A novel Implementation Technique for Genetic Algorithm based Auto-Tuning PID Controller

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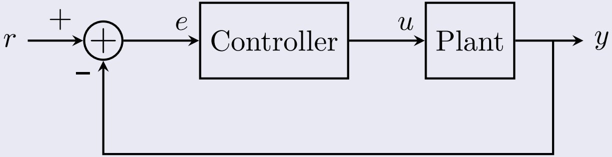
Closed loop system

Closed loop system with negative feedback



PID Controller model

Theoretical model:

$$u(t) = K_P e(t) + K_I \int e(t)\,\mathrm{d}t + K_D \frac{\mathrm{d}}{\mathrm{d}t}(e(t)) \quad (1)$$

$$\frac{u(s)}{e(s)} = K_P + K_I \left(\frac{1}{s}\right) + K_D s \quad (2)$$

Implementation model:

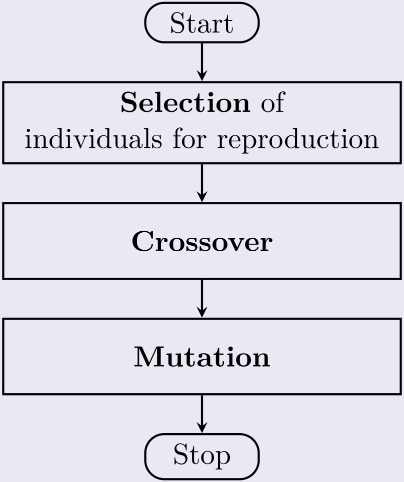
$$\frac{u(s)}{e(s)} = K_P + K_I \left(\frac{1}{s}\right) + K_D \left(\frac{Ns}{s+N}\right) \quad (3)$$

Tunable Parameters

K_P, K_I, K_D, and N

Genetic algorithm

Steps for New Generation



Genetic algorithm

Result: Obtain the optimum (fittest) individual for the environment

```
Start;
Generate initial population;
Identify the fittest individual;
while Need improvement do
    Make a new generation;
    Identify the fittest individual;
end
Stop;
```

Genetic algorithm

GA applied to PID Tuning

Result: Obtain the optimum individual (a set of values for K_P, K_I, K_D, and N) to suit the system

```
Start;
Generate initial population (a set of individuals);
Identify the fittest set of values;
while Error of the fittest individual is high do
    Under go the evolution to make a new generation ;
    Identify the fittest individual;
end
Stop;
```

Identification: This process involves testing each individual one after another and measuring error during its application period. The fittest is the one with minimum error.

The following problems may arise in the traditional GA based PID tuning.

1. Estimation errors caused due to other individuals,
2. Instability due to incompatible individuals, and
3. A set of tuned parameters may cause inferior performance to an inconsistent operating point.

Improved genetic algorithm

Proposed algorithm for finding the fittest individual

Data: Population $C \in \mathbb{R}^{n \times 4}$; Previsous generation's fittest individual C_F^-

Result: Find the fittest individual C_F

for $C_i \in C$ **do**
    Apply C_F^- for a certain time period;
    Apply C_i for a certain time period and calculate the root mean square error (RMSE), E_i, during this period;
    if *RMSE is in limit* **then**
        Wait till time finish;
    else
        Break;
    end
end
Individual with minimum RMSE is selected as C_F;

The proposed novel GA to tune PID parameters

Result: Obtain the optimum individual (a set of values for K_P, K_I, K_D, and N) to suit the system

```
1  Start;
2  Generate initial population (a set of individuals);
3  Identify the fittest individual using the proposed algorithm;
4  while Error of the fittest individual is high do
5  |   Under go the evolution to make a new generation ;
6  |   Identify the fittest individual using the proposed algorithm;
7  end
8  Measure moving root mean square error, M_E;
9  if M_E out of limits then
10 |   Goto 4;
11 else
12 |   Goto 8;
13 end
```

Simulation setup

A simulation is designed to change the plant from

$$\frac{y(s)}{u(s)} = \frac{s+3}{8s^2+5s+2}$$

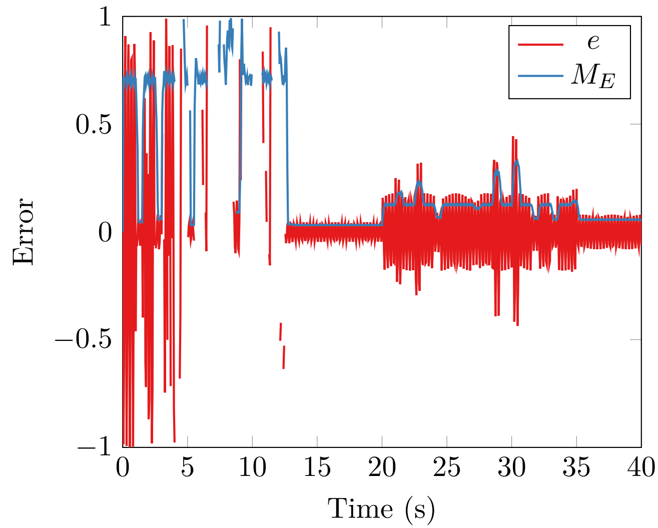
to

$$\frac{y(s)}{u(s)} = \frac{s+1}{2s^2+s+3}$$

at time $t = 20\,\mathrm{s}$.

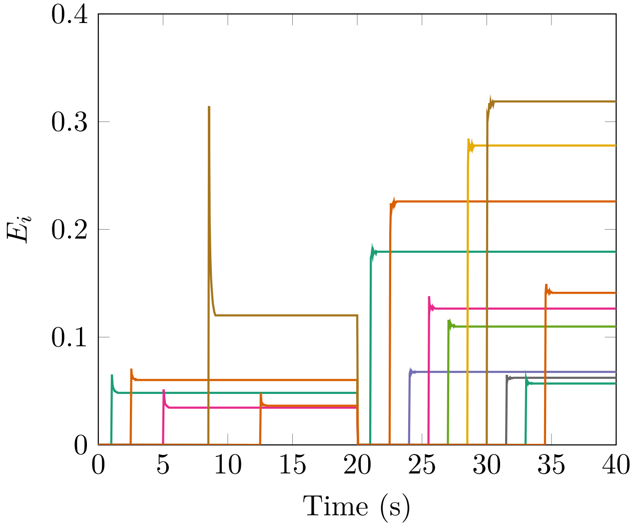
Simulation results

Simulation results showing error and moving RMS error for closed loop system whose plant is modified at $t = 20\,\mathrm{s}$.



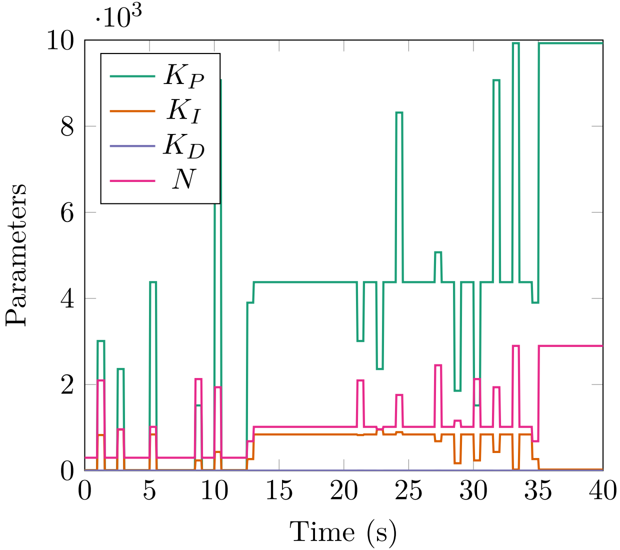
Simulation results

Simulation results showing the values for the objective function, E_i, $i \in \{1, 2, 3, \ldots, 10\}$



Simulation results

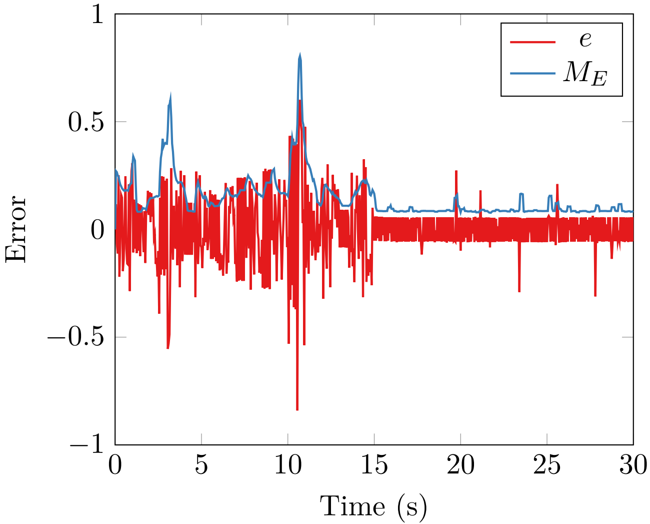
Simulation results showing parameter tuning by Genetic algorithm



Experimental setup

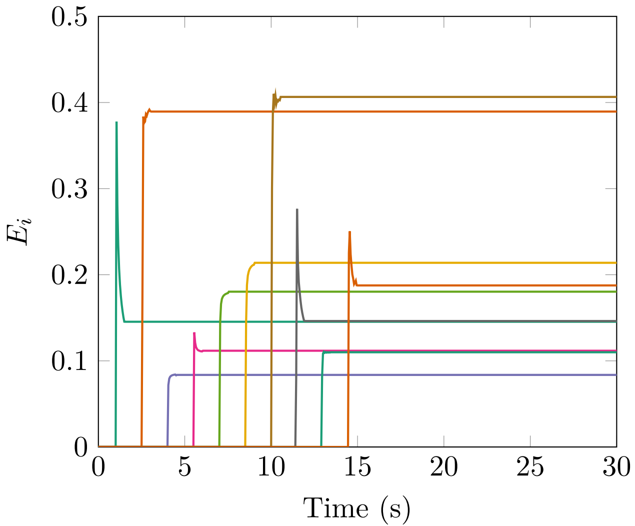
Experimental results

Experiment results showing error and moving RMS error for a closed loop system controlling a brushless servomotor in torque mode



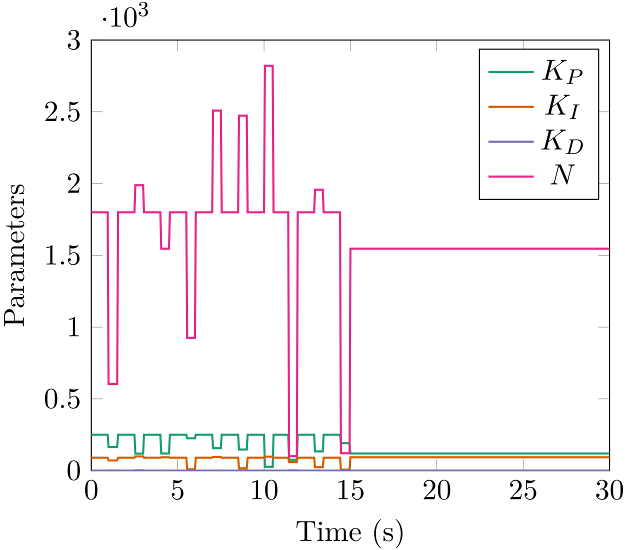
Experimental results

Experimental results showing the values for the objective function, E_i, $i \in \{1, 2, 3, \ldots, 10\}$



Experimental results

Experiment results showing parameter tuning by Genetic algorithm



Conclusions

The following problems associated with the implementation of the standard genetic algorithm based PID tuning algorithm are identified.

1. Estimation errors caused due to other chromosomes,
2. Instability due to incompatible chromosomes, and
3. A set of tuned parameters may cause inferior performance to an inconsistent operating point.

These are solved by implementing the following:

1. Wait for a certain period of time in between the application of two chromosomes.
2. Put a certain allowed maximum value for the error. If the system reaches beyond this, controller uses previous stable parameters.
3. Controller monitors the performance continuously and implements genetic algorithm if required.

Thank you

for your attention.