Research and thesis opportunities at the Operations Research Lab @ UNITS

Esami in presenza / da remoto

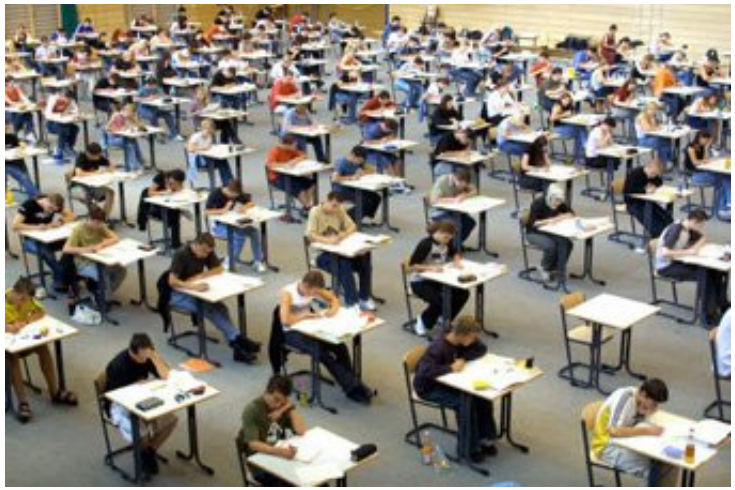
1. gli appelli degli esami di profitto **vanno svolti in presenza**, salvo le eccezioni previste ai punti successivi;
2. **nei casi in cui le lezioni siano state svolte interamente in modalità remota**, di norma, il relativo esame viene svolto **in modalità remota**; è facoltà del docente concordare con il proprio Dipartimento e Corso di Studio lo svolgimento dell'esame in presenza;
3. **nei casi in cui il docente di un corso svolto in presenza sia impossibilitato ad essere presente** per motivazioni relative all'emergenza in atto, da comunicare al Direttore di Dipartimento, l'esame può essere svolto in modalità remota;

Studente in remoto

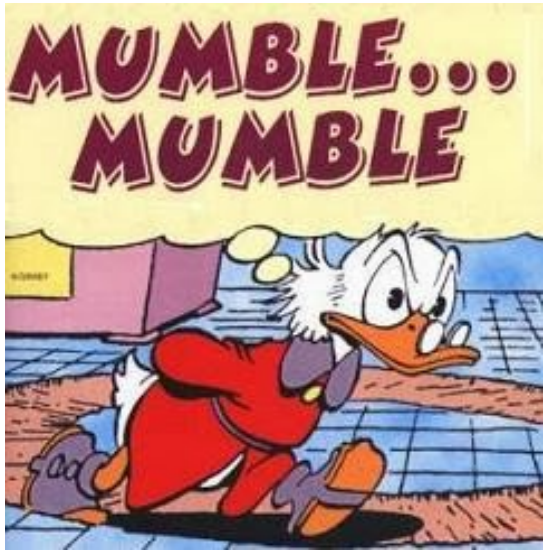
6. in tutti i casi in cui gli esami si tengano in presenza, **deve comunque essere garantita la possibilità di svolgimento in remoto su richiesta motivata del singolo studente**. In questo caso:
    a. le modalità di svolgimento dell'esame in presenza e in remoto sono stabilite dal docente e possono anche essere distinte per le due modalità; è consentito svolgere, in tal caso, gli esami in remoto in momenti diversi da quelli svolti in presenza;
    b. gli studenti che intendono svolgere l'esame in remoto devono **inviare via mail al Presidente della commissione** la richiesta in cui dichiarano le motivazioni che devono essere dipendenti da:
        i. motivi di tipo sanitario legati all'emergenza in corso;
        ii. impossibilità a spostarsi dalla loro residenza in virtù delle restrizioni legate all'emergenza;
        iii. impossibilità a uscire da regioni diverse da quella della sede del proprio corso di studi;
        iv. aver frequentato l'intero semestre in remoto così come concesso dall'Ateneo;
    c. la richiesta, da inviare anche in copia alla Segreteria didattica del Dipartimento, fungerà da **autodichiarazione** che potrà essere richiesta in caso di eventuali controlli;

Exams

- Risoluzione di un problema di ottimizzazione
- Solo esame scritto
- 4 e 22 giugno, 29 luglio
- Chiusura prenotazioni: 14 gg



- Remoto: Implementare un modello tratto da un paper scientifico
  - 12 ore
  - Orale di 30 min il giorno dopo
  - Su appuntamento



OR lab (ORTS)

http://www2.units.it/orts/

Interreg Italy - Croatia E-CHAIN

EUROPEAN UNION

engage

BEACON

Lorenzo Castelli

Dipartimento di Ingegneria e Architettura

castelli@units.it

Horizon 2020 *Engage (18-21), Beacon (20-22)* **Interreg ITA-HRO** *E-Chain (19-22)*

Engage is a knowledge transfer network between the scientific community and the major players in the European air transport system (e.g. airports, airlines) for the definition of research priorities of interest to the industry in the ATM sector.

BEACON studies the feasibility of multi-prioritisation processes in the airspace through behavioural economics (endowment, loss-aversion, hyperbolic discounting).

E-CHAIN: enhance connectivity and harmonization of data for the Adriatic Intermodal Network, through the realization of a modular integrated software, to provide new services such as an improved port multimodal infomobility system for the passengers, a ticketing system integrated with other transport modes, an advanced touristic co-marketing tool for the operators in Ancona, Split and Venice.

UNITS funding: 600 K€

salient.

EASA European Aviation Safety Agency

EUROCONTROL

FREQUENTIS

University of Belgrade

TU Delft

UNIVERSITY OF WESTMINSTER

NOMMON

SWISS

innaxis

Choosing your thesis - WHO

- Unless you have VERY clear ideas, visit more than one possible supervisors
- The supervisor choice is one of the very few which is totally free. You are not accountable to anyone
- Choose as supervisor someone you trust and have a good opinion of
- **Sant'Agostino "Per essere grandi bisogna stare con i grandi"**

Choosing your thesis - WHEN

- Don’t go too early (e.g., still 8 exams to pass!)
  - Topics may change in the meantime
- Don’t wait too much (i.e., when you have already finished your exams)
  - There could be a lot of downtime at the beginning of your work

Choosing your thesis
To make it faster

- Internship and thesis on the same topic with the same supervisor
  - the latter is the continuation of the former
- Relationships with companies normally slow down the entire process
- How long it should last
  - DSSC: 12+24 = 36 CFU (9 months)
  - ING ELETT INFO: 3+15 = 18 CFU (6-9 months)

Dottorandi e Assegnisti

Nome	Finanziato	Argomento	Durata
Natalia	EUROCONTROL	Evolution of route charges	36
Andrea	BEACON/E-Chain	Aircraft prioritisation / data analysis	36
Giovanni		ATM pricing	12
Margherita		Weather ship routing	12
Sara	E-Chain	Infomobility, e-ticketing, co-marketing	16
In progress	UNITS	University timetabling	12
In progress	BEACON	ATM Data analysis, open data	12
In progress	E-Chain	Infomobility, e-ticketing, co-marketing	12
In progress	E-Chian	Infomobility, e-ticketing, co-marketing	12

Tesisti

Nome	Laurea	Azienda	Argomento	Data
Valeria	SM35	-	Community detection for ATM	10/20
Federico	SM35	ESTECO	RL for pedestrian-car intersection	12/20
Francesco	IN20	-	University timetabling	03/21
Luca	IN20	ESTECO	Requisiti progettuali modelli SysML	05/21
Fulvio	IN20	-	Tempo permanenza a terra aeromobile da OpenData	05/21
Igor	IN20	-	Trajectory pricing (ATM)	
Marco	IN20	AcegasApsAmga	Prioritizzazione investimenti (sostituzione o manutenzione?)	
Davide	IN20	Porto di TS	(ottimizzazione della logistica) ?	
Irene	SM35	-	Distributed combinatorial resource allocation	
Chiara	SM34	Maior (FI)	Managing airline disruptions	
Anna	SM34	?	Extended Design Structure Matrix (XDSM) x rappresentare architettura di problemi di ottimiz. multidisciplinare (MDO).	
Letizia	IN20	-	GA/GP for bilevel programming	
Loris	IN14	SIOT	?	

Thesis opportunities @ORTSLab

- **Computational behavioural economics**
  - Mathematical optimisation and simulation to model agents' irrationality
- **Machine learning for optimisation problems**
- **Air traffic analysis through open data**
  - https://opensky-network.org
- **Evolutionary metaheuristics for bilevel programming**
  - Network pricing problem
- **Connections with**
  - ***industry*** – Esteco, Autorità di Sistema Portuale del Mare Adriatico Orientale, AcegasApsAmga, Maior
  - ***research centres*** – Univ. Gustave Eiffel (Lille), Innaxis (Madrid), Univ. Politecnica de Catalunya (Barcelona)

Optimization Models for Machine Learning

PART I: Introduction to Numerical Optimization

- The optimization problems;
- The min-max problems;
- Convexity;
- Global and local minima;
- Optimality conditions;
- The Wolfe dual problem.

PART II: Numerical Optimization and Machine Learning

- Introduction to Machine Learning;
- Optimization and pattern classification;
- Optimization models for supervised classification;
  - Linear separation; Spherical separation; Polyhedral separation; Support Vector Machine; The kernel trick; Proximal Support Vector Machine; Spherical separation with margin;
- Optimization models for unsupervised classification;
  - The non-smooth clustering optimization model;
- Optimization models for semi-supervised classification;
  - Transductive Support Vector Machine; Semi-supervised spherical separation; Semi-supervised polyhedral separation;
- Multiple Instance Learning;
  - Instance-space, bag-space and embedding-space approaches;
  - Support Vector Machine for Multiple Instance Learning;
- Evaluation of a classifier;
  - Accuracy; Sensitivity; Specificity; Precision; F-score;
- Model selection: cross validation and leave-one-out strategies.

Optimization for ML

- https://riseneeds.eu/2020/12/09/upcoming-seminar-series-machine-learning-needs-mathematical-optimization/

- https://www.sciencedirect.com/science/article/pii/S037722172030758X

ML for Optimization

- https://www.sciencedirect.com/science/article/pii/S0377221720306895
- https://arxiv.org/pdf/2012.13349.pdf
- https://arxiv.org/pdf/1906.01629.pdf

Bilevel Programming and Price Setting Problems

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Département d'Informatique
Université Libre de Bruxelles

Bilevel Program

$$\max_{x,y} \quad f(x,y)$$

$$s.t. \quad (x,y) \in X$$

$$y \in S(x)$$

$$where \quad S(x) = argmax_y g(x,y)$$

$$s.t \quad (x,y) \in Y$$

Adequate Framework for Stackelberg Game

- Leader: 1st level,
- Follower: 2nd level.
- Leader takes follower's optimal reaction into account.

Adequate framework for Price Setting Problem

- 1st level sets taxes on some activities
- 2nd level selects activities among taxed and untaxed ones to minimize operating costs

$$\begin{aligned} \max_{T} \quad & F(T, x, y) \\ \min_{x,y} \quad & f(T, x, y) \\ s.t. \quad & (x, y) \in \Pi \end{aligned}$$

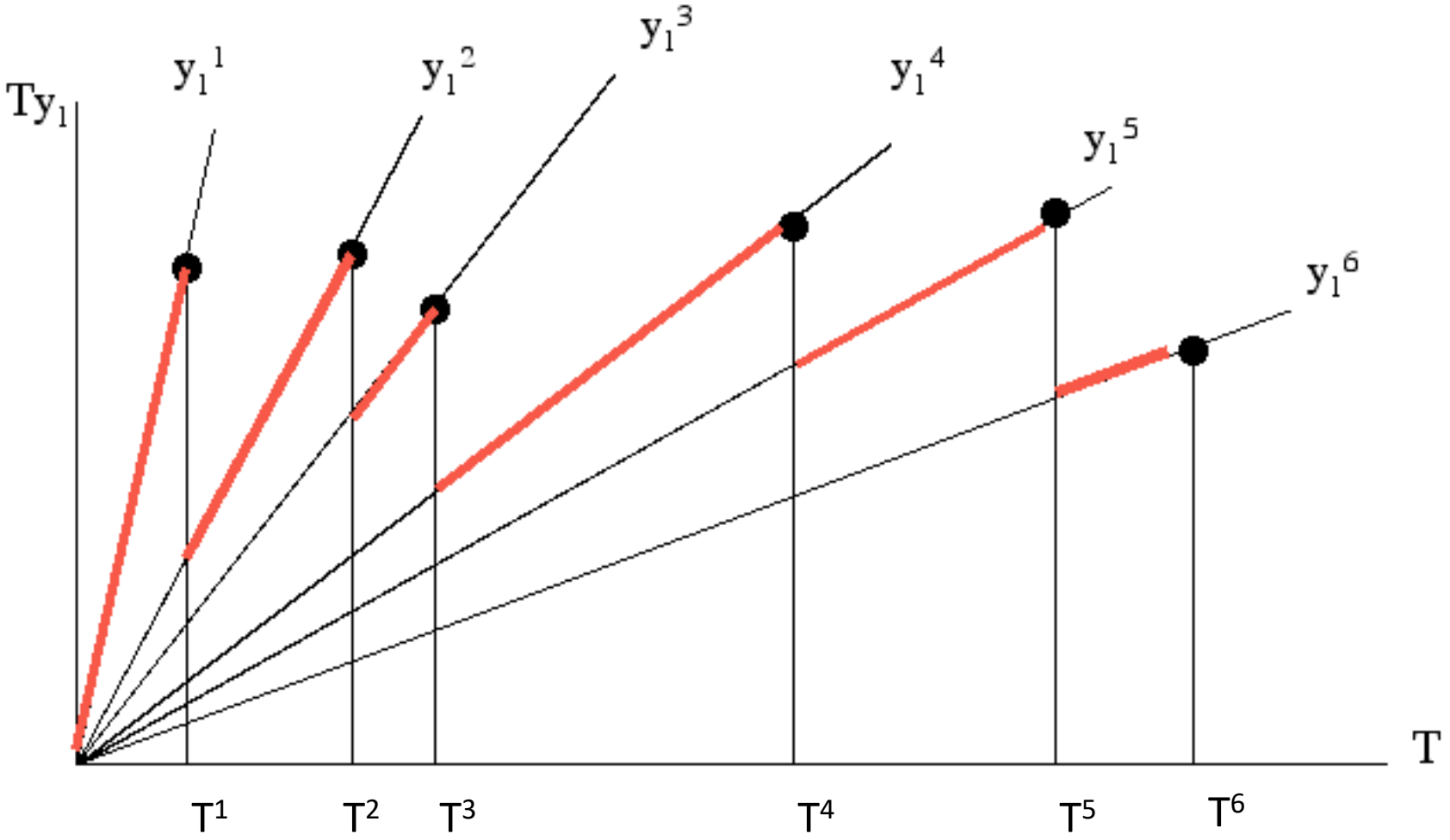
Price Setting Problem with linear constraints

$$
\begin{aligned}
\max_{x} \quad & Ty_1 \\
\min_{y_1, y_2} \quad & (c_1 + T)y_1 + c_2 y_2 \\
s.t. \quad & A_1 y_1 + A_2 y_2 = b \\
& y_1, y_2 \geq 0
\end{aligned}
$$

where $\Pi = \{(y_1, y_2) : A_1 y_1 + A_2 y_2 = b, y_1, y_2 \geq 0\}$ nonempty and bounded

$= \{y_2 : A_2 y_2 = b, y_2 \geq 0\}$ nonempty

The profit function



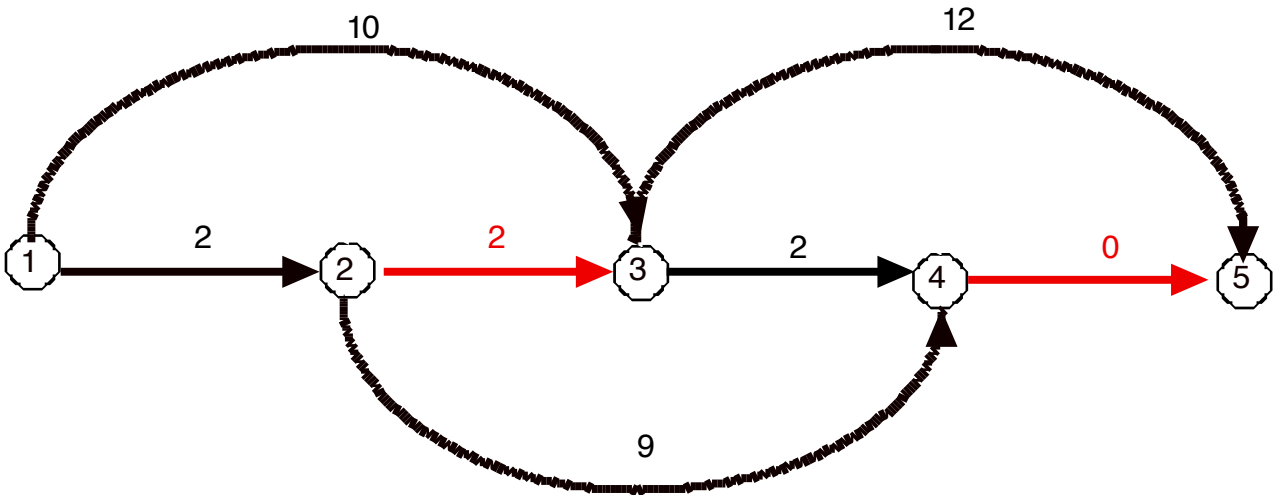
Price setting problem

- Bilinear bilevel program
- Reformulation as linear bilevel program
- Reformulation as bilinear single level program

Network pricing problem

- Network with taxed arcs (A_1) and non taxed arcs (A_2).
- Costs on arcs
- K commodities: (o_k, d_k, n_k)
- Routing on cheapest (cost+toll) path
- Maximize total profit

Example



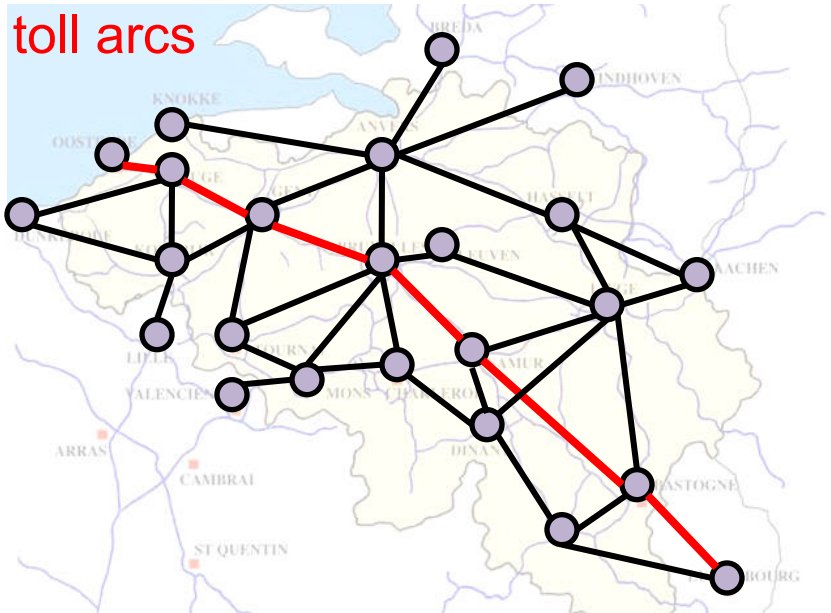
UB on $T_1 + T_2 = SPL(T= \infty) - SPL(T=0) = 22 - 6 = 16$

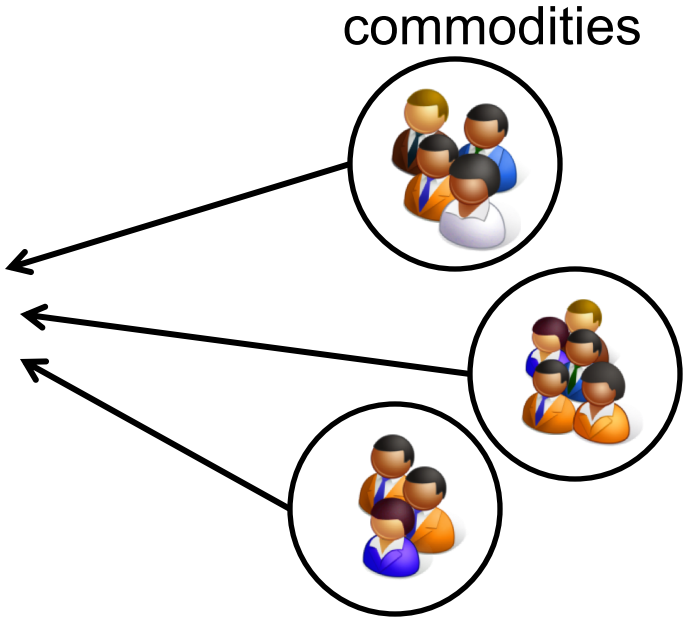
$T_{23} = 5,\ T_{45} = 10$

Network pricing problem

- Strongly NP-hard even for only one commodity.
- Polynomial for one commodity if lower level path is known
- Polynomial for one commodity if toll arcs with positive flows are known
- Polynomial if one single toll arc.
- Polynomial algorithm with worst-case guarantee of $(\log|A_1|)/2+1$

Particular case: highway pricing





NPP : to détermine taxes s.t maximizing company's revenue
customers' reaction : shortest path

→ Prices high enough to generate revenue
low enough to attract customers

Conclusions

- Bilevel model: rich framework for pricing in network-based industries.
- Models: theoretically and computationally challenging.
- Need to exploit problem's inner structure.
- Analysis of basic model: relevant and useful for attacking real applications (http://www.expretio.com/).
- Integration of real-life features (congestion, market segmentation, dynamics, randomness...).
- Investigate variants of product pricing.