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Controller Tuning for DC Motor Speed Control Using Genetic Algorithms

Saurabh Jain
Cleveland State University, s.jain1@csuohio.edu

Daniel J. Simon
Cleveland State University, d.j.simon@csuohio.edu

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Controller Tuning for DC Motor Speed Control Using Genetic Algorithms

Saurabh Jain
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September 21, 2004

Presentation Overview

- Purpose of research
- Solution strategy
- Introduction to Genetic Algorithms (GA's)
  - Concept of GAs
  - Basic Algorithm
  - Representation
- Simplorer and Matlab implementation
- Conclusions and future work

Purpose of research

- To investigate a new method (Diploid GA) of motor control
- To use Simplorer to evaluate design performance
- To consider a broad optimization function for parameter evaluation

Problem Statement

- Speed Control of DC Motors
  - Controller tuning (finding Kp & Ki)
- Aerospace Applications
  - Flywheel energy storage
  - Flight control trim surfaces
  - Hydraulics
  - Fans
  - Thrust vector control
  - Fuel pumps

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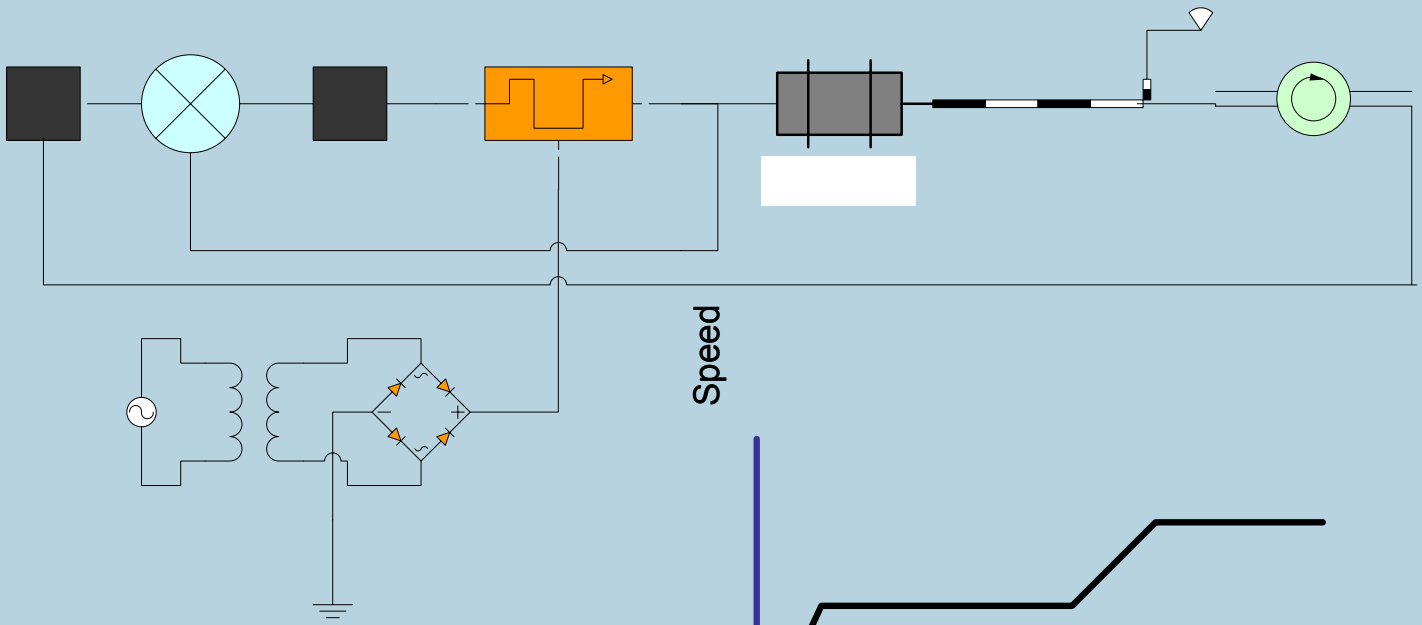
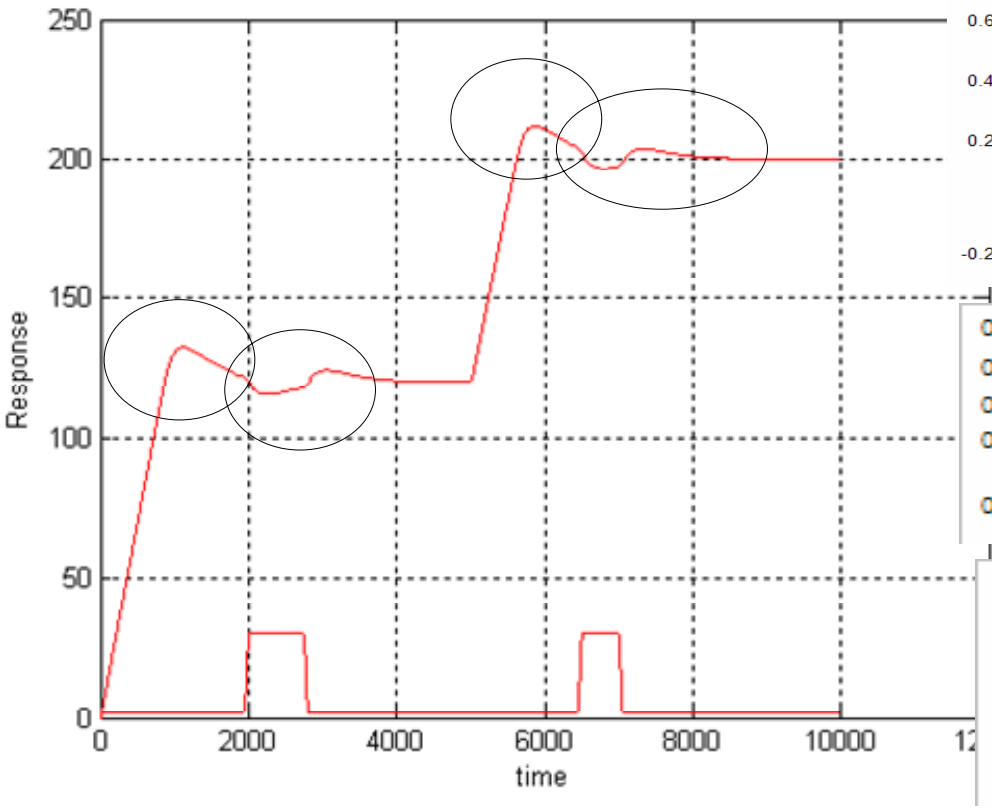
Solution Strategy

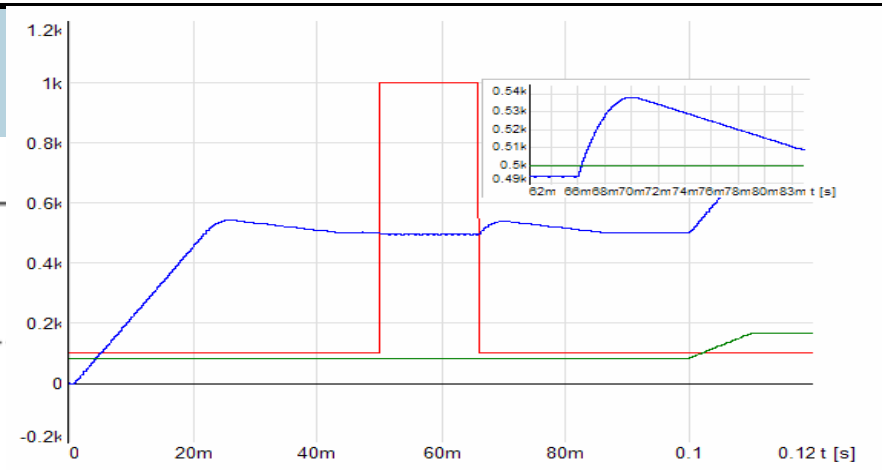


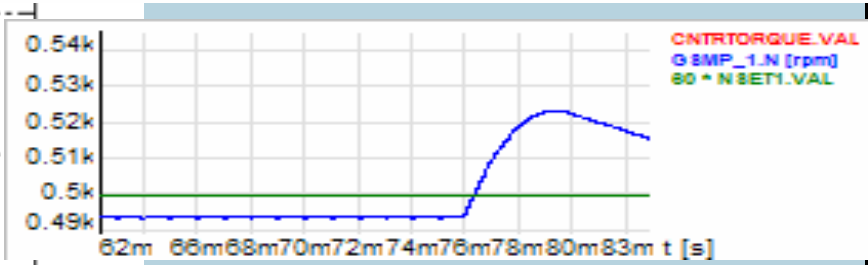
POSITION/
SPEED
CURR

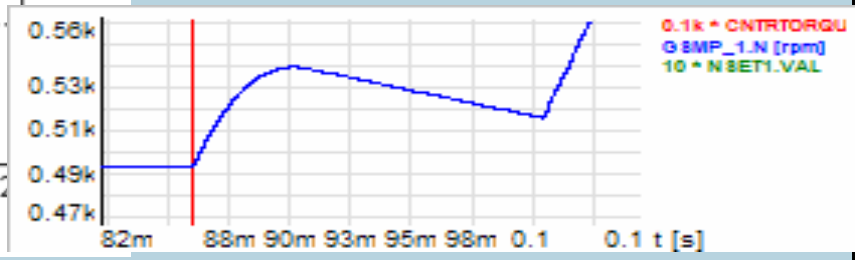
Optimization function I

Minimize Overshoots









Optimization function II

$$F_s = \phi(i(t), O_m(t))$$

$$F_s = w_1 \max_t i_a(t) + (k_1 O_m|_{s1} + k_2 O_m|_{tc} + k_3 O_m|_{s2} + k_4 O_m|_{tc})$$

$$\min F_s \text{ or } \max 1/F_s$$

O_m is the maximum overshoot

i_a is the rotor current

k_i are the weighting factors

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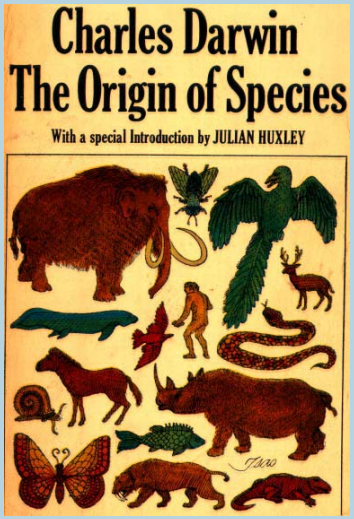
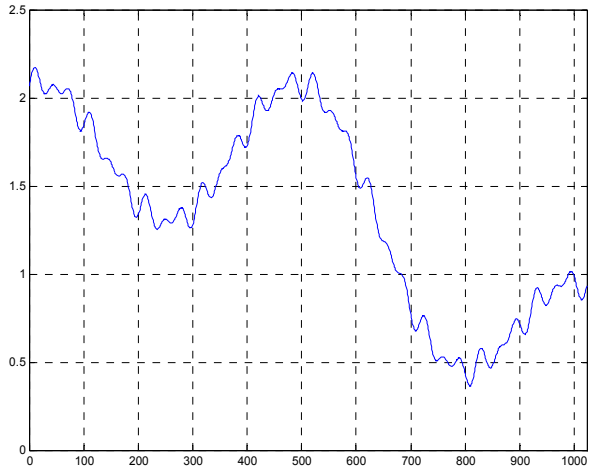
Introduction to GAs

- Genetic algorithms (GA's) are a technique to solve problems which need optimization
- GA's are a subclass of **Evolutionary Computing**
- GA's are based on Darwin's theory of evolution



Concept of GAs I

- Most often one is looking for the best solution in a specific subset of solutions
- This subset is called the **search space** (or state space)
- Every point in the search space is a possible solution
- Therefore every point has a fitness value, depending on the problem definition
- GA's are used to search the search space for the best solution, e.g. a minimum
- Difficulties are the local minima and the starting point of the search



Concept of GAs II

- Starting with a subset of *n* randomly chosen solutions from the search space (i.e. chromosomes). This is the **population**
- This population is used to produce a next **generation** of individuals by reproduction
- Individuals with higher **fitness** have more chance to reproduce (i.e. natural selection)

The Basic Algorithm

0 **START** : Create random population of **n** chromosomes

1 **FITNESS** : Evaluate fitness **f(x)** of each chromosome in the population

2 **NEW POPULATION**

- 0 **SELECTION** : Based on **f(x)**
- 1 **RECOMBINATION** : Cross-over chromosomes
- 2 **MUTATION** : Mutate chromosomes
- 3 **ACCEPTATION** : Reject or accept new one

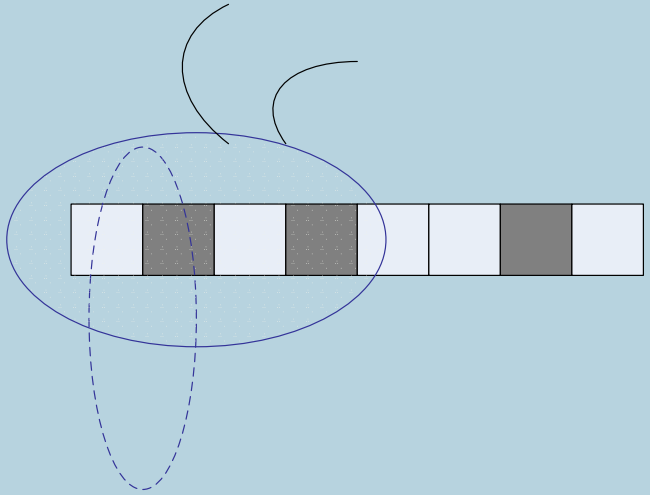
3 **REPLACE** : Replace old with new population: the new generation

4 **TEST** : Test problem criterium

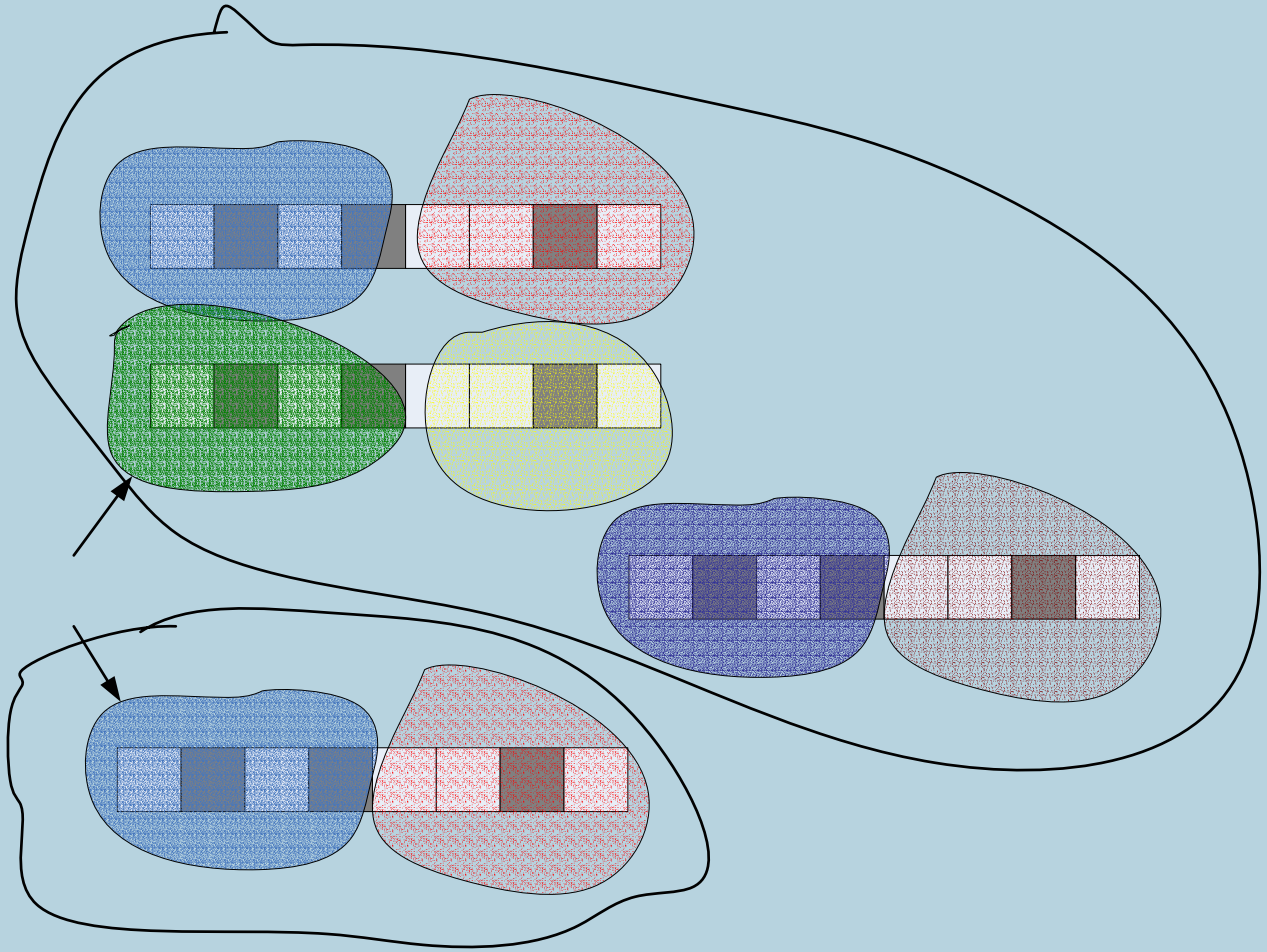
5 **LOOP** : Continue step 1 – 4 until criterium is satisfied

Representation I

- Genetic information is stored in the **chromosomes**
- Each chromosome is build of **DNA**
- The chromosome is divided in parts: **genes**
- Genes code for properties
- The posibilities of the genes for one property is called: **allele**
- Every gene has an unique position on the chromosome: **locus**



Types of GAs



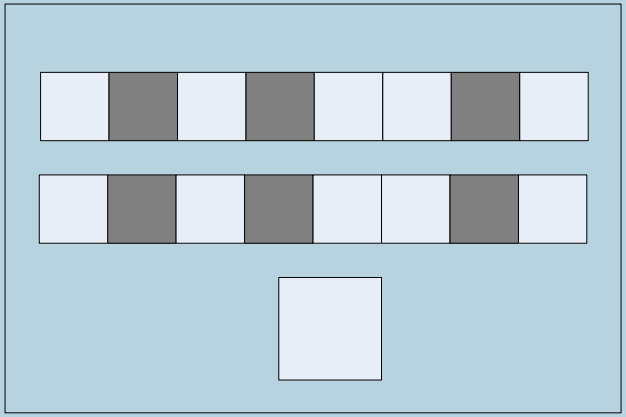
Haploid GAs
- Easy to use
- Less Computation

Diploid GAs
- Good for Dynamic Environments
- More Diversity

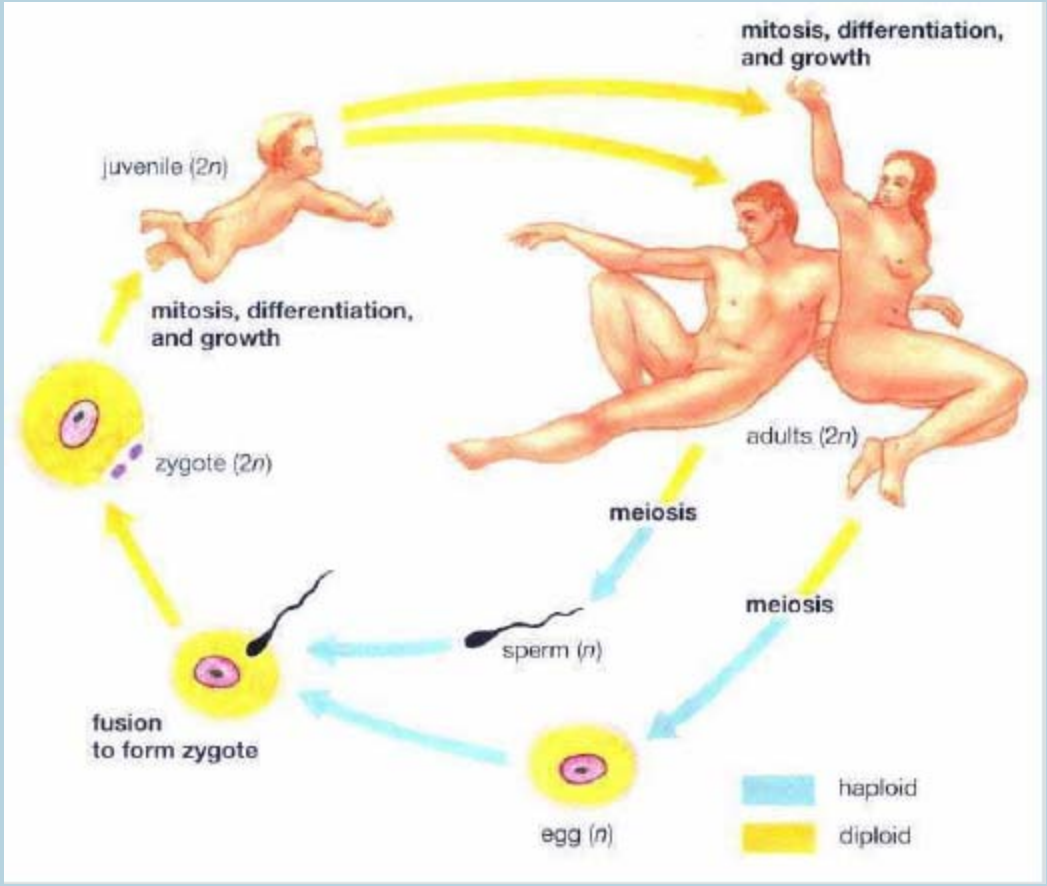
Eye Color

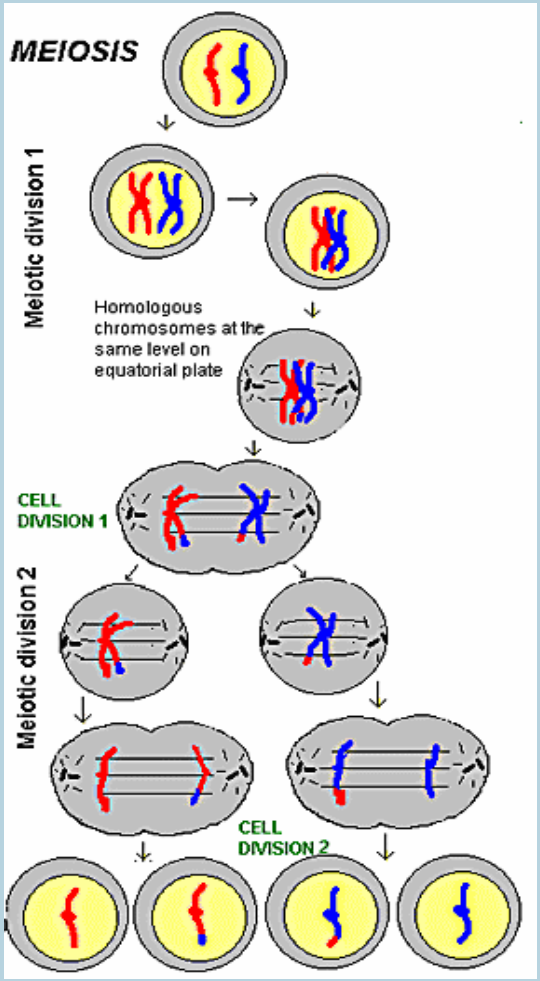
Representation II

- The entire combination of genes is called genotype
- A genotype develops to a phenotype
- Alleles can be either dominant or recessive
- Dominant alleles will always express from the genotype to the phenotype
- Recessive alleles can survive in the population for many generations, without being expressed

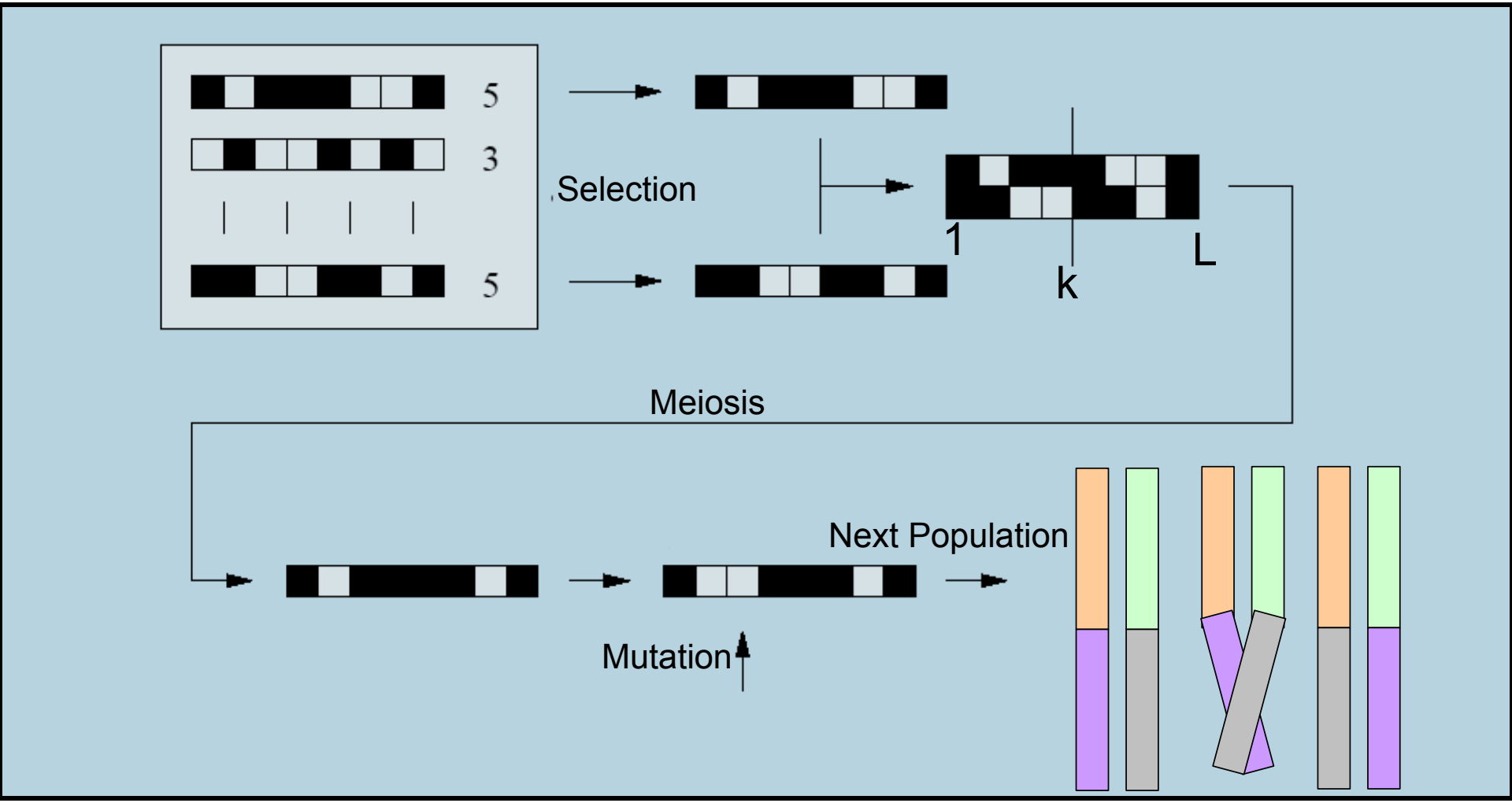


Cell Division

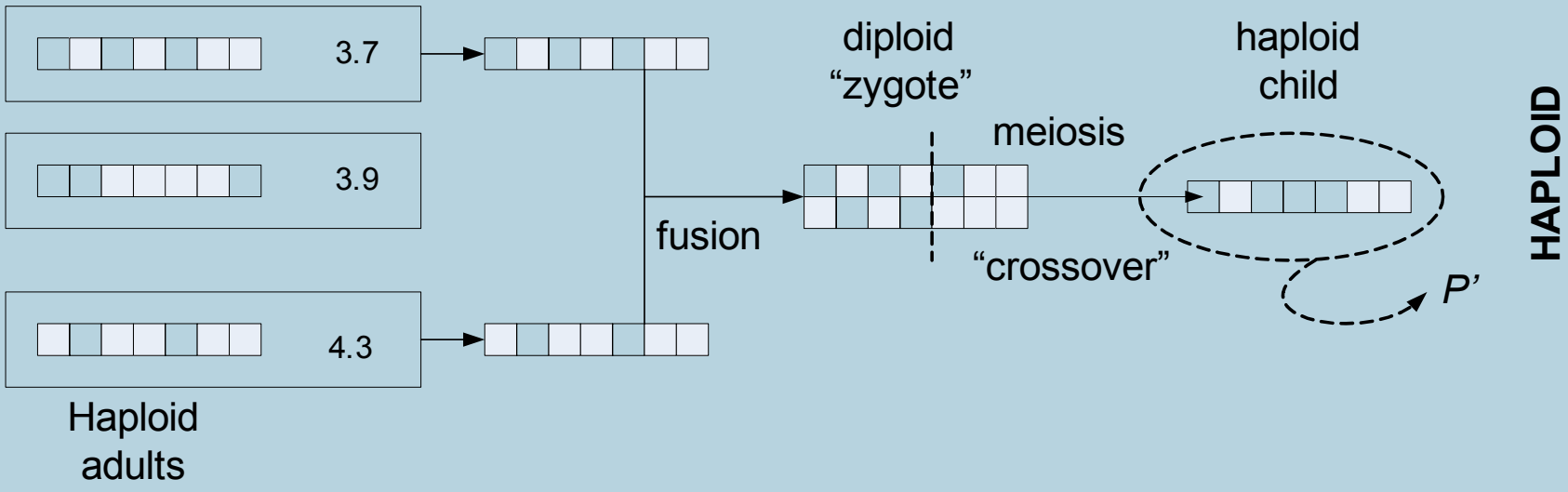




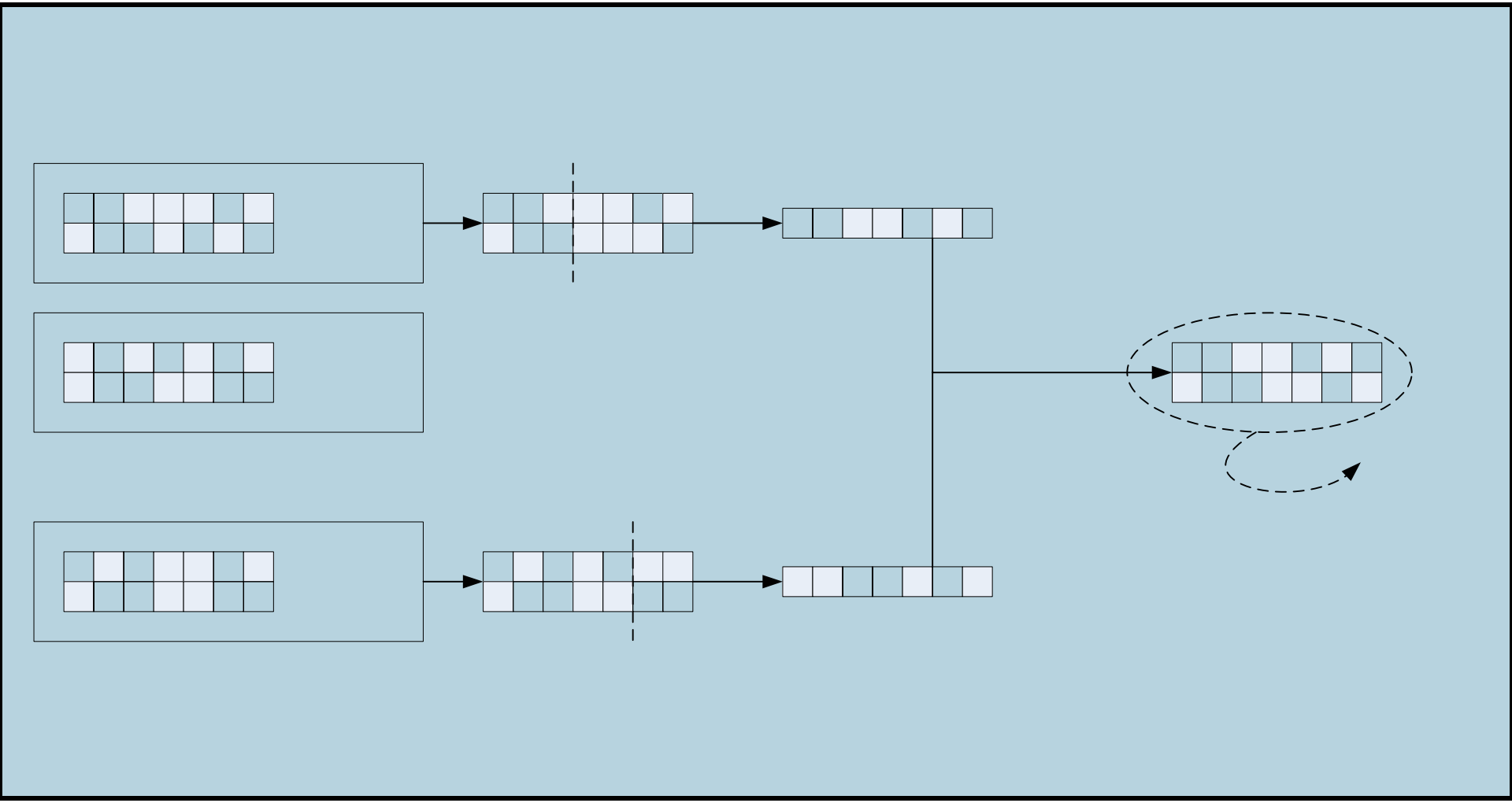
Genetic Operators



Haploid Reproduction



Diploid Reproduction



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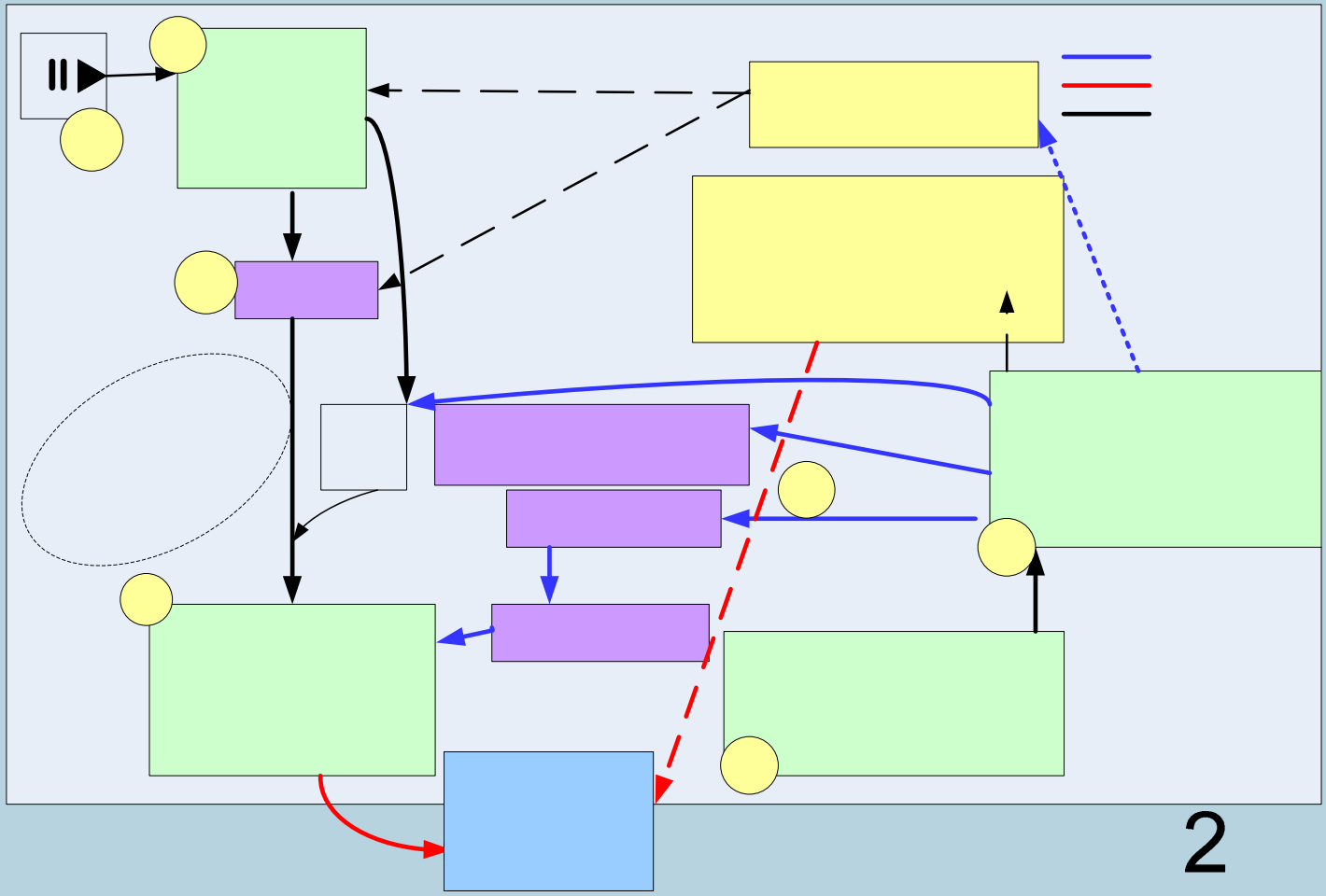
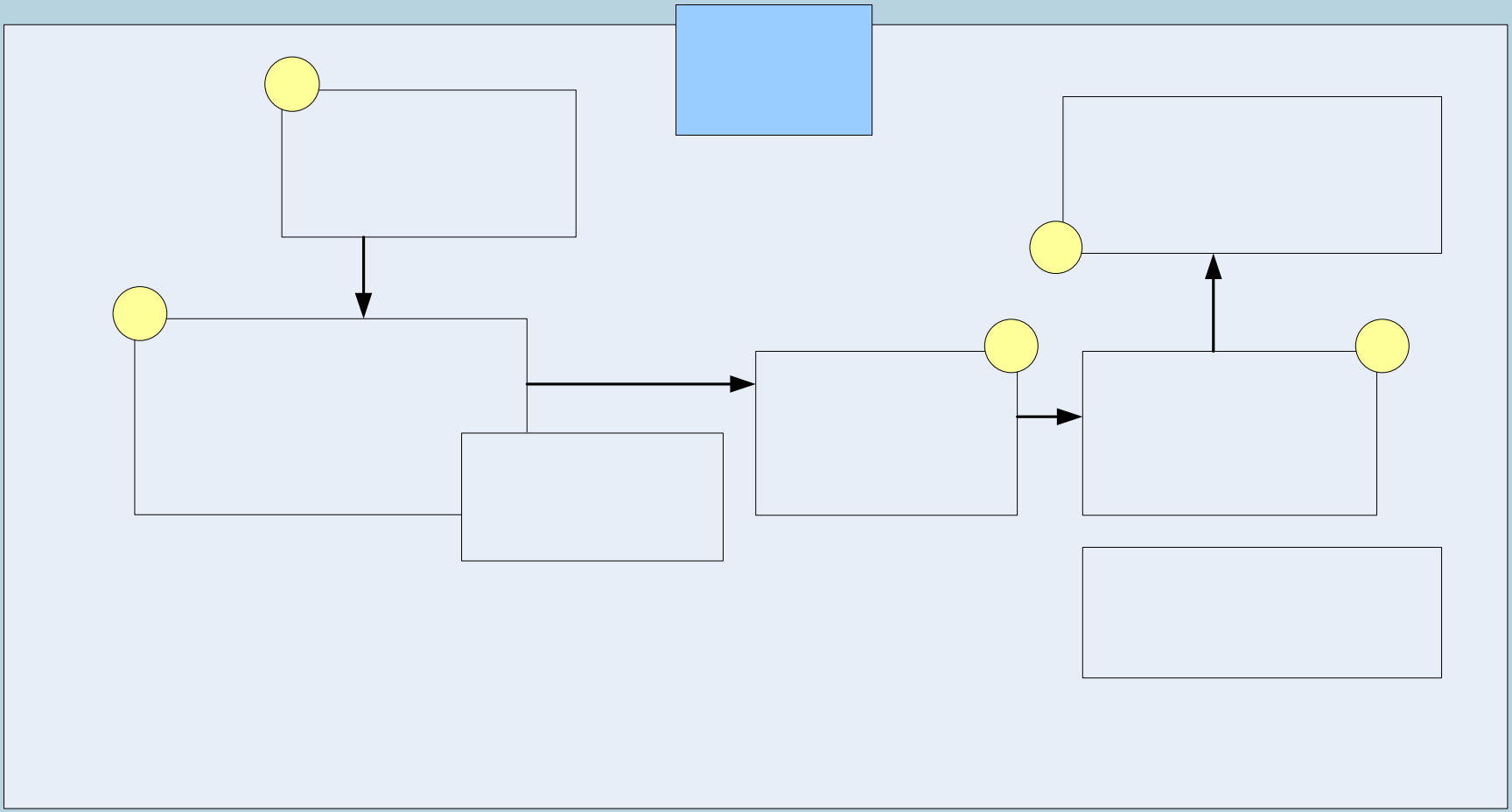
Simplorer and Matlab implementation: Matlab Processing



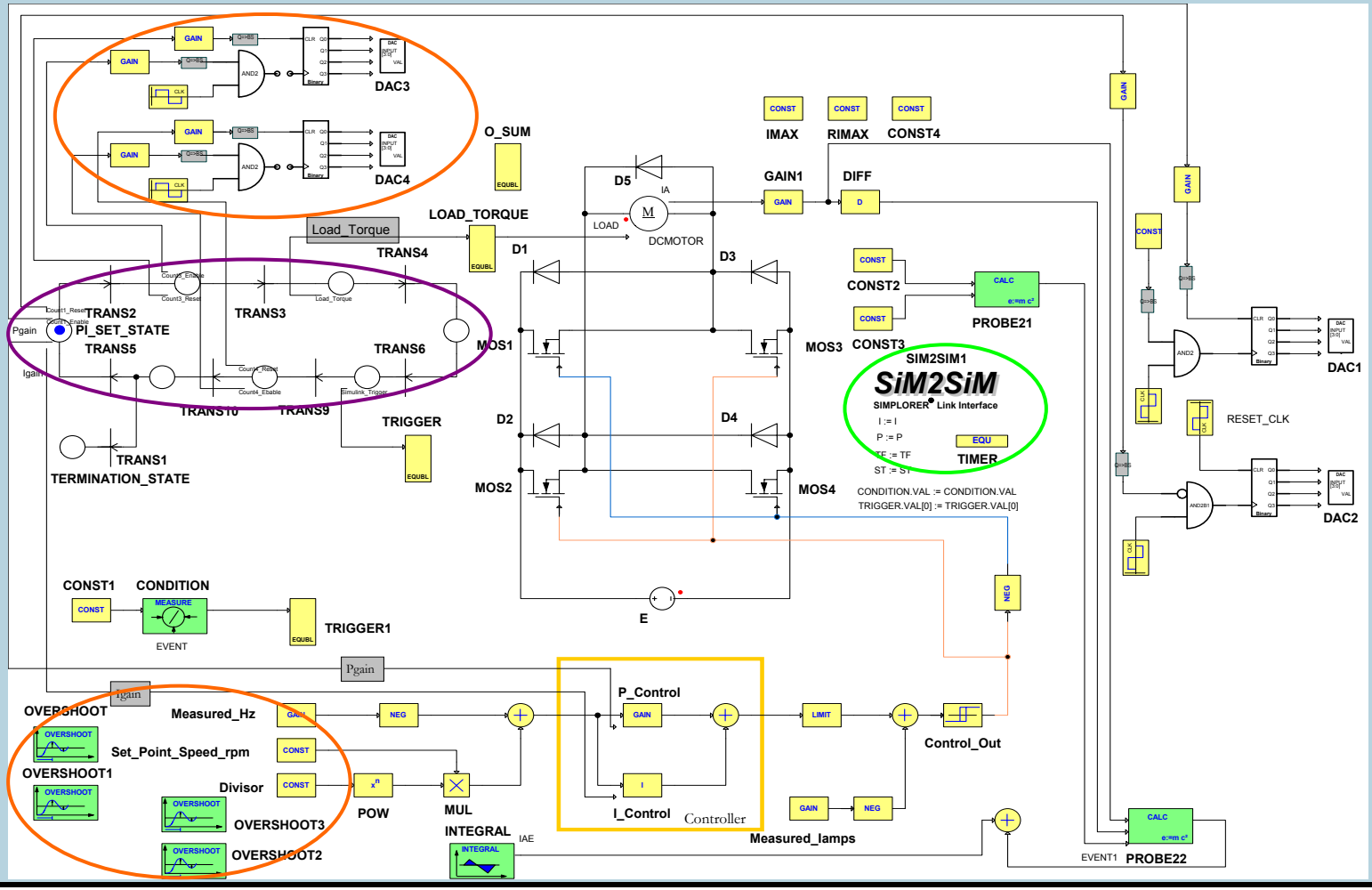
Genera

Rando

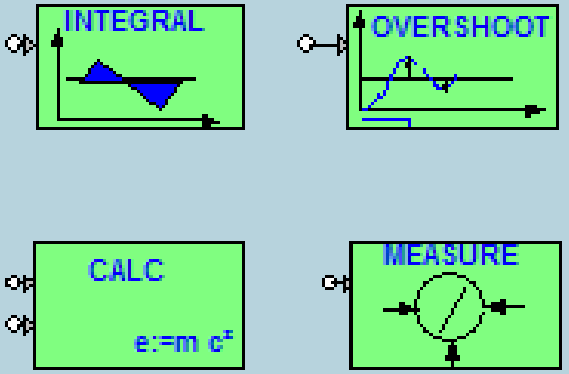
Simplorer and Matlab implementation: Simplorer Processing

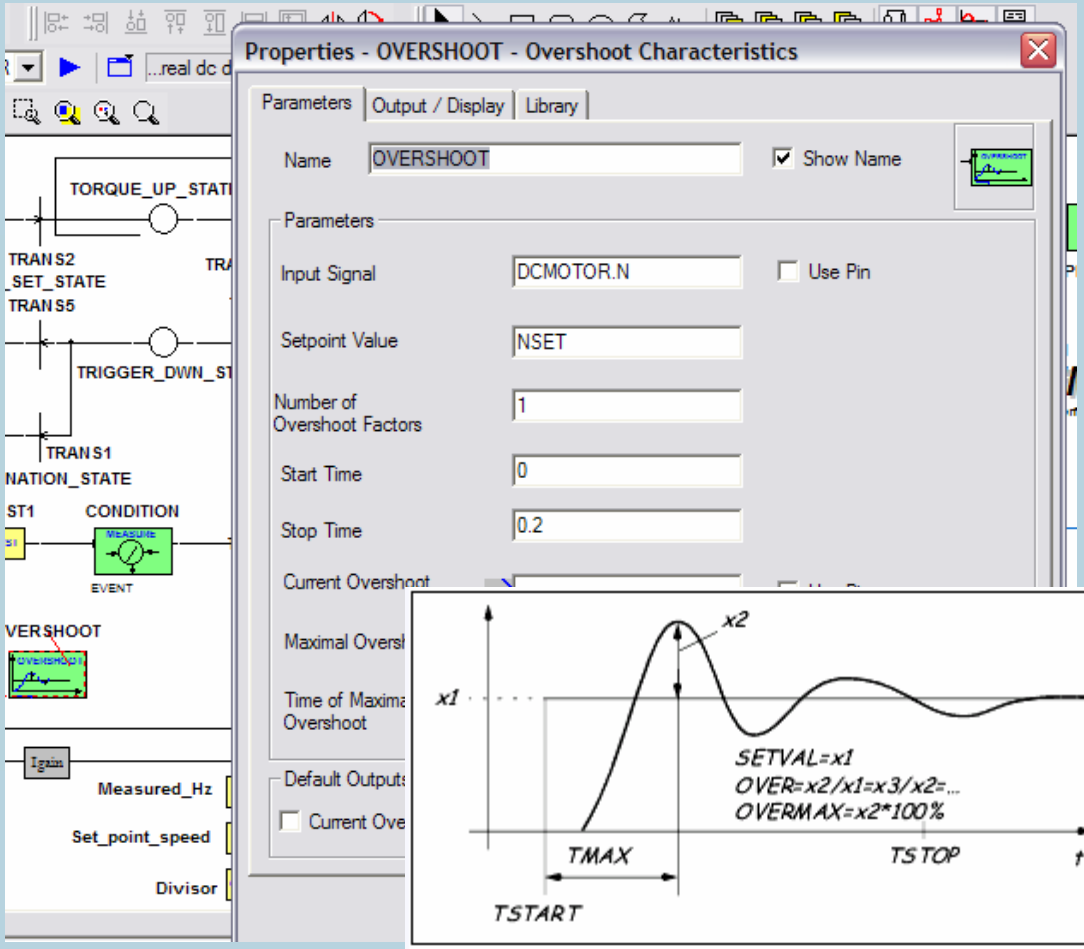


Simplorer Model

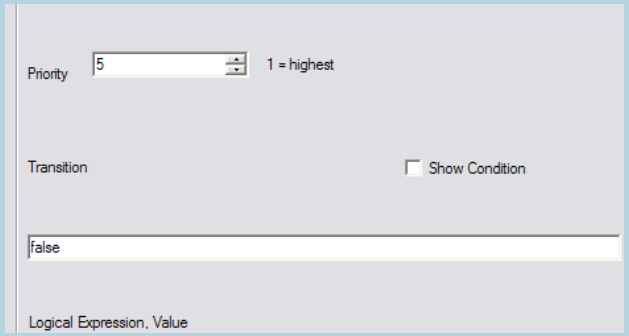


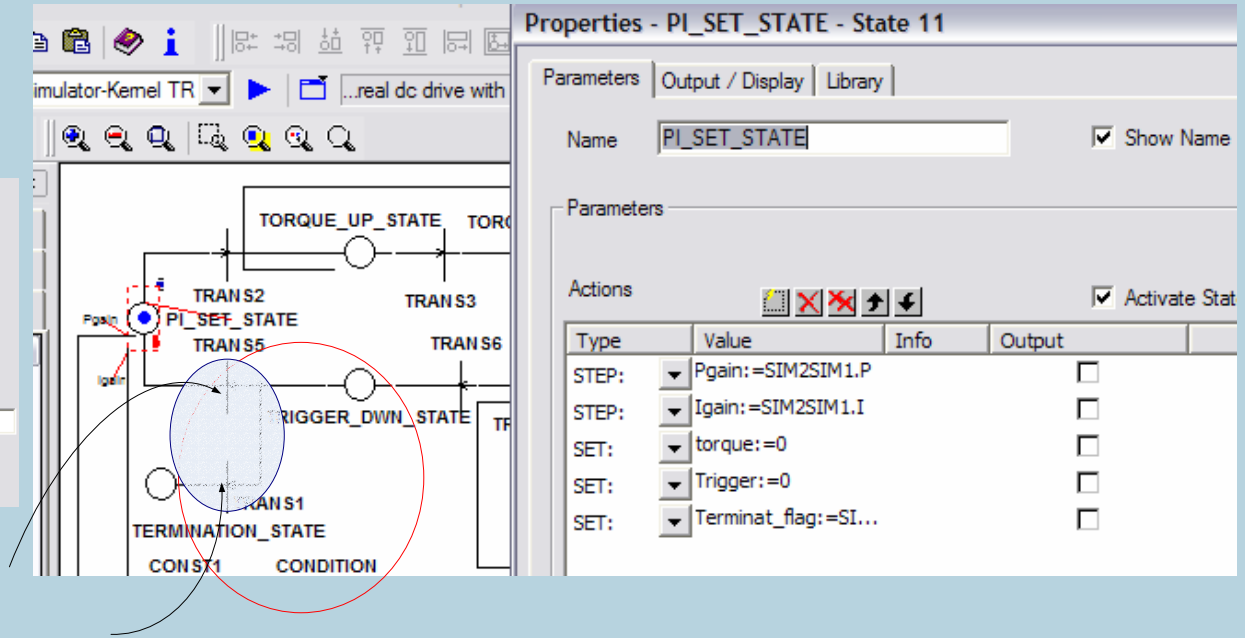
Functional Blocks



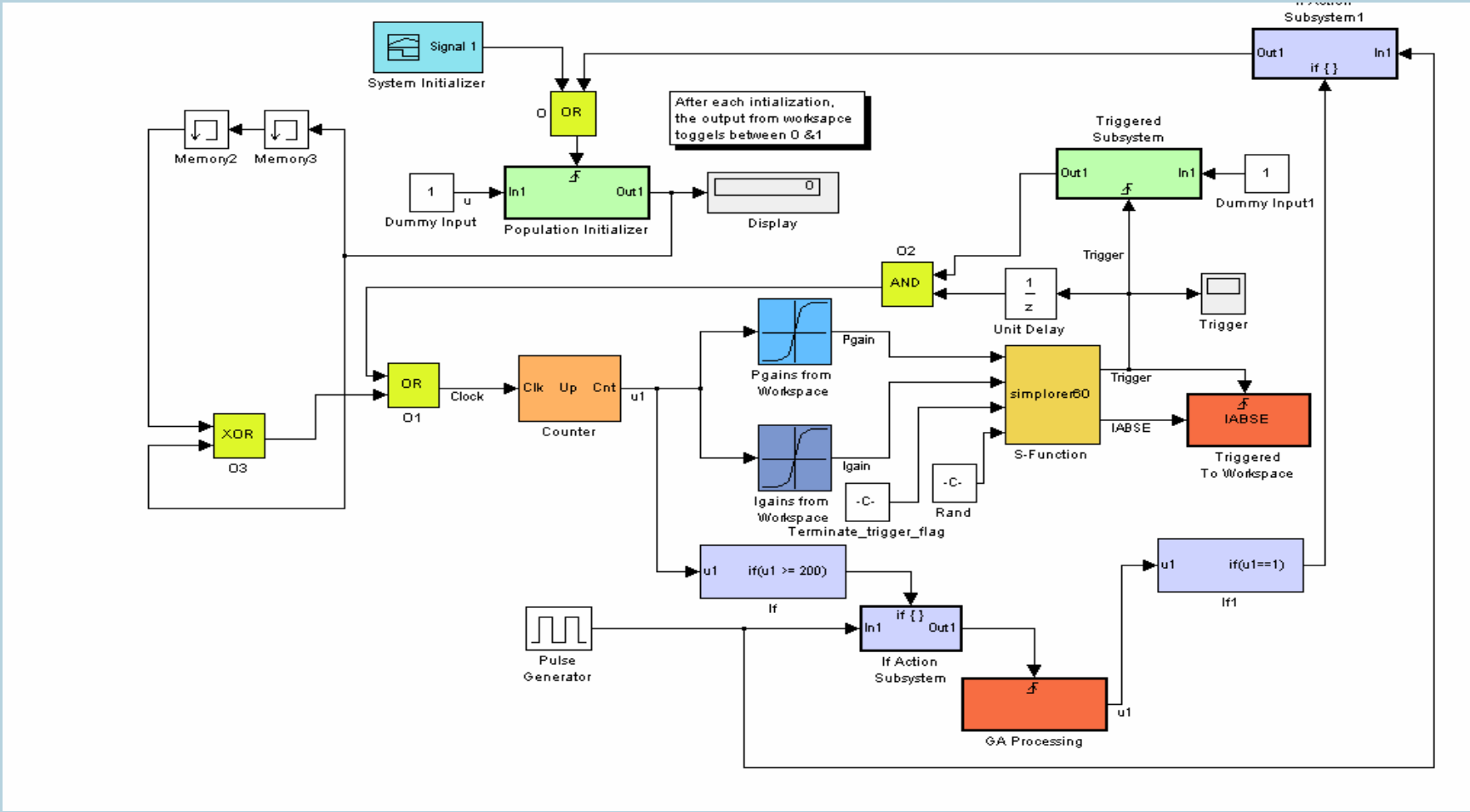


State Flow

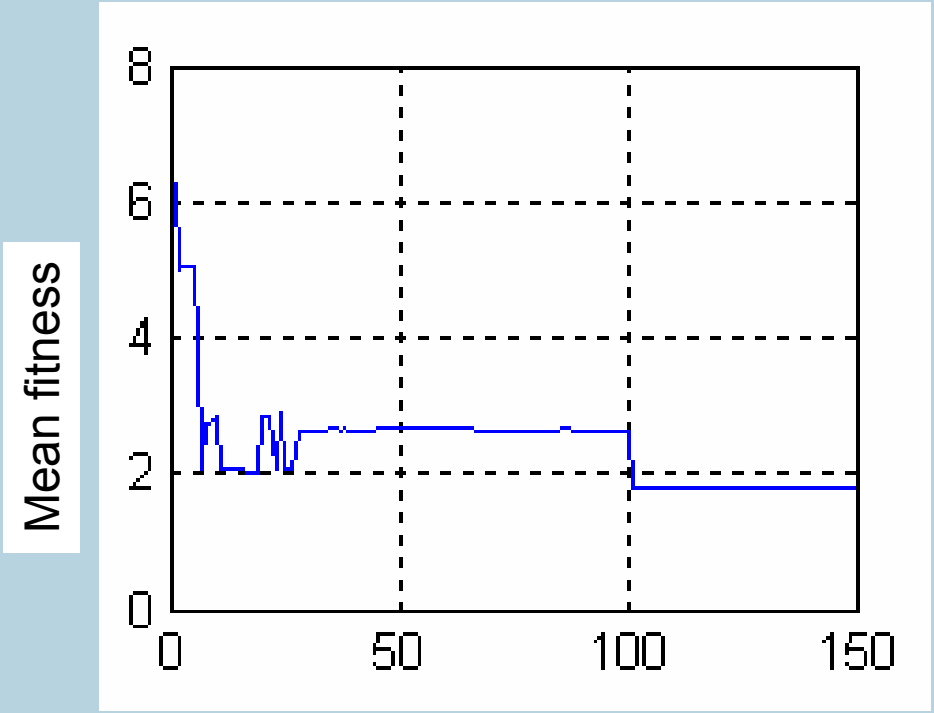

Priority
5
1 = highest
Transition
Show Condition
false
Logical Expression, Value


imulator-Kernel TR
...real dc drive with
TORQUE_UP_STATE
TRANS2
TRANS3
PI_SET_STATE
TRANS5
TRANS6
RIGGER_DWN_STATE
TERMINATION_STATE
CONDITION
Properties - PI_SET_STATE - State 11
Parameters
Output / Display
Library
Name
PI_SET_STATE
Show Name
Parameters
Actions
Activate Stat
Type
Value
Info
Output
STEP:
Pgain:=SIM2SIM1.P
STEP:
Igain:=SIM2SIM1.I
SET:
torque:=0
SET:
Trigger:=0
SET:
Terminat_flag:=SI...

Simulink Model



Simulation Results

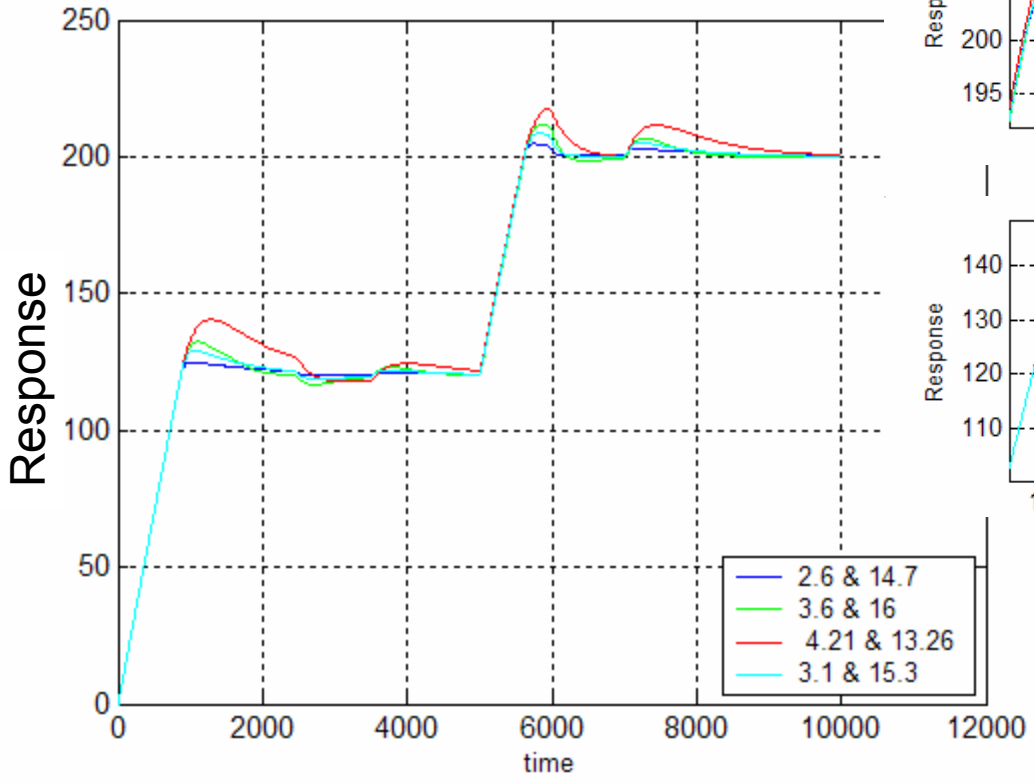


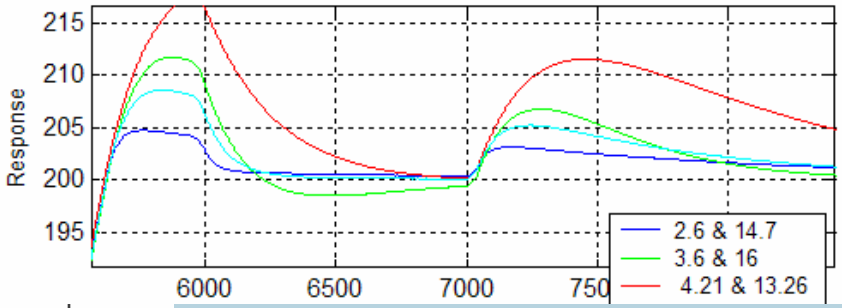
Parameters

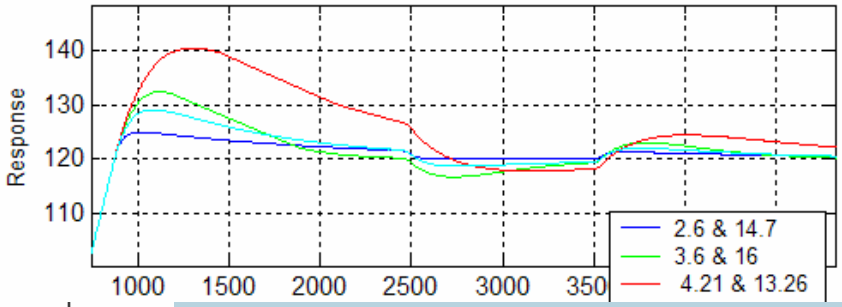
Population Size 200
Max Generations 150

Plot of Population Average Fitness and Maximum fitness in each generation vs Number of Generations

Simulation Results







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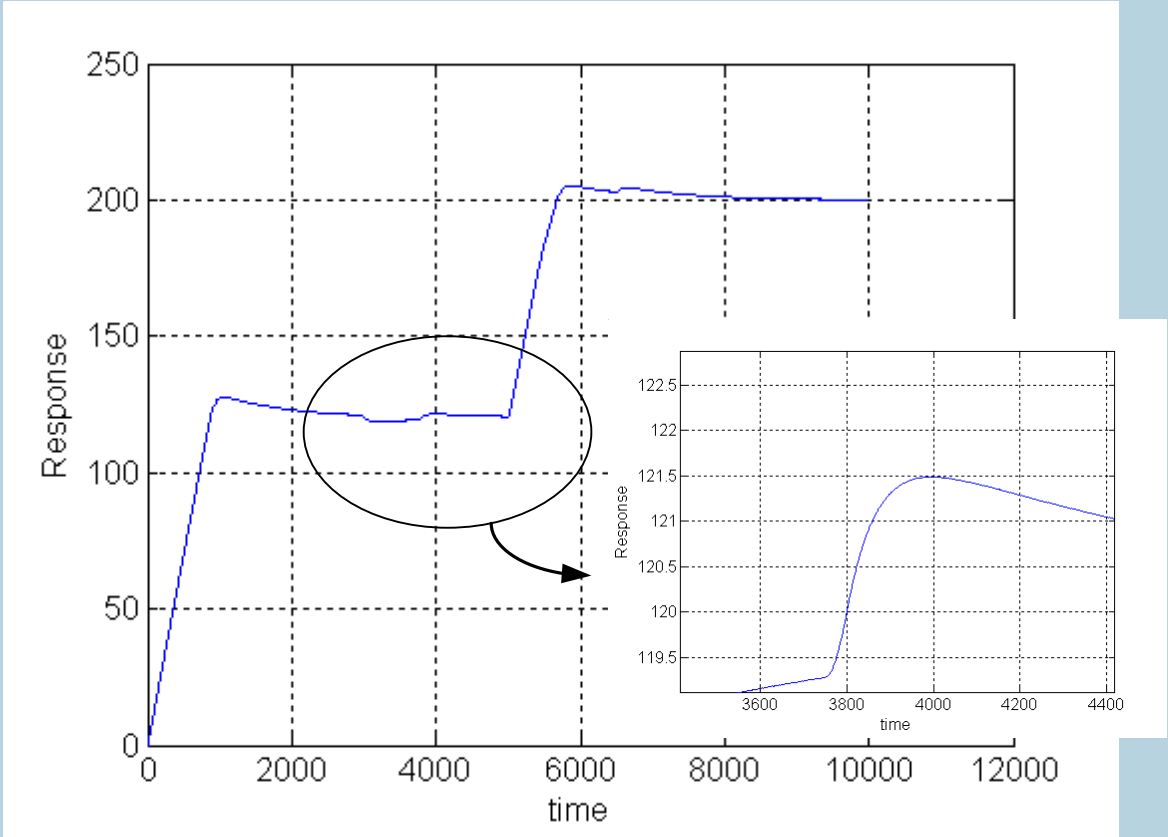

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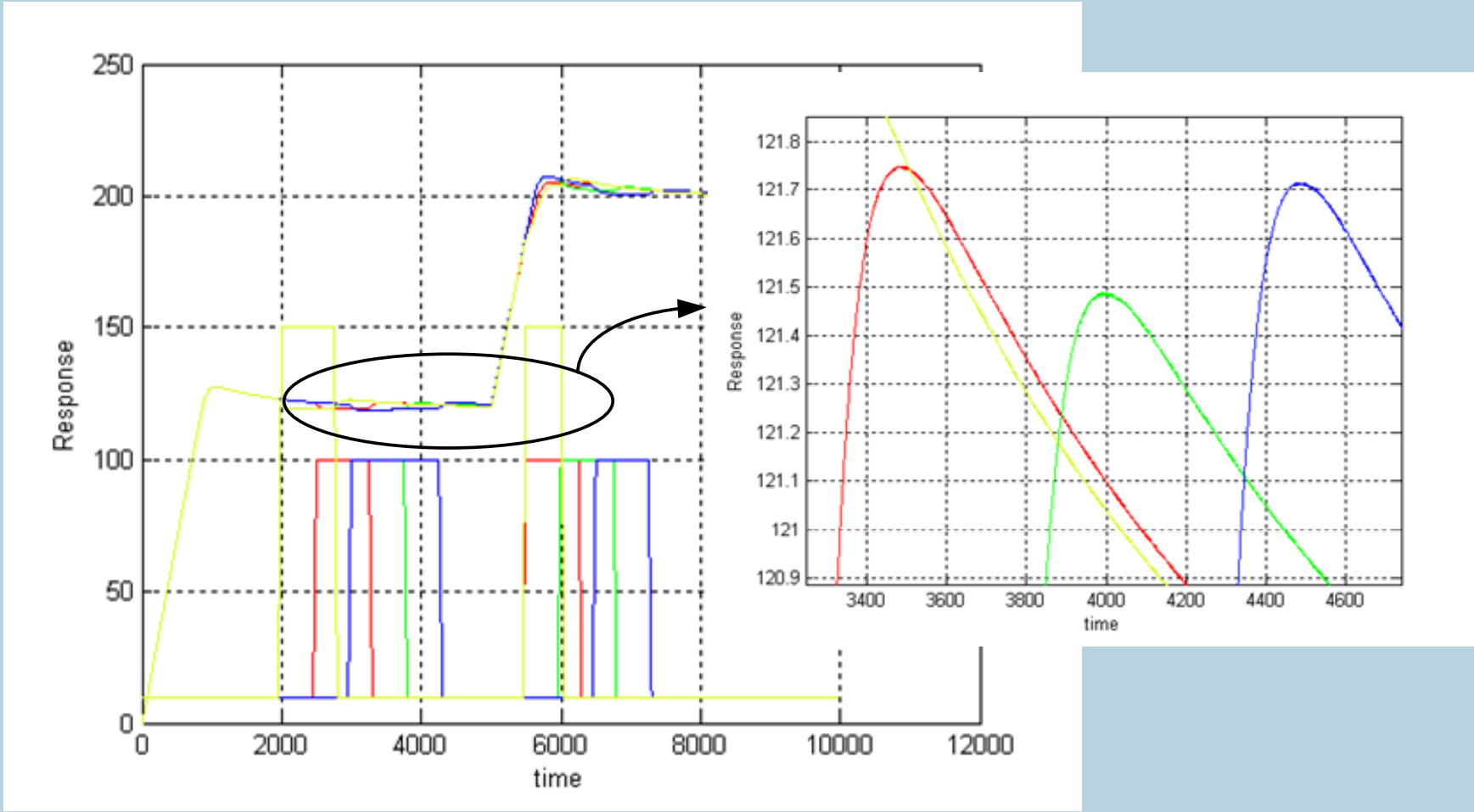

Conclusions and Future work

- Considering the optimization criteria we have achieved satisfactory results. Longer GA runs are expected to perform even better
- This can be expanded to encompass more parameters from the system
- Real time implementation (on-line tuning)
- Comparison with other tuning methods / haploid GA's