1. maintains angle to ground via PID

Suppose we want to maintain the inclination angle between the segway and the ground to α_0 (if it is perpendicular to the ground, it is $\alpha_0 = 90°$)

The current time is t, the inclination of the segway is α_t。

Calculate the error err_t

$$err_t = \alpha_t - \alpha_0$$

The controllable variable is the torque acting on the two wheels, that is, the $qval_t$ of the wheel in the majoco model（about time t）

Then there is the following formula：

$$qval_t = K_p \cdot err_t + K_i \cdot \sum_{n=t-t_0}^{t} err_n + K_d \cdot (err_t - err_{t-1})$$

$K_p \cdot err_t$ is the P item, namely proportion, the error err_t is multiplied by a certain constant K_p

$K_i \cdot \sum_{n=t-t_0}^{t} err_n$ is the I item, that is, integration, the sum of the error err_t(because the time in majoco is discrete, it is not an integral but a summation) multiplied by a certain constantK_I。

$K_d \cdot (err_t - err_{t-1})$ is the D item, that is, differentiation, the change of error err with respect to time t, multiplied by a certain constant K_d。

The value of K_p, K_i, K_d is determined by observation and experiment.

In particular, we use K_i= 0 in this project because the physical environment of the simulated environment is ideal and there is not much noise.

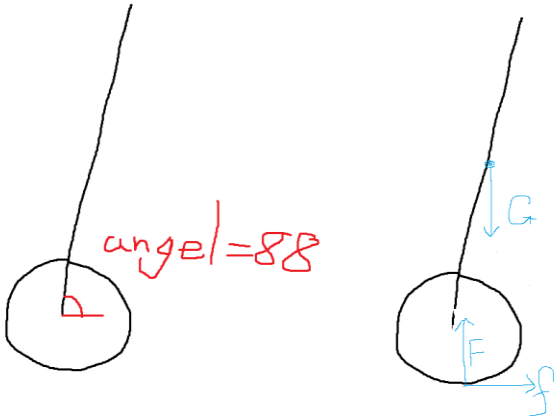
2. forward, backward, turn

By the means in 1, we maintain the angle α_0. If we want the car to move forward, only α_0 needs to be changed.

For example, suppose $\alpha_0 = 90$, the segway remains stationary.

Then α_{forward} =88 means that the car is tilted forward. At this time, the car moves forward in a straight line at a constant speed, because the resultant force of gravity G, the support force F of the ground, and the friction force f of the tire is 0, and the resultant moment is also 0.

In the same way, we can know that α_{backward} =92 means that the car tilts backward, and the car moves backward at a uniform speed in a straight line.



The turning of the car is done by unequal $qval_{t,left}$ and $qval_{t,right}$.

for example:

$$qval_{t,left} = 1 \cdot qval_t$$

$$qval_{t,right} = K_{diff} \cdot qval_t$$

$$K_{diff} = 1.8 > 1$$

will make the right and left wheels turn faster than the left wheel, and the car will turn left.

The value of K_{diff} is determined experimentally.

3. manually defined sequence of actions

Next, we want the segway to pass through certain terrain and obstacles.

We can define the following motion sequence by trial and error.

$$a = (a_t)_{t \in N}$$

For example:

$$a_{34} = go\ fast, but\ turn\ right\ slowly$$

means:

$$qval_{34,left} = 1.1 \cdot qval_{34}$$

$$\alpha_{0,\ for\ t=34} = 86$$

That is, the 86° inclination is maintained, and the rotation speed of the left wheel is slightly faster than that of the right wheel.