Naval Architecture & Ocean Engineering

Computer Aided Ship Design

Part I. Optimization Method

Term Project

September, 2013

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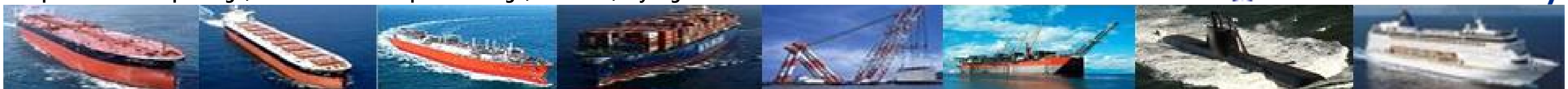
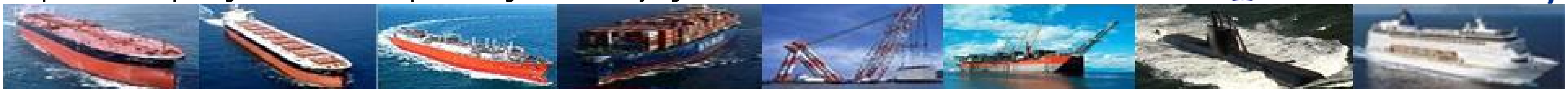


Term Project



Overview (1/2)

☑ Objective

- To develop a program for the determination of optimal principal dimensions of a ship by using a constrained optimization method

☑ Optimization Method

- Exterior Penalty Function Method

$$\Phi(\mathbf{x}, r_k) = f(\mathbf{x}) + r_k \sum_{j=1}^{m} \max\left\{g_j(\mathbf{x}), 0\right\} \quad \text{or} \quad \Phi(\mathbf{x}, r_k) = f(\mathbf{x}) + r_k \sum_{j=1}^{m} \left[\max\left\{g_j(\mathbf{x}), 0\right\}\right]^2$$

- Hooke & Jeeves Method or Nelder & Mead Simplex Method for minimizing the above penalty function
  ➡ Select one of them!

Overview (2/2)

☑ **Implementation**

- Any program language (C++[Recommended], FORTRAN) or tool (Matlab, MS Excel) can be used.
- However, the grading is different according to the language or tool what you select.
- Evaluate the validity of your program by applying it to all test examples and discuss its results in your report.
- You can refer materials on the internet, but do not copy!

☑ **Due date: 23:59 on 24th November, 2013**

☑ **Submissions**

- Report for the term project (MS word file)
- Source files including an executable file.
- After compressing all files in one file (e.g., YourStudentNumber.zip) and upload to our eTL homepage.

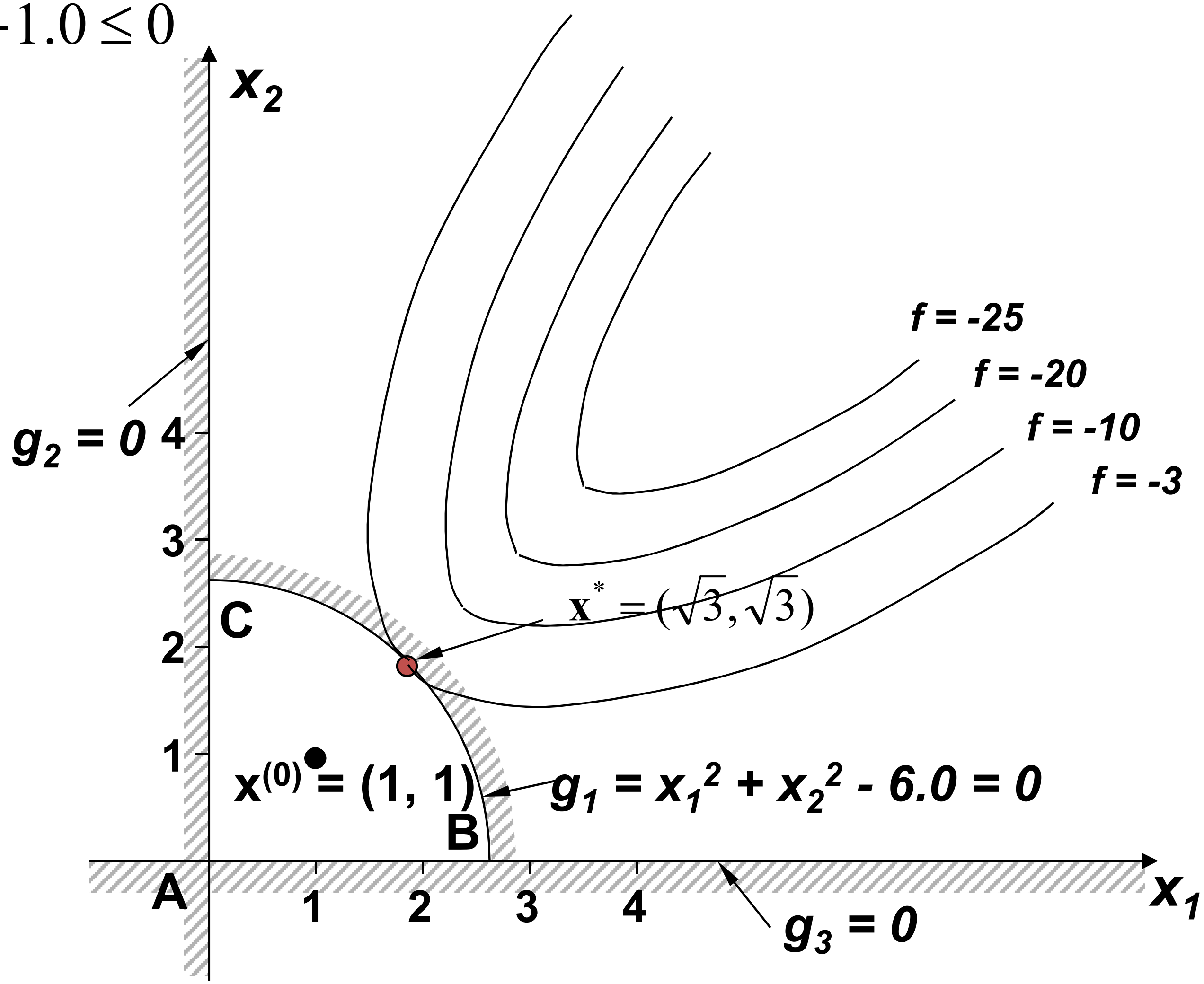
Test Examples #1

Minimize $f(\mathbf{x}) = x_1^2 + x_2^2 - 3x_1x_2$

Subject to $g_1(\mathbf{x}) = \frac{1}{6}x_1^2 + \frac{1}{6}x_2^2 - 1.0 \le 0$

$g_2(\mathbf{x}) = -x_1 \le 0$

$g_3(\mathbf{x}) = -x_1 \le 0$



Optimal Solution:

$$\mathbf{x}^* = (\sqrt{3}, \sqrt{3}),\ f(\mathbf{x}^*) = -3$$

Test Examples #2

Minimize

$$f(x_1, x_2) = -\left[25 - (x_1 - 5)^2 - (x_2 - 5)^2\right]$$

Subject to

$$g_1(x_1, x_2) = -32 + 4x_1 + x_2^{\ 2} \le 0$$

$$g_2(x_1, x_2) = -x_1 \le 0$$

$$g_3(x_1, x_2) = x_1 \le 10$$

$$g_4(x_1, x_2) = -x_2 \le 0$$

$$g_5(x_1, x_2) = x_2 \le 10$$

Solution

$$x_1^{\ *} = 4.374, x_2^{\ *} = 3.808, f(x_1^{\ *}, x_2^{\ *}) = -4.815$$

Test Examples #3

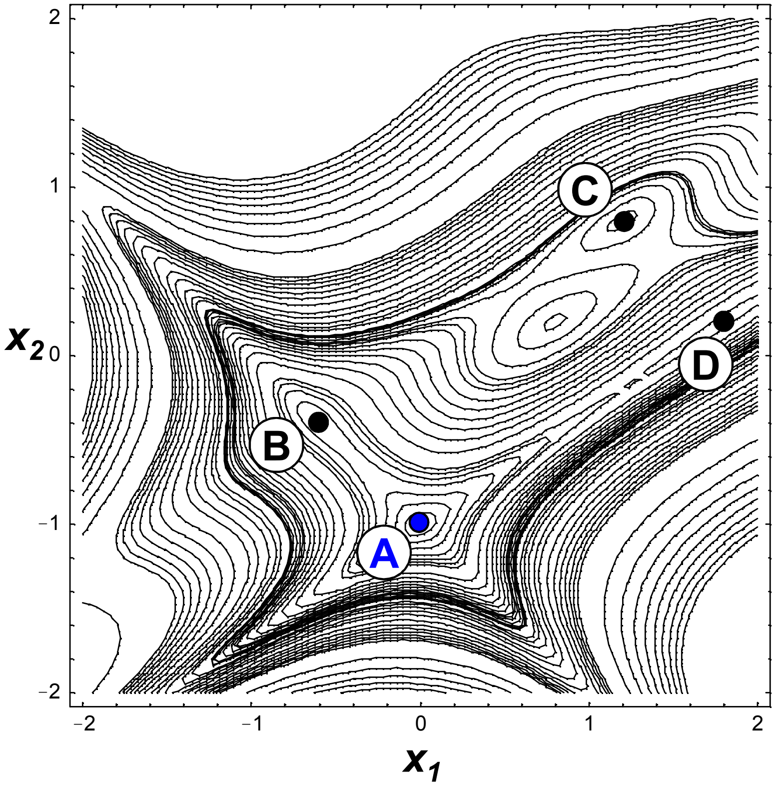
Goldstein-Price Function

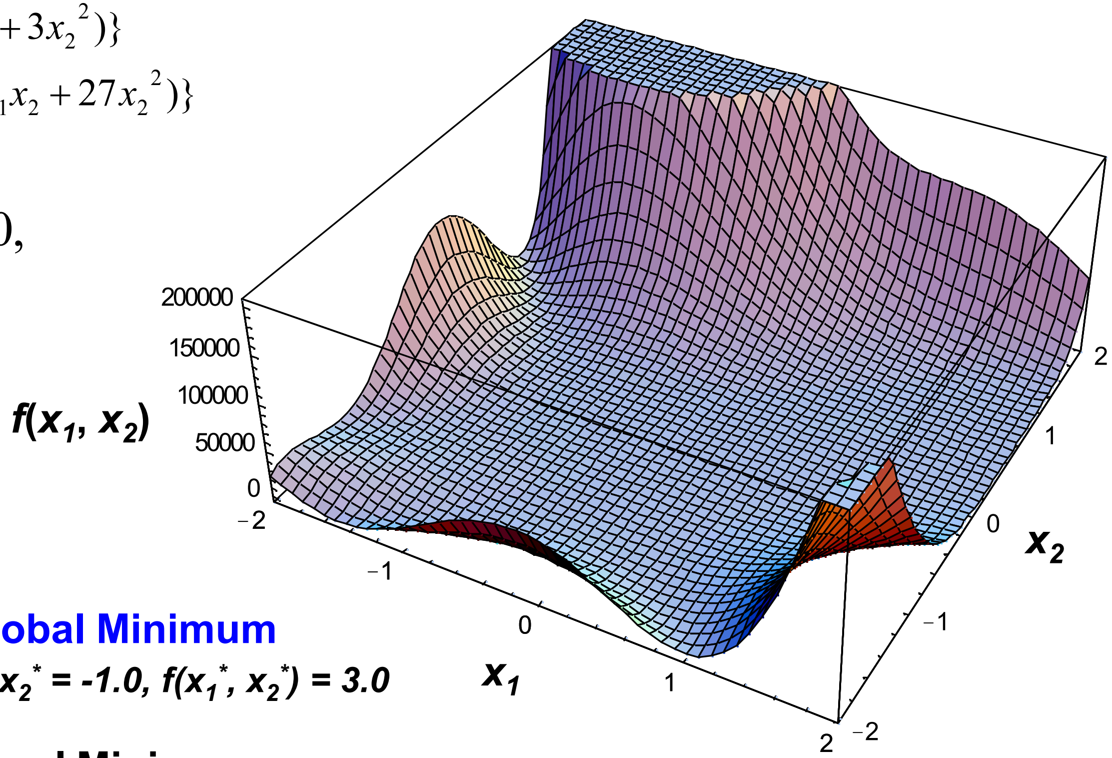
Minimize

$$f(x_1,x_2) = \{1+(x_1+x_2+1)^2 \cdot (19-14x_1+3x_1^2-14x_2+6x_1x_2+3x_2^2)\}$$
$$\cdot\{30+(2x_1-3x_2)^2 \cdot (18-32x_1+12x_1^2+48x_2-36x_1x_2+27x_2^2)\}$$

Subject to

$$g_1(x_1,x_2) = -2-x_1 \le 0,\ g_2(x_1,x_2) = -2-x_2 \le 0,$$
$$g_3(x_1,x_2) = x_1-2 \le 0,\ g_4(x_1,x_2) = x_2-2 \le 0$$





A : Global Minimum

$x_1^* = 0.0,\ x_2^* = -1.0,\ f(x_1^*, x_2^*) = 3.0$

B : Local Minimum

$x_1^* = -0.6,\ x_2^* = -0.4,\ f(x_1^*, x_2^*) = 30.0$

C : Local Minimum

$x_1^* = 1.2,\ x_2^* = 0.8,\ f(x_1^*, x_2^*) = 840.0$

D : Local Minimum

$x_1^* = 1.8,\ x_2^* = 0.2,\ f(x_1^*, x_2^*) = 84.0$

Test Examples #4
- Determination of the Optimal Principal Dimensions of a Ship (1/4)

- ***Given***: $DWT, V_{H.req}, D, T_s, T_d$
- ***Find***: L, B, C_B
  - **Hydrostatic equilibrium(Weight equation)**

$$L \cdot B \cdot T_s \cdot C_B \cdot \rho_{sw} \cdot C_\alpha = DWT_{given} + LWT(L,B,D,C_B)$$

$$= DWT_{given} + C_s \cdot L^{1.6} \cdot (B+D) + C_o \cdot L \cdot B + C_{power} \cdot (L \cdot B \cdot T_d \cdot C_B)^{2/3} \cdot V^3 \quad ...(a)$$

Simplify ① $\rightarrow C_s' \cdot L^{2.0} \cdot (B+D)$

Simplify ② $\rightarrow C_{power}' \cdot (2 \cdot B \cdot T_d + 2 \cdot L \cdot T_d + L \cdot B) \cdot V^3$

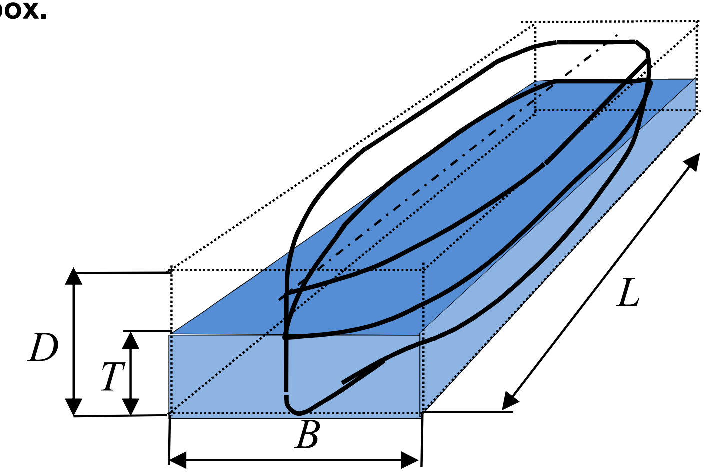
$(L \cdot B \cdot T_d \cdot C_B)^{2/3}$ **is (Volume)$^{2/3}$ and means the submerged area of the ship.**
So, we assume that the submerged area of the ship is equal to the submerged area of the rectangular box.

  - **Required cargo hold capacity(Volume equation)**

$$V_{H.req} = C_H \cdot L \cdot B \cdot D \quad ...(b)$$

  - **Recommended range of obesity coefficient considering maneuverability of a ship**

$$\frac{C_B}{(L/B)} < 0.15 \quad ...(c)$$



➡ **Indeterminate Equation: 3 variables(L, B, C_B), 2 equality constraints((a), (b))**

⇨ **It can be formulated as an optimization problem to minimize an objective function.**

Test Examples #4
- Determination of the Optimal Principal Dimensions of a Ship (2/4)

- ***Given***: $DWT, V_{H.req}, D, T_s, T_d$
- ***Find***: L, B, C_B
- ***Minimize***: **Building Cost**

$$f(L,B,C_B) = C_{PS} \cdot C_s{}' \cdot L^{2.0} \cdot (B+D) + C_{PO} \cdot C_o \cdot L \cdot B + C_{PM} \cdot C_{power}{}' \cdot (2 \cdot B \cdot T_d + 2 \cdot L \cdot T_d + L \cdot B) \cdot V^3 \quad \ldots(d)$$

- ***Subject to***
  - **Hydrostatic equilibrium(Simplified weight equation)**

$$L \cdot B \cdot T_s \cdot C_B \cdot \rho_{sw} \cdot C_\alpha = DWT_{given} + LWT(L,B,D,C_B)$$

$$= DWT_{given} + C_s{}' \cdot L^{2.0} \cdot (B+D) + C_o \cdot L \cdot B + C_{power}{}' \cdot (2 \cdot B \cdot T_d + 2 \cdot L \cdot T_d + L \cdot B) \cdot V^3 \quad \ldots(a')$$

$$V_{H.req} = C_H \cdot L \cdot B \cdot D \quad \ldots(b)$$

$$\frac{C_B}{(L/B)} < 0.15 \quad \ldots(c)$$

Test Examples #4
- Determination of the Optimal Principal Dimensions of a Ship (3/4)

Given data for basis ship and owner's requirements for design ship

Item		Basis ship(150,000ton Bulk Carrier)	Design ship(160,000ton Bulk Carrier)	Notes
Principal Dimensions	L_{OA}	abt. 274.00 m	max. 284.00 m	
	L_{BP}	264.00 m	?	
	B_{mld}	45.00 m	?	
	D_{mld}	23.20 m	23.20m	
	T_{mld}	16.90 m	17.20 m	
	T_{scant}	16.90 m	17.20 m	
	C_B	0.8214	?	
Deadweight		150,960 ton	160,000 ton	at 17.20 m
Speed		13.5 kts	13.5 kts	90 % MCR (with 20 % SM)
M/E	TYPE	B&W 5S70MC		
	NMCR	17,450 HP × 88.0 RPM		Derating Ratio = 0.9
	DMCR	15,450 HP × 77.9 RPM		E.M = 0.9
	NCR	13,910 HP × 75.2 RPM		
FOC	SFOC	126.0 g/HP. H		Standardize to NCR
	TON/DAY	41.6		
Cruising Range		28,000 N/M	26,000 N/M	
Midship Section		Single Hull Double Bottom/Hopper /Top Side Wing Tank	Single Hull Double Bottom/Hopper /Top Side Wing Tank	
Capacity	Cargo	abt. 169,380 m^3	abt. 179,000 m^3	Including Hatch Coaming
	Fuel Oil	abt. 3,960 m^3		Total
	Fuel Oil	abt. 3,850 m^3		Bunker Tank Only
	Ballast	abt. 48,360 m^3		Including F.P and A.P Tank

Test Examples #4
- Determination of the Optimal Principal Dimensions of a Ship (3/4)

Given data for basis ship(150,000 ton Bulk Carrier)

Item	Value
Lightweight	18,269 ton
Hull structural weight (Ws)	15,289 ton
Outfit weight (Wo)	1,694 ton
Machinery weight (Wm)	1,281 ton
$C_{s'}$, C_o, C_{power}	Calculate!
Coefficient for hull structural cost (C_{PS})	972.80
Coefficient for outfitting cost (C_{PO})	20,256
Coefficient for machinery cost (C_{PM})	7,760
$C\alpha$	Calculate!
ρ_{sw}	1.025 ton/m^3

[Reference] Transformation of an Equality Constraint into Two Inequality Constraints

☑ For convenience, one equality constraint into two inequality constraints, as follows.

$$h(\mathbf{x}) = 0 \quad \Rightarrow \quad 0 \le h(\mathbf{x}) \le 0 \quad \Rightarrow \quad -\varepsilon \le h(\mathbf{x}) \le \varepsilon$$

ε : positive small value

⬇

$$g_1(\mathbf{x}) = -\varepsilon - h(\mathbf{x}) \le 0$$

$$g_2(\mathbf{x}) = h(\mathbf{x}) - \varepsilon \le 0$$