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Electronic Systems Laboratory

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Neural Network Disturbance Rejection for a Quadcopter

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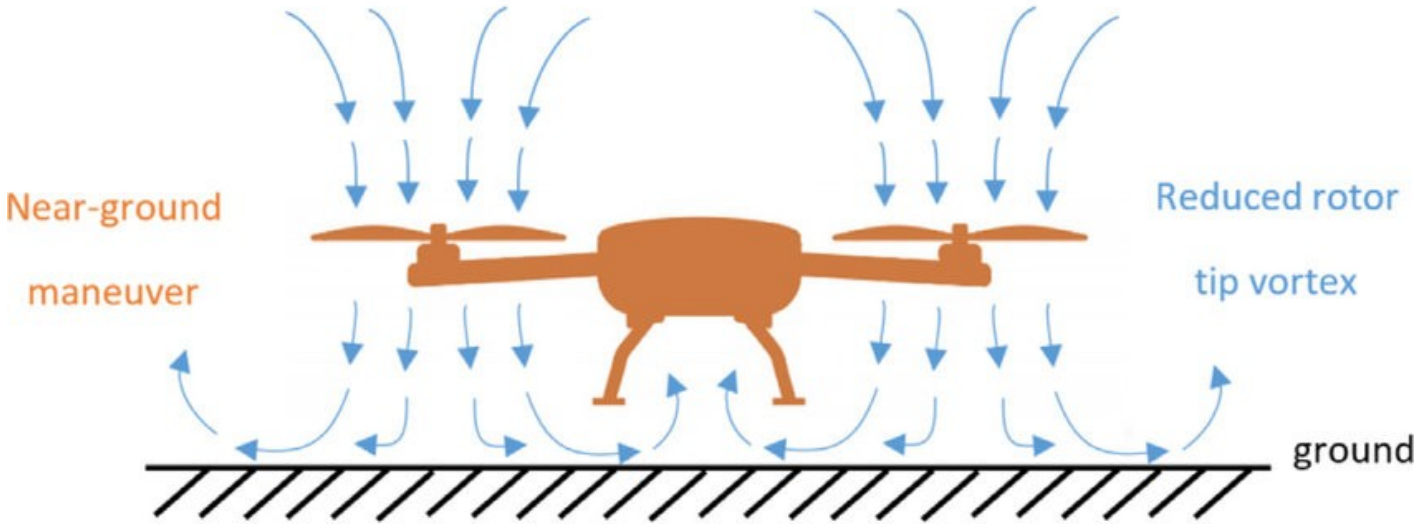
- Quadcopters are being introduced in various sectors for proximity inspection, delivery and surveillance purposes.
- These requirements introduces phenomena not encounter by the hobbyist.
- A phenomenon during take-off and landing of a quadcopter is ground effects.

Inspecting walls

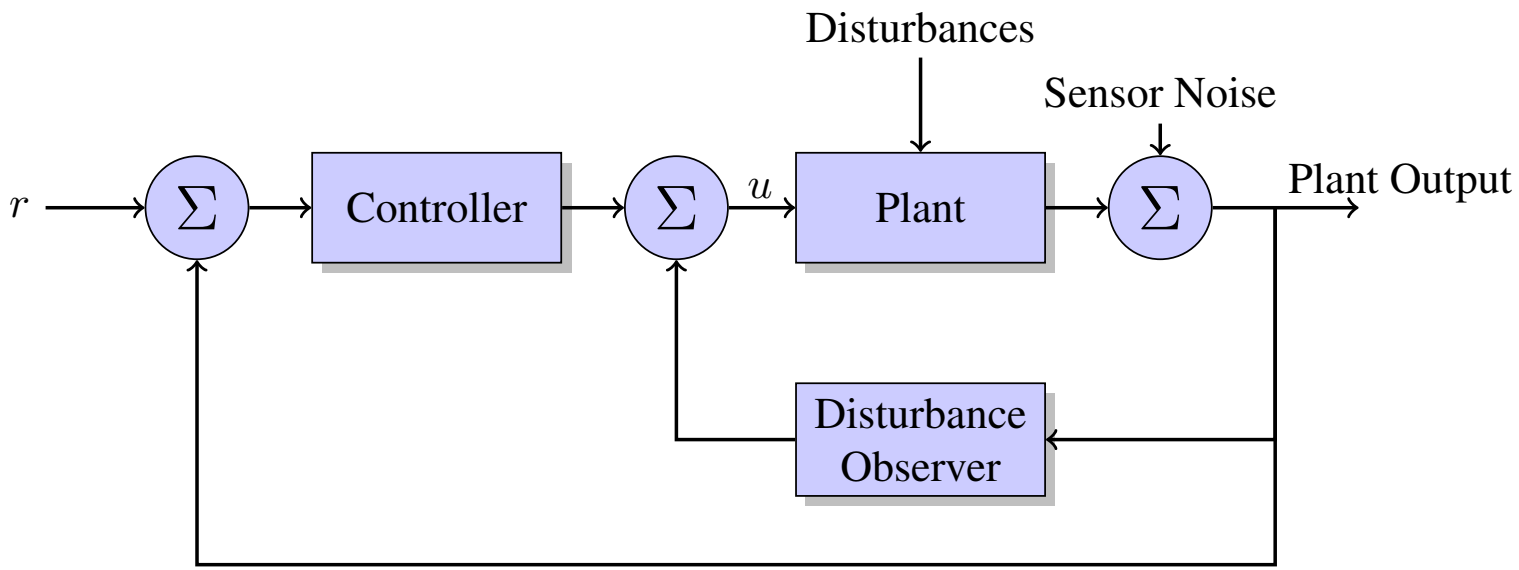
Transporting a suspended package

- Ground effects are seen as disturbance from a control system perspective.
- It is omitted during the mathematical modelling and thus the control system is unaware of these dynamics.
- Obtaining a mathematical model is very difficult.
- Neural networks can be of use in this regards.



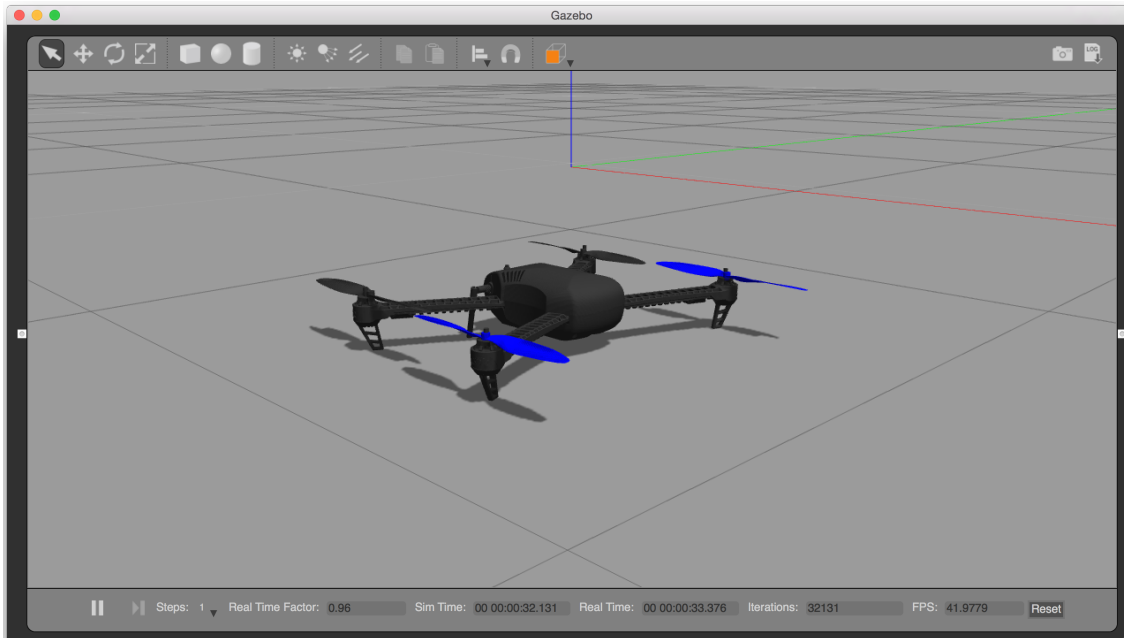
Ground Effects

- The neural network assist the classical controller and does not replace it.
- The neural network should provide an estimate of this disturbance using the sensor measurements.
- This estimated disturbance can be introduced in the controller architecture to improve the disturbance rejection.



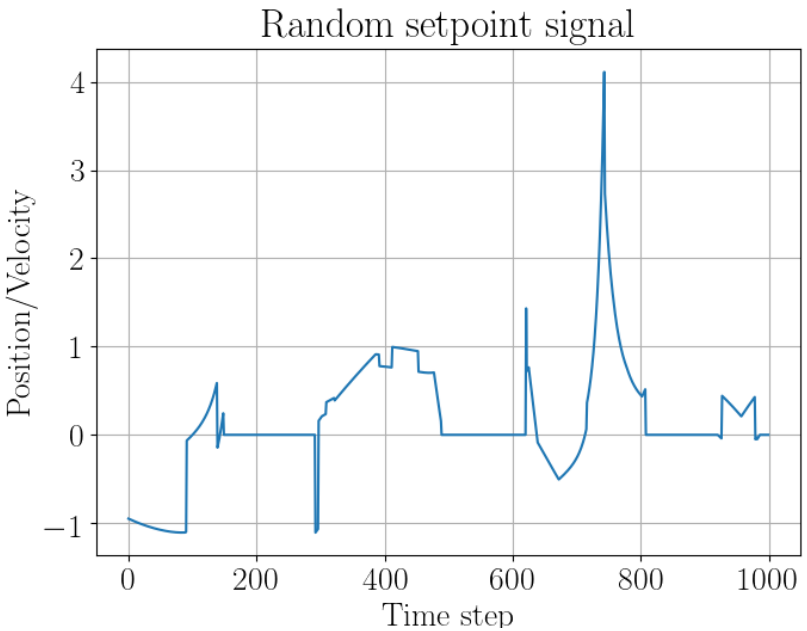
Active disturbance rejection

- Data generation does not scale well in robotics.
- Training data is generated in a simulation environment.
- Gazebo is a physic engine to simulated rigid body dynamics.
- Includes realistic sensor models.

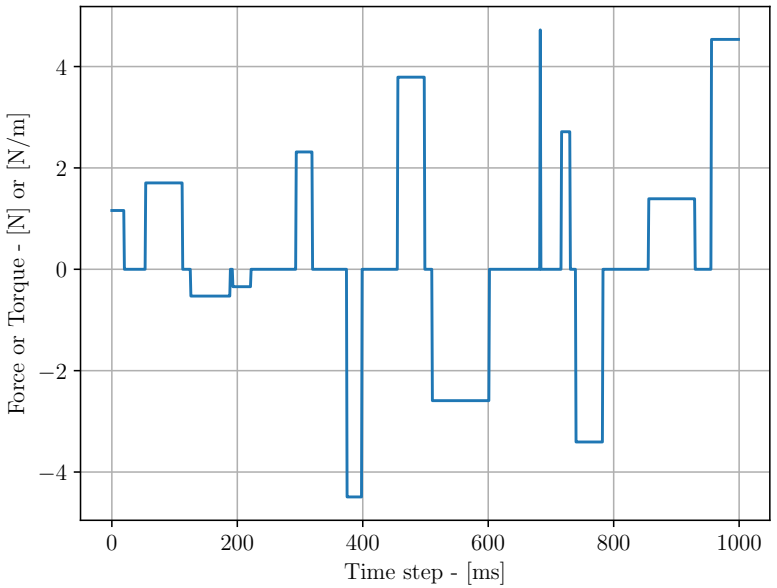


Quadcopter in Gazebo.

- The setpoints which the quadcopter flies contains step, ramp and exponential functions.
- Disturbances are random pulse trains in each body direction.



Setpoint containing expected properties.



Random pulse train

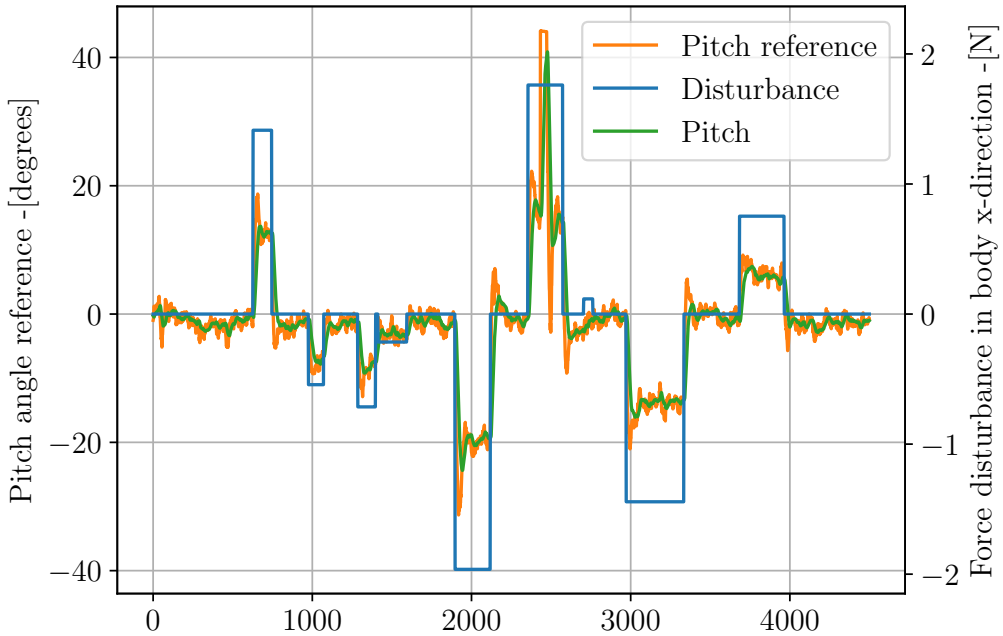
- Environmental and model variables are randomised.
- Helps with Sim2Real tranfer.
- Model must learn multiple environments.

Parameter	Scaling factor range	Additive term range
mass	uniform([0.95,1.05])	-
principles of inertia	uniform([0.95,1.05])	-
products of inertia	-	uniform([0,0.0005])
gravity vector(x,y,z)	-	$\mathcal{N}(0, 0.2)$

Ranges of physics parameter randomisations

Learning to Identify Disturbances

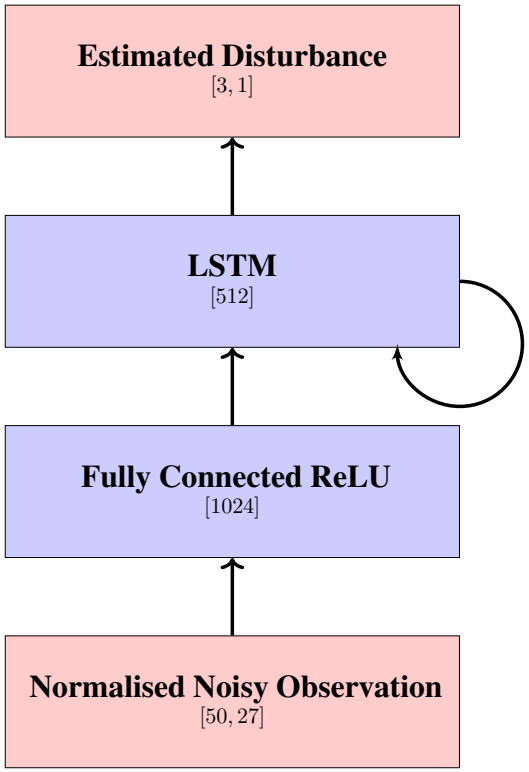
- The neural network must first learn how a quadcopter behaves without disturbances.
- Any deviation from the expected behaviour is the manifestation of a disturbance.
- By viewing the correct signals, the neural network aught to identify when a disturbance is occurring and estimating its force.



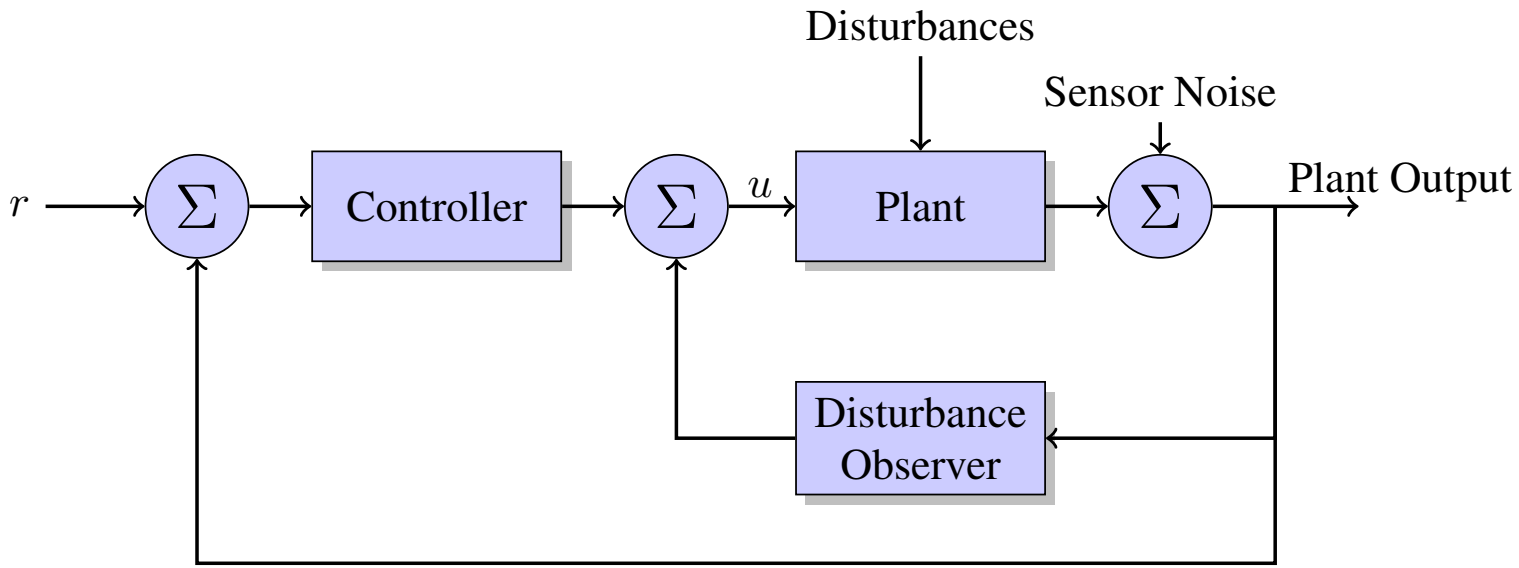
- Input to neural network is a time window of about 0.3s
- Time window contains 24 vectors corresponding to the quadcopters position, velocity, acceleration and more.

Parameter	Number of elements	Storing frequency
Inertial velocity	3	25
Inertial velocity setpoint	3	25
Quaternions	4	100
Quaternion setpoint	4	100
Angular Rates	3	250
Angular Rate setpoints	3	250
PWM signal to motors	4	250
Total	24	-

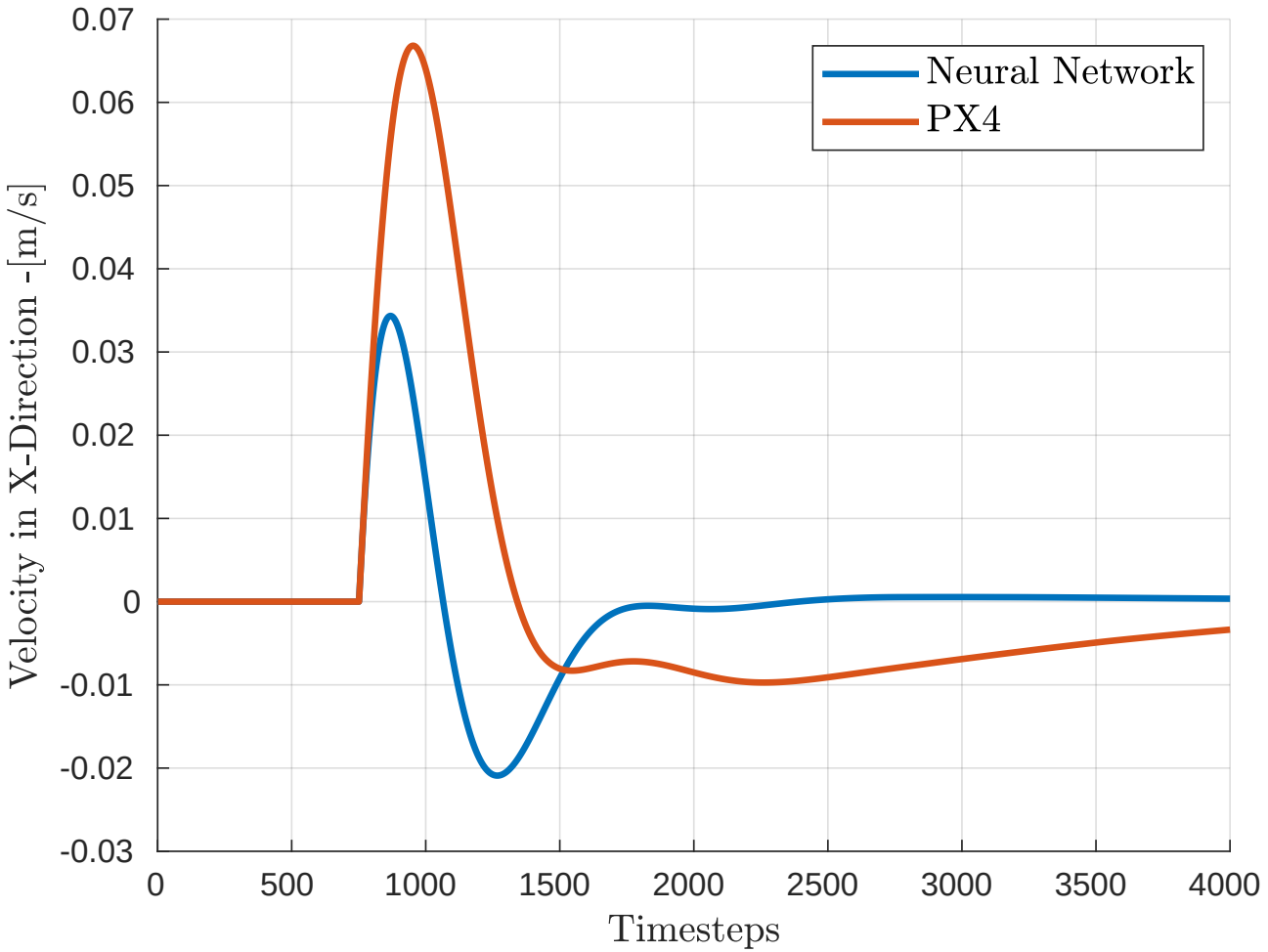
- Based on OpenAI's neural network architecture
- Dense ReLU layer with LSTM
- Optimiser: Adam



- Feeding the estimated disturbance in the correct feedback loop of the control system will counteract the disturbance much faster than originally.



Responses from Disturbance Observers



Response of quadcopter using standard control laws and using disturbance rejection with neural network.

Thank you

- Questions?
- Any suggestions is appreciated