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S5_1 Dodging the matrix bullet

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Abstract

The matrix trilogy has several ground breaking and memorable action set pieces but none more iconic than Neo's rooftop bullet dodge. The scene is broken down and physical aspects of the motion are examined closely. It is found that the torque required to pull off the dodge would be 2.7×10^6Nm

Introduction

The Matrix is a widely acclaimed science fiction film in which the human beings of the world are living in a simulated virtual reality. Neo in an action scene dodges several bullets travelling with a muzzle velocity of 470 ms^{-1} fired from a Desert Eagle .50 AE [4] at him from a distance of approximately 10 metres. We examine the mechanics of the scene within human physical and biological boundaries.

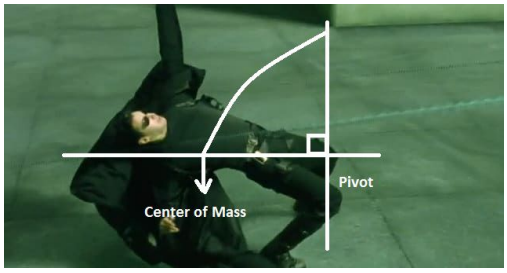


Figure 1: Motion during bullet dodge [4]

Theory

As the bullets are fired at Neo, he moves 90 degrees backwards with his knees acting as a pivot to the motion (Fig. 1). His motion can be approximated as being an arc of a circle and his knees are considered to be acting as a pivot to this motion. To simplify the resulting mathematics, his knees act as a single pivot point and the angle it's making to the ground isn't considered. A simple model is considered wherein the rotational inertia of the body coupled with the angular acceleration exhorts a torque on the pivot point. In order to calculate the necessary forces, estimations are made about the masses and the lengths concerned. Neo's weight and height are found to be 80 kg and 1.85 m respectively. For an average human the knee is found at 30.5% of the height [3], and the mass concentrated above the knees is 95.2% [2]. This implies that Neo's knee is at a height 0.56 m and subsequently the rest of his body has a length of 1.29 m. The mass contained above the knee is therefore 76.2 kg. The mass is considered to be acting at the Centre of mass of the body which is 0.645 m from the pivot point. Given the muzzle velocity and the distance between the gun and Neo, the bullets would reach him in 0.02 seconds. Human reaction time to a sound stimuli averages 0.17 seconds which would not give Neo any time to dodge. However in the Matrix, Neo is able

to perform superhuman feats, so we estimate his reaction time to be 10 times quicker. If Neo is able to register the event 0.017 seconds after the bullet is shot, it leaves him with 3 milliseconds in which to dodge the bullet. We calculate angular acceleration by rearranging the following equation for α.

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0), \tag{1}$$

Where $\theta - \theta_0$is the angular displacement $(\pi/2)$ and $\omega = \theta/t$ and t is the time Neo has to dodge the bullet. The moment of Inertia is found by:

$$I = mr^2, \tag{2}$$

Where r is the distance to the pivot and m is the mass contained above the knee. Finally the torque is calculated using:

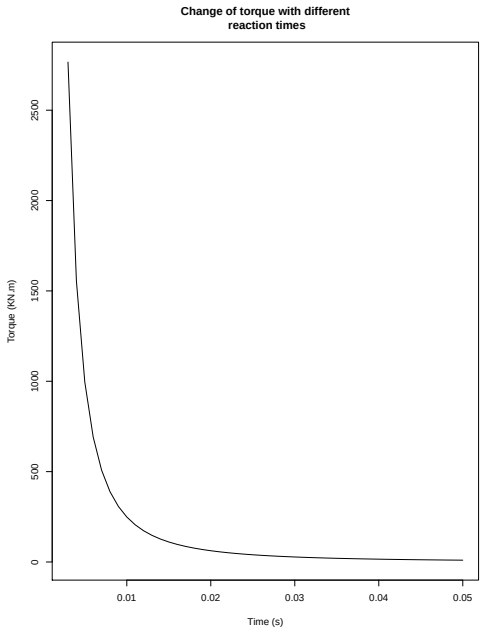
$$\tau = I\alpha. \tag{3}$$

Results and Discussion

It is found that the torque produced by Neo's motion is 2.7×10^6Nm. This Torque is comparable to the magnitude of thrust produced by the launch of a space shuttle! The force required to break a human bone is approximately 4000 N [1] so based on this result, it's conclusive to say that the pivot won't be able to sustain this load and the knees would shatter. This magnitude of torque would crack even diamonds. However it's worth noting that this result has a major dependence on time, the moment of inertia stays constant with angular acceleration and consequently time being the major variable. Based on this we plot a graph to show the relationship between torque and time (Figure 2). It is observed that as time increases the torque asymptotes very quickly. This goes to a point where if Neo's reaction time is 100 times faster, the time he would have to dodge the bullet will go up to 0.198 s which would see the resultant Torque drop to 633 Nm.

Conclusion

The mechanics of Neo's bullet dodge were explored and it's conclusive that it is impossible



to dodge the bullet with normal human reaction times. However, given his abilities in the matrix, his speed and physiology is unclear, based on the assumptions we've made and the subsequent analysis it's seen that range of reaction time will have a major effect on torque.

References

[1] `https://www.seeker.com/how-much-force-does-it-take-to-break-a-bone-2056139307.html`[McDonald, G.(2017, November). seeker.com]

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[3] Teichtahl, A. J. (2012). The associations between body and knee height measurements and knee joint structure in an asymptomatic cohort. BMC Musculoskeletal Disorders.

[4] `http://www.imfdb.org/wiki/Matrix,_The#IMI_Desert_Eagle_Mark_XIX` from www.imfdb.org. (2017, October 31).