USING A MULTI-CAMERA TRACKING SYSTEM TO ESTIMATE BALL SPIN IN TENNIS

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OVERVIEW

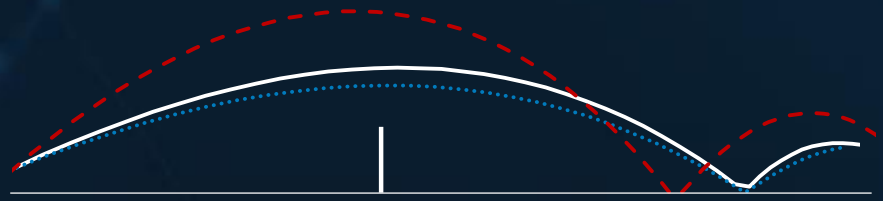
Ball spin in tennis

Minimise errors

Limit aggressive hitting

↑ probability of winning a point

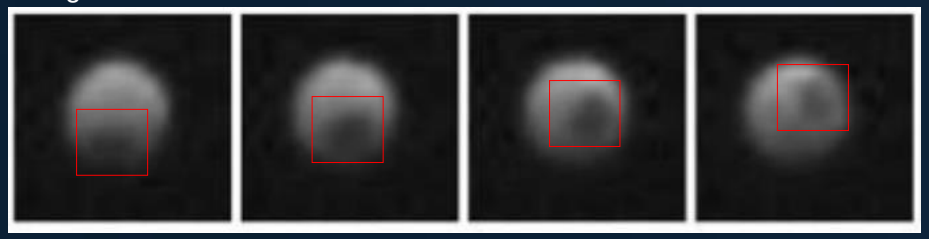
Mecheri et al. 2016



OVERVIEW

Ball spin measurement

Image 1



Kelley 2011

Image 2

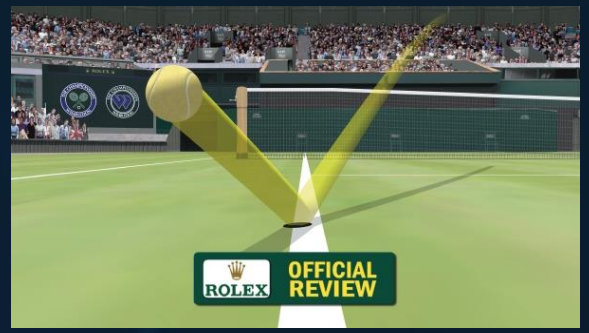


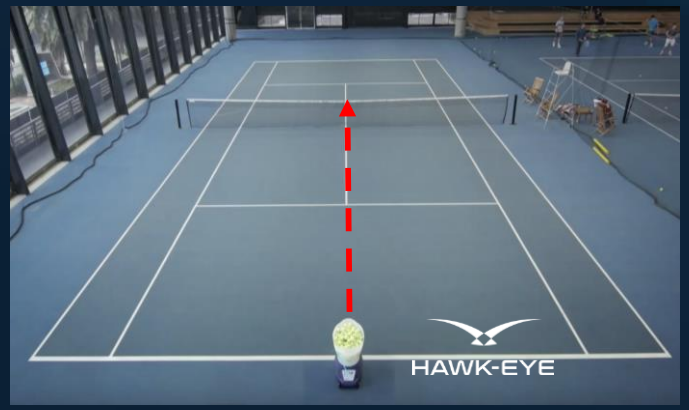
Image 3

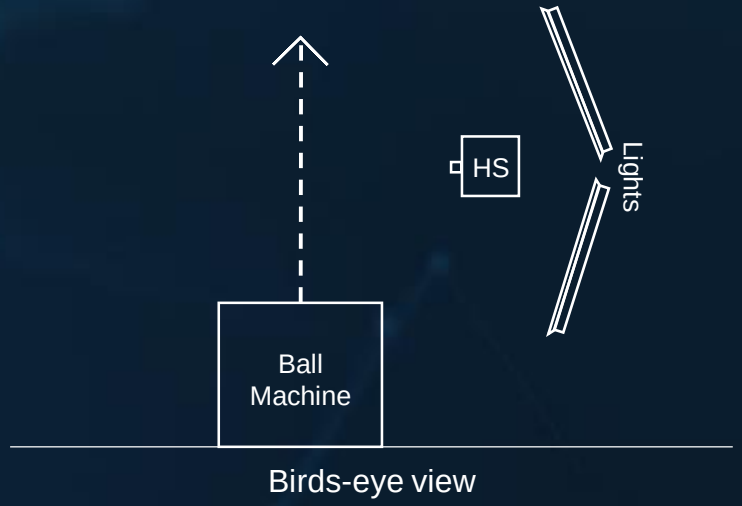
STUDY AIMS

1) Determine the accuracy of the current Hawk-Eye ball spin measure for both spin rate and direction (i.e., topspin, backspin)

2) Assess if an alternate measure could provide a more accurate estimate of ball spin rate and direction.

EXPERIMENTAL SETUP

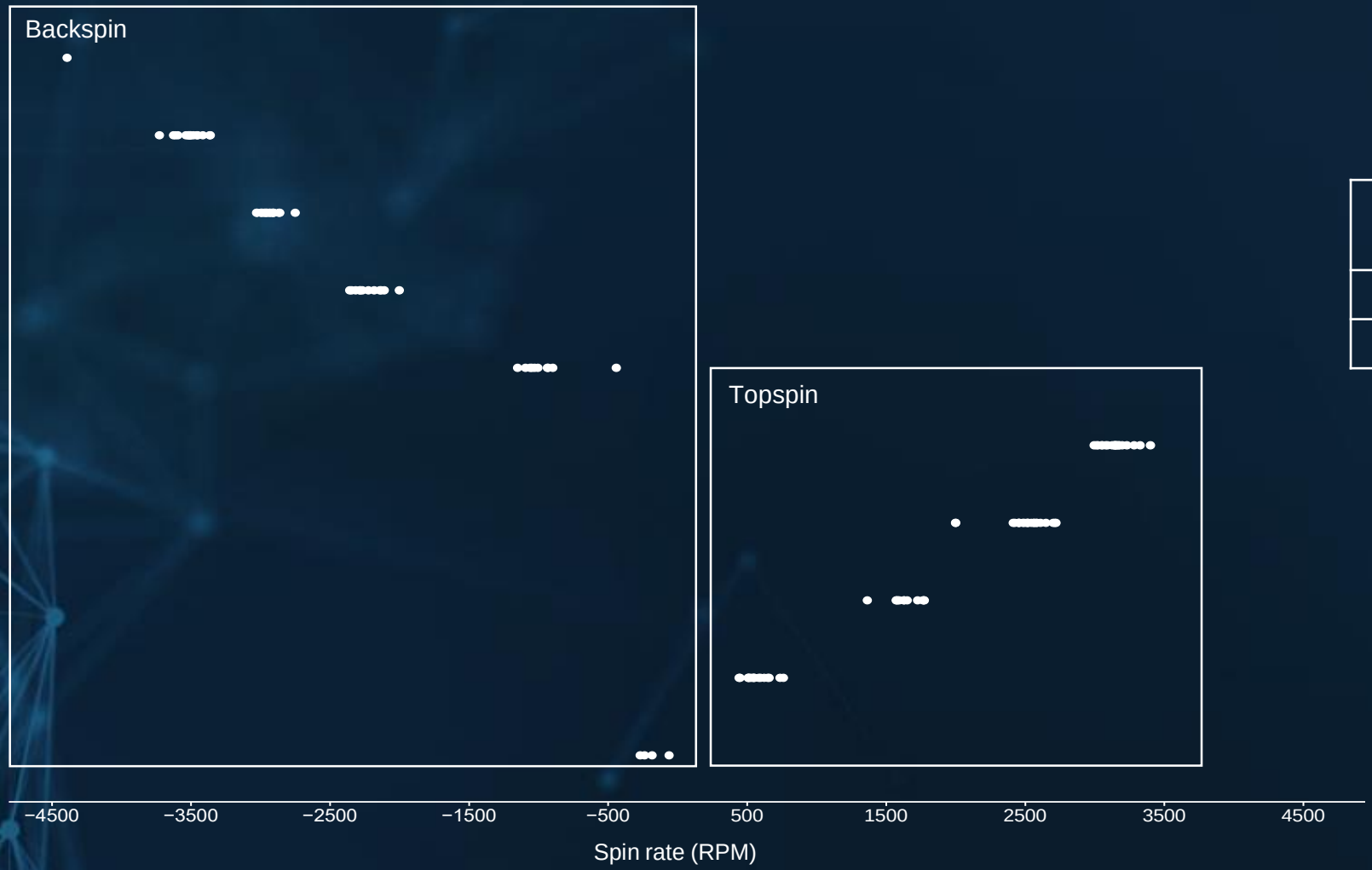




Birds-eye view

Ball mark up

DATA COLLECTION



Spin direction	Minimum spin rate	Maximum spin rate
Backspin	-62	-4,392
Topspin	442	3,400

DATA PROCESSING

Spin direction	Number of valid trials
Topspin	70
Backspin	62
	132

Tracker
Video Analysis and Modeling Tool

DATA PROCESSING

Hawk-Eye ball spin validation

- Hawk-Eye ball spin value and direction for each trial matched with digitised ball spin value

Ball trajectory model

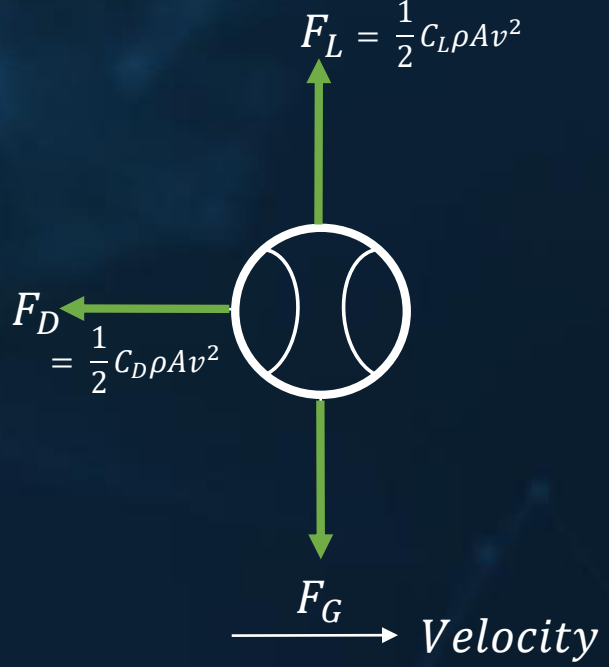


Figure 1: forces acting on a ball

Equations describing a balls motion in 2D:

(1) $dv_x/dt = -kv(C_D v_x + C_L v_z)$

(2) $dv_z/dt = kv(C_L v_x + C_D v_z) - g$

Where,

$k = \frac{1}{2} \rho \pi R^2 / m$

$R = ball\ radius = 66\ mm$

$m = ball\ mass = 58\ grams$

$\rho = air\ density = 1.21\ kg/m^3$

(Choppin et al. 2018, Cross and Lindsey 2014)

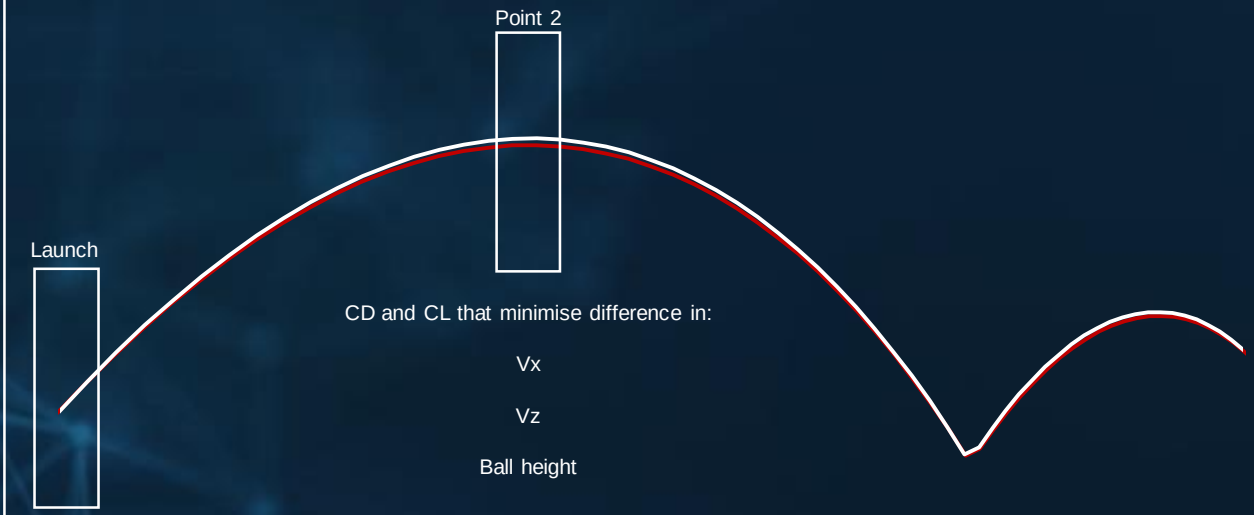
DATA PROCESSING

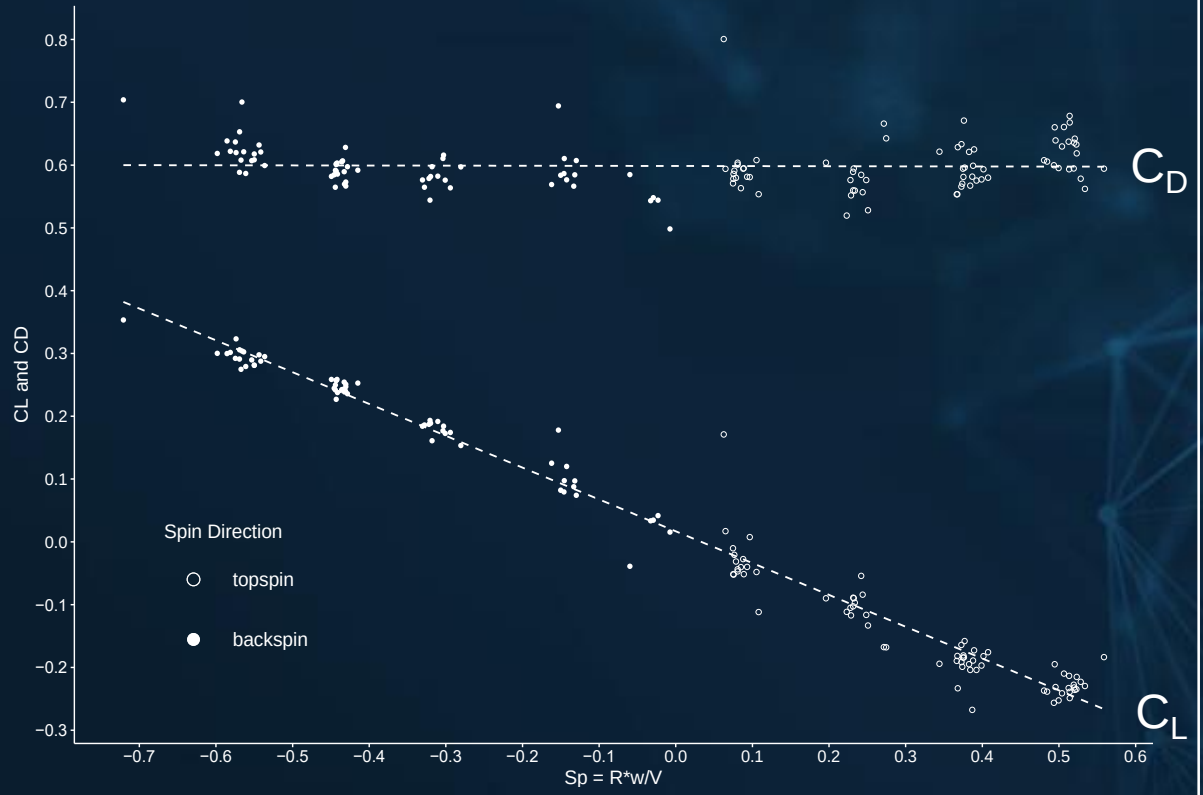
Ball trajectory model

Launch parameters:	Other:	Forces:
• Height	• Ball mass	• C_L
• Location	• Ball radius	• C_D
• Angle	• Air density	
• Velocity		

DATA PROCESSING

Ball trajectory model: Best fit CD and CL *(Cross and Lindsey 2014)*





DATA PROCESSING

Ball trajectory model: spin estimation

Launch parameters:

- Height
- Location
- Angle
- Speed

Optimised values:

- CD
- Spin

?

Optimisers:

- Nelder-Mead (optim package)
- L-BFGS-B (optim package)
- Nmkb (dfoptim package)

Landing parameters:

- Height
- Angle
- Vx
- Vz

→

Error:

- Height
- Height + angle
- Height + velocity
- Height + angle + velocity

DATA ANALYSIS

1) Hawk-Eye ball spin validation: Hawk-Eye spin estimate compared to true spin (high-speed vision)

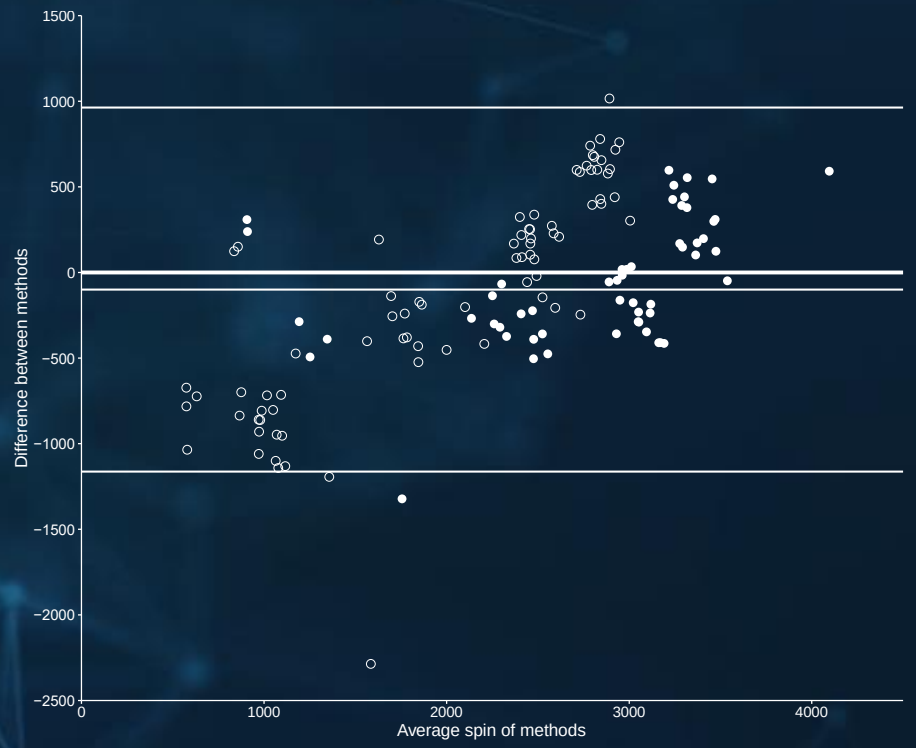
2) Ball trajectory model validation: Ball trajectory model estimates compared to true spin (high-speed vision)

Analysis:

- Paired t-test
- RMSE
- Cohen’s d
- Bland-Altman

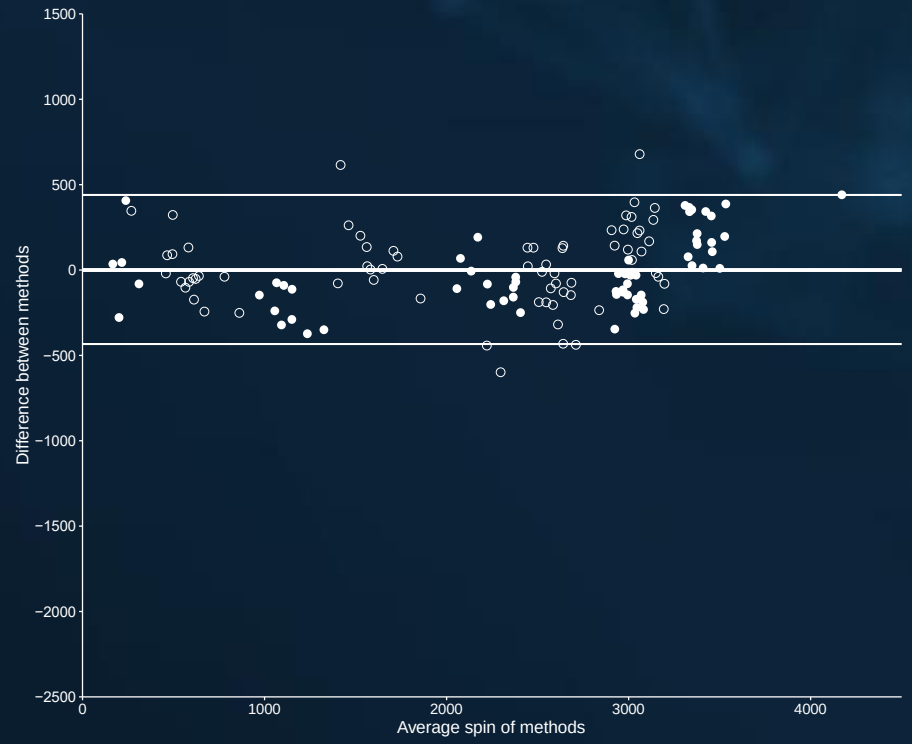
RESULTS

Hawk-Eye current measure



	Bias ± SD	RMSE	Spin direction correctly classified
Hawk-Eye	-100.01 ± 542.44*	549.56	98%

Ball trajectory model



Spin Direction
- topspin
- backspin

	Bias ± SD	RMSE	Spin direction correctly classified
Ball trajectory method	2.92 ± 222.76	221.93	100%

RESULTS + IMPLICATIONS

- Ball trajectory model outperformed the current measure used by Hawk-Eye
- Practical method to implement during matches
- Allows for large scale collection of spin rates

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