Adaptive PID

AI lab, LG Electronics.

Classical PID

PID stands for:

- P (proportional)
- I (Integral)
- D (Derivate)

Standard form of PID is

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{\partial}{\partial t} e(t)$$

Limitation of PID

1. PID only works in LTI-system. Therefore, it should be possible to assume that the dynamics of past and the present are almost the same.
2. In PID, one controller cannot cope with more than two environments.

Classical vs Adaptive PID

Classical PID controll in NEXT3

1. $2evastate = F$.

$$u_1(t) = K_p e_1(t) + K_i \int_0^t e_1(\tau) d\tau + K_d \frac{\partial}{\partial t} e_1(t)$$

2. $2evastate = R$.

$$u_2(t) = \tilde{K}_p e_2(t) + \tilde{K}_i \int_0^t e_2(\tau) d\tau + \tilde{K}_d \frac{\partial}{\partial t} e_2(t)$$

Here $e_1(t) = Ftemp - Fsp$ and $e_2(t) = Rtemp - Rsp$.

Adaptive PID controll in NEXT3

$$u(t) = L(t) K_p e(t, \lambda) + K_i \int_0^t e(\tau, \lambda) d\tau + K_d \frac{\partial}{\partial t} e(t, \lambda)$$

where $e(t, \lambda) = e_2 + \lambda e_1$ for any $\lambda \in (0, 1)$ and $L(t)$ inverse probability density function of Laplace distribution at t.

Adaptive PID

How to solve following problem:

"PID only works in LTI-system."

The role of $L(t)$: Detect system change automatically. $\Longrightarrow$ It has the effect as like using a PID controller for two or more LTI systems.

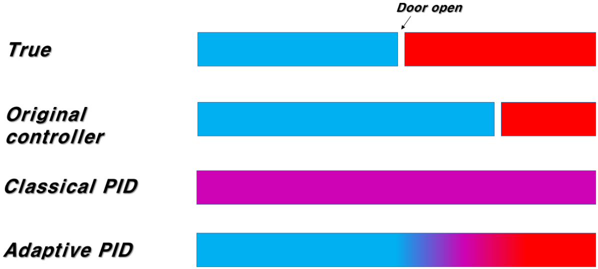
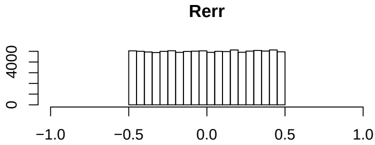


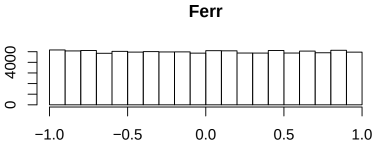
Figure 1: First row represent the situation that the user opened the refrigerator door at t_0. The next three rows describe the process of understanding and controlling the refrigerator situation with different algorithms.

Adaptive PID

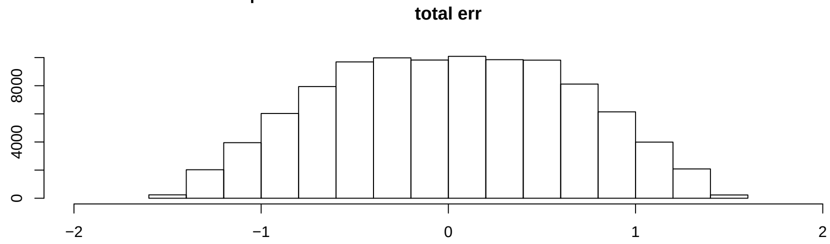
How to design $L(t)$?

Let $X_1, \ldots, X_n \overset{iid}{\sim} U(0,a)$ and $Y_1, \ldots, Y_n \overset{iid}{\sim} U(0,b)$.



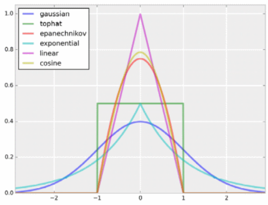


The probability density function of $X + \lambda Y$ can be obtain by **convolution** of above two histogram, i.e., $f_{X+\lambda Y}(\cdot) = (f_X * f_{\lambda Y})(\cdot)$. Here λ controlls dispersion of Y.



Adaptive PID

How to estimate the density of $X + \lambda Y$ from emprical distribution? (1) Parametric method and (2) Non-parametric method, i.e., kernel density estimation.



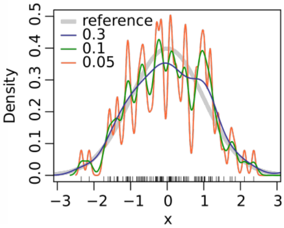


Figure 2: Left: parametric method, Right: Kernel-density estimation

Adaptive PID

We use the Laplace distribution $f(x)$ such that

$$f(x|\mu, b) = \frac{1}{2b} \exp\left(-\frac{|x-\mu|}{b}\right)$$

and choose $\mu = 0$ huristically and estimate b from data. Define $L(t)$ as inverse of probability density function at t by subsituting $x = e_t$, i.e.,

$$L(t) = \frac{1}{\frac{1}{2b} \exp\left(-\frac{|e_t|}{b}\right)}$$

where $e_t = (Ftemp - Fsp) + \lambda(Rtemp - Rsp)$.

Adaptive PID

Note that b controlls the smoothness of shifting two LTI-system, Thus it can controlls the trade-off between energy-saving and ability of controlling temperature.

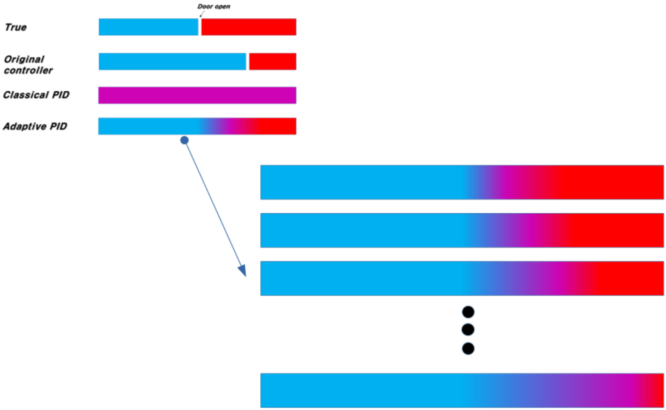


Figure 3: Effect of parameter b.

Experiments

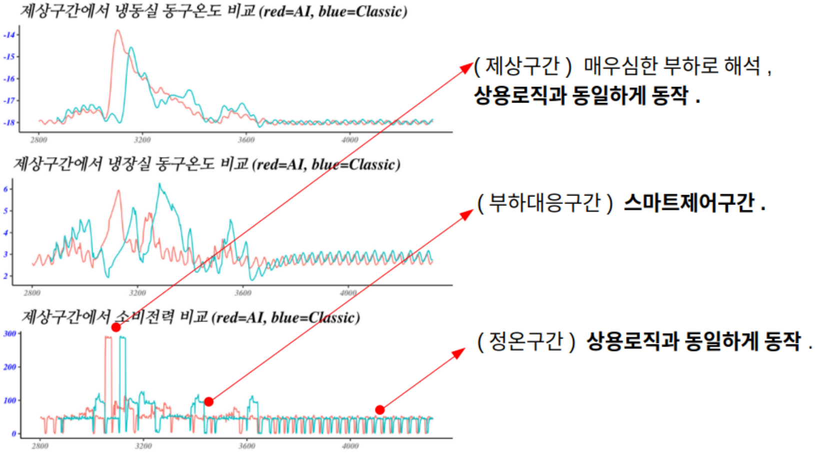


Figure 4: Results of adaptive-PID alogrithm in SAMART-GRID.