)	(640, 573)
984	(662, 101)	(707, 146)	(729, 146)	(752, 258)	(752, 236)	(707, 146)	(662, 236)	(572, 280)	(684, 326)	(639, 460)	(617, 595)	(707, 326)	(730, 483)	(842, 573)	(640, 483)	(640, 573)
985	(662, 101)	(707, 146)	(685, 146)	(662, 235)	(730, 236)	(707, 146)	(662, 236)	(594, 281)	(684, 326)	(639, 439)	(639, 595)	(707, 326)	(707, 483)	(819, 551)	(640, 483)	(640, 551)
986	(662, 101)	(707, 146)	(685, 145)	(662, 235)	(639, 236)	(707, 146)	(684, 236)	(595, 281)	(684, 326)	(640, 460)	(640, 596)	(707, 326)	(706, 483)	(819, 551)	(640, 483)	(640, 551)

## 2.1. Señal de ubicación (cuerpo+)

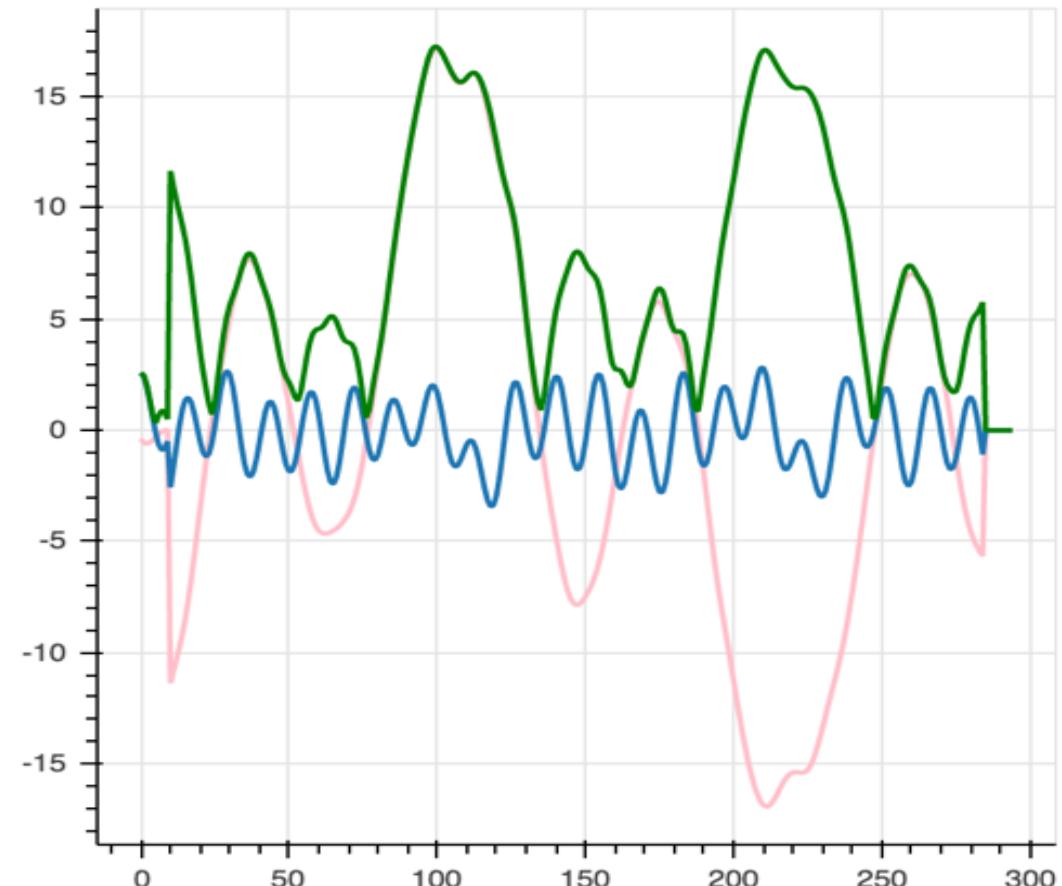


## 2.2. Desplazamiento del Cuerpo



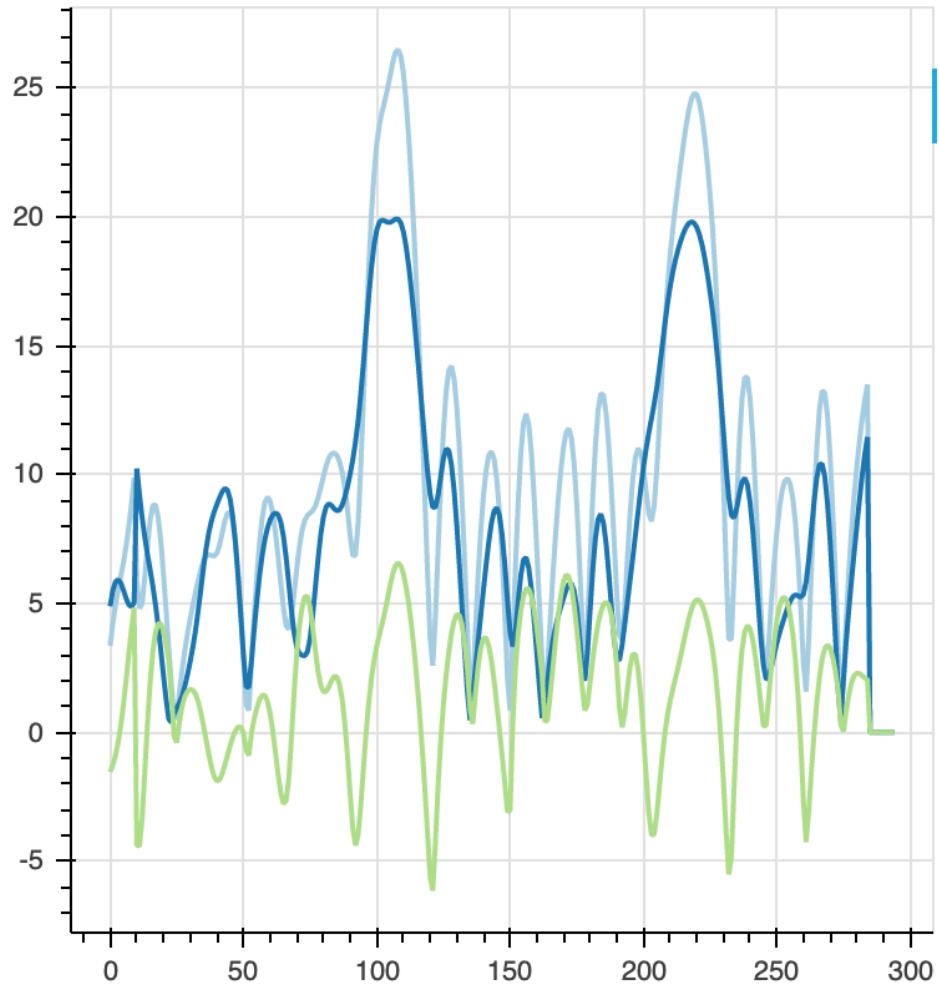
$$f'(a) \approx f(a + 1) - f(a)$$

$$f'(a) \approx \frac{1}{2} \left( \frac{f(a + h) - f(a)}{h} + \frac{f(a) - f(a - h)}{h} \right) = \frac{f(a + h) - f(a - h)}{2h}$$



## 2.3. Velocidad de las Articulaciones

### Velocidad Relativa



Azul Claro Mano  
Azul Oscuro Codo

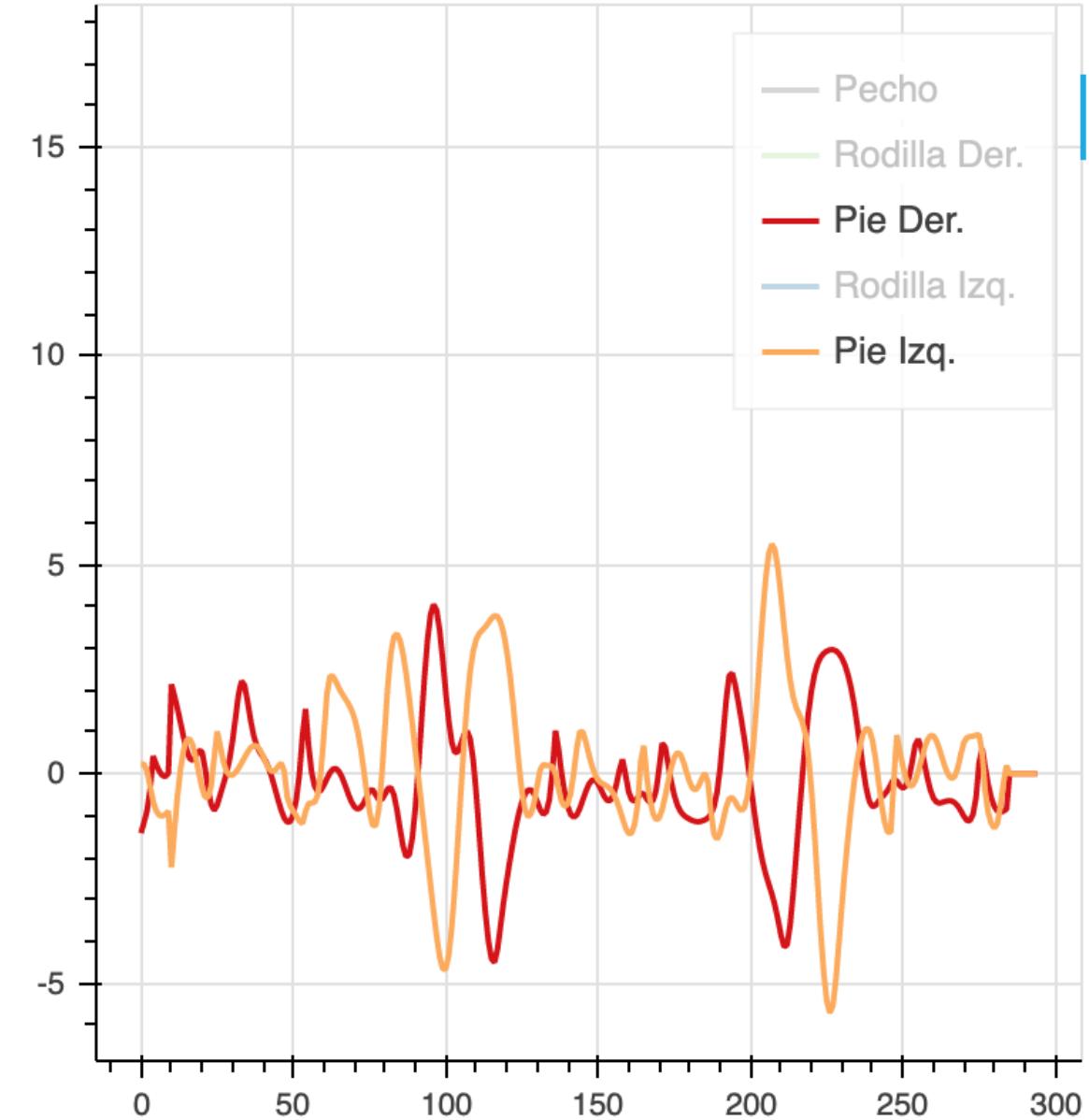
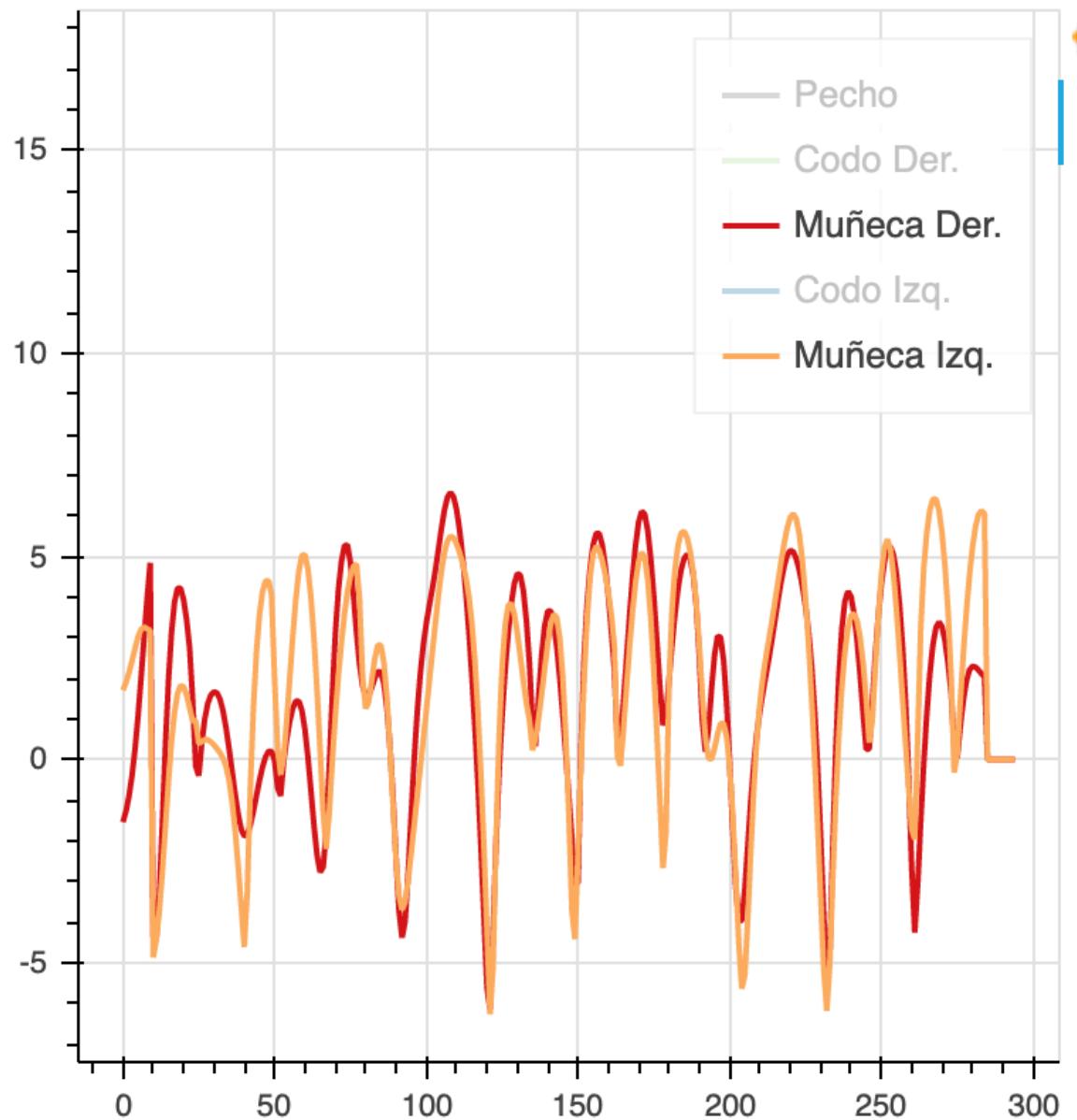
Verde: DR(mano)

$$fX_{muñeca} = |V_{muñeca}(x, y)| - |V_{codo}(x, y)|$$

$$X_{muñeca} = \sum_{i=0}^n |V_{muñeca}(x, y)| - \sum_{i=0}^n |V_{codo}(x, y)|$$

$$X_{codo} = \sum_{i=0}^n |V_{codo}(x, y)| - \sum_{i=0}^n |V_{hombro}(x, y)|$$

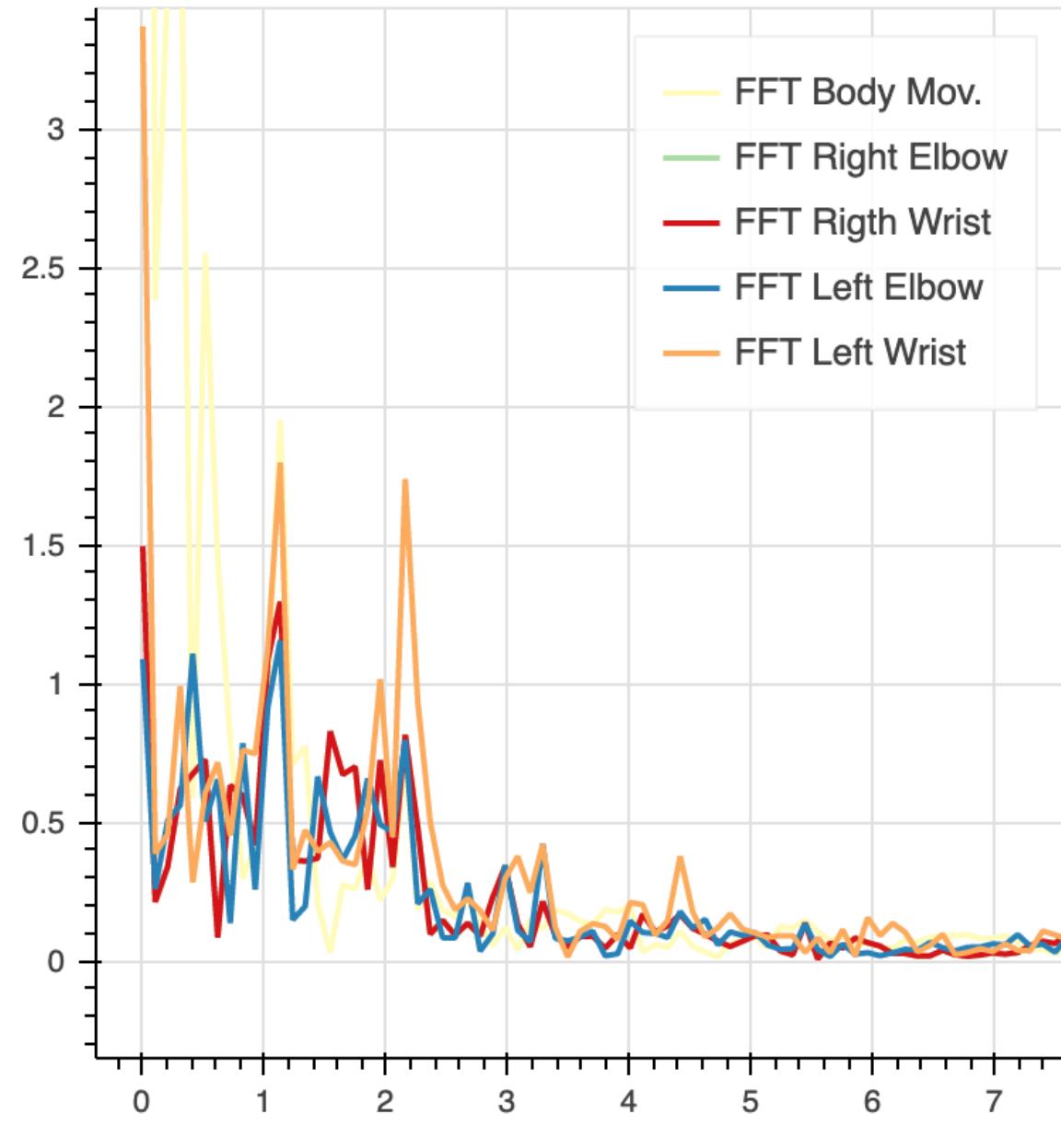
## 2.3. Desplazamiento de las Articulaciones



## 2.4. Indicadores de movimiento agregados

	MULTIPOSE	hexColor	hexCoordQ	hexCoordR	name_es	displacement	abs_dspclc	max_speed	avg_speed
neck	1	#7570b3	0.0	0.0	Pecho	2094.102852	2094.102852	17.263601	7.098654
right_shoulder	2	#d95f02	-1.0	0.0	Hombro Der.	94.543830	2099.620147	1.124338	0.320488
right_elbow	3	#d95f02	-2.0	0.0	Codo Der.	556.308817	2320.114460	5.531609	1.885793
right_wrist	4	#d95f02	-3.0	1.0	Muñeca Der.	755.477527	2780.735206	6.576743	2.560941
left_shoulder	5	#1b9e77	1.0	0.0	Hombro Izq.	89.399184	2085.168711	1.150544	0.303048
left_elbow	6	#1b9e77	2.0	0.0	Codo Izq.	513.427278	2245.565206	5.330101	1.740431
left_wrist	7	#1b9e77	2.0	1.0	Muñeca Izq.	812.200278	2742.698595	6.415271	2.753221
right_hip	8	#66a61e	-1.0	1.0	Cadera Der.	249.178412	1968.175165	2.684710	0.844673
right_knee	9	#66a61e	-2.0	2.0	Rodilla Der.	627.336636	2319.013195	9.045712	2.126565
right_foot	10	#66a61e	-3.0	3.0	Pie Der.	304.738957	2268.748835	4.513054	1.033013
left_hip	11	#e7298a	0.0	1.0	Cadera Izq.	275.683051	1935.123184	2.713274	0.934519
left_knee	12	#e7298a	0.0	2.0	Rodilla Izq.	524.011695	2178.101234	5.603867	1.776311
left_foot	13	#e7298a	0.0	3.0	Pie Izq.	304.738957	2268.748835	4.513054	1.033013

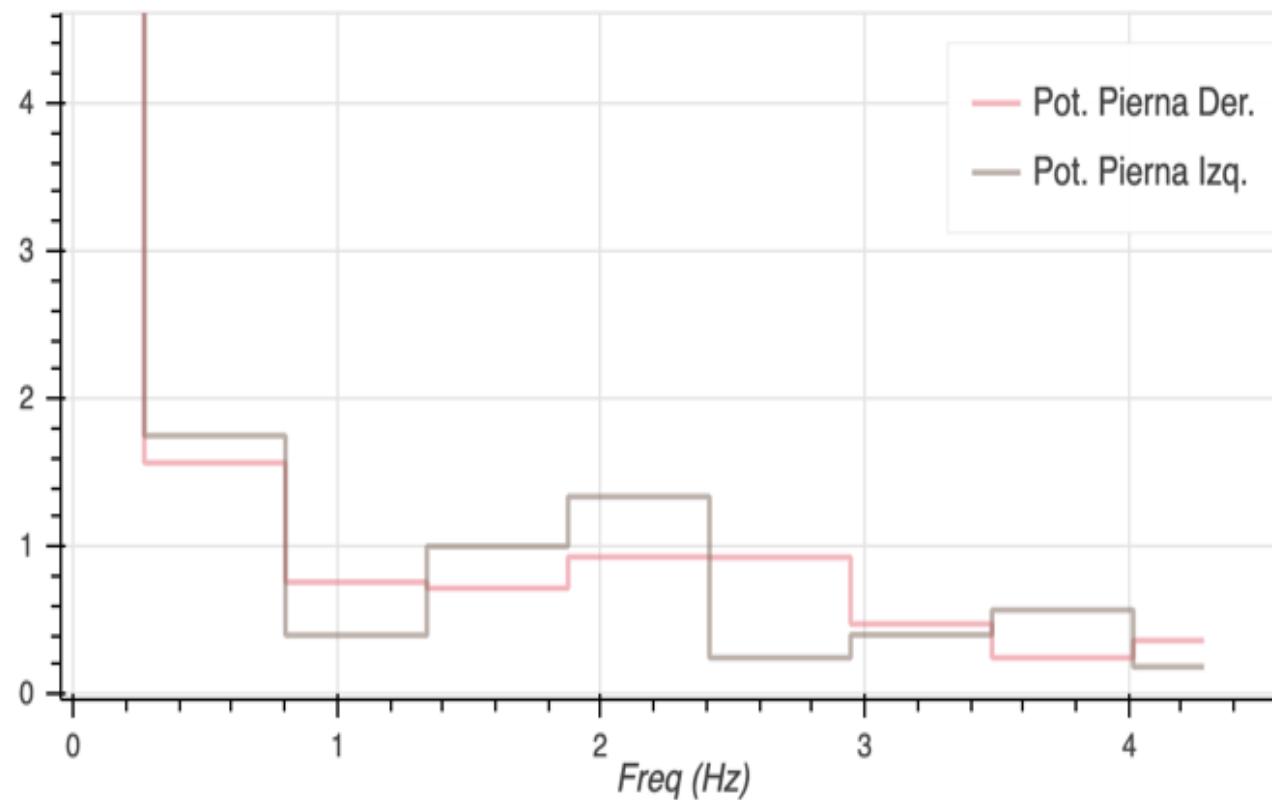
## 3.1 Análisis Frecuencial



Agregar señales afines + enventanar

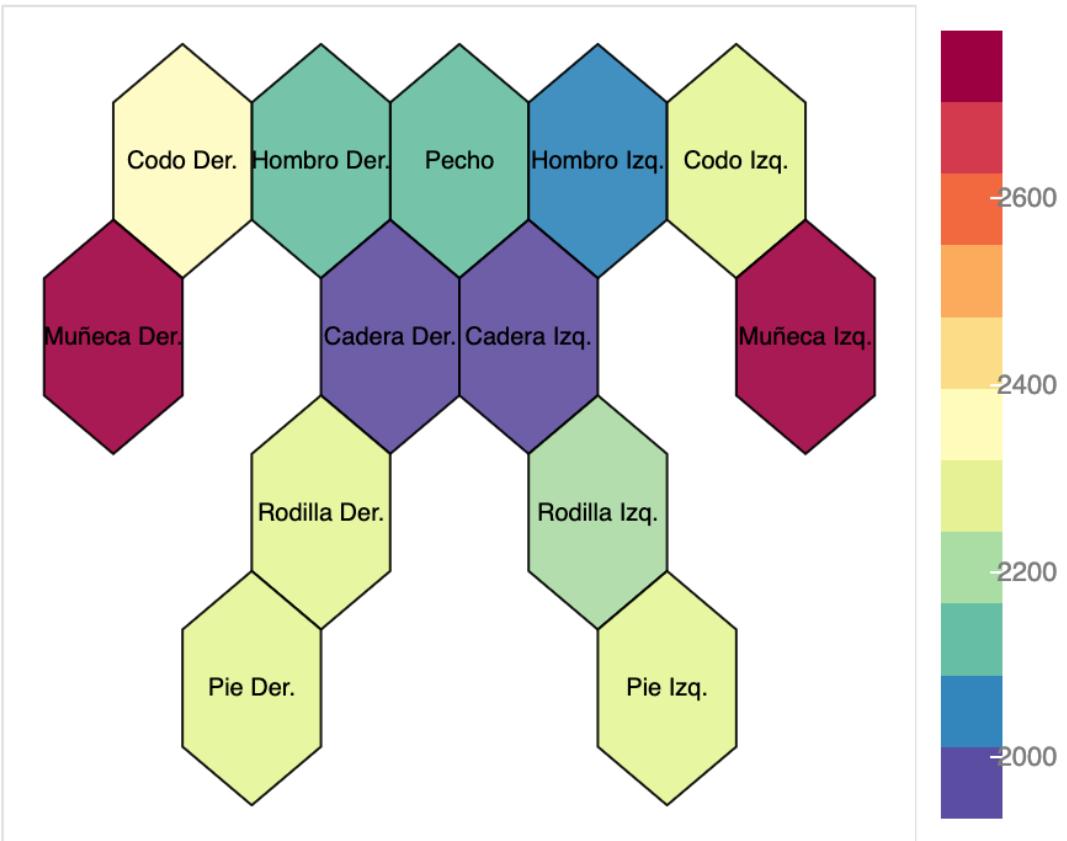
$$|X_{TotalBrazo}| = |X_{brazo}| + |X_{antebrazo}|$$

$$|X_{TotalPierna}| = |X_{pierna}| + |X_{muslo}|$$

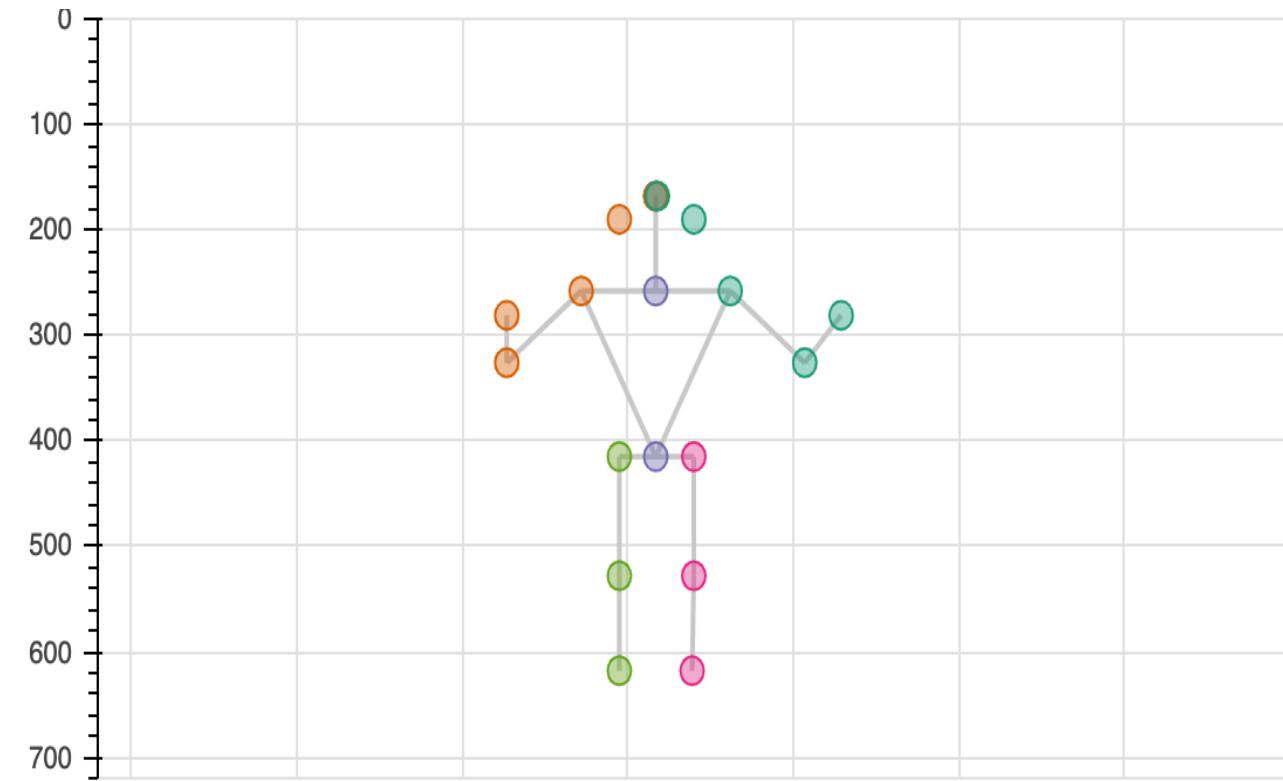


# 3.1 Análisis Temporal de Alto Nivel

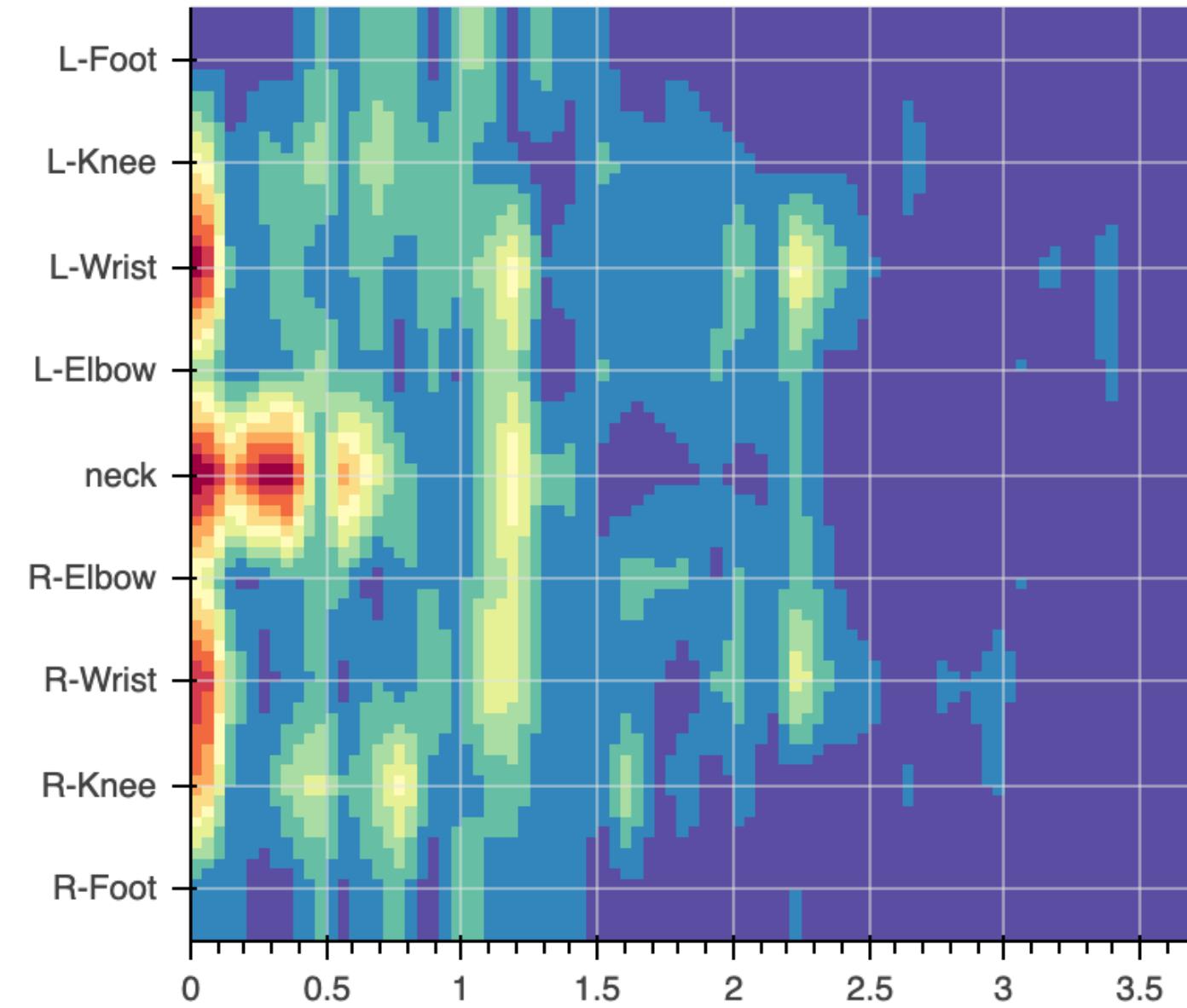
Heatmap Interactivo de Actividad Corporal



Network Graph interactivo de Articulaciones



## 3.1 Análisis Frecuencial Alto Nivel



- Extender el Cuerpo Humano en un eje
- Inyectar analisis de FFT
- Cortar picos máximos
- Reconstruir con interpolacion bilineal
- Graficar en escala continua