NICTA Victoria Laboratories
Department of Computer Science and Software Engineering
The University of Melbourne
433-637 Constraint Programming
Second Semester, 2010

Course Summary

Introduction

Welcome to 433-637 Constraint Programming (COMP90046 2010 SM2).

Constraint programming is a new high-level language paradigm expressly developed for solving complex combinatorial satisfaction and optimization problems. Solving such problems requires searching through a very large space of possible solutions to find a solution or an optimal solution. In the constraint programming paradigm, constraints are used to limit the search as much as possible. Hence, the two main components in a constraint programming system are the constraint solver and the search engine which implements some strategy, such as backtracking, for exploring the search space.

In this course we will investigate methods to solve combinatorial problems. We will begin by learning how to model the problems in a high level manner. We will then learn how the underlying solving technologies solve these problems, which will allow us to write better models that take into account the strengths and weaknesses of the solving technology we use.

Objectives

When you complete the subject you should be able to:

- model constraint satisfaction and optimization problems of reasonable complexity using a modelling language;
- explain (to a senior computer science student) how some constraint solvers work (e.g. linear programming, finite domain propagation, Boolean satisfaction);
- use the MiniZinc modelling language to model integer constraint problems;
- evaluate the suitability of a particular constraint model for solving a problem;
- program different effective search strategies for combinatorial problems;
- improve the execution of a constraint program by reasoning about its search behaviour.

When you complete the subject you should have some appreciation of the uses of constraint programming and the wealth of combinatorial problems. You should also have improved analytical, problem-solving, programming, and team-working skills.

Lectures

Lectures will be held on Mondays and Thursdays 13:15–14:15 in Theatre 3 of the ICT Building (111 Barry St). There is also a workshop Wednesdays 12:00–13:00 in room ICT-137 which we shall not always use. There will be 24 hours of lectures. The lecturer is

- Peter Stuckey (phone: 8344-1341, e-mail: pjs+637@cs.mu.oz.au, office 5.27).

Syllabus

Modelling: simple modelling, modelling with data structures, predicates, global constraints, effective modelling

Constraint solving methods: Finite domain propagation, linear programming, mixed integer programming, Boolean satisfiability lazy clause generation, local search

Programming search and optimization.

Constraint logic programming

Recommended Texts

- (Recommended) Programming with Constraints: an Introduction. Kim Marriott and Peter J. Stuckey, MIT Press. 1998. *The basis of half the course.*
- (Recommended) Operations Research: Applications and Algorithms. Wayne L. Winston, Brooks Cole, 1998. *The basis of the other half*
- (Recommended) Principles of Constraint Programming. Krzysztof Apt. Cambridge. 2003. *A highly theoretical book, interesting and well written.*
- (Of interest) Essentials of Constraint Programming. Thom Frühwirth and Slim Abdennadher Springer Verlag. 2003. *A view of constraint programming using constraint handling rules.*

MiniZinc

MiniZinc is available for download from

`http://www.g12.csse.unimelb.edu.au/minizinc/`

Assessment

There will be three assignments/projects. An exam will be held at the end of the term. The exam will count for 70% of your final grade. The remaining 30% will come from the project, with the marks split between assignments/projects. The usual rules for passing apply, but in addition, at least 15/30 must be scored for the projects and at least 35/70 must be scored for the exam.

Challenge Problems

There will be challenge problems that you can submit solutions to in order to gain bonus marks. The best solution (optimal value) that is submitted for each problem gains 1 or 2 bonus marks depending on how good it is. Bonus marks for other solutions may also be obtained.

Solutions must be submitted with a clear definition of the variables of the model, the values they take in the solution, and arguments for how each possible constraint is satisfied. You must also explain how you discovered the solution. If there is considerable interest I will devise a mechanical form of submission (MiniZinc file) which will be checked automatically. Note you can solve the challenge problems with whatever technology you like.

The first challenge problem is defined below, others will be made available throughout the course.

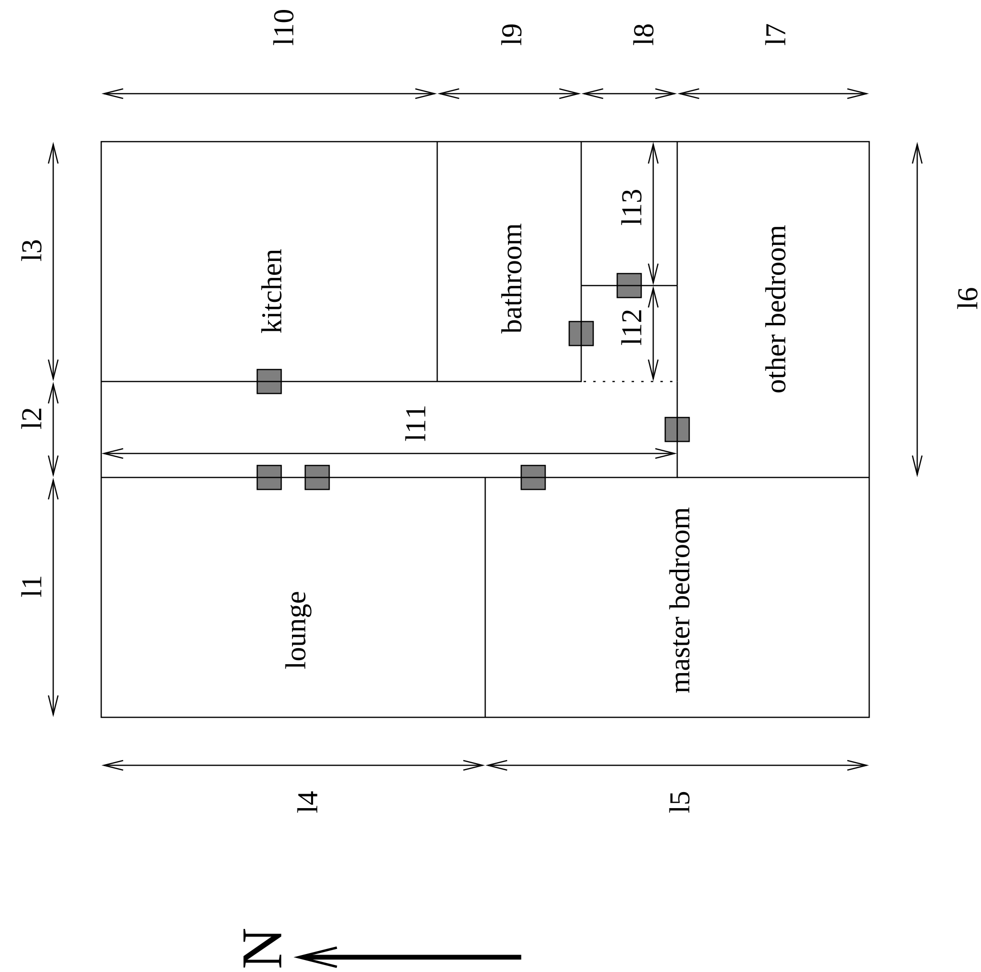

Figure 1: A possible flat design

Designing an apartment

This problem is to design an apartment, satisfying certain constraints to maximise profit to the builder.

The apartment is constrained to fit in a 8 $m \times 10$ m area. It must have the form of a single hallway with each room coming off the hallway, and possibly a single bend in the hallway. An example design is shown in Figure 1

The constraints on the flat are as follows.

- There are $k + 4$ rooms made up of: kitchen, bathroom, toilet, lounge, and k bedrooms.
- There is a corridor that meets the north wall. It can have a single bend.
- Each room must connect to the corridor via a door. The lounge must connect via a double door
- Each room has a rectangular shape, and the entire area is filled by rooms.
- Each room dimension is at least 1 m.
- Each door requires 1 m of wall space. A double door requires 2 m of wall space.

- Each room except the bath room and toilet needs to have windows, which are only possible on the east or west sides of the area. The minimum window size is $0.5m$.
- The minimum area of the lounge is 15 m^2
- One bedroom must be at least area 12 m^2. This bedroom must have at least $4m$ of internal wall space, not taken by the door. This does not need to be on one wall.
- Each bedroom must be at least 8 m^2
- The bathroom must be at least 6 m^2
- The kitchen must be at least 10 m^2
- The toilet needs a dimension of at least 1 m and the other dimension at least 1.5 m.

The aim is to maximize the profit on the flat which is given as estimated selling price - estimated building price.

The estimated selling price is given by the following:

- 200,000 base price
- 20,000 per bedroom
- 5,000 per m^2 of lounge rooom
- 4,000 per m^2 of the largest bedroom
- 3,000 per m^2 of the other bedrooms
- 3,500 per m^2 of kitchen
- 2,500 per m^2 of bathroom
- 5,000 if the bathroom fits a bath, that is has dimensions greater than $2.5m$ on each side
- 5,000 if the lounge room doors are no further than 3 m from the kitchen door.
- 1,000 per m of window in the lounge or bedrooms
- 10,000 if the central corridor is at least 2 m wide.
- 5,000 if the bathroom door is no more than 2 m from the largest bedroom door.

The building price is given by the following:

- 100,000 base price
- 4,000 per m of internal wall
- 500 per m of window
- 1,000 per door (double doors are 2,000)
- -5,000 if the bathroom is next to the toilet, (that is the share an internal wall)
- -5,000 if the kitchen is next to the bathroom.
- -3,000 if the kitchen is next to the toilet.

Give a design with the best profit you can find.