“Modelling the flight of a javelin in a prevailing wind”

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Overview

An elite young thrower in a training session …

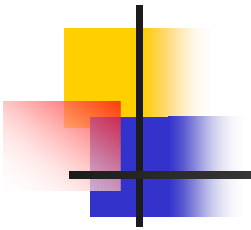
Parameters:-

- Distance: 70m.
- Release speed: ~27m./s.
- Flight duration ~5s.
- Max height ~26m.
- Athlete, 1.91m, 100kg

With the same parameters and biomechanics, another 3m/s release speed is necessary to reach ~87m.

Video kindly supplied by Brian Parkes, UKA level 4 javelin coach

Overview



- Trivial pursuits guide to the javelin
  - Senior implement is >= 800gm, >= 2.6m
  - The javelin was re-weighted in 1986 after Uwe Hohn established a new world record of 104.80m
  - The current world record is 98.48m by the Czech thrower Jan Zelezny.

Overview

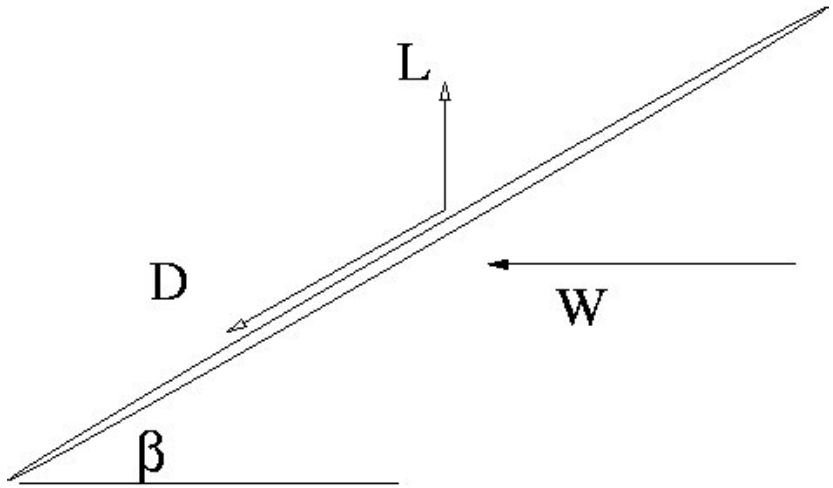
- No previous work on the effect of wind
- 1cm is enough to lose in 90m
- The javelin is significantly affected by wind

Folklore

Modelling - assumptions

- No 3-D effects, (an athlete's best throws tend to be 2-dimensional)
- Axial rotation ignored, (although it can be as high as 25 revs/s)

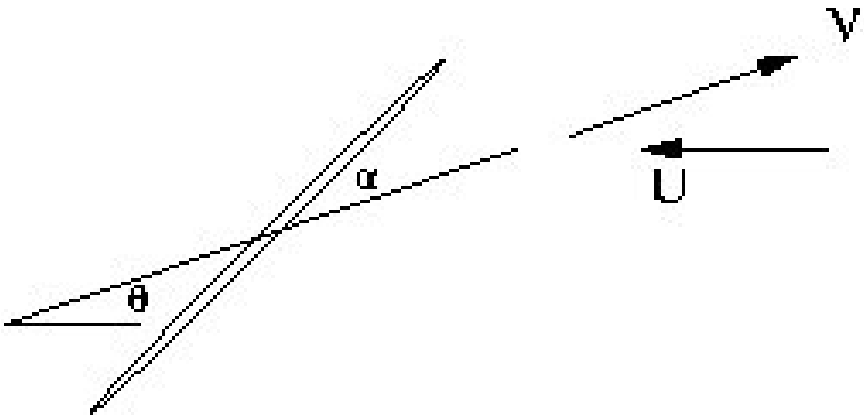
Forces acting on a fixed aerofoil due to a horizontal wind



Fixed aerofoil in a horizontal wind:

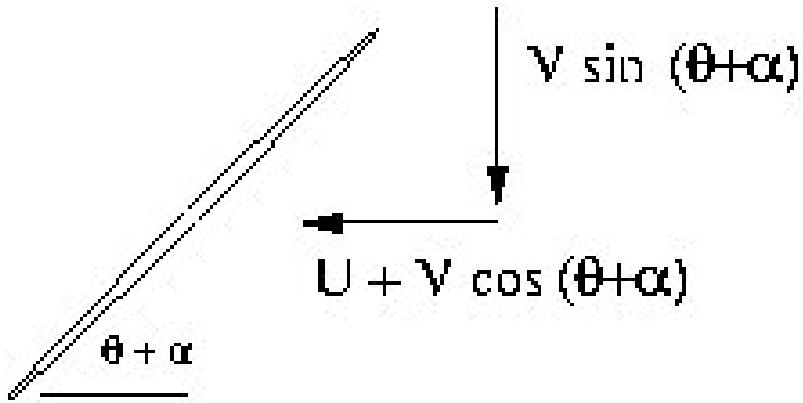
- The lift is L is due to inviscid effects, (no drag).
- D is a drag term for viscous effects

Transforming to frame of reference of javelin

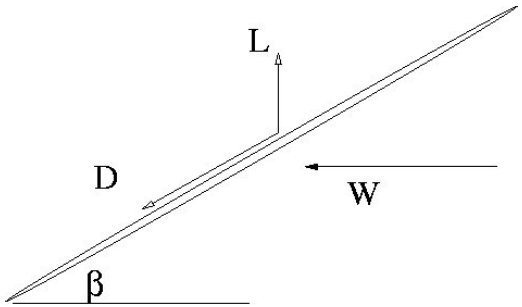


Javelin flying in a wind

Transforming frame of reference to javelin

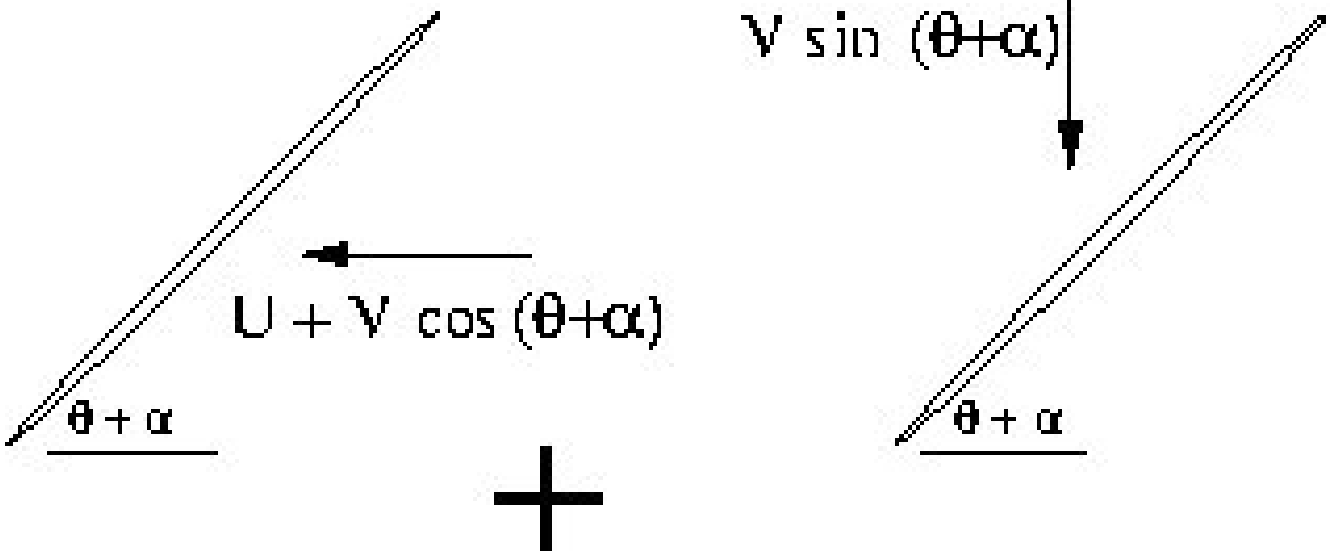


Separation of solutions



Reference

Separation
(and we have
to add gravity)



The model

The vertical equation looks like ...

$$m\frac{d^2s}{dt^2} = -mg$$ Gravity

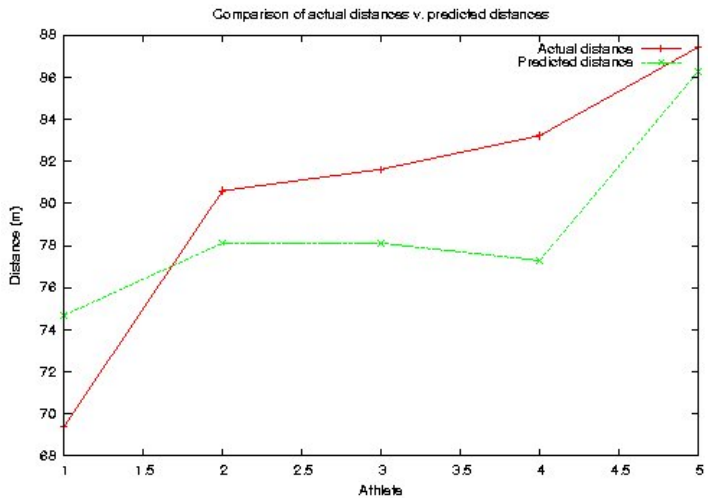
$$+4\pi\rho\left(\frac{dr}{dt}+U\cos\psi\right)^2\sin(\theta+\alpha)$$ Lift

$$-2\gamma\rho\left(\frac{dr}{dt}+U\cos\psi\right)^2\sin(\theta+\alpha)\left\{\pi\varepsilon^2+4L\varepsilon\cos\alpha\right\}$$ Drag 1

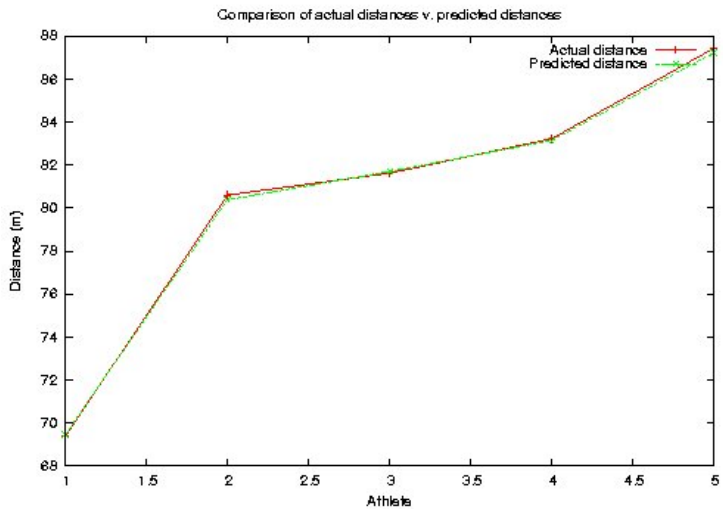
$$-2\gamma\rho\left(\frac{ds}{dt}\right)^2\sin(\theta+\alpha)\left\{\pi\varepsilon^2+4L\varepsilon\cos\alpha\right\}$$ Drag 2

Solved as coupled non-linear odes

1991 World Student Games

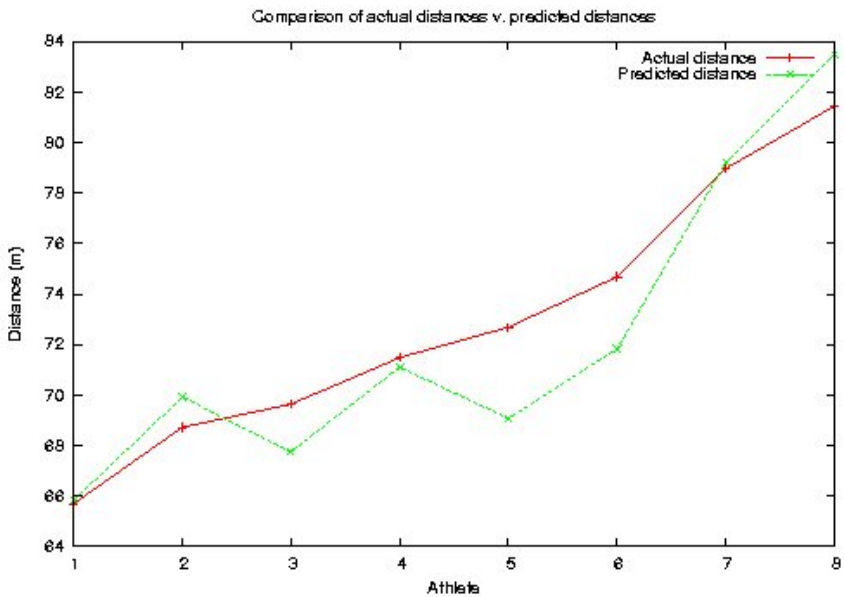


Assumption of no wind

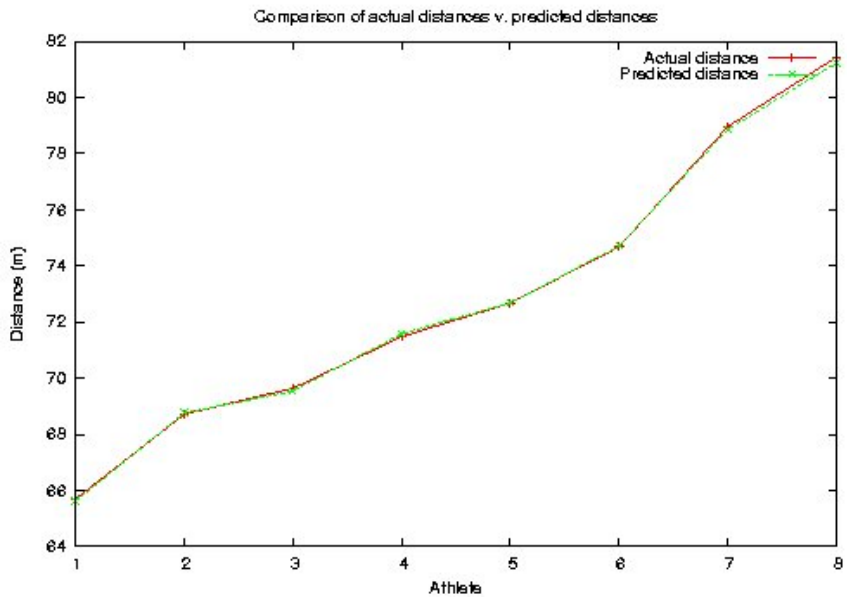


Assumption of gentle tail wind

BAF 1993 Championships

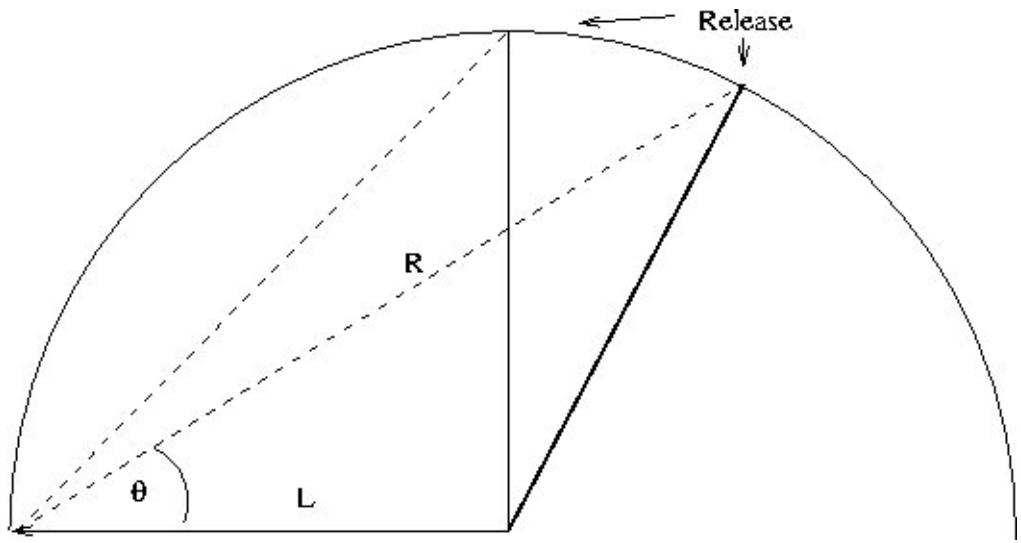


Assumption of no wind



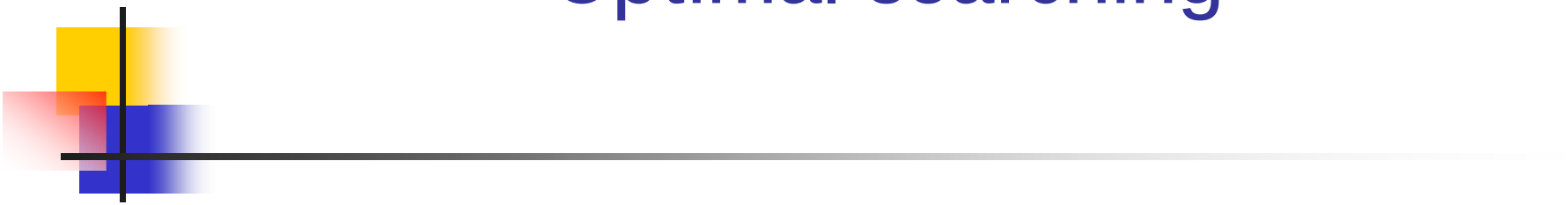
Assumption of gentle variable but mostly head wind

Influence of biomechanics



As the angle θ decreases, the length of pull increases.

Optimal searching



- Given a wind direction and strength, and athlete biomechanics, what is the optimum
  - Attack angle ?
  - Delivery angle ?

Simulate ...

Conclusions

- Mathematical modelling of javelin flight may well provide an important tool in optimising a thrower's performance
- Further work calibrating in the presence of wind is necessary
- In its present form, the model produces gratifyingly similar flight paths to those observed.

Other information

For more information and downloadable papers see:-

http://www.leshatton.org/