Universidade Federal de São Carlos
Departamento de Engenharia de Produção

Otimização Linear Contínua e Discreta

Tópico 6.4: Métodos de pontos interiores: Exercício resolvido

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Métodos de pontos interiores: Exercício resolvido $\qquad$ 1

Apresentação - Tópico 6.4

Objetivos deste tópico:

▶ Fixar os conceitos estudados e compreender o funcionamento do método primal-dual de pontos interiores por meio de um exercício resolvido passo-a-passo.

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Métodos de pontos interiores: Exercício resolvido 2

Método primal-dual de pontos interiores
▷ Exercício

Determine a solução ótima usando o método primal-dual de pontos interiores.
Escolha o tamanho do passo sem considerar uma vizinhança do caminho
central, adotando o teste da razão simples.

$$\begin{aligned}
\max \quad & f(x_1, x_2) = 3x_1 + 2x_2 \\
\text{s.a} \quad & 0{,}5x_1 + 0{,}3x_2 \leq 3 \\
& 0{,}1x_1 + 0{,}2x_2 \leq 1 \\
& 0{,}4x_1 + 0{,}5x_2 \leq 3 \\
& x_1 \geq 0, x_2 \geq 0
\end{aligned}$$

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Métodos de pontos interiores: Exercício resolvido   3

Método primal-dual de pontos interiores
▷ Exercício

Determine a solução ótima usando o método primal-dual de pontos interiores.
Escolha o tamanho do passo sem considerar uma vizinhança do caminho
central, adotando o teste da razão simples.

$$\begin{aligned}
\min \quad & -3x_1 - 2x_2 + 0x_3 + 0x_4 + 0x_5 \\
\text{s.a} \quad & 0{,}5x_1 + 0{,}3x_2 + x_3 = 3 \\
& 0{,}1x_1 + 0{,}2x_2 + x_4 = 1 \\
& 0{,}4x_1 + 0{,}5x_2 + x_5 = 3 \\
& x_1, x_2, x_3, x_4, x_5 \geq 0
\end{aligned}$$

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Métodos de pontos interiores: Exercício resolvido 4

Método primal-dual de pontos interiores
▷ Exercício: Inicialização

Dados do problema:

$$c^T = \begin{bmatrix} -3 & -2 & 0 & 0 & 0 \end{bmatrix}$$

$$A = \begin{bmatrix} 0,5 & 0,3 & 1 & 0 & 0 \\ 0,1 & 0,2 & 0 & 1 & 0 \\ 0,4 & 0,5 & 0 & 0 & 1 \end{bmatrix} \quad b = \begin{bmatrix} 3 \\ 1 \\ 3 \end{bmatrix}$$

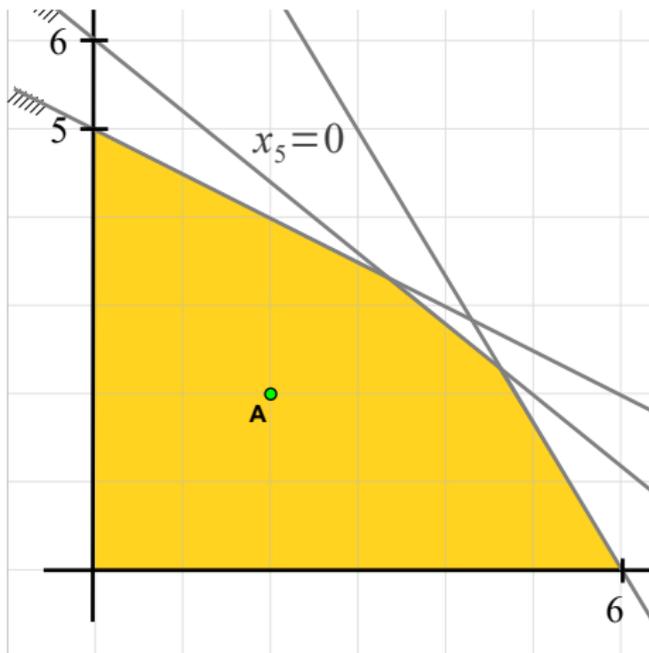Começamos com a solução inicial arbitrária:

$$\bar{x} = (2,\ 2,\ 1{,}4,\ 0{,}4,\ 1{,}2),\quad \bar{p} = (-5,\ -5,\ -5),\quad \bar{s} = (2,\ 3,\ 5,\ 5,\ 5)$$

(escolhemos $x_1 = x_2 = 2$ e as demais são determinadas pelo sistema primal; de forma análoga, escolhemos $\bar{p}$ de modo a se ter $\bar{s} > 0$ pelo sistema dual)

Parâmetros: $\sigma = 0{,}5$; $\delta_p = \delta_d = \delta_o = 0{,}01$; $\alpha_0 = 0{,}95$.

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Métodos de pontos interiores: Exercício resolvido 5

Método primal-dual de pontos interiores

▷ Exercício: Inicialização

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Métodos de pontos interiores: Exercício resolvido 6

Método primal-dual de pontos interiores
▷ Exercício: Código em Octave

```
A = [0.5 0.3 1 0 0; 0.1 0.2 0 1 0; 0.4 0.5 0 0 1]
c = [-3; -2; 0; 0; 0]
b = [3; 1; 3]

n = 5
m = 3

x = [2 ; 2; 1.4; 0.4; 1.2]
p = [-5; -5; -5]
s = [2; 3; 5; 5; 5]

sigma = 0.5
alpha0 = 0.95

e = [1; 1; 1; 1; 1]
```

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Métodos de pontos interiores: Exercício resolvido 7

Método primal-dual de pontos interiores

▷ Exercício: Código em Octave

```octave
mu = (x' * s) / n

X = diag(x)
S = diag(s)

J = [A zeros(m,m) zeros(m,n); zeros(n,n) A' eye(n); S zeros(n,m) X]
F = [A * x - b; A' * p + s - c; X * S * e - sigma * mu *e]
D = J \ (-F)

Dx = D(1:n)
Dp = D(n+1:n+m)
Ds = D(n+m+1:2*n+m)

-x ./ Dx
-s ./ Ds

alpha = alpha0 * (- s(1)/Ds(1)) /* Coloque aqui a variável com menor razao */

x = x + alpha * Dx
p = p + alpha * Dp
s = s + alpha * Ds
```

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Métodos de pontos interiores: Exercício resolvido   8

Iteração 1:

▶ $\bar{x} = \begin{bmatrix} 2.0 \\ 2.0 \\ 1.4 \\ 0.4 \\ 1.2 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5 \\ -5 \\ -5 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 2 \\ 3 \\ 5 \\ 5 \\ 5 \end{bmatrix}$.

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Métodos de pontos interiores: Exercício resolvido   8

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▶ $\bar{\mu} =$

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Métodos de pontos interiores: Exercício resolvido   8

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- $\bar{x} = \begin{bmatrix} 2.0 \\ 2.0 \\ 1.4 \\ 0.4 \\ 1.2 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5 \\ -5 \\ -5 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 2 \\ 3 \\ 5 \\ 5 \\ 5 \end{bmatrix}$.

- $\bar{\mu} = \bar{x}^T \bar{s}/n =$

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Métodos de pontos interiores: Exercício resolvido   8

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▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = (2*2 + 2*3 + 1.4*5 + 0.4*5 + 1.2*5)/5 = 25/5 = 5$;

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Métodos de pontos interiores: Exercício resolvido 8

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▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido
8

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▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$

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Métodos de pontos interiores: Exercício resolvido   8

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$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 8

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 8

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$$\Delta x = \begin{bmatrix} 0.889908 \\ -0.302752 \\ -0.354128 \\ -0.028440 \\ -0.204587 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   8

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$$\Delta x = \begin{bmatrix} 0.889908 \\ -0.302752 \\ -0.354128 \\ -0.028440 \\ -0.204587 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 1.9495 \\ -1.6055 \\ 2.0642 \end{bmatrix},$$

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▶ $\bar{\alpha} = \min\{1, \alpha_0(s_1/-\Delta s_1)\} = \min\{1, 0.95*(2.0/1.6399)\} = 1$;

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Métodos de pontos interiores: Exercício resolvido   8

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▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido   9

Iteração 2:

$$
\blacktriangleright \quad \bar{x} = \begin{bmatrix} 2.88991 \\ 1.69725 \\ 1.04587 \\ 0.37156 \\ 0.99541 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -3.0505 \\ -6.6055 \\ -2.9358 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.36009 \\ 1.70413 \\ 3.05046 \\ 6.60550 \\ 2.93578 \end{bmatrix}.
$$

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Métodos de pontos interiores: Exercício resolvido   9

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$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 2.5;$

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Métodos de pontos interiores: Exercício resolvido   9

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- $\bar{\mu} = \bar{x}^T \bar{s}/n = 2.5$;

- Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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▶ $\bar{\mu} = \bar{x}^T \bar{s} / n = 2.5;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   9

Iteração 2:

$$\bar{x} = \begin{bmatrix} 2.88991 \\ 1.69725 \\ 1.04587 \\ 0.37156 \\ 0.99541 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -3.0505 \\ -6.6055 \\ -2.9358 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.36009 \\ 1.70413 \\ 3.05046 \\ 6.60550 \\ 2.93578 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 2.5$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 9

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Métodos de pontos interiores: Exercício resolvido 9

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido   9

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 1.811616 \\ -0.526005 \\ -0.748006 \\ -0.075960 \\ -0.461644 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 9

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$$\blacktriangleright \ \bar{x} = \begin{bmatrix} 2.88991 \\ 1.69725 \\ 1.04587 \\ 0.37156 \\ 0.99541 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -3.0505 \\ -6.6055 \\ -2.9358 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.36009 \\ 1.70413 \\ 3.05046 \\ 6.60550 \\ 2.93578 \end{bmatrix}.$$

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 1.811616 \\ -0.526005 \\ -0.748006 \\ -0.075960 \\ -0.461644 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.32640 \\ 1.89090 \\ 0.31849 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 9

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Métodos de pontos interiores: Exercício resolvido   9

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▶ $\bar{\alpha} = \min\{1, \alpha_0(x_3/ - \Delta x_3)\} = \min\{1, 1.3283\} = 1$;

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Métodos de pontos interiores: Exercício resolvido 9

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▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido   10

Iteração 3:

▶ $\bar{x} = \begin{bmatrix} 4.70152 \\ 1.17124 \\ 0.29787 \\ 0.29560 \\ 0.53377 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -3.3769 \\ -4.7146 \\ -2.6173 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.20681 \\ 1.26462 \\ 3.37686 \\ 4.71461 \\ 2.61729 \end{bmatrix}$.

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Métodos de pontos interiores: Exercício resolvido   10

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$$
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$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 1.25;$

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Métodos de pontos interiores: Exercício resolvido   10

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Métodos de pontos interiores: Exercício resolvido   10

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Métodos de pontos interiores: Exercício resolvido 10

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Métodos de pontos interiores: Exercício resolvido 10

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Métodos de pontos interiores: Exercício resolvido   10

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido   10

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.467937 \\ -0.128180 \\ -0.195514 \\ -0.021158 \\ -0.123085 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 10

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$$\Delta x = \begin{bmatrix} 0.467937 \\ -0.128180 \\ -0.195514 \\ -0.021158 \\ -0.123085 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.93792 \\ 2.26281 \\ 0.84284 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   10

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$$\Delta x = \begin{bmatrix} 0.467937 \\ -0.128180 \\ -0.195514 \\ -0.021158 \\ -0.123085 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.93792 \\ 2.26281 \\ 0.84284 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.094454 \\ -0.592603 \\ 0.937923 \\ -2.262806 \\ -0.842837 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 10

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$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.34731 \\ 0.85618 \\ 0.38085 \\ 0.76863 \\ 0.77203 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.467937 \\ -0.128180 \\ -0.195514 \\ -0.021158 \\ -0.123085 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.93792 \\ 2.26281 \\ 0.84284 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.094454 \\ -0.592603 \\ 0.937923 \\ -2.262806 \\ -0.842837 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(x_3/-\Delta x_3)\} = \min\{1, 1.4473\} = 1$;

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Métodos de pontos interiores: Exercício resolvido   10

Iteração 3:

▶ $\bar{x} = \begin{bmatrix} 4.70152 \\ 1.17124 \\ 0.29787 \\ 0.29560 \\ 0.53377 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -3.3769 \\ -4.7146 \\ -2.6173 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.20681 \\ 1.26462 \\ 3.37686 \\ 4.71461 \\ 2.61729 \end{bmatrix}.$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 1.25;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.34731 \\ 0.85618 \\ 0.38085 \\ 0.76863 \\ 0.77203 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.467937 \\ -0.128180 \\ -0.195514 \\ -0.021158 \\ -0.123085 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.93792 \\ 2.26281 \\ 0.84284 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.094454 \\ -0.592603 \\ 0.937923 \\ -2.262806 \\ -0.842837 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(x_3/-\Delta x_3)\} = \min\{1, 1.4473\} = 1;$

▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500;$

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Métodos de pontos interiores: Exercício resolvido
11

Iteração 4:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido
11

Iteração 4:

▶ $\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$

▶ $\bar{\mu} = \bar{x}^T \bar{s} / n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

$$\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$$

► $\bar{\mu} = \bar{x}^T \bar{s} / n = 0.62500$;

► Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 11

Iteração 4:

▶ $\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

$$\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.068105 \\ 0.046590 \\ -0.048029 \\ -0.016128 \\ -0.050537 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

▶ $\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}.$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x}-b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p}+\bar{s}-c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s}-\sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.068105 \\ 0.046590 \\ -0.048029 \\ -0.016128 \\ -0.050537 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.76318 \\ 1.16904 \\ 0.79517 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 11

Iteração 4:

▶ $\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s} / n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.068105 \\ 0.046590 \\ -0.048029 \\ -0.016128 \\ -0.050537 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.76318 \\ 1.16904 \\ 0.79517 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.053381 \\ -0.402439 \\ 0.763183 \\ -1.169037 \\ -0.795174 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 11

Iteração 4:

▶ $\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.068105 \\ 0.046590 \\ -0.048029 \\ -0.016128 \\ -0.050537 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.76318 \\ 1.16904 \\ 0.79517 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.053381 \\ -0.402439 \\ 0.763183 \\ -1.169037 \\ -0.795174 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(s_2/-\Delta s_2)\} = \min\{1, 1.5864\} = 1$;

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Métodos de pontos interiores: Exercício resolvido   11

Iteração 4:

▶ $\bar{x} = \begin{bmatrix} 5.16946 \\ 1.04306 \\ 0.10235 \\ 0.27444 \\ 0.41068 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -4.3148 \\ -2.4518 \\ -1.7745 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.11235 \\ 0.67202 \\ 4.31478 \\ 2.45180 \\ 1.77445 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.62500$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.26830 \\ 0.38846 \\ 0.12912 \\ 0.36038 \\ 0.41624 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} 0.068105 \\ 0.046590 \\ -0.048029 \\ -0.016128 \\ -0.050537 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.76318 \\ 1.16904 \\ 0.79517 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.053381 \\ -0.402439 \\ 0.763183 \\ -1.169037 \\ -0.795174 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(s_2/-\Delta s_2)\} = \min\{1, 1.5864\} = 1$;

▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s$;

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Métodos de pontos interiores: Exercício resolvido   12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

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Métodos de pontos interiores: Exercício resolvido   12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

$$
\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}.
$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$
r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},
$$

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Métodos de pontos interiores: Exercício resolvido   12

Iteração 5:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido   12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido   12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s} / n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.069311 \\ 0.205371 \\ -0.026956 \\ -0.034143 \\ -0.074961 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.069311 \\ 0.205371 \\ -0.026956 \\ -0.034143 \\ -0.074961 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.31823 \\ 0.50832 \\ 0.34160 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

$$\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.069311 \\ 0.205371 \\ -0.026956 \\ -0.034143 \\ -0.074961 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.31823 \\ 0.50832 \\ 0.34160 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.028358 \\ -0.176997 \\ 0.318230 \\ -0.508325 \\ -0.341602 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.069311 \\ 0.205371 \\ -0.026956 \\ -0.034143 \\ -0.074961 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.31823 \\ 0.50832 \\ 0.34160 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.028358 \\ -0.176997 \\ 0.318230 \\ -0.508325 \\ -0.341602 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(s_2/-\Delta s_2)\} = \min\{1, 1.4469\} = 1$;

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Métodos de pontos interiores: Exercício resolvido 12

Iteração 5:

▶ $\bar{x} = \begin{bmatrix} 5.237565 \\ 1.089652 \\ 0.054322 \\ 0.258313 \\ 0.360148 \end{bmatrix}$, $\bar{p} = \begin{bmatrix} -5.07797 \\ -1.28276 \\ -0.97928 \end{bmatrix}$, $\bar{s} = \begin{bmatrix} 0.058971 \\ 0.269582 \\ 5.077966 \\ 1.282764 \\ 0.979279 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.3125$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \ r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \ r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.15261 \\ 0.13750 \\ 0.11959 \\ 0.17510 \\ 0.19644 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.069311 \\ 0.205371 \\ -0.026956 \\ -0.034143 \\ -0.074961 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.31823 \\ 0.50832 \\ 0.34160 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.028358 \\ -0.176997 \\ 0.318230 \\ -0.508325 \\ -0.341602 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(s_2/-\Delta s_2)\} = \min\{1, 1.4469\} = 1$;

▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido   13

Iteração 6:

▶ $\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}$, $\bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}$, $\bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}$.

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Métodos de pontos interiores: Exercício resolvido   13

Iteração 6:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}.$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625;$

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Métodos de pontos interiores: Exercício resolvido   13

Iteração 6:

▶ $\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido

13

Iteração 6:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

▶ $\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido   13

Iteração 6:

$$
\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}.
$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$
r_p = A\bar{x}-b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p}+\bar{s}-c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s}-\sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.
$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

▶ $\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.227362 \\ 0.423402 \\ -0.013340 \\ -0.061944 \\ -0.120756 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}.$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625;$

$\blacktriangleright$ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.$$

$\blacktriangleright$ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.227362 \\ 0.423402 \\ -0.013340 \\ -0.061944 \\ -0.120756 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.089065 \\ 0.211932 \\ 0.093723 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

▶ $\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s} / n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.227362 \\ 0.423402 \\ -0.013340 \\ -0.061944 \\ -0.120756 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.089065 \\ 0.211932 \\ 0.093723 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.014150 \\ -0.062528 \\ 0.089065 \\ -0.211932 \\ -0.093723 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

▶ $\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}$, $\bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}$, $\bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.227362 \\ 0.423402 \\ -0.013340 \\ -0.061944 \\ -0.120756 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.089065 \\ 0.211932 \\ 0.093723 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.014150 \\ -0.062528 \\ 0.089065 \\ -0.211932 \\ -0.093723 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(x_2/ - \Delta x_2)\} = \min\{1, 1.4067\} = 1$;

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Métodos de pontos interiores: Exercício resolvido 13

Iteração 6:

$$\bar{x} = \begin{bmatrix} 5.168254 \\ 1.295023 \\ 0.027366 \\ 0.224170 \\ 0.285187 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.39620 \\ -0.77444 \\ -0.63768 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.030613 \\ 0.092585 \\ 5.396197 \\ 0.774439 \\ 0.637677 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.15625$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.08009 \\ 0.04177 \\ 0.06955 \\ 0.09548 \\ 0.10373 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.227362 \\ 0.423402 \\ -0.013340 \\ -0.061944 \\ -0.120756 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} -0.089065 \\ 0.211932 \\ 0.093723 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.014150 \\ -0.062528 \\ 0.089065 \\ -0.211932 \\ -0.093723 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(x_2/-\Delta x_2)\} = \min\{1, 1.4067\} = 1$;

▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido 14

Iteração 7:

▶ $\bar{x} = \begin{bmatrix} 4.940893 \\ 1.718425 \\ 0.014026 \\ 0.162226 \\ 0.164430 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.48526 \\ -0.56251 \\ -0.54395 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.016463 \\ 0.030057 \\ 5.485261 \\ 0.562506 \\ 0.543954 \end{bmatrix}$.

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Métodos de pontos interiores: Exercício resolvido 14

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$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.078125;$

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Métodos de pontos interiores: Exercício resolvido   14

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$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.078125;$

$\blacktriangleright \quad$ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido   14

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Métodos de pontos interiores: Exercício resolvido 14

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Métodos de pontos interiores: Exercício resolvido
14

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Métodos de pontos interiores: Exercício resolvido　14

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 14

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► Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.2128270 \\ 0.3775727 \\ -0.0068583 \\ -0.0542318 \\ -0.1036555 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido
14

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 14

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$$\Delta x = \begin{bmatrix} -0.2128270 \\ 0.3775727 \\ -0.0068583 \\ -0.0542318 \\ -0.1036555 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.018172 \\ 0.133670 \\ -0.036513 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.0078479 \\ -0.0139293 \\ -0.0181719 \\ -0.1336701 \\ 0.0365125 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 14

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▶ $\bar{\alpha} = \min\{1, \alpha_0(x_5/ - \Delta x_5)\} = \min\{1, 1.5070\} = 1$;

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Métodos de pontos interiores: Exercício resolvido 14

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Métodos de pontos interiores: Exercício resolvido 15

Iteração 8:

▶ $\bar{x} = \begin{bmatrix} 4.7280657 \\ 2.0959978 \\ 0.0071678 \\ 0.1079939 \\ 0.0607748 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.46709 \\ -0.42884 \\ -0.58047 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0086151 \\ 0.0161275 \\ 5.4670895 \\ 0.4288361 \\ 0.5804668 \end{bmatrix}.$

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Métodos de pontos interiores: Exercício resolvido   15

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Métodos de pontos interiores: Exercício resolvido   15

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Métodos de pontos interiores: Exercício resolvido 15

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Métodos de pontos interiores: Exercício resolvido   15

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Métodos de pontos interiores: Exercício resolvido   15

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Métodos de pontos interiores: Exercício resolvido 15

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 15

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0671122 \\ 0.1236912 \\ -0.0035513 \\ -0.0180270 \\ -0.0350007 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido
15

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$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.021202 \\ 0.014272 \\ 0.019656 \\ 0.026780 \\ 0.015747 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0671122 \\ 0.1236912 \\ -0.0035513 \\ -0.0180270 \\ -0.0350007 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.033604 \\ 0.176397 \\ -0.075199 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 15

Iteração 8:

▶ $\bar{x} = \begin{bmatrix} 4.7280657 \\ 2.0959978 \\ 0.0071678 \\ 0.1079939 \\ 0.0607748 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.46709 \\ -0.42884 \\ -0.58047 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0086151 \\ 0.0161275 \\ 5.4670895 \\ 0.4288361 \\ 0.5804668 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.039063$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.021202 \\ 0.014272 \\ 0.019656 \\ 0.026780 \\ 0.015747 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0671122 \\ 0.1236912 \\ -0.0035513 \\ -0.0180270 \\ -0.0350007 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.033604 \\ 0.176397 \\ -0.075199 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.0043619 \\ -0.0077609 \\ -0.0336039 \\ -0.1763969 \\ 0.0751994 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 15

Iteração 8:

▶ $\bar{x} = \begin{bmatrix} 4.7280657 \\ 2.0959978 \\ 0.0071678 \\ 0.1079939 \\ 0.0607748 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.46709 \\ -0.42884 \\ -0.58047 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0086151 \\ 0.0161275 \\ 5.4670895 \\ 0.4288361 \\ 0.5804668 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.039063$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.021202 \\ 0.014272 \\ 0.019656 \\ 0.026780 \\ 0.015747 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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▶ $\bar{\alpha} = \min\{1, \alpha_0(x_5/ - \Delta x_5)\} = \min\{1, 1.6496\} = 1$;

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Métodos de pontos interiores: Exercício resolvido 15

Iteração 8:

▶ $\bar{x} = \begin{bmatrix} 4.7280657 \\ 2.0959978 \\ 0.0071678 \\ 0.1079939 \\ 0.0607748 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.46709 \\ -0.42884 \\ -0.58047 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0086151 \\ 0.0161275 \\ 5.4670895 \\ 0.4288361 \\ 0.5804668 \end{bmatrix}$.

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$$r_p = A\bar{x}-b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p}+\bar{s}-c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s}-\sigma\bar{\mu}e = \begin{bmatrix} 0.021202 \\ 0.014272 \\ 0.019656 \\ 0.026780 \\ 0.015747 \end{bmatrix}.$$

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▶ $\bar{\alpha} = \min\{1, \alpha_0(x_5/-\Delta x_5)\} = \min\{1, 1.6496\} = 1$;

▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido   16

Iteração 9:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

$$\blacktriangleright \ \bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}.$$

$\blacktriangleright \ \bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531;$

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Métodos de pontos interiores: Exercício resolvido   16

Iteração 9:

$$\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}.$$

► $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531;$

► Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido   16

Iteração 9:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}.$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531;$

$\blacktriangleright$ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 16

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$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}.$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531;$

$\blacktriangleright$ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

▶ $\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531$;

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$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.010058 \\ 0.008806 \\ 0.009885 \\ 0.012946 \\ 0.007134 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 16

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▶ $\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}$.

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▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

▶ $\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.010058 \\ 0.008806 \\ 0.009885 \\ 0.012946 \\ 0.007134 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0232959 \\ 0.0448365 \\ -0.0018030 \\ -0.0066377 \\ -0.0130999 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

▶ $\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.010058 \\ 0.008806 \\ 0.009885 \\ 0.012946 \\ 0.007134 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0232959 \\ 0.0448365 \\ -0.0018030 \\ -0.0066377 \\ -0.0130999 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.024400 \\ 0.125267 \\ -0.056475 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

▶ $\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}$.

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$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.010058 \\ 0.008806 \\ 0.009885 \\ 0.012946 \\ 0.007134 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0232959 \\ 0.0448365 \\ -0.0018030 \\ -0.0066377 \\ -0.0130999 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.024400 \\ 0.125267 \\ -0.056475 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.0021367 \\ -0.0041361 \\ -0.0243997 \\ -0.1252674 \\ 0.0564747 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

▶ $\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531$;

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$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T \bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.010058 \\ 0.008806 \\ 0.009885 \\ 0.012946 \\ 0.007134 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0232959 \\ 0.0448365 \\ -0.0018030 \\ -0.0066377 \\ -0.0130999 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.024400 \\ 0.125267 \\ -0.056475 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.0021367 \\ -0.0041361 \\ -0.0243997 \\ -0.1252674 \\ 0.0564747 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(x_5/-\Delta x_5)\} = \min\{1, 1.8691\} = 1$;

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Métodos de pontos interiores: Exercício resolvido 16

Iteração 9:

$$\bar{x} = \begin{bmatrix} 4.6609535 \\ 2.2196890 \\ 0.0036166 \\ 0.0899669 \\ 0.0257741 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.43349 \\ -0.25244 \\ -0.65567 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0042532 \\ 0.0083666 \\ 5.4334856 \\ 0.2524392 \\ 0.6556662 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.019531$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.010058 \\ 0.008806 \\ 0.009885 \\ 0.012946 \\ 0.007134 \end{bmatrix}.$$

▶ Resolvendo-se $\nabla F(\bar{x}, \bar{p}, \bar{s})(\Delta x, \Delta p, \Delta s)^T = -F(\bar{x}, \bar{p}, \bar{s})$:

$$\Delta x = \begin{bmatrix} -0.0232959 \\ 0.0448365 \\ -0.0018030 \\ -0.0066377 \\ -0.0130999 \end{bmatrix}, \quad \Delta p = \begin{bmatrix} 0.024400 \\ 0.125267 \\ -0.056475 \end{bmatrix}, \quad \Delta s = \begin{bmatrix} -0.0021367 \\ -0.0041361 \\ -0.0243997 \\ -0.1252674 \\ 0.0564747 \end{bmatrix}.$$

▶ $\bar{\alpha} = \min\{1, \alpha_0(x_5/-\Delta x_5)\} = \min\{1, 1.8691\} = 1$;

▶ $\bar{x} = \bar{x} + \bar{\alpha}\Delta x; \quad \bar{p} = \bar{p} + \bar{\alpha}\Delta p; \quad \bar{s} = \bar{s} + \bar{\alpha}\Delta s;$

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Métodos de pontos interiores: Exercício resolvido   17

Iteração 10:

▶ $\bar{x} = \begin{bmatrix} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.40909 \\ -0.12717 \\ -0.71214 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{bmatrix}$.

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Métodos de pontos interiores: Exercício resolvido 17

Iteração 10:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.40909 \\ -0.12717 \\ -0.71214 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{bmatrix}.$$

$\blacktriangleright \quad \bar{\mu} = \bar{x}^T \bar{s}/n = 0.0097656;$

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Métodos de pontos interiores: Exercício resolvido 17

Iteração 10:

$$\blacktriangleright \quad \bar{x} = \begin{bmatrix} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{bmatrix}, \quad \bar{p} = \begin{bmatrix} -5.40909 \\ -0.12717 \\ -0.71214 \end{bmatrix}, \quad \bar{s} = \begin{bmatrix} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{bmatrix}.$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.0097656$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

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Métodos de pontos interiores: Exercício resolvido 17

Iteração 10:

▶ $\bar{x} = \begin{bmatrix} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.40909 \\ -0.12717 \\ -0.71214 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.0097656$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix},$$

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Métodos de pontos interiores: Exercício resolvido 17

Iteração 10:

$$\bar{x} = \left[\begin{array}{c} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{array}\right], \quad \bar{p} = \left[\begin{array}{c} -5.40909 \\ -0.12717 \\ -0.71214 \end{array}\right], \quad \bar{s} = \left[\begin{array}{c} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{array}\right].$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.0097656$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \left[\begin{array}{c} 0 \\ 0 \\ 0 \end{array}\right], \quad r_d = A^T\bar{p} + \bar{s} - c = \left[\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{array}\right],$$

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Métodos de pontos interiores: Exercício resolvido   17

Iteração 10:

▶ $\bar{x} = \begin{bmatrix} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.40909 \\ -0.12717 \\ -0.71214 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{bmatrix}$.

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▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x}-b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p}+\bar{s}-c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s}-\sigma\bar{\mu}e = \begin{bmatrix} 0.0049326 \\ 0.0046974 \\ 0.0049268 \\ 0.0057143 \\ 0.0041430 \end{bmatrix}.$$

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Métodos de pontos interiores: Exercício resolvido   17

Iteração 10:

$$
\blacktriangleright \quad \bar{x} = \left[\begin{array}{c} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{array} \right], \quad \bar{p} = \left[\begin{array}{c} -5.40909 \\ -0.12717 \\ -0.71214 \end{array} \right], \quad \bar{s} = \left[\begin{array}{c} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{array} \right].
$$

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.0097656;$

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$
r_p = A\bar{x} - b = \left[\begin{array}{c} 0 \\ 0 \\ 0 \end{array} \right], \quad r_d = A^T\bar{p} + \bar{s} - c = \left[\begin{array}{c} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{array} \right], \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \left[\begin{array}{c} 0.0049326 \\ 0.0046974 \\ 0.0049268 \\ 0.0057143 \\ 0.0041430 \end{array} \right].
$$

▶ Critérios de parada satisfeitos!

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Métodos de pontos interiores: Exercício resolvido   17

Iteração 10:

▶ $\bar{x} = \begin{bmatrix} 4.6376576 \\ 2.2645255 \\ 0.0018135 \\ 0.0833291 \\ 0.0126742 \end{bmatrix}$, $\quad \bar{p} = \begin{bmatrix} -5.40909 \\ -0.12717 \\ -0.71214 \end{bmatrix}$, $\quad \bar{s} = \begin{bmatrix} 0.0021165 \\ 0.0042305 \\ 5.4090859 \\ 0.1271718 \\ 0.7121408 \end{bmatrix}$.

▶ $\bar{\mu} = \bar{x}^T \bar{s}/n = 0.0097656$;

▶ Calcular as componentes de $F(\bar{x}, \bar{p}, \bar{s})$:

$$r_p = A\bar{x} - b = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_d = A^T\bar{p} + \bar{s} - c = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}, \quad r_\mu = \bar{X}\bar{s} - \sigma\bar{\mu}e = \begin{bmatrix} 0.0049326 \\ 0.0046974 \\ 0.0049268 \\ 0.0057143 \\ 0.0041430 \end{bmatrix}.$$

▶ Critérios de parada satisfeitos!

▶ A solução ótima (com precisão de 10^{-2}) é:
  $(\bar{x}_1, \bar{x}_2) \approx (4.64, 2.26)$, com valor ótimo ≈ 18.44;

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Métodos de pontos interiores: Exercício resolvido   18

Método simplex

Iteração 3: $\mathcal{B} = \{1, 4, 2\}$ e $\mathcal{N} = \{3, 5\}$;

$$B = \begin{bmatrix} 0.5 & 0 & 0.3 \\ 0.1 & 1 & 0.2 \\ 0.4 & 0 & 0.5 \end{bmatrix} \quad B^{-1} = \begin{bmatrix} 3.84 & 0 & -2.30 \\ 0.23 & 1 & -0.54 \\ -3.07 & 0 & 3.84 \end{bmatrix}$$

▶ Calcular a solução básica primal:

$$\bar{x}_{\mathcal{B}} = B^{-1}b = \begin{bmatrix} 4.62 \\ 0.08 \\ 2.30 \end{bmatrix}$$

▶ Calcular a solução básica dual:

$$\bar{p}^T = c_{\mathcal{B}}^T B^{-1} = \begin{bmatrix} -5.36 & 0 & -0.78 \end{bmatrix}$$

$$\bar{s}_3 = c_3 - \bar{p}^T a_3 = 5.36$$
$$\bar{s}_5 = c_5 - \bar{p}^T a_5 = 0.78$$

$$c^T = \begin{bmatrix} -3 & -2 & 0 & 0 & 0 \end{bmatrix}$$

$$A = \begin{bmatrix} 0.5 & 0.3 & 1 & 0 & 0 \\ 0.1 & 0.2 & 0 & 1 & 0 \\ 0.4 & 0.5 & 0 & 0 & 1 \end{bmatrix} \quad b = \begin{bmatrix} 3 \\ 1 \\ 3 \end{bmatrix}$$

▶ É possível melhorar essa solução?

▶ Não! Os custos relativos são ≥ 0.

▶ Ou seja, a solução dual é factível.

▶ Portanto: solução ótima encontrada!

▶ $x^\star = (4.62,\ 2.3,\ 0,\ 0.08,\ 0)$;

▶ $f(x^\star) = c_{\mathcal{B}}^T x_{\mathcal{B}} = -18.46$;

Método simplex
▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

▶ **A**: $(0,\ 0,\ 3,\ 1,\ 3)$
▶ **B**: $(0,\ 5,\ 1.5,\ 0,\ 0.5)$
▶ **C**: $(3.33,\ 3.33,\ 0.33,\ 0,\ 0)$
▶ **D**: $(4.62,\ 2.3,\ 0,\ 0.08,\ 0)$
▶ **E**: $(6,\ 0,\ 0,\ 0.4,\ 0.6)$

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Métodos de pontos interiores: Exercício resolvido
20
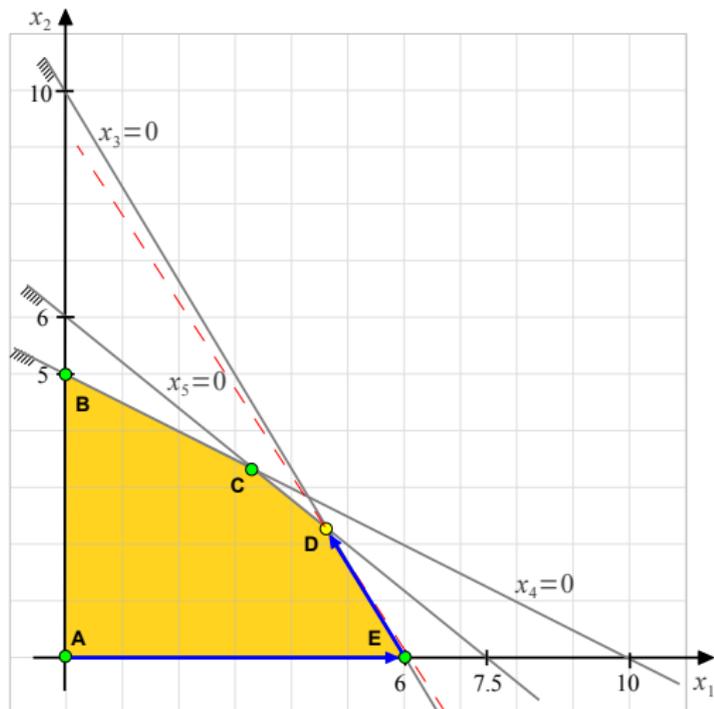
Método primal-dual de pontos interiores

▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:
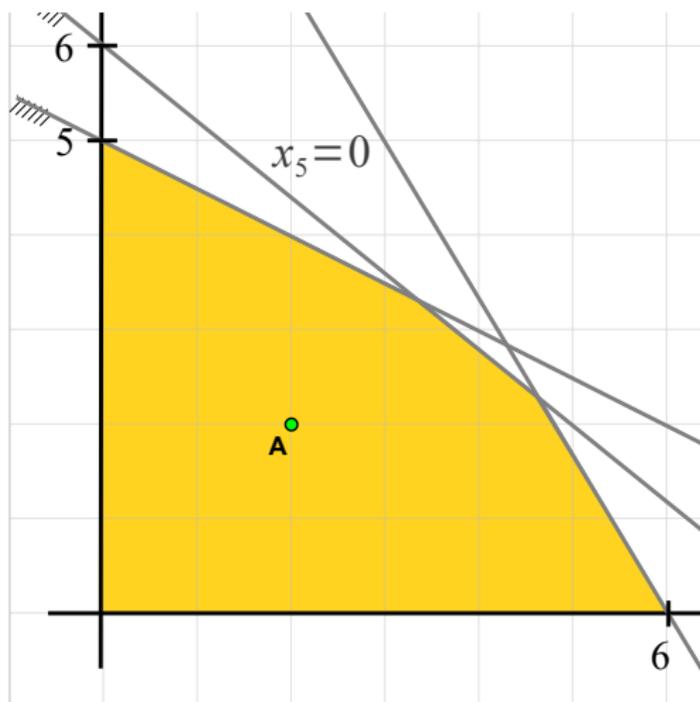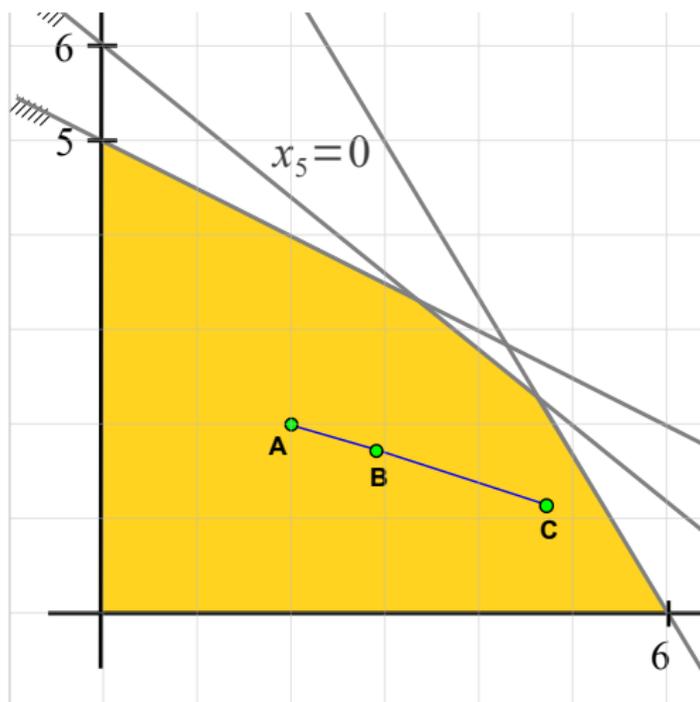
▶ **A** $\approx (2,\ 2,\ 1.4,\ 0.4,\ 1.2)$

Método primal-dual de pontos interiores
▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:
- ▶ **A** $\approx$ (2, 2, 1.4, 0.4, 1.2)
- ▶ **B** $\approx$ (2.89, 1.70, 1.05, 0.37, 0.99)
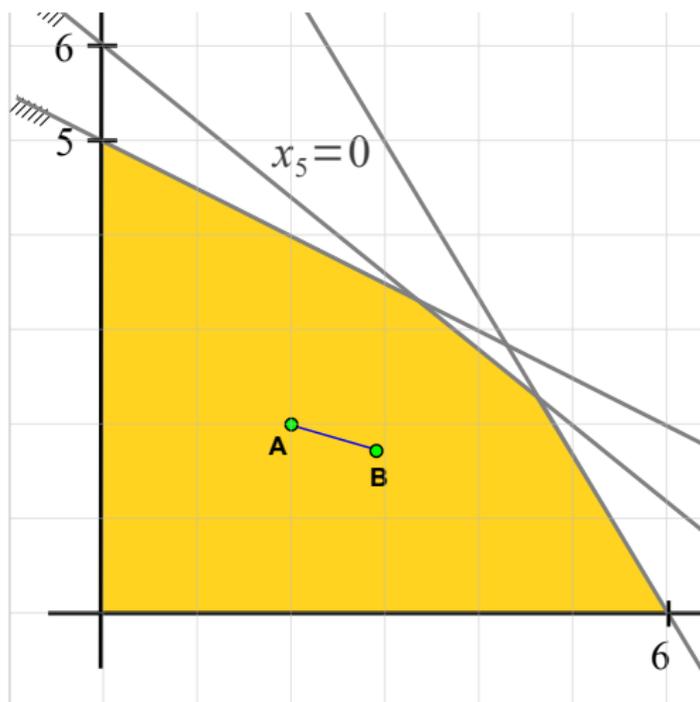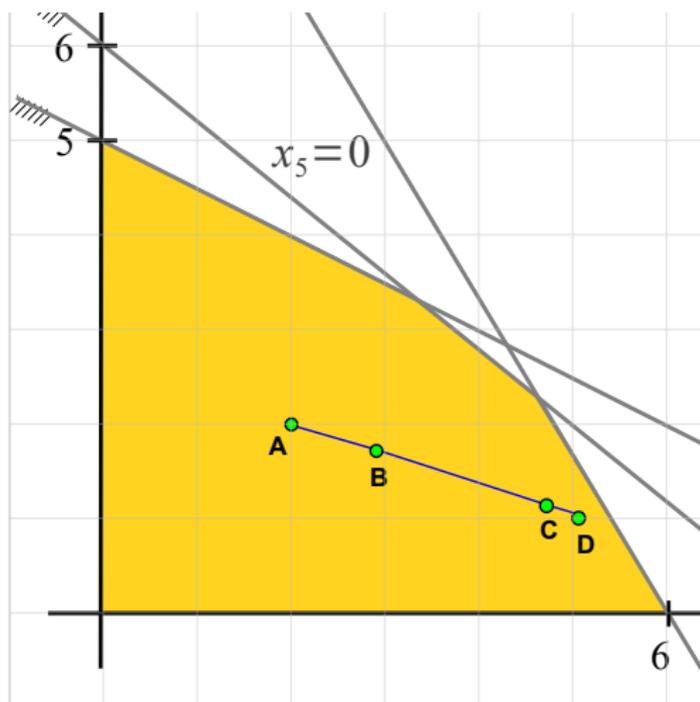
Método primal-dual de pontos interiores
▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

▶ **A** $\approx (2,\ 2,\ 1.4,\ 0.4,\ 1.2)$

▶ **B** $\approx (2.89,\ 1.70,\ 1.05,\ 0.37,\ 0.99)$
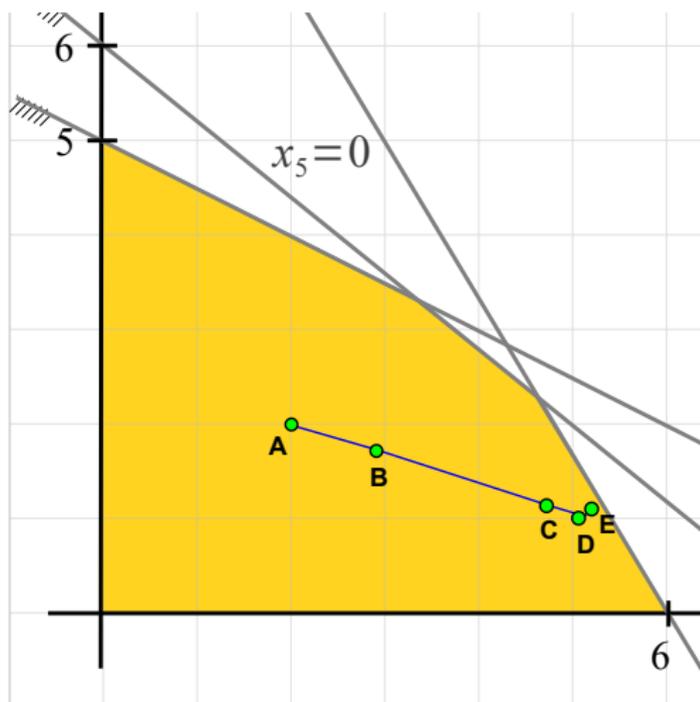
▶ **C** $\approx (4.70, 1.17,\ 0.30,\ 0.30,\ 0.53)$

Método primal-dual de pontos interiores

▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

▶ **A** $\approx (2, 2, 1.4, 0.4, 1.2)$

▶ **B** $\approx (2.89, 1.70, 1.05, 0.37, 0.99)$

▶ **C** $\approx (4.70, 1.17, 0.30, 0.30, 0.53)$

▶ **D** $\approx (5.17, 1.04\ 0.10, 0.27, 0.41)$

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Métodos de pontos interiores: Exercício resolvido 24

Método primal-dual de pontos interiores

▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

- **A** $\approx (2, \; 2, \; 1.4, \; 0.4, \; 1.2)$
- **B** $\approx (2.89, \; 1.70, \; 1.05, \; 0.37, \; 0.99)$
- **C** $\approx (4.70, \; 1.17, \; 0.30, \; 0.30, \; 0.53)$
- **D** $\approx (5.17, \; 1.04 \;\; 0.10, \; 0.27, \; 0.41)$
- **E** $\approx (5.24, \; 1.09, \; 0.05, \; 0.26, \; 0.36)$

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Métodos de pontos interiores: Exercício resolvido

25

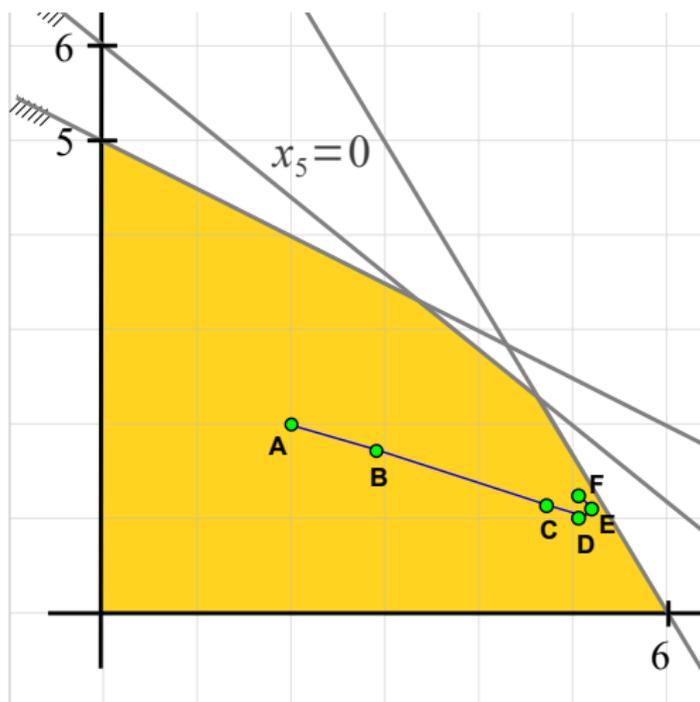# Método primal-dual de pontos interiores

▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

- **A** $\approx$ (2, 2, 1.4, 0.4, 1.2)
- **B** $\approx$ (2.89, 1.70, 1.05, 0.37, 0.99)
- **C** $\approx$ (4.70, 1.17, 0.30, 0.30, 0.53)
- **D** $\approx$ (5.17, 1.04 0.10, 0.27, 0.41)
- **E** $\approx$ (5.24, 1.09, 0.05, 0.26, 0.36)
- **F** $\approx$ (5.17, 1.30, 0.02, 0.22, 0.29)

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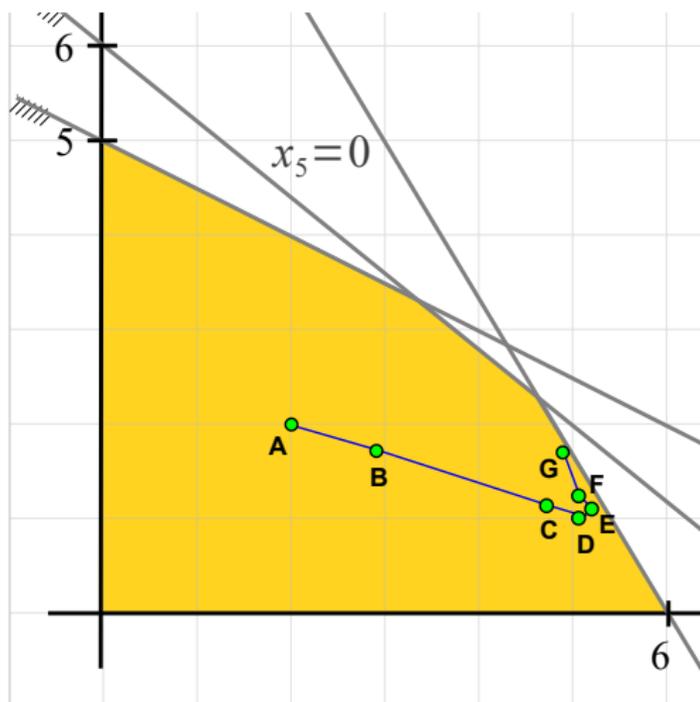Métodos de pontos interiores: Exercício resolvido 26

Método primal-dual de pontos interiores
▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

- **A** $\approx (2,\ 2,\ 1.4,\ 0.4,\ 1.2)$
- **B** $\approx (2.89,\ 1.70,\ 1.05,\ 0.37,\ 0.99)$
- **C** $\approx (4.70,\ 1.17,\ 0.30,\ 0.30,\ 0.53)$
- **D** $\approx (5.17,\ 1.04\ 0.10,\ 0.27,\ 0.41)$
- **E** $\approx (5.24,\ 1.09,\ 0.05,\ 0.26,\ 0.36)$
- **F** $\approx (5.17,\ 1.30,\ 0.02,\ 0.22,\ 0.29)$
- **G** $\approx (4.94,\ 1.71,\ 0.01,\ 0.16,\ 0.16)$

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Métodos de pontos interiores: Exercício resolvido   27
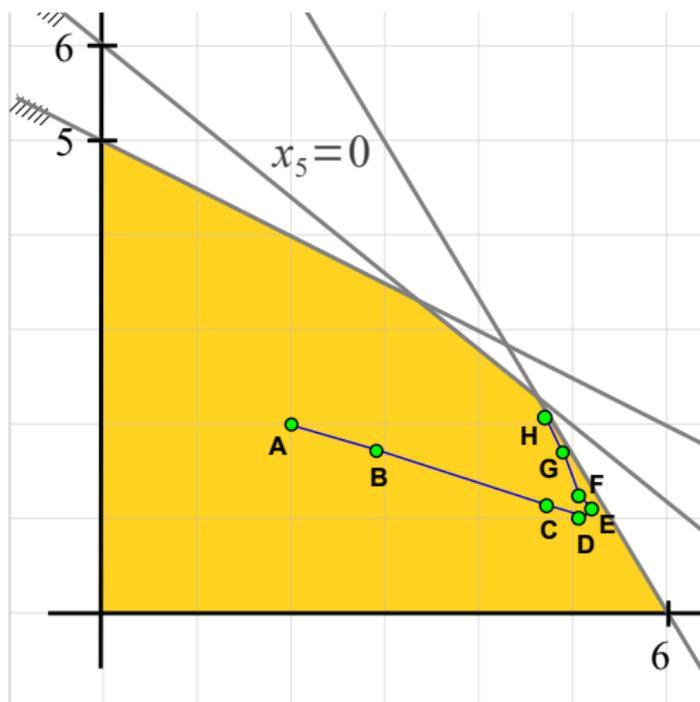
Método primal-dual de pontos interiores

▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

- **A** $\approx$ (2, 2, 1.4, 0.4, 1.2)
- **B** $\approx$ (2.89, 1.70, 1.05, 0.37, 0.99)
- **C** $\approx$ (4.70, 1.17, 0.30, 0.30, 0.53)
- **D** $\approx$ (5.17, 1.04 0.10, 0.27, 0.41)
- **E** $\approx$ (5.24, 1.09, 0.05, 0.26, 0.36)
- **F** $\approx$ (5.17, 1.30, 0.02, 0.22, 0.29)
- **G** $\approx$ (4.94, 1.71, 0.01, 0.16, 0.16)
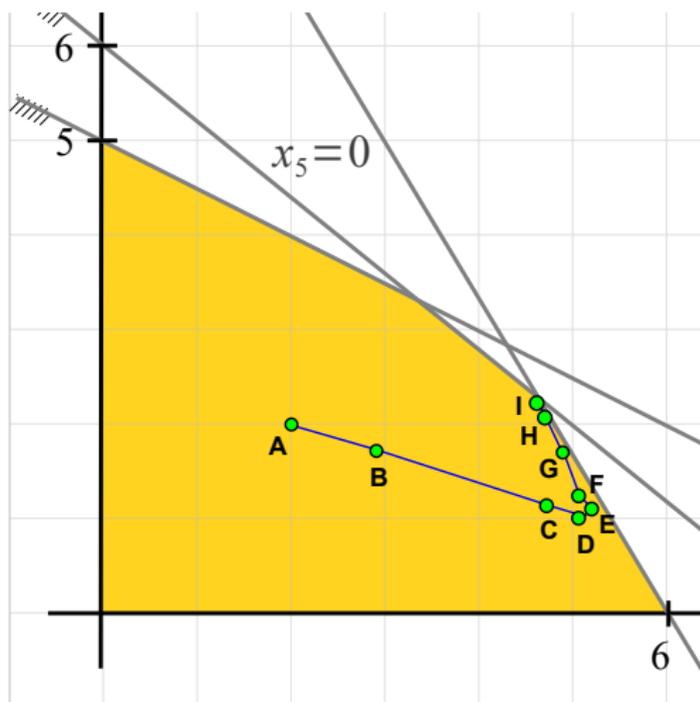- **H** $\approx$ (4.73, 2.10, 0.01, 0.11, 0.06)

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Métodos de pontos interiores: Exercício resolvido   28

Método primal-dual de pontos interiores
▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

▶ **A** $\approx (2, \ 2, \ 1.4, \ 0.4, \ 1.2)$

▶ **B** $\approx (2.89, \ 1.70, \ 1.05, \ 0.37, \ 0.99)$

▶ **C** $\approx (4.70, 1.17, \ 0.30, \ 0.30, \ 0.53)$

▶ **D** $\approx (5.17, \ 1.04 \ 0.10, \ 0.27, \ 0.41)$

▶ **E** $\approx (5.24, \ 1.09, \ 0.05, \ 0.26, \ 0.36)$

▶ **F** $\approx (5.17, \ 1.30, \ 0.02, \ 0.22, \ 0.29)$

▶ **G** $\approx (4.94, \ 1.71, \ 0.01, \ 0.16, \ 0.16)$

▶ **H** $\approx (4.73, \ 2.10, \ 0.01, \ 0.11, \ 0.06)$

▶ **I** $\approx (4.66, \ 2.22, \ 0.00, \ 0.09, \ 0.03)$

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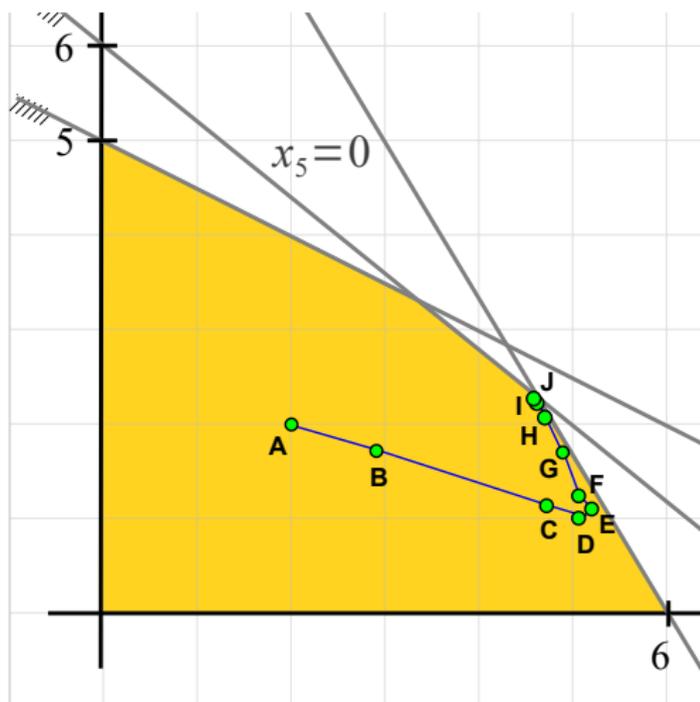Métodos de pontos interiores: Exercício resolvido 29

Método primal-dual de pontos interiores
▷ Ilustração

Para $x = (x_1, x_2, x_3, x_4, x_5)$:

- **A** $\approx (2,\ 2,\ 1.4,\ 0.4,\ 1.2)$
- **B** $\approx (2.89,\ 1.70,\ 1.05,\ 0.37,\ 0.99)$
- **C** $\approx (4.70,\ 1.17,\ 0.30,\ 0.30,\ 0.53)$
- **D** $\approx (5.17,\ 1.04\ 0.10,\ 0.27,\ 0.41)$
- **E** $\approx (5.24,\ 1.09,\ 0.05,\ 0.26,\ 0.36)$
- **F** $\approx (5.17,\ 1.30,\ 0.02,\ 0.22,\ 0.29)$
- **G** $\approx (4.94,\ 1.71,\ 0.01,\ 0.16,\ 0.16)$
- **H** $\approx (4.73,\ 2.10,\ 0.01,\ 0.11,\ 0.06)$
- **I** $\approx (4.66,\ 2.22,\ 0.00,\ 0.09,\ 0.03)$
- **J** $\approx (4.64,\ 2.26,\ 0.00,\ 0.08,\ 0.01)$

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Métodos de pontos interiores: Exercício resolvido   30

Método primal-dual de pontos interiores
▷ Exercício

Determine a solução ótima usando o método primal-dual de pontos interiores,
adotando uma das vizinhanças definidas em aula.

$$\max \quad f(x_1, x_2) = 3x_1 + 2x_2$$

$$\text{s.a} \quad 0{,}5x_1 + 0{,}3x_2 \leq 3$$

$$0{,}1x_1 + 0{,}2x_2 \leq 1$$

$$0{,}4x_1 + 0{,}5x_2 \leq 3$$

$$x_1 \geq 0, x_2 \geq 0$$

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Métodos de pontos interiores: Exercício resolvido   31

- ▶ Obrigado pela atenção!
- ▶ Dúvidas?