Golf Simulator in Scilab: Capturing a swing and estimating the cary with a tiny low-cost Radar

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Publication Perso

February 2, 2025

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ABSTRACT

By using the equations of golf ball flight dynamics, this article demonstrates how to code a swing simulator for a ball in Scilab.

The simulator uses an ODE (ordinary differential equation) solver from Scilab, the fluid dynamics equations on a ball (taking into account gravity, drag forces, and Magnus forces), the restitution of forces from a golf club applied to a ball for launches, its flight, bounce and roll.

In the second part, the article presents a method for capturing the speed of the ball in flight using 2 low-cost radars, coupled with an Arduino Mini and an adapted sound card.

The radar signal is recorded in WAV format and filtered to extract speed and spin information during flight, using spectral density.

Keywords: *Golf Ball, Simulator, Scilab, Radar, Spectral dentisty.*

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Chapter 1

Introduction

After spending a few years playing golf, I wanted to learn more about the dynamics of the interactions between the club, the ball, and the elements.

Of course, the academic literature and publications were quite abundant. But I came accross articles [PWB76] written in 1976 and [SS94] in 1994. The description of the ball's physics pushed me to undertake modeling this system in Scilab. Subsequently, I did it in Java, C++, and then C# to use it under *Unity game engine*®™.

When the results were satisfactory, I thought about capturing the flight of a golf ball with instrumentation. After tests with sonar, which were largely insufficient, I took small presence detection radars for automatic doors.

I didn't know what I was getting into, but after a updating my knowledge on signal filtering and a few lines of programming in Scilab, I found a way to capture the essential data. Namely the speed and backspin of the flight of a golf ball.

This article describes all items I found, and how I set all them together. Equations, programs, filtering, estimators and electronics compounents to make a Virtual Golf Simulation.

All the equations presented in this article are derived from public publications or books, with references listed in the bibliography. I will not revisit the demonstrations and physical explanations, as they are not the focus of these pages. What matters to me is the relationship between this information and how I have used or adapted it.

Chapter 2

Golf Ball Flight

The main equation is the ball's flight. The equation accounts 3 forces : Magnus Force, Air Drag Force and gravity, such as :

$$\sum F = F_M - m.g + F_d \tag{2.1}$$

2.1 Drag Force

2.1.1 Air characteristics

The Air Drag Force resitance is determined by the relation given by [BR] as 2.3 :

$$\rho(T) = 1,292 * \frac{273,15}{273,15 + T} \tag{2.2}$$

$$F_d(V) = -\frac{1}{2}.\rho(T).Cd.S.V^2(t) \tag{2.3}$$

where:

$$
\begin{aligned}
\rho(T) &= Rho\ depending\ on\ temperature\ T \\
Cd &= Drag\ Coefficient,\ depending\ on\ the\ object \\
F_d(V) &= Drag\ Force\ due\ to\ Air\ Resistance\ depending\ on\ velocity\ V
\end{aligned}
$$

2.1.2 Ball's characteristics in the air

Considering those characteristics of a dimpled ball model,

$$
\begin{aligned}
mass\ m &= 0,04593\ g \\
Dynamic\ viscosity\ \mu &= 1,5.10^{-6}\ m^2/s \\
Diameter\ D &= 0,04267\ m \\
Radius\ r &= \frac{D}{2} \\
Inertia\ I &= \frac{2}{5}.m.R^2 \\
Cross-section\ S &= \pi.R^2 \\
Ball\ Velocity &= V
\end{aligned}
$$

We have an estimated models,

$$
Re = \frac{\rho(T).V.D}{\mu} \tag{2.4}
$$

$$
Cd = 0,36 + \frac{24}{Re} + \frac{6}{1 + \sqrt{Re}} \tag{2.5}
$$

$$
\overrightarrow{F_d} = -\frac{1}{2}.\rho(T).Cd.S.\sqrt{(V(x)^2 + V(y)^2 + V(z)^2)}.\widehat{V}(x) \tag{2.6}
$$

where,

$$
\begin{aligned}
Re &= Reynolds\ Number\ estimator \\
Cd &= Drag\ Coefficient\ White's\ relation \\
\overrightarrow{F_d} &= Drag\ Force
\end{aligned}
$$

Remark 1: Finally, the equation of the drag Force along the 3-axes becomes 2.7	$\overrightarrow{F_d} = \begin{pmatrix} -\frac{1}{2}.\rho(T).Cd.S.V_x^2 \\ -\frac{1}{2}.\rho(T).Cd.S.V_y^2 \\ -\frac{1}{2}.\rho(T).Cd.S.V_z^2 \end{pmatrix}$ (2.7)

2.2 Magnus Force

The main bibliography is [PAL05] et [SS94]. The Magnus Force depends on the Lift Coefficient. I have found several ways to calculate the Cl. given in 2.11, 2.13 or 2.13.

Given severals Magnus Force equations bellow, found in litterature,

$$
\overrightarrow{F_M} = Cm.(\overrightarrow{\omega}\ x\ \overrightarrow{V}) \tag{2.8}
$$

$$
F_M = 1/2.Cm.\rho.\mu^2 \tag{2.9}
$$

$$
Cm = \frac{r\omega}{V} \tag{2.10}
$$

$$
Cm = -0,05 + \sqrt{0,0025 + 0,36\left(\frac{r\omega}{V_m}\right)}\ ([PAL05]) \tag{2.11}
$$

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where,

$$\omega = spin\ in\ rad/s$$
$$V_p = r\omega\ periferal\ velocity$$
$$V_m = Ball\ Velocity$$

And, espacially in [SS94] or [Ala98], an expression of Magnus Lift Coefficient.

$$Cl = \frac{1}{2 + (v/R * sin(\zeta))}\ \zeta\ to\ be\ the\ angle\ between\ the\ axis\ of\ rotation\ and\ the\ direction\ of\ motion \tag{2.12}$$

$$Cm = 0,5.\rho(T).S.R^2.Cl.\left|\frac{\omega}{Vm}\right|^{0,4}.Vm\ ([SS94]) \tag{2.13}$$

In order to meet my needs, I have chosen to provide adapted Cl values to (2.13) from experience with my own balls (texture and number dipples). These data are recorded in a Scilab table Cl_1 :

$$Cm = 0,5.\rho(T).S.R^2.Cl_1.\left|\frac{\omega}{Vm}\right|^{0,4}.Vm \tag{2.14}$$

$$with\ my\ own\ Cl_1(Club, myball) = ['D';'W5';'H3';'5';'6';'7';'8';'9';'PW';'AW';'SW';'LW';'PU']$$
$$[0.64; 0.65; 0.54; 0.54; 0.83; 0.42; 0.53; 0.53; 0.52; 0.52; 0.51; 0.51; 0]$$

Remark 2: Knowing 2.8 and 2.14, we have the following Magnus force vector	$\overrightarrow{F_m} = \begin{pmatrix} Cm * (\omega_j * v_k - \omega_k * v_j) \\ Cm * (\omega_k * v_i - \omega_i * v_k) \\ Cm * (\omega_i * v_j - \omega_j * v_i) \end{pmatrix}$	(2.15)

2.3   Gravity Force

2.4   Launch Velocity

[Pen01]

2.5   Complete Model of flight

2.6   Ball's characteristics bouncing on the grass

[RL10]

2.7   Ball's characteristics rolling on the grass

[Pen02b] [Pen02a]

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Chapter 3

Golf Ball Capturing

3.1   section

section

3.1.1   subsection

subsection

Chapter 4

Listings

4.1   Golfball.sci

```
1  // Copyright (C) 2016 - Corporation - Author
2  //
3  // About your license if you have any
4  //
5  // Date of creation: 16 juin 2016
6  //
7  //SCI2C: DEFAULT_PRECISION= DOUBLE
8  //
9  // ReadWave : FFT_Mat.sce
10 //
```

Listing 4.1: Listing of the golf ball fligth

free

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