Auto Tuning of PID Controller using Artificial Intelligence

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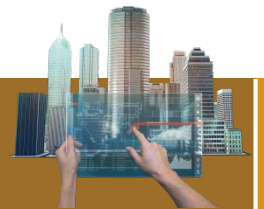
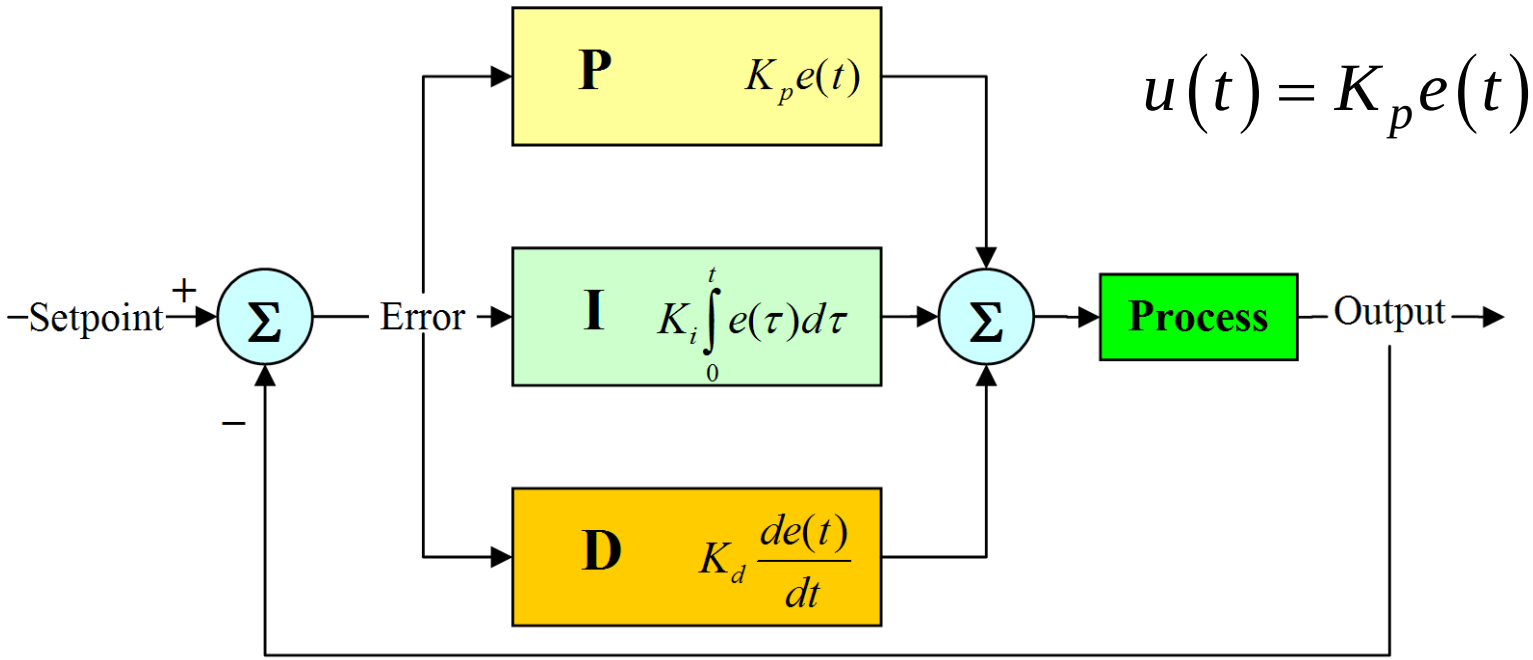


PID controller

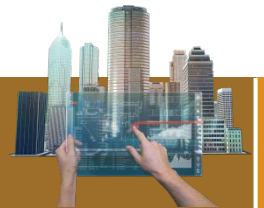


$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\,d\tau + K_d \frac{de(t)}{dt}$$

$$G_{sys}(s) = \frac{b_1 s + b_0}{a_2 s^2 + a_1 s + a_0}$$

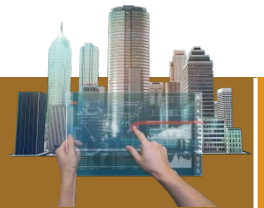
Tuning process

- Adjustment of:
  - Proportional gain K_p
  - Integral gain K_i
  - Derivative gain K_d
- Basic requirement is stability, but others can be considered such as:
  - peek overshoot
  - rising time
  - settling time



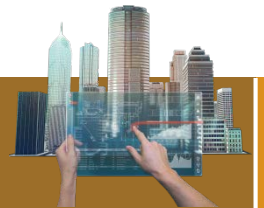
Genetic Algorithm

- Stochastic search algorithm based on principles of evolution:
  - Selection
  - Crossover
  - Mutation
- Each solution candidate is called individual, described by its genotype
- Set of individuals – population
- Iteration - generation



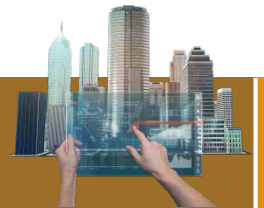
Genetic Algorithm

- Fitness of an individual is measured by optimization criteria
- Based on fitness, individuals are selected as the parents for crossover forming a new generation of descendants
- Descendants are result of recombination of parent's genotype and random mutation of genes.
- Consequence: wider coverage of the search space

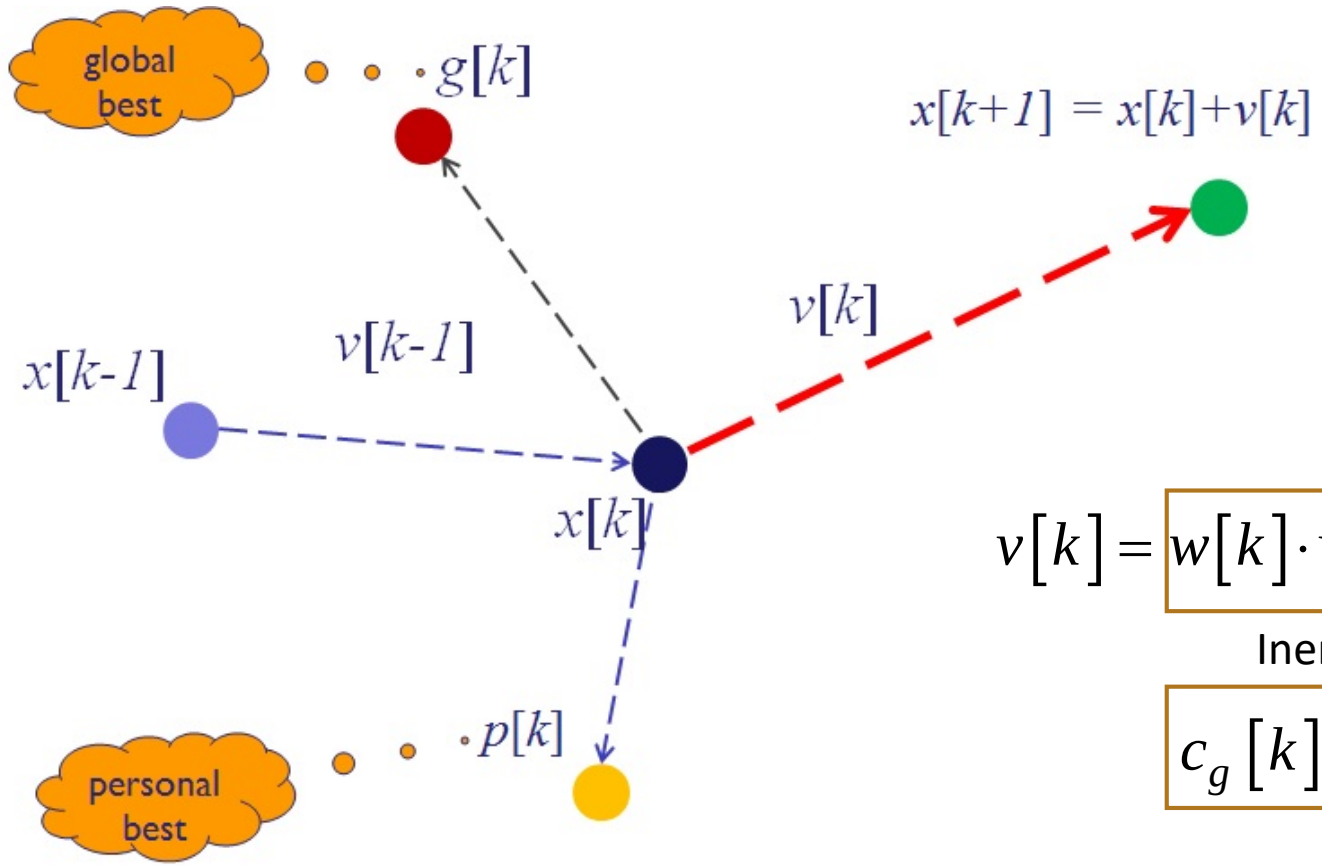


Particle Swarm Optimization

- PSO is iterative algorithm based on imitation of the behavior of animal groups (birds, fish or insects)
- Each solution candidate is called particle
- Set of particles – swarm
- Each particle remembers their best position, *p*
- Swarm remembers the best position ever attained by any of its particles, *g*



Particle Swarm Optimization



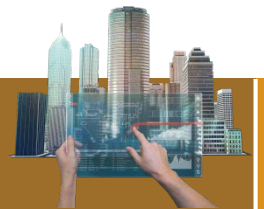
$$x[k+1] = x[k] + v[k]$$

$$v[k] = \underbrace{w[k] \cdot v[k-1]}_{\text{Inertial}} + \underbrace{c_p[k] \cdot r_p[k]\left(p[k] - x[k]\right)}_{\text{Cognitive}} + \underbrace{c_g[k] \cdot r_g[k]\left(g[k] - x[k]\right)}_{\text{Social}}$$

Auto tuning of PID controller

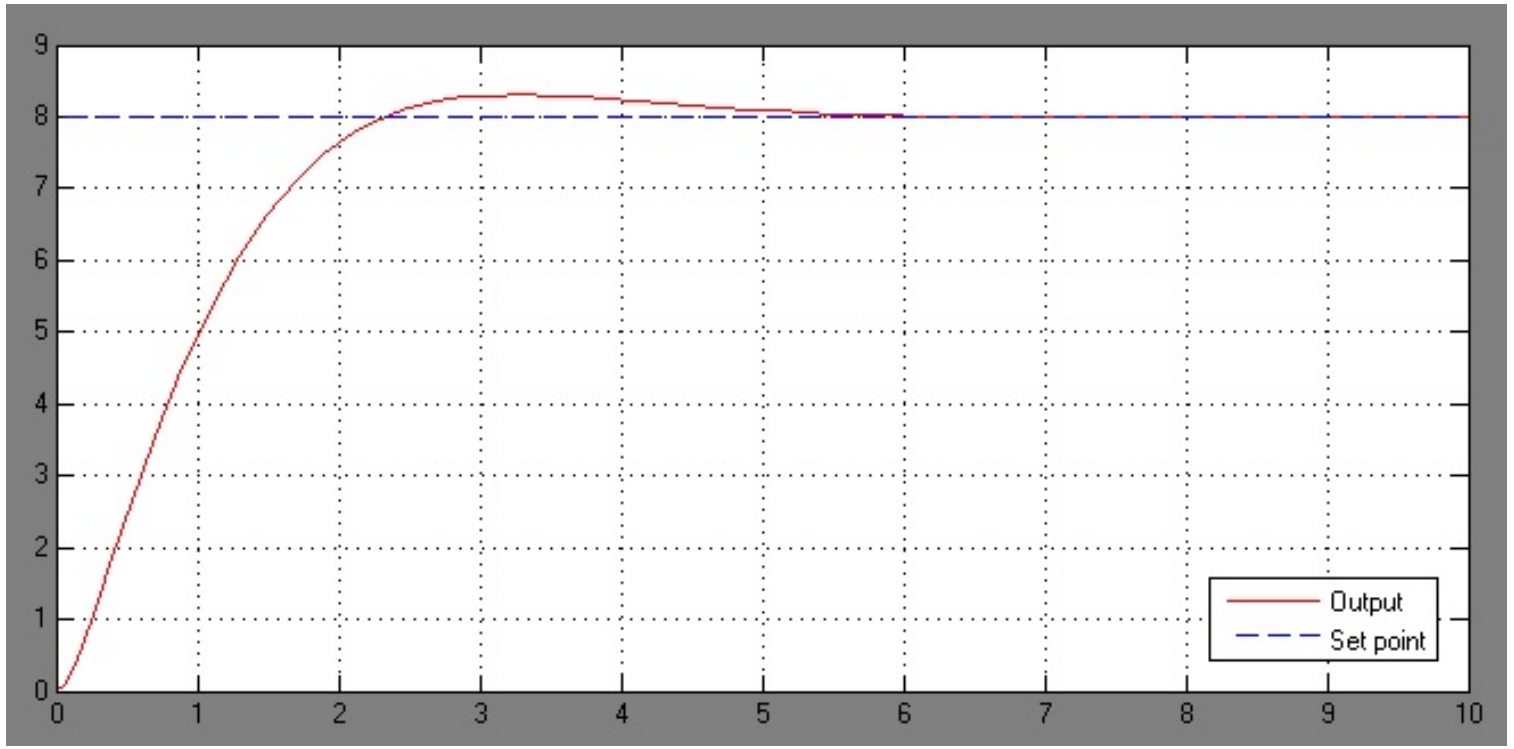
- Potential solutions are given in form of [K_p K_i K_d].
- Every potential solution is graded using fuzzy logic based on peak overshoot and transient time
- 30 potential solutions are propagated through 30 iterations
- In HVAC systems, supply air pressure is regulated by the speed of supply air fan:

$$G_{sap}(s) = \frac{1}{0.12s^2 + 1.33s + 1.24}$$



Results and discussion

› GA– best solution obtained after 22 iterations



$$K_p = 0.92303$$

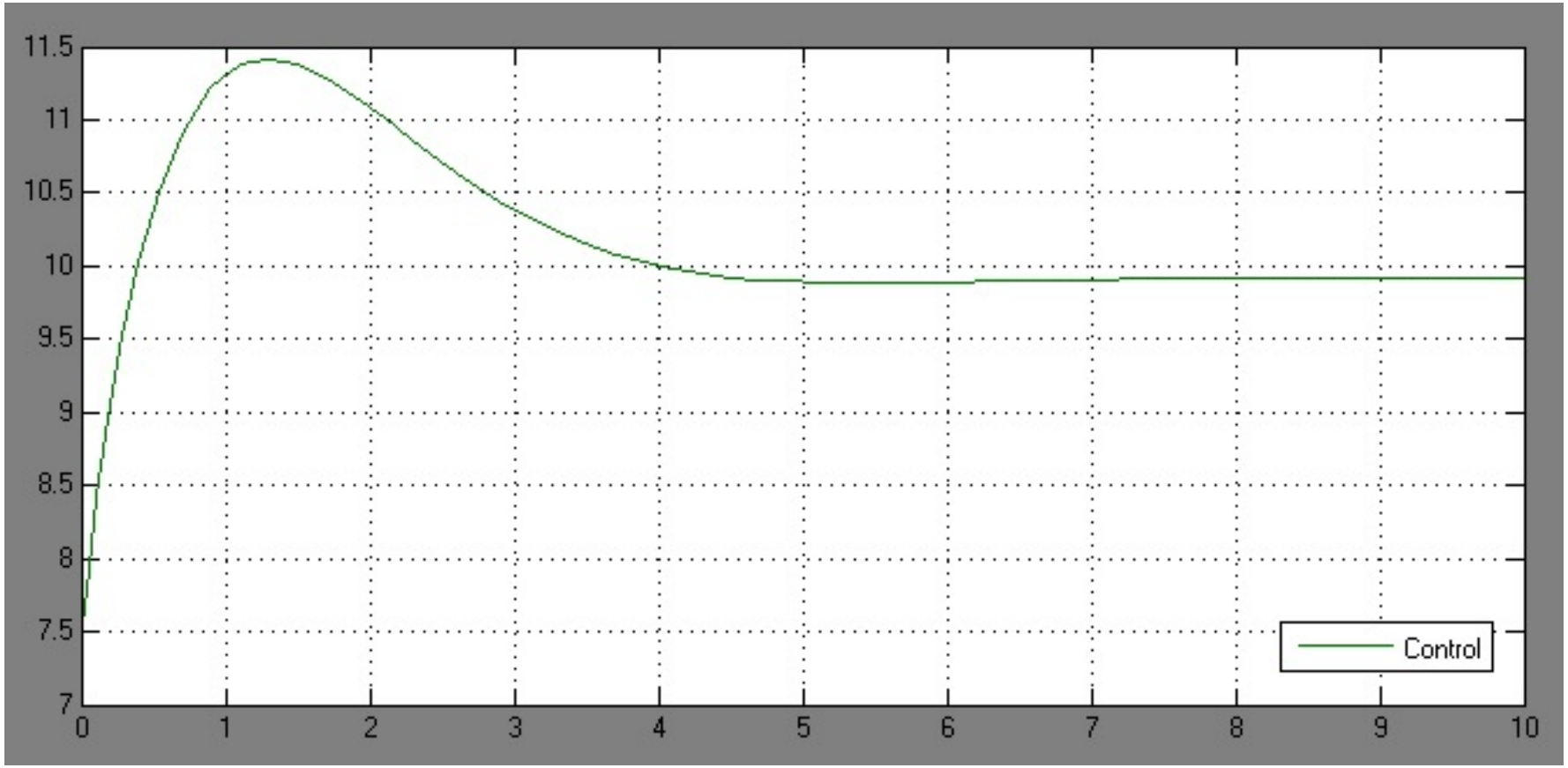
$$K_i = 1.5221$$

$$K_d = 0.021553$$

Overshoot: 3.79%

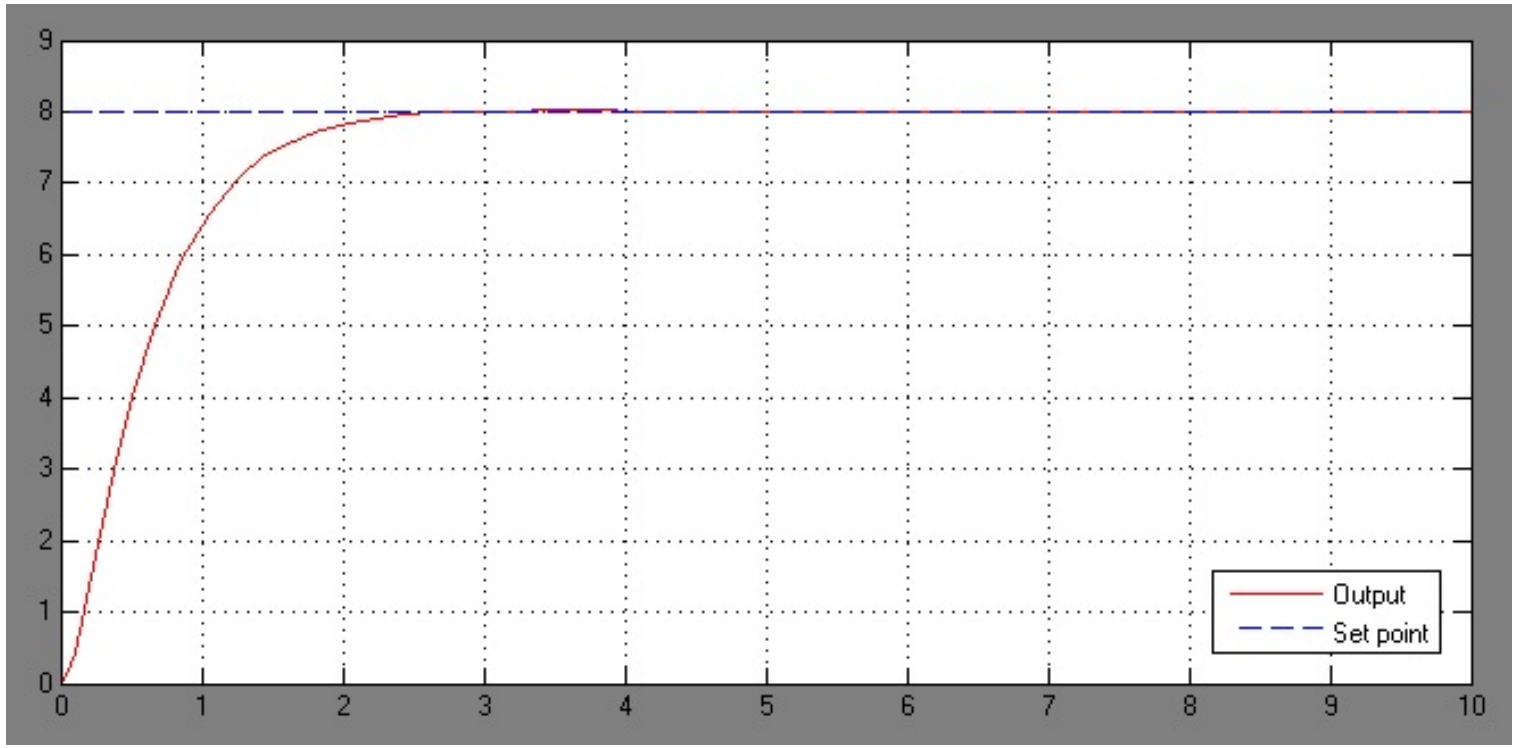
Settling time: 6.29 s

Results and discussion



Results and discussion

› PSO– best solution obtained after 7 iterations



$K_p = 1.802$

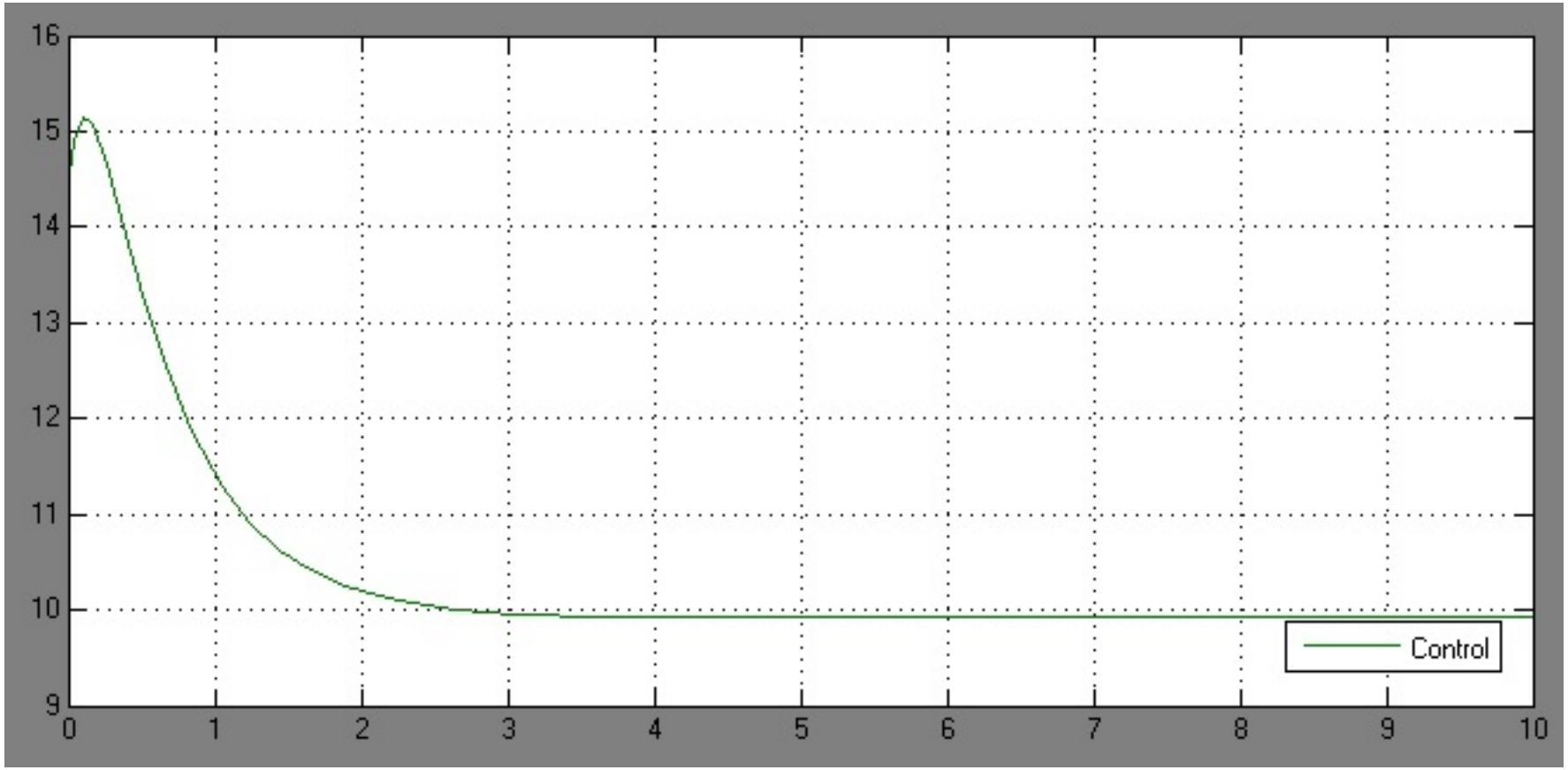
$K_i = 1.9504$

$K_d = 0.2473$

Overshoot: 0.1942%

Settling time: 3.31 s

Results and discussion



Conclusion

- Search algorithms are depending on initial solution set
  - It is preferable to have large set of solution candidates – time consuming
- Multiple executions of the auto tuning algorithms have shown that even with smaller sets of candidates PSO algorithm is faster in obtaining the optimal PID parameters and system response, was always better regarding the overshoot and settling time
- PSO particles are much more flexible having greater freedom of movement in the search space