Project report

Project topic: Comparison of PID and fuzzy controllers in the cruise control model.

Authors:
135860 Oskar Mikołajczyk
140318 Adrian Szandała

1. Object model

There are three forces acting on the vehicle (Tesla Model 3) in the model:

- driving force - F_{engine}
- air resistance force - F_{drag}
- rolling resistance force - F_{roll}

The task of the cruise control is to achieve the set speed.

The forces counteracting the movement of the vehicle can be obtained from the following equations:

$$F_{roll} = C_r \cdot m \cdot g,$$

$$F_{drag} = 0.5 \cdot p \cdot V^2 \cdot Cd \cdot A,$$

$$F_{engine} = \frac{\tau}{r}$$

where:

$C_r = 0.01$ - coefficient of rolling resistance of rubber on asphalt

m = 2050 [kg] - weight of the vehicle and average driver

V - speed of the vehicle at a given moment

g = 9,81 [m/s^2] - gravity constant acceleration

p = 1.293 [kg/m^3] - approximate air density for an altitude of 0-5000 m above sea level, pressure 101.325 kPa and temperature 273 K.

$C_d = 0.23$ - drag coefficient for the vehicle

A = 2,22 [m^2] - vehicle surface area perpendicular to the drag force

T = 639 [Nm] - engine torque

r = 23.5 inches = 0.6 [m] - vehicle wheel radius

$$F\_roll = 0{,}01 \cdot 2050 \cdot 9{,}81 = 201{,}1\ [N],$$

$$F\_drag = 0{,}5 \cdot 1{,}293 \cdot 25^2 \cdot 0.23 \cdot 2.22 = 206.3\ [N] \text{ - for } V = 25 \text{ m/s}$$
$$F\_drag = 0{,}5 \cdot 1{,}293 \cdot 0{,}23 \cdot 2{,}22 \ * V^2 = 0.3301029 * V^2$$
$$F\_drag(V) = 0{,}3301029 * V^2$$

$$F_{engine} = \frac{\tau}{r} = \frac{639}{0{,}6} = 1065\ [N]$$

To maintain the set speed, the cruise control must accelerate and then maintain the set speed.

For acceleration:

$$F_{engine} > F_{drag} + F_{roll}$$

To maintain speed:

$$F_{engine} = F_{drag} + F_{roll}$$

$$V\_max = ((F\_engineMax - F\_roll)/0{,}3301029)\hat{}2$$

During acceleration, the limit is the maximum force that the vehicle's drive system can generate.

The model does not take into account the possibility of braking - if the speed exceeds the set resistance, the vehicle brakes.

The force that affects the acceleration of the vehicle is the real force $F_r$which is defined by the following formula:

$$F_r = F_{engine} - (F_{drag} + F_{roll})$$

The formula for velocity at a given moment:

$$IN_t = V_{t-1} + F_r * t/m$$
$$F_r = F_{AND} - (F_{drag} + F_{roll})$$
$$IN_t = V_{t-1} + (F_{AND} - (F_{drag} + F_{roll})) * t/m$$

$$IN_{max} = 210 \text{ kh/h} \approx 60 \text{ m/s}$$

We have limited the maximum speed of the vehicle to 210 km/h according to the manufacturer's data.

2. Tools used.

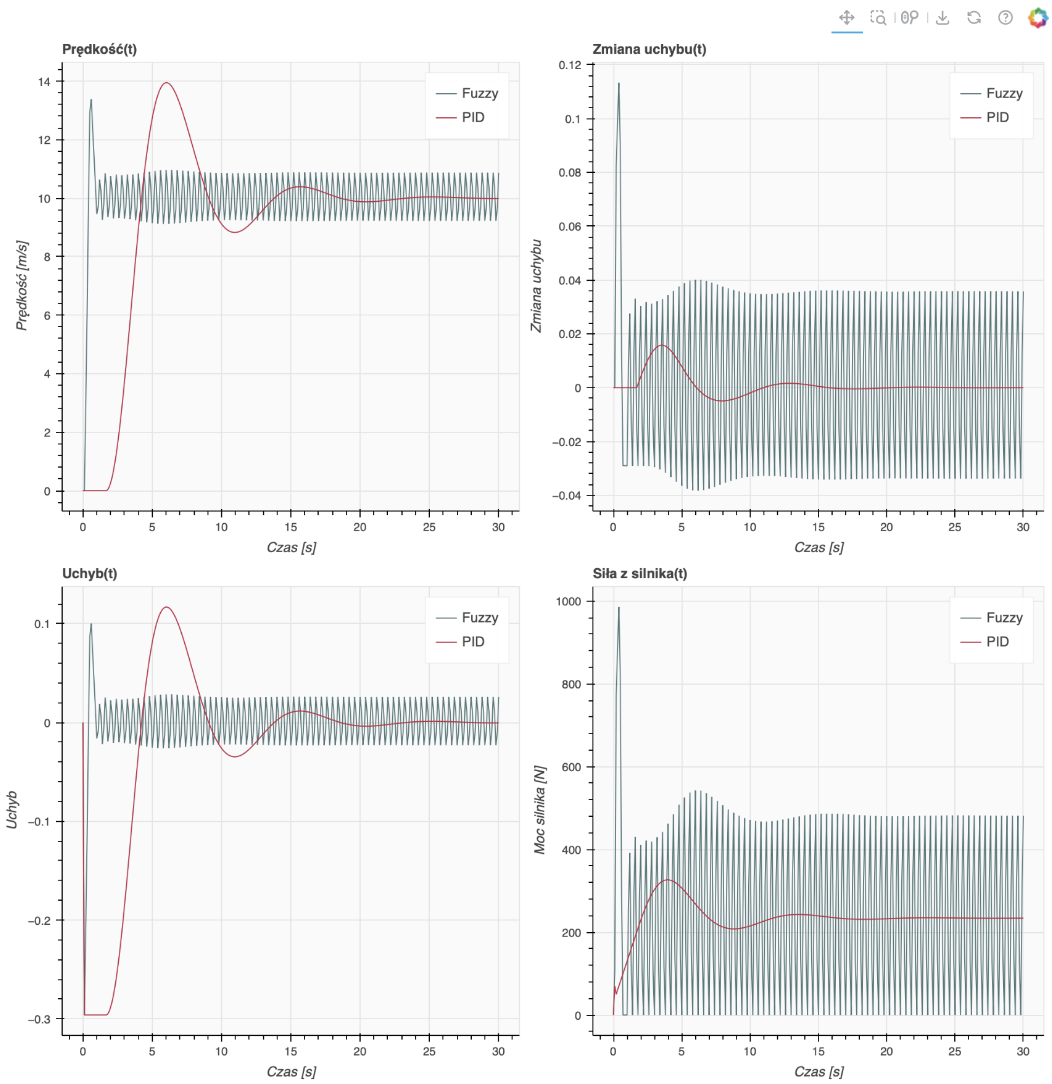
Simpful library was used for fuzzy logic, which brings the fuzzy controller design closer to logical sentences.
Bokeh library was used to present the data, which allows for the aesthetic presentation of data and the programming of interactive charts in the form of an html file.

3. Results

Simulation for set value - velocity = 10 [m/s]

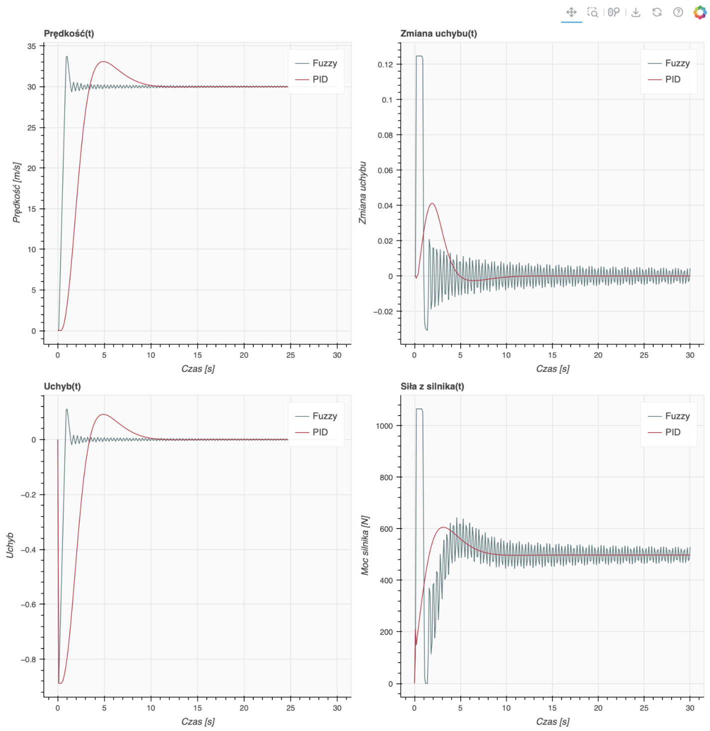
1st chart Velocity(t), 2nd contole error change(t), 3rd control error(t), 4th F_engine(t)

Porównanie regulatorów typu PID i Fuzzy dla tempomatu modelu samochodu Tesla Model 3.



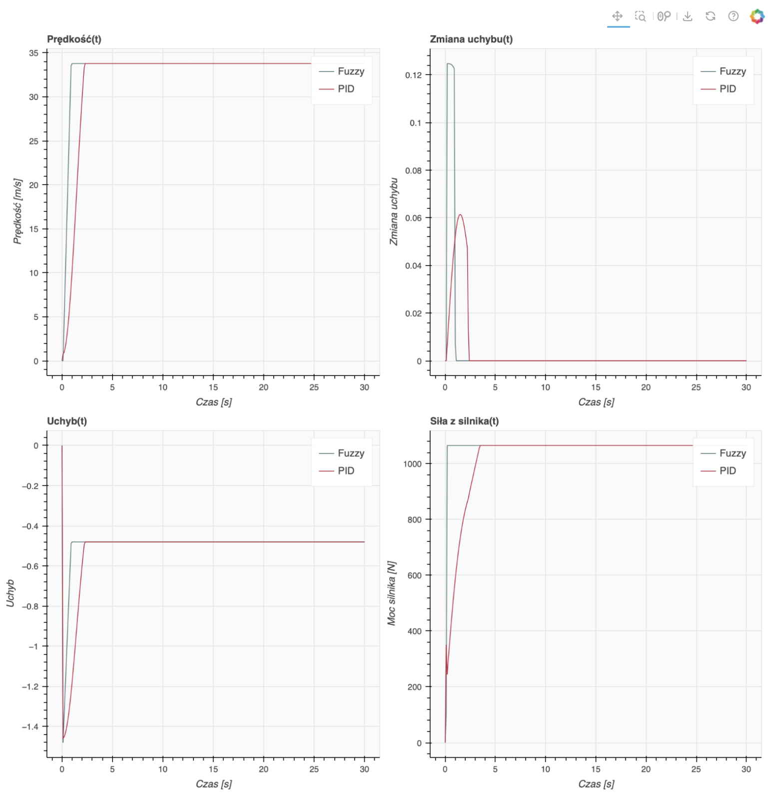
Simulation for set value - velocity = 30 [m/s]
1st chart Velocity(t), 2nd contole error change(t), 3rd control error(t), 4th F_engine(t)

Porównanie regulatorów typu PID i Fuzzy dla tempomatu modelu samochodu Tesla Model 3.



Simulation for set value - velocity = 50 [m/s]
1st chart Velocity(t), 2nd contole error change(t), 3rd control error(t), 4th F_engine(t)

Porównanie regulatorów typu PID i Fuzzy dla tempomatu modelu samochodu Tesla Model 3.



In the last case, the regulator is no longer able to obtain the set value because the vehicle resistance is too high.

4. Conclusions

The fuzzy controller approaches the set value faster. Unfortunately, in our case, the fuzzy controller oscillates around the set point and has a slightly larger overshoot than the PID controller. The PID controller does not approach the set value as quickly, but stabilizes much faster. The exception is the maximum value that can be reached, because in this situation oscillations do not appear, which means that the fuzzy controller has a shorter control time.
Errors in the fuzzy controller do not result from its construction but from not fully correctly selected parameters if chosen more carefully Fuzzy Logic controller would have higher quality than PID.