

Metaheurística *Late Acceptance Hill Climbing* aplicada ao Problema de Escalonamento de Enfermagem

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Roteiro

- 1 Introdução
- 2 Definição do Problema
- 3 Algoritmo Proposto
- 4 Experimentos computacionais
- 5 Considerações Finais

Introdução

Introdução

O processo de elaboração de *escalas de enfermagem* é um problema operacional geralmente encontrado no ambiente hospitalar.

O objetivo desse processo é definir os turnos de trabalho de cada enfermeiro considerando um horizonte de planejamento e um determinado conjunto de restrições:

- Restrições impostas por lei.
- Normas particulares da instituição.
- Preferências dos funcionários.

Uma escala deficiente pode trazer consequências negativas para os pacientes e funcionários.

Exemplo de escala de enfermagem

	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}	d_{16}	d_{17}	d_{18}	d_{19}	d_{20}	d_{21}	d_{22}	d_{23}	d_{24}	d_{25}	d_{26}	d_{27}	d_{28}
N_1	D	M	M	M	-	-	-	D	M	N	-	-	D	M	M	M	-	-	-	D	D	M	N	-	-	D	M	-
N_2	N	-	N	-	N	-	N	-	N	-	N	-	N	-	N	-	N	-	N	-	-	N	-	N	-	N	-	N
N_3	D	D	D	D	D	-	-	D	D	D	D	D	D	D	D	D	-	-	D	D	D	D	D	D	D	D	D	-
N_4	M	M	M	-	-	M	M	M	M	M	-	-	M	M	M	-	-	M	M	M	M	M	M	-	-	M	M	M
N_5	-	-	M	M	D	-	D	D	-	D	D	D	-	-	M	M	D	-	D	D	D	-	D	D	D	-	-	D
N_6	N	N	-	-	N	-	N	-	N	-	N	-	N	N	-	-	N	-	N	-	-	N	-	N	-	N	N	N

Trabalhos relacionados

International Nurse Rostering Competition (INRC-I) (Haspeslagh et al., 2010).

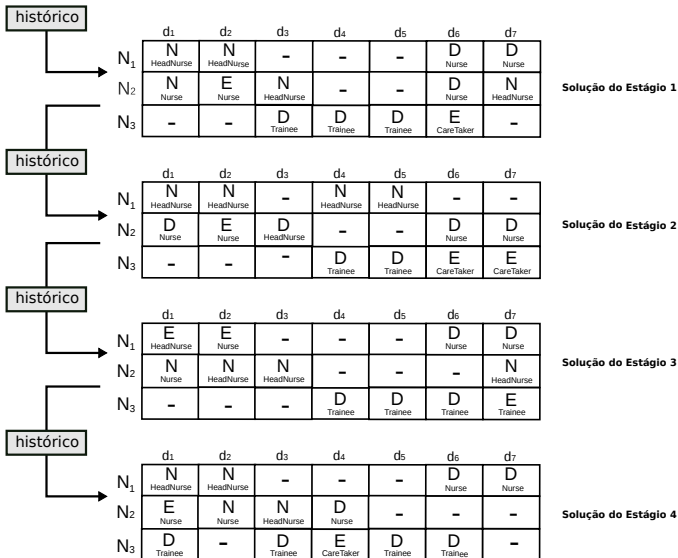
- Problema de um único estágio
- Programação Inteira (Valouxis et al., 2012)
- Programação por Restrições (Nonobe, 2010)
- *Branch and Price e Ejection Chain* (Burke & Curtois, 2010)

Second International Nurse Rostering Competition (INRC-II) (Ceschia et al., 2015)

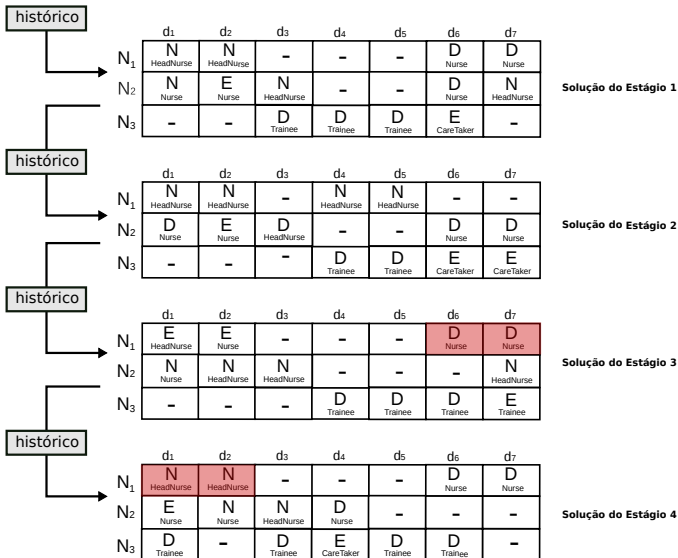
- Problema multi-estágio
- Programação Inteira Mista baseada em fluxo de rede *multi-commodity* (Römer, 2015);
- Hiper-heurística (Kheiri et al., 2016)
- Geração de Colunas combinada com VNS (Gomes et al., 2017)

Definição do Problema

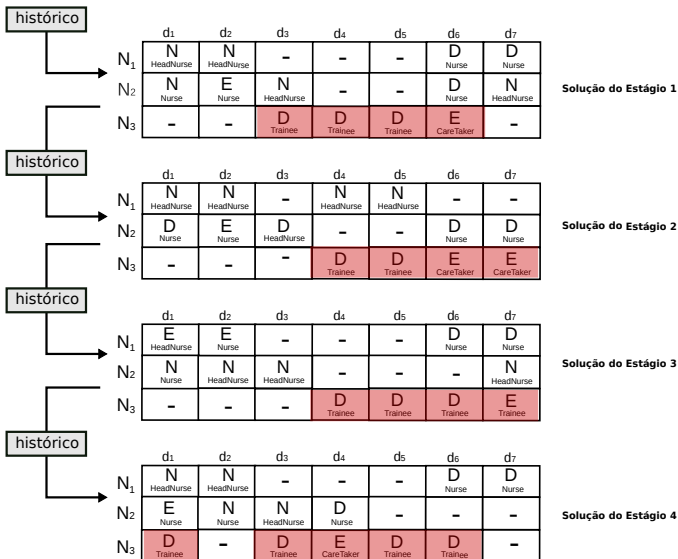
Problema multi-estágio



Problema multi-estágio



Problema multi-estágio



Definição das restrições da INRC-II

Restrições Fortes

- H1** O enfermeiro deve trabalhar apenas um turno por dia.
- H2** A cobertura mínima deve ser respeitada.
- H3** A sucessão de turnos deve ser válida.
- H4** Qualificações atribuídas devem pertencem ao conjunto de qualificações do enfermeiro.

Restrições Fracas

- S1** A cobertura ótima deve ser atendida tanto quanto possível.
- S2ab** Número mínimo/máximo de dias consecutivos trabalhados.
- S2cd** Número mínimo/máximo de alocações consecutivas no mesmo turno.
- S3ab** Número mínimo/máximo de dias consecutivos de folga.
- S4ab** Enfermeiro prefere não trabalhar em um determinado dia/turno.
- S5** Preferência por fins de semana completo.
- S6ab** Número mínimo/máximo de dias trabalhados.
- S7** Número máximo de fins de semana trabalhados.

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- S5** Preferência por fins de semana completo.

Restrições locais: envolvem dados do estágio atual + histórico

- S7** Número máximo de fins de semana trabalhados.

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- S4ab** Enfermeiro prefere não trabalhar em um determinado dia/turno.

Restrições globais: envolvem dados de todos os estágios

- S6ab** Número mínimo/máximo de dias trabalhados.
- S7** Número máximo de fins de semana trabalhados.

Definição formal das restrições utilizando formulação matemática

Proposta de um modelo não linear mais fácil de compreender que o modelo definido na competição que oferece dois pontos de vista do problema:

- Modelo μ_1 :
 - Visão de um **único estágio**.
 - Compreende apenas **restrições locais**.
- Modelo μ_2 :
 - Visão de **vários estágios**.
 - Expande o modelo μ_1 adicionando **restrições globais**.

Modelo μ_1 : apenas um estágio (Parte I)

$$\begin{aligned}
 \min Z_e = & W^{S1} \sum_{d \in D} \sum_{s \in S} \sum_{k \in K} C_{dsk}^{S1} + W^{S2ab} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S2a} + C_{nij}^{S2b}) + \\
 & W^{S2cd} \sum_{n \in N} \sum_{(i,j) \in B} \sum_{s \in S'} (C_{najs}^{S2c} + C_{najs}^{S2d}) + W^{S3} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S3a} + C_{nij}^{S3b}) + \\
 & W^{S4} \sum_{n \in N} \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} (x_{ndsk}^e * P_{nds} + x_{ndsk}^e * P_{nd}) + W^{S5} \sum_{n \in N} V_n * (1 - \prod_{d \in W} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e) - \delta^e
 \end{aligned}$$

$$\sum_{s \in S} \sum_{k \in K} x_{ndsk}^e = 1 \quad \forall n \in N, d \in D \quad (1)$$

$$\sum_{n \in N} x_{ndsk}^e \geq V_{dsk}^- \quad \forall d \in D, s \in S, k \in K \quad (2)$$

$$\sum_{k \in K} (x_{n,d-1,s_1,k}^e + x_{n,d,s_2,k}^e) \leq 1 \quad \forall n \in N, d \in D \setminus \{1\}, (s_1, s_2) \in F \quad (3)$$

$$\sum_{k \in K} (x_{n,d,s_1,k}^{e-1} + x_{n,1,s_2,k}^e) \leq 1 \quad \forall n \in N, d = |D|, (s_1, s_2) \in F \quad (4)$$

$$x_{ndsk}^e = 0 \quad \forall n \in N, d \in D, s \in S, k \in K \setminus K_n \quad (5)$$

Modelo μ_1 : apenas um estágio (Parte I)

$$\begin{aligned}
 \min Z_e = & W^{S1} \sum_{d \in D} \sum_{s \in S} \sum_{k \in K} C_{dsk}^{S1} + W^{S2ab} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S2a} + C_{nij}^{S2b}) + \\
 & W^{S2cd} \sum_{n \in N} \sum_{(i,j) \in B} \sum_{s \in S'} (C_{najs}^{S2c} + C_{najs}^{S2d}) + W^{S3} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S3a} + C_{nij}^{S3b}) + \\
 & W^{S4} \sum_{n \in N} \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} (x_{ndsk}^e * P_{nds} + x_{ndsk}^e * P_{nd}) + W^{S5} \sum_{n \in N} V_n * (1 - \prod_{d \in W} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e) - \delta^e
 \end{aligned}$$

Função objetivo penalizando as restrições S1 a S5.

$$\forall n \in N, d \in D \quad (1)$$

$$s \in S, k \in K$$

$$\sum_{n \in N} x_{ndsk}^e \geq V_{dsk}^- \quad \forall d \in D, s \in S, k \in K \quad (2)$$

$$\sum_{k \in K} (x_{n,d-1,s_1,k}^e + x_{n,d,s_2,k}^e) \leq 1 \quad \forall n \in N, d \in D \setminus \{1\}, (s_1, s_2) \in F \quad (3)$$

$$\sum_{k \in K} (x_{n,d,s_1,k}^{e-1} + x_{n,1,s_2,k}^e) \leq 1 \quad \forall n \in N, d = |D|, (s_1, s_2) \in F \quad (4)$$

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$$\sum_{s \in S} \sum_{k \in K} x_{ndsk}^e = 1 \quad \forall n \in N, d \in D \quad (1)$$

Restrição H1

$$\sum_{n \in N} x_{ndsk}^e = 1 \quad \forall d \in D, s \in S, k \in K \quad (2)$$

$$\sum_{k \in K} (x_{n,d-1,s_1,k}^e + x_{n,d,s_2,k}^e) \leq 1 \quad \forall n \in N, d \in D \setminus \{1\}, (s_1, s_2) \in F \quad (3)$$

$$\sum_{k \in K} (x_{n,d,s_1,k}^{e-1} + x_{n,1,s_2,k}^e) \leq 1 \quad \forall n \in N, d = |D|, (s_1, s_2) \in F \quad (4)$$

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$$\begin{aligned}
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& W^{S4} \sum_{n \in N} \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} (x_{ndsk}^e * P_{nds} + x_{ndsk}^e * P_{nd}) + W^{S5} \sum_{n \in N} V_n * (1 - \prod_{d \in W} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e) - \delta^e
\end{aligned}$$

$$\sum_{s \in S} \sum_{k \in K} x_{ndsk}^e = 1 \quad \forall n \in N, d \in D \quad (1)$$

$$\sum_{n \in N} x_{ndsk}^e \geq V_{dsk}^- \quad \forall d \in D, s \in S, k \in K \quad (2)$$

$$\text{Restrição H2} \quad x_{n,d,s_2,k}^e \leq 1 \quad \forall n \in N, d \in D \setminus \{1\}, (s_1, s_2) \in F \quad (3)$$

$$\sum_{k \in K} (x_{n,d,s_1,k}^{e-1} + x_{n,1,s_2,k}^e) \leq 1 \quad \forall n \in N, d = |D|, (s_1, s_2) \in F \quad (4)$$

$$x_{ndsk}^e = 0 \quad \forall n \in N, d \in D, s \in S, k \in K \setminus K_n \quad (5)$$

Modelo μ_1 : apenas um estágio (Parte I)

$$\begin{aligned}
\min Z_e = & W^{S1} \sum_{d \in D} \sum_{s \in S} \sum_{k \in K} C_{dsk}^{S1} + W^{S2ab} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S2a} + C_{nij}^{S2b}) + \\
& W^{S2cd} \sum_{n \in N} \sum_{(i,j) \in B} \sum_{s \in S'} (C_{nifs}^{S2c} + C_{nifs}^{S2d}) + W^{S3} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S3a} + C_{nij}^{S3b}) + \\
& W^{S4} \sum_{n \in N} \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} (x_{ndsk}^e * P_{nds} + x_{ndsk}^e * P_{nd}) + W^{S5} \sum_{n \in N} V_n * (1 - \prod_{d \in W} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e) - \delta^e
\end{aligned}$$

$$\sum_{s \in S} \sum_{k \in K} x_{ndsk}^e = 1 \quad \forall n \in N, d \in D \quad (1)$$

$$\sum_{n \in N} x_{ndsk}^e \geq V_{dsk}^- \quad \forall d \in D, s \in S, k \in K \quad (2)$$

$$\sum_{k \in K} (x_{n,d-1,s_1,k}^e + x_{n,d,s_2,k}^e) \leq 1 \quad \forall n \in N, d \in D \setminus \{1\}, (s_1, s_2) \in F \quad (3)$$

$$\sum_{k \in K} (x_{n,d,s_1,k}^{e-1} + x_{n,1,s_2,k}^e) \leq 1 \quad \forall n \in N, d = |D|, (s_1, s_2) \in F \quad (4)$$

Restrição H3

$$\forall n \in N, d \in D, s \in S, k \in K \setminus K_n \quad (5)$$

Modelo μ_1 : apenas um estágio (Parte I)

$$\begin{aligned} \min Z_e = & W^{S1} \sum_{d \in D} \sum_{s \in S} \sum_{k \in K} C_{dsk}^{S1} + W^{S2ab} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S2a} + C_{nij}^{S2b}) + \\ & W^{S2cd} \sum_{n \in N} \sum_{(i,j) \in B} \sum_{s \in S'} (C_{nifs}^{S2c} + C_{nifs}^{S2d}) + W^{S3} \sum_{n \in N} \sum_{(i,j) \in B} (C_{nij}^{S3a} + C_{nij}^{S3b}) + \\ & W^{S4} \sum_{n \in N} \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} (x_{ndsk}^e * P_{nds} + x_{ndsk}^e * P_{nd}) + W^{S5} \sum_{n \in N} V_n * (1 - \prod_{d \in W} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e) - \delta^e \end{aligned}$$

$$\sum_{s \in S} \sum_{k \in K} x_{ndsk}^e = 1 \quad \forall n \in N, d \in D \quad (1)$$

$$\sum_{n \in N} x_{ndsk}^e \geq V_{dsk}^- \quad \forall d \in D, s \in S, k \in K \quad (2)$$

$$\sum_{k \in K} (x_{n,d-1,s_1,k}^e + x_{n,d,s_2,k}^e) \leq 1 \quad \forall n \in N, d \in D \setminus \{1\}, (s_1, s_2) \in F \quad (3)$$

$$\sum_{k \in K} (x_{n,d,s_1,k}^{e-1} + x_{n,1,s_2,k}^e) \leq 1 \quad \forall n \in N, d = |D|, (s_1, s_2) \in F \quad (4)$$

$$x_{ndsk}^e = 0 \quad \forall n \in N, d \in D, s \in S, k \in K \setminus K_n \quad (5)$$

Restrição H4

Modelo μ_1 : apenas um estágio (Parte II)

$$C_{dsk}^{S1} = \max\{V_{dsk}^* - \sum_{n \in N} x_{ndsk}^e, 0\} \quad \forall d \in D, s \in S', k \in K \quad (6)$$

$$b_{nuv}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nij}^e\} \quad \forall n \in N, (u,v) \in B \quad (7)$$

$$b_{nuvs}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{njs}^e\} \quad \forall n \in N, (u,v) \in B, s \in S \quad (8)$$

$${}^e C_{nij}^{S2a} = \max\{0, b_{nij}^e * ((j-i+1 + h_n^e * \lfloor 1/i \rfloor) - L_n^+)\} \quad \forall n \in N, (i,j) \in B \quad (9)$$

$${}^e C_{nij}^{S2b} = \max\{0, b_{nij}^e * (L_n^- - (j-i+1 + h_n^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B \quad (10)$$

$${}^e C_{njs}^{S2c} = \max\{0, b_{njs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - L_{ns}^+)\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (11)$$

$${}^e C_{njs}^{S2d} = \max\{0, b_{njs}^e * (L_{ns}^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (12)$$

$${}^e C_{nij}^{S3a} = \max\{0, b_{njs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - G_n^+)\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (13)$$

$${}^e C_{nij}^{S3b} = \max\{0, b_{njs}^e * (G_n^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (14)$$

$$x_{ndsk}^e \in \{0, 1\} \quad \forall n \in N, d \in D, s \in S, k \in K$$

$$b_{njs}^e, b_{nij}^e \in \{0, 1\} \quad \forall n \in N, (i,j) \in B, s \in S$$

$${}^e C_{nij}^{S2a}, {}^e C_{nij}^{S2b}, {}^e C_{njs}^{S2c}, {}^e C_{njs}^{S2d}, {}^e C_{nij}^{S3a}, {}^e C_{nij}^{S3b} \in \mathbb{N}^* \quad \forall n \in N, (i,j) \in B, s \in S$$

Modelo μ_1 : apenas um estágio (Parte II)

$$C_{dsk}^{S1} = \max\{V_{dsk}^* - \sum_{n \in N} x_{ndsk}^e, 0\} \quad \forall d \in D, s \in S', k \in K \quad (6)$$

$$\text{Restrição S1} \quad \sum_{u=u} \sum_{v=v} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nij}^e \quad \forall n \in N, (u,v) \in B \quad (7)$$

$$b_{nuvs}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{njs}^e\} \quad \forall n \in N, (u,v) \in B, s \in S \quad (8)$$

$$^e C_{nij}^{S2a} = \max\{0, b_{nij}^e * ((j-i+1 + h_n^e * \lfloor 1/i \rfloor) - L_n^+)\} \quad \forall n \in N, (i,j) \in B \quad (9)$$

$$^e C_{nij}^{S2b} = \max\{0, b_{nij}^e * (L_n^- - (j-i+1 + h_n^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B \quad (10)$$

$$^e C_{njs}^{S2c} = \max\{0, b_{njs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - L_{ns}^+)\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (11)$$

$$^e C_{njs}^{S2d} = \max\{0, b_{njs}^e * (L_{ns}^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (12)$$

$$^e C_{nij}^{S3a} = \max\{0, b_{njs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - G_n^+)\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (13)$$

$$^e C_{nij}^{S3b} = \max\{0, b_{njs}^e * (G_n^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (14)$$

$$x_{ndsk}^e \in \{0, 1\} \quad \forall n \in N, d \in D, s \in S, k \in K$$

$$b_{njs}^e, b_{nij}^e \in \{0, 1\} \quad \forall n \in N, (i,j) \in B, s \in S$$

$$^e C_{nij}^{S2a}, ^e C_{nij}^{S2b}, ^e C_{njs}^{S2c}, ^e C_{njs}^{S2d}, ^e C_{nij}^{S3a}, ^e C_{nij}^{S3b} \in \mathbb{N}^* \quad \forall n \in N, (i,j) \in B, s \in S$$

Modelo μ_1 : apenas um estágio (Parte II)

$$C_{dsk}^{S1} = \max\{V_{dsk}^* - \sum_{n \in N} x_{ndsk}^e, 0\} \quad \forall d \in D, s \in S', k \in K \quad (6)$$

$$b_{nuv}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nij}^e\} \quad \forall n \in N, (u,v) \in B \quad (7)$$

$$b_{nuvs}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nifs}^e\} \quad \forall n \in N, (u,v) \in B, s \in S \quad (8)$$

$$\text{Restrições auxiliares adicionadas no modelo para identificar blocos de alocações consecutivas} \quad B \quad (9)$$

$$\text{Restrições auxiliares adicionadas no modelo para identificar blocos de alocações consecutivas} \quad B \quad (10)$$

$${}^e C_{nifs}^{S2c} = \max\{0, b_{nifs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - L_{ns}^+)\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (11)$$

$${}^e C_{nifs}^{S2d} = \max\{0, b_{nifs}^e * (L_{ns}^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (12)$$

$${}^e C_{nij}^{S3a} = \max\{0, b_{nij}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - G_n^+)\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (13)$$

$${}^e C_{nij}^{S3b} = \max\{0, b_{nij}^e * (G_n^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (14)$$

$$x_{ndsk}^e \in \{0, 1\} \quad \forall n \in N, d \in D, s \in S, k \in K$$

$$b_{nifs}^e, b_{nij}^e \in \{0, 1\} \quad \forall n \in N, (i,j) \in B, s \in S$$

$${}^e C_{nij}^{S2a}, {}^e C_{nij}^{S2b}, {}^e C_{nifs}^{S2c}, {}^e C_{nifs}^{S2d}, {}^e C_{nij}^{S3a}, {}^e C_{nij}^{S3b} \in \mathbb{N}^* \quad \forall n \in N, (i,j) \in B, s \in S$$

Modelo μ_1 : apenas um estágio (Parte II)

$$C_{dsk}^{S1} = \max\{V_{dsk}^* - \sum_{n \in N} x_{ndsk}^e, 0\} \quad \forall d \in D, s \in S', k \in K \quad (6)$$

$$b_{nuv}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nij}^e\} \quad \forall n \in N, (u,v) \in B \quad (7)$$

$$b_{nuvs}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nifs}^e\} \quad \forall n \in N, (u,v) \in B, s \in S \quad (8)$$

$$^e C_{nij}^{S2a} = \max\{0, b_{nij}^e * ((j-i+1 + h_n^e * \lfloor 1/i \rfloor) - L_n^+)\} \quad \forall n \in N, (i,j) \in B \quad (9)$$

$$^e C_{nij}^{S2b} = \max\{0, b_{nij}^e * (L_n^- - (j-i+1 + h_n^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B \quad (10)$$

$$\text{Restrições S2a e S2b} \quad -1 + h_{ns}^e * \lfloor 1/i \rfloor) - L_{ns}^+)\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (11)$$

$$^e C_{nifs}^{S2d} = \max\{0, b_{nifs}^e * (L_{ns}^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (12)$$

$$^e C_{nij}^{S3a} = \max\{0, b_{nij}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - G_n^+)\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (13)$$

$$^e C_{nij}^{S3b} = \max\{0, b_{nij}^e * (G_n^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (14)$$

$$x_{ndsk}^e \in \{0, 1\} \quad \forall n \in N, d \in D, s \in S, k \in K$$

$$b_{nifs}^e, b_{nij}^e \in \{0, 1\} \quad \forall n \in N, (i,j) \in B, s \in S$$

$$^e C_{nij}^{S2a}, ^e C_{nij}^{S2b}, ^e C_{nifs}^{S2c}, ^e C_{nifs}^{S2d}, ^e C_{nij}^{S3a}, ^e C_{nij}^{S3b} \in \mathbb{N}^* \quad \forall n \in N, (i,j) \in B, s \in S$$

Modelo μ_1 : apenas um estágio (Parte II)

$$C_{dsk}^{S1} = \max\{V_{dsk}^* - \sum_{n \in N} x_{ndsk}^e, 0\} \quad \forall d \in D, s \in S', k \in K \quad (6)$$

$$b_{nuv}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nij}^e\} \quad \forall n \in N, (u,v) \in B \quad (7)$$

$$b_{nuvs}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nijos}^e\} \quad \forall n \in N, (u,v) \in B, s \in S \quad (8)$$

$$^e C_{nij}^{S2a} = \max\{0, b_{nij}^e * ((j-i+1 + h_n^e * \lfloor 1/i \rfloor) - L_n^+)\} \quad \forall n \in N, (i,j) \in B \quad (9)$$

$$^e C_{nij}^{S2b} = \max\{0, b_{nij}^e * (L_n^- - (j-i+1 + h_n^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B \quad (10)$$

$$^e C_{nijos}^{S2c} = \max\{0, b_{nijos}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - L_{ns}^+)\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (11)$$

$$^e C_{nijos}^{S2d} = \max\{0, b_{nijos}^e * (L_{ns}^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (12)$$

$$\text{Restrições S2c e S2d} \quad -1 + h_{ns}^e * \lfloor 1/i \rfloor - G_n^+) \quad \forall n \in N, (i,j) \in B, s=|S| \quad (13)$$

$$^e C_{nij}^{S3b} = \max\{0, b_{nijos}^e * (G_n^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (14)$$

$$x_{ndsk}^e \in \{0, 1\} \quad \forall n \in N, d \in D, s \in S, k \in K$$

$$b_{nijos}^e, b_{nij}^e \in \{0, 1\} \quad \forall n \in N, (i,j) \in B, s \in S$$

$$^e C_{nij}^{S2a}, ^e C_{nij}^{S2b}, ^e C_{nijos}^{S2c}, ^e C_{nijos}^{S2d}, ^e C_{nijos}^{S3a}, ^e C_{nijos}^{S3b} \in \mathbb{N}^* \quad \forall n \in N, (i,j) \in B, s \in S$$

Modelo μ_1 : apenas um estágio (Parte II)

$$C_{dsk}^{S1} = \max\{V_{dsk}^* - \sum_{n \in N} x_{ndsk}^e, 0\} \quad \forall d \in D, s \in S', k \in K \quad (6)$$

$$b_{nuv}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{nij}^e\} \quad \forall n \in N, (u,v) \in B \quad (7)$$

$$b_{nuvs}^e = \max\{0, \sum_{u \leq d \leq v} \sum_{k \in K} x_{ndsk}^e - (v-u) - \sum_{(i,j) \in B_{uv}} b_{njs}^e\} \quad \forall n \in N, (u,v) \in B, s \in S \quad (8)$$

$${}^e C_{nij}^{S2a} = \max\{0, b_{nij}^e * ((j-i+1 + h_n^e * \lfloor 1/i \rfloor) - L_n^+)\} \quad \forall n \in N, (i,j) \in B \quad (9)$$

$${}^e C_{nij}^{S2b} = \max\{0, b_{nij}^e * (L_n^- - (j-i+1 + h_n^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B \quad (10)$$

$${}^e C_{njs}^{S2c} = \max\{0, b_{njs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - L_{ns}^+)\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (11)$$

$${}^e C_{njs}^{S2d} = \max\{0, b_{njs}^e * (L_{ns}^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s \in S' \quad (12)$$

$${}^e C_{nij}^{S3a} = \max\{0, b_{njs}^e * ((j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor) - G_n^+)\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (13)$$

$${}^e C_{nij}^{S3b} = \max\{0, b_{njs}^e * (G_n^- - (j-i+1 + h_{ns}^e * \lfloor 1/i \rfloor))\} \quad \forall n \in N, (i,j) \in B, s=|S| \quad (14)$$

Restrições S3a e S3b

$$b_{njs}^e, b_{nij}^e \in \{0, 1\}$$

$${}^e C_{nij}^{S2a}, {}^e C_{nij}^{S2b}, {}^e C_{njs}^{S2c}, {}^e C_{njs}^{S2d}, {}^e C_{nij}^{S3a}, {}^e C_{nij}^{S3b} \in \mathbb{N}^*$$

$$\forall n \in N, d \in D, s \in S, k \in K$$

$$\forall n \in N, (i,j) \in B, s \in S$$

$$\forall n \in N, (i,j) \in B, s \in S$$

Modelo μ_2 : considera todos os estágios ao mesmo tempo

$$\min Y = \sum_{e \in E} Z_e + \sum_{n \in N} (W^{S6} C_n^{S6a} + W^{S6} C_n^{S6b} + W^{S7} C_n^{S7}) \quad (15)$$

$$C_n^{S6a} = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q_n^+\} \quad \forall e \in E, n \in N \quad (16)$$

$$C_n^{S6b} = \max\{0, Q_n^- - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad \forall e \in E, n \in N \quad (17)$$

$$C_n^{S7} = \max\{0, \sum_{e \in E} \max_{d \in W, k \in K, s \in S'} (x_{ndsk}^e) - R_n^+\} \quad \forall n \in N \quad (18)$$

$$C_n^{S6a}, C_n^{S6b}, C_n^{S7} \in \mathbb{N} \quad \forall n \in N$$

Modelo μ_2 : considera todos os estágios ao mesmo tempo

$$\min Y = \sum_{e \in E} Z_e + \sum_{n \in N} (W^{S6} C_n^{S6a} + W^{S6} C_n^{S6b} + W^{S7} C_n^{S7}) \quad (15)$$

Função objetivo

$$C_n^{S6a} = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q_n^+\} \quad \forall e \in E, n \in N \quad (16)$$

$$C_n^{S6b} = \max\{0, Q_n^- - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad \forall e \in E, n \in N \quad (17)$$

$$C_n^{S7} = \max\{0, \sum_{e \in E} \max_{d \in W, k \in K, s \in S'} (x_{ndsk}^e) - R_n^+\} \quad \forall n \in N \quad (18)$$

$$C_n^{S6a}, C_n^{S6b}, C_n^{S7} \in \mathbb{N} \quad \forall n \in N$$

Modelo μ_2 : considera todos os estágios ao mesmo tempo

$$\min Y = \sum_{e \in E} Z_e + \sum_{n \in N} (W^{S6} C_n^{S6a} + W^{S6} C_n^{S6b} + W^{S7} C_n^{S7}) \quad (15)$$

$$C_n^{S6a} = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q_n^+\} \quad \forall e \in E, n \in N \quad (16)$$

$$C_n^{S6b} = \max\{0, Q_n^- - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad \forall e \in E, n \in N \quad (17)$$

$$\text{Restrição S6} \quad \max_{e \in W, k \in K, s \in S'} (x_{ndsk}^e) - R_n^+ \quad \forall n \in N \quad (18)$$

$$C_n^{S6a}, C_n^{S6b}, C_n^{S7} \in \mathbb{N} \quad \forall n \in N$$

Modelo μ_2 : considera todos os estágios ao mesmo tempo

$$\min Y = \sum_{e \in E} Z_e + \sum_{n \in N} (W^{S6} C_n^{S6a} + W^{S6} C_n^{S6b} + W^{S7} C_n^{S7}) \quad (15)$$

$$C_n^{S6a} = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q_n^+\} \quad \forall e \in E, n \in N \quad (16)$$

$$C_n^{S6b} = \max\{0, Q_n^- - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad \forall e \in E, n \in N \quad (17)$$

$$C_n^{S7} = \max\{0, \sum_{e \in E} \max_{d \in W, k \in K, s \in S'} (x_{ndsk}^e) - R_n^+\} \quad \forall n \in N \quad (18)$$

Restrição S7

$\forall n \in N$

Algoritmo Proposto

Late Acceptance Hill Climbing (Burke & Bykov (2012))

Algoritmo *LAHC* (t)

```
1: Gera solução inicial  $s$ 
2:  $s^* \leftarrow s$ 
3: for  $w \in 0 \dots t - 1$  do
4:    $L_w \leftarrow C(s)$ 
5: end for
6:  $i \leftarrow 0$ 
7: repeat
8:   Gera uma solução candidata  $s'$ 
9:    $v \leftarrow i \bmod t$ 
10:  if  $C(s') \leq L_v$  ou  $C(s') \leq C(s)$  then
11:     $s \leftarrow s'$ 
12:    if  $C(s) \leq C(s^*)$  then
13:       $s^* \leftarrow s$ 
14:    end if
15:  end if
16:   $L_v \leftarrow C(s)$ 
17:   $i \leftarrow i + 1$ 
18: until condição de parada seja satisfeita
19: return  $s^*$ 
```


Late Acceptance Hill Climbing (Burke & Bykov (2012))

Algoritmo *LAHC* (t)

```
1: Gera solução inicial  $s$ 
2: Geração da Solução Inicial
3:
4:    $L_w \leftarrow C(s)$ 
5: end for
6:  $i \leftarrow 0$ 
7: repeat
8:   Gera uma solução candidata  $s'$ 
9:    $v \leftarrow i \bmod t$ 
10:  if  $C(s') \leq L_v$  ou  $C(s') \leq C(s)$  then
11:     $s \leftarrow s'$ 
12:    if  $C(s) \leq C(s^*)$  then
13:       $s^* \leftarrow s$ 
14:    end if
15:  end if
16:   $L_v \leftarrow C(s)$ 
17:   $i \leftarrow i + 1$ 
18: until condição de parada seja satisfeita
19: return  $s^*$ 
```

Late Acceptance Hill Climbing (Burke & Bykov (2012))

Algoritmo *LAHC* (t)

```
1: Gera solução inicial  $s$ 
2:  $s^* \leftarrow s$ 
3: for  $w \in 0 \dots t - 1$  do
4:    $L_w \leftarrow C(s)$ 
5: end for
6:  $i \leftarrow 0$ 
7: repeat
8:   Gera uma solução candidata  $s'$ 
9:
10:  Geração da Solução Candidata
11:    $s \leftarrow s'$ 
12:   if  $C(s) \leq C(s^*)$  then
13:      $s^* \leftarrow s$ 
14:   end if
15: end if
16:    $L_v \leftarrow C(s)$ 
17:    $i \leftarrow i + 1$ 
18: until condição de parada seja satisfeita
19: return  $s^*$ 
```

Late Acceptance Hill Climbing (Burke & Bykov (2012))

Algoritmo *LAHC* (t)

```

1: Gera solução inicial  $s$ 
2:  $s^* \leftarrow s$ 
3: for  $w \in 0 \dots t - 1$  do
4:    $L_w \leftarrow C(s)$ 
5: end for
6:  $i \leftarrow 0$ 
7: repeat
8:   Gera uma solução candidata  $s'$ 
9:    $v \leftarrow i \bmod t$ 
10:  if  $C(s') \leq L_v$  ou  $C(s') \leq C(s)$  then
11:     $s \leftarrow s'$ 
12:    if  $C(s) \leq C(s^*)$  then
13:       $s^* \leftarrow s$ 
14:    end if
15:  end if
16:   $L_v \leftarrow C(s)$ 
17:   $i \leftarrow i + 1$ 
18: until condição de parada seja satisfeita
19: return  $s^*$ 

```

Função objetivo custo $C(.)$

Geração da solução candidata

Solução s' é escolhida a partir de uma estrutura de vizinhança $\mathcal{N}(s)$ onde s é a solução atual. A estrutura $\mathcal{N}(s)$ possui 7 movimentos que compõe a vizinhança, de M_1 a M_7 :

- 1 Movimento 1 (M_1): Modificação de um turno;
- 2 Movimento 2 (M_2): Troca de turnos em blocos;
- 3 Movimento 3 (M_3): Modificação de qualificação;
- 4 Movimento 4 (M_4): Atribuição de uma folga;
- 5 Movimento 5 (M_5): Fim de semana completo;
- 6 Movimento 6 (M_6): Troca de turno de trabalho com turno de folga;
- 7 Movimento 7 (M_7): Troca de blocos para um enfermeiro.

Seleção do movimento: Seleccionados de acordo com uma dada probabilidade.

Função objetivo do LAHC usada em um estágio e

$$C(.) = Z_e + \sum_{n \in N} \left(C^{S6a}(n, e) + C^{S6b}(n, e) + C^{S7}(n, e) \right) \quad (19)$$

Função objetivo

$$Q^+(n, e) = \max\{0, \lceil ((Q_n^+ - \beta(n, e)) / (|E| - e) + 0.5) \rceil \} \quad (20)$$

$$Q^-(n, e) = \lfloor (Q_n^- - \beta(n, e)) / (|E| - e) \rfloor \quad (21)$$

$$R^+(n, e) = \max\{0, \lceil ((R_n^+ - \gamma(n, e)) / (|E| - e) + 0.5) \rceil \} \quad (22)$$

$$C^{S6a}(n, e) = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q^+(n, e)\} \quad (23)$$

$$C^{S6b}(n, e) = \max\{0, Q^-(n, e) - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad (24)$$

$$C^{S7}(n, e) = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - R^+(n, e)\} \quad (25)$$

Função objetivo do LAHC usada em um estágio e

$$C(.) = Z_e + \sum_{n \in N} \left(C^{S6a}(n, e) + C^{S6b}(n, e) + C^{S7}(n, e) \right) \quad (19)$$

$$Q^+(n, e) = \max\{0, \lceil ((Q_n^+ - \beta(n, e)) / (|E| - e) + 0.5) \rceil \} \quad (20)$$

$$Q^-(n, e) = \lfloor (Q_n^- - \beta(n, e)) / (|E| - e) \rfloor \quad (21)$$

$$R^+(n, e) = \max\{0, \lceil ((R_n^+ - \gamma(n, e)) / (|E| - e) + 0.5) \rceil \} \quad (22)$$

Novos limites locais para restrições globais

$$C^{S6a}(n, e) = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q^+(n, e)\} \quad (23)$$

$$C^{S6b}(n, e) = \max\{0, Q^-(n, e) - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad (24)$$

$$C^{S7}(n, e) = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - R^+(n, e)\} \quad (25)$$

Função objetivo do LAHC usada em um estágio e

$$C(.) = Z_e + \sum_{n \in N} \left(C^{S6a}(n, e) + C^{S6b}(n, e) + C^{S7}(n, e) \right) \quad (19)$$

$$Q^+(n, e) = \max\{0, \lceil ((Q_n^+ - \beta(n, e)) / (|E| - e) + 0.5) \rceil \} \quad (20)$$

$$Q^-(n, e) = \lfloor (Q_n^- - \beta(n, e)) / (|E| - e) \rfloor \quad (21)$$

$$R^+(n, e) = \max\{0, \lceil ((R_n^+ - \gamma(n, e)) / (|E| - e) + 0.5) \rceil \} \quad (22)$$

$$C^{S6a}(n, e) = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - Q^+(n, e)\} \quad (23)$$

$$C^{S6b}(n, e) = \max\{0, Q^-(n, e) - \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e\} \quad (24)$$

$$C^{S7}(n, e) = \max\{0, \sum_{d \in D} \sum_{s \in S'} \sum_{k \in K} x_{ndsk}^e - R^+(n, e)\} \quad (25)$$

Estimativa das restrições S6 e S7

Exemplo de estimativa da restrição S6a considerando $Q_3^+ = 16$

histórico

	d ₁	d ₂	d ₃	d ₄	d ₅	d ₆	d ₇
N ₁	N HeadNurse	N HeadNurse	-	-	-	D Nurse	D Nurse
N ₂	N Nurse	E Nurse	N HeadNurse	-	-	D Nurse	N HeadNurse
N ₃	-	-	-	-	D Trainee	E CareTaker	-

$$Q^+(3,0) = \lceil 16/4 + 0.5 \rceil = 4$$

histórico

	d ₁	d ₂	d ₃	d ₄	d ₅	d ₆	d ₇
N ₁	N HeadNurse	N HeadNurse	-	N HeadNurse	N HeadNurse	-	-
N ₂	D Nurse	E Nurse	D HeadNurse	-	-	D Nurse	D Nurse
N ₃	-	-	-	D Trainee	D Trainee	E CareTaker	E CareTaker

$$Q^+(3,1) = \lceil 14/3 + 0.5 \rceil = 5$$

histórico

	d ₁	d ₂	d ₃	d ₄	d ₅	d ₆	d ₇
N ₁	E HeadNurse	E Nurse	-	-	-	D Nurse	D Nurse
N ₂	N Nurse	N HeadNurse	N HeadNurse	-	-	-	N HeadNurse
N ₃	-	-	-	D Trainee	D Trainee	D Trainee	E Trainee

$$Q^+(3,2) = \lceil 10/2 + 0.5 \rceil = 5$$

histórico

	d ₁	d ₂	d ₃	d ₄	d ₅	d ₆	d ₇
N ₁	N HeadNurse	N HeadNurse	-	-	-	D Nurse	D Nurse
N ₂	E Nurse	N Nurse	N HeadNurse	D Nurse	-	-	-
N ₃	D Trainee	-	D Trainee	E CareTaker	D Trainee	D Trainee	-

$$Q^+(3,3) = \lceil 6/1 + 0.5 \rceil = 6$$

Experimentos computacionais

Questões de pesquisa

- 1 Qual a combinação de parâmetros é mais apropriada para o algoritmo proposto?
- 2 Como o algoritmo se compara com os demais competidores?
- 3 O método proposto conseguiria ser classificado para a final?
- 4 O método proposto é robusto quanto à reprodução dos resultados?

Ambiente experimental

- *Hardware*: computador servidor com um processador Intel Xeon 2.83GHz x 4, 8GB RAM. Utilização de uma única *thread*;
- Sistema Operacional Linux Ubuntu 16.04 LTS - 64 bits;
- Linguagem de programação C++, compilador g++ (v. 5.4.0);
- Computação do processo de variação de amostras foi usado *Mersenne Twister*;
- Resultados do experimentos foram certificados pelo *validador da competição*;
- 15 competidores internacionais, incluindo *empresas e grupos de pesquisa*;
- *Tempo limite* para cada semana determinado pelo *benchmark*:

<i>Enfermeiros</i>	30	35	40	50	60	70	80	100	110	120
<i>Tempo(s)</i>	59.7	82.0	104.5	149.3	194.1	238.5	283.7	373.3	417.4	462.0

Conjunto de instâncias da INRC-II

Instâncias *Late*:

- Conjuntos de enfermeiros: 30, 40, 50, 60, 80, 100 e 120;
- Horizonte de planejamento: 4 e 8 semanas;
- Total: 28 instâncias.

Instâncias *Hidden*:

- Conjunto de enfermeiros: 35, 70 e 110;
- Horizonte de planejamento: 4 e 8 semanas;
- Total: 60 instâncias.

Resultados do ajuste de parâmetros do LAHC com a ferramenta I-Race

Objetivo:

- Definir parâmetro TL (Tamanho da Lista).
- Definir os parâmetros P_{M1} a P_{M7} (probabilidade dos movimentos).

Configurações:

- Usamos instâncias *Late* como treino.
- $Budget = 1000$.

Parâmetros	Intervalo	Melhores parâmetros
TL	{5000, 10000, 15000, 20000}	5000
P_{M1}	{0 ... 10}	8 (19%)
P_{M2}	{0 ... 10}	9 (21%)
P_{M3}	{0 ... 10}	8 (19%)
P_{M4}	{0 ... 10}	10 (23%)
P_{M5}	{0 ... 10}	0 (0%)
P_{M6}	{0 ... 10}	1 (2%)
P_{M7}	{0 ... 10}	7 (16%)

Resultados do ajuste de parâmetros do LAHC com a ferramenta I-Race

Objetivo:

- Definir parâmetro TL (Tamanho da Lista).
- Definir os parâmetros P_{M1} a P_{M7} (probabilidade dos movimentos).

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- $Budget = 1000$.

Parâmetros	Intervalo	Melhores parâmetros
TL	{5000, 10000, 15000, 20000}	5000
P_{M1}	{0 ... 10}	8 (19%)
P_{M2}	{0 ... 10}	9 (21%)
P_{M3}	{0 ... 10}	8 (19%)
P_{M4}	{0 ... 10}	10 (23%)
P_{M5}	{0 ... 10}	0 (0%)
P_{M6}	{0 ... 10}	1 (2%)
P_{M7}	{0 ... 10}	7 (16%)

Resultados do ajuste de parâmetros do LAHC com a ferramenta I-Race

Objetivo:

- Definir parâmetro TL (Tamanho da Lista).
- Definir os parâmetros P_{M1} a P_{M7} (probabilidade dos movimentos).

Configurações:

- Usamos instâncias *Late* como treino.
- $Budget = 1000$.

Parâmetros	Intervalo	Melhores parâmetros
TL	{5000, 10000, 15000, 20000}	5000
P_{M1}	{0 ... 10}	8 (19%)
P_{M2}	{0 ... 10}	9 (21%)
P_{M3}	{0 ... 10}	8 (19%)
P_{M4}	{0 ... 10}	10 (23%)
P_{M5}	{0 ... 10}	0 (0%)
P_{M6}	{0 ... 10}	1 (2%)
P_{M7}	{0 ... 10}	7 (16%)

Resultados do ajuste de parâmetros do LAHC com a ferramenta I-Race

Objetivo:

- Definir parâmetro TL (Tamanho da Lista).
- Definir os parâmetros P_{M1} a P_{M7} (probabilidade dos movimentos).

Configurações:

- Usamos instâncias *Late* como treino.
- $Budget = 1000$.

Parâmetros	Intervalo	Melhores parâmetros
TL	{5000, 10000, 15000, 20000}	5000
P_{M1}	{0 ... 10}	8 (19%)
P_{M2}	{0 ... 10}	9 (21%)
P_{M3}	{0 ... 10}	8 (19%)
P_{M4}	{0 ... 10}	10 (23%)
P_{M5}	{0 ... 10}	0 (0%)
P_{M6}	{0 ... 10}	1 (2%)
P_{M7}	{0 ... 10}	7 (16%)

Resultados da etapa de classificação da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁	A ₁₂	A ₁₃	A ₁₄	A ₁₅
1	24.07	0	2.01	10.60	15.19	14.61	18.62	18.34	*36.68	*34.96	*42.69	*87.97	*54.15	*89.11	*225.50	*464.50
2	21.45	0	0.78	10.08	10.34	8.53	11.63	15.25	*24.81	*36.43	*38.50	*69.25	*53.23	*72.09	*229.20	*448.10
3	37.04	0	1.31	28.11	28.32	13.72	34.20	36.17	*56.21	*72.77	*75.82	*94.99	*79.74	*115.47	*307.60	*823.10
4	42.63	0	4.74	25.26	36.05	24.74	38.95	38.42	*49.47	*81.05	*82.63	*90.26	*112.89	*169.47	*359.20	*1012.90
5	17.39	0	2.32	9.86	8.41	*20.29	*22.90	*31.88	*25.22	*48.12	*59.42	*87.25	*71.88	*135.65	*391.00	*751.00
6	18.06	0	5.24	13.35	8.90	17.02	*22.51	*23.82	*35.08	*41.88	*61.26	*77.23	*72.51	*102.09	*374.60	*657.10
7	49.76	0	6.76	20.93	21.26	30.43	*49.76	45.09	46.05	*59.10	*92.11	*94.20	*118.68	*142.35	*421.30	*1027.50
8	35.88	0	-1.18	20.60	15.28	24.09	*42.69	*37.54	26.91	*57.97	*78.74	*88.54	*101.33	*147.01	*398.70	*996.30
9	45.90	0	6.89	20.98	13.44	23.93	33.77	40.00	*60.98	*73.77	*94.75	*120.33	*111.48	*160.66	*537.40	*1063.60
10	40.54	0	11.15	26.69	20.61	32.09	*44.59	*47.64	*64.53	*84.80	*106.08	*101.01	*113.51	*167.91	*542.60	*969.60
11	31.21	0	3.06	9.80	22.12	19.25	25.90	29.95	*44.51	*43.62	*52.70	*80.13	*65.11	*77.25	*362.10	*674.10
12	35.07	0	2.28	6.03	21.28	21.10	30.41	29.77	*46.67	*44.84	*57.17	*78.81	*66.58	*80.18	*339.80	*681.10
13	25.97	0	0.00	6.18	6.36	22.09	17.67	21.55	17.31	*42.93	*47.00	*66.43	*61.66	*74.91	*335.00	*579.50
14	17.58	0	-2.20	4.81	7.46	17.41	*21.72	*23.22	*25.21	*36.65	*61.53	*72.31	*57.71	*101.33	*283.40	*576.60
15	48.59	0	3.17	32.75	30.81	41.20	*50.88	*66.37	*72.36	*107.39	*137.15	*111.80	*155.11	*194.37	*753.70	*1453.90
16	47.66	0	2.50	21.41	30.78	40.78	*53.91	*63.44	*75.47	*100.62	*119.84	*105.16	*125.94	*166.25	*664.70	*1288.40
17	22.88	0	4.03	9.93	16.69	18.85	*29.35	*29.06	*43.45	*53.96	*60.86	*62.01	*57.55	*88.92	*512.80	*675.10
18	23.06	0	3.25	11.88	13.01	16.83	*25.60	*28.15	*50.50	*49.65	*51.91	*66.20	*66.34	*71.43	*462.00	*669.70
19	36.22	0	4.02	20.95	10.94	*39.01	*41.28	*41.18	*52.94	*72.86	*96.80	*73.37	*96.39	*145.30	*643.00	*1239.80
20	42.31	0	6.07	23.90	17.63	32.52	*45.54	*46.52	42.21	*74.14	*102.25	*82.57	*101.08	*136.14	*621.80	*1202.90
21	78.18	0	-6.23	10.10	28.34	53.09	56.35	66.12	*82.41	*120.85	*150.16	*134.85	*173.29	*254.72	*886.30	*2098.00
22	49.28	0	1.45	11.35	17.87	40.82	42.75	*49.28	*57.73	*97.34	*112.80	*95.65	*143.00	*183.82	*657.70	*1516.70
23	67.29	0	-3.23	11.11	29.58	60.09	53.83	65.57	52.90	*113.15	*164.95	*104.85	*186.07	*260.09	*897.70	*2568.50
24	74.64	0	7.02	32.85	37.48	*75.60	*78.31	*78.47	71.29	*134.93	*172.73	*119.14	*207.50	*295.85	*911.60	*2689.30
25	53.64	0	1.82	3.44	25.30	37.05	34.41	47.77	*90.28	*100.00	*121.86	*114.37	*112.75	*140.69	*725.90	*1367.00
26	49.41	0	0.20	13.24	22.13	35.77	38.74	46.25	*105.53	*101.98	*113.83	*118.77	*111.86	*156.52	*774.30	*1335.60
27	62.45	0	13.36	14.06	37.41	*72.86	60.34	*77.64	*120.39	*141.77	*159.77	*130.24	*175.25	*240.79	*1218.40	*2251.30
28	87.63	0	15.72	23.14	54.59	83.84	83.99	75.84	*154.73	*135.23	*165.50	*179.18	*184.43	*308.15	*1197.40	*2291.40
Rank	7	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16

Resultados da etapa de classificação da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁	A ₁₂	A ₁₃	A ₁₄	A ₁₅
1	24.07	0	2.01	10.60	15.19	14.61	18.62	18.34	*36.68	*34.96	*42.69	*87.97	*54.15	*89.11	*225.50	*464.50
2	21.45	0	0.78	10.08	10.34	8.53	11.63	15.25	*24.81	*36.43	*38.50	*69.25	*53.23	*72.09	*229.20	*448.10
3	37.04	0	1.31	28.11	28.32	13.72	34.20	36.17	*56.21	*72.77	*75.82	*94.99	*79.74	*115.47	*307.60	*823.10
4	42.63	0	4.74	25.26	36.05	24.74	38.95	38.42	*49.47	*81.05	*82.63	*90.26	*112.89	*169.47	*359.20	*1012.90
5	17.39	0	2.32	9.86	8.41	*20.29	*22.90	*31.88	*25.22	*48.12	*59.42	*87.25	*71.88	*135.65	*391.00	*751.00
6	18.06	0	5.24	13.35	8.90	17.02	*22.51	*23.82	*35.08	*41.88	*61.26	*77.23	*72.51	*102.09	*374.60	*657.10
7	49.76	0	6.76	20.93	21.26	30.43	*49.76	45.09	46.05	*59.10	*92.11	*94.20	*118.68	*142.35	*421.30	*1027.50
8	35.88	0	-1.18	20.60	15.28	24.09	*42.69	*37.54	26.91	*57.97	*78.74	*88.54	*101.33	*147.01	*398.70	*996.30
9	45.90	0	6.89	20.98	13.44	23.93	33.77	40.00	*60.98	*73.77	*94.75	*120.33	*111.48	*160.66	*537.40	*1063.60
10	40.54	0	11.15	26.69	20.61	32.09	*44.59	*47.64	*64.53	*84.80	*106.08	*101.01	*113.51	*167.91	*542.60	*969.60
11	31.21	0	3.06	9.80	22.12	19.25	25.90	29.95	*44.51	*43.62	*52.70	*80.13	*65.11	*77.25	*362.10	*674.10
12	35.07	0	2.28	6.03	21.28	21.10	30.41	29.77	*46.67	*44.84	*57.17	*78.81	*66.58	*80.18	*339.80	*681.10
13	25.97	0	0.00	6.18	6.36	22.09	17.67	21.55	17.31	*42.93	*47.00	*66.43	*61.66	*74.91	*335.00	*579.50
14	17.58	0	-2.20	4.81	7.46	17.41	*21.72	*23.22	*25.21	*36.65	*61.53	*72.31	*57.71	*101.33	*283.40	*576.60
15	48.59	0	3.17	32.75	30.81	41.20	*50.88	*66.37	*72.36	*107.39	*137.15	*111.80	*155.11	*194.37	*753.70	*1453.90
16	47.66	0	2.50	21.41	30.78	40.78	*53.91	*63.44	*75.47	*100.62	*119.84	*105.16	*125.94	*166.25	*664.70	*1288.40
17	22.88	0	4.03	9.93	16.69	18.85	*29.35	*29.06	*43.45	*53.96	*60.86	*62.01	*57.55	*88.92	*512.80	*675.10
18	23.06	0	3.25	11.88	13.01	16.83	*25.60	*28.15	*50.50	*49.65	*51.91	*66.20	*66.34	*71.43	*462.00	*669.70
19	36.22	0	4.02	20.95	10.94	*39.01	*41.28	*41.18	*52.94	*72.86	*96.80	*73.37	*96.39	*145.30	*643.00	*1239.80
20	42.31	0	6.07	23.90	17.63	32.52	*45.54	*46.52	42.21	*74.14	*102.25	*82.57	*101.08	*136.14	*621.80	*1202.90
21	78.18	0	-6.23	10.10	28.34	53.09	56.35	66.12	*82.41	*120.85	*150.16	*134.85	*173.29	*254.72	*886.30	*2098.00
22	49.28	0	1.45	11.35	17.87	40.82	42.75	*49.28	*57.73	*97.34	*112.80	*95.65	*143.00	*183.82	*657.70	*1516.70
23	67.29	0	-3.23	11.11	29.58	60.09	53.83	65.57	52.90	*113.15	*164.95	*104.85	*186.07	*260.09	*897.70	*2568.50
24	74.64	0	7.02	32.85	37.48	*75.60	*78.31	*78.47	71.29	*134.93	*172.73	*119.14	*207.50	*295.85	*911.60	*2689.30
25	53.64	0	1.82	3.44	25.30	37.05	34.41	47.77	*90.28	*100.00	*121.86	*114.37	*112.75	*140.69	*725.90	*1367.00
26	49.41	0	0.20	13.24	22.13	35.77	38.74	46.25	*105.53	*101.98	*113.83	*118.77	*111.86	*156.52	*774.30	*1335.60
27	62.45	0	13.36	14.06	37.41	*72.86	60.34	*77.64	*120.39	*141.77	*159.77	*130.24	*175.25	*240.79	*1218.40	*2251.30
28	87.63	0	15.72	23.14	54.59	83.84	83.99	75.84	*154.73	*135.23	*165.50	*179.18	*184.43	*308.15	*1197.40	*2291.40
Rank	7	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16

Resultados da etapa de classificação da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁	A ₁₂	A ₁₃	A ₁₄	A ₁₅
1	24.07	0	2.01	10.60	15.19	14.61	18.62	18.34	*36.68	*34.96	*42.69	*87.97	*54.15	*89.11	*225.50	*464.50
2	21.45	0	0.78	10.08	10.34	8.53	11.63	15.25	*24.81	*36.43	*38.50	*69.25	*53.23	*72.09	*229.20	*448.10
3	37.04	0	1.31	28.11	28.32	13.72	34.20	36.17	*56.21	*72.77	*75.82	*94.99	*79.74	*115.47	*307.60	*823.10
4	42.63	0	4.74	25.26	36.05	24.74	38.95	38.42	*49.47	*81.05	*82.63	*90.26	*112.89	*169.47	*359.20	*1012.90
5	17.39	0	2.32	9.86	8.41	*20.29	*22.90	*31.88	*25.22	*48.12	*59.42	*87.25	*71.88	*135.65	*391.00	*751.00
6	18.06	0	5.24	13.35	8.90	17.02	*22.51	*23.82	*35.08	*41.88	*61.26	*77.23	*72.51	*102.09	*374.60	*657.10
7	49.76	0	6.76	20.93	21.26	30.43	*49.76	45.09	46.05	*59.10	*92.11	*94.20	*118.68	*142.35	*421.30	*1027.50
8	35.88	0	-1.18	20.60	15.28	24.09	*42.69	*37.54	26.91	*57.97	*78.74	*88.54	*101.33	*147.01	*398.70	*996.30
9	45.90	0	6.89	20.98	13.44	23.93	33.77	40.00	*60.98	*73.77	*94.75	*120.33	*111.48	*160.66	*537.40	*1063.60
10	40.54	0	11.15	26.69	20.61	32.09	*44.59	*47.64	*64.53	*84.80	*106.08	*101.01	*113.51	*167.91	*542.60	*969.60
11	31.21	0	3.06	9.80	22.12	19.25	25.90	29.95	*44.51	*43.62	*52.70	*80.13	*65.11	*77.25	*362.10	*674.10
12	35.07	0	2.28	6.03	21.28	21.10	30.41	29.77	*46.67	*44.84	*57.17	*78.81	*66.58	*80.18	*339.80	*681.10
13	25.97	0	0.00	6.18	6.36	22.09	17.67	21.55	17.31	*42.93	*47.00	*66.43	*61.66	*74.91	*335.00	*579.50
14	17.58	0	-2.20	4.81	7.46	17.41	*21.72	*23.22	*25.21	*36.65	*61.53	*72.31	*57.71	*101.33	*283.40	*576.60
15	48.59	0	3.17	32.75	30.81	41.20	*50.88	*66.37	*72.36	107.39	*137.15	*111.80	*155.11	*194.37	*753.70	*1453.90
16	47.66	0	2.50	21.41	30.78	40.78	*53.91	*63.44	*75.47	100.62	*119.84	*105.16	*125.94	*166.25	*664.70	*1288.40
17	22.88	0	4.03	9.93	16.69	18.85	*29.35	*29.06	*43.45	*53.96	*60.86	*62.01	*57.55	*88.92	*512.80	*675.10
18	23.06	0	3.25	11.88	13.01	16.83	*25.60	*28.15	*50.50	*49.65	*51.91	*66.20	*66.34	*71.43	*462.00	*669.70
19	36.22	0	4.02	20.95	10.94	*39.01	*41.28	*41.18	*52.94	*72.86	*96.80	*73.37	*96.39	*145.30	*643.00	*1239.80
20	42.31	0	6.07	23.90	17.63	32.52	*45.54	*46.52	42.21	*74.14	*102.25	*82.57	*101.08	*136.14	*621.80	*1202.90
21	78.18	0	-6.23	10.10	28.34	53.09	56.35	66.12	*82.41	120.85	*150.16	*134.85	*173.29	*254.72	*886.30	*2098.00
22	49.28	0	1.45	11.35	17.87	40.82	42.75	*49.28	*57.73	*97.34	*112.80	*95.65	*143.00	*183.82	*657.70	*1516.70
23	67.29	0	-3.23	11.11	29.58	60.09	53.83	65.57	52.90	113.15	*164.95	*104.85	*186.07	*260.09	*897.70	*2568.50
24	74.64	0	7.02	32.85	37.48	*75.60	*78.31	*78.47	71.29	134.93	*172.73	*119.14	*207.50	*295.85	*911.60	*2689.30
25	53.64	0	1.82	3.44	25.30	37.05	34.41	47.77	*90.28	100.00	*121.86	*114.37	*112.75	*140.69	*725.90	*1367.00
26	49.41	0	0.20	13.24	22.13	35.77	38.74	46.25	*105.53	101.98	*113.83	*118.77	*111.86	*156.52	*774.30	*1335.60
27	62.45	0	13.36	14.06	37.41	*72.86	60.34	*77.64	*120.39	141.77	*159.77	*130.24	*175.25	*240.79	*1218.40	*2251.30
28	87.63	0	15.72	23.14	54.59	83.84	83.99	75.84	*154.73	135.23	*165.50	*179.18	*184.43	*308.15	*1197.40	*2291.40
Rank	7	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16

Resultados da etapa de classificação da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉	A ₁₀	A ₁₁	A ₁₂	A ₁₃	A ₁₄	A ₁₅
1	24.07	0	2.01	10.60	15.19	14.61	18.62	18.34	*36.68	*34.96	*42.69	*87.97	*54.15	*89.11	*225.50	*464.50
2	21.45	0	0.78	10.08	10.34	8.53	11.63	15.25	*24.81	*36.43	*38.50	*69.25	*53.23	*72.09	*229.20	*448.10
3	37.04	0	1.31	28.11	28.32	13.72	34.20	36.17	*56.21	*72.77	*75.82	*94.99	*79.74	*115.47	*307.60	*823.10
4	42.63	0	4.74	25.26	36.05	24.74	38.95	38.42	*49.47	*81.05	*82.63	*90.26	*112.89	*169.47	*359.20	*1012.90
5	17.39	0	2.32	9.86	8.41	*20.29	*22.90	*31.88	*25.22	*48.12	*59.42	*87.25	*71.88	*135.65	*391.00	*751.00
6	18.06	0	5.24	13.35	8.90	17.02	*22.51	*23.82	*35.08	*41.88	*61.26	*77.23	*72.51	*102.09	*374.60	*657.10
7	49.76	0	6.76	20.93	21.26	30.43	*49.76	45.09	46.05	*59.10	*92.11	*94.20	*118.68	*142.35	*421.30	*1027.50
8	35.88	0	-1.18	20.60	15.28	24.09	*42.69	*37.54	26.91	*57.97	*78.74	*88.54	*101.33	*147.01	*398.70	*996.30
9	45.90	0	6.89	20.98	13.44	23.93	33.77	40.00	*60.98	*73.77	*94.75	*120.33	*111.48	*160.66	*537.40	*1063.60
10	40.54	0	11.15	26.69	20.61	32.09	*44.59	*47.64	*64.53	*84.80	*106.08	*101.01	*113.51	*167.91	*542.60	*969.60
11	31.21	0	3.06	9.80	22.12	19.25	25.90	29.95	*44.51	*43.62	*52.70	*80.13	*65.11	*77.25	*362.10	*674.10
12	35.07	0	2.28	6.03	21.28	21.10	30.41	29.77	*46.67	*44.84	*57.17	*78.81	*66.58	*80.18	*339.80	*681.10
13	25.97	0	0.00	6.18	6.36	22.09	17.67	21.55	17.31	*42.93	*47.00	*66.43	*61.66	*74.91	*335.00	*579.50
14	17.58	0	-2.20	4.81	7.46	17.41	*21.72	*23.22	*25.21	*36.65	*61.53	*72.31	*57.71	*101.33	*283.40	*576.60
15	48.59	0	3.17	32.75	30.81	41.20	*50.88	*66.37	*72.36	*107.39	*137.15	*111.80	*155.11	*194.37	*753.70	*1453.90
16	47.66	0	2.50	21.41	30.78	40.78	*53.91	*63.44	*75.47	*100.62	*119.84	*105.16	*125.94	*166.25	*664.70	*1288.40
17	22.88	0	4.03	9.93	16.69	18.85	*29.35	*29.06	*43.45	*53.96	*60.86	*62.01	*57.55	*88.92	*512.80	*675.10
18	23.06	0	3.25	11.88	13.01	16.83	*25.60	*28.15	*50.50	*49.65	*51.91	*66.20	*66.34	*71.43	*462.00	*669.70
19	36.22	0	4.02	20.95	10.94	*39.01	*41.28	*41.18	*52.94	*72.86	*96.80	*73.37	*96.39	*145.30	*643.00	*1239.80
20	42.31	0	6.07	23.90	17.63	32.52	*45.54	*46.52	42.21	*74.14	*102.25	*82.57	*101.08	*136.14	*621.80	*1202.90
21	78.18	0	-6.23	10.10	28.34	53.09	56.35	66.12	*82.41	*120.85	*150.16	*134.85	*173.29	*254.72	*886.30	*2098.00
22	49.28	0	1.45	11.35	17.87	40.82	42.75	*49.28	*57.73	*97.34	*112.80	*95.65	*143.00	*183.82	*657.70	*1516.70
23	67.29	0	-3.23	11.11	29.58	60.09	53.83	65.57	52.90	*113.15	*164.95	*104.85	*186.07	*260.09	*897.70	*2568.50
24	74.64	0	7.02	32.85	37.48	*75.60	*78.31	*78.47	71.29	*134.93	*172.73	*119.14	*207.50	*295.85	*911.60	*2689.30
25	53.64	0	1.82	3.44	25.30	37.05	34.41	47.77	*90.28	*100.00	*121.86	*114.37	*112.75	*140.69	*725.90	*1367.00
26	49.41	0	0.20	13.24	22.13	35.77	38.74	46.25	*105.53	*101.98	*113.83	*118.77	*111.86	*156.52	*774.30	*1335.60
27	62.45	0	13.36	14.06	37.41	*72.86	60.34	*77.64	*120.39	*141.77	*159.77	*130.24	*175.25	*240.79	*1218.40	*2251.30
28	87.63	0	15.72	23.14	54.59	83.84	83.99	75.84	*154.73	*135.23	*165.50	*179.18	*184.43	*308.15	*1197.40	*2291.40
Rank	7	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16

LAHC classificado em 7º

Resultados da etapa final da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
1	25.46	0	2.15	1.84	3.37	15.95	25.15	21.47
2	27.07	0	-0.56	4.70	8.84	16.57	22.65	20.17
3	20.51	0	4.84	7.69	0.28	*20.51	19.66	17.38
4	21.04	0	-0.32	3.24	7.44	*21.36	*29.13	18.12
5	25.90	0	-1.67	5.57	8.20	20.98	24.92	*31.15
6	25.17	0	-1.34	3.97	5.96	13.25	22.85	*25.83
7	27.09	0	0.40	5.58	6.37	26.29	*31.87	23.51
8	23.17	0	1.47	5.87	11.14	18.48	*24.63	*26.10
9	33.03	0	3.94	6.97	17.58	23.33	*34.55	31.52
10	31.17	0	2.47	8.33	16.05	22.22	26.54	27.47
11	-	-	-	-	-	-	-	-
12	33.10	0	-4.69	15.69	17.41	31.72	29.14	*41.03
13	37.11	0	-3.42	16.03	11.15	31.88	34.15	36.06
14	34.52	0	-0.18	19.57	13.17	*38.08	*34.70	*39.86
15	42.61	0	1.06	14.44	21.13	31.34	38.56	*44.37
16	33.44	0	-4.81	7.05	12.95	29.02	26.89	31.15
17	34.46	0	2.53	16.39	19.59	34.12	*38.51	*43.92
18	43.69	0	3.91	23.45	20.25	36.77	41.03	40.85
19	32.51	0	1.64	16.75	10.02	*33.66	*35.47	*34.15
20	35.43	0	-5.52	18.50	15.01	31.76	*35.95	*39.44
21	28.10	0	3.88	-0.19	14.23	23.48	27.73	*34.94
22	24.28	0	3.70	3.50	14.81	21.40	*29.01	*31.07
23	25.05	0	4.65	2.42	15.76	*26.67	*32.73	*37.58
24	30.80	0	6.37	7.39	17.25	*32.44	*38.40	*47.64
25	29.53	0	6.25	6.25	17.46	26.08	29.09	*39.44
26	22.96	0	3.70	4.26	12.41	20.56	*25.93	*26.67
27	26.59	0	6.55	10.32	14.29	23.41	*32.54	*39.68
28	25.43	0	0.38	2.49	16.63	21.61	23.33	*40.54
29	25.79	0	3.74	5.91	13.19	25.00	*27.95	*34.84
30	28.49	0	2.49	5.16	13.77	19.31	*31.17	*30.21

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
31	31.48	0	7.72	12.51	17.30	*33.43	*32.45	28.45
32	23.47	0	3.43	7.33	19.11	*28.48	*30.43	23.01
33	23.74	0	2.83	6.30	11.32	*26.21	22.10	17.72
34	28.53	0	4.12	5.49	11.76	26.96	*29.41	26.76
35	22.92	0	0.55	5.08	10.72	*26.16	*30.78	20.52
36	28.98	0	5.30	10.70	13.16	28.79	*33.52	22.82
37	23.89	0	3.54	6.36	12.81	*25.98	*26.61	18.35
38	29.20	0	3.71	11.13	16.41	28.52	*30.27	27.15
39	29.25	0	3.74	8.88	15.98	27.85	*29.91	22.52
40	24.34	0	4.42	8.93	10.81	*27.91	*28.01	23.78
41	36.40	0	-0.37	2.21	24.82	32.17	32.72	*40.99
42	31.82	0	-1.71	0.84	17.00	30.81	*34.51	*49.66
43	32.19	0	-2.46	-0.86	26.20	*33.22	*34.42	*48.97
44	30.92	0	-2.66	1.90	18.83	*31.78	*38.00	*43.18
45	27.07	0	-1.05	1.92	18.20	*28.55	*31.95	*39.05
46	28.52	0	2.85	4.28	25.31	*37.43	*44.74	*49.20
47	25.98	0	-5.66	1.57	19.53	*27.40	*28.98	*41.42
48	26.28	0	-3.42	2.48	16.36	*27.11	*38.18	*43.31
49	22.33	0	-1.61	3.60	12.25	*29.39	*29.54	*32.71
50	22.49	0	-6.38	0.60	9.15	18.89	*26.39	*34.78
51	41.92	0	-0.19	1.74	24.30	39.30	37.66	*46.66
52	46.38	0	-0.52	4.35	24.53	34.89	41.30	*50.72
53	38.19	0	-2.53	4.31	24.54	33.98	35.42	*51.95
54	38.56	0	-3.09	-0.50	21.98	35.26	*40.66	*53.15
55	30.78	0	-10.97	-6.67	19.48	28.05	*32.29	*31.89
56	27.69	0	-11.72	-6.67	16.10	23.09	22.54	*38.91
57	40.77	0	-1.67	-1.07	22.32	30.82	34.88	*46.86
58	43.16	0	-10.89	-2.03	23.82	32.39	35.42	*47.02
59	35.19	0	-9.01	0.58	12.31	33.56	*35.29	*42.50
60	34.84	0	-9.29	-3.03	16.26	31.37	*36.62	*50.37
Rank	6	1	2	3	4	5	7	8

Resultados da etapa final da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
1	25.46	0	2.15	1.84	3.37	15.95	25.15	21.47
2	27.07	0	-0.56	4.70	8.84	16.57	22.65	20.17
3	20.51	0	4.84	7.69	0.28	*20.51	19.66	17.38
4	21.04	0	-0.32	3.24	7.44	*21.36	*29.13	18.12
5	25.90	0	-1.67	5.57	8.20	20.98	24.92	*31.15
6	25.17	0	-1.34	3.97	5.96	13.25	22.85	*25.83
7	27.09	0	0.40	5.58	6.37	26.29	*31.87	23.51
8	23.17	0	1.47	5.87	11.14	18.48	*24.63	*26.10
9	33.03	0	3.94	6.97	17.58	23.33	*34.55	31.52
10	31.17	0	2.47	8.33	16.05	22.22	26.54	27.47
11	-	-	-	-	-	-	-	-
12	33.10	0	-4.69	15.69	17.41	31.72	29.14	*41.03
13	37.11	0	-3.42	16.03	11.15	31.88	34.15	36.06
14	34.52	0	-0.18	19.57	13.17	*38.08	*34.70	*39.86
15	42.61	0	1.06	14.44	21.13	31.34	38.56	*44.37
16	33.44	0	-4.81	7.05	12.95	29.02	26.89	31.15
17	34.46	0	2.53	16.39	19.59	34.12	*38.51	*43.92
18	43.69	0	3.91	23.45	20.25	36.77	41.03	40.85
19	32.51	0	1.64	16.75	10.02	*33.66	*35.47	*34.15
20	35.43	0	-5.52	18.50	15.01	31.76	*35.95	*39.44
21	28.10	0	3.88	-0.19	14.23	23.48	27.73	*34.94
22	24.28	0	3.70	3.50	14.81	21.40	*29.01	*31.07
23	25.05	0	4.65	2.42	15.76	*26.67	*32.73	*37.58
24	30.80	0	6.37	7.39	17.25	*32.44	*38.40	*47.64
25	29.53	0	6.25	6.25	17.46	26.08	29.09	*39.44
26	22.96	0	3.70	4.26	12.41	20.56	*25.93	*26.67
27	26.59	0	6.55	10.32	14.29	23.41	*32.54	*39.68
28	25.43	0	0.38	2.49	16.63	21.61	23.33	*40.54
29	25.79	0	3.74	5.91	13.19	25.00	*27.95	*34.84
30	28.49	0	2.49	5.16	13.77	19.31	*31.17	*30.21

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
31	31.48	0	7.72	12.51	17.30	*33.43	*32.45	28.45
32	23.47	0	3.43	7.33	19.11	*28.48	*30.43	23.01
33	23.74	0	2.83	6.30	11.32	*26.21	22.10	17.72
34	28.53	0	4.12	5.49	11.76	26.96	*29.41	26.76
35	22.92	0	0.55	5.08	10.72	*26.16	*30.78	20.52
36	28.98	0	5.30	10.70	13.16	28.79	*33.52	22.82
37	23.89	0	3.54	6.36	12.81	*25.98	*26.61	18.35
38	29.20	0	3.71	11.13	16.41	28.52	*30.27	27.15
39	29.25	0	3.74	8.88	15.98	27.85	*29.91	22.52
40	24.34	0	4.42	8.93	10.81	*27.91	*28.01	23.78
41	36.40	0	-0.37	2.21	24.82	32.17	32.72	*40.99
42	31.82	0	-1.71	0.84	17.00	30.81	*34.51	*49.66
43	32.19	0	-2.46	-0.86	26.20	*33.22	*34.42	*48.97
44	30.92	0	-2.66	1.90	18.83	*31.78	*38.00	*43.18
45	27.07	0	-1.05	1.92	18.20	*28.55	*31.95	*39.05
46	28.52	0	2.85	4.28	25.31	*37.43	*44.74	*49.20
47	25.98	0	-5.66	1.57	19.53	*27.40	*28.98	*41.42
48	26.28	0	-3.42	2.48	16.36	*27.11	*38.18	*43.31
49	22.33	0	-1.61	3.60	12.25	*29.39	*29.54	*32.71
50	22.49	0	-6.38	0.60	9.15	18.89	*26.39	*34.78
51	41.92	0	-0.19	1.74	24.30	39.30	37.66	*46.66
52	46.38	0	-0.52	4.35	24.53	34.89	41.30	*50.72
53	38.19	0	-2.53	4.31	24.54	33.98	35.42	*51.95
54	38.56	0	-3.09	-0.50	21.98	35.26	*40.66	*53.15
55	30.78	0	-10.97	-6.67	19.48	28.05	*32.29	*31.89
56	27.69	0	-11.72	-6.67	16.10	23.09	22.54	*38.91
57	40.77	0	-1.67	-1.07	22.32	30.82	34.88	*46.86
58	43.16	0	-10.89	-2.03	23.82	32.39	35.42	*47.02
59	35.19	0	-9.01	0.58	12.31	33.56	*35.29	*42.50
60	34.84	0	-9.29	-3.03	16.26	31.37	*36.62	*50.37
Rank	6	1	2	3	4	5	7	8

Resultados da etapa final da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
1	25.46	0	2.15	1.84	3.37	15.95	25.15	21.47
2	27.07	0	-0.56	4.70	8.84	16.57	22.65	20.17
3	20.51	0	4.84	7.69	0.28	*20.51	19.66	17.38
4	21.04	0	-0.32	3.24	7.44	*21.36	*29.13	18.12
5	25.90	0	-1.67	5.57	8.20	20.98	24.92	*31.15
6	25.17	0	-1.34	3.97	5.96	13.25	22.85	*25.83
7	27.09	0	0.40	5.58	6.37	26.29	*31.87	23.51
8	23.17	0	1.47	5.87	11.14	18.48	*24.63	*26.10
9	33.03	0	3.94	6.97	17.58	23.33	*34.55	31.52
10	31.17	0	2.47	8.23	16.05	22.22	26.54	27.47
11	-	-	-	-	-	-	-	-
12	33.10	0	-4.69	15.69	17.41	31.72	29.14	*41.03
13	37.11	0	-3.42	16.03	11.15	31.88	34.15	36.06
14	34.52	0	-0.18	19.57	13.17	*38.08	*34.70	*39.86
15	42.61	0	1.06	14.44	21.13	31.34	38.56	*44.37
16	33.44	0	-4.81	7.05	12.95	29.02	26.89	31.15
17	34.46	0	2.53	16.39	19.59	34.12	*38.51	*43.92
18	43.69	0	3.91	23.45	20.25	36.77	41.03	40.85
19	32.51	0	1.64	16.75	10.02	*33.66	*35.47	*34.15
20	35.43	0	-5.52	18.50	15.01	31.76	*35.95	*39.44
21	28.10	0	3.88	-0.19	14.23	23.48	27.73	*34.94
22	24.28	0	3.70	3.50	14.81	21.40	*29.01	*31.07
23	25.05	0	4.65	2.42	15.76	*26.67	*32.73	*37.58
24	30.80	0	6.37	7.39	17.25	*32.44	*38.40	*47.64
25	29.53	0	6.25	6.25	17.46	26.08	29.09	*39.44
26	22.96	0	3.70	4.26	12.41	20.56	*25.93	*26.67
27	26.59	0	6.55	10.32	14.29	23.41	*32.54	*39.68
28	25.43	0	0.38	2.49	16.63	21.61	23.33	*40.54
29	25.79	0	3.74	5.91	13.19	25.00	*27.95	*34.84
30	28.49	0	2.49	5.16	13.77	19.31	*31.17	*30.21

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
31	31.48	0	7.72	12.51	17.30	*33.43	*32.45	28.45
32	23.47	0	3.43	7.33	19.11	*28.48	*30.43	23.01
33	23.74	0	2.83	6.30	11.32	*26.21	22.10	17.72
34	28.53	0	4.12	5.49	11.76	26.96	*29.41	26.76
35	22.92	0	0.55	5.08	10.72	*26.16	*30.78	20.52
36	28.98	0	5.30	10.70	13.16	28.79	*33.52	22.82
37	23.89	0	3.54	6.36	12.81	*25.98	*26.61	18.35
38	29.20	0	3.71	11.13	16.41	28.52	*30.27	27.15
39	29.25	0	3.74	8.88	15.98	27.85	*29.91	22.52
40	24.34	0	4.42	8.93	10.81	*27.91	*28.01	23.78
41	36.40	0	-0.37	2.21	24.82	32.17	32.72	*40.99
42	31.82	0	-1.71	0.84	17.00	30.81	*34.51	*49.66
43	32.19	0	-2.46	-0.86	26.20	*33.22	*34.42	*48.97
44	30.92	0	-2.66	1.90	18.83	*31.78	*38.00	*43.18
45	27.07	0	-1.05	1.92	18.20	*28.55	*31.95	*39.05
46	28.52	0	2.85	4.28	25.31	*37.43	*44.74	*49.20
47	25.98	0	-5.66	1.57	19.53	*27.40	*28.98	*41.42
48	26.28	0	-3.42	2.48	16.36	*27.11	*38.18	*43.31
49	22.33	0	-1.61	3.60	12.25	*29.39	*29.54	*32.71
50	22.49	0	-6.38	0.60	9.15	18.89	*26.39	*34.78
51	41.92	0	-0.19	1.74	24.30	39.30	37.66	*46.66
52	46.38	0	-0.52	4.35	24.53	34.89	41.30	*50.72
53	38.19	0	-2.53	4.31	24.54	33.98	35.42	*51.95
54	38.56	0	-3.09	-0.50	21.98	35.26	*40.66	*53.15
55	30.78	0	-10.97	-6.67	19.48	28.05	*32.29	*31.89
56	27.69	0	-11.72	-6.67	16.10	23.09	22.54	*38.91
57	40.77	0	-1.67	-1.07	22.32	30.82	34.88	*46.86
58	43.16	0	-10.89	-2.03	23.82	32.39	35.42	*47.02
59	35.19	0	-9.01	0.58	12.31	33.56	*35.29	*42.50
60	34.84	0	-9.29	-3.03	16.26	31.37	*36.62	*50.37
Rank	6	1	2	3	4	5	7	8

Resultados da etapa final da INRC-II

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
1	25.46	0	2.15	1.84	3.37	15.95	25.15	21.47
2	27.07	0	-0.56	4.70	8.84	16.57	22.65	20.17
3	20.51	0	4.84	7.69	0.28	*20.51	19.66	17.38
4	21.04	0	-0.32	3.24	7.44	*21.36	*29.13	18.12
5	25.90	0	-1.67	5.57	8.20	20.98	24.92	*31.15
6	25.17	0	-1.34	3.97	5.96	13.25	22.85	*25.83
7	27.09	0	0.40	5.58	6.37	26.29	*31.87	23.51
8	23.17	0	1.47	5.87	11.14	18.48	*24.63	*26.10
9	33.03	0	3.94	6.97	17.58	23.33	*34.55	31.52
10	31.17	0	2.47	8.33	16.05	22.22	26.54	27.47
11	-	*	-	-	-	*	*	*
12	33.10	0	-4.69	15.69	17.41	31.72	29.14	*41.03
13	37.11	0	-3.42	16.03	11.15	31.88	34.15	36.06
14	34.52	0	-0.18	19.57	13.17	*38.08	*34.70	*39.86
15	42.61	0	1.06	14.44	21.13	31.34	38.56	*44.37
16	33.44	0	-4.81	7.05	12.95	29.02	26.89	31.15
17	34.46	0	2.53	16.39	19.59	34.12	*38.51	*43.92
18	43.69	0	3.91	23.45	20.25	36.77	41.03	40.85
19	32.51	0	1.64	16.75	10.02	*33.66	*35.47	*34.15
20	35.43	0	-5.52	18.50	15.01	31.76	*35.95	*39.44
21	28.10	0	3.88	-0.19	14.23	23.48	27.73	*34.94
22	24.28	0	3.70	3.50	14.81	21.40	*29.01	*31.07
23	25.05	0	4.65	2.42	15.76	*26.67	*32.73	*37.58
24	30.80	0	6.37	7.39	17.25	*32.44	*38.40	*47.64
25	29.53	0	6.25	6.25	17.46	26.08	29.09	*39.44
26	22.96	0	3.70	4.26	12.41	20.56	*25.93	*26.67
27	26.59	0	6.55	10.32	14.29	23.41	*32.54	*39.68
28	25.43	0	0.38	2.49	16.63	21.61	23.33	*40.54
29	25.79	0	3.74	5.91	13.19	25.00	*27.95	*34.84
30	28.49	0	2.49	5.16	13.77	19.31	*31.17	*30.21

id	LAHC	A ₁	A ₂	A ₃	A ₄	A ₅	A ₇	A ₆
31	31.48	0	7.72	12.51	17.30	*33.43	*32.45	28.45
32	23.47	0	3.43	7.33	19.11	*28.48	*30.43	23.01
33	23.74	0	2.83	6.30	11.32	*26.21	22.10	17.72
34	28.53	0	4.12	5.49	11.76	26.96	*29.41	26.76
35	22.92	0	0.55	5.08	10.72	*26.16	*30.78	20.52
36	28.98	0	5.30	10.70	13.16	28.79	*33.52	22.82
37	23.89	0	3.54	6.36	12.81	*25.98	*26.61	18.35
38	29.20	0	3.71	11.13	16.41	28.52	*30.27	27.15
39	29.25	0	3.74	8.88	15.98	27.85	*29.91	22.52
40	24.34	0	4.42	8.93	10.81	*27.91	*28.01	23.78
41	36.40	0	-0.37	2.21	24.82	32.17	32.72	*40.99
42	31.82	0	-1.71	0.84	17.00	30.81	*34.51	*49.66
43	32.19	0	-2.46	-0.86	26.20	*33.22	*34.42	*48.97
44	30.92	0	-2.66	1.90	18.83	*31.78	*38.00	*43.18
45	27.07	0	-1.05	1.92	18.20	*28.55	*31.95	*39.05
46	28.52	0	2.85	4.28	25.31	*37.43	*44.74	*49.20
47	25.98	0	-5.66	1.57	19.53	*27.40	*28.98	*41.42
48	26.28	0	-3.42	2.48	16.36	*27.11	*38.18	*43.31
49	22.33	0	-1.61	3.60	12.25	*29.39	*29.54	*32.71
50	22.49	0	-6.38	0.60	9.15	18.89	*26.39	*34.78
51	41.92	0	-0.19	1.74	24.30	39.30	37.66	*46.66
52	46.38	0	-0.52	4.35	24.53	34.89	41.30	*50.72
53	38.19	0	-2.53	4.31	24.54	33.98	35.42	*51.95
54	38.56	0	-3.09	-0.50	21.98	35.26	*40.66	*53.15
55	30.78	0	-10.97	-6.67	19.48	28.05	*32.29	*31.89
56	27.69	0	-11.72	-6.67	16.10	23.09	22.54	*38.91
57	40.77	0	-1.67	-1.07	22.32	30.82	34.88	*46.86
58	43.16	0	-10.89	-2.03	23.82	32.39	35.42	*47.02
59	35.19	0	-9.01	0.58	12.31	33.56	*35.29	*42.50
60	34.84	0	-9.29	-3.03	16.26	31.37	*36.62	*50.37

Rank	6	1	2	3	4	5	7	8
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LAHC classificado em 6º

Resultados comparando o LAHC com as melhores soluções conhecidas

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
1	140	1425	2133	2045	49.68	2260	70.29	3.30
2	140	1615	2378.5	2300	47.28	2520	77.28	3.25
3	140	1540	2190.5	2115	42.24	2320	72.36	3.30
4	140	1365	2061.5	1870	51.03	2235	111.00	5.38
5	140	1385	2081.5	1920	50.29	2300	94.58	4.54
6	140	1335	2005.5	1890	50.22	2175	86.46	4.31
7	140	1085	1737	1595	60.09	1805	63.39	3.65
8	140	1525	2318.5	2100	52.03	2450	114.48	4.94
9	140	1480	2345.5	2195	58.48	2485	107.97	4.60
10	140	1620	2283.5	2125	40.96	2405	106.04	4.64
11	280	3020	4215	3920	39.57	4400	170.00	4.03
12	280	2770	4132	3860	49.17	4395	155.56	3.76
13	280	2775	4144	3935	49.33	4315	112.09	2.70
14	280	2805	3977	3780	41.78	4270	153.33	3.86
15	280	2840	4261	4050	50.04	4515	158.75	3.73
16	280	2910	4206	4070	44.54	4400	96.00	2.28
17	280	2960	4235.5	3980	43.09	4400	130.24	3.07
18	280	2815	4201	4045	49.24	4395	122.24	2.91
19	280	3045	4220	4035	38.59	4500	152.15	3.61
20	280	2715	4061	3880	49.58	4325	119.18	2.93
21	280	2460	3623.5	3465	47.30	3765	76.60	2.11
22	280	2330	3216	3020	38.03	3335	92.73	2.88
23	280	2315	3232	3095	39.61	3370	98.66	3.05
24	280	2400	3244.5	3185	35.19	3315	40.38	1.24
25	280	2225	3218	3005	44.63	3385	114.94	3.57
26	280	2615	3397	3320	29.90	3535	64.17	1.89
27	280	2415	3315	3190	37.27	3615	123.17	3.72
28	280	2405	3370	3280	40.12	3460	66.75	1.98
29	280	2390	3276	3195	37.07	3355	47.60	1.45
30	280	2480	3454.5	3360	39.29	3550	64.53	1.87
Média das instâncias pequenas		-	-	-	44.85	-	-	3.29

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
41	440	2560	3865	3710	50.98	4135	141.55	3.66
42	440	2640	4162	3915	57.65	4345	139.82	3.36
43	440	2690	4035	3860	50.00	4180	106.56	2.64
44	440	2705	3946	3790	45.88	4175	113.10	2.87
45	440	3170	4405.5	4295	38.97	4500	69.70	1.58
46	440	2630	3948	3605	50.11	4160	149.13	3.78
47	440	2960	4189.5	4000	41.54	4300	93.61	2.23
48	440	2770	3998.5	3820	44.35	4125	83.70	2.09
49	440	3140	4394	4245	39.94	4460	70.15	1.60
50	440	3005	4222.5	4085	40.52	4350	83.57	1.98
31	560	5115	6847	6725	33.86	7195	140.85	2.06
32	560	5390	7064	6655	31.06	7310	200.44	2.84
33	560	5475	7092.5	6775	29.54	7350	206.41	2.91
34	560	5100	6773	6555	32.80	7025	141.05	2.08
35	560	5410	6946	6650	28.39	7230	198.28	2.85
36	560	5280	7012.5	6810	32.81	7370	162.74	2.32
37	560	5505	7061.5	6820	28.27	7295	173.54	2.46
38	560	5120	6855	6615	33.89	7070	157.25	2.29
39	560	5350	7180	6915	34.21	7445	167.84	2.34
40	560	5320	6780	6615	27.44	7015	120.71	1.78
Média das instâncias médias		-	-	-	38.61	-	-	2.49
51	880	5155	7412	7330	43.78	7520	68.36	0.92
52	880	4805	7355.5	7070	53.08	7575	163.15	2.22
53	880	4750	7045.5	6730	48.33	7410	188.98	2.68
54	880	4855	7197.5	6935	48.25	7455	173.64	2.41
55	880	4465	6919	6480	54.96	7180	201.90	2.92
56	880	4865	7321	6940	50.48	7615	179.56	2.45
57	880	5090	7590	7285	49.12	7805	151.58	2.00
58	880	4315	6988	6850	61.95	7110	92.56	1.32
59	880	4770	7256.5	7030	52.13	7520	155.77	2.15
60	880	4360	6778	6425	55.46	7080	189.85	2.80
Média das instâncias grandes		-	-	-	51.75	-	-	2.18
Média Geral		-	-	-	45.07	-	-	2.82

Resultados comparando o LAHC com as melhores soluções conhecidas

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
1	140	1425	2133	2045	49.68	2260	70.29	3.30
2	140	1615	2378.5	2300	47.28	2520	77.28	3.25
3	140	1540	2190.5	2115	42.24	2320	72.36	3.30
4	140	1365	2061.5	1870	51.03	2235	111.00	5.38
5	140	1385	2081.5	1920	50.29	2300	94.58	4.54
6	140	1335	2005.5	1890	50.22	2175	86.46	4.31
7	140	1085	1737	1595	60.09	1805	63.39	3.65
8	140	1525	2318.5	2100	52.03	2450	114.48	4.94
9	140	1480	2345.5	2195	58.48	2485	107.97	4.60
10	140	1620	2283.5	2125	40.96	2405	106.04	4.64
11	280	3020	4215	3920	39.57	4400	170.00	4.03
12	280	2770	4132	3860	49.17	4395	155.56	3.76
13	280	2775	4144	3935	49.33	4315	112.09	2.70
14	280	2805	3977	3780	41.78	4270	153.33	3.86
15	280	2840	4261	4050	50.04	4515	158.75	3.73
16	280	2910	4206	4070	44.54	4400	96.00	2.28
17	280	2960	4235.5	3980	43.09	4400	130.24	3.07
18	280	2815	4201	4045	49.24	4395	122.24	2.91
19	280	3045	4220	4035	38.59	4500	152.15	3.61
20	280	2715	4061	3880	49.58	4325	119.18	2.93
21	280	2460	3623.5	3465	47.30	3765	76.60	2.11
22	280	2330	3216	3020	38.03	3335	92.73	2.88
23	280	2315	3232	3095	39.61	3370	98.66	3.05
24	280	2400	3244.5	3185	35.19	3315	40.38	1.24
25	280	2225	3218	3005	44.63	3385	114.94	3.57
26	280	2615	3397	3320	29.90	3535	64.17	1.89
27	280	2415	3315	3190	37.27	3615	123.17	3.72
28	280	2405	3370	3280	40.12	3460	66.75	1.98
29	280	2390	3276	3195	37.07	3355	47.60	1.45
30	280	2480	3454.5	3360	39.29	3550	64.53	1.87

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
41	440	2560	3865	3710	50.98	4135	141.55	3.66
42	440	2640	4162	3915	57.65	4345	139.82	3.36
43	440	2690	4035	3860	50.00	4180	106.56	2.64
44	440	2705	3946	3790	45.88	4175	113.10	2.87
45	440	3170	4405.5	4295	38.97	4500	69.70	1.58
46	440	2630	3948	3605	50.11	4160	149.13	3.78
47	440	2960	4189.5	4000	41.54	4300	93.61	2.23
48	440	2770	3998.5	3820	44.35	4125	83.70	2.09
49	440	3140	4394	4245	39.94	4460	70.15	1.60
50	440	3005	4222.5	4085	40.52	4350	83.57	1.98
31	560	5115	6847	6725	33.86	7195	140.85	2.06
32	560	5390	7064	6655	31.06	7310	200.44	2.84
33	560	5475	7092.5	6775	29.54	7350	206.41	2.91
34	560	5100	6773	6555	32.80	7025	141.05	2.08
35	560	5410	6946	6650	28.39	7230	198.28	2.85
36	560	5280	7012.5	6810	32.81	7370	162.74	2.32
37	560	5505	7061.5	6820	28.27	7295	173.54	2.46
38	560	5120	6855	6615	33.89	7070	157.25	2.29
39	560	5350	7180	6915	34.21	7445	167.84	2.34
40	560	5320	6780	6615	27.44	7015	120.71	1.78
Média das instâncias médias		-	-	-	38.61	-	-	2.49
51	880	5155	7412	7330	43.78	7520	68.36	0.92
52	880	4805	7355.5	7070	53.08	7575	163.15	2.22
53	880	4750	7045.5	6730	48.33	7410	188.98	2.68
54	880	4855	7197.5	6935	48.25	7455	173.64	2.41
55	880	4465	6919	6480	54.96	7180	201.90	2.92
56	880	4865	7321	6940	50.48	7615	179.56	2.45
57	880	5090	7590	7285	49.12	7805	151.58	2.00
58	880	4315	6988	6850	61.95	7110	92.56	1.32
59	880	4770	7256.5	7030	52.13	7520	155.77	2.15
60	880	4360	6778	6425	55.46	7080	189.85	2.80
Média das instâncias grandes		-	-	-	51.75	-	-	2.18
Média Geral		-	-	-	45.07	-	-	2.82

Dimensão = n^o enfermeiros x n^o semanas

Resultados comparando o LAHC com as melhores soluções conhecidas

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
1	140	1425	2133	2045	49.68	2260	70.29	3.30
2	140	1615	2378.5	2300	47.28	2520	77.28	3.25
3	140	1540	2190.5	2115	42.24	2320	72.36	3.30
4	140	1365	2061.5	1870	51.03	2235	111.00	5.38
5	140	1385	2081.5	1920	50.29	2300	94.58	4.54
6	140	1335	2005.5	1890	50.22	2175	86.46	4.31
7	140	1085	1737	1595	60.09	1805	63.39	3.65
8	140	1525	2318.5	2100	52.03	2450	114.48	4.94
9	140	1480	2345.5	2195	58.48	2485	107.97	4.60
10	140	1620	2283.5	2125	40.96	2405	106.04	4.64
11	280	3020	4215	3920	39.57	4400	170.00	4.03
12	280	2770	4132	3860	49.17	4395	155.56	3.76
13	280	2775	4144	3935	49.33	4315	112.09	2.70
14	280	2805	3977	3780	41.78	4270	153.33	3.86
15	280	2840	4261	4050	50.04	4515	158.75	3.73
16	280	2910	4206	4070	44.54	4400	96.00	2.28
17	280	2960	4235.5	3980	43.09	4400	130.24	3.07
18	280	2815	4201	4045	49.24	4395	122.24	2.91
19	280	3045	4220	4035	38.59	4500	152.15	3.61
20	280	2715	4061	3880	49.58	4325	119.18	2.93
21	280	2460	3623.5	3465	47.30	3765	76.60	2.11
22	280	2330	3216	3020	38.03	3335	92.73	2.88
23	280	2315	3232	3095	39.61	3370	98.66	3.05
24	280	2400	3244.5	3185	35.19	3315	40.38	1.24
25	280	2225	3218	3005	44.63	3385	114.94	3.57
26	280	2615	3397	3320	29.90	3535	64.17	1.89
27	280	2415	3315	3190	37.27	3615	123.17	3.72
28	280	2405	3370	3280	40.12	3460	66.75	1.98
29	280	2390	3276	3195	37.07	3355	47.60	1.45
30	280	2480	3454.5	3360	39.29	3550	64.53	1.87

Média das instâncias pequenas	-	-	-	44.85	-	-	3.29
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id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
41	440	2560	3865	3710	50.98	4135	141.55	3.66
42	440	2640	4162	3915	57.65	4345	139.82	3.36
43	440	2690	4035	3860	50.00	4180	106.56	2.64
44	440	2705	3946	3790	45.88	4175	113.10	2.87
45	440	3170	4405.5	4295	38.97	4500	69.70	1.58
46	440	2630	3948	3605	50.11	4160	149.13	3.78
47	440	2960	4189.5	4000	41.54	4300	93.61	2.23
48	440	2770	3998.5	3820	44.35	4125	83.70	2.09
49	440	3140	4394	4245	39.94	4460	70.15	1.60
50	440	3005	4222.5	4085	40.52	4350	83.57	1.98
31	560	5115	6847	6725	33.86	7195	140.85	2.06
32	560	5390	7064	6655	31.06	7310	200.44	2.84
33	560	5475	7092.5	6775	29.54	7350	206.41	2.91
34	560	5100	6773	6555	32.80	7025	141.05	2.08
35	560	5410	6946	6650	28.39	7230	198.28	2.85
36	560	5280	7012.5	6810	32.81	7370	162.74	2.32
37	560	5505	7061.5	6820	28.27	7295	173.54	2.46
38	560	5120	6855	6615	33.89	7070	157.25	2.29
39	560	5350	7180	6915	34.21	7445	167.84	2.34
40	560	5320	6780	6615	27.44	7015	120.71	1.78

Média das instâncias médias	-	-	-	38.61	-	-	2.49
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51	880	5155	7412	7330	43.78	7520	68.36	0.92
52	880	4805	7355.5	7070	53.08	7575	163.15	2.22
53	880	4750	7045.5	6730	48.33	7410	188.98	2.68
54	880	4855	7197.5	6935	48.25	7455	173.64	2.41
55	880	4465	6919	6480	54.96	7180	201.90	2.92
56	880	4865	7321	6940	50.48	7615	179.56	2.45
57	880	5090	7590	7285	49.12	7805	151.58	2.00
58	880	4315	6988	6850	61.95	7110	92.56	1.32
59	880	4770	7256.5	7030	52.13	7520	155.77	2.15
60	880	4360	6778	6425	55.46	7080	189.85	2.80

Média das instâncias grandes	-	-	-	51.75	-	-	2.18
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Média Geral	-	-	-	45.07	-	-	2.82
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Resultados comparando o LAHC com as melhores soluções conhecidas

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
1	140	1425	2133	2045	49.68	2260	70.29	3.30
2	140	1615	2378.5	2300	47.28	2520	77.28	3.25
3	140	1540	2190.5	2115	42.24	2320	72.36	3.30
4	140	1365	2061.5	1870	51.03	2235	111.00	5.38
5	140	1385	2081.5	1920	50.29	2300	94.58	4.54
6	140	1335	2005.5	1890	50.22	2175	86.46	4.31
7	140	1085	1737	1595	60.09	1805	63.39	3.65
8	140	1525	2318.5	2100	52.03	2450	114.48	4.94
9	140	1480	2345.5	2195	58.48	2485	107.97	4.60
10	140	1620	2283.5	2125	40.96	2405	106.04	4.64
11	280	3020	4215	3920	39.57	4400	170.00	4.03
12	280	2770	4132	3860	49.17	4395	155.56	3.76
13	280	2775	4144	3935	49.33	4315	112.09	2.70
14	280	2805	3977	3780	41.78	4270	153.33	3.86
15	280	2840	4261	4050	50.04	4515	158.75	3.73
16	280	2910	4206	4070	44.54	4400	96.00	2.28
17	280	2960	4235.5	3980	43.09	4400	130.24	3.07
18	280	2815	4201	4045	49.24	4395	122.24	2.91
19	280	3045	4220	4035	38.59	4500	152.15	3.61
20	280	2715	4061	3880	49.58	4325	119.18	2.93
21	280	2460	3623.5	3465	47.30	3765	76.60	2.11
22	280	2330	3216	3020	38.03	3335	92.73	2.88
23	280	2315	3232	3095	39.61	3370	98.66	3.05
24	280	2400	3244.5	3185	35.19	3315	40.38	1.24
25	280	2225	3218	3005	44.63	3385	114.94	3.57
26	280	2615	3397	3320	29.90	3535	64.17	1.89
27	280	2415	3315	3190	37.27	3615	123.17	3.72
28	280	2405	3370	3280	40.12	3460	66.75	1.98
29	280	2390	3276	3195	37.07	3355	47.60	1.45
30	280	2480	3454.5	3360	39.29	3550	64.53	1.87
Média das instâncias pequenas		-	-	-	44.85	-	-	3.29

id	Dimensão	BKS	\overline{obj}	obj^*	gap (%)	obj^-	σ	CV (%)
41	440	2560	3865	3710	50.98	4135	141.55	3.66
42	440	2640	4162	3915	57.65	4345	139.82	3.36
43	440	2690	4035	3860	50.00	4180	106.56	2.64
44	440	2705	3946	3790	45.88	4175	113.10	2.87
45	440	3170	4405.5	4295	38.97	4500	69.70	1.58
46	440	2630	3948	3605	50.11	4160	149.13	3.78
47	440	2960	4189.5	4000	41.54	4300	93.61	2.23
48	440	2770	3998.5	3820	44.35	4125	83.70	2.09
49	440	3140	4394	4245	39.94	4460	70.15	1.60
50	440	3005	4222.5	4085	40.52	4350	83.57	1.98
31	560	5115	6847	6725	33.86	7195	140.85	2.06
32	560	5390	7064	6655	31.06	7310	200.44	2.84
33	560	5475	7092.5	6775	29.54	7350	206.41	2.91
34	560	5100	6773	6555	32.80	7025	141.05	2.08
35	560	5410	6946	6650	28.39	7230	198.28	2.85
36	560	5280	7012.5	6810	32.81	7370	162.74	2.32
37	560	5505	7061.5	6820	28.27	7295	173.54	2.46
38	560	5120	6855	6615	33.89	7070	157.25	2.29
39	560	5350	7180	6915	34.21	7445	167.84	2.34
40	560	5320	6780	6615	27.44	7015	120.71	1.78
Média das instâncias médias		-	-	-	38.61	-	-	2.49
51	880	5155	7412	7330	43.78	7520	68.36	0.92
52	880	4805	7355.5	7070	53.08	7575	163.15	2.22
53	880	4750	7045.5	6730	48.33	7410	188.98	2.68
54	880	4855	7197.5	6935	48.25	7455	173.64	2.41
55	880	4465	6919	6480	54.96	7180	201.90	2.92
56	880	4865	7321	6940	50.48	7615	179.56	2.45
57	880	5090	7590	7285	49.12	7805	151.58	2.00
58	880	4315	6988	6850	61.95	7110	92.56	1.32
59	880	4770	7256.5	7030	52.13	7520	155.77	2.15
60	880	4360	6778	6425	55.46	7080	189.85	2.80
Média das instâncias grandes		-	-	-	51.75	-	-	2.18
Média Geral		-	-	-	45.07	-	-	2.82

Considerações Finais

Conclusões

- 1 **Principais contribuições:** modelo matemático e o algoritmo baseado no LAHC;
- 2 Modelo proposto possui uma **descrição mais fácil** de compreender que o apresentado na definição da INRC-II;
- 3 Algoritmo é **robusto** em relação à variação dos resultados e produziu boas soluções para instâncias de **dimensões médias** com uma implementação relativamente simples;
- 4 No ajuste de parâmetros do LAHC, dos **sete movimentos propostos**, cinco apresentaram uma utilidade significativa;
- 5 Na primeira etapa da INRC-II, o LAHC **se classificou na sétima colocação**;
- 6 Na etapa final, o LAHC **se classificou em sexto lugar**, de um total de quinze competidores internacionais, o que consideramos um resultado competitivo.

Trabalhos Futuros

- 1 Ajuste dinâmico dos parâmetros conforme dimensão da instância;
- 2 Avaliação de novos movimentos e inclusão de uma Busca Local no final do LAHC;
- 3 Linearização do modelo matemático e avaliação dos métodos exatos;
- 4 Realização de estudo de caso em um ambiente hospitalar real com o objetivo de coletar instâncias reais e analisar qualitativamente a adequação do método proposto.

Referências I

- Burke, E. K. & Bykov, Y.** (2012). The late acceptance hill-climbing heuristic. *Department of Computing Science and Mathematics University of Stirling—Technical Report CSM-192*. ISSN, pages 1460–9673.
- Burke, E. K. & Curtois, T.** (2010). An ejection chain method and a branch and price algorithm applied to the instances of the first international nurse rostering competition, 2010. In *Proceedings of the 8th International Conference on the Practice and Theory of Automated Timetabling PATAT*, volume 10, page 13.
- Ceschia, S., Dang, N. T. T., De Causmaecker, P., Haspeslagh, S., & Schaerf, A.** (2015). Second international nurse rostering competition: mathematical model.
- Gomes, R. A., Toffolo, T. A., & Santos, H. G.** (2017). Variable neighborhood search accelerated column generation for the nurse rostering problem. *Electronic Notes in Discrete Mathematics*, 58:31–38.
- Haspeslagh, S., De Causmaecker, P., Stølevik, M., & Schaerf, A.** (2010). First international nurse rostering competition 2010 (august 10-13, 2010, belfast, uk). In *PATAT 2010-Proceedings of the 8th International Conference on the Practice and Theory of Automated Timetabling, Belfast, Northern-Ireland, UK*.
- Kheiri, A., Ozcan, E., Lewis, R., & Thompson, J.** (2016). A sequence-based selection hyper-heuristic. In *Proceedings of the 11th International Conference of the Practice and Theory of Automated Timetabling. PATAT*.

Referências II

- Nonobe, K.** (2010). Inrc2010: An approach using a general constraint optimization solver. *The First International Nurse Rostering Competition (INRC 2010)*.
- Römer, M.** (2015). A multi-commodity flow-based mixed-integer linear programming formulation for nurse rostering problems. In *OR2015-International Conference on Operations Research, Vienna*.
- Valouxis, C., Gogos, C., Goulas, G., Alefragis, P., & Housos, E.** (2012). A systematic two phase approach for the nurse rostering problem. *European Journal of Operational Research*, 219(2):425–433.

Obrigada!

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