

# Airbounce

FMF

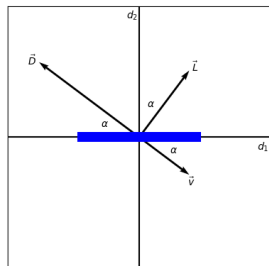
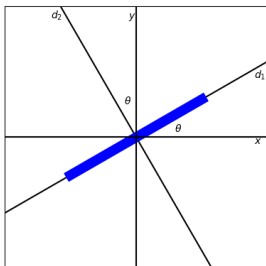
15. april 2022

# Official problem statement

When a Frisbee is thrown in a certain way it can be made to bounce in mid-air. Study the physics of this phenomenon.

# Stabilen frizbi

- Frizbi zaradi vrtenja ohranja orientacijo.



Slika 1: Graf osi, koordinatni sistem N

Slika 2: Koordinatni sistem frizbija D

V sistemu frizbija (D):

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

$$C_L = C_{L0} + C_{L\alpha}\alpha \quad C_D = C_{D0} + C_{D\alpha}\alpha^2 \quad (2)$$

$$K = \frac{A\rho}{2m} \quad \tan \alpha = \frac{-v_2}{v_1} \quad (3)$$

$$\mathbf{L} = mKv^2 C_L \begin{pmatrix} \sin \alpha \\ \cos \alpha \end{pmatrix} = mKv^2 C_L \begin{pmatrix} -v_2 \\ v_1 \end{pmatrix} \quad (4)$$

$$\mathbf{D} = mKv^2 C_D \begin{pmatrix} -\cos \alpha \\ \sin \alpha \end{pmatrix} = mKv^2 C_D \begin{pmatrix} -v_1 \\ -v_2 \end{pmatrix} \quad (5)$$

$$\mathbf{F}_g = -mg \begin{pmatrix} \sin \theta \\ \cos \theta \end{pmatrix} \quad (6)$$

$$m\mathbf{a} = \mathbf{L} + \mathbf{D} + \mathbf{F}_g \quad (7)$$

$$v = \sqrt{v_1^2 + v_2^2} \quad (8)$$

$$a_1 = -K(C_{L0} + C_{L\alpha}\alpha)vv_2 - K(C_{D0} + C_{D\alpha}\alpha^2)vv_1 - g \sin \theta \quad (9)$$

$$a_2 = K(C_{L0} + C_{L\alpha}\alpha)vv_1 - K(C_{D0} + C_{D\alpha}\alpha^2)vv_2 - g \cos \theta \quad (10)$$

Rešimo:  $d_1, d_2, v_1, v_2$ .

Zarotiramo v N sistem.

$$R = \begin{pmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{pmatrix} \quad (11)$$

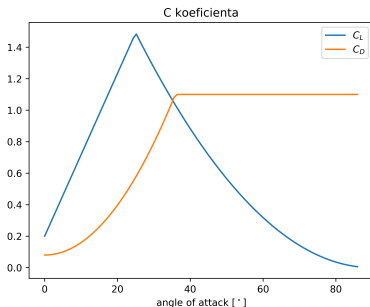
$$\begin{pmatrix} x \\ y \end{pmatrix}_N = R \begin{pmatrix} d_1 \\ d_2 \end{pmatrix}_D \quad (12)$$

$$\begin{pmatrix} v_x \\ v_y \end{pmatrix}_N = R \begin{pmatrix} v_1 \\ v_2 \end{pmatrix}_D \quad (13)$$

## Koeficienti lift-a in drag-a.

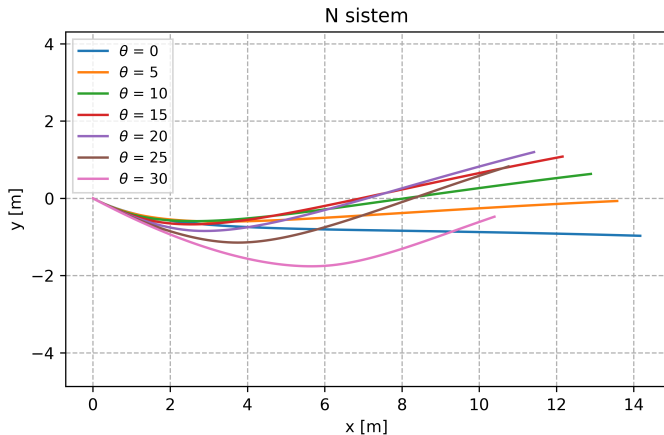
$$C_L = C_{L0} + C_{L\alpha}\alpha \quad C_D = C_{D0} + C_{D\alpha}\alpha^2$$

- Za koeficient drag-a  $C_D$  cutoff, ko doseže  $C_D$  vrednost diska, ki je pravokoten na hitrost.
- Za koeficient lift-a  $C_L$ , cutoff pri stall angle.



Slika 3: Cutoff koeficientov

## Met: različni začetnimi koti.



Slika 4: Začetna hitrost = (15, -8) m/s. Začetni kot v stopinjah.

# Problemi

- Pri mojem metu ni stabilen.
- Wobbling frisbee.



# Plan za naprej

- Naučim se boljši met, da ni treba simulirati wobble-a.
- Če se ujema s simulacijo: v brezdimenzijsko, fazni diagram kdaj se pojavi je airbounce...