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A4_2 How Many Lies Could Pinocchio Tell?

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Abstract

The 1940 animated film 'Pinocchio' tells the story of a puppet who is brought magically to life and finds that his nose grows when he tells a lie. In this paper, we attempt to determine the effect that this growth might have on Pinocchio's balance. By comparing Pinocchio's apparent size to that of his creator, Geppetto, we estimate his approximate dimensions. We then examine the rate of growth of his nose and calculate the displacement of his centre of mass from its original position after each successive lie he tells. From this, we determine that the maximum number of lies Pinocchio can tell without compromising his balance is five.

Introduction

When Pinocchio tells a lie the length of his nose increases; this causes a change in his mass distribution, bringing his centre of mass further forwards. At some point this change will cause Pinocchio to become unstable and topple over face first. In general, an object will topple over if its centre of mass is not positioned above the area of its base. As Pinocchio tells lies and the length and mass of his nose increase, his centre of mass will be displaced forwards. If we assume that he does not move to compensate for this in any way, and model his body as a simple cylindrical column, then he will fall over once the displacement of his centre of mass becomes greater than his radius.

Method and Results

To determine the point at which Pinocchio will become unbalanced we must estimate his size and the dimensions of his nose. Pinocchio appears to be approximately half as tall as his creator Geppetto [1]. We assume that the film is set in around 1883, the year that the original novel was published, and that Geppetto is around sixty years old. The average height of an Italian man born in 1820 was 165.8 cm [2], so we take this to be Geppetto's height. This then gives us an estimate for Pinocchio's height of 82.9 cm. We estimate the width of Pinocchio's body to be approximately one fifth of his height [1], or around 18.2 cm. Hence, if his centre of mass is initially located in the centre of his body, then it will lie outside of his base once it has been displaced by more than his radius of 9.1 cm; this is the point beyond which he will fall over. If we model Pinocchio's nose as a second, smaller cylinder protruding from the main cylinder of his body, then we can find the position of the overall centre of mass of the two cylinders using equation 1 [3]:

$$COM_x = \frac{M_p.x_p + M_n.x_n}{M_p + M_n}, \tag{1}$$

where COM_x is the x coordinate of the combined centre of mass and M_p, x_p, M_n and x_n are the masses and the coordinates of the centres of mass for the body and for the nose, respectively.

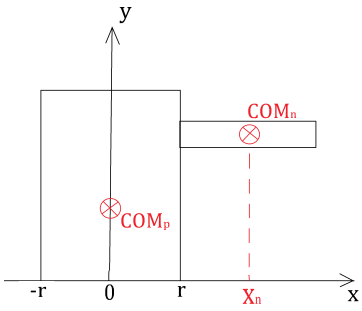

Figure 1: Figure showing Pinocchio's body and nose modelled as two connected cylinders, with the body centred on the origin.

If we define our coordinate axis such that Pinocchio's body is centred on the origin, as shown in figure 1, then the value of x_p is zero and equation 1 instead becomes:

$$COM_x = \frac{M_n.x_n}{M_p + M_n}. \quad (2)$$

This means that to calculate the position of Pinocchio's overall centre of mass, COM_x, for any given length of his nose we must have values for M_n, x_n and M_p.

A healthy weight for a child 83.3 cm tall is 11.2 kg [4]. By comparing the density of the human body, 1010 kgm^{-3} [5], to that of pine, 410 kgm^{-3} [6], we estimate Pinocchio's mass to be 4.55 kg. The mass and centre of mass of his nose will depend on its length; modelling the nose as a cylinder of uniform density gives it a mass equal to the product of its density, length and cross-sectional area. The x coordinate of its centre of mass, meanwhile, is given by the radius of Pinocchio's body plus half the length of the nose. We estimate the initial length of his nose to be around 0.3 times the width of his body, and its diameter to be approximately half of its length [1]. Hence, Pinocchio's nose is initially around 5.5 cm long and 2.7 cm in diameter, with a cross-sectional area of 5.9 cm^2.

By examining a clip from the film, we can see that Pinocchio's nose seems to roughly double in length after each lie [7]. Using equation 2 to calculate the value of COM_x after each lie, and plotting these values against the number of lies told produces the curve in figure 2. The figure shows that the displacement of the combined centre of mass exceeds the 9.1 cm threshold after his sixth lie.

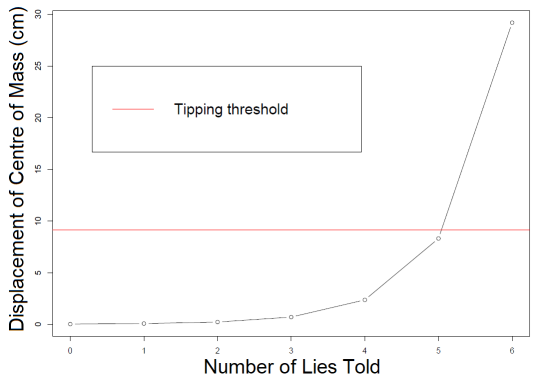

Figure 2: Plot showing the increase in the displacement of Pinocchio's centre of mass as he tells a series of lies. The red line shows the threshold displacement beyond which he will topple over.

Discussion and Conclusion

Our estimate for the number of lies Pinocchio can tell before falling is quite low; after only six lies he should be unable to maintain balance. Furthermore, we have assumed that Pinocchio gains mass each time his nose grows. This appears to be the case in the film, as Pinocchio is never seen to noticably shrink even after quite significant increases in the length of his nose. However, if instead his total mass remained constant such that his body shrank as his nose grew, then he would topple over sooner. On the other hand, we have made a major simplification by treating Pinocchio's body as a cylinder and not accounting for his ability to move. Realistically, he may be able to move his legs further apart, effectively increasing his radius. Additionally, he may be able to tilt his head in order to bring the centre of mass of his nose back towards the origin. It may be possible for him to position his head such that the centre of mass of his nose is directly above that of his body, negating his nose's effect on his balance and allowing him to stand until his nose becomes too heavy for him to support. Determining the number of lies Pinocchio might be able to tell before this occured could be an area for further research; however it would be impractical for Pinocchio to keep his head tilted back at all times, so having told six or more lies would still be a hinderance.

References

[1] `https://www.disneyclips.com/imagesnewb/images/pinocchioreadyforschool.gif`[Accessed 23 October 2018]

[2] `http://ourworldindata.org/human-height`[Accessed 27 September 2018]

[3] `https://www.khanacademy.org/science/physics/linear-momentum/center-of-mass/a/what-is-center-of-mass`[Accessed 27 September 2018]

[4] `www.disabled-world.com/calculators-charts/height-weight-teens.php`[Accessed 28 September 2018]

[5] `www.aqua-calc.com/page/density-table/substance/human-blank-body`[Accessed 28 September 2018]

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[7] `https://www.youtube.com/watch?v=rUdA54Xk8cg`[Accessed 6 October 2018]