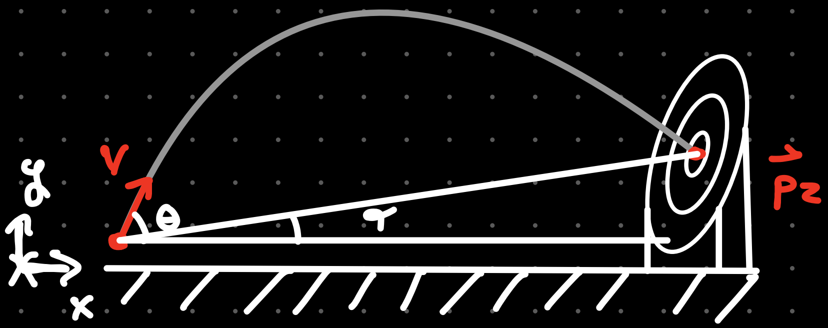


$$\min_{\theta,\ \|v\|,\ T} \|v\|$$

$$\|v\| \overset{?}{=} 5 \ m/s$$

$$\text{s.t. } \exists T : p(T) = \vec{p}_2$$

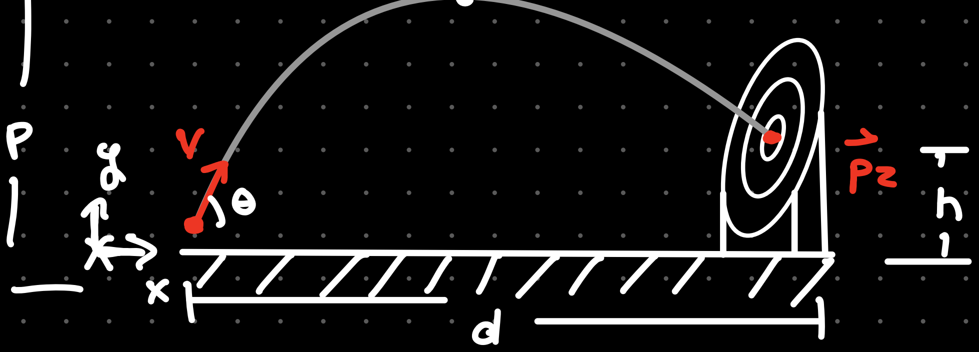
$$\vec{p}(0) = \begin{bmatrix} x_0 \\ y_0 \end{bmatrix}$$

$$p(T) = \begin{bmatrix} x(T) \\ y(T) \end{bmatrix} = \begin{bmatrix} x_0 + d \\ y_0 + \varepsilon \end{bmatrix}$$

$$x(t) = v_x t = \|v\| \cos\theta \ t$$

$$y(t) = v_y t - \frac{1}{2} g t^2$$

$$= \|v\| \sin\theta \ t - \frac{1}{2} g t^2$$



$$T = T_{up} + T_{down}$$

$$v\sin\theta - gT_{up} = 0$$

$$\frac{v\sin\theta}{g} = T_{up}$$

$$p = v\sin\theta\,\frac{v\sin\theta}{g} - \frac{1}{2}g\left(\frac{v\sin\theta}{g}\right)^2$$

$$= \frac{(v\sin\theta)^2}{g} - \frac{1}{2}\frac{(v\sin\theta)^2}{g}$$

$$= \frac{1}{2}\frac{(v\sin\theta)^2}{g}$$

$$p - h = \frac{1}{2}gT_d^{\,2}$$

$$\sqrt{\frac{2(p-h)}{g}} = T_d$$

$$T = \frac{v\sin\theta}{g} + \sqrt{\frac{2(p-h)}{g}}$$

$$d = v\cos\theta\,T = v\cos\theta\left(\frac{v\sin\theta}{g} + \sqrt{\frac{\frac{(v\sin\theta)^2}{g} - h}{g}}\right)$$

$$\frac{d}{d\theta}\left(d = \frac{v^2}{2}\sin 2\theta + v\cos\theta\sqrt{\frac{v^2\sin^2\theta}{g^2} - \frac{h}{g}}\right)$$

$$0 = v\cdot\frac{dv}{d\theta}\sin 2\theta + v^2\cos 2\theta$$

$$+ \frac{dv}{d\theta}\cos\theta\sqrt{\frac{v^2\sin^2\theta}{g^2} - \frac{h}{g}} - v\sin\theta\sqrt{\frac{v^2\sin^2\theta}{g^2} - \frac{h}{g}}$$

$$\frac{v}{2}\cos\theta\left(\frac{v\cdot\frac{dv}{d\theta}\sin^2\theta}{g^2}+v^2\right)^{-\frac{1}{2}}$$

$$\begin{bmatrix} x(T) \\ y(T) \end{bmatrix} = \begin{bmatrix} d \\ y_0+\varepsilon \end{bmatrix} = \begin{bmatrix} \|v\|\cos\theta T \\ \|v\|\sin\theta T - \frac{1}{2}gT^2 \end{bmatrix}$$

$x_0, y_0 = 0, 0$

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$$\min_{\theta,\ \|v\|,\ T,\ \theta^2} \quad \|v\|$$

s.t. $\quad 0 \leq \|v\| \leq 5 \ m/s$

$$d = \|v\| \left(1 - \frac{\theta^2}{2.085}\right) T$$

2. $y_0 + \varepsilon = \|v\| \left(\theta - \frac{\theta \cdot \theta^2}{6.16}\right) T - \frac{1}{2} g T^2$

3. $\theta^2 = \theta \cdot \theta$

$$\varphi = \|v\| \, \theta^2 T$$

$$d = \|v\| T - \varphi$$

$$y_0 + \varepsilon = \theta - \frac{\theta \varphi}{6.16} - \frac{1}{2} g T^2$$

$$\theta^2 = \theta \cdot \theta$$

4. $\varphi = \|v\| \, \theta^2 T =: \varphi' T$

5. $\varphi' = \|v\| \, \theta^2$

$$\vec{u} := \begin{bmatrix} \|v\| \\ \theta \\ \theta^2 \\ b \\ \varphi' \\ T \end{bmatrix} \qquad \vec{o} := \begin{bmatrix} d \\ y_0 + \varepsilon \\ \theta^2 \\ \varphi \\ \varphi' \end{bmatrix}$$

Goal: find A and B s.t.

$$\vec{o} = \vec{u}^T A u + B u$$

(1) $d = \|v\| T - \varphi$

$$= u^T \underbrace{\begin{bmatrix} & & 1/2 \\ & 0 & \\ 1/2 & & \end{bmatrix}}_{A_1} u + \underbrace{\begin{bmatrix} 0 & 0 & 0 & -1 & 0 & 0 \end{bmatrix}}_{B_1} u$$

2). $y_0 + \varepsilon = \theta - \dfrac{\theta \varphi}{6.16} - \frac{1}{2} g T^2$

$$= u^T \underbrace{\begin{bmatrix} \cdot & \cdot & \cdot & \cdot & \cdot \\ \vdots & & 0 & & \\ \vdots & -1/6.16 & & & \\ \cdot & 0 & & & -\frac{1}{2} g \end{bmatrix}}_{A_2} u + \underbrace{\begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}}_{B_2} u$$

$A_2 =$

$$A_{2ij} = \begin{cases} -\frac{1}{2} g & i = j = 6 \\ -1/12.32 & i = 4, j = 2 \\ 0 & \text{else} \end{cases}$$

3. $\theta^2 = \theta \cdot \theta$

$$0 = \underbrace{u^T \begin{bmatrix} 0 & & & & & \\ & 1 & & & & \\ & & 0 & & & \\ & & & 0 & & \\ & & & & 0 & \\ & & & & & 0 \end{bmatrix}}_{A_3} u + \underbrace{\begin{bmatrix} 0 & 0 & -1 & 0 & 0 & 0 \end{bmatrix}}_{B_3} u$$

4. $0 = \varphi' T + \begin{bmatrix} 0 & 0 & 0 & -1 & 0 & 0 \end{bmatrix} u$

$$A_{4ij} = \begin{cases} 1/2 & i,j \in \{(5,6),(6,5)\} \\ 0 & \text{else.} \end{cases}$$

5. $0 =$ $A_{5ij} = \begin{cases} 1/2 & i,j \in 1,3 \\ 0 & \text{else} \end{cases}$

$$+ \begin{bmatrix} 0 & 0 & 0 & 0 & -1 & 0 \end{bmatrix} u$$

Combined Together:

$$0 = u^T \begin{bmatrix} A_1 \\ \vdots \\ A_5 \end{bmatrix} u + \begin{bmatrix} B_1 \\ \vdots \\ B_5 \end{bmatrix} u$$

QCQP: $\min_x \frac{1}{2} x^T A x + c^T x + d$

std form $\quad$ s.t. $x^T Q_i x + a_i^T x \le b_i$

$Q_i \geq 0 \; \forall i$

The prob is now

$A = 0 = d$

$c = e_1 \in \mathbb{R}^6$

$$\min_u \overset{c^T}{\overset{\shortparallel}{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}^T}} u$$

$$\text{s.t.} \quad d = u^T A_1 u + B_1^T u$$

$$\vdots \qquad \vdots$$

$$0 = u^T A_5 u + B_5^T u$$

$c + \sum$

$L(x, \lambda) = c^T u +$