**The School of Mathematics**



# THE UNIVERSITY
# *of* EDINBURGH

# Incremental Learning
# of Recommender Systems

### by

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# Abstract

Here comes your abstract ...

# Acknowledgments

Here come your acknowledgments ...

# Own Work Declaration

Here comes your own work declaration

# Contents

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# 1 Introduction

Here I will write a very good, precise and brief introduction. Particularly Section 2 is good!

## 2 Background

In the following, I explain some background stuff. I should really cut this short, but BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla. Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla. BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla. BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla.

Note that I start a new paragraph when I have an empty line like this. BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla. BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla. Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla. BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla BlaBlaBlaBla BlaBlaBlaBlaBla Bla Bla BlaBlaBla Bla Bla BlaBlaBla Bla BlaBla BlaBla Bla BlaBlaBlaBla Bla BlaBla Bla Bla Bla BlaBla.
But I can also end a line with a double backslash.

## 2.1 Models

Models are *very* helpful because.

- They're good.

- They're helpful.

## 2.2   Techniques

Techniques even better because.

1. They're magnificent.

2. If they work.

# 3 Technical Stuff

Now it's getting very technical ... I will cite [2, 1]. I will also show my incredible $\alpha$, $\beta$ and $\gamma$ mathematics and do some other fancy stuff.

## 3.1 Formulae

For example look at this

$$\min \sum_{s \in \mathcal{S}} Pr_s \left[ \sum_{t=1}^{T} \left( \sum_{g \in \mathcal{G}} \left( \alpha_{gts} C_g^0 + p_{gts} C_g^1 + (p_{gts})^2 C_g^2 \right) + \sum_{g \in \mathcal{C}} \gamma_{gts} C_g^s \right) \right], \tag{3.1}$$

and you will see that it has a little number on the side so that I can refer to it as equation (3.1). Now if I do this

$$\sum_{i=1}^{n} k_i = 20 \tag{3.2}$$

$$\sum_{j=20}^{m} \delta_i \geq \eta$$

I can align two formulae and control which one has a number on the side. It is (3.2). I can also do something like this

$$Y_l = \begin{bmatrix} \left( y_s + i\frac{b_c}{2} \right) \frac{1}{\tau^2} & -y_s \frac{1}{\tau e^{-i\theta s}} \\ -y_s \frac{1}{\tau e^{i\theta s}} & y_s + i\frac{b_c}{2} \end{bmatrix},$$

and it won't have a number on the side. Now if I have to do some huge mathematics I'd better structure it a little and include linebreaks etc. so that it fits on one page.

$$\begin{aligned}
p_l^f &= G_{l11} \left( 2 v_{F(l)} \bar{v}_{F(l)} - \bar{v}_{F(l)}^2 \right) \\
&+ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[ B_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\
&+ \begin{bmatrix} \bar{v}_{T(l)} \left[ B_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ \bar{v}_{F(l)} \left[ B_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[ B_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) - G_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[ -B_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \end{bmatrix} \cdot \begin{bmatrix} v_{F(l)} - \bar{v}_{F(l)} \\ v_{T(l)} - \bar{v}_{T(l)} \\ \delta_{F(l)} - \bar{\delta}_{F(l)} \\ \delta_{T(l)} - \bar{\delta}_{T(l)} \end{bmatrix},
\end{aligned} \tag{3.3}$$

This is a lot of fun!

## 3.2 Important Things

Finally we should have a nice picture like this one. However, I won't forget that figures and table are environments which float around in my document. So LaTeX will place them wherever it thinks they fit well with the surrounding text. I can try to change that with a float specifier, e.g. [!ht]. Now I
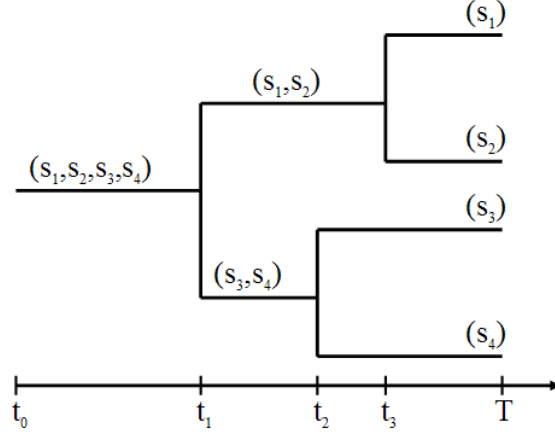


Figure 1: Look at this scenario tree with funny times $t_1$ and scenarios $s_1$ etc.

want to use one of my own environments. I want to define something.

**Definition 3.1** *I define*

$$\Gamma_\eta := \sum_{i=1}^{n} \sum_{j=i}^{n} \xi(i,j)$$

I definitely need some good tables, so I do this. I should really refer to Table 1.

| Case | Generators | Therm. Units | Lines | Peak load: [MW] | [MVar] |
|------|-----------|:---:|:---:|---:|---:|
| 6 bus | 3 at 3 buses | 2 | 11 | 210 | 210 |
| 9 bus | 3 at 3 buses | 3 | 9 | 315 | 115 |
| 24 bus | 33 at 11 buses | 26 | 38 | 2850 | 580 |
| 30 bus | 6 at 6 buses | 5 | 41 | 189.2 | 107.2 |
| 39 bus | 10 at 10 buses | 7 | 46 | 6254.2 | 1387.1 |
| 57 bus | 7 at 7 buses | 7 | 80 | 1250.8 | 336.4 |

Table 1: Something that doesn't make sense.

## 3.3 And now something else

Let:

$$
\begin{aligned}
\Omega_0 &= \{(x,y,z,f): \text{ satisfying } (9) - (19)\}, \\
\Omega_1 &= \{(x,y,z,f): \text{ satisfying } (9), (11) - (20)\}, \\
\overline{\Omega}_0 &= \{\mathbf{0} \le (x,y,z,f) \le \mathbf{1}: \text{ satisfying } (9) - (18)\}, \\
\overline{\Omega}_1 &= \{\mathbf{0} \le (x,y,z,f) \le \mathbf{1}: \text{ satisfying } (9), (11) - (18), (20)\}.
\end{aligned}
$$

where $\mathbf{0}$ and $\mathbf{1}$ are vectors of appropriate dimensions with 0's and 1's, respectively. Next we see that both $\Omega_0$ and $\Omega_1$ give equivalent formulations for the A-MSSP. In particular, the following statements hold:

**Proposition 1** $\Omega_0 \subseteq \Omega_1$.

**Proof.** Let us suppose there exists $(x, y, z, f) \in \Omega_1$ such that $(x, y, z, f) \notin \Omega_0$. Then, there exist indices $i \in I$ and $t \in \{0, \ldots, |T| - s_i\}$ with $x_i^t > 0.5 \left( \sum_{h=1}^{s_i} x_i^{t+h} + 1 \right)$. By definition, $x_i^t = 1$ and $x_i^{t+h} = 0$ for all $h \in \{1, \ldots, s_i\}$. By (11) and (12), $\sum_{h=1}^{s_i} f_i^{th} = 1$, so $f_i^{th'} = 1$ for some $h' \in \{1, \ldots, s_i\}$. But then,

$$0 = x_i^{t+h'} = \sum_{h=\max\{1, t+h'-(|T|-s_i)\}}^{\min\{s_i, t+h'\}} f_i^{t+h'-h, h} \geq f_i^{th'} = 1,$$

as $h' \in [\max\{1, t + h' - (|T| - s_i)\}, \min\{s_i, t + h'\}]$. $\square$

This immediately gives us

**Corollary 1** *AS is a valid formulation for the A-MSSP.*

Next we compare the Linear Programming (LP) relaxations of the two formulations.

**Proposition 2** $\overline{\Omega}_1 \subseteq \overline{\Omega}_0$.

**Proof.** Homework $\square$

# 4 Conclusions

I have no idea how to conclude, so I don't write much. But the stuff that follows is important.

# References

[1] N. Gröwe-Kuska and W. Römisch. *Stochastic unit commitment in hydro-thermal power production planning*. Preprints aus dem Institut für Mathematik. Humboldt-Universität zu Berlin, Institut für Mathematik, 2001.

[2] T. Shiina and J. R. Birge. Stochastic unit commitment problem. *International Transactions in Operational Research*, 11(1):19–32, 2004.

# Appendices

## A   An Appendix

Some stuff.

# B  Another Appendix

Some other stuff.