31300/31301 Linear Control Design 1
Spring 2022

Silvia Tolu - Dimitrios Papageorgiou

REGBOT balance – Control architecture

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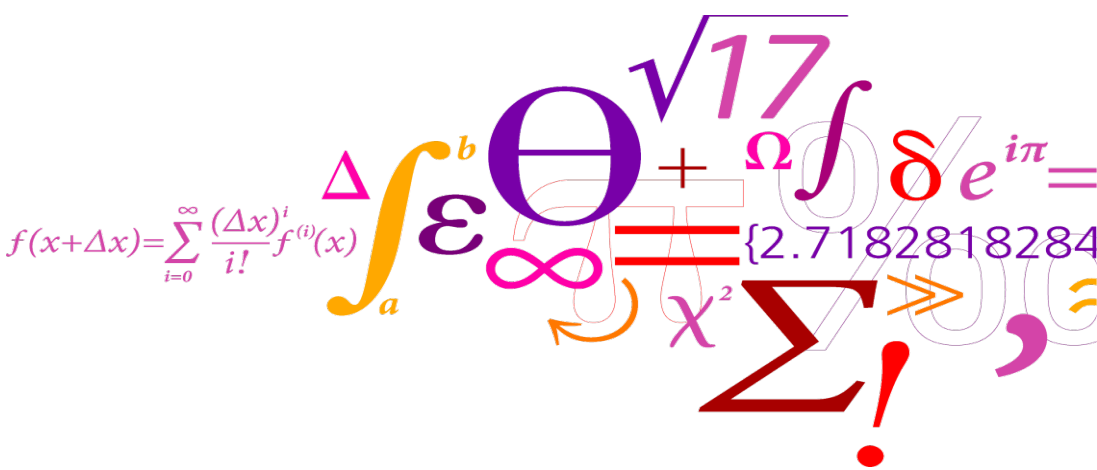
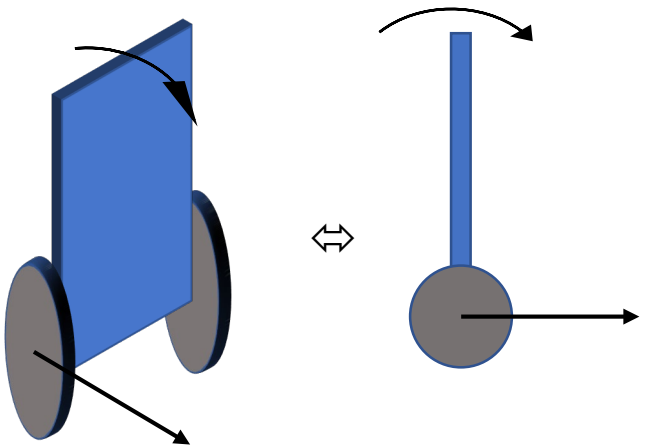


DTU Electrical Engineering
Department of Electrical Engineering

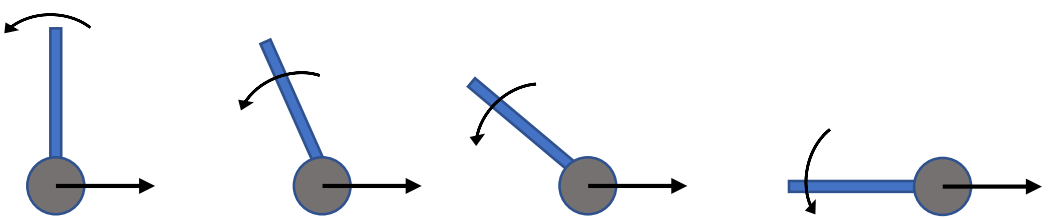
How to get to balance

Some facts:

- REGBOT ⇔ Inverted pendulum with a cart.



- Constant speed cannot give balance.



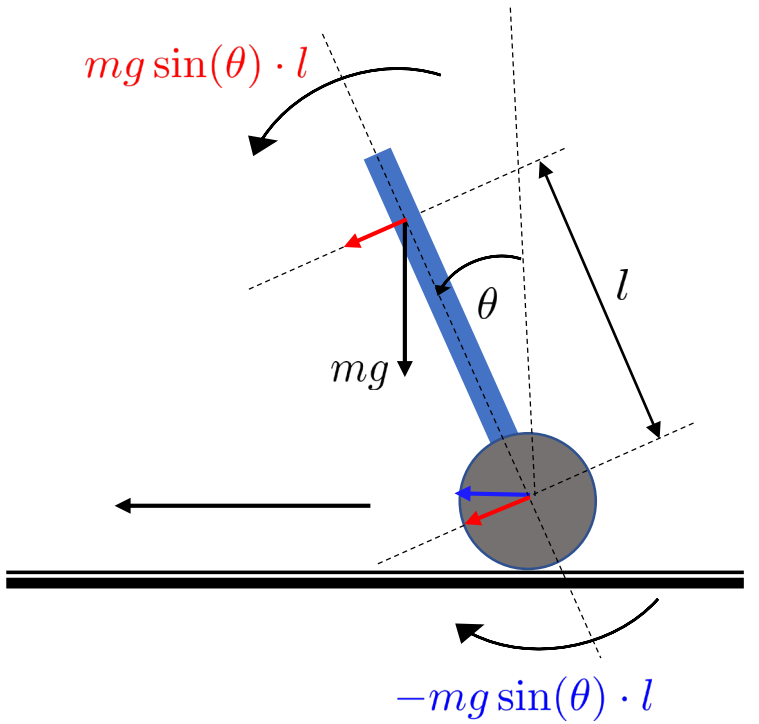
- REGBOT <u>linear</u> velocity = wheel radius × wheel angular speed = wheel radius × gear ratio × motor angular velocity

- We can achieve balance at some tilt angle with appropriate changing velocity command.

How to get to balance

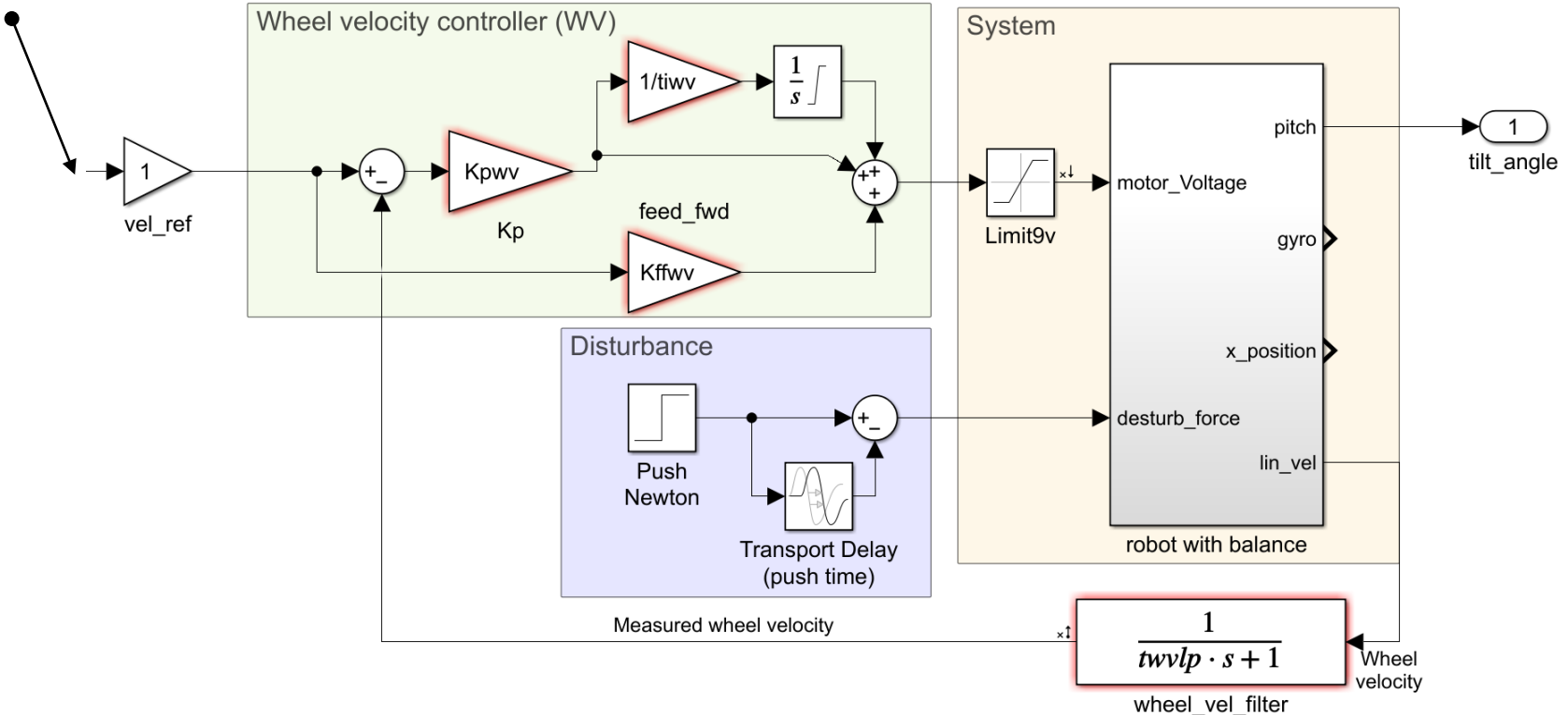
Some facts:

- Gravity has **component** that produces torque → tilt.
- We can counteract this **component** with a horizontal **force** in the same direction as the tilt.
- Force ⇔ acceleration: A demand on the REGBOT linear speed (i.e. the wheel angular velocity) will produce an acceleration (force) command.
- We can achieve balance at some tilt angle with appropriate changing velocity command.



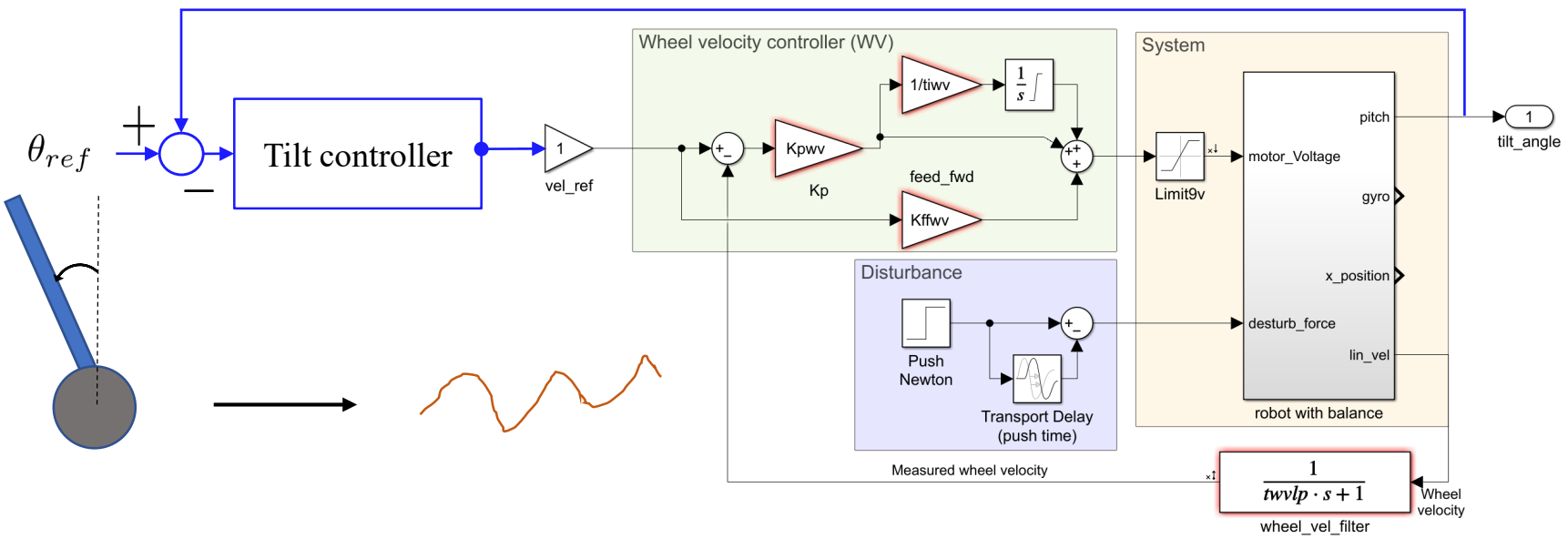
How to get to balance

Velocity demand such that it corresponds to the appropriate (for the balance) acceleration (i.e. force).



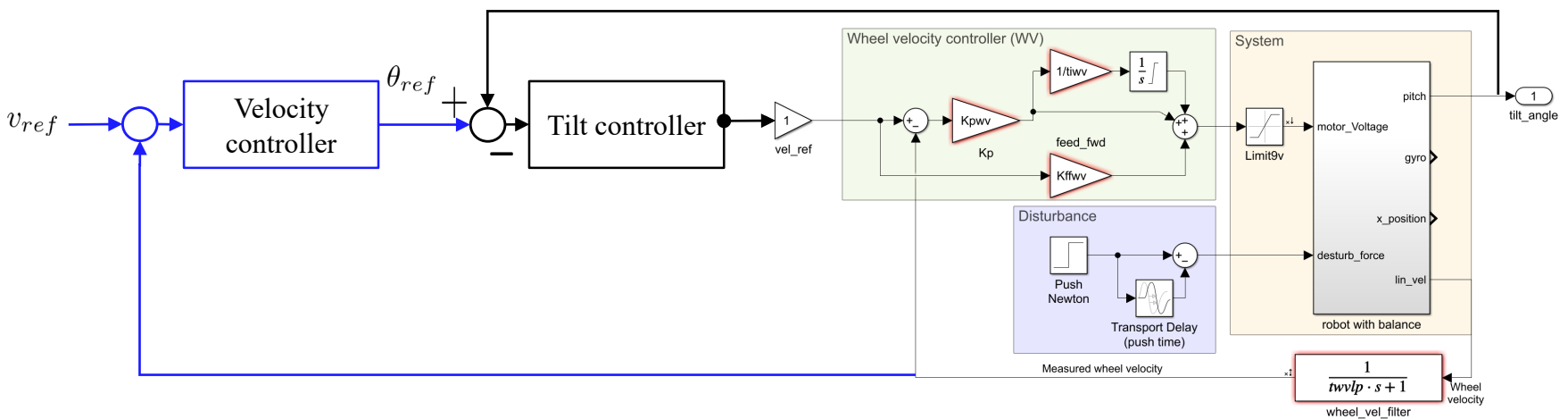
How to get to balance

Balance controller: Takes a desired tilt angle as reference (e.g. 3°) and outputs a special velocity demand (reference for the given velocity controller) such that it corresponds to the appropriate (for the balance) acceleration (i.e. force).



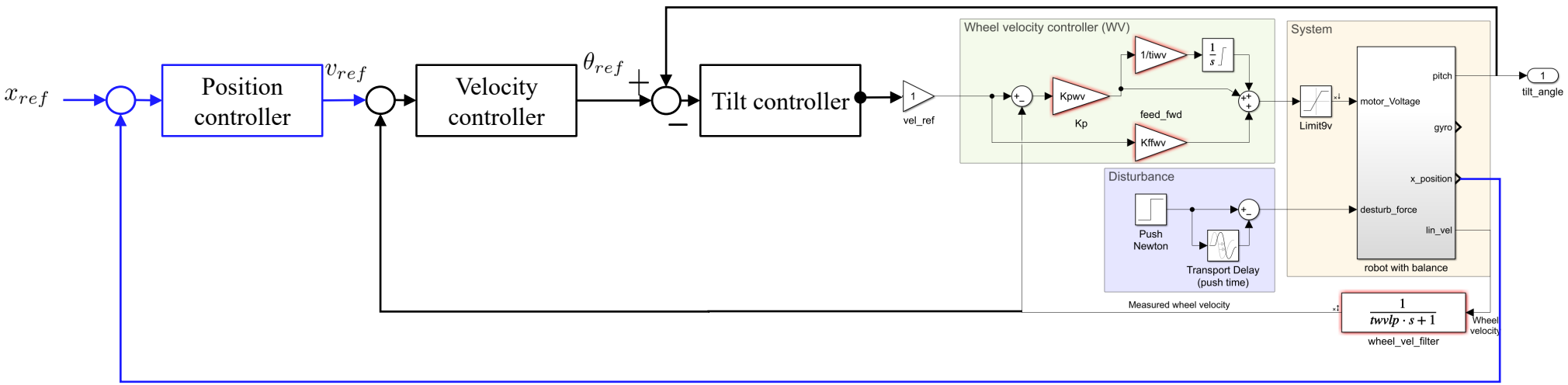
How to get to balance at a given velocity

Velocity controller: Takes a desired velocity as reference (e.g. 0.1 m/s) and outputs a special tilt angle demand (reference for the tilt controller) such that it forces the REGBOT move with the given velocity (e.g. tilt forward will make the robot move forward in order to maintain balance as well).



How to get to balance at a given position transit

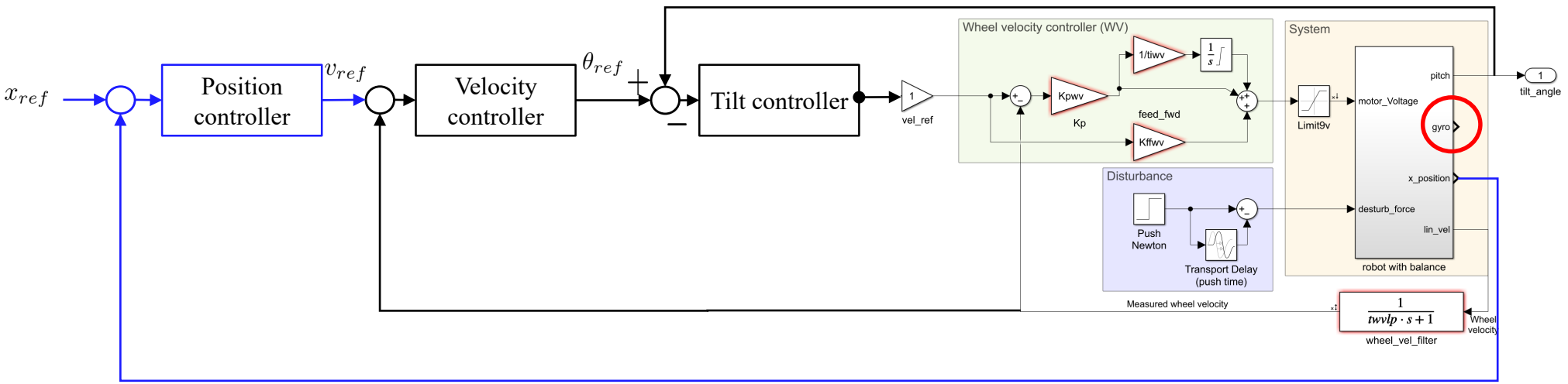
Position controller: Takes a desired positions reference (e.g. 2 m/s) and outputs a special velocity demand (reference for the velocity controller) such that it forces the REGBOT move to the given position (e.g. tilt forward until it almost reaches the target and then tilt backwards to start maintaining the balance).



Some tips

Tilt angle (balance) controller:

- You will need a PII-Lead controller (one more PI block in open loop). The second PI-part is also referred to as “post-integrator”.
- For the Lead part of the tilt angle controller you can use the gyro measurement (derivative of tilt angle).



$$\frac{\tau s + 1}{\alpha\tau s + 1}\theta = \underbrace{\frac{1}{\alpha\tau s + 1}}_{\text{low-pass filter}} \left(\tau \underbrace{s\theta}_{\dot{\theta}=\text{gyro}} + \theta \right) \rightarrow \tau \cdot \text{gyro} + \theta$$

Not needed