

数理計画法

第8回：双対問題と双対定理・相補性定理

前回(第7回)授業と演習問題の復習

復習：演習問題7

次の線形計画問題の双対問題を求め、単体法等を用いてこれを解き、最適解の与える両者の目的関数値が等しいことを確認してください。

maximize

$$z = x_1 + x_2$$

subject to

$$x_1 + 2x_2 \leq 2$$

$$2x_1 + x_2 \leq 2$$

$$x_1, x_2 \geq 0$$

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

$$2y_1 + y_2 \geq 1$$

$$y_1, y_2 \geq 0$$

復習：双対問題

$$\begin{aligned} &\text{minimize} \\ & z = \mathbf{c}^T \mathbf{x} \\ &\text{subject to} \\ & \mathbf{Ax} \geq \mathbf{b} \\ & \mathbf{x} \geq \mathbf{0} \end{aligned}$$

主問題

$$\mathbf{A} = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nm} \end{pmatrix}$$

$$\mathbf{x} = \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{pmatrix} \quad \mathbf{b} = \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{pmatrix}$$

$$\begin{aligned} &\text{maximize} \\ & w = \mathbf{b}^T \mathbf{y} \\ &\text{subject to} \\ & \mathbf{A}^T \mathbf{y} \leq \mathbf{c} \\ & \mathbf{y} \geq \mathbf{0} \end{aligned}$$

双対問題

$$\mathbf{A}^T = \begin{pmatrix} a_{11} & a_{21} & \dots & a_{n1} \\ a_{12} & a_{22} & \dots & a_{n2} \\ \vdots & \vdots & & \vdots \\ a_{1m} & a_{2m} & \dots & a_{nm} \end{pmatrix}$$

$$\mathbf{y} = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix} \quad \mathbf{c} = \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_m \end{pmatrix}$$

maximize
 $z = x_1 + x_2$
 subject to
 $x_1 + 2x_2 \leq 2$
 $2x_1 + x_2 \leq 2$
 $x_1, x_2 \geq 0$

minimize
 $\tilde{z} (= -z = -x_1 - x_2)$
 subject to
 $x_1 + 2x_2 + x_3 = 2$
 $2x_1 + x_2 + x_4 = 2$
 $\tilde{z} + x_1 + x_2 = 0$
 $x_1, x_2, x_3, x_4 \geq 0$

z	x1	x2	x3	x4	定数	
	1	2	1		2	$/1=2$
	2	1		1	2	$/2=1$
1	1	1			0	

z	x1	x2	x3	x4	定数	
	0	$3/2$	1	$-1/2$	$1/2$	$/1=2$
	1	$1/2$		$1/2$	1	$/2=1$
1	1	1		$-1/2$	0	

z	x1	x2	x3	x4	定数	
		$3/2$	1	$-1/2$	1	$/(3/2)=2/3$
	1	$1/2$		$1/2$	1	$/(1/2)=2$
1		$1/2$		$-1/2$	-1	

z	x1	x2	x3	x4	定数	
	0	$1/2$	$2/3$	$-1/3$	$2/3$	$/(3/2)=2/3$
	1	$1/2$		$1/2$	1	$/(1/2)=2$
1		$1/2$	0	$-1/3$	$2/3$	
		0	$-1/3$	$-1/3$	$-4/3$	

$x_1 = x_2 = 2/3, \tilde{z} = -4/3 \Rightarrow z = 4/3$

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

$$2y_1 + y_2 \geq 1$$

$$y_1, y_2 \geq 0$$

minimize

w^* , then w

subject to

$$y_1 + 2y_2 - y_3 + y_5 = 1$$

$$2y_1 + y_2 - y_4 + y_6 = 1$$

$$w - 2y_1 - 2y_2 = 0$$

$$w^* + 3y_1 + 3y_2 - y_3 - y_4 = 2$$

$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1 非	y_2 非	y_3 非	y_4 非	y_5	y_6	定数
	1	2	-1		1		1
	2	1		-1		1	1
1	-2	-2					0
1	3	3	-1	-1			2

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

$$2y_1 + y_2 \geq 1$$

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w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
	1	2	-1		1		1
	2	1		-1		1	1
1	-2	-2					0
1	3	3	-1	-1			2

minimize

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w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
	1	2	-1		1		1
	2	1		-1		1	1
1	-2	-2					0
1	3	3	-1	-1			2

minimize

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1 非	y_2 非	y_3 非	y_4 非	y_5	y_6 非	定数
	1	2	-1		1		1
	2	1		-1		1	1/2
1	-2	-2					0
1	3	3	-1	-1			2

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

$$2y_1 + y_2 \geq 1$$

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y1	y2	y3	y4	y5	y6	定数
	1	2	-1		1		1
$\times 1/2$	2	1		-1		1	$1/2$
1	-2	-2					0
1	3	3	-1	-1			2

minimize

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1 非	y_2 非	y_3 非	y_4 非	y_5	y_6 非	定数
	1	2	-1		1		1
$\times 1/2$	1	1		-1/2		1/2	1/2
	-2	-2					0
	3	3	-1	-1			2

minimize

$$w = 2y_1 + 2y_2$$

subject to

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1 非	y_2 非	y_3 非	y_4 非	y_5	y_6 非	定数
$- \times 1$	-1	1	2	-1		1	1
$\times 1/2$	1	2	1	$-1/2$		$1/2$	$1/2$
1	-2	-2					0
1	3	3	-1	-1			2

minimize

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
-1	1	2	-1		1		1
$1/2$	2	1		-1		1	$1/2$
1	-2	-2					0
1	3	3	-1	-1			2

minimize

$$w = 2y_1 + 2y_2$$

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$\times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1	-1/2	-1	1/2
	1	-2	-2				0
$\times 3$	1	3	-3/2	3	-1	3/2	-1

minimize

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subject to

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数	
$- \times 1$	-1	2	-1	1	1	-1/2	-1/2	1
$\times 1/2$	1	1	-1	-1	1	1/2	1/2	1/2
$+ \times 2$	1	-2	-2	-1	1	1	1	0
$- \times 3$	1	3	-1	-1	1	-3/2	-3/2	2

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1		-1/2	1/2
$+ \times 2$	1	-2	-2		-1		0
$- \times 3$	1	3	-3/2	3	-1	3/2	2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
	0	3/2	-1	1/2	1	-1/2	1/2
	1	1/2		-1/2		1/2	1/2
1	0	-1		-1		1	1
1	0	3/2	-1	1/2		-3/2	1/2

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1		-1/2	1
$+ \times 2$	1	-2	-2		-1		0
$- \times 3$	1	3	-3/2	3	-1	3/2	2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
	0	3/2	-1	1/2	1	-1/2	1/2
	1	1/2		-1/2		1/2	1/2
1	0	-1		-1		1	1
1	0	3/2	-1	1/2		-3/2	1/2

minimize

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	-2	-1	1/2	0
$+ \times 2$	1	-2	1	-2	-1	1	1
$- \times 3$	1	3	-3/2	3	-1	3/2	2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
	0	3/2	-1	1/2	1	-1/2	1/2
	1	1/2		-1/2		1/2	1/2
1	0	-1		-1		1	1
1	0	3/2	-1	1/2		-3/2	1/2

minimize

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subject to

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1		-1/2	1/2
$+ \times 2$	1	-2	-2		-1		0
$- \times 3$	1	3	-3/2	3	-1	3/2	2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
	0	3/2	-1	1/2	1	-1/2	1/2
	1	1/2		-1/2		1/2	1/2
1	0	-1		-1		1	1
1	0	3/2	-1	1/2		-3/2	1/2

minimize

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1 非	y_2 非	y_3 非	y_4 非	y_5	y_6 非	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1		-1/2	-1
$+ \times 2$	1	-2	1	-2		-1	0
$- \times 3$	1	-3	3	-3/2	-1	3/2	-1

w, w^*	y_1	y_2 非	y_3 非	y_4 非	y_5 非	y_6 非	定数
$\times 2/3$	0	3/2	-1	1/2	1	-1/2	1/2
	1	1/2		-1/2		1/2	1/2
1	0	-1		-1		1	1
1	0	3/2	-1	1/2		-3/2	1/2

minimize

$$w = 2y_1 + 2y_2$$

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1		-1/2	1/2
$+ \times 2$	1	-2	1	-2		-1	0
$- \times 3$	1	3	-3/2	3	-1	3/2	2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$\times 2/3$	0	3/2	-1	1/2	1	-1/2	1/2
$- \times 1/2$	1	1/2	1/3	-1/6	-1/3	1/6	1/2
$+ \times 1$	1	0	-1	-2/3	1/3	-1/3	1/3
$- \times 3/2$	1	0	1	-1	-1/2	-1	1/2

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$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	2	-1	1	-1/2	-1/2
$\times 1/2$	1	2	1	-1	1	1/2	1/2
$+ \times 2$	1	-2	-2	-1	1	1	0
$- \times 3$	1	3	3	-1	-1	-3/2	-3/2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
	1	0	1/3	-2/3	-1/3	2/3	1/3
1		0	-2/3	-2/3	2/3	2/3	4/3
1		0	0	0	-1	-1	0

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$\times 2/3$		1	-2/3	1/3	2/3	-1/3	1/3
$- \times 1/2$	1	1/2	1/3	-1/6	-1/3	1/6	-1/6
$+ \times 1$	1	0	-1	-2/3	1/3	-1/3	1/3
$- \times 3/2$	1	0	1	-1	-1	1/2	-1/2

minimize

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$$w^* + 3y_1 + 3y_2 - y_3 - y_4 = 2$$

$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1	-1	-1/2	1/2
$+ \times 2$	1	-2	-2	-1		1	1
$- \times 3$	1	-3	-3/2	3	-1	3/2	-3/2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
	1	0	1/3	-2/3	-1/3	2/3	1/3
1		0	-2/3	-2/3	2/3	2/3	4/3
1		0	0	0	-1	-1	0

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$\times 2/3$		0	3/2	-1	1/2	1	1/2
$- \times 1/2$		1	1/2	1/3	-1/6	-1/3	1/6
$+ \times 1$	1	0	-1	-2/3	1/3	-1	2/3
$- \times 3/2$	1	0	-3/2	1	-1/2	-1	1/2

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

$$2y_1 + y_2 \geq 1$$

$$y_1, y_2 \geq 0$$

minimize

w^* , then w

subject to

$$y_1 + 2y_2 - y_3 + y_5 = 1$$

$$2y_1 + y_2 - y_4 + y_6 = 1$$

$$w - 2y_1 - 2y_2 = 0$$

$$w^* + 3y_1 + 3y_2 - y_3 - y_4 = 2$$

$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$- \times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1	-1	-1/2	1/2
$+ \times 2$	1	-2	-2	-1		1	1
$- \times 3$	1	-3	-3/2	3	-1	3/2	-3/2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
	1	0	1/3	-2/3	-1/3	2/3	1/3
1		0	-2/3	-2/3	2/3	2/3	4/3
1		0	0	0	-1	-1	0

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
$- \times 1/2$		0	3/2	-1	1/2	1	1/2
	1	1/2	1/3	-1/6	-1/3	1/6	-1/6
$+ \times 1$	1	0	-1	-2/3	1/3	-1	2/3
$- \times 3/2$	1	0	-3/2	1	-1/2	-1	1/2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
	1		1/3	-2/3	-1/3	2/3	1/3
1			-2/3	-2/3	2/3	2/3	4/3
1			0	0	-1	-1	0

minimize

$$w = 2y_1 + 2y_2$$

subject to

$$y_1 + 2y_2 \geq 1$$

$$2y_1 + y_2 \geq 1$$

$$y_1, y_2 \geq 0$$

minimize

w^* , then w

subject to

$$y_1 + 2y_2 - y_3 + y_5 = 1$$

$$2y_1 + y_2 - y_4 + y_6 = 1$$

$$w - 2y_1 - 2y_2 = 0$$

$$w^* + 3y_1 + 3y_2 - y_3 - y_4 = 2$$

$$y_1, y_2, y_3, y_4, y_5, y_6 \geq 0$$

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$\times 1$	-1	1	-1/2	2	-1	1/2	1
$\times 1/2$	1	2	1/2	1	-1	-1/2	1/2
$\times 2$	1	-2	-2	-1	-1	1	1
$\times 3$	1	3	-3/2	3	-1	3/2	-1

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
	1	0	1/3	-2/3	-1/3	2/3	1/3
1		0	-2/3	-2/3	2/3	2/3	4/3
1		0	0	0	-1	-1	0

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
$\times 2/3$		0	3/2	-1	1/2	1	2/(3/2) = 1/3
$\times 1/2$		1	1/2	1/3	-1/6	-1/3	1/6
$\times 1$	1	0	-1	-2/3	1/3	-1	2/3
$\times 3/2$	1	0	3/2	-1	1/2	-1	1/2

w, w^*	y_1	y_2	y_3	y_4	y_5	y_6	定数
		1	-2/3	1/3	2/3	-1/3	1/3
	1		1/3	-2/3	-1/3	2/3	1/3
1			-2/3	-2/3	2/3	2/3	4/3
1			0	0	-1	-1	0

復習：演習問題7

次の線形計画問題の双対問題を求め、単体法を用いてこれを解き、最適解の与える両者の目的関数値が等しいことを確認してください。

