Constraint Programming 433-637

Peter J. Stuckey

Overview

- Introduction to 433-637
- Motivation for constraint programming
  - Combinatorial optimization problem in the real world
- Capturing the problem

Introduction to 433-637

- Course Website
- Introducing the academic staff
- Unit objectives
- Semester structure
- Text book and workload
- Assessment

Course Website

- LMS
  - http://app.lms.unimelb.edu.au/
  - Login
  - 433637_2010_2
  - COMP90046_2010_SM2

Academic staff

- Peter Stuckey
  - Room: 5.27 ICT building
  - Phone: x41341
  - Email: pjs+637@csse.unimelb.edu.au
    - WARNING whitelist means mail to pjs@csse.unimelb.edu.au may not go through (from unimelb account it will!)
  - Contact Hours: Thursday 12:00-13:15, but best to email me to make an appointment

Lecture and workshop

- Two 1-hour lecture per week
  - Monday 13:15-14:15   ICT Theatre 3
  - Thursday 13:15-14:15 ICT Theatre 3
- One 1-hour workshop per week
  - Wednesday 12:00-13:00 ICT-137 (ELS)
  - We may not always use this slot
- Eight hours per week preparation and project work

Lecture schedule

1. Motivation for constraint programming
2. Modelling using MiniZinc
3. Finite Domain Propagation
4. Linear Programming
5. Network Flow
6. Mixed Integer Programming
7. Boolean Satisfiability
9. Lazy Clause Generation
10. Constraint Logic Programming
11. Local Search
12. Revision

Invited Lecture – CTI

Optimization in Industry

Constraint programming

Finding the “best” solution from a HUGE set of alternatives

Examples

- solving Sudoku problems
- planning a mining operation
- designing an airplane

Sudoku

- How many ways can you fill a Sudoku board with numbers 1-9?

- How many Sudoku puzzles are there?

5	9	3	7	6	2	8	1	4
2	6	8	4	3	1	5	7	9
7	1	4	9	8	5	2	3	6
3	2	6	8	5	9	1	4	7
1	8	7	3	2	4	9	6	5
4	5	9	1	7	6	3	2	8
9	4	2	6	1	8	7	5	3
8	3	5	2	4	7	6	9	1
6	7	1	5	9	3	4	8	2

6,670,903,752,021,072,936,960

Learning Objectives

- Understand
  - what “combinatorial” problems are
  - the main technologies used for solving them
- Learn
  - the distinction between modelling and solving a problem
  - strengths and weaknesses of the solving technologies
  - different ways of achieving scalability in a solution
  - which problems should use which solving technologies

Textbooks

- Prescribed texts:
  - None
- Recommended texts:
  - MiniZinc (modelling language) tutorial and documentation
    - An informal guide free and accessible from LMS
  - Programming with Constraints: an Introduction. Kim Marriott and Peter J. Stuckey, MIT Press. 1998.
  - Operations Research: Applications and Algorithms. Wayne L. Winston, Brooks Cole, 1998.
  - Principles of Constraint Programming. Krzysztof Apt. Cambridge. 2003.

Assessment

- 30% - Assignments
  - 15/30 to pass the course
- 70% - Examination
  - 35/70 to pass the course
  - Three hour closed book exam scheduled during the normal exam period.

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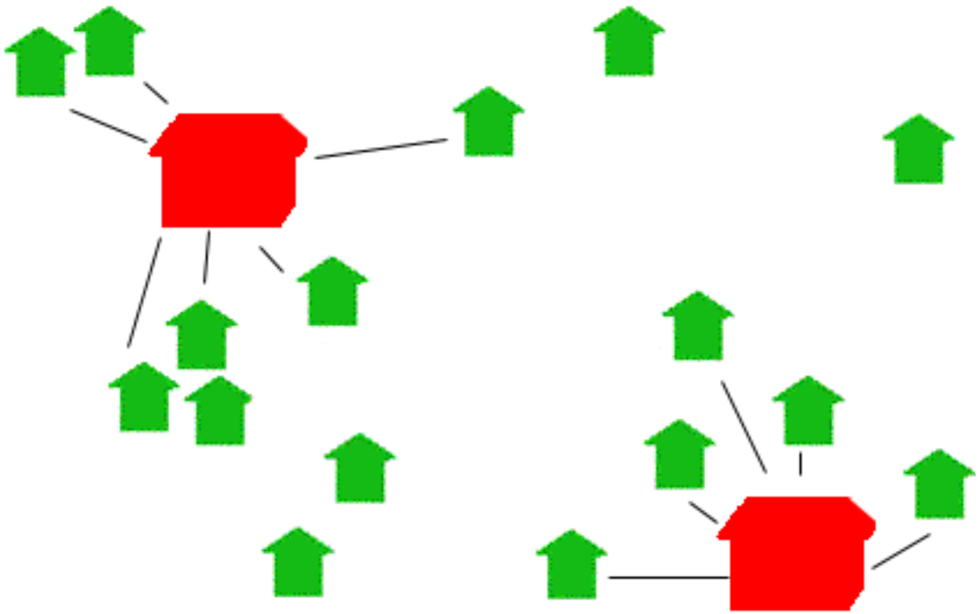
Combinatorial Problems in the Real World

- Combinatorial Problems
  - Where we have to choose amongst a set of decisions
  - Are ubiquitous
  - Good answers can save a great deal of money, pollution, carbon, etc
- They appear at all levels of an organization
  - Strategic (Typically years)
    - Where to build factories/distribution centres
    - How many aircraft to order
  - Tactical (Typically weeks or months)
    - What price to set
    - How many trips per day to schedule
  - Operational (Typically today or tomorrow)
    - How to handle priority jobs
    - How to recover when a pilot/doctor is absent

Strategic Planning: new distribution centres to serve outlets

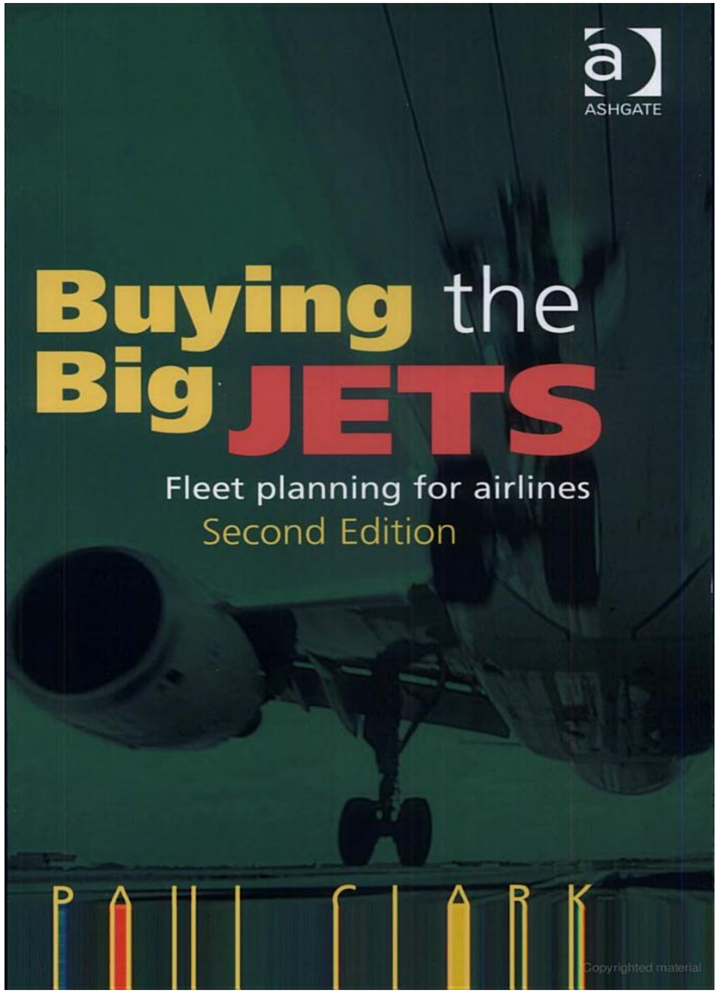


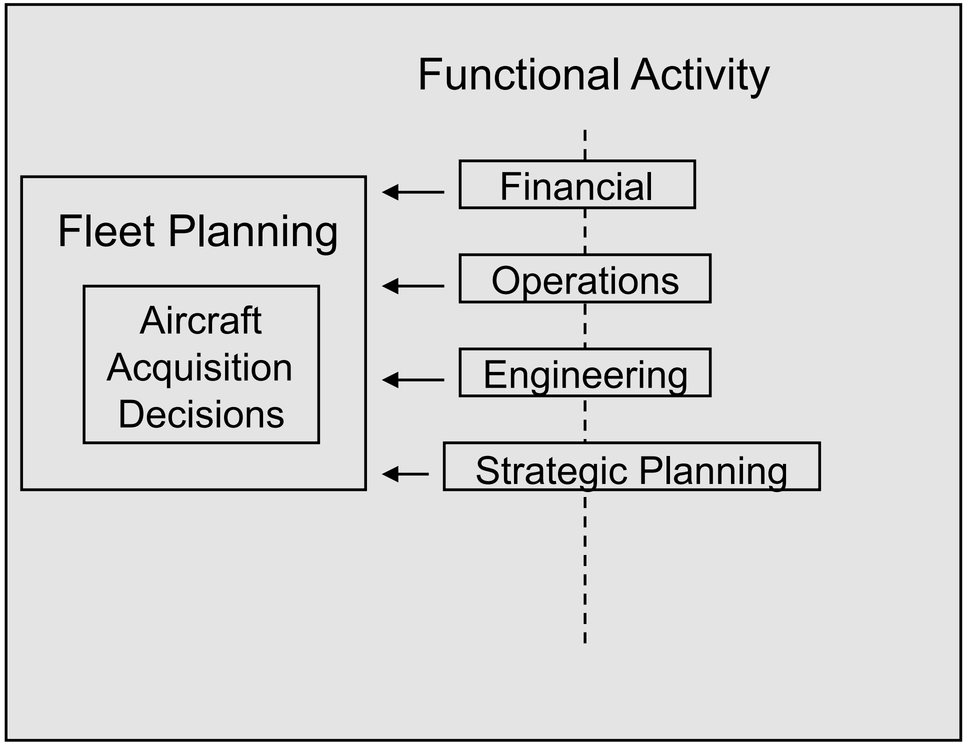
Which outlets will there be
in a years time?

What land will be available
with what building permissions?

How long will they take to
construct and how is this
impacted by the DC capacity?

Strategic Planning: buying new aircraft to meet demand





Strategic planning: road planning and design

Main road planning goals

- Safer communities
- Industry competitiveness
- Liveable communities
- Environmental conservation

Strategic Planning - characteristics

- Decisions - involve major commitments
  - Money
  - Time
  - Manpower and Resources
- Timescales - long
  - Years rather than weeks
- Outcomes - fundamental to the future of the organisation
  - The right decision will make a LOT of money
  - The right decision will delight the customers
  - The right decision will create further growth opportunities
- Choices - broad and loose
  - The number and nature of the options may be unclear
  - The required commitments may be imprecise
  - The payoffs may be a little vague

Tactical planning – flight leg pricing

- The airline industry is probably the industry that for which many of the revenue management concepts have been introduced.

- Each flight (leg) has 26 ticket classes

- Tickets for a single class may be sold at different prices

- Revenue management systems include a forecaster (estimating the future potential sales of tickets from now till the day of departure) and an optimizer (defining the appropriate inventory controls from the forecasted demand).

Tactical planning: lecture theatres and times

Allocate+

Subject	Description	Faculty	Group	#Activities	Places	Enrolments
FIT3015_CA_S1_DAY	IE PROJECT	50000566	Lecture	1	10	27
FIT3036_CL_S2_DAY	COMP SCI PROJECT	50000566	Support-Class	1	18	
FIT3047_SA_S1_DAY	IE PROJECT	50000566	Comp-Lab	1	24	37
FIT3066_CA_S1_DAY	IT STRATEGY & MGT	50000566	Tutorial	2	41	60
FIT3031_CA_S1_DAY	INFO & NETWORK SEC	50000566	Laboratory	4	69	100
FIT2034_CA_S1_DAY	PROGRAMMING 2	50000566	Lecture	1	60	85
FIT2048_CA_S1_DAY	GAME TECH	50000566	Laboratory	3	48	67
FIT3008_BE_S1_DAY	DIG VIDEO POST PROD	50000566	Lecture	1	20	27

- Allocate a lecture theatre of the right size to each lecture
- Don't put two lectures in the same theatre at the same time
- Timetable two lectures in the same unit to follow each other if required
- Ensure theatres have the facilities required for each unit allocated

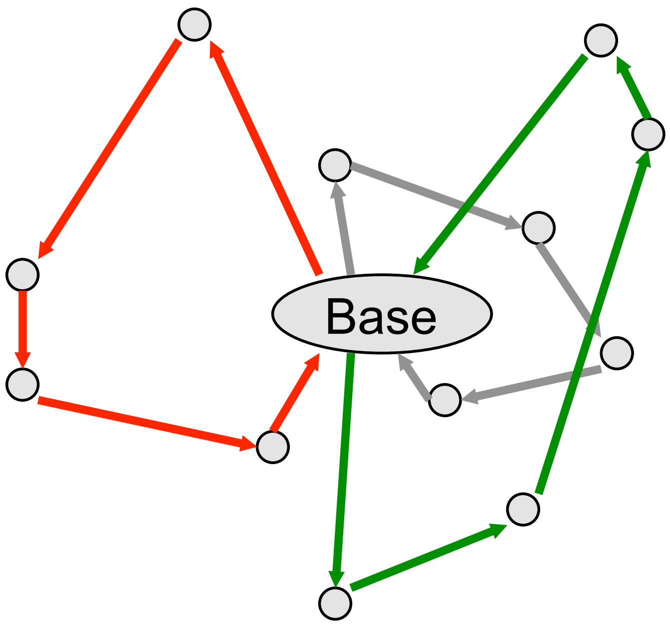
Tactical planning - characteristics

- Decisions - involve known resources
  - aircraft
  - lecture theatres
- Timescales - medium
  - Months or weeks
- Outcomes - significant
  - The right schedule is economical
  - The right schedule won't disappoint the customers
- Choices - optimise chosen goals under clear constraints
  - Revenue
  - Cost
  - Resource usage

Operational Planning - onsite engineers

Allocating sites to engineers (cont.)

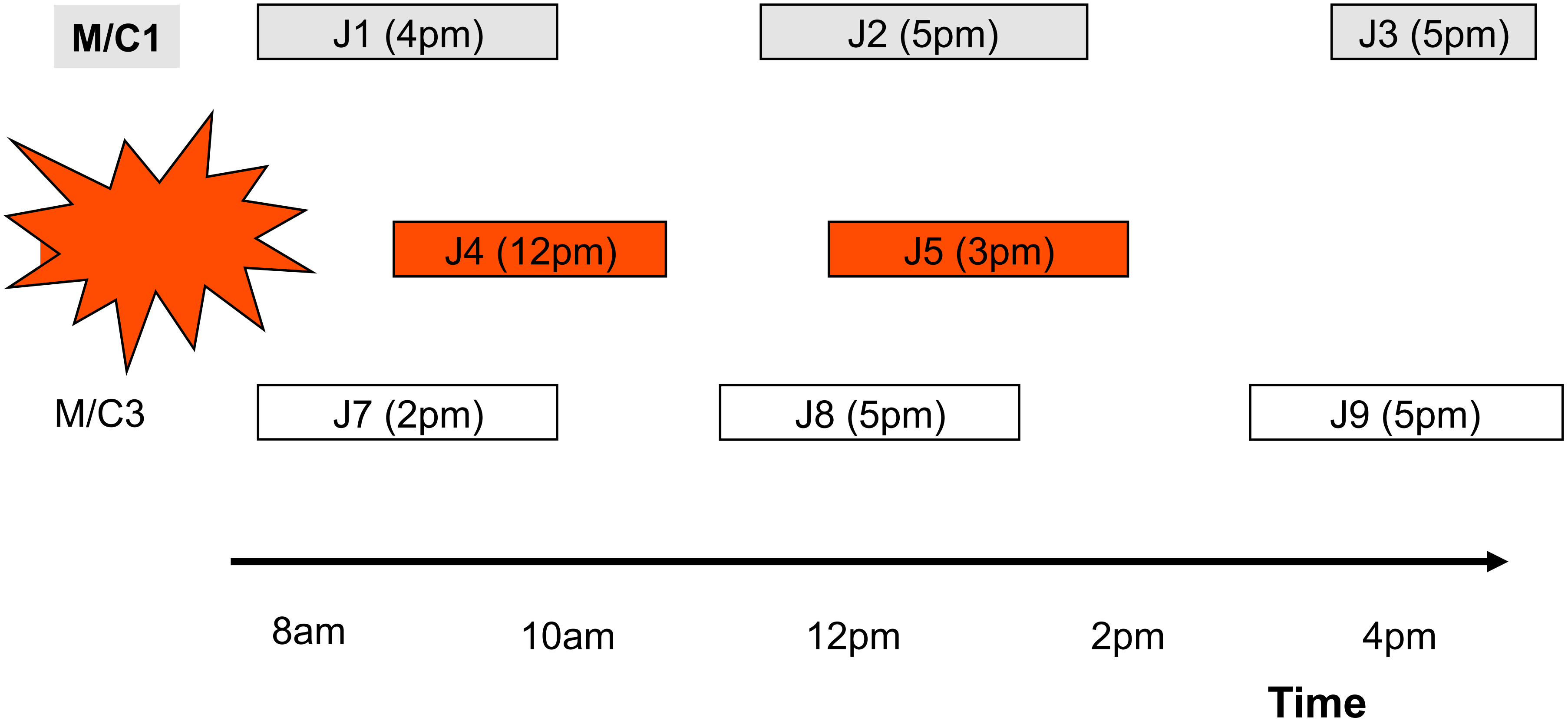
Clients:



Operational planning: machine rescheduling after disruption

The disruption was acute on Friday afternoon when vehicles belonging to construction contractors were abandoned for up to an hour and a half straddling a public road.

disruption handling (cont.)



Operational planning - characteristics

- Decisions - involve a current set of tasks and known resources
  - allocate tasks to resources
  - re-allocate and re-schedule after events
- Timescales - short
  - Today or tomorrow (or instantaneously!)
- Outcomes – short-term
  - impact on today's customers
- Choices - minimise disruption
  - Try to complete tasks
  - Minimise delay overtime or other extra costs
  - Get back on schedule (for tomorrow…)

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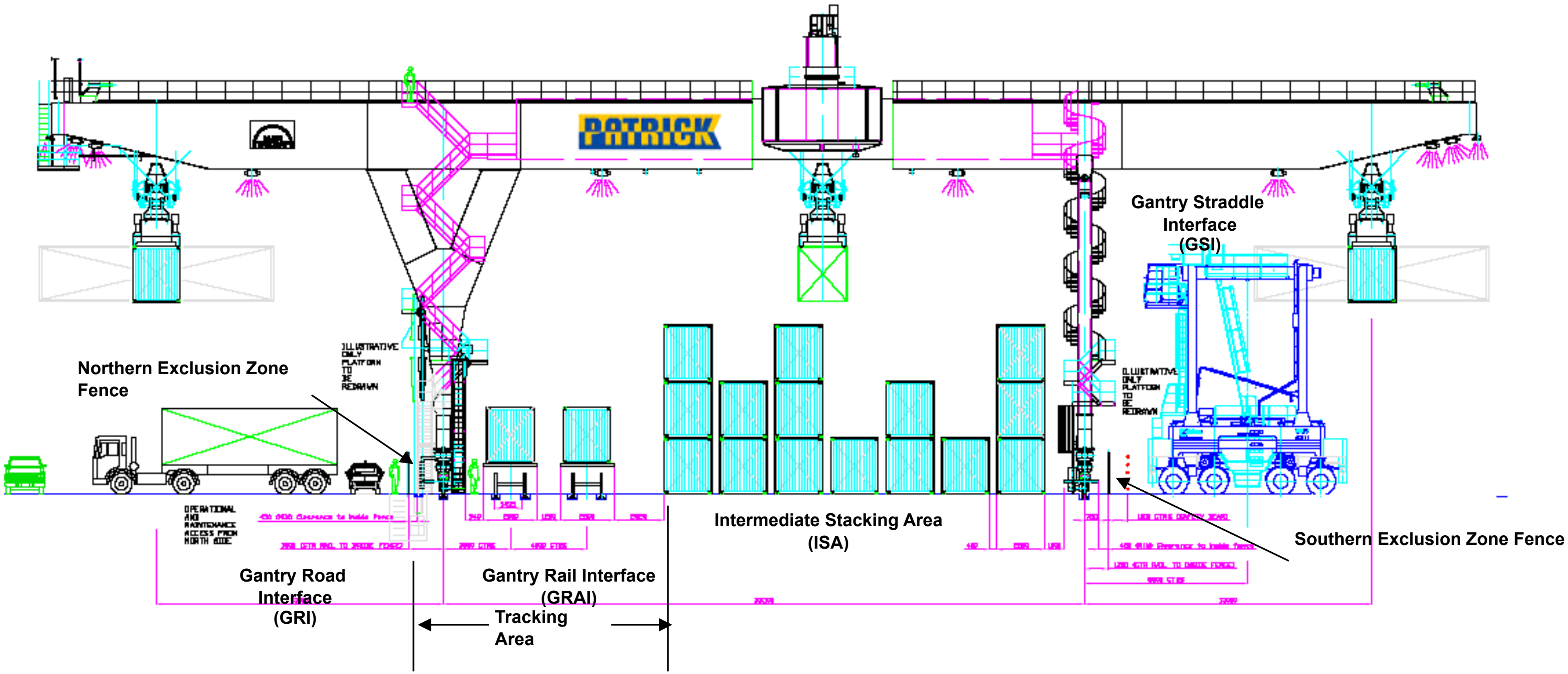
Capturing the problem

- Understanding what the real problem is that has to be solved can be
  - Challenging
  - Require “deep communication” with the people who solve it now
  - Wont be right the first time

Gantry Crane Planning Example



System Specification: gantry crane planning example

- Where should containers be placed ready for loading/straddling?
- In what order should the gantries pick up the containers?
- What planning should be done for trains/trucks which haven't arrived yet?
- How can we enable the gantries to unload all the trains and all the trucks?

Validation and User Confidence: gantry crane planning example

- Should you compel your straddle drivers to enter an area where an automated gantry crane was operating?

The Holy Grail for Constraint Programming

- Model Problems Naturally
  - constraints
  - solution properties
- Solve them efficiently
  - overcome combinatorial explosion
- Compile
  - Natural models to efficient solutions

Summary

- Combinatorial optimizations problems
  - Are everywhere
  - Are important
  - And are difficult to solve
- Capturing a real world problem
  - Is difficult
  - Filled with lots of choices
  - In reality needs a feedback loop with the end user

Homework

- For the first workshop we will tackle some smallish combinatorial optimization problems by hand
  - Assignment problems
  - Knapsack problems
  - Sudoku
  - Travelling salesman
- Attempt them all before the workshop