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2017

Study Of AI Algorithms For The Solution Of Puzzles With Minimum Number Of Moves

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Abstract

The goal of this project is to design, implement and compare algorithms for solving puzzles such as the sliding-tile and Rubik's Cube in the minimum number of moves. I will be implementing the iterative deepening A* algorithm, analysing and comparing it with the A* with Recursive Best First Search algorithm. I will also incoporate and test alternative algorithms such as Memory Bounded A*.

Acknowledgements

This section is used to acknowledge whoever's support and contribution. The command that introduces it is ignored in the project proposal, literature review and progress report. It is used in the final report, but is not compulsory. If you do not have an acknowledgements command in your preamble then there won't be any acknowledgement section in the document produced. *Abstract* and *Acknowledgements* sections should fit on the same page.

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1. Introduction

Before reading this report you should go through the LaTeX tutorials that have been provided for you to learn the basics of LaTeX such as sectioning, style, lists, referencing, bibliography and mathematics if applicable.

The basic structure of your reports is introduced in section 2 with the LaTeX commands used to implement it[1]. Section 3 shows how to create figures and gives examples of tables produced with the `cmpreport` class. Section 4 shows how you can produce a Gantt chart with LaTeX 2_ε.

2. The structure of the document

As any other LaTeX documents, your report starts by declaring the style of your document. For your final report this is done by issuing the command `\documentclass [final]{cmpreport}` which means that your report follows the style specified for the `final` report in the file `cmpreport.cls`. Your bibliography file (`bib` file) and any pictures you use in your figures should be placed in the same directory as your report. The option `final`, between the square brackets, must be replaced with `proposal`, `review` or `progress` for the corresponding pieces of assessment. There is another option `tutorial` that you will have used if you went through some of my tutorials. However, this is of no concern when using the class for your reports.

The main differences between the options of interest are:

- The options `proposal`, `review` and `progress` produce a simple title page and add a "performance sheet"[2] at the end of the document that indicates the evaluation criteria for the corresponding piece of work and provides a comment box for your supervisor.

[1] The beginning of your reports, usually the *Introduction* section, should include a "road map" that tells the reader about the organisation of the report.

[2] This is not a mark sheet, as this corresponds to a formative piece of coursework. However, your supervisor may indicate a level of performance for each of the criteria in the performance sheet.

- The option `final` provides a "more official" title page[3]. It also creates a table of contents, and possibly list of tables and list of figures (see below). It does not include mark sheets at the end of the document[3].

2.1. The preamble

The structure of your document preamble is as follows:

```
\documentclass[final]{cmpreport}
\title{A simple proof that $P \ne NP$}
\author{Harold P\'etard}
\registration{31415927}
\supervisor{Dr Ersatz Stanislaus Pondiczery}
\ccode{CMP-6012Y}
\summary{This document shows that $P \ne NP$.}
\acknowledgements{
I would like to thank my supervisor Dr Ersatz
Stanislaus Pondiczery, from the Royal Institute of
Poldavia, for observing that the fundamental
difference between $P$ and $NP$ is the letter $N$.
}
%\nolist
```

The source of this template contains extra comments to explain these commands.

If the command `\author` is present the name provided will appear as author of the report. The command `\author` is not compulsory because, at some point, you'll have to submit an electronic version of your final report to a School database that future students can consult. You may not want your name to appear in the electronic version. It is up to you.

`\registration`, `\supervisor` and `\ccode` are all compulsory for all reports. `\summary` and `\acknowledgements` produce the *Abstract* and *Acknowledgements*

[3] You may want to show your report to a future employer.

sections. These two commands are for the final report; the first one is compulsory, the second one, optional.

In the final report, a *List of figures* followed by a *List of tables* are automatically constructed after the *Contents* section. The `cmpreport` class is intelligent enough to realise that any such list should not be created if nothing goes in that list, that is if you do not have figures or do not have tables in your document. In addition, use the command `\onePageLists` if you have modest-size lists you want to fit on a single page.

Some supervisors are of the opinion that list of tables and list of figures should not be included in a report. If this is the case you just have to uncomment the command `\nolist`[4]. This also blocks the use of the standard LaTeX 2_ε commands for creating list of figures and list of tables.

Note that LaTeX truncates the final report to fifty-five pages as a limit of fifty pages is a requirement for this deliverable[5].

2.2. Your document

The structure of your document (after the preamble) should be of the form

```
\begin{document}
% Main content of report goes here
\clearpage
\bibliography{reportbib}
\clearpage
\appendix
\section{My first appendix}
% content of first appendix
\clearpage
\section{My second appendix}
% content of second appendix
\end{document}
```

[4]Reminder: By now you should know that anything that follows a % is a comment.

[5]A ten percent allowance above the required limit is made to comply with University regulations.

You do not need to use the command `\maketitle`. Making the title is compulsory and is taken care of by the `cmpreport` class.

3. Producing tables and figures

Tables are produced using a rewriting of the table environment that is specific to the report class. This new environment `cmptable` imposes some choices onto the user of the class to ensure a particular style in the report, but also provides new commands to facilitate the writing of quality tables. Tables 1, 2 and 3 show examples of tables produced using this environment. Details are provided in **?**.

Table 1: Homicides by race of the victim in 1993 in the USA[a]

Race	Population[b]	Homicides	Rate[c]
Black[d]	29 986	12 114	40.5*
White	199 686	12 153	6.1
Other[e]	19 038	635	3.3**
Total	248 710	24 932	10.0

[a] Data developped from the Statistical Abstract of the United States – 1993.

[b] Population in 1000s.

[c] Rate per 100 000 in the population.

[d] The rate for *Black* males was 69.2, for *White* males it was 9.0.

[e] About one-half of the *Other* category was composed of Asian Americans and Native Americans.

$*p < .001$, two-tailed test. $**p < 0.05$, two-tailed test.

Adapted from **?**.

Table 2: Rates of DHS[a] shelter use by selected characteristics

	Shelter system		
	Either[b] (%)	Family (%)	Single Adult (%)
History of out-of-home care:			
Yes	22.4	17.0	8.9
No	10.8	9.4	2.5
Type of final exit from ACS[c]:			
Reunification	19.4	14.7	7.6
Independent living	25.6	18.8	10.7
Absconding from care	33.6	22.4	15.6
Preventive services	12.4	11.0	3.0
Race and ethnicity:			
African American (non-Hispanic)	24.3	18.8	8.9
Hispanic	14.1	11.0	5.2
Caucasian (non-Hispanic)	6.0	4.0	3.0
Gender:			
Female	25.1	23.7	4.8
Male	11.1	3.8	9.3
Total	18.7	14.5	6.9

[a] Department of Homeless Services.

[b] This category reflects the unduplicated sum of the other two columns.

[c] The New-York City Administration for Children's Services.

All relationships are statistically significant for χ^2 test ($p < .001$).

Source: **?**.

Table 3: Effect of parameters on performance[a]

Parameter	Data set			
	SINGLE		MULTIPLE	
	CPU (msec)	Effective (%)	CPU (msec)	Effective (%)
$n(k = 10, p = 100)$				
2	75.5	55.5	174.2	22.2
3	21.5	50.4	79.4	19.9
4	16.9	47.5	66.1	16.3
$k(n = 2, p = 100)$				
10	57.5	51.3	171.4	21.7
100	60.0	56.1	163.1	21.3
1000	111.3	55.9	228.8	21.4
$p(n = 2, k = 10)$				
100	3.3	5.5	6.1	1.2
1000	13.8	12.6	19.8	2.1
10000	84.5	56.0	126.4	6.3
100000[b]	—	—	290.7	21.8

[a] Results on processing time and effectiveness for various combinations of the three parameters for both data sets. Default parameters are shown in parentheses.

[b] Value not meaningful for the data set SINGLE.

Adapted from **?**.

The figure environment has also been rewritten so that the caption is now a compulsory parameter of the environment. Note that the `label` command for the figure must be included just before the closing brace of the caption parameter. The code:

```
\begin{cmpfigure}[htb]{Cool cat \label{fig1}}
\includegraphics[width=0.5\textwidth]{coolcat.jpg}
\begin{tablenotes}
\item Image in the public domain.
\end{tablenotes}
\end{cmpfigure}
```

produces figure 1.

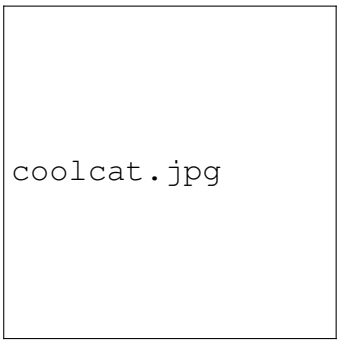

Image in the public domain.

Figure 1: Cool cat

Figures, as tables, should not be centred. Figure 2, whose code is given in Appendix A, shows an example of a figure that includes sub-figures. The choice of parameters in the code was slightly complicated by the fact that I used photographs that I did not crop to size. Only a few students working on Graphics projects may need sub-figures. The sub-figures can be referenced: the command `\ref{fig2:tired}` produces “2e”

(a) Cool (b) Bossy (c) Reflective

(d) Scared (e) Tired

Images in the public domain.

Figure 2: Cats

4. Producing a Gantt chart

The Gantt chart in figure 3 is produced by the code in figure 4. To compile this code you need to include the command `\usepackage{rotating}` in your preamble.

You may want to reuse this code and only modify the part that starts with the elements, bars and milestones, as the granularity of the schedule is right. The commands used in this part are as follows

- `\ganttbar{Final report writing}{25}{30}` creates a task named `Final report writing` and an associated bar that goes from the 25th time slot of the schedule to the 30th.
- `\ganttvoidbar{}{13}{16}` creates a grey bar from the 13th slot to the 16th to show a period of break in a task.
- `\ganttmilestone{Code delivery}{26}` shows a milestone in the 26th slot.
- `\\` indicates a change of line in the schedule. Notice how three bars without change of lines are used to show the tasks that include a break period in grey.
- `\ganttlink{elem0}{elem2}` creates a link from `elem0` to `elem2`. `elem0, elem1, ...` are identifiers of the bars and milestones in the order they are introduced in the code.

For more information on the `pgfgantt` package see (**?**).

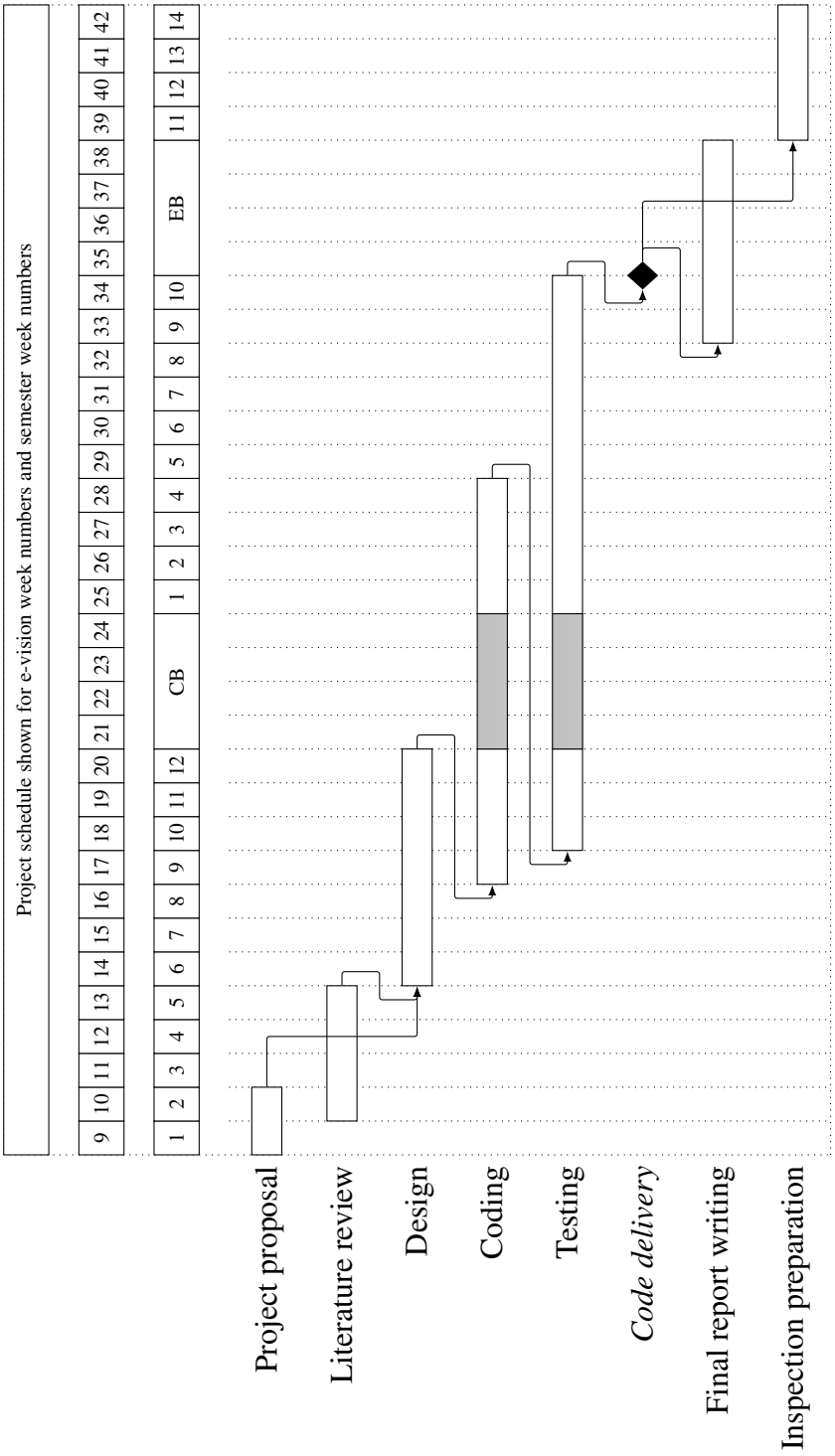

Figure 3: Project Gantt chart

```
\begin{cmpfigure}{Project Gantt chart \label{pplan}}
\begin{sideways}
\newganttchartelement{voidbar}{
voidbar/.style={
draw=black, top color=black!25, bottom color=black!23
}}
\begin{ganttchart}[x unit=0.45cm, vgrid, title label font=\scriptsize,
canvas/.style={draw=black, dotted}]{1}{34}
\gantttitle{Project schedule shown for e-vision week numbers
and semester week numbers}{34} \\
\gantttitlelist{9,...,42}{1}\\
\gantttitlelist{1,...,12}{1} \gantttitle{CB}{4}
\gantttitlelist{1,...,10}{1} \gantttitle{EB}{4}
\gantttitlelist{11,...,14}{1}\\

%The elements, bars and milestones, are identified as elem0, elem1, etc.
\ganttbar{Project proposal}{1}{2}     \\  %elem0
\ganttbar{Literature review}{2}{5}    \\  %elem1
\ganttbar{Design}{6}{12}              \\  %elem2
%week 1 of semester 2 is the 17th week in schedule
\ganttbar{Coding}{9}{12}                  %elem3
\ganttvoidbar{}{13}{16}                   %elem4
\ganttbar{}{17}{20}                   \\  %elem5
\ganttbar{Testing}{10}{12}                %elem6
\ganttvoidbar{}{13}{16}                   %elem7
\ganttbar{}{17}{26}                    \\ %elem8
\ganttmilestone{Code delivery}{26}     \\ %elem9
\ganttbar{Final report writing}{25}{30}        \\ %elem10
\ganttbar{Inspection preparation}{31}{34} %elem11

\ganttlink{elem0}{elem2} \ganttlink{elem1}{elem2}
\ganttlink{elem2}{elem3} \ganttlink{elem5}{elem6}
\ganttlink{elem8}{elem9} \ganttlink{elem9}{elem10}
\ganttlink{elem9}{elem11}
\end{ganttchart}
\end{sideways}
\end{cmpfigure}
```

Figure 4: Code for the Gantt chart of figure 3

References

A. Code for the “Cats” figure

```
\begin{cmpfigure}[htp]{Cats \label{fig2}}
         \begin{subfigure}[b]{0.2\textwidth}
                 \centering
                 \includegraphics[width=0.98\textwidth]{coolcat}
                 \caption{Cool} \label{fig2:coolcat}
         \end{subfigure}
         \begin{subfigure}[b]{0.398\textwidth}
                 \centering
                 \includegraphics[width=0.99\textwidth]{bossycat}
                 \caption{Bossy} \label{fig2:bossycat}
         \end{subfigure}%
         \begin{subfigure}[b]{0.4\textwidth}
                 \flushright
                 \includegraphics[width=0.98\textwidth]{frowningcat}
                 \caption{Reflective} \label{fig2:frowningcat}
         \end{subfigure}
% leave a blank line to change row

         \begin{subfigure}[b]{0.31\textwidth}
                 \centering
                 \includegraphics[width=0.985\textwidth]{scaredbabycat}
                 \caption{Scared} \label{fig2:scared}
         \end{subfigure}
         \begin{subfigure}[b]{0.69\textwidth}
                 \centering
                 \includegraphics[width=\textwidth]{tiredcat}
                 \caption{Tired} \label{fig2:tired}
         \end{subfigure}
\begin{tablenotes}
\item Images in the public domain.
\end{tablenotes}
\end{cmpfigure}
```