ddcontrol Documentation

Release 0

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Contents

Control Theory for humans. The PID controller design based entirely on experimental data collected from the plant.

Please Star me on GitHub for further development.

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CHAPTER 1

PID Controller Example

PIDController class can be used directly if the controller gains are already calculated. PIDController class is based on Thread Class. So it can be used as Tread. This features provides fixed PID loop frequency.

```
from ddcontrol.model import TransferFunction
from ddcontrol.control import PIDController
import numpy as np
import matplotlib.pyplot as plt
import time

#Creates PID controller and test model
pid = PIDController(kp=30, ki=70.0, kd=0.0, kn=0.0)
ref = 1.0
tf = TransferFunction([1.0], [1.0,10.0,20.0], udelay=0.1)

#Control loop
history = []
u = 0.0
pid.start()
start = time.time()
for _ in range(1000):
    t = time.time() - start
    y = tf.step(t, u)
    u = pid.update(ref-y)
    history.append([t,y])
    time.sleep(0.001)

#Stops PID controller
pid.stop()
pid.join()

#Plots result
np_hist = np.array(history)
fig, ax = plt.subplots()
ax.plot(np_hist[:,0], np_hist[:,1])
```

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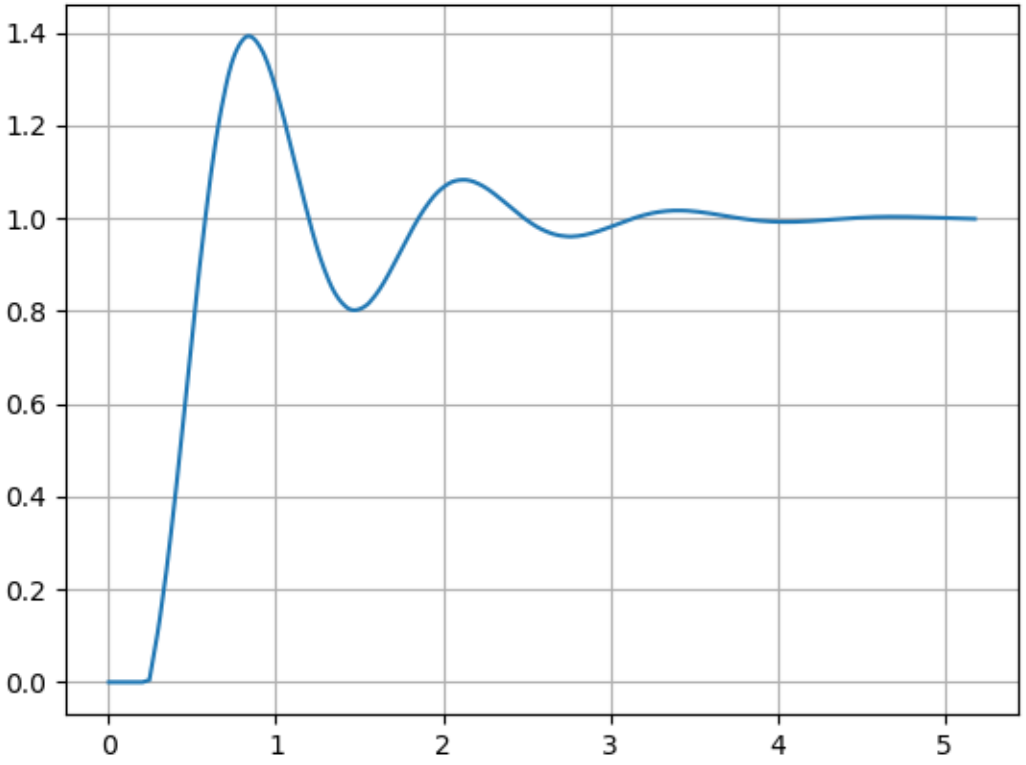
```
ax.grid()
plt.show()
```

Controlled output:



CHAPTER 2

PID optimization for known Transfer Function

If the transfer function is already known, controller gains can be calculated by pidopt method.

```
from ddcontrol.model import TransferFunction
from ddcontrol.control import pidopt
import numpy as np
import matplotlib.pyplot as plt
import time

#Creates transfer function
tf = TransferFunction([1.0], [1.0,10.0,20.0], udelay=0.1)

#Optimize PID controller
pid, _ = pidopt(tf)
ref = 1.0

#Control loop
history = []
u = 0.0
pid.start()
start = time.time()
for _ in range(1000):
    t = time.time() - start
    y = tf.step(t, u)
    u = pid.update(ref-y)
    history.append([t,y])
    time.sleep(0.001)

#Stops PID controller
pid.stop()
pid.join()

#Plots result
np_hist = np.array(history)
fig, ax = plt.subplots()
```

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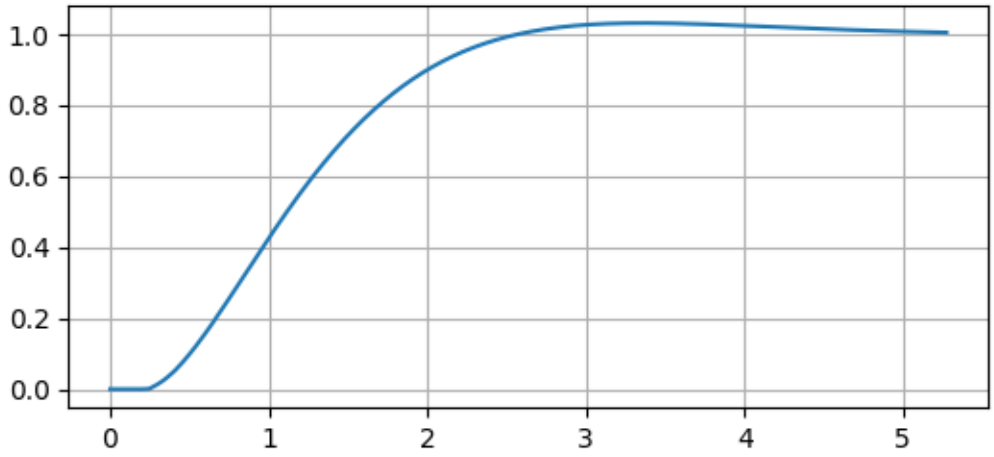
```
ax.plot(np_hist[:,0], np_hist[:,1])
ax.grid()
plt.show()
```

Controlled output:



CHAPTER 3

Transfer Function Estimation for unknown SISO system

If the transfer function is unknown for system, the transfer function can be estimated by tfest method.

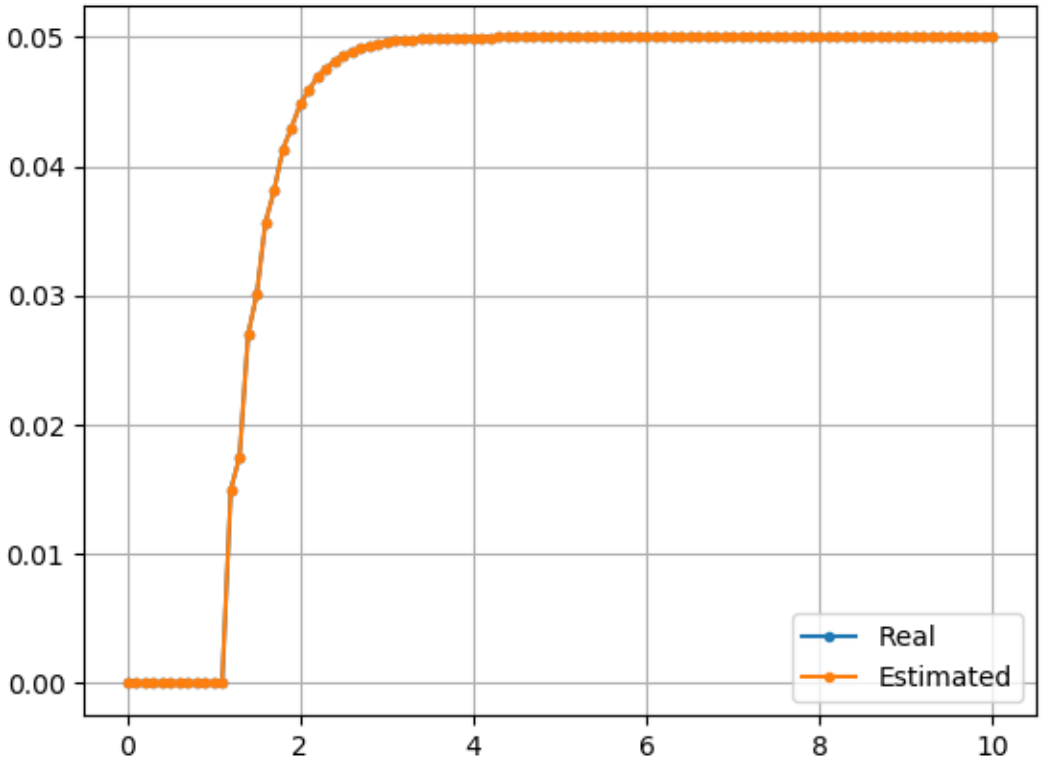
```
from ddcontrol.model import TransferFunction, tfest
import numpy as np
import matplotlib.pyplot as plt

#Creates a transfer function and input output data
tf = TransferFunction([1.0], [1.0,10.0,20.0], 1.0)
t, y, u = np.linspace(0,10,101), np.zeros(101), np.ones(101)
for index in range(t.size):
    y[index] = tf.step(t[index], u[index])

#Predicts transfer function
tf_est, _ = tfest(t, y, u, np=2, nz=0, delay=True)
y_est = np.zeros(101)
for index in range(t.size):
    y_est[index] = tf_est.step(t[index], u[index])

#Plots result
fig, ax = plt.subplots()
ax.plot(t, y, '.-', label='Real')
ax.plot(t, y_est, '.-', label='Estimated')
ax.legend()
ax.grid()
plt.show()
```

Step response of real system and estimated system:


0.05
0.04
0.03
0.02
0.01
0.00
0
2
4
6
8
10
Real
Estimated

CHAPTER 4

Installation

To install using pip

```
pip install ddcontrol
```

CHAPTER 5

ddcontrol.control module

Created on Thu Jan 9 20:18:58 2020

@author: eadali

class ddcontrol.control.**PIDController**(*kp*, *ki*, *kd*, *kn*, *freq=10.0*, *lmin=-inf*, *lmax=inf*)

Bases: threading.Thread

Advenced PID controller interface.

Parameters

- **kp** (*float*) – Proportional gain of controller.
- **ki** (*float*) – Integral gain of controller.
- **kd** (*float*) – Derivative gain of controller.
- **kn** (*float*) – Filter coefficient of controller.
- **freq** (*float, optional*) – PID controller calculation frequency.
- **lmax** (*lmin,*) – PID controller output limits.

Example

```
>>> from ddcontrol.model import TransferFunction
>>> from ddcontrol.control import PIDController
>>> import numpy as np
>>> import matplotlib.pyplot as plt
>>> import time
```

```
>>> #Creates PID controller and test model
>>> tf = TransferFunction([1.0], [1.0,10.0,20.0])
>>> pid = PIDController(kp=30, ki=70.0, kd=0.0, kn=0.0)
>>> ref = 1.0
```

```
>>> #Control loop
>>> pid.start()
>>> y, u = np.zeros(900), 0.0
>>> start = time.time()
>>> for index in range(y.size):
>>>     t = time.time() - start
>>>     y[index] = tf.step(t, u)
>>>     u = pid.update(ref-y[index])
>>>     time.sleep(0.001)
```

```
>>> #Stops PID controller
>>> .stop()
>>> pid.join()
```

```
>>> #Plots result
>>> fig, ax = plt.subplots()
>>> ax.plot(y)
>>> ax.grid()
>>> plt.show()
```

run()
Method representing the thread's activity.

You may override this method in a subclass. The standard run() method invokes the callable object passed to the object's constructor as the target argument, if any, with sequential and keyword arguments taken from the args and kwargs arguments, respectively.

set_initial_value(*integ=0.0*, *finteg=0.0*)
Resets PID controller state.

step(*e*, *dt*)
Calculates PID controller states and returns output of controller

Parameters

- **e** (*float*) – Input value of controller
- **dt** (*float*) – Time step used for integral calculations

stop()
Stops PID controller thread

update(*e*)
Updates error value of PIDController.

Parameters **e** (*float*) – Error signal value

Returns Control signal value

Return type float

class ddcontrol.control.**StanleyController**
Bases: object

ddcontrol.control.**pidopt**(*tf*, *end=10.0*, *wd=0.5*, *k0=(1.0, 1.0, 1.0, 1.0)*, *freq=10.0*, *lim=(-inf, inf)*)
PID optimization function for given transfer function

Parameters

- **tf** (TransferFunction) – TransferFunction object for optimization.
- **end** (*float, optional*) – Optimization end time

- **wd** (*float, optional*) – Disturbance loss weight [0,1].
- **k0** (*tuple, optional*) – Initial PID controller gains.
- **freq** (*float, optional*) – PID controller frequency.
- **lim** (*tuple, optional*) – Output limit values of PID controller

Returns Optimized PIDController and OptimizeResult.

Return type tuple

Example

```
>>> from ddcontrol.model import TransferFunction
>>> from ddcontrol.control import pidopt
```

```
>>> #Creates transfer function
>>> tf = TransferFunction([1.0], [1.0,10.0,20.0], udelay=0.1)
```

```
>>> #Optimizes pid controller
>>> pid, _ = pidopt(tf)
>>> print('Optimized PID gains..:', pid.kp, pid.ki, pid.kd, pid.kn)
```

CHAPTER 6

ddcontrol.model module

Created on Wed Jan 15 10:06:42 2020

@author: ERADALI

class ddcontrol.model.**StateSpace**(*A*, *B*, *C*, *D*, *delays=None*)

Bases: object

Time delayed linear system in state-space form.

Parameters

- **B, C, D** (*A,*) – State space matrices
- **delays** (*array_like, optional*) – Delay values

set_initial_value(*x0=None*, *u0=None*)

Sets initial conditions

Parameters

- **x0** (*array_like or callable, optional*) – Initial state values
- **u0** (*array_like or callable, optional*) – Initial input values

step(*t*, *u*)

Find dxdy = Ax + Bu, set x as an initial condition, and return y = Cx + Du.

Parameters

- **t** (*float*) – The endpoint of the integration step.
- **u** (*float*) – Input value

Returns array_like: Output of state space model

class ddcontrol.model.**TransferFunction**(*num*, *den*, *udelay=None*)

Bases: *ddcontrol.model.StateSpace*

Time delayed linear system in transfer function form.

Parameters

- **den** (*num,*) – Numerator and denumerator of the TransferFunction system.
- **udelay** (*float, optional*) – Input delay value

set_initial_value(*u0=None*)
Sets initial conditions.

Parameters **u0** (*array_like or callable, optional*) – Initial input values.

to_ss()

ddcontrol.model.**tfest**(*t*, *y*, *u*, *np*, *nz=None*, *delay=False*, *xtol=0.0001*, *epsfcn=0.0001*)
Estimates a continuous-time transfer function.

Parameters

- **t** (*float*) – The independent time variable where the data is measured.
- **y** (*float*) – The dependent output data.
- **u** (*float*) – The dependent input data.
- **np** (*float*) – Number of poles.
- **nz** (*float, optional*) – Number of zeros.
- **delay** (*bool, optional*) – Status of input delay.
- **xtol** (*float, optional*) – Relative error desired in the approximate solution.
- **epsfcn** (*float, optional*) – A variable used in determining a suitable step length for
- **forward- difference approximation of the Jacobian** (*the*) –

Returns Estimated TransferFunction and covariance ndarray

Return type tuple

Example

```
>>> from ddcontrol.model import TransferFunction, tfest
>>> import numpy as np
```

```
>>> #Creates a transfer function and input output data
>>> tf = TransferFunction([1.0], [1.0,10.0,20.0])
>>> t, y, u = np.linspace(0,10,101), np.zeros(101), np.ones(101)
>>> for index in range(t.size):
>>>     y[index] = tf.step(t[index], u[index])
```

```
>>> #Predicts transfer function
>>> tf, _ = tfest(t, y, u, np=2, nz=0)
>>> print('Transfer function numerator coeffs..:', tf.num)
>>> print('Transfer function denumerator coeffs..:', tf.den)
```

CHAPTER 7

ddcontrol.integrate module

Created on Thu Feb 6 22:05:52 2020

@author: eadali

class ddcontrol.integrate.**CInterp1d**(*x0*, *g*, *lsize=10000.0*)

Bases: object

A conditional interpolation function interface.

This class returns a value defined as y=g(x) if x<x0, else interpolate(x)

Parameters

- **g** (*callable, g(x)*) – A python function or method for x<x0.
- **x0** (*float, optional*) – Condition value for x.
- **lsize** (*int, optional*) – Limit size for interpolate history

__call__(*x*)

Returns a value defined as y=g(x) if x<x0, else interpolate(x)

Parameters **x** (*float*) – Input value

Returns Conditional interpolate value

Return type float

append(*x_new*, *y_new*)

Appends new values to interpolation

Parameters

- **x_new** (*float*) – New x value for interpolation
- **y_new** (*float*) – New y value for interpolation

class ddcontrol.integrate.**dde**(*f*)

Bases: *ddcontrol.integrate.ode*

A interface to to numeric integrator for Delay Differential Equations. For more detail: Thanks to http://zulko.github.io/

Parameters **f** (*callable*) – Right-hand side of the differential equation.

integrate(*t*)
Find y=y(t), set y as an initial condition, and return y.

Parameters **t** (*float*) – The endpoint of the integration step.

Returns The integrated value at t.

Return type float

set_initial_value(*t*, *g*)
Sets initial conditions

Parameters

- **t** (*float*) – Time value for condition
- **g** (*callable*) – A python function or method for t<t0.

class ddcontrol.integrate.**ode**(*f*)
Bases: object

A generic interface class to numeric integrators. Solve an equation system $y'(t) = f(t, y)$.

Parameters **f** (*callable*) – `f(t, y, *f_args)` Right-hand side of the differential equation. t is a scalar, `y.shape == (n,)`. `f_args` is set by calling `set_f_params(*args)`. *f* should return a scalar, array or list (not a tuple).

integrate(*t*)
Find y=y(t), set y as an initial condition, and return y.

Parameters **t** (*float*) – The endpoint of the integration step.

Returns The integrated value at t

Return type float

set_f_params(**args*)
Set extra parameters for user-supplied function f.

set_initial_value(*t*, *y*)
Set initial conditions y(t) = y.

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