A Brief Introduction to Genetic Optimization

S.D. Sudhoff

Fall 2005

Traditional Optimization Methods

- Newton’s Method

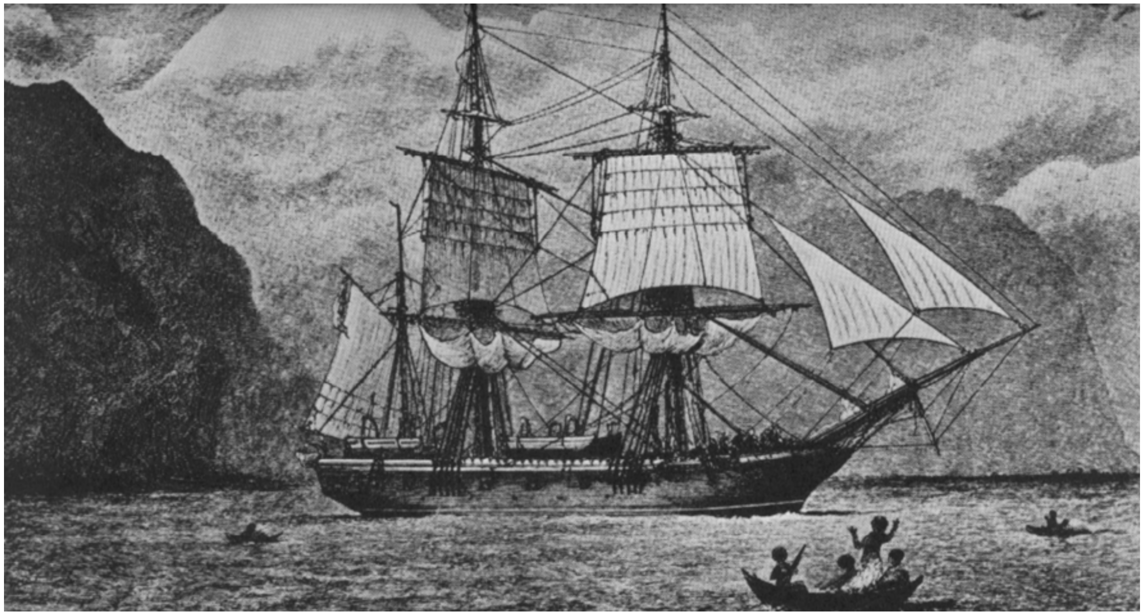
Traditional Optimization Methods

- Steepest Decent
- Conjugate Direction Algorithm
- Conjugate Gradient Algorithm
- Davidon, Fletcher, Powell, Algorithm (DFP)
- Broyden, Fletcher, Goldfarb, and Shanno Algorithm (BFGS)
- Nelder-Mead Simplex Method
- Take ECE580

Traditional Optimization Methods

- Properties of all of these methods
  - ➢Need an initial guess
  - ➢Very susceptible to finding local minimum
- Properties of most of these methods (not Nelder Meed Simplex)
  - ➢Take derivatives

An Alternate Approach



Genetic Algorithms in a Nutshell

- Probabilistic Optimization Technique
- Loosely Based in Principals of Genetics
- First Developed By Holland, Late 60’s – Early 70’s
- Does Not Require Gradients or Hessians
- Does Not Require Initial Guess
- Operates on a Population

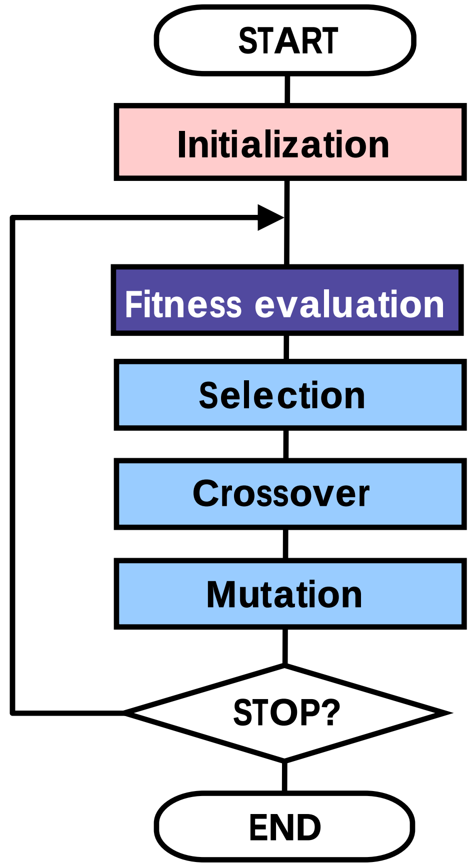
A Gene As A Parameter: Biological Systems

- Each Gene Has Value From Alphabet {AT,GC,CG,AT} from Nitrogenous Adenine, Guanine, Thymine, Cytosine
- Each Gene is Located on One of a Number of Chromosomes
- Chromosomes May Be Haploid, Diploid, Polyploid

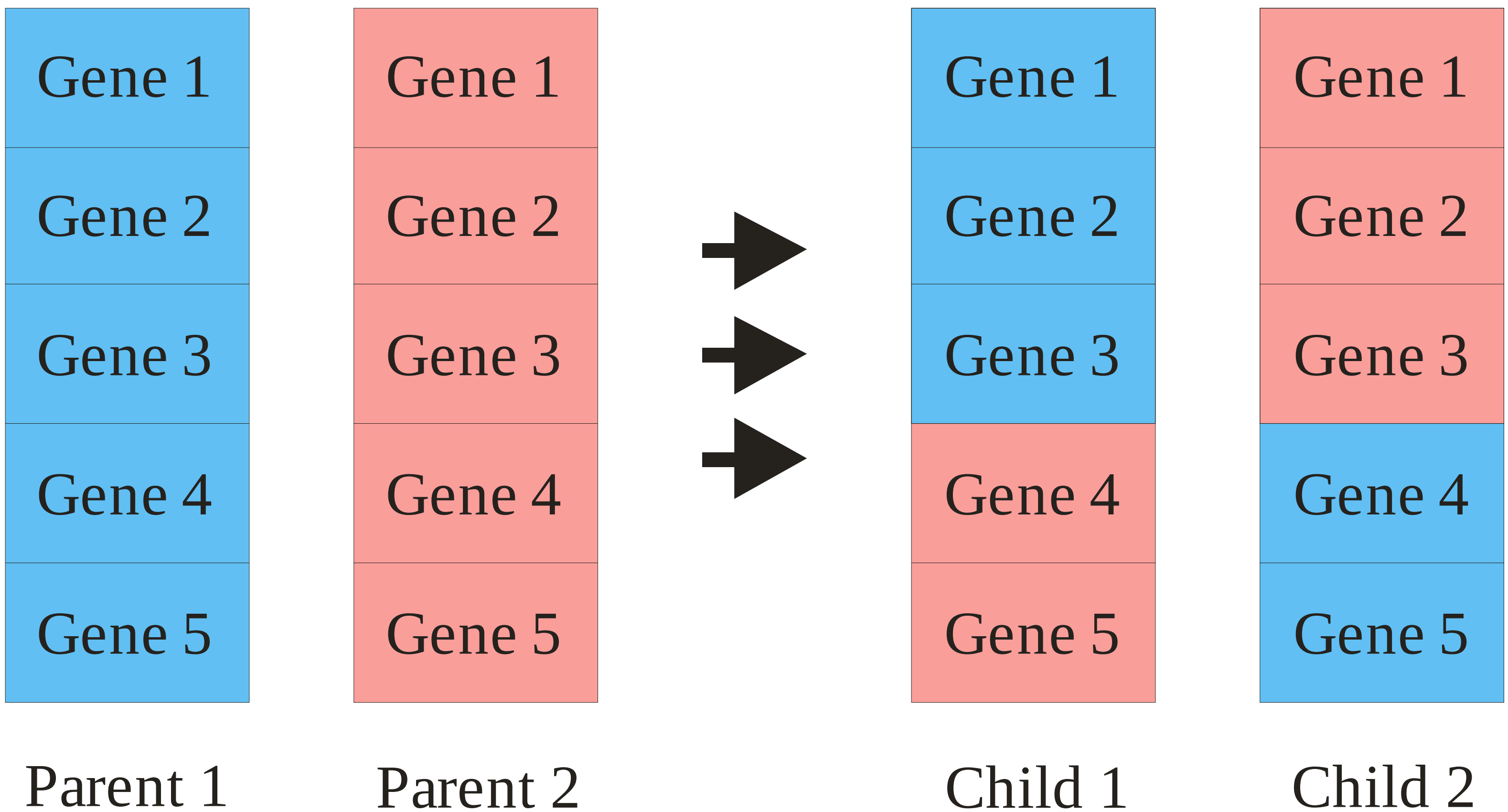
A Gene As A Parameter: Canonical Genetic Algorithm

- Each Gene Has a Value From Alphabet (Normally Binary {0,1})
- Each Gene is Located on a Chromosome (Normally 1)
- Chromosomes Generally Haploid

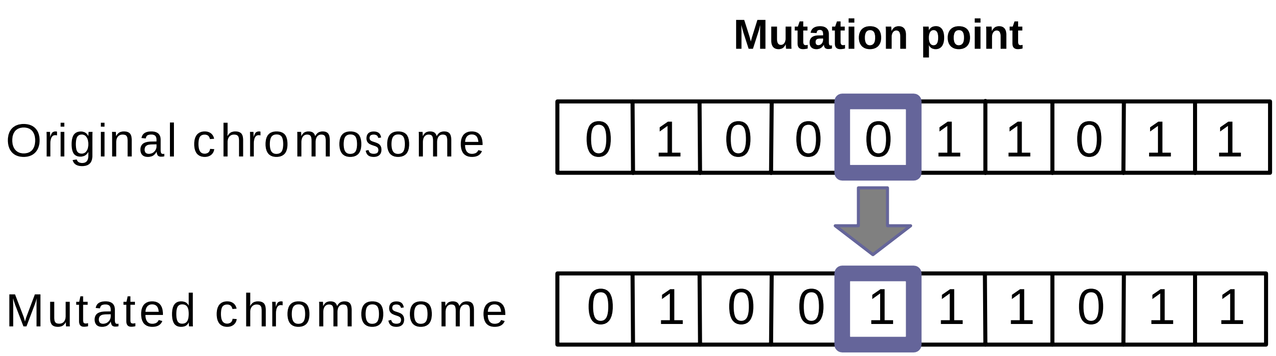
Evolution in a Canonical GA



Example Operator: Single Point Crossover



Example Operator: Mutation



A Gene As A Parameter: Non-Encoded Genetic Algorithms

- Each Gene Has A Range (Minimum Value, Maximum Value)
- Each Gene Has A Type (Mapping)
  - Integer
  - Linearly Mapped Real Number
  - Logarithmically Mapped Real Number
- Each Gene is Located on One of a Number of Chromosomes
- Chromosomes Are Haploid

Genetic Optimization System Engineering Tool (GOSET)

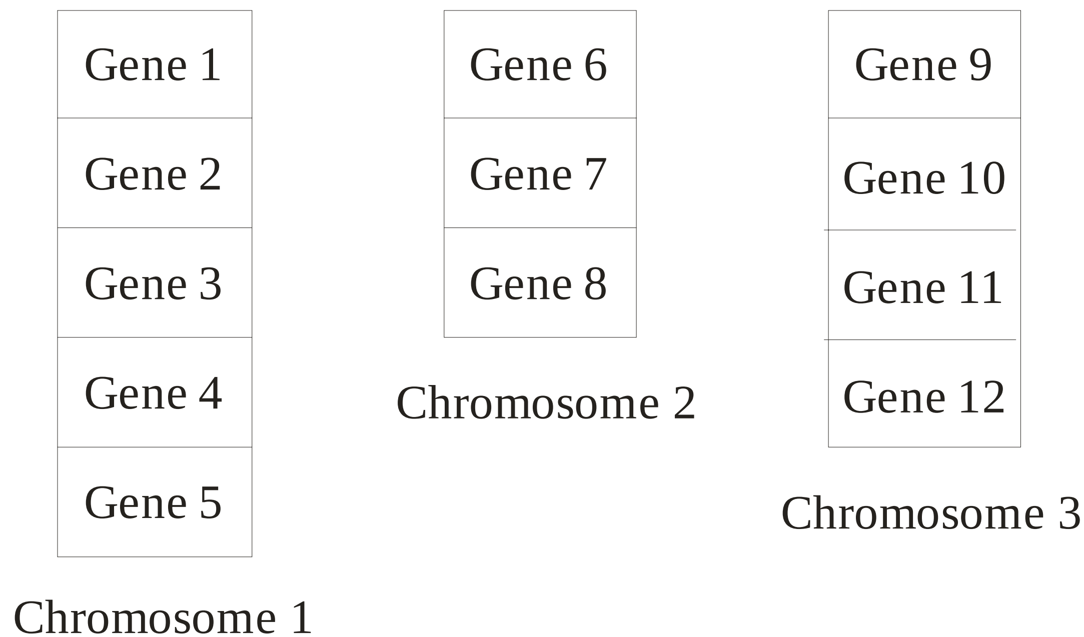
- Matlab based toolbox
- Usable with minimum knowledge
- Allows, if desired, high degree of algorithm control

An Individual in GOSET

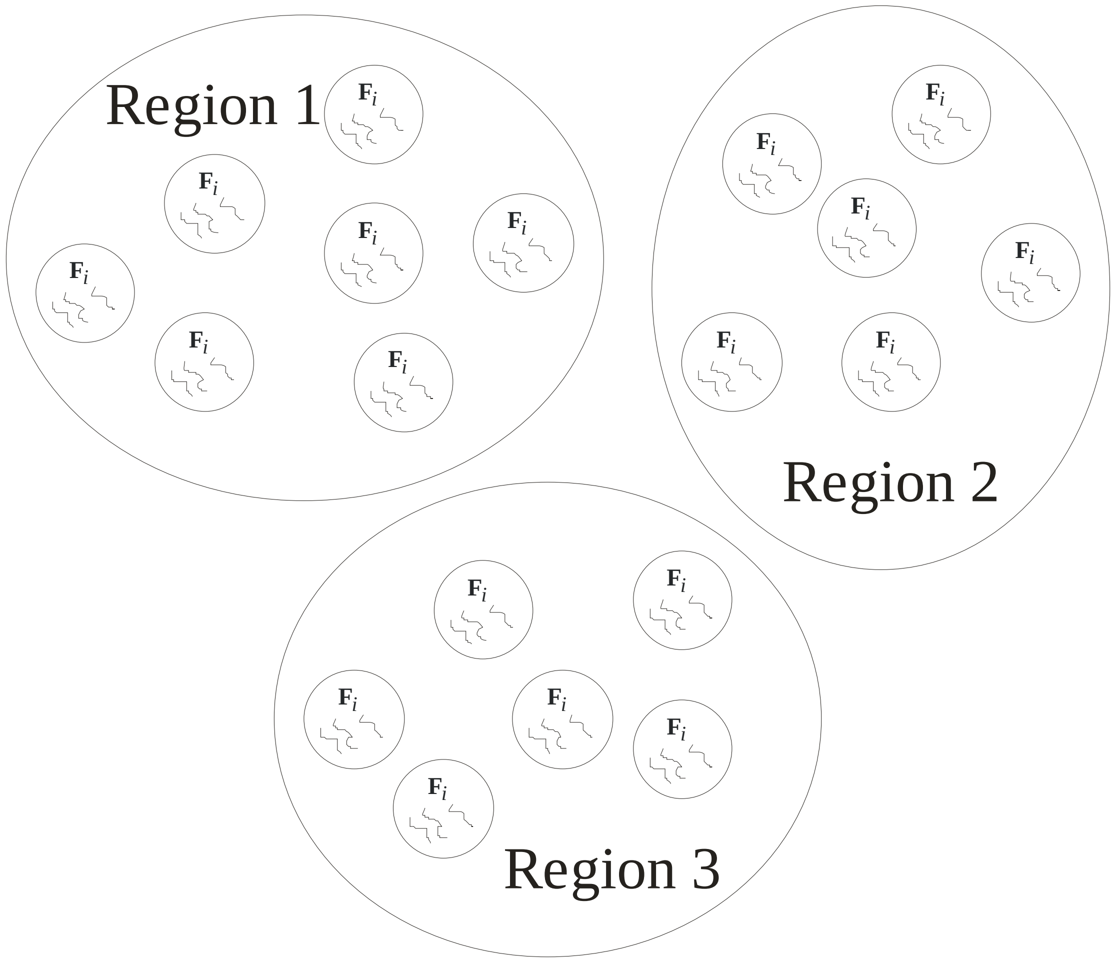
- A Collection of Genes on Chromosomes
- Fitness (Measures of Goodness)

$$\mathbf{f} = \begin{bmatrix} f_1 & f_2 & \cdots & f_N \end{bmatrix}^T$$

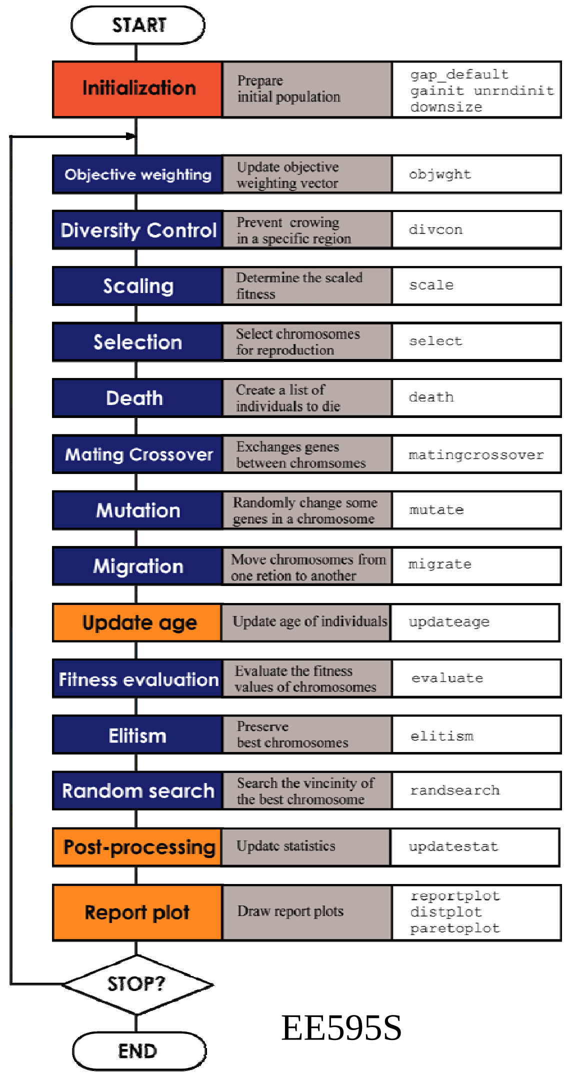
- Region



A Population In GOSET



Evolution in GOSET



Example: Powell's Problem

- Minimize

$$f(x) = (x_1 + 10x_2)^2 + 5(x_3 - x_4)^2 + (x_2 - 2x_3)^4 + 10(x_1 - x_4)^4$$

- Fitness

$$fitness(x) = 5 - \log 10(f(x) + 10^{-5})$$

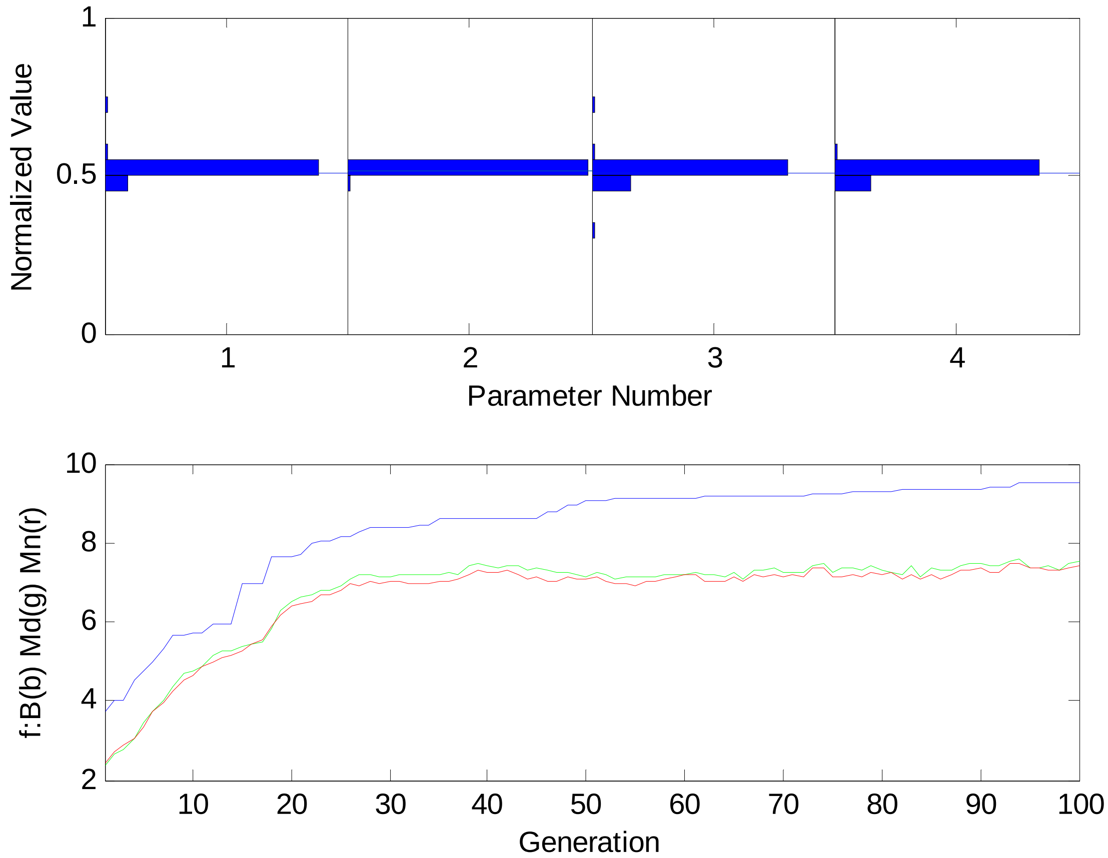
powell.m

```
% Optimization of Powell's Problem

% Initialize the parameters
GAP=gapdefault;

%              x1     x2    x3   x4
% gene           1      2     3    4
GAP.gd_min =[   -2.1   -2.1   -2.1  -2.1];
GAP.gd_max =[    2.0    2.0    2.0   2.0];
GAP.gd_type=[    2      2      2     2  ];
GAP.gd_cid =[    1      1      1     1  ];

[P,GAS]= gaoptimize(@powell_fit,GAP,[],[],[],[]);

parameters=GAS.bestgenes(:,GAS.cg);
```

powell_fit.m

```
function f = powell(x)

% Powell's function taken from Chong & Zak, p. 140.
% The global miniizer is powell(0,0,0,0) = 0

x1=x(1);
x2=x(2);
x3=x(3);
x4=x(4);
f1 = (x1 + 10*x2)^2 + 5*(x3 - x4)^2 + (x2 - 2*x3)^4 + 10*(x1-x4)^4;
f=5-log10(f1+0.00001);
```

Powell's Problem: Conclusion



parameters =

-0.0098
0.0014
-0.0097
-0.0105

IGBT Conduction Loss

- Fit IGBT Conduction Loss Data To:

$$v = ai + (bi)^c$$

igbt.m

```
% load experimental data
% voltage is first column
% current is second column
load igbt_data.mat
Data.v=v_data;
Data.i=i_data;

% gafit
GAP=gapdefault;
GAP.rp_lvl=1;
GAP.mg_nreg=4;
GAP.mg_tmig=20;
GAP.mg_pmig=0.05;
GAP.dp_fp=0.5;
GAP.dth_alg=2;
```

igbt.m (cont.)

```
% declare the types of all the parameters
GAP.gd_min = [1e-8 1.0e-6 1.0e-3];
GAP.gd_max = [1e+2 1.0e+3 1.0e+0];
GAP.gd_type= [  3      3      3 ];
GAP.gd_cid = [  1      1      1 ];

% do the optimization
[fP,GAS]= gaoptimize(@igbt_fit,GAP,Data,[],[],[]);

% plot the best fit
bestparameters=GAS.bestgenes(:,GAS.cg,1)
igbt_fit(bestparameters,Data,3);
```

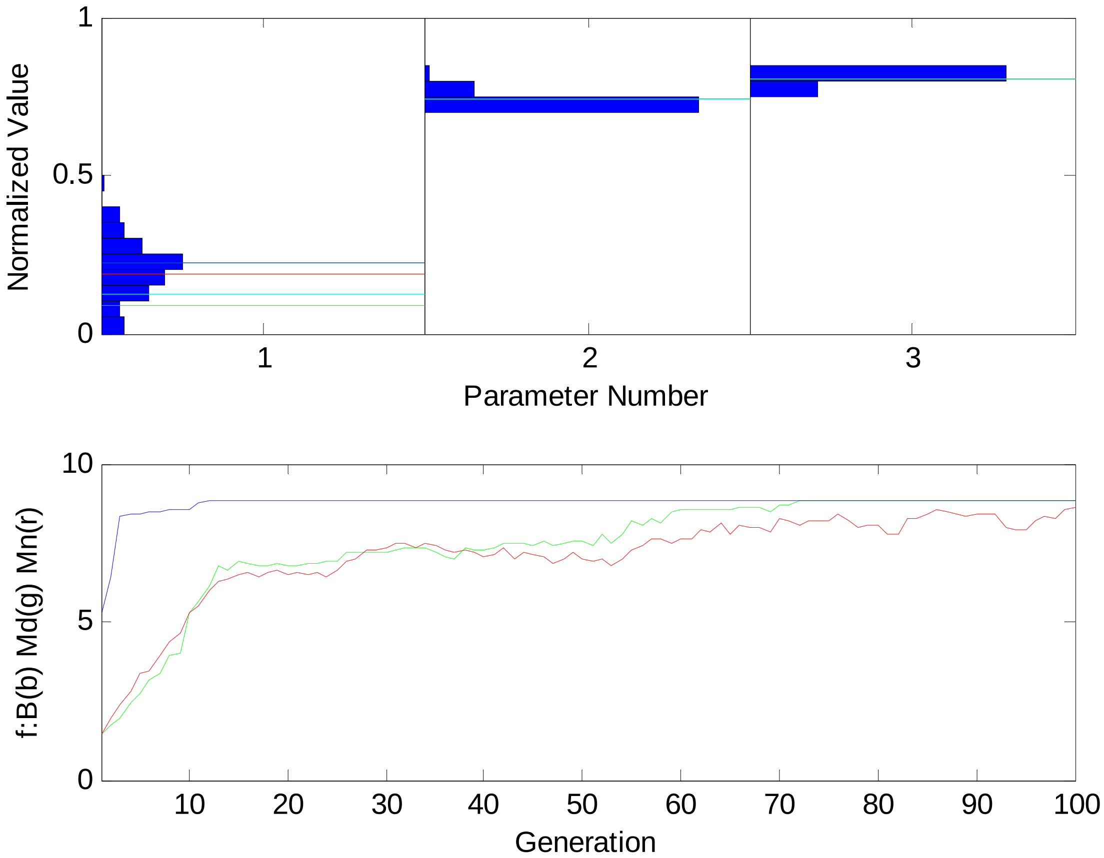
igbt_fit

```
% this rountine returns the fitness of the IGBT conduction
% loss parameters based on the mean percentage error
function fitness = IGBTfitness(parameters,data,fignum)

% assign genes to parameters
a=parameters(1);
b=parameters(2);
c=parameters(3);

vpred=a*data.i+(b*data.i).^c;
error=abs(1-vpred./data.v);
fitness=1.0/(1.0e-6+mean(error));
```

igbt_fit (cont)

```
if nargin>2

  fitness

  figure(fignum);
  Npoints=200;
  ip=linspace(0,max(data.i),Npoints);
  vp=a*ip+(b*ip).^c;
  plot(data.i,data.v,'bx',ip,vp,'r')
  title('Voltage Versus Currrent');
  xlabel('Current, A');
  ylabel('Voltage, V');
  legend({'Measured','Fit'});

  figure(fignum+1);
  Npoints=200;
  plot(data.i,data.v.*data.i,'bx',ip,vp.*ip,'r')
  title('Power Versus Currrent');
  xlabel('Current, A');
  ylabel('Power, V');
  legend({'Measured','Fit'});

end
```

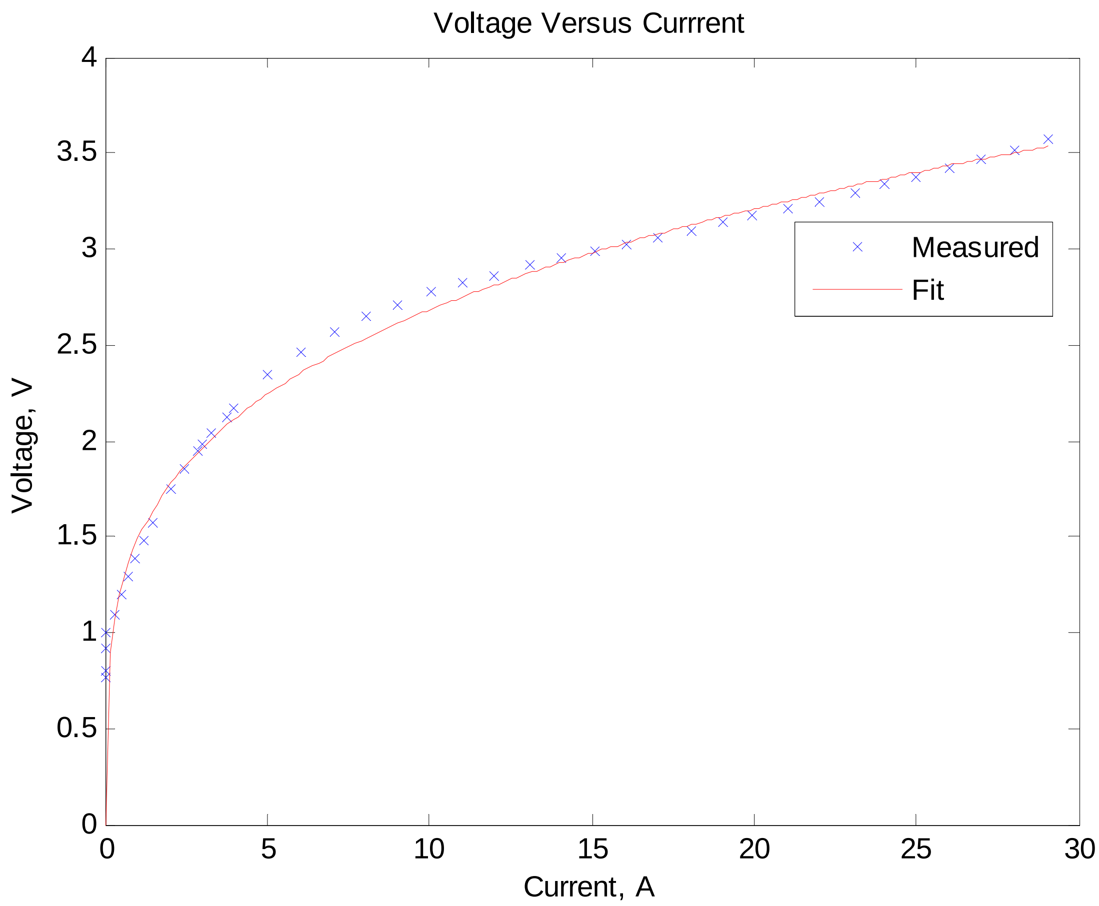
IGBT Results



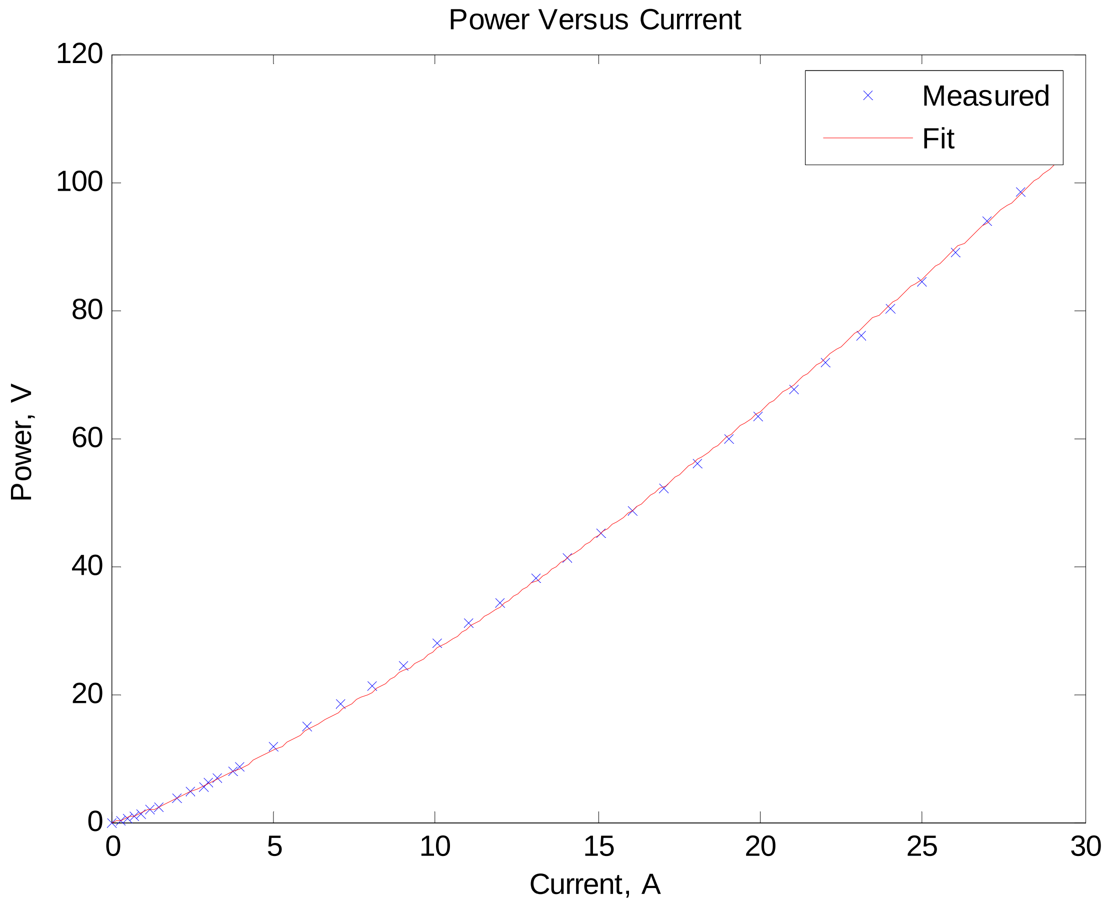
bestparameters =

0.0000
4.5288
0.2588

IGBT Results (Cont.)



IGBT Results (Cont.)



Your Problem

- Consider a machine for which

$$\lambda_m = 0.3 \quad VS$$

$$L_q = 15 \quad mH$$

$$L_d = 10 \quad mH$$

$$P = 4$$

Your Problem (Cont)

- Develop an approximate expression for the optimal q-axis current command (in MTPA sense) as a function of desired torque
- Deliverables: short write up with your expression, all *.m files etc used.
- NOTE: GOSET2.2 is on the web. See software distribution.

Comments on Approach