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The International Spring School on Integrated Operational Problems: What a PhD student can learn

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Outline

- What is the International Spring School on Integrated Operational Problems – ISSIOP?
- About Troyes in France
- Research and lectures at the ISSIOP
- My schedule at the ISSIOP
- Personal experience and acknowledgements

What is the ISSIOP?

It is the fourth edition of the GdR RO Young Researchers School, organized in collaboration with 4 working groups (GT2L, GT Bermuda, GT Meta, GT OSI)

In 2018 the school takes an international dimension: all the courses are made by scientists from several countries (Spain, Belgium, France).

What is the ISSIOP?

GdR RO
CNRS – GdR 3002

CHAIRE CONNECTED INNOVATION

utt
UNIVERSITÉ DE TECHNOLOGIE TROYES
Institut Charles Delaunay

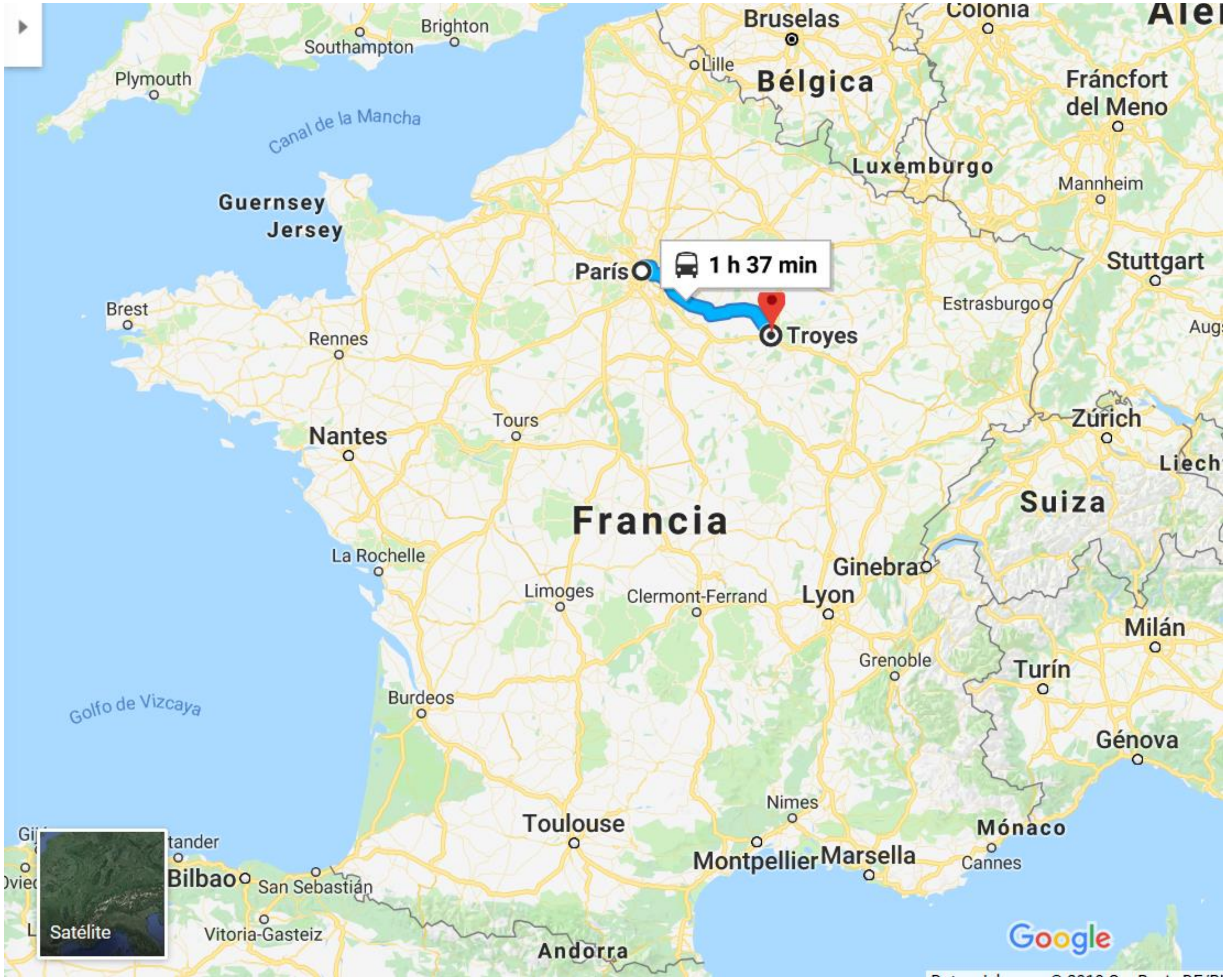
EWG EU/ME METAHEURISTICS

SEIO Sociedad de Estadística e Investigación Operativa

ROADEF

opta lp
l'efficience au coeur de votre métier

About Troyes in France



About Troyes in France

About Troyes in France

utt
université de technologie
Troyes

Research and lectures at ISSIOP

Ch. Prins
UTT

J. Billaut
Université F. Rabelais
(Tours)

A. Corberán
Universidad de Valencia

D. Feillet
E. Mines Saint-Etienne

Marc Sevaux
Université de Bretagne-Sud

Kenneth Sörensen
Univ. Antwerpen

Research and lectures at ISSIOP

1. Split algorithms - Ch. Prins
2. Column generation – D. Feillet
3. Integrated scheduling and routing – J. Billaut
4. Introduction to web services – M. Sevaux
5. Optimization of Smart grids – E.G. Talbi
6. Internet of things - L. Merghem-Boulahia
7. The trustfull promises of block chain – Ph. Entzman
8. Constraint programming – E. Hebrard
9. Linear programming for routing - A. Corberán
10. Last advances in metaheuristics – K. Sörensen

My schedule at ISSIOP

Lectures

Split algorithms

Column generation

Integrated scheduling and routing

Constraint programming

Linear programming for routing

Last advances in metaheuristics

Projects

Column generation

Integrated scheduling and routing

Column generation lecture

Vehicle Routing Problem with Time Windows (VRPTW)

Column generation algorithm

Implementation remarks

Image taken from: http://fc.isima.fr/~lacomme/Spring_School/conf/slides/

Column generation lecture

$$
\begin{aligned}
\text{minimize} \sum_{1\le u\le U}\ \sum_{(v_i,v_j)\in A} c_{ij}x_{ij}^u
\end{aligned}
$$

subject to

$$
\begin{aligned}
\sum_{1\le u\le U}\ \sum_{\{v_j\in V|(v_i,v_j)\in A\}} x_{ij}^u &\ge 1 && (v_i \in V\setminus\{v_0\}),\\
\sum_{\{v_j\in V|(v_i,v_j)\in A\}} x_{ij}^u - \sum_{\{v_j\in V|(v_j,v_i)\in A\}} x_{ji}^u &= 0 && (v_i\in V, 1\le u\le U),\\
\sum_{\{v_i\in V|(v_0,v_i)\in A\}} x_{0i}^u &\le 1 && (1\le u\le U),\\
\sum_{(v_i,v_j)\in A} d_i x_{ij}^u &\le Q && (1\le u\le U),\\
s_i^u + st_i + c_{ij} - s_j^u + Mx_{ij}^u &\le M && ((v_i,v_j)\in A, v_j\ne v_0, 1\le u\le U),\\
s_i^u + st_i + c_{i0} - b_0 + Mx_{i0}^u &\le M && ((v_i,v_0)\in A, 1\le u\le U),\\
a_i \le s_i^u &\le b_i && (v_i\in V, 1\le u\le U),\\
x_{ij}^u &\in \{0,1\} && ((v_i,v_j)\in A, 1\le u\le U),
\end{aligned}
$$

$$
\text{minimize} \sum_{r_k\in\Omega} c_k\theta_k
$$

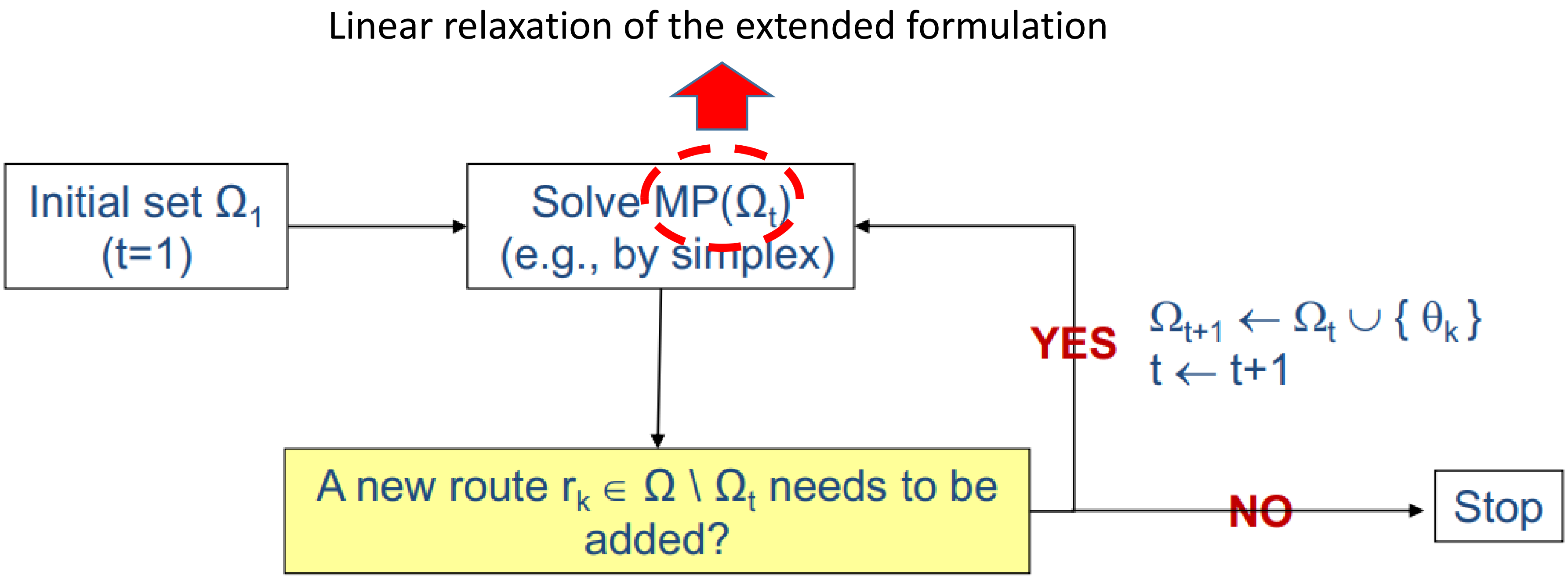
subject to

$$
\begin{aligned}
\sum_{r_k\in\Omega} a_{ik}\theta_k &\ge 1 && (v_i\in V\setminus\{v_0\}),\\
\sum_{r_k\in\Omega} \theta_k &\le U,\\
\theta_k &\in \mathbb{N} && (r_k\in\Omega).
\end{aligned}
$$

The set of all feasible routes

Image taken from: http://fc.isima.fr/~lacomme/Spring_School/conf/slides/

Column generation lecture



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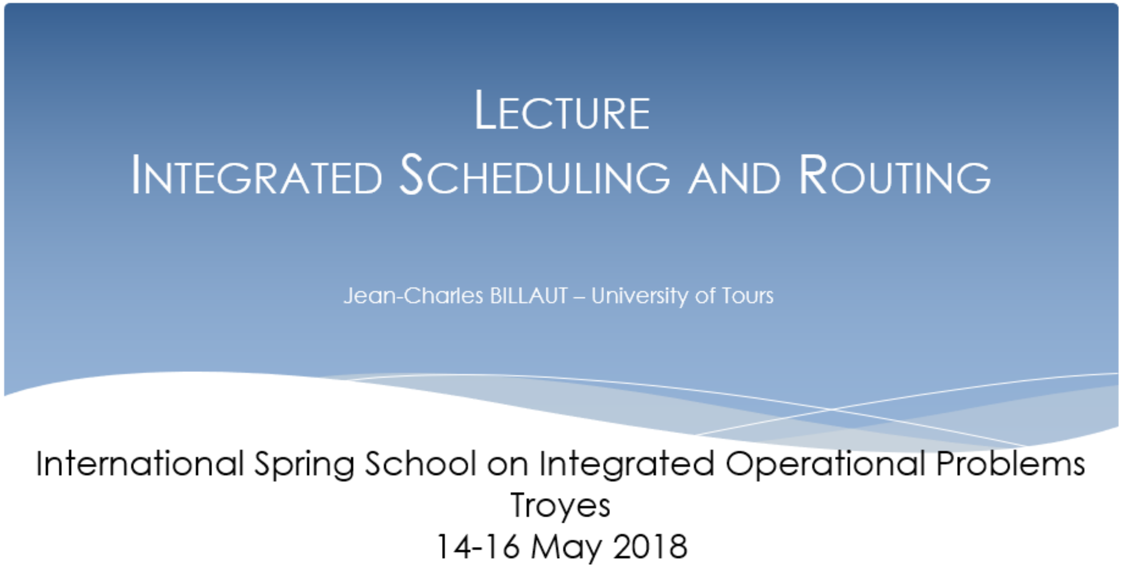
Integrated scheduling and routing lecture

Basics on scheduling and routing

Integrated problem

GLPK (for a MILP implementation)

Python (for a metaheuristic implementation)



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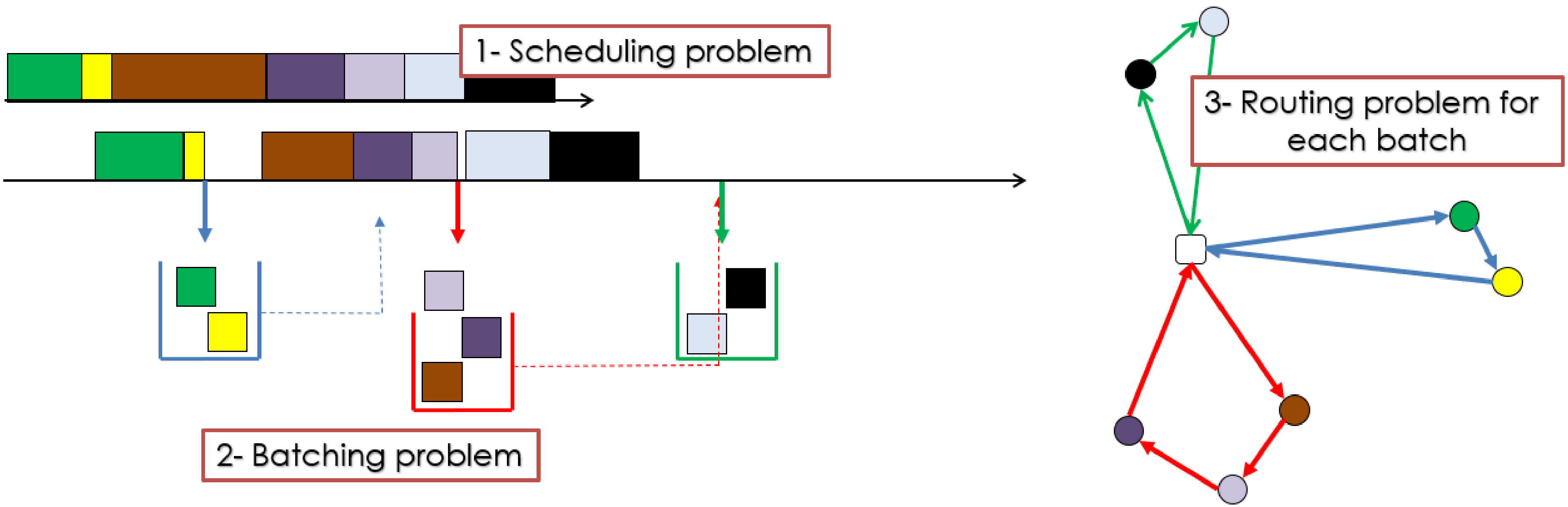
Integrated scheduling and routing lecture



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Integrated scheduling and routing lecture

```
#====================================================
# scheduling
#====================================================

s.t. contr_Ck_1 {i in 0..m-1, j1 in 0..n-1, j2 in 0..n-1:j1!=j2}:
# if j1 precedes j2
C[i,j2] >= C[i,j1] + p[i,j2] - BigM*(1-y[j1,j2]);

s.t. contr_Ck_2 {j1 in 0..n-1, j2 in 0..n-1:j1!=j2}:
# j1 before j2 or j2 before j1
y[j1,j2]+y[j2,j1]=1;

s.t. contr_Ck_2b {i in 1..m-1, j in 0..n-1}:
# "routing" constraint
C[i,j] >= C[i-1,j] + p[i,j];

s.t. contr_Ck_2a {j in 0..n-1}:
# first job
C[0,j] >= p[0,j];

s.t. def_TjM {j in 0..n-1}:
# tardiness expression
Tj[j] >= C[m-1,j] - d[j];

end;
```

MILP implementation for the scheduling part using GLKP

```
# Data
#==============
param n;
param m;
param p {i in 0..m-1, j in 0..n-1};
param d {j in 0..n-1};
param BigM:=sum{i in 0..m-1, j in 0..n-1} p[i,j];

# Variables
#==============
var y {j1 in 0..n-1, j2 in 0..n-1}, binary; #= 1 if j1 < j2
var C {i in 0..m-1, j in 0..n-1}, >= 0; # completion time of job j
var Tj {j in 0..n-1}, >= 0; # tardiness of job j

minimize Obj: sum{j in 0..n-1} Tj[j];
```

Integrated scheduling and routing lecture

```
def InsertTabu(voisinage,indi,indj):
    ElemTabu=[voisinage,indi,indj]
    if len(TabuList) == TabuSize:
        del(TabuList[0])
    TabuList.append(ElemTabu)

def NotTabu(voisinage,indi,indj):
    ElemTabu=[voisinage,indi,indj]
    notTabu = True
    if(ElemTabu in TabuList):
        notTabu = False
    return(notTabu)
```

```
# ====================================================
# Parameters
# ====================================================

nbjobs=len(pp)
INFINI = 999999999
TabuList=[]
TabuSize = 7
TIME_LIMIT = nbjobs * m / 4
DELTA = nbjobs/2 # is used to limit the swaps
FLAG_SWAP_BOTH = 1
FLAG_SWAP_SEQ = 1
FLAG_SWAP_BATCH = 1
FLAG_2OPT = 0
```

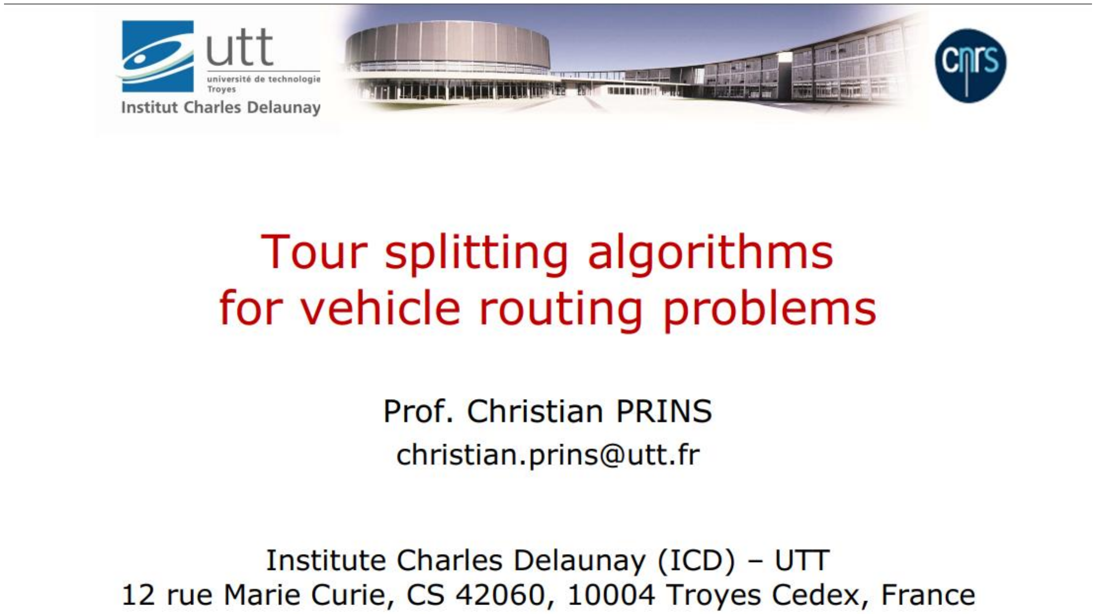
```
# ====================================================
# Neighborhood
# ====================================================

def swap_both(i,j,sol):
    # the sequence sol is modified by a swap both in the sequence and in the batches
    #=================================================================
    #print('before swap_seq:',i,j,sol)
    job_i = sol[0][i]
    job_1 = [job_i]
    job_j = sol[0][j]
    job_2 = [job_j]
    sol[0]=sol[0][0:i]+job_2+sol[0][i+1:j]+job_1+sol[0][j+1:nbjobs]
    u=0
```

Split algorithms lecture

Route-first cluster-second methods

Basic splitting procedure

Applications to heuristics and metaheuristics.



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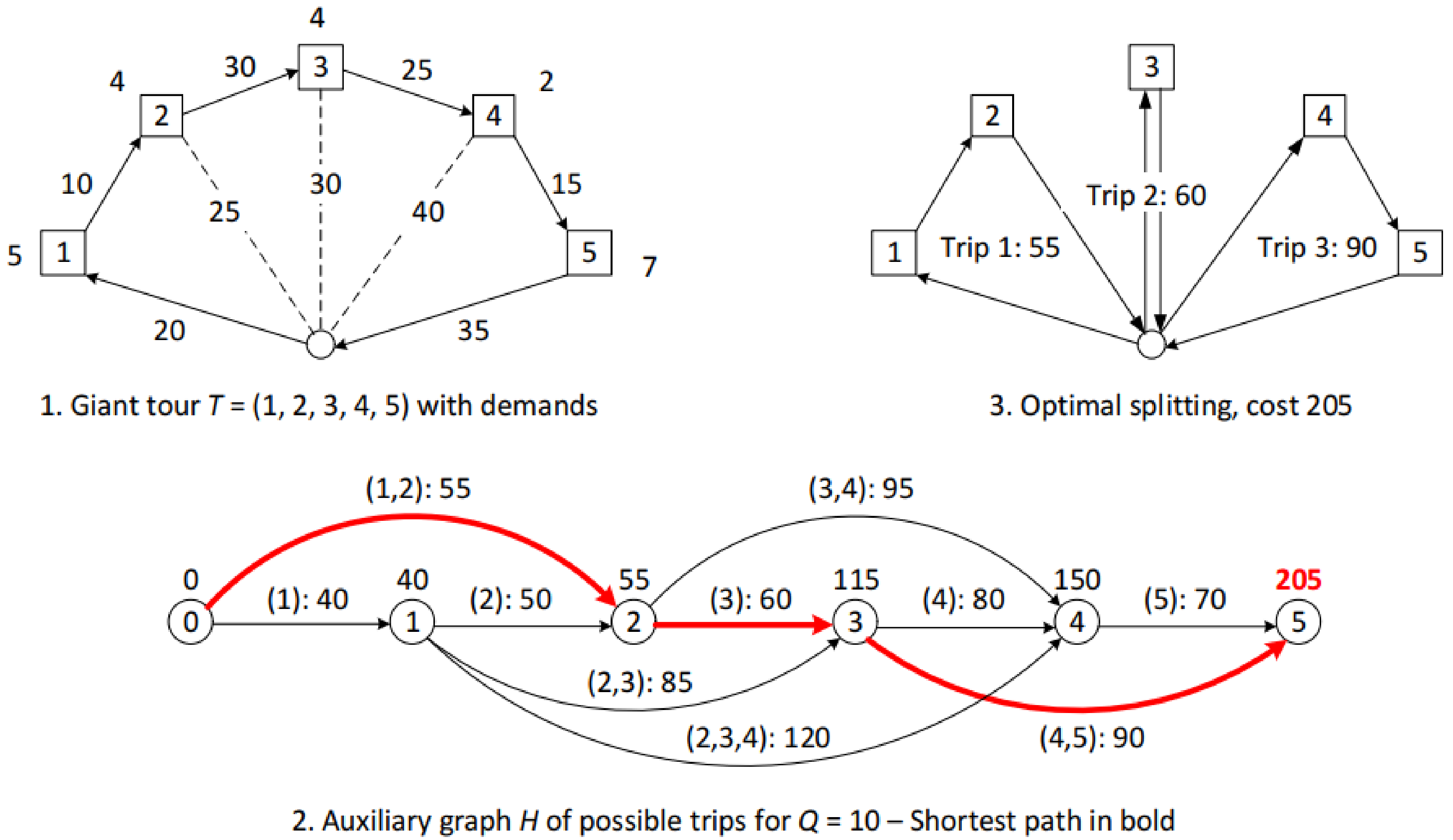
Split algorithms lecture



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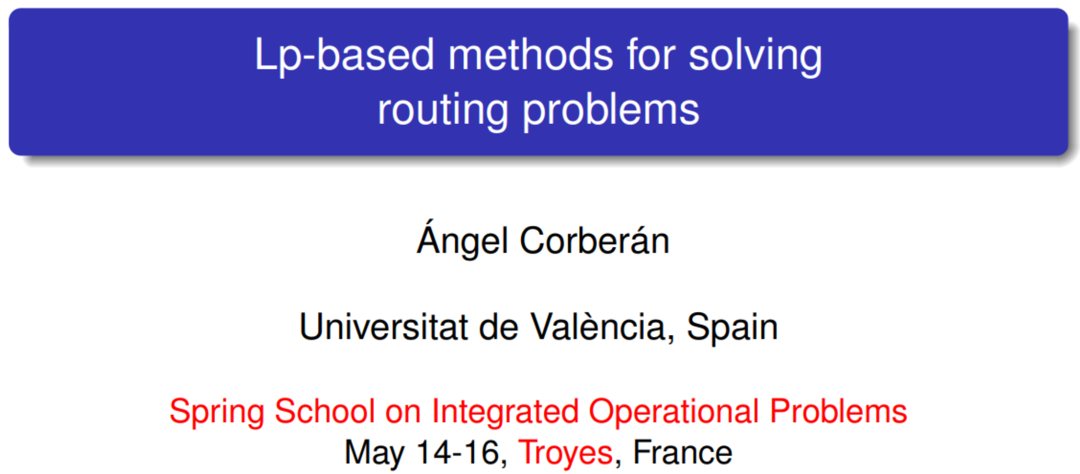
Lp-based methods for routing problems lecture

Polyhedral combinatorics applied to:

- TSP
- OARP
- Close –enough ARP



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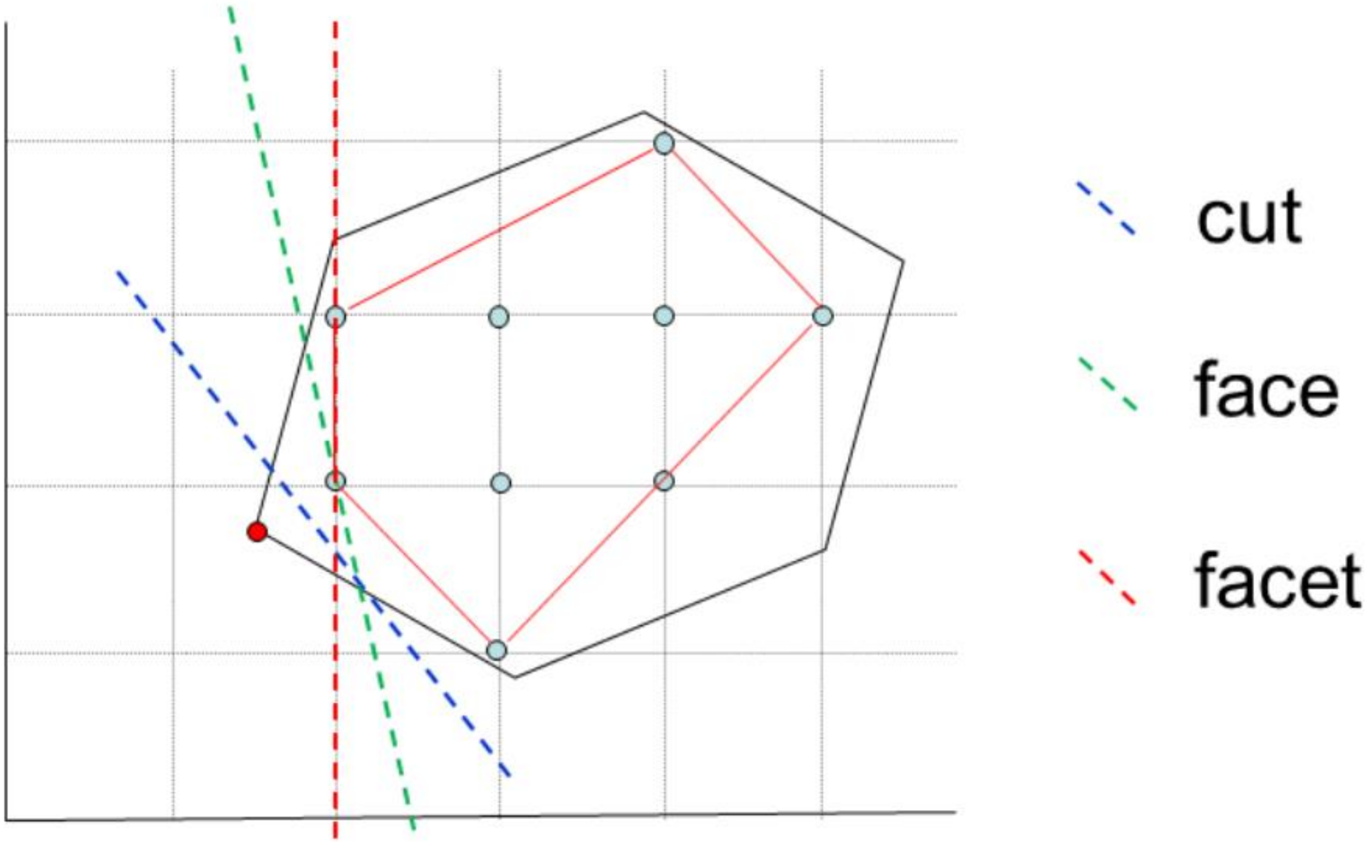
Lp-based methods for routing problems lecture



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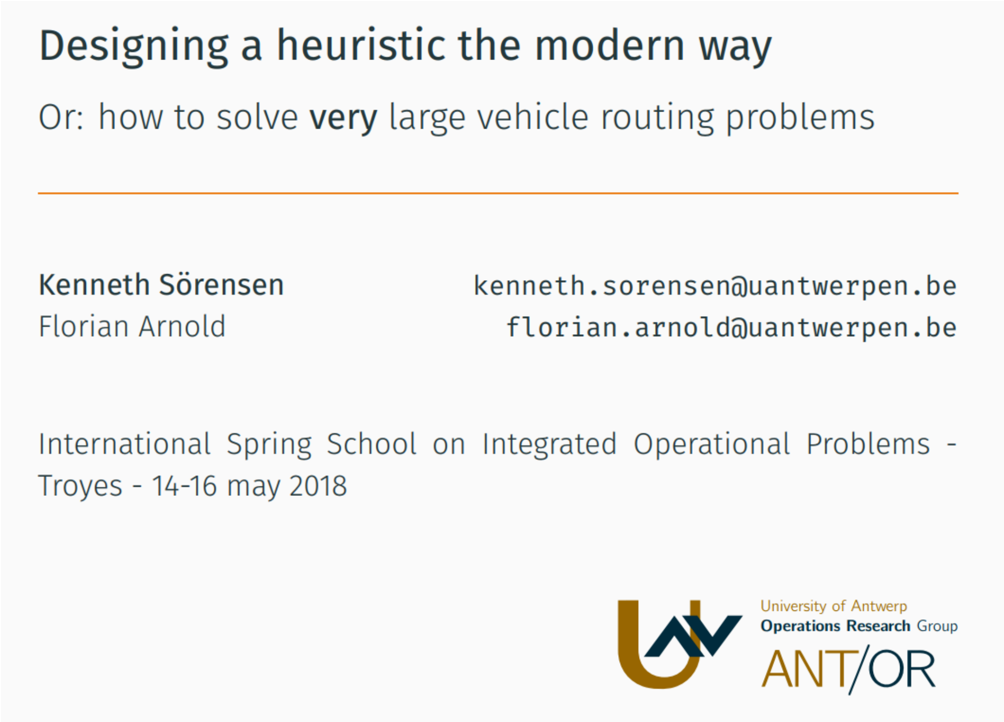
Last advances in metaheuristics lecture

Complementary local search operators

Properties of good solutions

Solution metrics



Designing a heuristic the modern way

Or: how to solve **very** large vehicle routing problems

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International Spring School on Integrated Operational Problems - Troyes - 14-16 may 2018

University of Antwerp Operations Research Group ANT/OR

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Last advances in metaheuristics lecture

State of the art

- Use as many local search (constructive) operators as possible
- Either VNS or LNS
- Fit in a metaheuristic framework
  - This is your Unique Selling Point
  - But it really does not matter all that much
- Beware of “Frankenstein” algorithms

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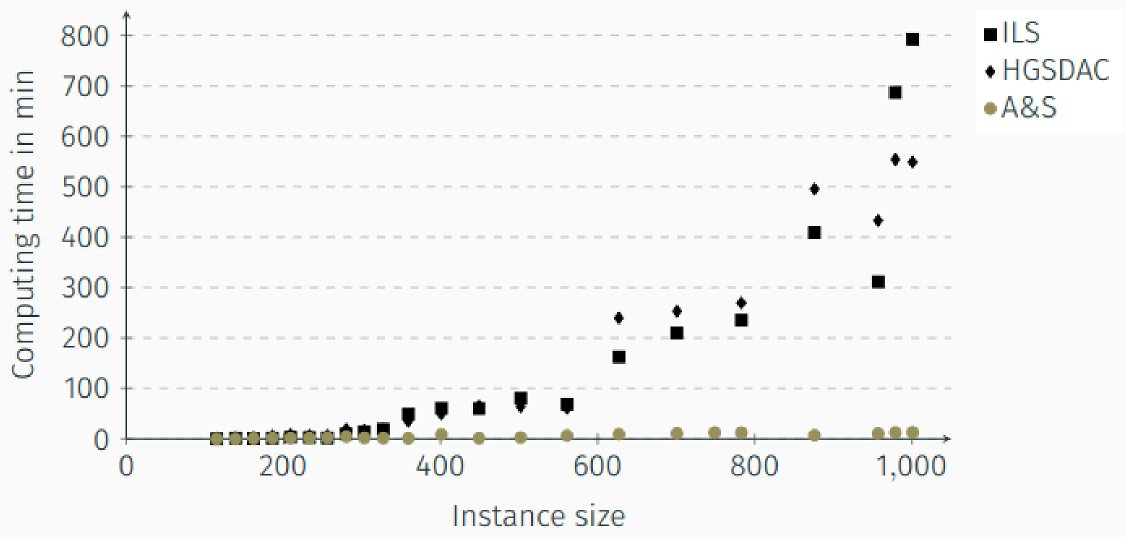
Last advances in metaheuristics lecture

Comparison to other algorithms



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Personal experience and acknowledgements

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