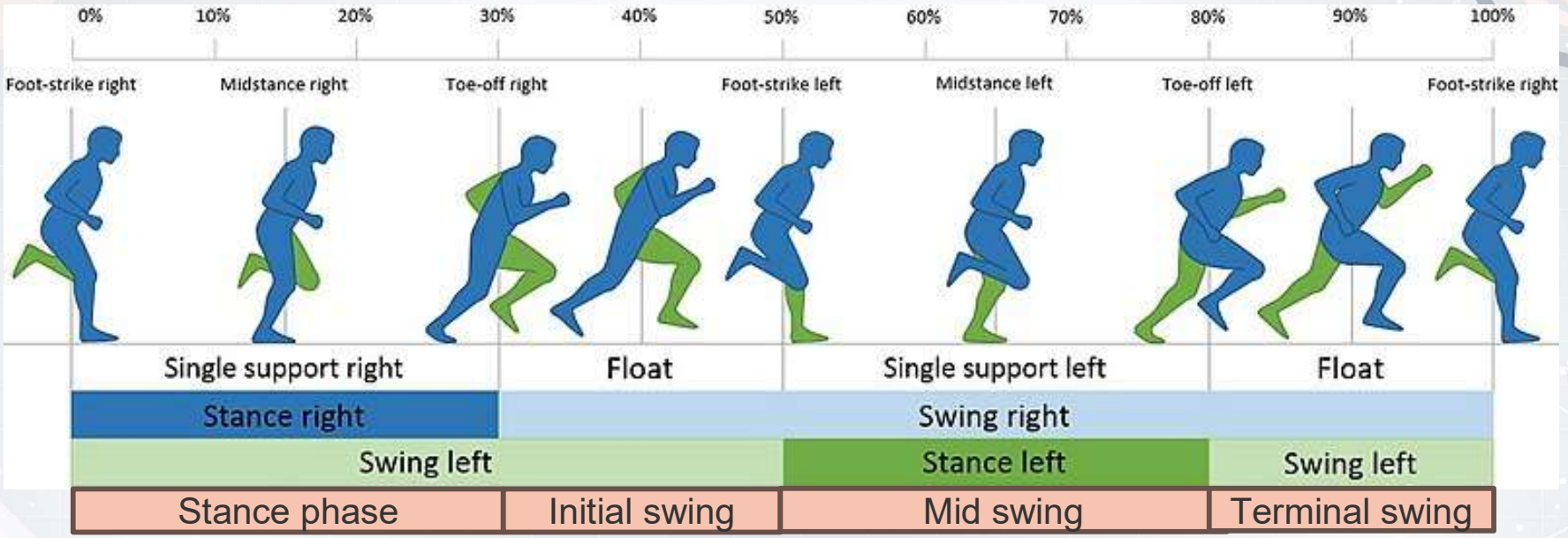
Joint Angles Visuallization in Running Exercise

1. Introduction

1.1. Phases of Sprinting



Which Muscle Groups Are Used in Running?
How the Hip Moves while Running

1. Introduction

1.2. Recording System

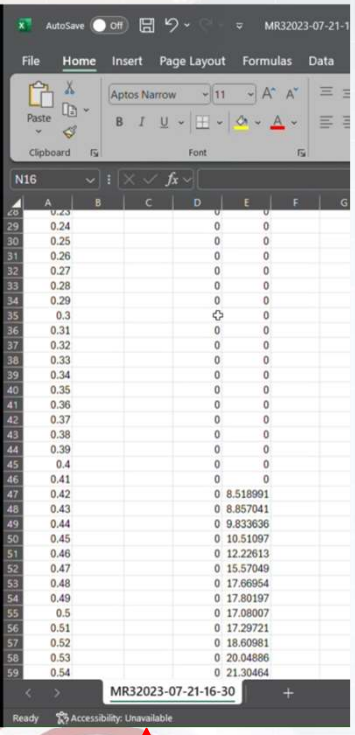
1.2.1. Pressure-Instrumented Treadmills - myoPRESSURE™

Individually-calibrated capacitive sensors measure data to conduct static and dynamic plantar pressure mapping.

1. Introduction

1.2. Recording System

1.2.1. Pressure-Instrumented Treadmills - myoPRESSURE™



	A	B	C	D	E	F	G	H	I	J	K	L
1	type	begin_time	frequency	count	created wi	exported w	project	last_name	first_name	born	sex	measurement_date
2	record	0	100	8560	Noraxon M	3.20.18	operator te	Hoang Trung	Hieu		male	2023-07-21T09:30:08.334Z
3												
4	time	Activity	Marker	LT Max Pre	RT Max Pressure (N/cm?)					Trials in Ne	4	2023-07-21T09:30:22.726Z
5	0	Activity		0	0						5	2023-07-21T09:30:25.415Z
6	0.01			0	0						6	2023-07-21T09:30:41.525Z
7	0.02			0	0						7	2023-07-21T09:30:54.234Z
8	0.03			0	0						8	2023-07-21T09:31:07.494Z
9	0.04			0	0							
10	0.05			0	0							
11	0.06			0	0							
12	0.07			0	0							
13	0.08			0	0							
14	0.09			0	0							

Frame

Left and Right Max pressure on each foot

Start time of each cutted file

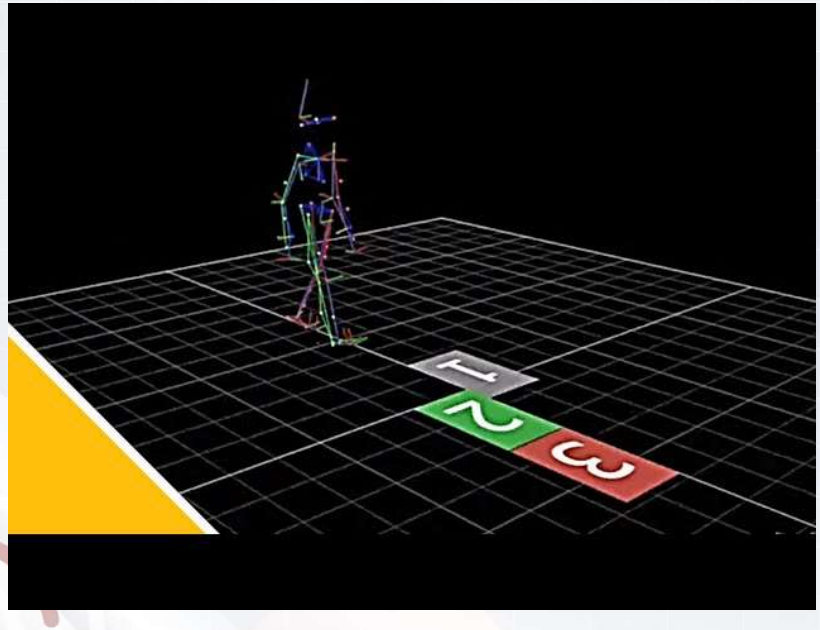
Start time of this file

The two legs should alternate with each other like this

1. Introduction

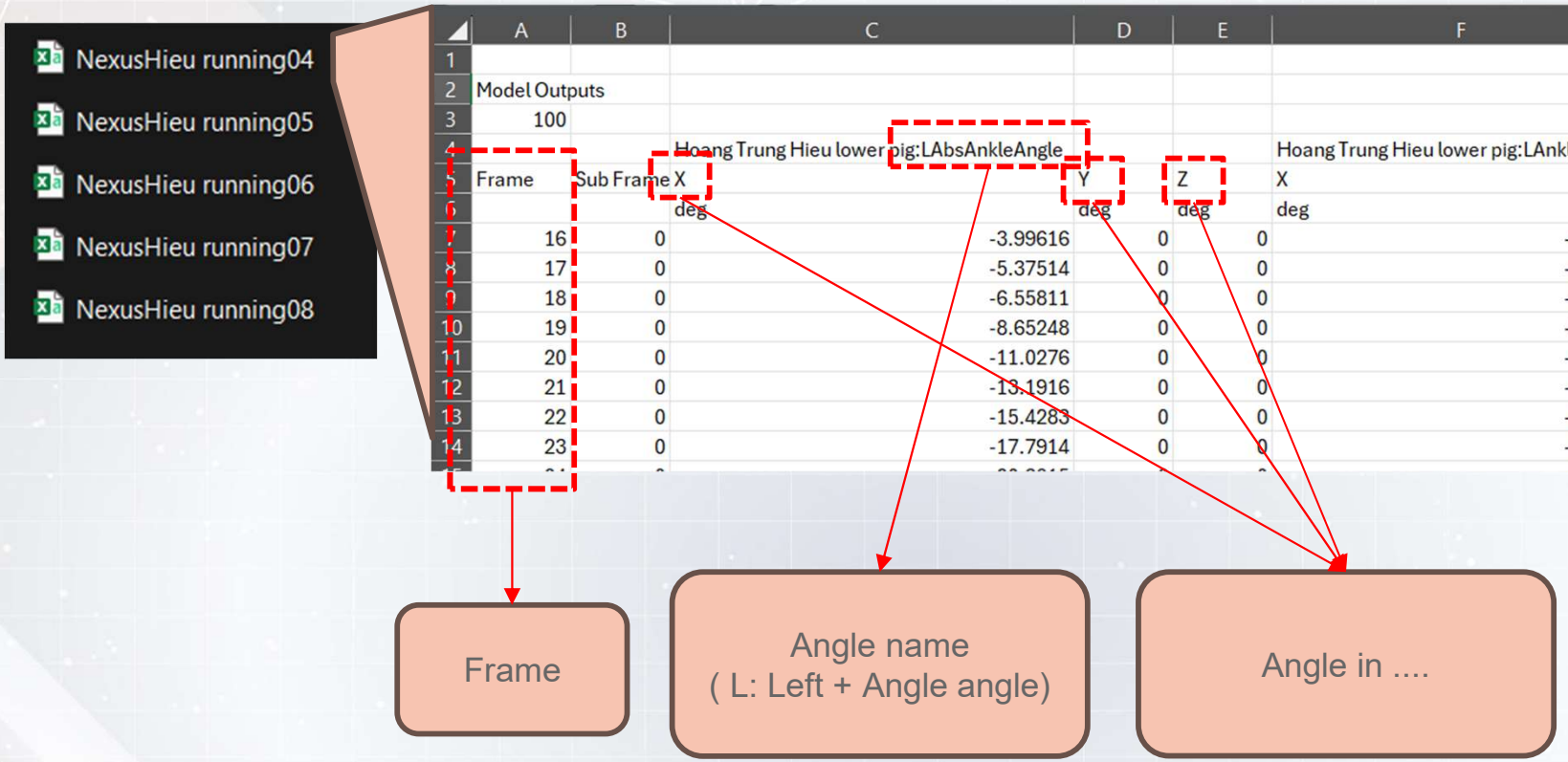
1.2. Recording System

1.2.2. Motion Capture for Biomechanics - Nexus



3D coordinates of markers

1.2.2. Motion Capture for Biomechanics - Nexus



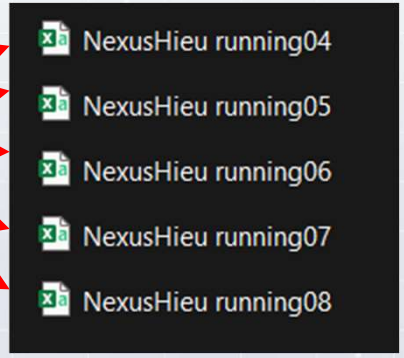
1. Introduction

1.2. Recording System

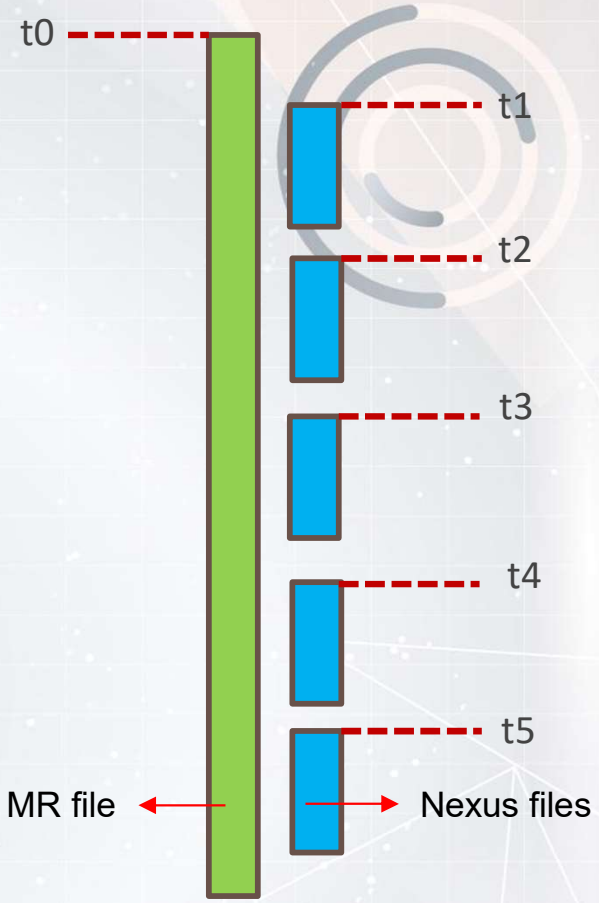
MR Output file

Nexus Output file

2 file is recorded in the same time and resolution (frame)



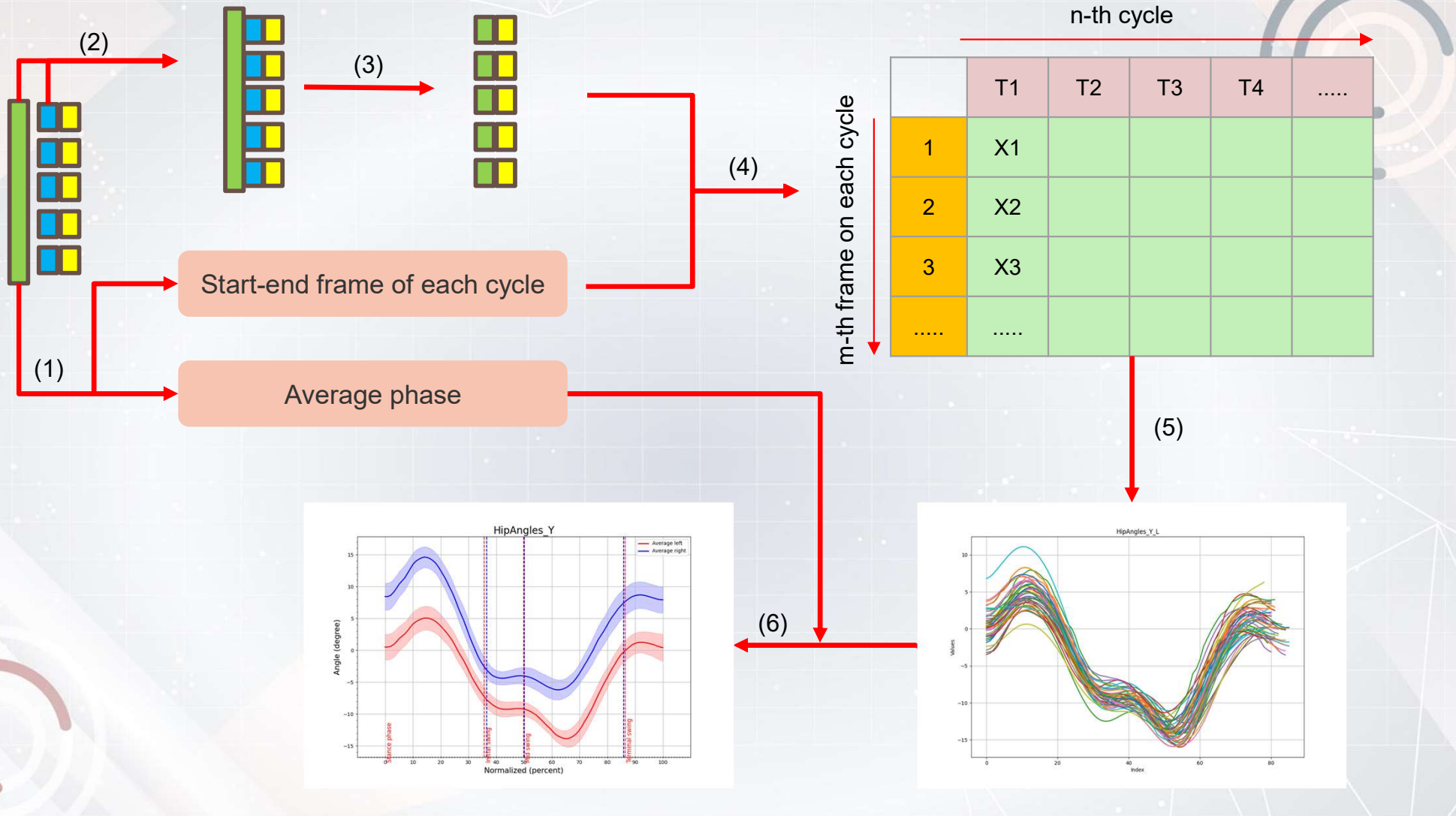
The Nexus file is cutted into several segments and still keep the start time when cutted



Simulation of file segments of Nexus corresponding to MR file in Frame field

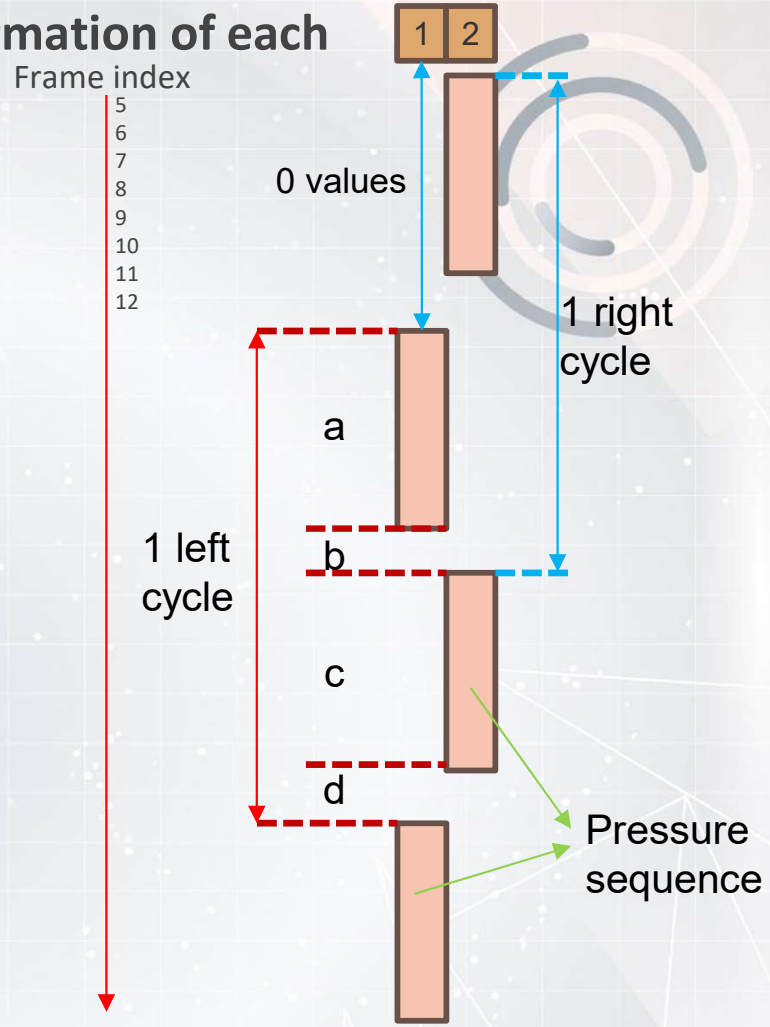
t1, t2, ... : start frame of n-th segment of Nexus file

2. Workflow


(2)
(3)
(4)
(1)
Start-end frame of each cycle
Average phase
n-th cycle
m-th frame on each cycle
T1
T2
T3
T4
.....
1
X1
2
X2
3
X3
.....
.....
(5)
(6)
HipAngles_Y
Angle (degree)
Normalized (percent)
Average left
Average right
HipAngles_Y_L
Values
Index

2.1. Process (1): Processing the MR file and receive the information of each phase in cycles

- First, we need to assign the process to the stick bar for easier visualization.
- The file is distributed longitudinally, so the longitudinal stick bar represents the pressure values that differ from 0 in two columns: Left foot pressure and Right foot pressure.
- The gap between each bar in the longitudinal direction represents values of 0.
- The frame increases from the top to the bottom of the chart.
- The main task of these bars is to identify the time when the pressure changes from 0 to a non-zero value. This is the moment when the phase changes.



1 Left pressure column

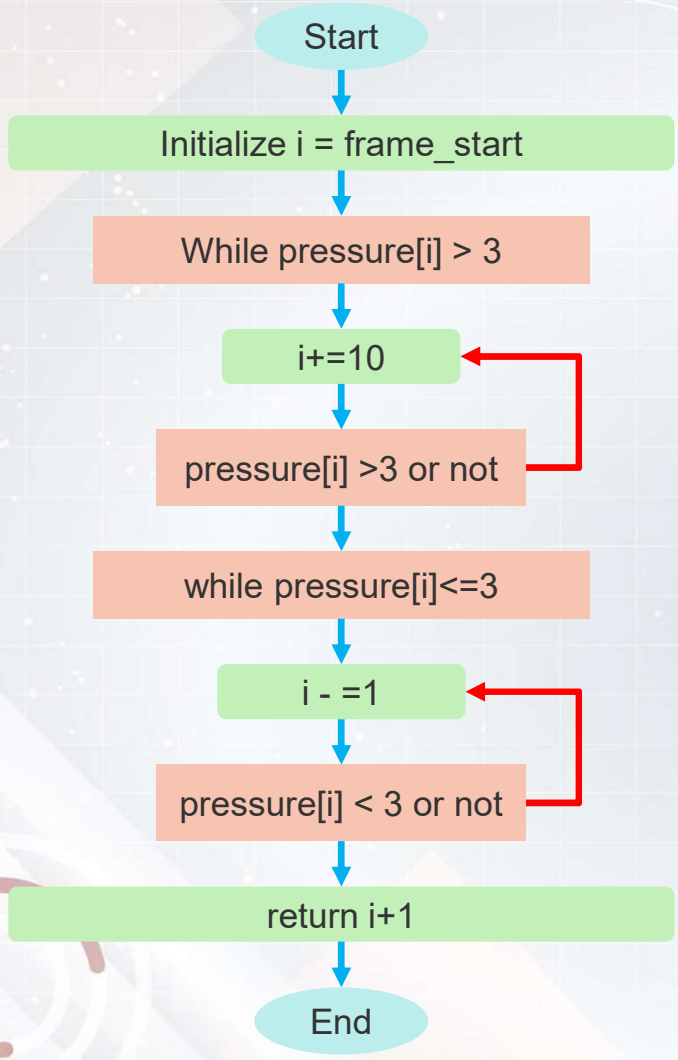
2 Right pressure column

Simulation of left & right pressure column

a: Stance ; b: Initial Swing

c: Mid Swing ; d: Terminal Swing

Function 1: Find value come back from pressure to zero : find_zero_seg

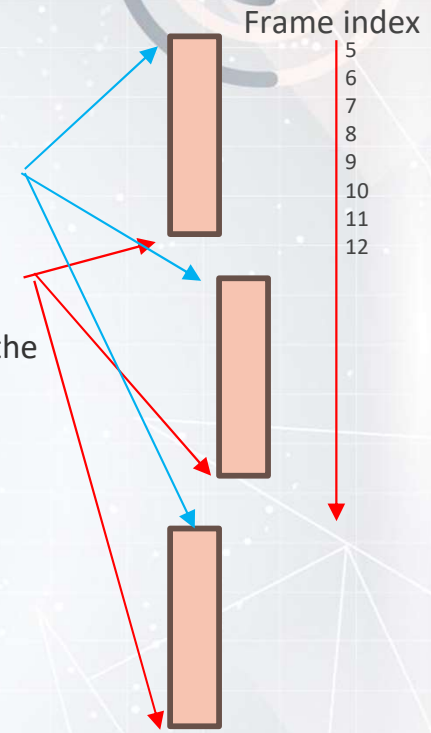


Input :

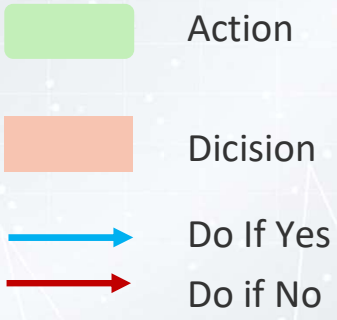
- pressure : array of column of pressure
- frame_start: first frame of pressure sequence

Output:

- The last frame of pressure sequence



This funcion aims to find what frame that the pressure sequence come back to zero sequence. This point can be end of stance phase or end of mid swing phase



Function 2: Find value come back from zero to pressure: find_pres_seg

Input :

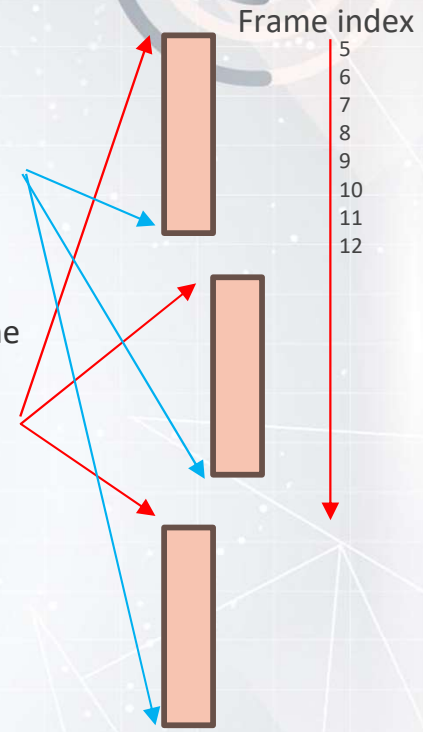
- pressure : array of column of pressure
- frame_end_pressure: last frame of pressure sequence

Output:

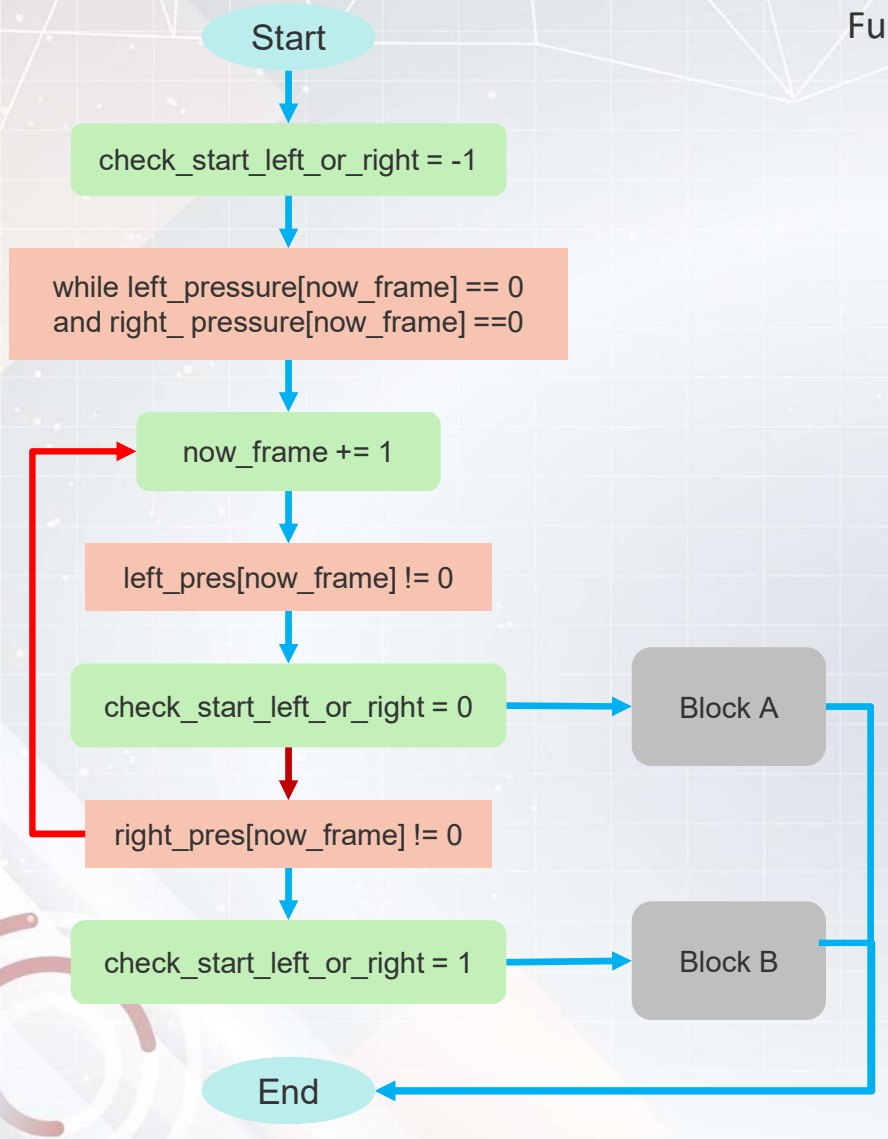
- The last frame of zero sequence

The structure is inverted with Function 1

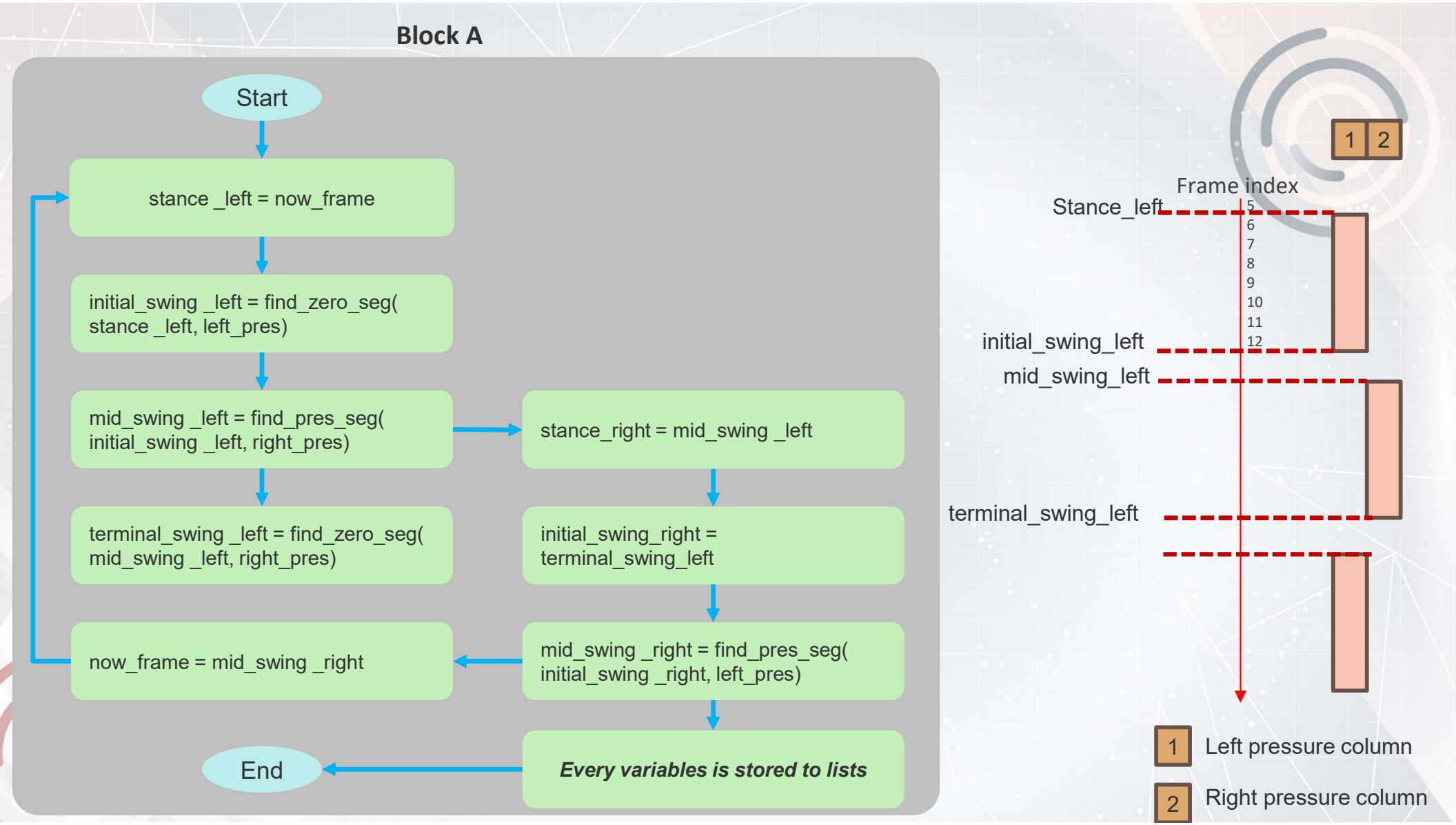
This funcion aims to find what frame that the zero sequence come back to pressure sequence. This point can be end of stance phase or end of mid swing phase



Function 3: Receive the phase information from MR file



- This function aims to determine which foot starts first.
- If the Left foot starts first, it means the value in the left pressure column differs from 0 first. The flag check_start_left_or_right is set to 0, and then Block A is executed.
- Block A loops through each row in the Excel file, returning a list containing the stance, initial swing, mid swing, and terminal swing phases of each foot, and saves the results to another Excel file.
- Otherwise, if the Right foot starts first, check_start_left_or_right is set to 1, and Block B is executed.
- The difference between Block A and Block B is that Block A is designed for cases where the Left foot starts first, while Block B is designed for cases where the Right foot starts first.

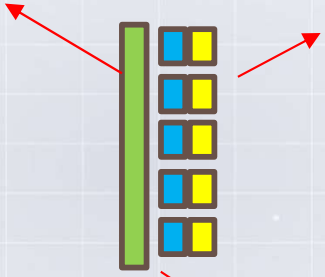

Block A
Start
stance _left = now_frame
initial_swing _left = find_zero_seg(stance _left, left_pres)
mid_swing _left = find_pres_seg(initial_swing _left, right_pres)
terminal_swing _left = find_zero_seg(mid_swing _left, right_pres)
now_frame = mid_swing _right
stance_right = mid_swing _left
initial_swing_right = terminal_swing_left
mid_swing _right = find_pres_seg(initial_swing _right, left_pres)
Every variables is stored to lists
End
1 2
Frame index
Stance_left
5
6
7
8
9
10
11
12
initial_swing_left
mid_swing_left
terminal_swing_left
1 Left pressure column
2 Right pressure column

2.2. Process (2) and (3): Find index of angle on Nexus file with corresponding frame on MR file

Define the initial construct

First, we need define the corressponding angle on each frame on Nexus file with the corresponding pressure on each frame on MR file. Because MR file contrain information about the cycles

Let imagine that initial we have the whole MR file, so we represent the frame column of MR file by a long green stick



Nexus produce several files, we represent it by several shot stick, with blue stick is frame column of Nexus file, yellow stick is corressponding angle at that frame

At the first time , there are a gap on 2 kind of file because we can not locate what frame of Nexus corresponding with what frame of MR

2.2. Process (2) and (3): Find index of angle on Nexus file with corresponding frame on MR file

Process (2):

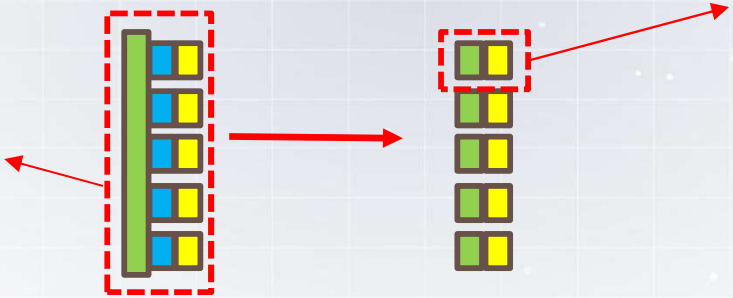
Let read the start time of the each recording.
Assume

- t0 is start time of MR file on second
- tn is start time of Nexus segment file on second
- 1 frame = 1/100 second

Then the first frame of Nexus file will be attached with the frame (tn – t0)*100 of MR file

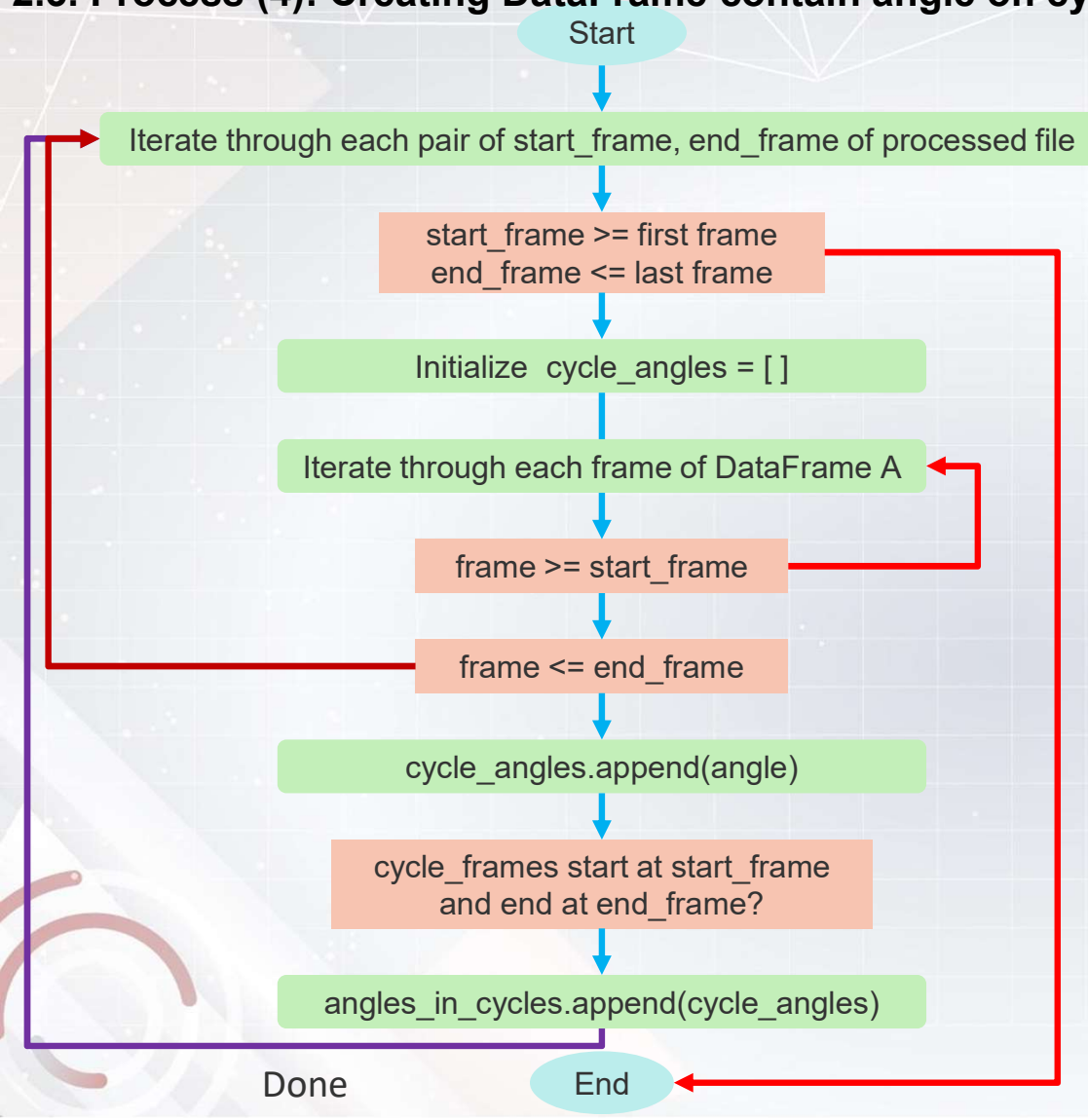
Process (3):
Only keep the corressponding frame on MR with angle on Nexus

Can be considered as a DataFrame contains 3 column with NaN at the gap of 2nd and 3rd column



Can be considered as a DataFrame contains 2 column without NaN, 1st column is frame, 2nd column is angle

2.3. Process (4): Creating DataFrame contain angle on cycles



Start frame of cycle i-th

End frame of cycle i-th

Frame	Angle
...	...
...	...
...	...

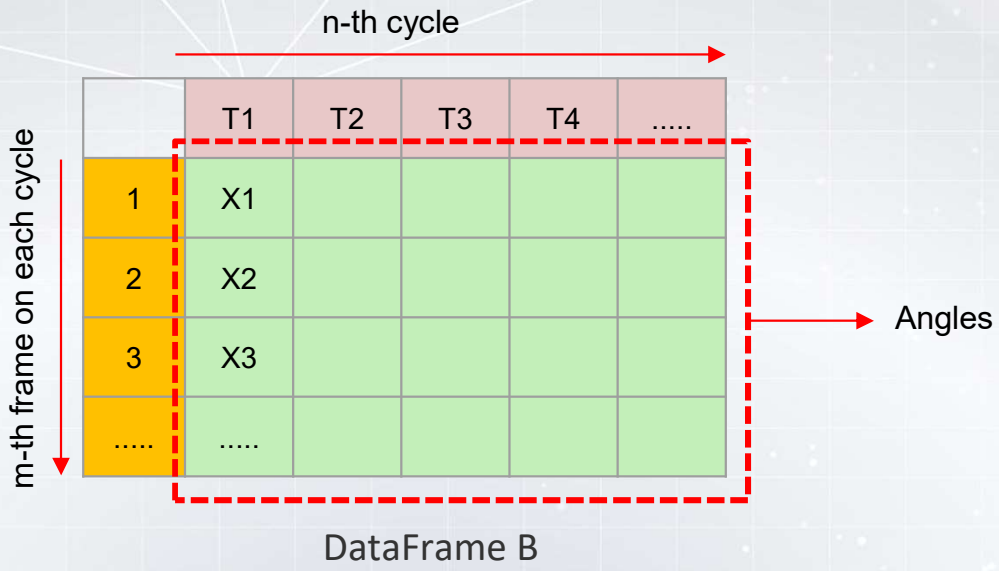
DataFrame A

Action

Dicision

Do If Yes

Do if No



angles_in_cycles then have the form as the dataframe above, with each column represent each cycle and each row represent each angle at each frame on that cycle. So It often contain the NaN value at several bottom row of some column because the length of each cycle are usually difference

2.4. Process (5) and (6): Plotting chart from the calculated information

Process (5):

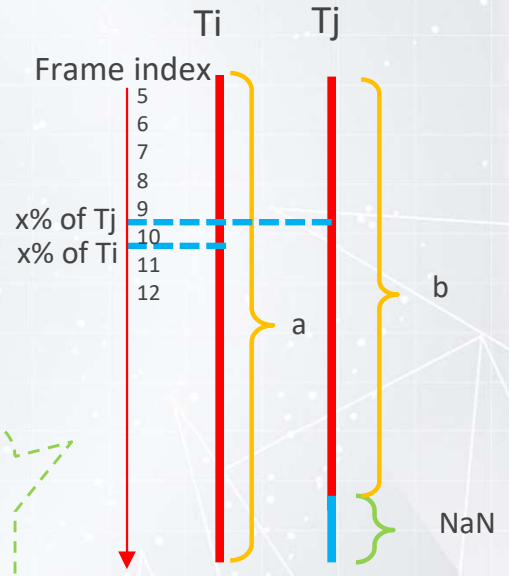
Plot the plot with x-axis represent the frame in cycle, y-axis represent the angle value at that frame. Each line is drawn from each column in DataFrame B this plot help to see the fluctuation of angle of person on running.

However, DataFrame B orriginaly have the cycles with the difference length, we need to normalize the length to one fixed value to se the all the average representations of angles in a cycle. Then the length will be normalized from 0 to 100% and the fluctuation will be vizullized by standard deviation of these point

Process (6): with each x from 1 to 100 (interger), we will take the angle at x% of each cycle, to calculate mean and std at point x%

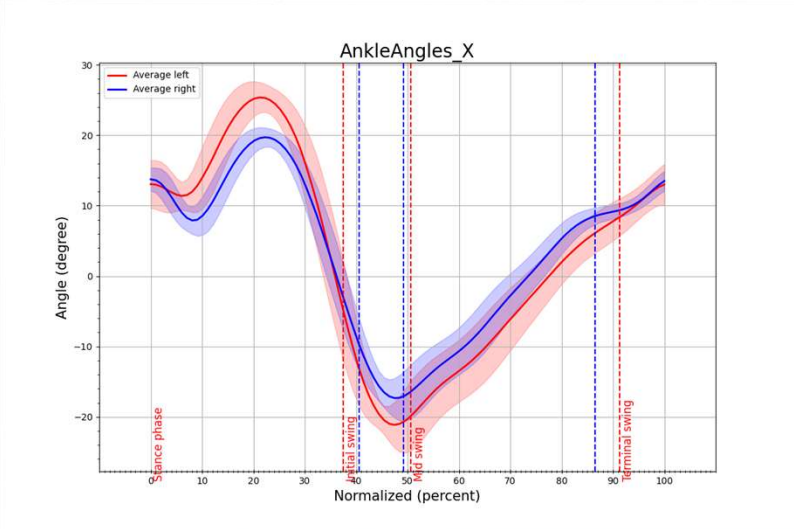
Assume:

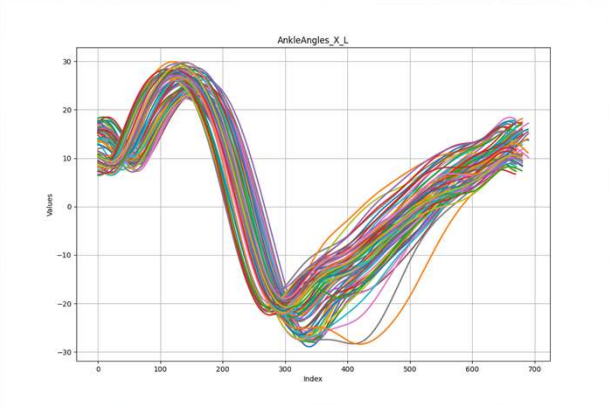
- Ti is the i-th cycle are considerring
- Iterate through each value x in range(1,100)
- Interate through each column in DataFrame B, determine the frame in cycle which is at x% of cycle length Ti, extract the angle at this frame, append to list containing the set of angle at x%
- The result is expected that at each x% from 1 to 100 will be contain a set of angle value

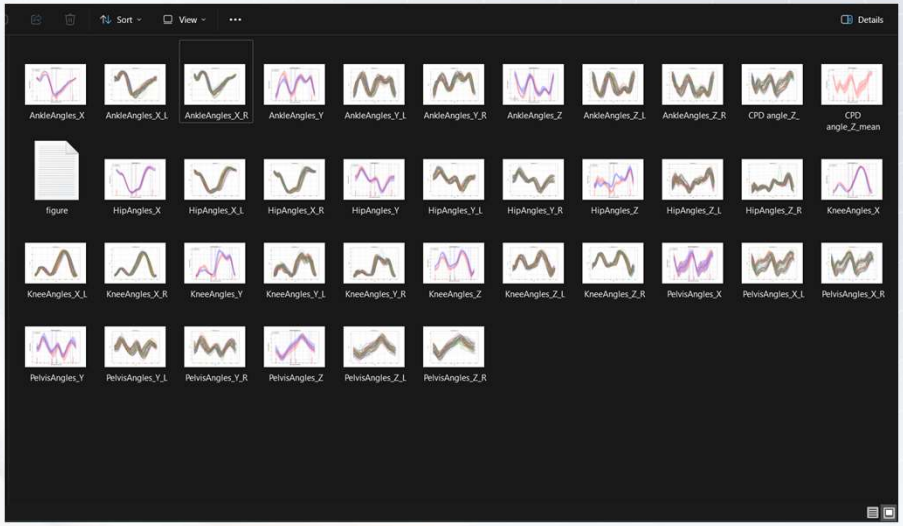


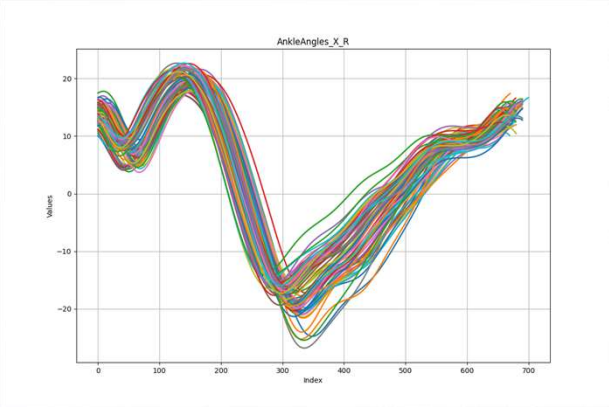
Here is an example of what happened in the process (6), with Ti (have length a), Tj (have length b) is two ramdon cycle, they have difference value of cycle length although bot lies on an DataFrame B, so the shoter cycle (Tj) will contain some NaN values. So x% of Tj and x% of Ti will have difference index on the frame column. This is why we need to re-calculate the frame index in the term of percent

3. Results:


AnkleAngles_X
Average left
Average right
Angle (degree)
Normalized (percent)
Stance phase
Initial swing
Mid swing
Terminal swing


AnkleAngles_X_L
Values
Index


Sort
View
Details
AnkleAngles_X
AnkleAngles_X_L
AnkleAngles_X_R
AnkleAngles_Y
AnkleAngles_Y_L
AnkleAngles_Y_R
AnkleAngles_Z
AnkleAngles_Z_L
AnkleAngles_Z_R
CPD angle_Z_
CPD angle_Z_mean
figure
HipAngles_X
HipAngles_X_L
HipAngles_X_R
HipAngles_Y
HipAngles_Y_L
HipAngles_Y_R
HipAngles_Z
HipAngles_Z_L
HipAngles_Z_R
KneeAngles_X
KneeAngles_X_L
KneeAngles_X_R
KneeAngles_Y
KneeAngles_Y_L
KneeAngles_Y_R
KneeAngles_Z
KneeAngles_Z_L
KneeAngles_Z_R
PelvisAngles_X
PelvisAngles_X_L
PelvisAngles_X_R
PelvisAngles_Y
PelvisAngles_Y_L
PelvisAngles_Y_R
PelvisAngles_Z
PelvisAngles_Z_L
PelvisAngles_Z_R


AnkleAngles_X_R
Values
Index