

# A Unified Nurse Rostering Model Based on XHSTT

Jeffrey H. Kingston (University of Sydney)

Gerhard Post (University of Twente)

Greet Vanden Berghe (KU Leuven)

## **The current state of nurse rostering modelling**

- General agreement on concepts (nurses, shifts, etc.)
- Two competitions
- Several good data sets

But:

- Every advance seems to bring a new model

## **The current state of high school timetabling modelling**

- A standard model: XHSTT
- One competition
- One very good data set (XHSTT-2014)
- Free software (HSEval and KHE)

## The XESTT project

- XESTT extends XHSTT: two new constraints, plus small enhancements
- ‘ES’ stands for ‘Employee Scheduling’ (but really just nurse rostering)
- HSEval and KHE extended to also accept XESTT
- NRConv program converts other formats to XESTT:
  - Curtois ‘original’ instances + solutions from Curtois web site
  - INRC1 instances + GOAL solutions
  - Curtois and Qu (2014) instances + solutions contributed by Curtois
- These conversions are exact

## The XESTT model

- XML syntax
- Archive file: holds a set of instances plus any number of sets of solutions
- Each instance contains *times*, *resources*, *events*, and *constraints*

## Times and time groups

A *time* is an indivisible interval of time. One for each shift on each day:

1Mon1 – time of morning shift on the first Monday  
1Mon2 – time of afternoon shift on the first Monday  
1Mon3 – time of night shift on the first Monday  
1Tue1 – time of morning shift on the first Tuesday  
... .

A *time group* is a set of times:

1Mon = {1Mon1, 1Mon2, 1Mon3}  
Nights = {1Mon3, 1Tue3, ... , 4Sun3}  
1Weekend = {1Sat1, 1Sat2, 1Sat3, 1Sun1, 1Sun2, 1Sun3}

## Resources and resource groups

A *resource* is something that attends events. In nurse rostering, all resources are nurses:

Nurse1 – first nurse

Nurse2 – second nurse

. . .

A *resource group* is a set of resources:

FullTime = {Nurse1, Nurse4, Nurse8}

Senior = {Nurse1, Nurse2, Nurse3}

## Events

An *event* is a meeting, with a starting time, duration (number of times), and resources.

Each nurse rostering event is one shift, with a preassigned starting time and duration 1:

```
Event E-1Mon1
  Duration 1
  StartingTime 1Mon1
  5 Nurses
End Event
```

- Constraints on choice of nurses given separately
- Optional `Workload` attribute (e.g. minutes)



## Constraints

A *constraint* is a rule that solutions should obey, containing attributes

- Required: true or false
- Weight: a non-negative integer
- CostFunction: Linear, Quadratic, or Step

The cost is the weight times the cost function applied to the *deviation*. This is added to either the hard cost total or the soft cost total, depending on Required.

## The nine types of XESTT constraints used in nurse rostering

### *Event resource (cover) constraints*

Assign Resource constraint

Assign resource to event resource

Prefer Resources constraint

Assign resource from given set

Limit Resources constraint

Limits a whole set of event resources

### *Resource constraints*

Avoid Clashes constraint

Avoid clashes involving resource

Avoid Unavailable Times constraint

Make resource free at given times

Cluster Busy Times constraint

Limit resource's busy days

Limit Busy Times constraint

Limit resource's busy times each day

Limit Workload constraint

Limit resource's total workload

Limit Active Intervals constraint

Limit consecutive busy or free days

## The cluster busy times constraint

A constraint on the timetable of some resource  $r$ .

Contains a set of time groups:

$\{1\text{Mon}1, 1\text{Mon}2, 1\text{Mon}3\}$

$\{1\text{Tue}1, 1\text{Tue}2, 1\text{Tue}3\}$

$\{1\text{Wed}1, 1\text{Wed}2, 1\text{Wed}3\}$

Plus minimum and maximum limits on the number of *busy* time groups: time groups containing a time when  $r$  attends an event.

Also *negative time groups* for limiting free time groups – see paper.

## Examples of cluster busy times constraints

At least 20 and at most 24 busy days:

$$\{1\text{Mon}1, 1\text{Mon}2, 1\text{Mon}3\}$$

$$\cdot \cdot \cdot$$

$$\{4\text{Sun}1, 4\text{Sun}2, 4\text{Sun}3\}$$

At most 2 busy weekends:

$$\{1\text{Sat}1, 1\text{Sat}2, 1\text{Sat}3, 1\text{Sun}1, 1\text{Sun}2, 1\text{Sun}3\}$$

$$\cdot \cdot \cdot$$

$$\{4\text{Sat}1, 4\text{Sat}2, 4\text{Sat}3, 4\text{Sun}1, 4\text{Sun}2, 4\text{Sun}3\}$$

Morning or afternoon shift may not follow night shift:

$$\{1\text{Mon}3\}$$

$$\{1\text{Tue}1, 1\text{Tue}2\}$$

## Limit active intervals constraints

Same, except that the limits apply to the number of *consecutive* busy time groups:

At least 2 and at most 5 consecutive busy days:

$$\{1\text{Mon}1, 1\text{Mon}2, 1\text{Mon}3\}$$

$$\cdot \cdot \cdot$$

$$\{4\text{Sun}1, 4\text{Sun}2, 4\text{Sun}3\}$$

At most 3 consecutive night shifts:

$$\{1\text{Mon}3\}$$

$$\cdot \cdot \cdot$$

$$\{4\text{Sun}3\}$$

and so on.

## Conclusion

- XESTT seems very general, it may do everything
- Converted so far: 4 formats, 111 instances, 192 solutions
- More conversions may be done, if people are interested
- May make some instances more accessible, e.g. the Curtois original instances
- <http://jeffreykingston.id.au/xestt>