1.0 Introduction

- Challenge of batch process control:
  - highly nonlinear
  - varying with time
- In some cases (polymerisation)
  - heat is liberating during processing (EXOTHERMIC)
- If heat released > plant cooling capacity (Thermal runaway)
  - reaction becomes unstable
    - affect the final product quality
    - affect the profit
    - has potential to harm workers, public and environment

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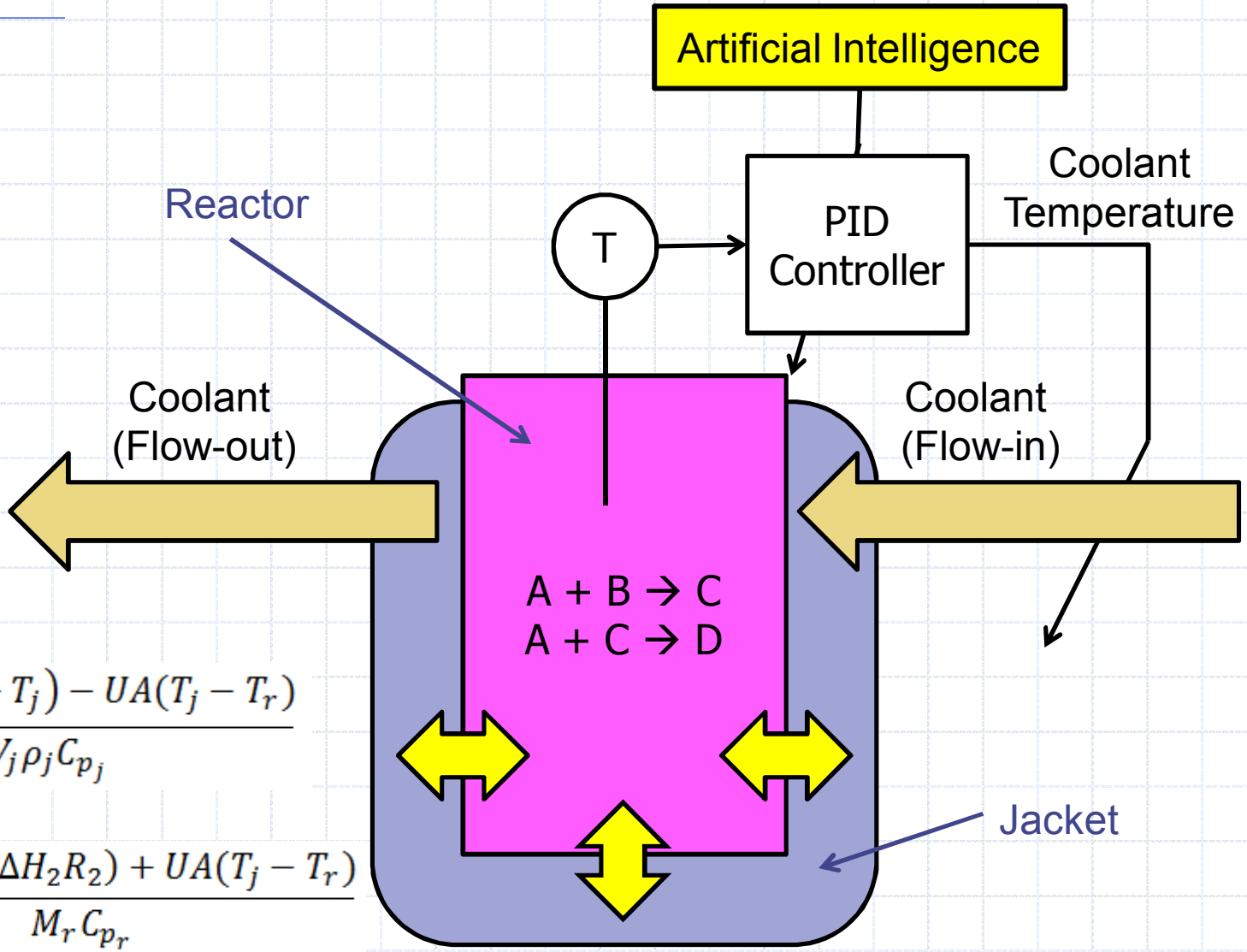
1.0 Introduction



$$\frac{dT_j}{dt} = \frac{F_j \rho_j C_{p_j}(T_c - T_j) - UA(T_j - T_r)}{V_j \rho_j C_{p_j}}$$

$$\frac{dT_r}{dt} = \frac{(-\Delta H_1 R_1 - \Delta H_2 R_2) + UA(T_j - T_r)}{M_r C_{p_r}}$$

2.0 Objective

- The purpose of this paper is to present a PID optimization technique using a newly design genetic algorithm (GA) to improve the batch operation performance.
- This proposed method with the additional information of the online estimated model parameters is able to adapt its fitness function and then evolve an optimum set of PID parameters to control the reactor temperature.

3.0 Methodology (Framework of GA)

- Fitness function:

$$T_{est} = M \times T_c + C$$

$$Fitness = \frac{1}{(T_r - T_{est})^2} + \frac{1}{(T_{ref} - T_{est})^2}$$

- Selection:
  - Fittest solutions will have higher chance to become the parents

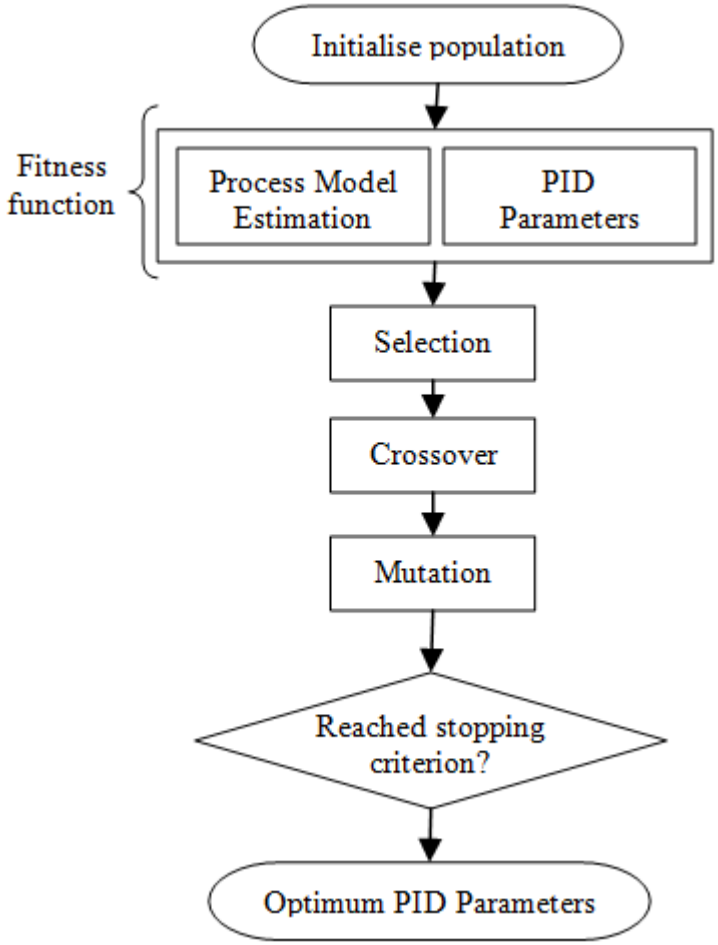
- Crossover:

$$x_{n1} = \beta \cdot x_{p1} + (1-\beta) \cdot x_{p2}$$

$$x_{n2} = \beta \cdot x_{p2} + (1-\beta) \cdot x_{p1}$$

- Mutation
  - To prevent trap in local maxima

- Stopping criteria



4.0 Simulations

- The plant model developed by Cott and Machhietto (1989) is used as the case study

Reaction 1: $A + B \rightarrow C$
Reaction 2: $A + C \rightarrow D$

where

A and B = reactants
C = desired product
D = undesired by-product

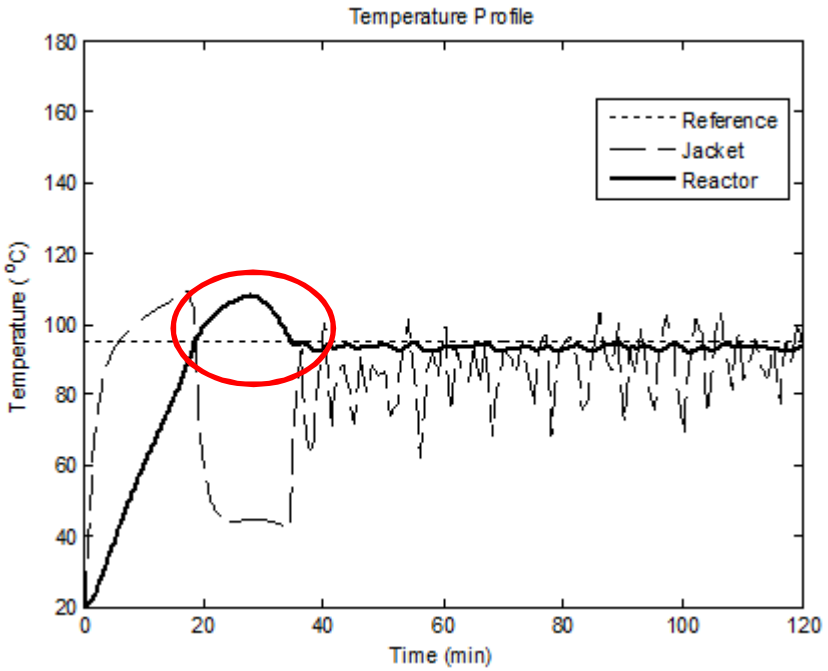
- Plant design constraint:
  - The heat exchanger capacity is limited in the range of 20°C to 120°C.
  - The jacket temperature will not exceeds this temperature range

4.0 Simulations

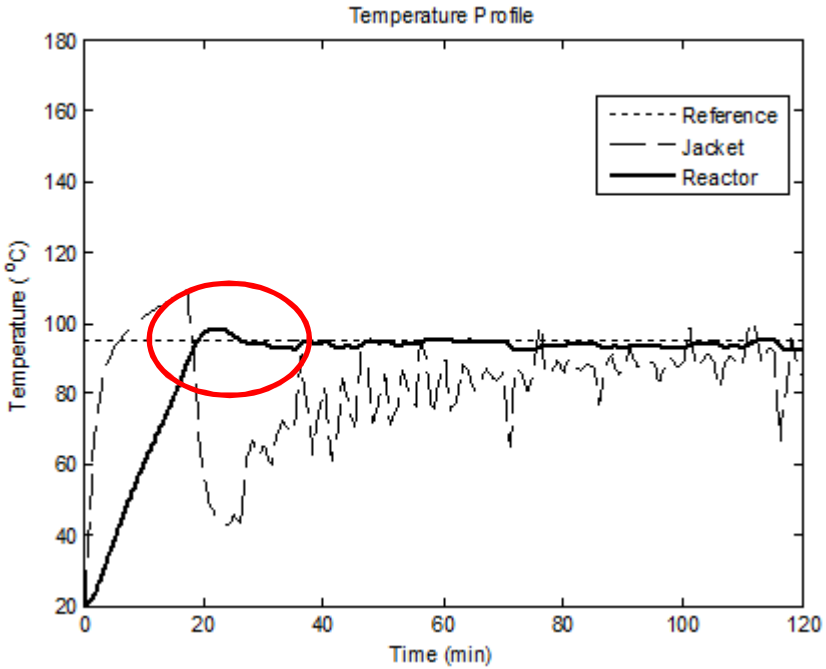
- The performance of proposed GA-PID is compared with performance of regular GA-PID controller

- Robustness tests:
  - Model mismatch condition
    - 30 % and 10 % increment from the nominal value in reaction rate 1 and reaction rate 2 respectively (unmodelled reactions)
  - Disturbance
    - a sudden shut down of the valve in jacket inlet stream at time 20 min to 23 min, and 90 min to 95 min.
  - Combination of model mismatch condition and disturbance situations

5.0 Results and Discussions (Model Mismatch Condition)



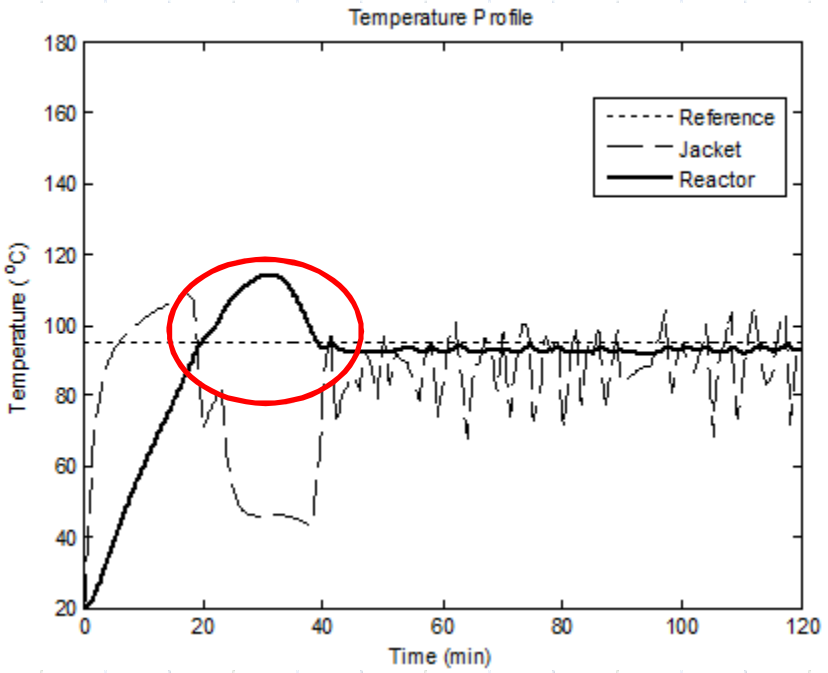
Regular GA-PID performance



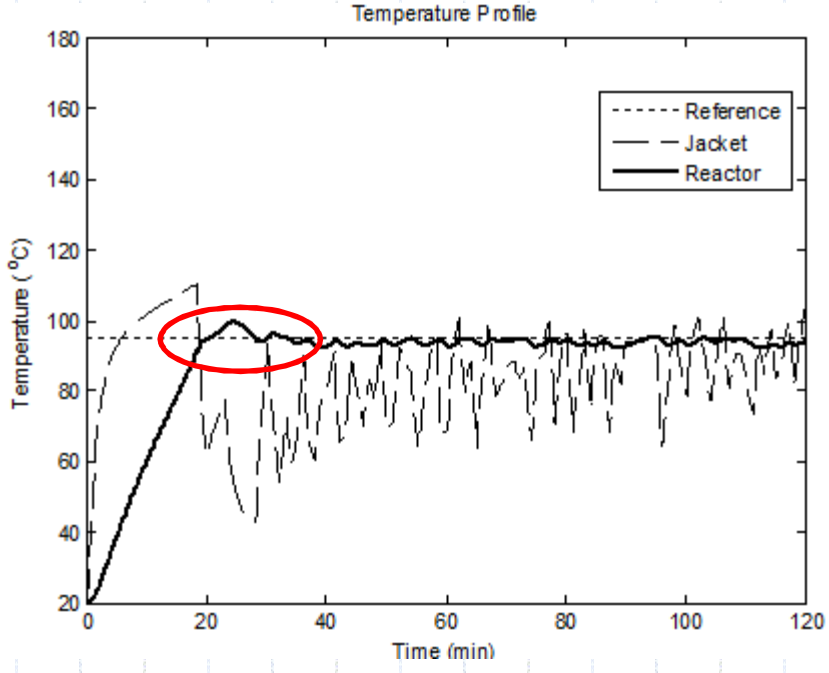
Proposed GA-PID performance

The regular GA-PID with predetermined model parameters has an acceptable performance, whereas the proposed method shows that the proposed GA-PID has the best performance since it has the smallest overshoot in the reactor temperature

5.0 Results and Discussions (External Disturbance)



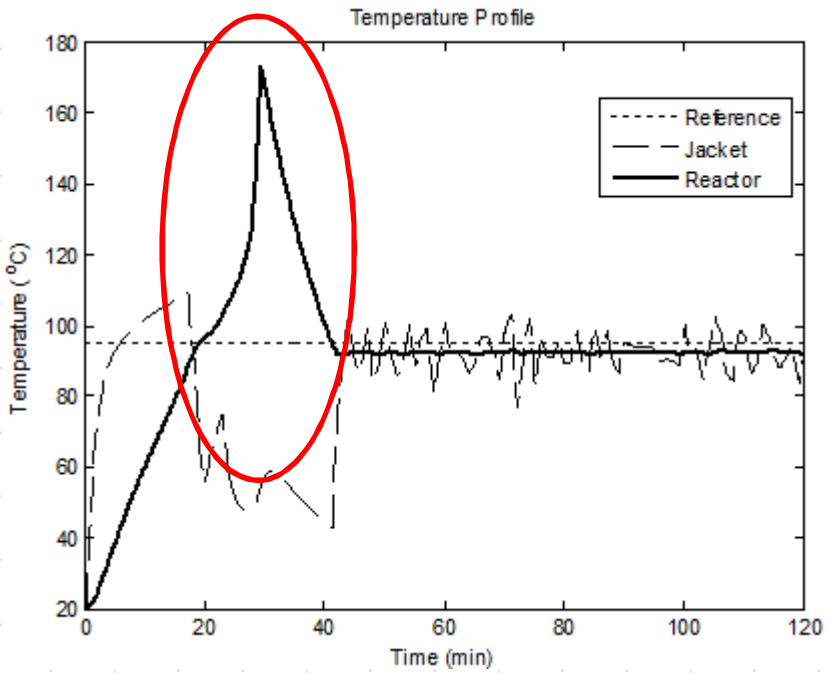
Regular GA-PID performance



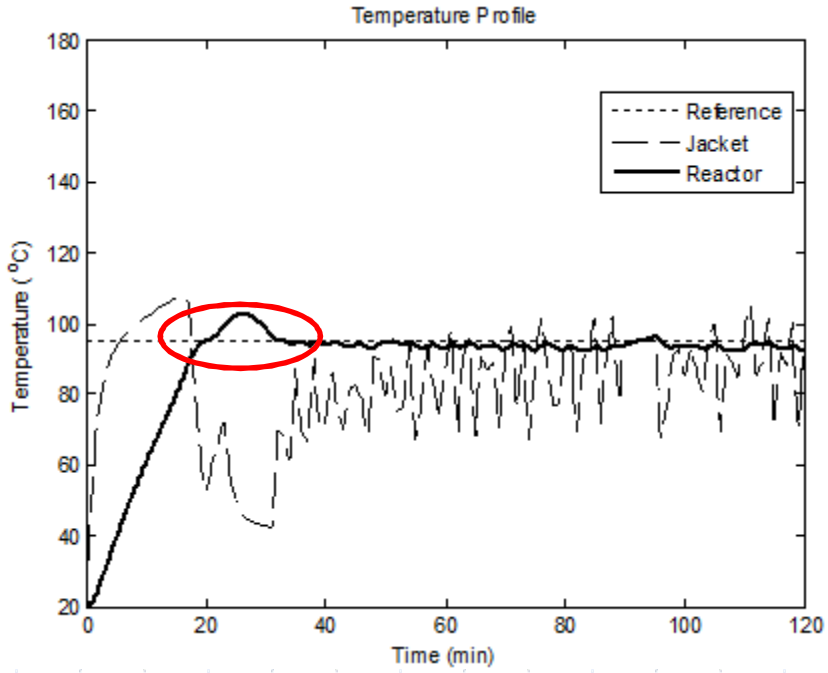
Proposed GA-PID performance

The results show that the proposed control technique has the best performance in controlling the temperature when the external disturbance is introduced.

5.0 Results and Discussions (Model Mismatch + Disturbance)



Regular GA-PID performance



Proposed GA-PID performance

The vigorous parameters changes force the process towards instability. Regular GA-PID with predetermined model in fitness function is not able to prevent the temperature runaway effectively. On the other hand, proposed GA-PID shows a less overshoot in the reactor temperature before the desired temperature is attained.

6.0 Conclusions

- In this study, an exothermic process model with online estimated model parameters with the GA optimization scheme of PID controller has been developed based on the characteristic of the batch process.

- The proposed control technique consists of two components: optimization scheme and controller.

- The proposed GA optimizer is used to adapt its fitness function parameters and then optimize the PID parameters, whereas PID controller is used to control the reactor temperature by controlling the coolant temperature.

- From the simulation results, it can be verified that the proposed control method provides a more effective solution in temperature control due to its robustness against the variable time delay, model mismatch and external disturbance situations compared to the regular GA-PID with predetermined model parameter