Overall Assessment

Statistics for each component (labs, assignment, exam)

<table>
<thead>
<tr>
<th></th>
<th>Labs</th>
<th>Assignment</th>
<th>Exam</th>
<th>Overall</th>
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<tr>
<td>Min</td>
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<td>40</td>
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<tr>
<td>Average</td>
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<td>59</td>
<td>61</td>
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<tr>
<td>Max</td>
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Statistics for marks

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<tbody>
<tr>
<td>Mark range</td>
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<td>50-59</td>
<td>60-69</td>
<td>70-79</td>
<td>80-89</td>
<td>90-100</td>
</tr>
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Examination Feedback

Statistics for each question

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Overall</th>
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</thead>
<tbody>
<tr>
<td>No. of students</td>
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<td>8</td>
<td>12</td>
<td>11</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>6</td>
<td>7</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>Average</td>
<td>13</td>
<td>13</td>
<td>17</td>
<td>18</td>
<td>16</td>
<td>12</td>
<td>59</td>
</tr>
<tr>
<td>Max</td>
<td>25</td>
<td>23</td>
<td>25</td>
<td>24</td>
<td>21</td>
<td>15</td>
<td>90</td>
</tr>
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</table>

Feedback on each exam question

**Question 1: Compulsory question: Constrained Based Scheduling**
This problem instance is an extension of the example in lecture slides. Correct answers can be derived in the similar way as showed in the lectures. Half of the class obtained more than 50% of the marks.

**Question 2: Optional question: Consistency and Search**
(a) Mark allocation: (total mark for this question is 5 marks and marks are allocated as followed)
   Stating the correct difference between two techniques = 3 marks
   Providing one correct look back technique = 1 mark
   Explaining how it works = 1 mark
   Most students correctly answered how look back and look ahead techniques work, however, failed to state the **difference** between two techniques **during the search**. Only a few students provided the correct answer.
   Most students provided example of look back technique and explain how it works and obtained full marks for that part of question.

(b) Mark allocation:
   k-consistency guarantee a solution (yes or no) = 1 mark
   Explaining reason or giving an example = 2 marks
   Most students answered this question correctly.

(c )-(d) Most students answered this question correctly and obtained full marks.
Question 3: Optional question: Modelling
(a) Most students who attempted this question provided correct answers. Some students provide more than one model (for which the mark for correct answers is the same if at least one correct model is provided).
However, only a few students can provide all correct rules for symmetry breaking in the n-queen problem.

(b) Most students can provide correct answer. However, there are a few students who just stated it can be reused and without giving details of the transformation.

Question 4: Optional question: Ordering
This question is attempted by most students (i.e. 12 students), and overall, most students obtained good marks in this question.

Question 5: Optional question: Constraint Optimization
(a) Correctly defining the problem = 5 marks
Reduction = 2 marks
Most students can define the problem correctly. However some students only answered the problem reduction correctly.
(b) Correct definition of COP = 3 marks
Providing explanation of Optimal solution for COP = 2 marks
Some students defined the COP of SEND+MOST= MONEY instead of generally giving the definition of COP. Corresponding marks have been awarded for correct answers for question (a).
(c) Most students answered this question correctly and obtained full marks.
(d) Most students answered this question correctly.

Question 6: Optional question: Basics
(a) Most students answered this question correctly.
(b) Only a few students provided correct answers.
(c) Not many students obtained high mark in this question. Many students attempted to explain the differences between CSP and COP.
(d) Most students answered this question correctly and obtained full marks.
(e) Not many students obtained high mark in this question, most of which provided the steps to model the CSP instead.

2010/2011 Exam Paper

1. Compulsory question: Constrained Based Scheduling
a) In a class timetabling problem, seven one-hour classes need to be scheduled in one classroom. The following table provides the earliest starting and latest starting time of the classes. PRG should be scheduled as early as possible, and also be scheduled before PRG_Lab. MCS1 should be scheduled as early as possible, and be scheduled before MCS2.

<table>
<thead>
<tr>
<th>Class C</th>
<th>est(C)</th>
<th>lst(C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRG</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>MCS1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>PRG_Lab</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>MCS2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>IAI</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>
Formally define this class timetabling problem (i.e. variables, domains, precedence constraints, unary resource) as a Constraint Optimization Problem.

b) In a machine scheduling problem, makespan is defined as the completion time of all activities. Briefly explain, by using a precedence graph, how to model the machine scheduling problem with an optimisation objective of minimising makespan based on a CSP model, i.e. the CSP problem becomes Constraint Optimization Problem.

c) Define the three constraints given below.

For the two tasks MCS1 and MCS2 given in a), formally define the following constraints.

(i) non-preemption constraint
(ii) precedence constraint
(iii) disjunctive constraint

d) What can be observed for activity A in the chart below? Write the rule to define this.

By using the edge finding rule, explain what can be done to propagate on activity A.

2. Optional question: Consistency and Search

a) What is the difference between look back and look ahead techniques during the search? Provide a look back technique and explain the idea of it, and how it works.

b) Define the term ‘k-consistency’.

Does “k-consistency” guarantee that there exists a solution? Explain your reason by using an example.

What is the problem of obtaining a k-consistency constraint graph? What can be done in practice to solve this problem?

c) Under which condition can a solution can be found without backtracking by
   (i) obtaining an arc consistency and node consistency?
   (ii) obtaining a strong k-consistency and width of the constraint graph?

d) What is the definition of “support”? Use an example to explain the how bound propagation is done by using the term “support”.

3. Optional question: Modelling
The n-queen problem in chess consists of placing n queens on a n*n board so that no two queens attack each other, i.e. no two queens on the same row, same column and same diagonal.

(i) Present a CSP model for the n-queen problem. List what variables are needed for the problem, their domains, and formulate the constraints. (9 marks)

(ii) Explain how you calculate the upper bound of the size of the search space for the above two models you give in part (i). (6 marks)

(iii) Why does symmetry in the search tree for solving CSPs cause problems? Explain how to break symmetry in solving the 8-queen problem. (6 marks)

b) Explain, by using an example, how a CSP model designed for one problem might be reused for solving a different problem. (4 marks)

4. **Optional question: Ordering**

a) Define the bandwidth of a node and of an ordering for constraint graphs. (2 marks)

Show how to calculate the bandwidth of the ordering below. (3 marks)

b) Briefly explain what are the aims of heuristics in search? (2 marks)

Briefly explain how the Min-conflict heuristic works. (3 marks)

Provide a heuristic in variable ordering and value ordering, respectively. (3 marks)

c) Write the pseudo-code of the Max-Cardinality Ordering algorithm. (5 marks)

Find the max-cardinality ordering of the constraint graph shown below. What is the bandwidth of this ordering? (5 marks)

What is the purpose of finding the max-cardinality ordering? (2 marks)

5. **Optional question: Constraint Optimization**

a) Model the SEND + MOST = MONEY problem given below. The objective is to maximize z. Explain what problem reduction can be made before the search for solving this problem.

\[
\begin{align*}
S & \quad E & \quad N & \quad D \\
+ & \quad M & \quad O & \quad S & \quad T \\
\hline
z & = & M & O & N & E & Y
\end{align*}
\]
b) Define the Constraint Optimization Problem (COP). What is the optimal solution for a COP? (7 marks)

c) What are the two important factors in the Branch & Bound technique? Briefly explain them. (5 marks)

d) Define what is an admissible heuristic in Branch & Bound technique. What is a good heuristic in Branch & Bound techniques? (6 marks)

6. **Optional question: Basics**

a) Define “Compound Label” in CSPs. Define “Solution” using the concept of compound label. (4 marks)

b) Explain how the size of the search tree for a solving CSP is measured. (5 marks)

c) What are the two branches in Constraint Programming? Briefly explain the difference between these two branches. (4 marks)

d) Explain what each of the following terms mean in CSP.

   i) search tree
   ii) node
   iii) branch
   iv) dead-end (8 marks)

e) What are the guidelines for designing a model for CSPs? (4 marks)
Statistics for each question

This is the first year lab sessions and assignment are introduced in the module.

A majority of students successfully completed lab tasks, although it took some students longer time in the lab to complete the first and second sessions. In total 14 students obtained 90% and above in the lab sessions; the other 3 students obtained 60%.

Performance of the assignment is scattered, however, in general well, in the class (see below).