Sports Analytics

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Introduction

Context: Lab 3 covers motion sensors used in Sport Analytics. Sport is a huge industry, since it provides entertainment and excitement to people of all ages. By analyzing the field, it will give us an insight that allows us to view various components such as the players, business, recruitment, and performance. In this lab we will explore some levels of sport analysis by playing a few games of cornhole. We will collect the data using a high and a low fidelity system.

High Fidelity System: Vicon

Vicon is a company that specialized in motion sensors and the world's first choice for motion seniors for 35 years

Low Fidelity System: iPhone

We will capture the data by having a sheet of graph paper in the background and record it in slow motion with an iPhone

As stated, we can use sport analytics to analyze different components in the field. By collecting past data, we can use that to predict the opponent's next move, by analyzing how they play. We can also inform the player of a different strategy on how to play to ensure a victory. We can also use that to view the outcome of a future match by comparing how two players might compete against each other by looking at their records.

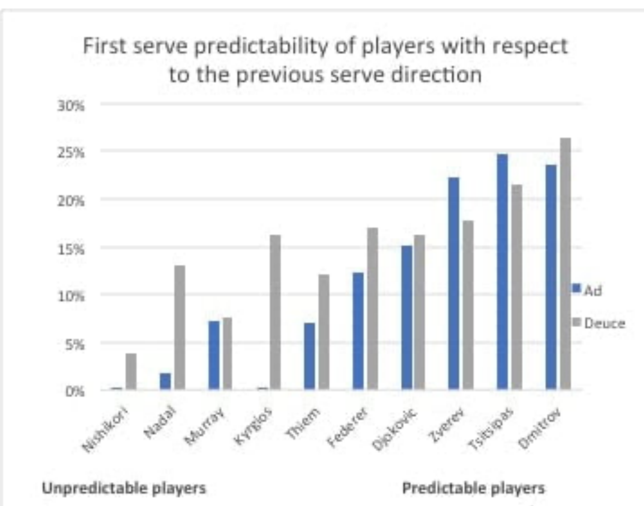


Figure 1: prediction serves of tennis players

This graph (figure 2) shows a prediction of whether the players would serve left or right. This is helpful depending on who is looking at it. It can give the opponent an advantage since they would know what to expect or it will allow the players to be self-aware of their pattern and switch it up [2]

In this lab we will focus on the performance of the user. We will see how accurate the players are with the cornhole challenge and how they can improve

Objectives:

Terminal Objectives:

- Determine optimal
  - o Throwing motion
  - o Throwing velocity
- Provide feedbacks to players

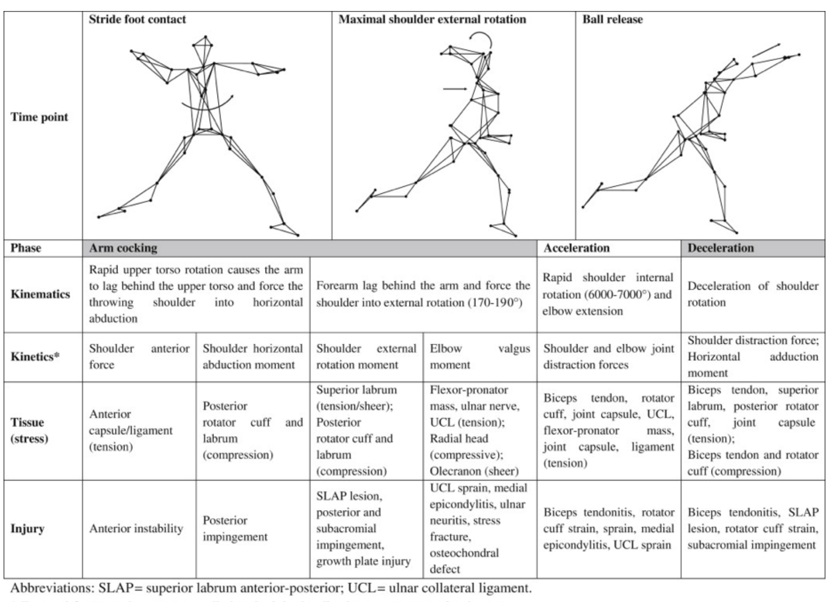
Performance Objective:

- Maximizing accuracy by finding the ideal projectile motion

Enabling Objective:
Experiments:

1. High Fidelity System, Vicon
   a. Characterize the players performance accuracy
   b. Develop a model for each player based on projectile motion and validate using Vicon data
   c. Develop suggestions for improving the accuracy for the player and the group
2. Low Fidelity System, iPhone
   a. Estimate the projection motion model parameters and compare with Vicon data

In this lab I was able to find the ideal angles according to the players' throws, which would help them aim more accurately. By knowing the projectile launch of the bean bag, we can then use that to predict the ideal angle for the Y and Z of the player's wrist, elbow, and shoulder.
To determine that we will need to understand more about the body.



Time point	**Stride foot contact**		**Maximal shoulder external rotation**		**Ball release**	
Phase	**Arm cocking**				**Acceleration**	**Deceleration**
Kinematics	Rapid upper torso rotation causes the arm to lag behind the upper torso and force the throwing shoulder into horizontal abduction		Forearm lag behind the arm and force the shoulder into external rotation (170-190°)		Rapid shoulder internal rotation (6000-7000°) and elbow extension	Deceleration of shoulder rotation
Kinetics*	Shoulder anterior force	Shoulder horizontal abduction moment	Shoulder external rotation moment	Elbow valgus moment	Shoulder and elbow joint distraction forces	Shoulder distraction force; Horizontal adduction moment
Tissue (stress)	Anterior capsule/ligament (tension)	Posterior rotator cuff and labrum (compression)	Superior labrum (tension/sheer); Posterior rotator cuff and labrum (compression)	Flexor-pronator mass, ulnar nerve, UCL (tension); Radial head (compressive); Olecranon (sheer)	Biceps tendon, rotator cuff, joint capsule, UCL, flexor-pronator mass, joint capsule, ligament (tension)	Biceps tendon, superior labrum, posterior rotator cuff, joint capsule (tension); Biceps tendon and rotator cuff (compression)
Injury	Anterior instability	Posterior impingement	SLAP lesion, posterior and subacromial impingement, growth plate injury	UCL sprain, medial epicondylitis, ulnar neuritis, stress fracture, osteochondral defect	Biceps tendonitis, rotator cuff strain, sprain, medial epicondylitis, UCL sprain	Biceps tendonitis, SLAP lesion, rotator cuff strain, subacromial impingement

Abbreviations: SLAP= superior labrum anterior-posterior; UCL= ulnar collateral ligament.
* External forces and moments applied at the joint by distal segment to proximal segment.

This diagram (figure 2) shoes that the power comes from shoulder and elbow

And the wrist is the projection angle of when the ball was last in contact.

Figure 2: throwing motions of shoulder and elbow [3]

Procedures

In these experiments we will be using two different systems and provide insights that would help the players achieve a higher accuracy.
A game of cornhole would be one of the easiest games to collect data, since there is only one goal, and it is stationary. It also only involves one arm to play. The rule is also simple, stand behind the foul line and throw.

Procedures:

1. High Fidelity System, Vicon
    a. Start the program, activate the sensors, and make sure it is picking up the signals
        i. Wave a stick with red lights, which would allow the camera to detect and calibrate
    b. Attach the sensors to your body (refer to Figure 3)
        i. One on each shoulder
        ii. Two on wrist, one on the center of the back hand
        iii. Two on the elbow that you will be throwing with
    c. Throw the bean bag
    d. Repeat 2-3 times for each player
    e. Collect data, upload to excel

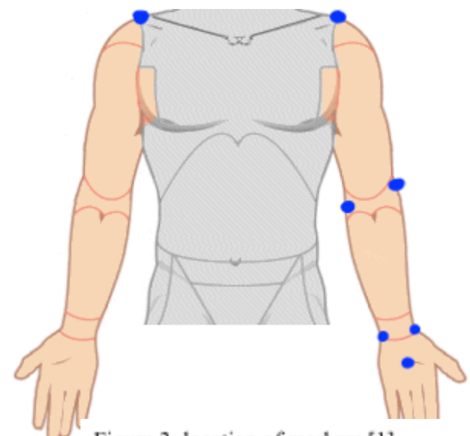
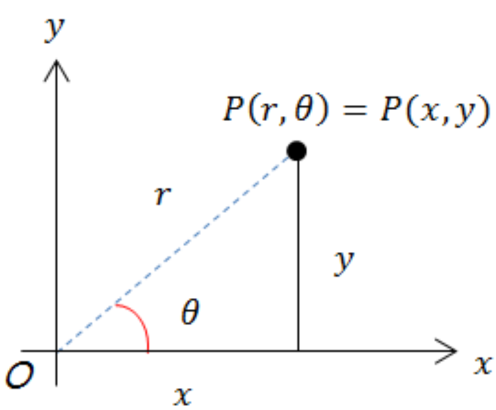


Figure 3: location of markers [1]

2. Low Fidelity System, iPhone
    a. Set up the graph paper
        i. Trace over or put dots on each square if it's not visible on the camera
    b. Position camera to where the player will be located
    c. Record
    d. Crop video if too long and keep only the part necessary

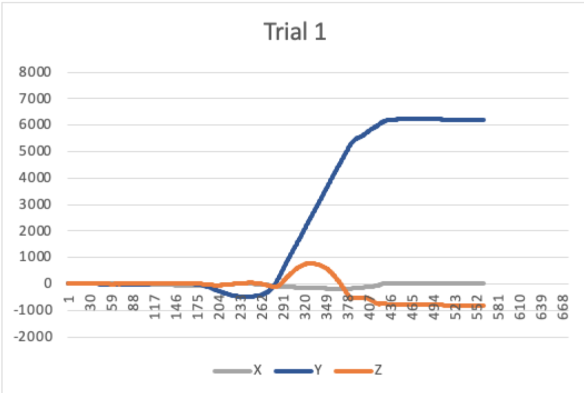


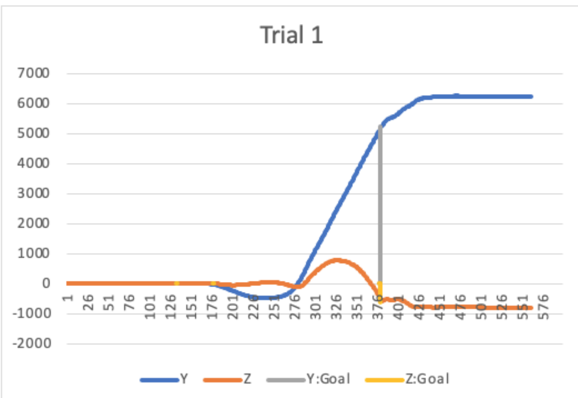
We will find the angle and then use that to find r, r will tell us the path of the beanbag when in the air.

After doing so we will have to find the velocity and the position in y axis.

Results

Participant 1, Test 1





This is the data for Player 1, The graph shows the locations of the beanbag in X, Y and Z.
The beanbag is in relation to the hip.
Ex: If Z is 10mm, that means it is 10mm above the hip.

X: Horizontal (left and right)
Y: Forward
Z: Height (up and down)

For the seconds graph, I removed the X axis since it is just a straight line and doesn't provide much data because we aren't stepping left and right.
I also added in where the goal would be located.
The goal's location is Y: 5216.14 mm, Z: -630.223mm

The goal is in relation to where the bean bag was. So, in this case, the beanbag was close to the goal's location.

	Y launch	Z launch	
	-0.58	-26.212	
282	41.46	0.519	326
	85.92	31.014	
	132.73	63.778	
Angle	88.6183	27.4293	
Goal	5216.14	-630.223	601
	y	z	
x	319	275	
y	6214	-768	
r	6222.18266	815.75057	

I found the angle of Y and Z by going through the data to find when it was thrown. So, for Y it was launch from 0 to 41.46 at 282
The angle for that is arc tan (41.46) which gives me 88 degrees

The goal is at position 601, it isn't the real position, but it is where the data was closest to the goal.

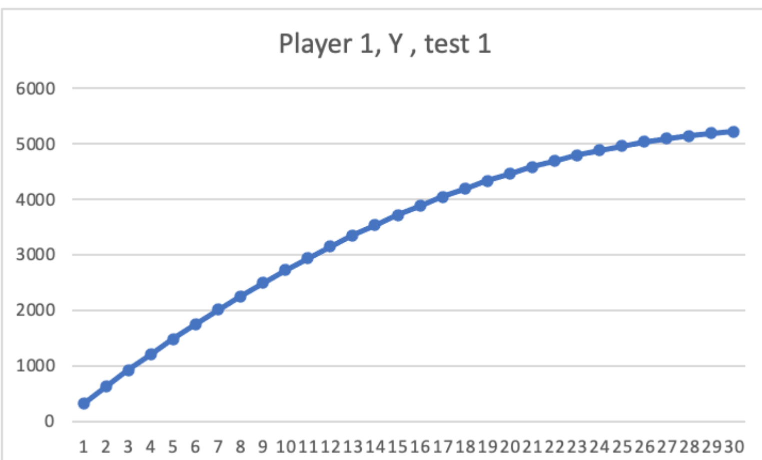
So, the x axis for Y would be 601- 282 = 319
The Y axis for Y is 6214 because that's where it landed. So, r is Sqrt of (x^2 + y^2).
The r tells us the hypotenuse of the shape.
In this case, we got 6222 and – 815 which means went farther from the goal and in term of z it didn't land on the goal.
To provide feedback to the users, we will have to determine the velocity.
We can find Velocity as distance over time. I couldn't figure out how long it took, so I did 319/.01, which gave me 31900.
I made an excel that will provide a graph and we can change it based on the angle and Velocity

The data are listed down below:
Angle: (insert degree)
Vo: D/t mm/s
Vo_x: Vo * cos(degree) mm/s
Vo_y: Vo * sin(degree) mm/s
g: -9806.65 mm /s^2

We can find X and Y of the graph by
X: Vo_x * t
Y: V0_y * t - .5gt^2

In this case, x doesn't matter as much since we aren't too sure about the time and just need the y axis to give us the height of Y.
So, if we enter
Angle: 88.613
Vo: 31900
We get the following graph

This is in a span of 3 seconds at, it reaches 5154, which is close to the goal.



If we change the angle to 80 degree and at a speed of 32602 mm/s, then we will reach 5219 which is closer to the goal of 5216

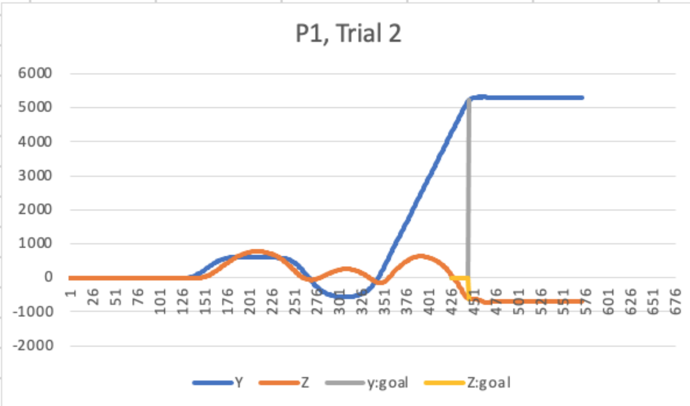
Now that we have a better understanding of the graph, it is time to figure out the ideal angle and velocity of Y and Z. We can't exactly just change one speed, so I took the avg of both.

After trial and error, I got
V= 33300 mm/s

Y: 74 Degree 5190 mm/s
Z: 22.34 Degree -615 mm/s

And this is the graph.

Participant 1, Test 2



The launch angle of Z was too high (78 degrees) it is on par with Y. So, I went to one of the parabolas and took the reading. Which is .245 and it gave me a degree of 13.766

V= (3550+319)/2 / .02= 33450

After plotting this we see that at 3 seconds it gives a value of
Y: 5619
Z: -2024

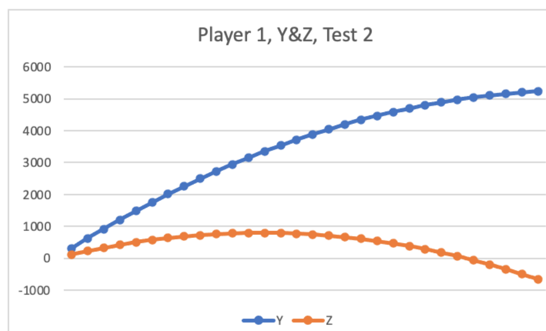
Which is way off, assume that it still took 3 seconds,

We can do trial and error again and see that even though the speed changed, the angle is similar to the previous test

	brought iut back and then launch		
	Y	Z	
	-0.13	-25.483	
327	45.14	4.786	358
	92.07	36.455	
	140.51	67.602	
Angle	88.730917	78.198251	
Goal	5216.14	-630.223	
	y	z	
x	350	319	
y	5303	-715	
r	5314.5375	782.93422	

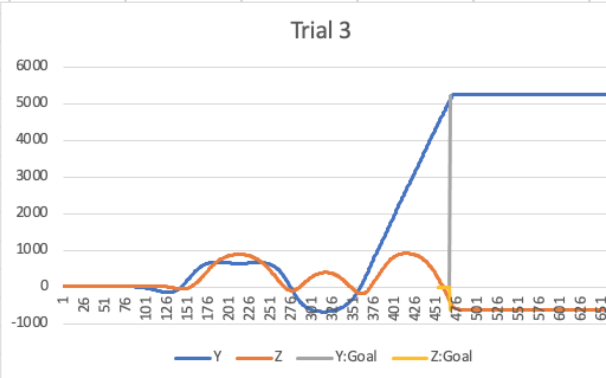
Y	Z
316.639037	120.403405
623.472075	231.001811
920.499112	331.795216
1207.72015	422.783622
1485.13519	503.967027
1752.74422	575.345433
2010.54726	636.918838
2258.5443	688.687244
2496.73534	730.650649
2725.12037	762.809055
2943.69941	785.16246
3152.47245	797.710866
3351.43948	800.454271
3540.60052	793.392677
3719.95556	776.526082
3889.5046	749.854488
4049.24763	713.377893
4199.18467	667.096299
4339.31571	611.009704
4469.64075	545.11811
4590.15978	469.421515
4700.87282	383.919921
4801.77986	288.613326
4892.88089	183.501732
4974.17593	68.5851374
5045.66497	-56.136457
5107.34801	-190.66305
5159.22504	-334.99465
5201.29608	-489.13124
5233.56112	-653.07284

V: 33450 mm/s
Y: 74 deg — 5233 m/s
Z: 22 deg — -650 m/s



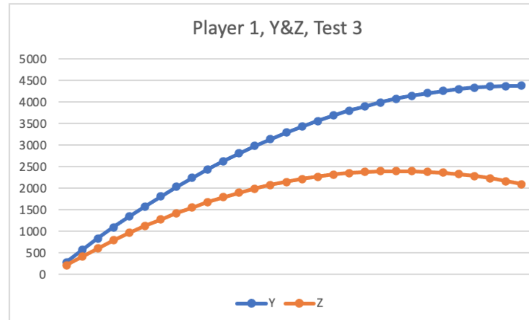
	Y	Z		
yo	0	0	mm	
angle	74	22	deg	
Vo	33450	33450	mm/s	
Vox	9220.06955	31014.2999	mm/s	X ignore
voy	32154.2037	12530.5905	mm/s	
g	-9806	-9805	mm/s^2	

Participant 1, Test 3



		-23.24	-31.538	
	361	17.18	1.097	406
		59.09	37.666	
	Angle	86.66873	47.64842	
	Goal	5216.14	-630.223	677
		y	z	
	x	316	271	
	y	5235	-637	
	r	5244.529	692.25	

Y	Z
288.080389	211.972255
566.354779	414.139511
834.823168	606.501766
1093.48556	789.059021
1342.34195	961.811277
1581.39234	1124.75853
1810.63673	1277.90079
2030.07512	1421.23804
2239.70751	1554.7703
2439.53389	1678.49755
2629.55428	1792.41981
2809.76867	1896.53706
2980.17706	1990.84932
3140.77945	2075.35657
3291.57584	2150.05883
3432.56623	2214.95609
3563.75062	2270.04834
3685.12901	2315.3356
3796.7014	2350.81785
3898.46779	2376.49511
3990.42818	2392.36736
4072.58257	2398.43462
4144.93096	2394.69687
4207.47335	2381.15413
4260.20974	2357.80638
4303.14013	2324.65364
4336.26452	2281.69589
4359.58291	2228.93315
4373.0953	2166.3654
4376.80168	2093.99266



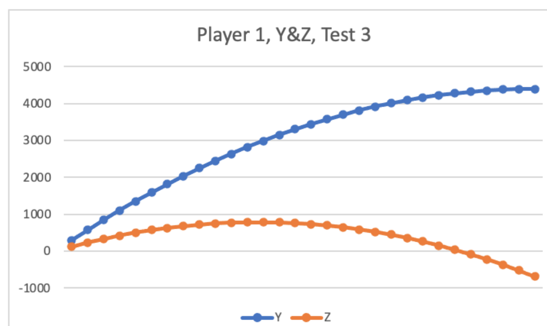
	Y	Z	
yo	0	0	mm
angle	86.6	47.64	deg
Vo	29350	29350	mm/s
voy	29298.3389	21687.4755	mm/s
g	-9806	-9805	mm/s^2

The data that we collected didn't quite match up with the graph I made since we don't have the exact time.

For the feedback, Z will have to be at an angel of 25 but for Y I wasn't able to find the ideal angle.

I would repeat this for all the data we had collected, since it's just all the same process of plug-in chug and the graph all looked similar, I will jump straight to the final feed backs

Y	Z
288.597	119.13596
567.388	228.46692
836.373	327.992879
1095.552	417.713839
1344.925	497.629799
1584.492	567.740759
1814.253	628.046719
2034.208	678.547679
2244.357	719.243638
2444.7	750.134598
2635.237	771.220558
2815.968	782.501518
2986.893	783.977478
3148.012	775.648437
3299.325	757.514397
3440.832	729.575357
3572.533	691.831317
3694.428	644.282277
3806.517	586.928237
3908.8	519.769196
4001.277	442.805156
4083.948	356.036116
4156.813	259.462076
4219.872	153.083036
4273.125	36.8989955
4316.572	-89.090045
4350.213	-224.88408
4374.048	-370.48313
4388.077	-525.88717
4392.3	-691.09621
4386.717	-866.11025
4371.328	-1050.9293
4346.133	-1245.5533



	Y	Z	
yo	0	0	mm
angle	90	25	deg
Vo	29350	29350	mm/s
voy	29350	12403.846	mm/s
g	-9806	-9805	mm/s^2

Players bean bag position results in degrees

	Player 1		
	Original		
	trial 1	trial 2	trial 3
Y	88.61	88.7	86.688
Z	27.42	13.766	47.64
	New		
Y	74	74	NA
Z	22.34	22	25

	Player 2		
	Original		
	trial 1	trial 2	trial 3
Y	80.3	86	63
Z	3.83	41.13	48
	New		
Y	NA	60	60
Z	27	20	20

	Player 3		
	Original		
	trial 1	trial 2	trial 3
Y	88.33	88.3	87
Z	32	58.13	32
	New		
Y	NA	79	66
Z	32	23	21.5

	Player 4		
	Original		
	trial 1	trial 2	trial 3
Y	81	87	88
Z	71	16	39
	New		
Y	NA	65	NA
Z	26.5	21	26

Green: Increase
Red: No results
Yellow: Decrease
Blue: Same

As I was analyzing the results I came across a pattern

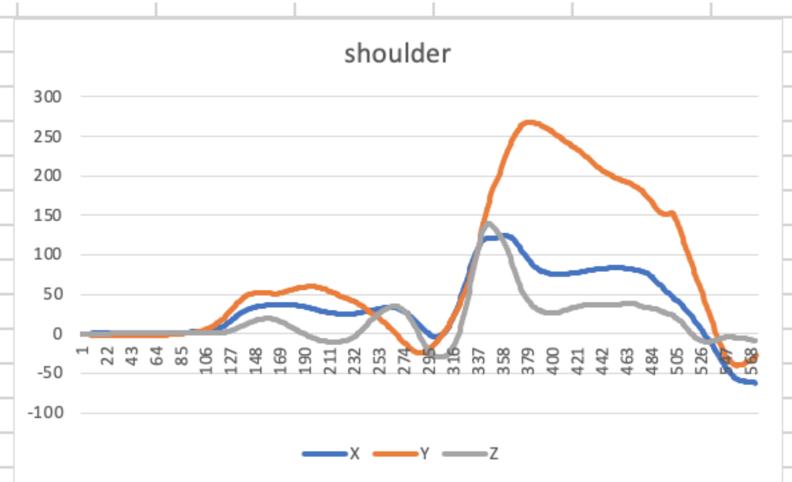
Red: Couldn't find an ideal angle because the speed was too slow

A High-speed result in a

- higher angle in Y and Z and to combat that we will have to lower the angle Shoulders, Elbow, Wrist

Player 1

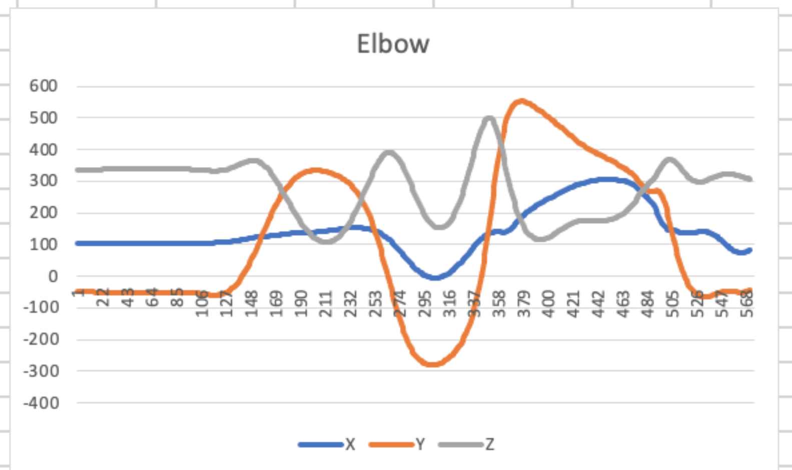
From the graph we can see



X: There were some twisting involved

Y: moved forward to twist

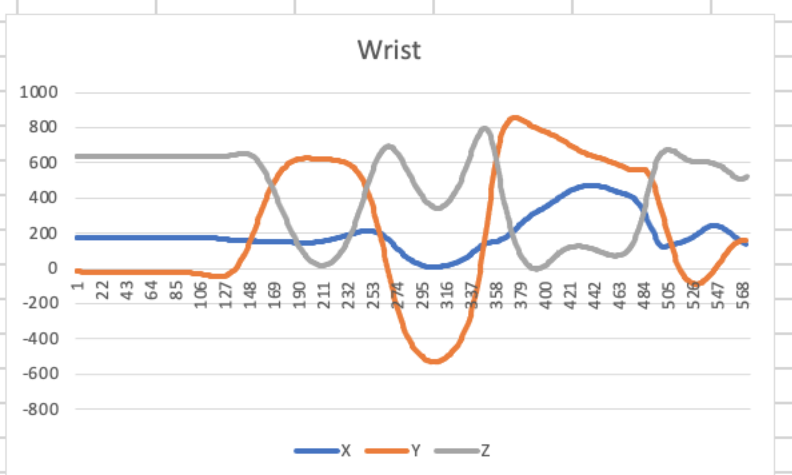
Z: Shoulder were raised when ready to throw



X: Elbow went inward and outward when thrown

Y: Brought it in and out.

Z: Up and down motion

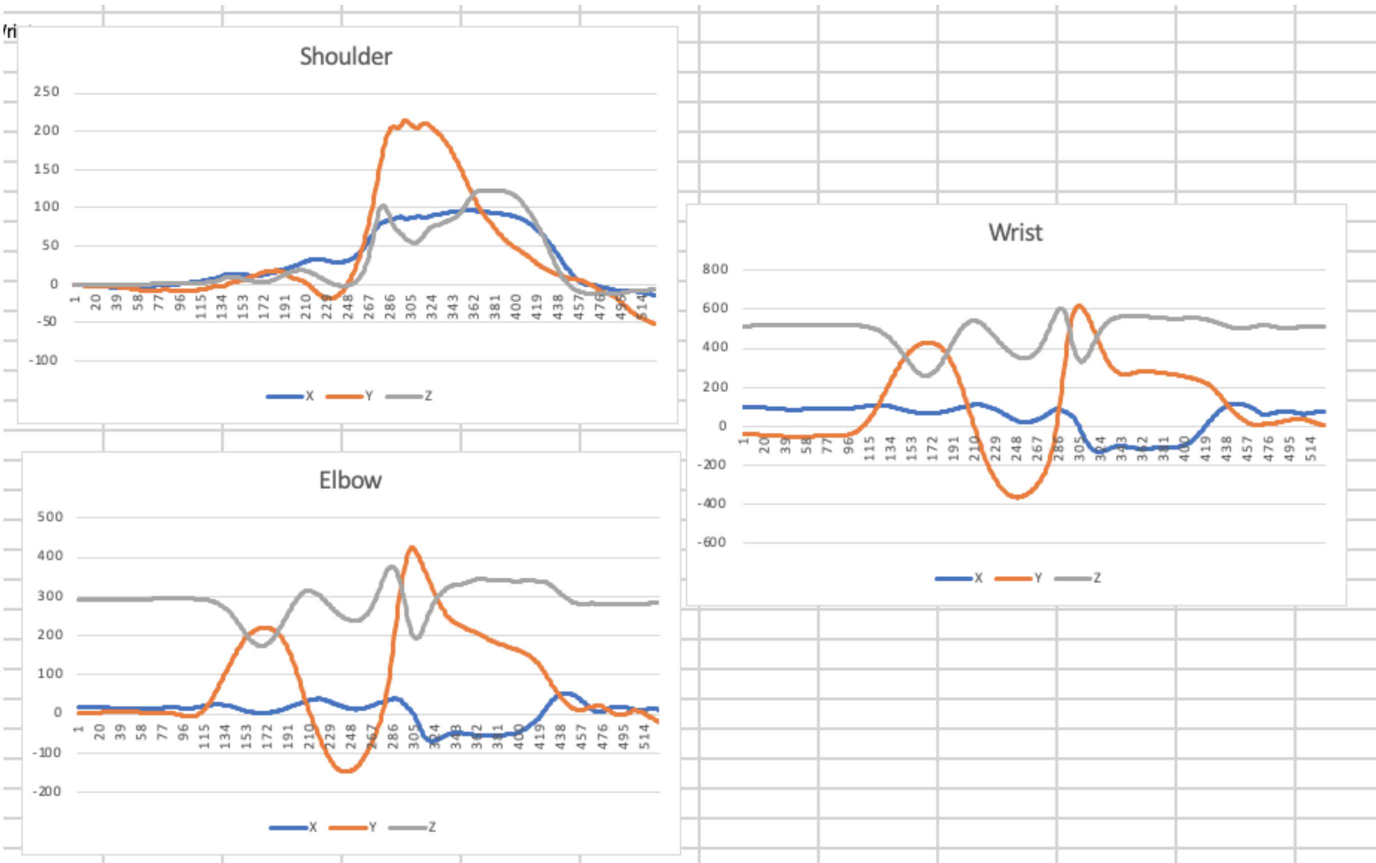


X: not much change until the end

Y: went far back and then forward really fast

Z: up and down multiple times

Player 2



Player 1 VS Player 2

P1 shoulder and elbow are higher than P2, which makes sense since it was much faster.

Since higher power = higher angle

That means p1 can do one of the following
A lower angle (wrist)
Or less force (shoulder and elbow)

Player 1		
Original		
trial 1	trial 2	trial 3
88.61	88.7	86.688
27.42	13.766	47.64
New		
74	74	NA
22.34	22	25

Player 2		
Original		
trial 1	trial 2	trial 3
80.3	86	63
3.83	41.13	48
New		
NA	60	60
27	20	20

Player 1: higher shoulder, wrist, and elbow

We see that P1 have a higher angle in Y and Z.

We will subtract the original and new to see how they would compare

Player 1		
Difference		
trial 1	trial 2	trial 3
14.61	14.7	NA
5	8.3	22

Player 2		
Difference		
trial 1	trial 2	trial 3
NA	86	63
23.17	21	28

So, by looking at the differences we can see that player 1 is a better player than 2 because not only were they closer to the target, but also have a much stronger power.
Player 1 can lower and increase the angle by the wrist or decrease the speed by lowering their elbow and shoulder

Low Fidelity System

The low fidelity system didn't help because
- the video doesn't play and only shows a picture.
- Most of the pictures were just of the player standing still
- Grid was hard to see
- One of the pictures shows the player about to throw, but not sure because the beanbag still in hand

Therefore, I couldn't get anything off it

Discussion

Next time, I would go more in depth on how the body works because I didn't think too much about the body at first when I was working with the data. I focused mainly on the angle and forgot about the force. It was also hard to connect the body to the bean bag because of the x y and z. There was just too much to keep track of and hard to see it if it's not visually. The graph helped clear up some confusion, but it was still hard to picture it without a video of the projection motion of the arm. We also need more data on the time, because it was hard for me to figure out the speed since I didn't know how much time had passed.

Next time, it would be nice to get the video to work. That way we can see the motion of the arm while also having the data and we would be able to pinpoint the moment to the graph.

Reference

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