

Air Hockey Disk Collision Analysis

Discussion Log

Experimental Setup

Two disks (4 inch diameter) move on an air table in the XY plane. Each disk is equipped with an IMU chip (LSM6DS3) measuring acceleration and angular velocity. Data is collected via BLE at 50 Hz sampling rate. Disk 1 is launched from the edge using a string/bow mechanism, while Disk 2 is initially stationary in the center.

Discussion

User:

This is data from two devices moving on an air table in the XY plane. The devices are chips on 4-inch diameter disks. The first disk is at the edge of the table, the second in the center. The first disk is launched by string tension at the edge of the table toward the second one - this event occurs between 3.6 and 3.7 seconds. Around 4.6 seconds, the first disk collides with the second, visible as a weak peak on the acceleration graph. Subsequent peaks are collisions with the walls. It is expected that at the moment of impact, the acceleration magnitudes of the first and second balls will be approximately equal, because the objects have equal mass. Is this correct reasoning?

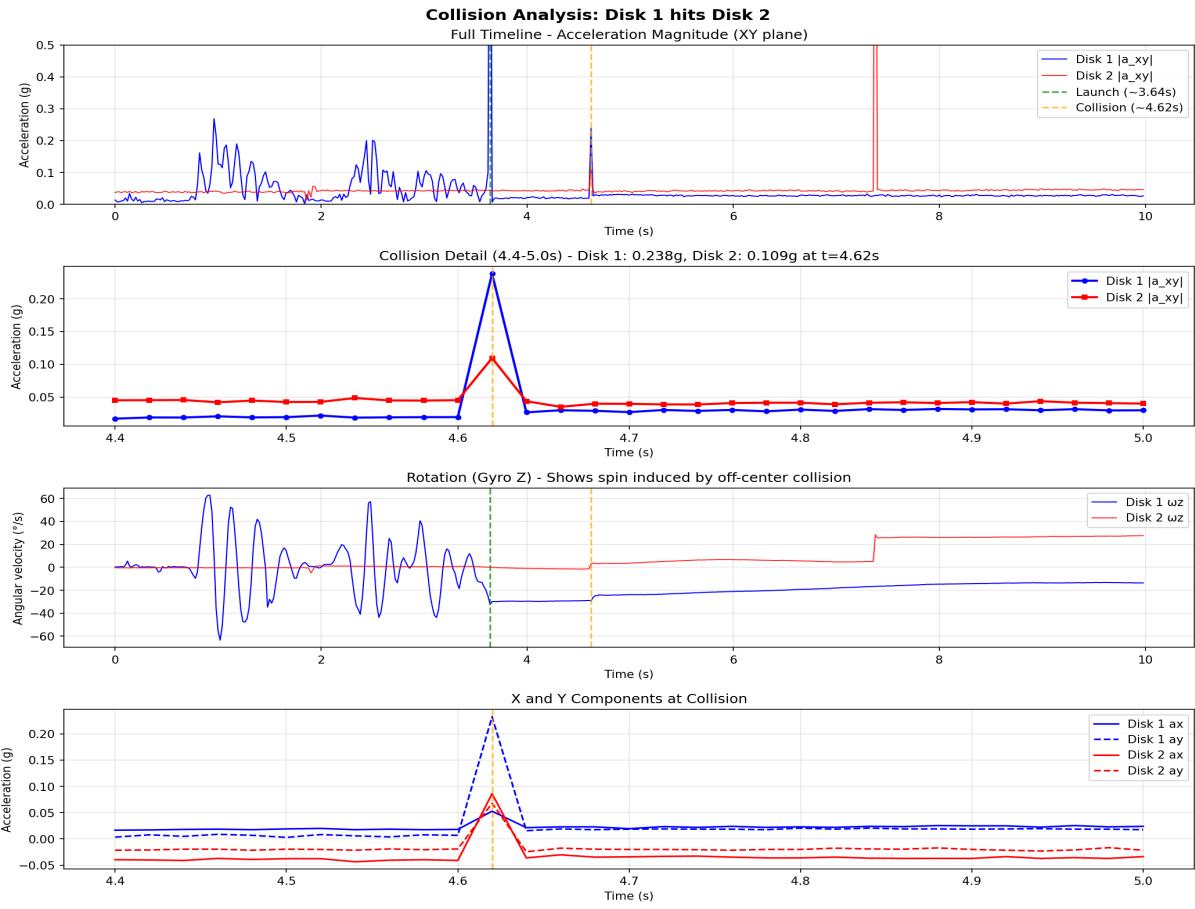
Analysis Results:

Collision at t=4.62s:

- Disk 1: 0.238 g
- Disk 2: 0.109 g
- Ratio: approximately 2:1, not 1:1 as expected

The reasoning is partially correct but there are nuances. According to Newton's Third Law, the forces during collision are equal and opposite: $F_1 = -F_2$. Since the masses are equal ($m_1 = m_2$), the accelerations should be equal in magnitude: $a_1 = a_2$. However, this is not observed in the data.

Central Collision Analysis (1hits2-central.csv)



Off-Center Collision Analysis (1hits2.csv)

User:

Here is another dataset. This one has an off-center collision.

Analysis Results:

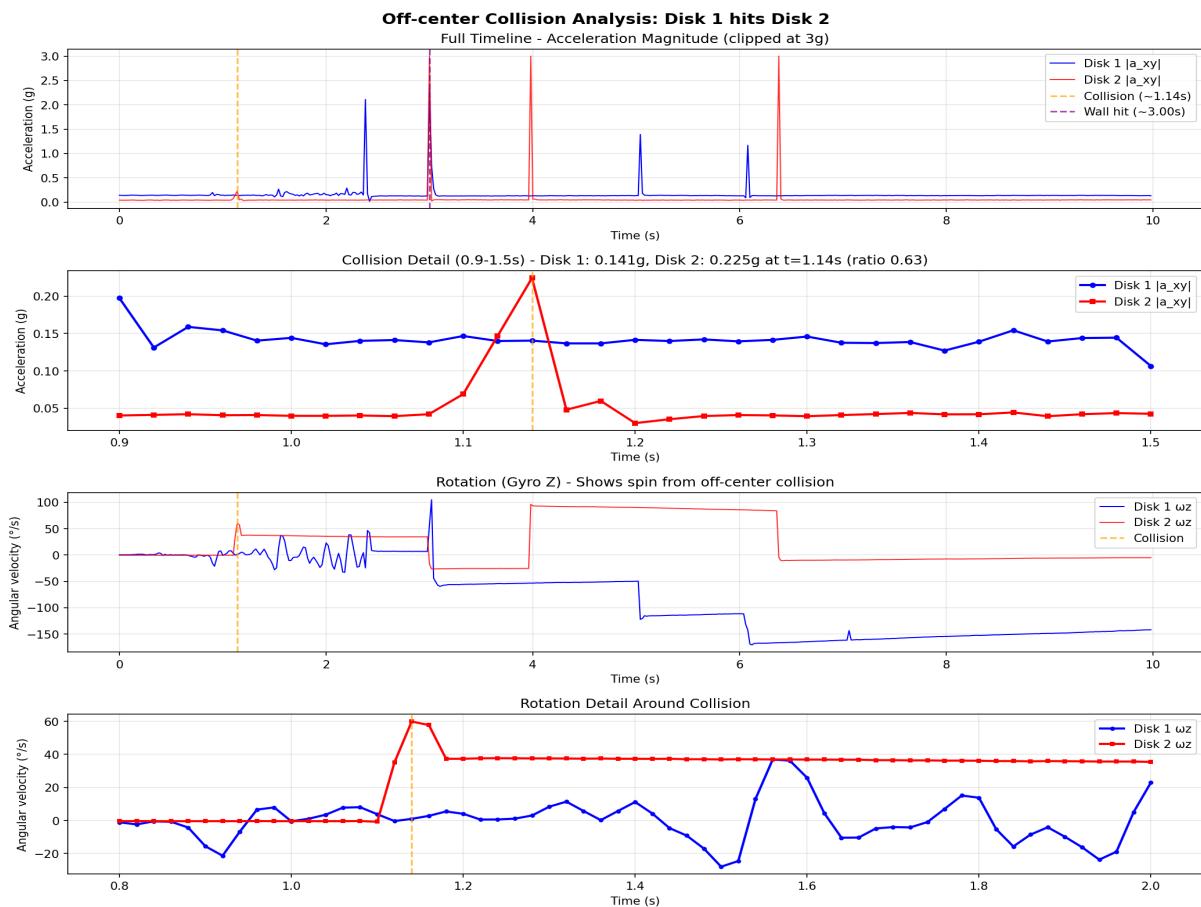
Collision at t=1.14s:

- Disk 1: 0.141 g
- Disk 2: 0.225 g
- Ratio: 0.63 (reversed!)

Key difference - rotation:

- Disk 1: practically no spin ($\Delta = 3.8 \text{ }^{\circ}/\text{s}$)
- Disk 2: strong spin ($\Delta = 37.4 \text{ }^{\circ}/\text{s}$, up to $60 \text{ }^{\circ}/\text{s}$ at impact)

In an off-center collision, the force is applied with an offset from the center of mass, creating torque. Energy is distributed between linear motion (acceleration) and rotational motion (angular acceleration). Disk 2 received most of the impulse as rotation rather than linear motion.

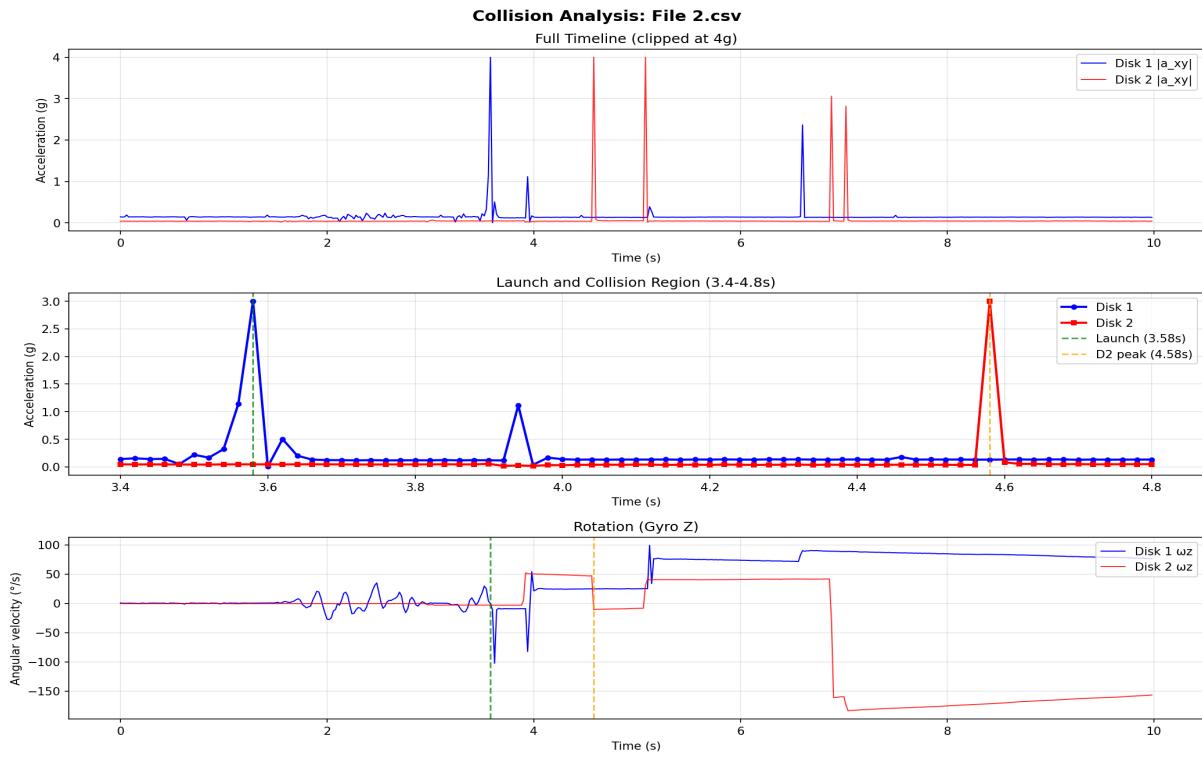


Dataset 3 Analysis (2.csv)

Timeline of events:

- 3.58s — Launch of Disk 1 (10g from bowstring)
- 3.94s — Tangential hit on Disk 2 (Disk 2 spun up to 52°/s)
- 4.58s — Disk 2 hits the wall

Disk 2 rotated steadily at ~50°/s after the collision and gradually slowed down until it hit the wall.



Physics Discussion

User:

Let's set aside doubts about sensor mounting and assume it is rigidly attached. In that case, the acceleration recorded by the sensor is proportional to the normal component of the interaction force during impact. These forces are equal and opposite according to Newton's Third Law. That is, the accelerations should be equal in magnitude. Correct?

Response:

Yes, correct! With rigid sensor mounting:

$$F_{\text{disk}} = -F_{\text{wall}} \quad (\text{Newton's Third Law})$$

$$m_{\text{disk}} = m_{\text{wall}} \quad (\text{identical disks})$$

$$\text{Therefore: } |a_{\text{disk}}| = |a_{\text{wall}}|$$

The accelerations should be equal in magnitude at the moment of impact. But this is not what we see in the data.

Conclusion: The Sampling Rate Problem

At **50 Hz sampling** (20 ms between samples), the collision duration (~1-5 ms) is **shorter than one sample period**. This means:

- We capture at most **one data point** during the collision
- Each sensor samples at a slightly different phase of the impulse curve
- One sensor might catch the peak, another the rising/falling edge
- The measured accelerations appear unequal even though the true impulse is symmetric

User:

We probably don't have enough resolution because there's only one point per collision.

Response:

Exactly. At 50 Hz (20 ms between samples) and collision duration of ~1-5 ms, we get at best **one point** per impact impulse. This point can land on the peak, on the rise, on the fall, or completely miss the collision between samples. And for two sensors, these points will land at **different phases** of the force curve even if the impact is identical.

Solution: Increase Sampling Rate to 500 Hz

Upgrading from 50 Hz to **500 Hz** will provide 10-25 data points per collision instead of 1. The LSM6DS3 sensor supports up to 833 Hz or 1.66 kHz.

Required firmware changes:

```
// Increase sensor rate
imu.settings.accelSampleRate = 833;
imu.settings.gyroSampleRate = 833;

// Decrease sample interval
#define SAMPLE_INTERVAL_MS 2 // was 20

// Increase buffer size (10x more data)
#define MAX_SAMPLES 5000 // was 500
```