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A2_9 Trajectory of a falling Batman

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Abstract

The film *Batman Begins* shows the character of Batman gliding using a rigid form of his cape. This paper assesses the feasibility of such a glide and finds that while a reasonable distance could be travelled if gliding from a tall building, the speed at which Batman would be travelling would be too dangerous to stop without some method of slowing down.

Introduction

In the film *Batman Begins*, Batman can glide from tall buildings using his 'memory cloth' cape, which becomes rigid when a current is passed through it [1]. This method of gliding is similar to that used by base jumpers with wingsuits, where the wingsuit acts as an aerofoil to create a horizontal force propelling the base jumper forwards [2].

This paper analyses whether Batman could generate enough lift to glide successfully.

Theory

The forces acting on a skydiver travelling with a velocity $\mathbf{v}$ are shown in Fig. 1. The drag and lift forces acting on the skydiver in the x and y directions are therefore

$$D_x = D\cos\theta \quad (1)$$
$$D_y = D\sin\theta \quad (2)$$
$$L_x = L\cos(\pi/2-\theta) = L\sin\theta \quad (3)$$
$$L_y = L\sin(\pi/2-\theta) = L\cos\theta \quad (4)$$

where L and D are the magnitudes of the lift and drag forces respectively. The forces acting on the skydiver in the horizontal (x) and vertical (y) directions are then

$$F_x = L\sin\theta - D\cos\theta \quad (5)$$
$$F_y = mg - L\cos\theta - D\sin\theta. \quad (6)$$

Lift and drag are given by (see [3] and [4])

$$L = \frac{1}{2}C_L\rho A v^2 \quad (7)$$
$$D = \frac{1}{2}C_D\rho A v^2 \quad (8)$$

where C_L and C_D are the lift and drag coefficients, ρ is air density and A is the wing area. Assuming that the angle of the skydiver with respect to the direction they are travelling remains constant, as shown in Fig. 2, C_L and C_D will be constant.

Given that the horizontal and vertical velocities can be expressed as $v_x = v\sin\theta$ and $v_y = v\cos\theta$, the equations above can then be used to give the acceleration a of the skydiver in the x and y directions

$$a_x = \frac{\rho A}{2m}v(C_L v_y - C_D v_x) \quad (9)$$
$$a_y = g - \frac{\rho A}{2m}v(C_L v_x + C_D v_y) \quad (10)$$

where $v = \sqrt{v_x^2 + v_y^2}$.

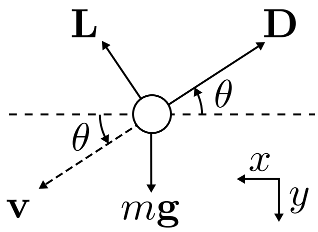

Fig. 1: Forces acting on a skydiver. The solid lines indicate forces while the dotted lines indicate the skydiver's direction of motion and the horizon. $\mathbf{L}$, $\mathbf{D}$ and $m\mathbf{g}$ are the lift, drag and gravitational forces respectively, where m is the mass of the skydiver and $\mathbf{g} = 9.81\,\mathrm{ms^{-2}}$ is acceleration due to gravity. The skydiver is travelling at an angle θ to the horizon.

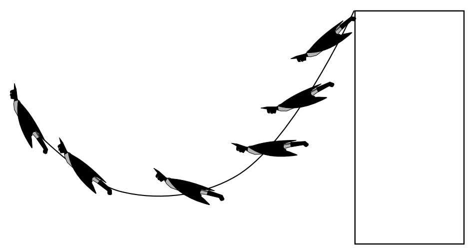

Fig. 2: Batman gliding at a constant angle with respect to his direction of travel.

The glide of Batman

The path of Batman as he glides from the top of a building can be estimated by iteratively calculating the x and y components of the acceleration at each point, which are then added to the velocity components in the next

Fig. 3: A frame from Batman Begins [1] showing the area of Batman's cape during flight. The area of the cape is approximated using a triangle of height half that of Batman. Given that the height of Batman is $6'2'' = 1.88\,\mathrm{m}$ [5], the height of the triangle is then $0.94\,\mathrm{m}$, and by comparing the lengths of the lines the base is $4.69\,\mathrm{m}$. The area of the triangle is then $2.20\,\mathrm{m}^2$.

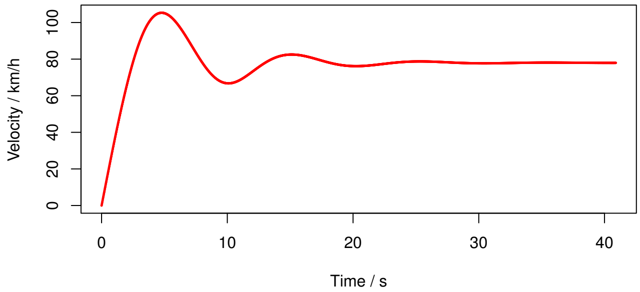

Fig. 5: Velocity profile of Batman's glide.

iteration. The velocity at each iteration is multiplied by the time step to approximate the distance moved during that time. This method essentially approximates the motion as a series of linear accelerations.

The area of Batman's cape during flight is shown in Fig. 3, to give $A = 2.20\,\mathrm{m}^2$. At room temperature $\rho = 1.20\,\mathrm{kg\,m^{-3}}$ [6]. Batman's mass is $m = 95\,\mathrm{kg}$ [5]. The drag coefficient is approximated using the value for a bird as $C_D \approx 0.4$ [7], approximating the cape as a plain aerofoil $C_L \approx 1.45$ [8]. The lift coefficient may be lower in reality, this value assumes that the cape is highly optimised. Using these values the iteration is performed for a stationary start with a time step of $0.02\,\mathrm{s}$. The results are plotted in Figs. 4 and 5 over a time period of $40\,\mathrm{s}$ to show Batman's position as he glides and the velocity profile for the glide.

Discussion

Batman's descent is rapid, even for this high estimate for the lift coefficient. Looking at the case for gliding from a fairly tall building of height $150\,\mathrm{m}$, Batman can glide to a distance of about $350\,\mathrm{m}$, which is reasonable; the problem with the glide lies in his velocity as he reaches ground level. The velocity rises rapidly to a maximum of a little over $110\,\mathrm{km/hr}$ before steadying to a constant speed of around $80\,\mathrm{km/hr}$. At these high speeds any impact would likely be fatal if not severely damaging (consider impact with a car travelling at these speeds).

This paper presents a simple model for use as a feasibility study, in reality the flight path can be controlled by varying the angle of the glide. Technological problems are not considered here, it is assumed that the advanced fabric of Batman's cape can hold the cape into the shape of a rigid aerofoil.

Clearly gliding using a batcape is not a safe way to travel, unless a method to rapidly slow down is used such as a parachute.

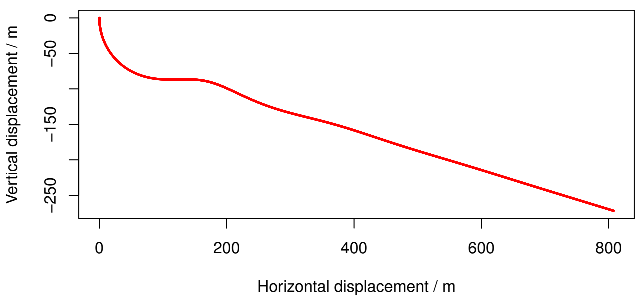

Fig. 4: Plot of Batman's position as he glides.

References

[1] Nolan. C (Director), Batman Begins (2005) [DVD] (Warner Bros. Pictures)

[2] `http://www.phoenix-fly.com/userfiles/PF_Wingsuit%20flying%20and%20Basic%20Aerodynamics_1.pdf` (28/11/2011)

[3] `http://www.grc.nasa.gov/WWW/k-12/airplane/liftco.html` (28/11/2011)

[4] `http://www.grc.nasa.gov/WWW/k-12/airplane/dragco.html` (28/11/2011)

[5] `http://www.dcuguide.com/who.php?name=BATMAN` (09/12/2011)

[6] `http://www.engineeringtoolbox.com/air-properties-d_156.html` (28/11/2011)

[7] `http://www.engineeringtoolbox.com/drag-coefficient-d_627.html` (28/11/2011)

[8] `http://www.mp.haw-hamburg.de/pers/Scholz/dimensionierung/st_cl.htm` (28/11/2011)