Solving the Capacitated Vehicle Routing Problem with Dynamic Graph Transformers

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Abstract: This paper presents a novel approach to solving the Capacitated Vehicle Routing Problem (CVRP) using Dynamic Graph Transformers. We leverage the power of deep reinforcement learning to train an agent that can dynamically construct high-quality routes for a fleet of vehicles. Our model is evaluated on a set of well-known CVRP benchmarks, and we show that it outperforms existing methods in terms of both solution quality and computational time.

1 INTRODUCTION

2 Model settings

2.1 Instances

2.2 GAT

2.3 GT

3 Optimal and suboptimal benchmarks

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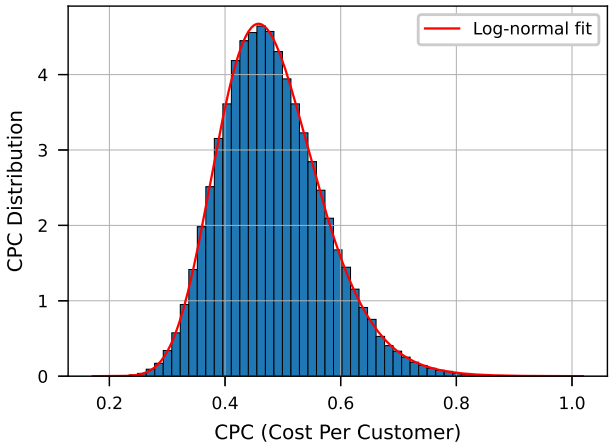

Figure 1: Distribution of CPC for N=10 CVRP instances solved using GPU dynamic programming. The histogram shows 100,000 random instances with the fitted log-normal distribution overlaid ($\mu = -0.748$, $\sigma = 0.183$). The log-normal fit demonstrates that CPC follows a log-normal distribution (Kolmogorov-Smirnov test, $p = 0.189$).

4 MANUSCRIPT PREPARATION

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Please remember that all the papers must be in English and without orthographic errors.

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Table 1: Optimal and sub-optimal (OR-Tools GLS) CPC values (10k instances per configuration)

Method	N	Cap.	Timeout	GM	GSD	95% Range	95% CI	KS	D'Agost.	JB	AD
Exact (100k)	10	20	–	0.4735	1.2012	[0.3306, 0.6782]	[0.4730, 0.4741]	0.19	<0.001	<0.001	1.405*
Exact (10k)	10	20	–	0.4737	1.1996	[0.3316, 0.6767]	[0.4720, 0.4754]	0.93	0.37	0.37	0.295
OR-Tools GLS	10	20	2s	0.4744	1.2025	[0.3305, 0.6809]	[0.4727, 0.4761]	0.91	0.08	0.08	0.503
OR-Tools GLS	20	30	2s	0.3257	1.1473	[0.2488, 0.4264]	[0.3248, 0.3266]	0.15	<0.01	<0.01	1.711*
OR-Tools GLS	50	40	10s	0.2366	1.1233	[0.1884, 0.2972]	[0.2270, 0.2467]	0.89	0.33	0.55	0.411
OR-Tools GLS	50	40	20s	0.2391	1.1270	[0.1892, 0.3023]	[0.2323, 0.2462]	0.05	0.12	0.32	1.580*
OR-Tools GLS	100	50	10s	0.1729	1.1061	[0.1419, 0.2108]	[0.1676, 0.1784]	¡0.01	0.09	0.11	2.018*
OR-Tools GLS	100	50	20s	0.1673	1.1353	[0.1305, 0.2146]	[0.1612, 0.1737]	¡0.01	¡0.01	¡0.01	4.906*
OR-Tools GLS	100	50	30s	0.1552	1.0338	[0.1454, 0.1657]	[0.1538, 0.1567]	¡0.01	¡0.01	0.06	4.285*

GM: Geometric Mean, GSD: Geometric Standard Deviation
95% Range: GM $\times$ [GSD$^{-1.96}$, GSD$^{+1.96}$]
KS: Kolmogorov-Smirnov, D'Agost.: D'Agostino, JB: Jarque-Bera (p-values for log(CPC) normality)
AD: Anderson-Darling test statistic (critical value at 5% = 0.787; * indicates rejection)
Timeout column indicates per-instance time limit used by OR-Tools GLS
Test run with 20 instances per configuration

Do not add any text to the headers (do not set running heads) and footers, not even page numbers, because text will be added electronically.

For a best viewing experience the used font must be Times New Roman, except on special occasions, such as program code 4.4.8.

4.1 Manuscript Setup

The template is composed by a set of 7 files, in the following 2 groups:
Group 1. To format your paper you will need to copy into your working directory, but NOT edit, the following 4 files:

- `apalike.bst`
- `apalike.sty`
- `article.cls`
- `scitepress.sty`

Group 2. Additionally, you may wish to copy and edit the following 3 example files:

- `example.bib`
- `example.tex`
- `scitepress.eps`

4.2 Page Setup

The paper size must be set to A4 (210x297 mm). The document margins must be the following:

- Top: 3,3 cm;
- Bottom: 4,2 cm;
- Left: 2,6 cm;
- Right: 2,6 cm.

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4.3 First Section

This section must be in one column.

4.3.1 Title and Subtitle

Use the command *title* and follow the given structure in "example.tex". The title and subtitle must be with initial letters capitalized (titlecased). The separation between the title and subtitle is done by adding a colon ":" just before the subtitle beginning. In the title or subtitle, words like "is", "or", "then", etc. should not be capitalized unless they are the first word of the title or subtitle. No formulas or special characters of any form or language are allowed in the title or subtitle.

4.3.2 Authors and Affiliations

Use the command *author* and follow the given structure in "example.tex". Please note that the name of each author must start with its first name.

4.3.3 Keywords

Use the command *keywords* and follow the given structure in "example.tex". Each paper must have at least one keyword. If more than one is specified, please use a comma as a separator. The sentence must end with a period.

4.3.4 Abstract

Use the command *abstract* and follow the given structure in "example.tex". Each paper must have an abstract up to 200 words. The sentence must end with a period.

4.4 Second Section

Files ”example.tex” and ”example.bib” show how to create a paper with a corresponding list of references.

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Each column must be 7,5-centimeter wide with a column spacing of 0,8-centimeter.

The section text must be set to 10-point.

Section, subsection and sub-subsection first paragraph should not have the first line indent.

To remove the paragraph indentation (only necessary for the sections), use the command $\backslash$*noindent* before the paragraph first word.

If you use other style files (.sty) you MUST include them in the final manuscript zip file.

4.4.1 Section Titles

The heading of a section title should be in all-capitals.

Example: $\backslash$*section*{*FIRST TITLE*}

4.4.2 Subsection Titles

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Example: $\backslash$*subsection*{*First Subtitle*}

4.4.3 Sub-Subsection Titles

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Words like ”is”, ”or”, ”then”, etc should not be capitalized unless they are the first word of the sub subsection title.

Example: $\backslash$*subsubsection*{*First Subsubtitle*}

4.4.4 Tables

Tables must appear inside the designated margins or they may span the two columns.

Tables in two columns must be positioned at the top or bottom of the page within the given margins. To span a table in two columns please add an asterisk (*) to the table *begin* and *end* command.

Example: $\backslash$*begin*{*table**}
$\backslash$*end*{*table**}

Tables should be centered and should always have a caption positioned above it. The font size to use is 9-point. No bold or italic font style should be used.

The final sentence of a caption should end with a period.

Please note that the word ”Table” is spelled out.

Table 2: This caption has one line so it is centered.

Example column 1	Example column 2
Example text 1	Example text 2

Table 3: This caption has more than one line so it has to be justified.

Example column 1	Example column 2
Example text 1	Example text 2

4.4.5 Figures

Please produce your figures electronically, and integrate them into your document and zip file.

Check that in line drawings, lines are not interrupted and have a constant width. Grids and details within the figures must be clearly readable and may not be written one on top of the other.

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4.4.6 Equations

Equations should be placed on a separate line, numbered and centered.
The numbers accorded to equations should appear in consecutive order inside each section or within the contribution, with the number enclosed in brackets and justified to the right, starting with the number 1.

Example:

$$a = b + c \tag{1}$$

4.4.7 Algorithms and Listings

Algorithms and Listings captions should have font size 9-point, no bold or italic font style should be used and the final sentence of a caption should end with a period. The separator between the title of algorithms/listings and the name of the algorithm/listing must be a colon. Captions with one line should be centered and if it has more than one line it should be set to justified.

Data: this text
Result: how to write algorithm with LaTeX2e
initialization;
while *not at end of this document* **do**
  read current;
  if *understand* **then**
    go to next section;
    current section becomes this one;
  else
    go back to the beginning of current section;
  end
end

Algorithm 1: How to write algorithms.

4.4.8 Program Code

Program listing or program commands in text should be set in typewriter form such as Courier New.

Example of a Computer Program in Pascal:

```
Begin
    Writeln('Hello World!!');
End.
```

The text must be aligned to the left and in 9-point type.

4.4.9 Reference Text and Citations

References and citations should follow the APA (Author, date) System Convention (see the References section in the compiled manuscript). As example you may consider the citation (**?**). Besides that, all references should be cited in the text. No numbers with or without brackets should be used to list the references.

References should be set to 9-point. Citations should be 10-point font size.

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ACKNOWLEDGEMENTS

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APPENDIX

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