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Prediction of baseball pitch trajectory based on Machine Learning and 6-Axis Accelerometer & Gyroscope

EECS08

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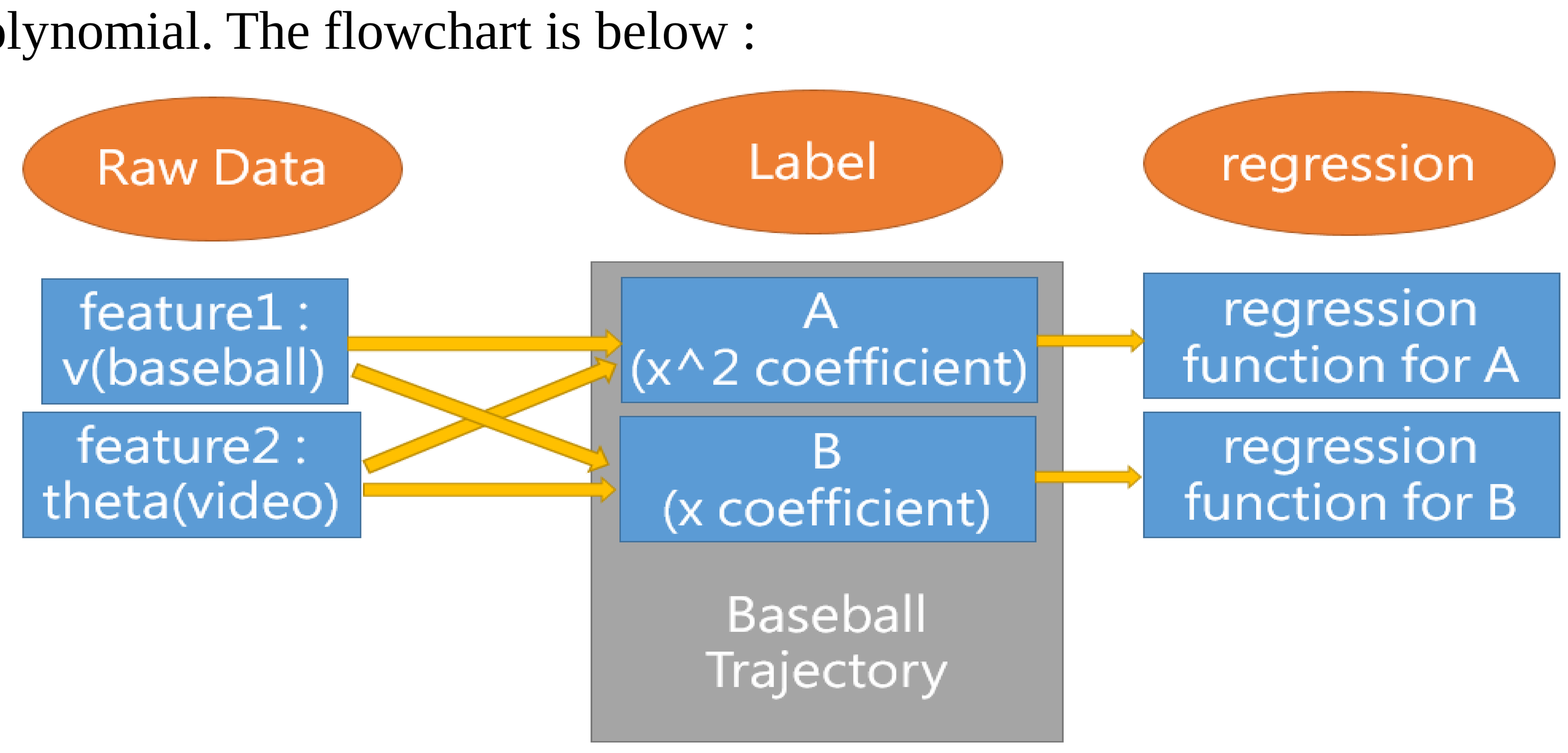
Abstract

This project is mainly about the reconstruction of baseball trajectory. The simulations of 2D and 3D tracks are covered in the work. It is quite important for batters to scrutinize the trajectory of pitchers, but the main approach is using video analysis, which needing some expensive equipment and a decent place. Therefore, to get rid of the limitations, we try to reconstruct the trajectory just from some observed values of a baseball. In the project, we use machine learning, projectile motion formula, and the derivative relation between acceleration and velocity as our theoretical tools. On the hardware sides, we use a strike smart baseball and a 6-axis micro-sensor. The strike smart baseball is a ready-made product that can provide the information of velocity, rotating speed, etc. From the 6-axis micro-sensor, we get instant values of acceleration and angular acceleration at X, Y, and Z-axis. With the information above, we try to reconstruct 2D and 3D tracks respectively.

Introduction

In the part of the 2D trajectory simulation, we suppose the real trajectory of the ball would be a quadratic polynomial, and we try a linear model with 34 training data and 9 testing data to train the parameter of the quadratic polynomial. The flowchart is below :



In the part of the 3D trajectory simulation, we use 6-Axis Accelerometer & Gyroscope to catch raw data. The data can be transformed into instant velocity and angular velocity, and then we get the instant displacement of the ball. It is noticeable that since the sensors rotates with the ball, the coordinate will keep changing when the ball is flying. To get rid of the condition, we implement the transform matrix which would project the observed value into the initial coordinate. With the transfer matrix, we can get the instant velocity vector with the initial coordinate by the matrix multiplication. The transfer matrix is the 3*3 one in the equation.

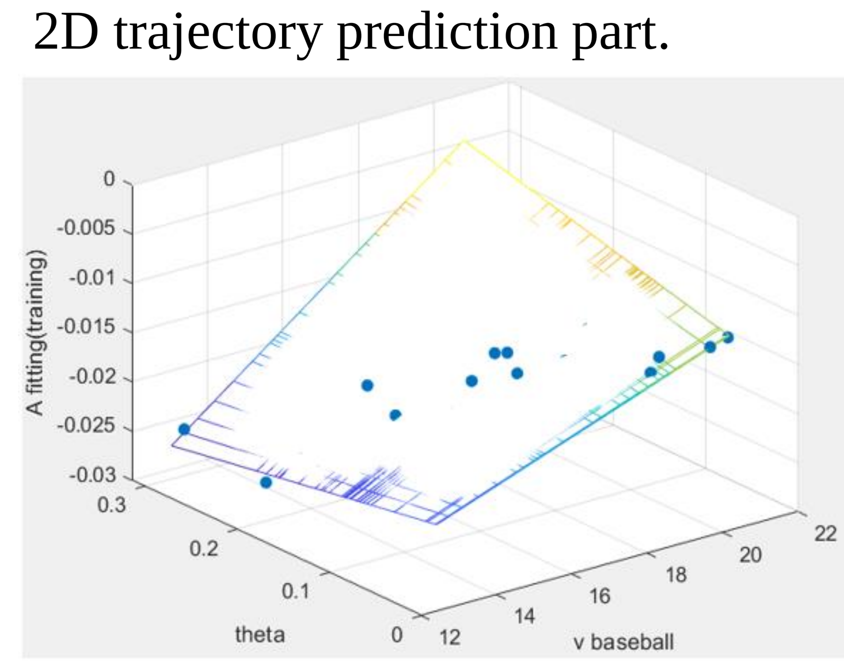
$$\Delta t\begin{pmatrix}\cos(\theta_y)\bullet\cos(\theta_z) & -\cos(\theta_x)\bullet\sin(\theta_z) & -\cos(\theta_x)\bullet\sin(\theta_y)\\ -\cos(\theta_y)\bullet\sin(\theta_z) & \cos(\theta_x)\bullet\cos(\theta_z) & \sin(\theta_y)\\ \sin(\theta_y) & \sin(\theta_x) & \cos(\theta_x)\bullet\cos(\theta_y)\end{pmatrix}\begin{pmatrix}a\_x\\ a\_y\\ a\_y\end{pmatrix}=\begin{pmatrix}v\_x\\ v\_y\\ v\_z\end{pmatrix}$$

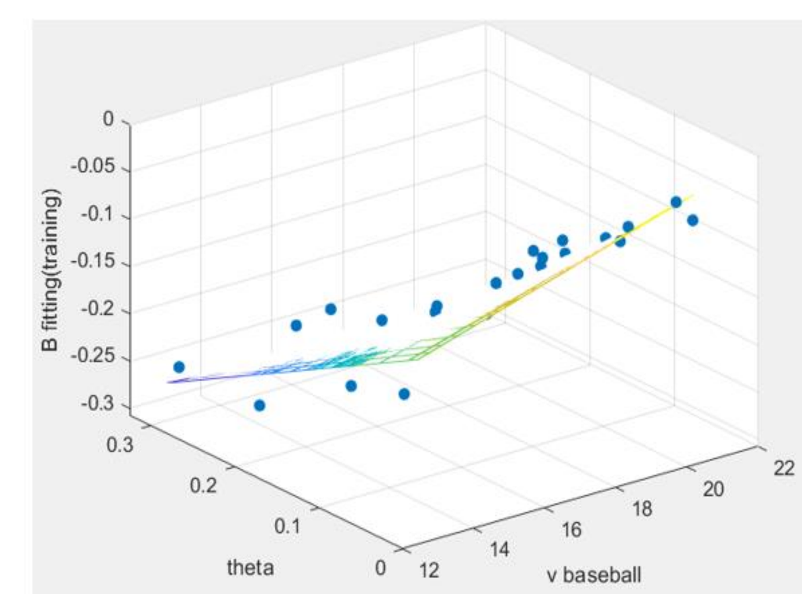
With the instant velocity vector, it is easy to get the instant displacement of the ball and to get the trajectory.

$$\begin{pmatrix}v\_x_{i+1}\\ v\_y_{i+1}\\ v\_z_{i+1}\end{pmatrix}=\begin{pmatrix}v\_x_i\\ v\_y_i\\ v\_z_i\end{pmatrix}+\begin{pmatrix}\Delta v\_x\\ \Delta v\_y\\ \Delta v\_z\end{pmatrix}\qquad\begin{pmatrix}\Delta x\\ \Delta y\\ \Delta z\end{pmatrix}=\Delta t\begin{pmatrix}v\_x_i\\ v\_y_i\\ v\_z_i\end{pmatrix}$$

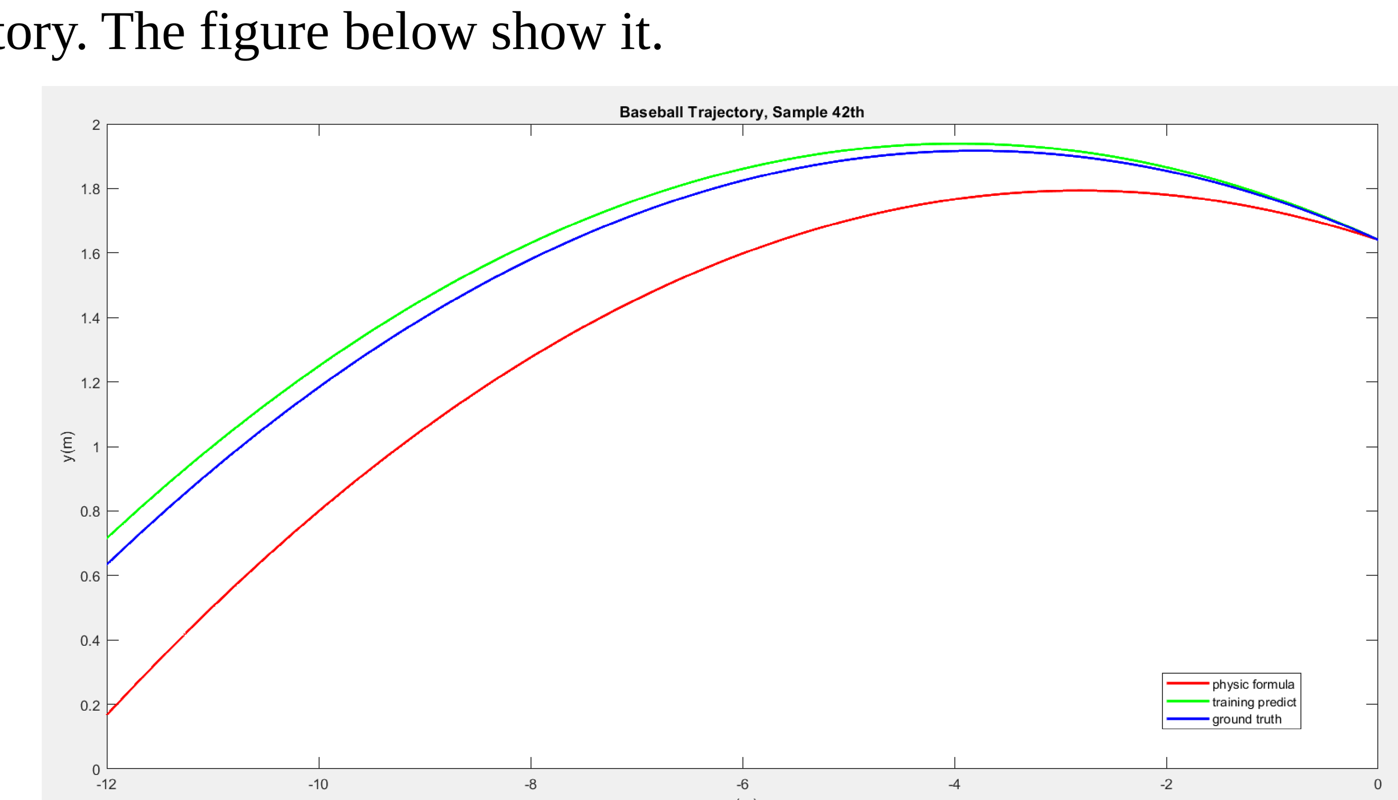
Experimental Results

Below are the results of multiple linear regression of x^2 and x coefficients in 2D trajectory prediction part.

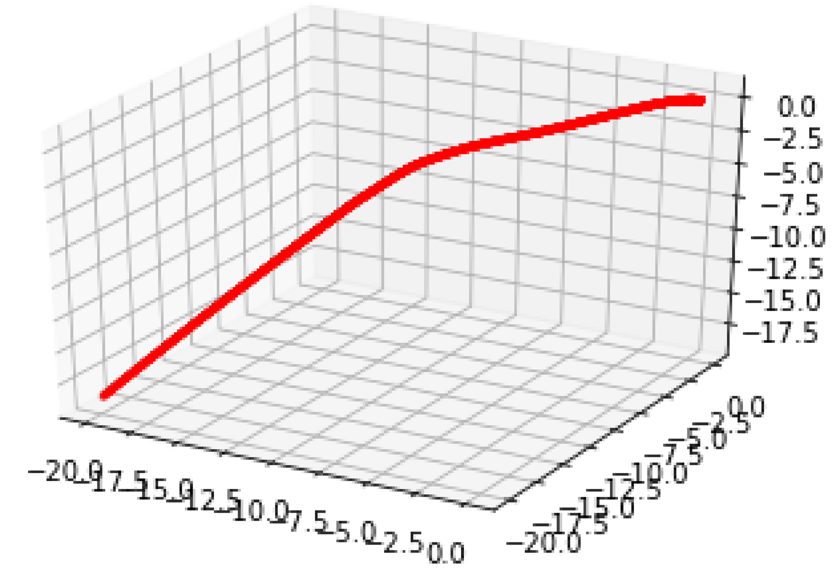


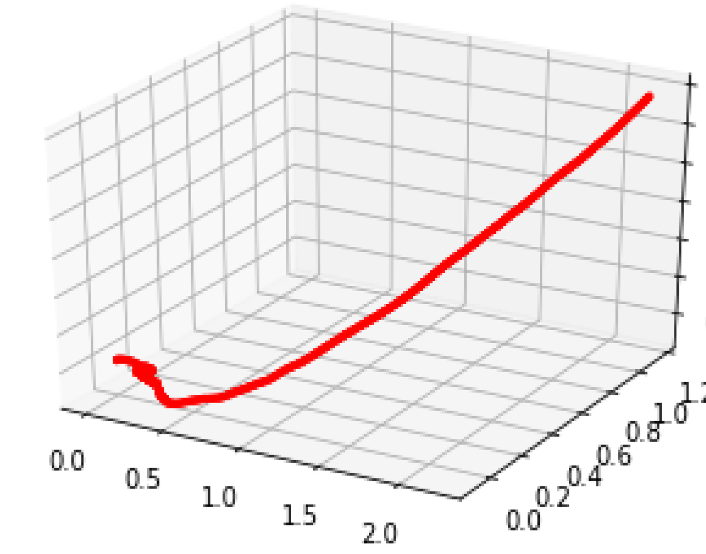


We come to the conclusion that as long as having the pitching initial speed and the pitching elevation angle, we can use our method to get the pitching trajectory. The figure below show it.



Besides, the mean square error between our prediction and ground truth will be less than 0.01 which is obviously more precise than using physical formula directly. In the future, we will try to use raw data from 6-Axis Accelerometer & Gyroscope to get the pitching initial speed and the pitching elevation angle. Once we can get the precise initial speed and elevation angle from it, we are able to know the pitching trajectory. Then we can finally achieve our goal: using 6-Axis Accelerometer & Gyroscope to predict baseball pitch trajectory.





The above are results of the 3D track simulation. Unfortunately, We still have two big problems in our 3D trajectory simulation part: wrong proportion and coordinate transformation. First, to solve the wrong proportion problem, using the sensor with the higher sampling rate and trying some numerical solutions can perhaps solve this problem. However, there must exist errors giving rise to an inaccurate trajectory. Comparing with the above problem, the second one is easier. Since if we fix the baseball pitching grip and use the peaks of the signal of the accelerometer to check the flying period, the incorrect coordinate problem could be solved.