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Optimization and Minimization of Disturbance to the Operating Room

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ABSTRACT:

Requests for surgical surgery can occur unexpectedly. We can not, in any circumstances when the demand for care arises.Some requests can be queued and scheduled for future dates. These applications are generally surgeries that are not of an urgent nature, they can be delayed without danger to the patient.

In medical language, this type of application is generally designated by the elective surgery, or scheduled. However, a significant proportion of applications within the field of emergency and requires immediate care. This type of application is inherently difficult to predict, and therefore not schedulable and is generally designated by the emergency surgery. Depending on the legal structure of the hospital, it may be obliged to accept all emergency patients

In this paper, we study the problem of reactive scheduling surgeries in operating rooms with consideration arriving urgent cases.In this context, we propose a reactive programming model procedure whose purpose is to minimize the cost of inserting these urgent cases and also take in consideration the availability of operating theaters and Surgeons. To solve this problem, we propose a heuristic based on constraint programming

INDEXING TERMS/KEYWORDS :

Constraint programming, Critical resources, Optimization; Modeling, Scheduling,CSP.

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1 .INTRODUCTION

The efficiency of hospital management is influenced by multiple factors including anticipation and responsiveness. An exceptional situation is characterized by the sudden appearance of several perturbations that disturb the execution ofthe operating program. Faced with such a situation, the hospital said having to put patients in the emergency planning already established, which sometimes causes malfunctions and usually additional operating costs.
In recent years, some studies have focused on reactive problems in hospitals under normal circumstances, especially when it comes to consider urgent surgical surgery in the operating room (Lamiri et al., 2008), (Hammami, 2004), (Roland et al, 2009) and(IssamNouaouri, 2010). But there is no work, to our knowledge, that address the problem of insertion of urgent surgery in a real-time scheduling, with the possibility to reschedule the planned surgery already sequenced if necessary by the use of programming later constraints. This is the problem we are addressing in the context of this article.
This article is divided into 2 sections. In Section 1, we presented the principle of constraint programming and a review of the literature dealing with work scheduling and allocation of surgical emergency. In section 2, we describe the problem studie. Finally, the conclusion can take stock and consider future avenues of research.

2. PRINCIPLES OF CONSTRAINT PROGRAMMING

The constraint satisfaction problems or CSP (constraint satisfaction problem) are used both in ArtificialIntelligence Research in Surgeryal. They allow to express the problems in management time and resources (eg models of planning and scheduling models).
A constraint satisfaction problem or CSP = (X, D, C) is defined by:
• a set X (x_1 , x_2, , x_n) of n variables ;
• a set D (d_1, d_2,d_n) of the n areas for variables X. d_i domain is associated with the variable x_i ;
• a set C = (c_1, c_2, ..., c_m) of m constraints. Each constraint is defined on a subset of v_i variables ($v_i \subseteq X$).
Constraint programming has been used for scheduling problems (Baptiste et al, 2001 ; El Khayat et al, 2006 ;Harjunkoski and Grossmann, 2002; Ozkarahan and Topaloglu, 2010).

3. DESCRIPTION OF THE PROPOSED APPROACH

The operation of the block is determined by a predictive time t = t_0 operating program. However, disturbances can occur at any time during program execution.
In normal situations, emergencies are the type of disturbance that causes the most change in the operating program established [Lafon and Landry, 2001 S.Hammami]. Following a disturbance at time t = t_p, the hospital must react quickly in order to minimize the consequences, including the number of urgent cases to treat.
In this context, we address the problem insertion emergencies in prédicitf already established program. we present a method for the introduction of the urgency with the goal of minimizing the cost of delays surgery programmed and the insertion of urgent cases cost.

A. Hypotheses:

To formulate the problem, we have adopted the following assumptions:

• Implement the strategy of " block scheduling",we schedule surgery in a skeleton (PDA) existing;
• All operating rooms are multifunctional;
• Once a surgical case gets started in an operating room, it cannot be interrupted, i.e. there is no preemption;
• The time needed to clean the operating rooms (setup) are not taken;
• For each surgical procedure, a surgeon is assigned and will not be changed;
• No surgeon can operate on more than one patient at the same time; similarly, no recovery bed can be occupied by more than one patient at the same time;
• It is assumed that surgeons are available to urgent surgical procedures;

B. proposed Solution:

The proposed solution receives as input a pile P containing surgery with their characteristics(lr_u:beginning at the earliest, LR_u:latest start of the urgent surgery, d_u:Time to complete urgent surgery)

It performs the first operation of sorting emergency prioritized (surgery of the highest priority a time interval between the beginning and later the early opening of the small emergency surgery).
Second, the solution made several passes over the elements in this list until all surgeries are assigned to surgery operating room.
The first pass is used to assign the different surgeries to critical resources.
The second is looking for the best location in the surgery rooms.

STEP 1:Assign successive values (resources) to the variable (urgent surgery):

Algorithm:

We try to successively assign values (resources)to thevariables (urgent surgery). If a failure occurs when it is redirecting the urgent surgery to another care facility and try with another surgery Assignment surgery (u)

/ / u : Urgent Surgery

If (P = ϕ) then / / P : Pile of Urgent Surgery (List of urgent surgeries)
 Pile ← u / / start Pile
Otherwise go_pile_ end(Pile) P← u / / u is added to the end of the pile
End If
End
/ / Surgical Sort_ urgent surgery ( )
pos , N_k, PgU
/ / PgU the most urgent surgery
/ / N_k Total number of urgent surgeries
/ / Pos is the position of urgent surgery in the pile P
/ / LR_u and lru are the parameters of the urgent surgery
For (i = 1; i<N_k-1 , i + +)
pos ← i
PgU← (u_{pos} . lru_{pos} - u_{pos} . LR_{pos})
For (j = 1; j<N_k , j + +)
If ((u_{pos} . lru_{pos} - u_{pos} . LR_{pos}) <PgU) then
PgU← j;
End if
Pos ← u_{pos} . lru_{pos} - u_{pos} . LR_{pos}
End for
Echange (u_i,u_{pos})
End for
/ / Affecter_Pile_Ressource the PgUurgent surgery
Begin
If (R <> φ) then R: pile of critical resources for urgent surgery PgU
R← Ri / / Ri: a critical resource
Otherwise / / Go_End_Resource (R) R← Ri
End If
End
Sort_Resource (Ri) / / R: Pile of resources for the urgent surgery PgU, a resource is characterized by a note and a variable available
Begin
Ri ← first_resource
 While (Ri.disponible = true)
Ri ← Next_ Resource
 End While
If (Ri. Available = false) then
 Write "no Available Resource and redirect the urgent surgery to another care facility"
Otherwise
Surgical Assign _Resource_ urgent surgery (R, P)
End If
End

STEP 2: Insert urgent surgery in the planning:

Pas1: urgent surgery to affect the beach unusable operating room:

Modeling:

The proposed solution receives as input a list L containing urgent surgery with their characteristics :

S : Number of operating rooms,
s : Surgery operating room (**s** ∈ **[1 , S]**),
N_e : Number of elective surgeries scheduled in the operating rooms s,
i : Index on elective surgery i, (**i∈[1, N_e]**),
LR_i : Date of earliest start of the elective surgery i,
lri : Date is later than the beginning of the elective surgery i,
d_i : Time to complete electif surgery i,
N_k^1 : Maximum number of urgent surgery may be inserted into the surgical program in the Pas1,
u : Index on urgent surgery u, **u** ∈ **[1, N_k^1],**
LR_u : The time to insert the urgent in the schedule = Date of earliest start of the urgent surgery u,
lr_u : Date is later than the beginning of the urgent surgery u,

d_u^i : Time to complete urgent surgery. (In number of time slots),
C_u : Cost of inserting urgent surgery in the planning,
C_p : The cost of unusable time period per unit of time,
Hd : The total number of surgeons available,
T : The total number of time intervals considered by the model,
t : Time interval t∈ {0, T},
J : Planning horizon,
j : Index on a period of the horizon (j = day) , j∈ {0, J},
M : Very large positive number,
Ps : The length of the beach unusable before insertion of elective surgery
ε_S : Unusable time after the insertion of urgent surgery between surgical response programmed i and i +1 in the operating room,

The decision variables

Z_{ustj} = 1 if the urgent surgery begins in the operating room s at time t in the day j, 0 otherwise,

X_{istj} = 1 if the elective surgery begins in the operating room s at time t in the day j, 0 otherwise,

we assume that we insert a single urgent surgery in the operating program

The objective function:

$$F_1 = min\left\{\sum_{u=1}^{N_k^1} C_u + \varepsilon_S \times C_p\right\} \qquad (1)$$

Constraints:
Constraints (1): Minimizes the cost of inserting an urgent surgery in the operating program and also minimize the cost of downtime between two elective surgeries.

$$P_S = T - \sum_{i=1}^{N_e} d_i . X_{istj} = \sum_{i=1}^{N_k^1} d_u^i . Z_{ustj} + \varepsilon_S \qquad \forall j \in J, \forall u \in N_k^1, \forall i \in N_e, \forall t \in T, \forall s \in S \qquad (2)$$

Constraints (2): Used to calculate the duration of urgent surgery.

$$\varepsilon_S = \sum_{i=1}^{N_e} (t_{i+1} - t_i - d_i) - d_u^i . Z_{ustj} \qquad \forall j \in J, \forall u \in N_k^1, \forall s \in S, \forall t \in T \qquad (3)$$

Constraints (3):Used to calculate the length of time between inoperative elective surgeries after insertion of emergency surgery.

$$\varepsilon_S = \left(0, T - \sum_{i=1}^{N_e} d_i . X_{istj} + \sum_{i=1}^{N_k^1} d_u^i . Z_{ustj}\right) \qquad \forall j \in J, \forall u \in N_k^1, \forall i \in N_e, \forall t \in T, \forall s \in S \qquad (4)$$

Constraints (4): Allows to calculate the expected duration of inéxplitable time in the day j of operating room s.

$$\sum_{s=1}^{S} \sum_{t=LRu}^{lru} Z_{ustj} = 1, \qquad \forall j \in J, \forall u \in N_k^1 \qquad (5)$$

Constraints (5): Ensure that an elective surgery u started and more, once in an operating room s.

$$t_u + M\left(1 - \sum_{s=1}^{S} \sum_{t=LR_u}^{lr_u} Z_{ustj}\right) \geq LR_u, \qquad \forall j \in J, \forall u \in N_k^1, \forall s \in S \qquad (6)$$

Constraints (6): Prove that one urgent surgery cannot be inserted before the date at the beginning later.

$$\sum_{u=1}^{N_k} \sum_{\tau=max(t-d_u+1,1)}^{t} Z_{ustj} \leq 1, \qquad \forall j \in J, \forall s \in S, \forall t \in T \qquad (7)$$

Constraints (7): Assure that urgent surgery do not overlap them some them others within the same operating room.

$$Z_{ustj} = \{0, 1\}, \qquad \forall j \in J, \forall u \in N_k^1, \forall s \in S, \forall t \in T \qquad (8)$$

$$X_{istj} = \{0, 1\}, \qquad \forall j \in J, \forall i \in N_e, \forall s \in S, \forall t \in T \qquad (9)$$

Constraints (8)and (9): Are integrity constraints.

Algorithm:
/ / Insert the urgent surgery u:

while
$P_s \geq d_u^i$
/ / Insert the urgent surgery
End while
If $P_s \leq d_u^i$
Goes to next step
Otherwise
Write"Insert the urgent surgery"
End if
/ / Calculate the lost cost of downtime between two surgeries scheduled
$\varepsilon_S = 0$
For (i = 1; i<N_e , i + +) do
ε_S=$\varepsilon_S + [(t_{i+1} - t_i - d_i) - d_u^i]$;
End for
// display « the cost of downtime between two surgeries scheduled,= », $\boldsymbol{\varepsilon_S}$*$C_p$

Pas2: Assign the new urgency to the operating room and the surgeon has the largest Δg :

Seeks to assign the new urgent in the operating room or surgeon and have the largest Δg When surgery is assigned to an operating room, we apply the method right shift to shift all surgery after surgery inserted with a period equal to the duration of surgery and we will calculate the new value of the objective function.
The total margin is the difference between the latest date and the earliest date of a task.
This calculation method is based on the method PERT.

Modeling

$\mathbf{N_k^2}$: Maximum number of urgent surgery may be inserted into the surgical program in the Pas2, $\mathbf{N_k^2} = N_K - \mathbf{N_k^1}$
u : Index on urgent surgery u **u**∈ **[1, $\mathbf{N_k^2}$]**,
Δgs : Total margin of elective surgery has affected the operating room s,
w : The delay penalty of elective surgery i per unit of time,
$\mathbf{N_p}$: Number of elective surgeries shifted after the insertion of urgent surgery in the operating room s,
$\mathbf{d_u}$: Time to complete urgent surgery. (In number of time slots),

$$F_2 = min\left\{\sum_{i=1}^{N_p} w \sum_{t=lr_i}^{T-d_i} (tX_{istj} - lr_i) + \sum_{u=1}^{N_k^2} C_u\right\} \qquad (10)$$

Constraints :
Constraintes (10): Reduce the cost of postponing elective surgery and the cost of insertions urgent surgery in a operating room s.

$$\Delta g_s \geq d_u .\ Z_{ustj}, \qquad \forall j \in J, \forall u \in N_k^2, \forall s \in S, \forall t \in T \qquad (11)$$

Constraints (11): Respect to the capacity of the largest free total margin of a operating room s in the day.

$$\Delta g_s = \sum_{i=1}^{N_p} \mathbf{lr_i} - \mathbf{LR_i}, \qquad \forall i \in \mathbf{N_p}, \forall s \in S \qquad (12)$$

Constraints (12): Used to calculate the total free margin elective surgery in a operating room s (using PERT).

$$\sum_{s=1}^{S} \sum_{t=LRu}^{lru} Z_{ustj} = 1, \qquad \forall j \in J, \forall u \in N_k^2 \qquad (13)$$

Constraints (13): Ensure that an elective surgery u started and more, once in an operating room.

$$t_u + M\left(1 - \sum_{s=1}^{S} \sum_{t=LR_u}^{lr_u} Z_{ustj}\right) \geq LR_u, \qquad \forall j \in J, \forall u \in N_k^2, \forall s \in S \qquad (14)$$

Constraints (14): Prove that one urgent surgery cannot be inserted before the date at the beginning later.

$$\sum_{u=1}^{N_k^2} \sum_{\tau=max(t-d_u+1,1)}^{t} Z_{ustj} \leq 1, \qquad \forall j \in J, \forall s \in S, \forall t \in T \qquad (15)$$

Constraints (15): Assure that urgent surgery do not overlap them some them others within the same operating room.

$$Z_{ustj} = \{0, 1\}, \qquad \forall j \in J, \forall u \in N_k^2, \forall s \in S, \forall t \in T \qquad (16)$$

$$X_{istj} = \{0, 1\}, \qquad \forall j \in J, \forall i \in N_p, \forall s \in S, \forall t \in T \qquad (17)$$

Constraints (16)and (17): are integrity constraints.

Algorithm :

```
Variable
/ / p : full vacuum.
/ /max:max of  Δgs
/ /pos:position  of Δgs
/ / Δgs : free total margin en s

1/ / Calculate the Δi_s
For ( i = 1; i<N_p , i + +)
Δis = lr_i - LR_i ;
End for

2/ / Calculate the max of Δgs
 pos ⟵1;
Max ⟵  Δgs_1 ;
For((i = 2; i< S;  i + +)
If (Δgs_i  > max)  then
max   ⟵  Δgs_i ;
pos   ⟵  i;
End if
End for
3/ / Test position for urgent surgery u :
If   Δgs ≤ d_u
Then insert the urgent surgery u and go to 4
Otherwise go to 1 ( move to the next operating room s = s +1)
End if

4/ / Move to the right , from the urgent surgery  , all surgery assigned to the operating room s with a duration
equal to the  d_u:
For (i = p +1;i< N_p;  i + +)
t_i = t_i + d_u ;
End for

5/ / Calculate the cost of postponing surgery scheduled
/ /somme : time of postponing elective surgery i
 somme = 0
For ( t = lr_i; i<(T- d_u), t+ +) do
somme=somme + (t − lr_i);
End for
 // display « the cost of postponing elective surgery i,= », somme*w
```

4. CONCLUSIONS AND PERSPECTIVES

In an emergency, the programming procedure should allow to cope with disturbances. We have developed in this context, a planning model optimization surgeries in the operating room in a reactive mode. To minimize the cost of disrupting the timing preset in all rooms and surgery for all surgeons, we have developed an approach to solve multi-step based on constraint programming. First, we seek to allocate critical resources chirurgcales urgent surgeries. Then we try to insert elective surgery in the empty beaches. If the problem still can not be resolved in this case we insert the surgical emergency room for surgery and surgeons that have the highest total margin

- In terms of outlook, this work opens up questions to take into account other types of disturbances namely the arrival of a new and urgent exceeded the estimated operating life.

- We also plan to integrate other constraints related to the various components of the hospital chain in an exceptional situation (hospital services , the availability of beds and wake care staff , etc. .) . In this case , new approaches Resolutions for surgical planning in the operating rooms are needed to solve the problem of computation time, which is sometimes prohibitive.

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