

# 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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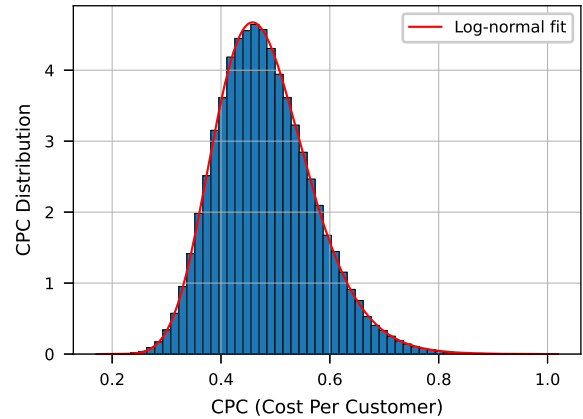



Figure 1: Distribution of CPC for N=10 CVRP instances solved using GPU dynamic programming. The histogram shows 100,000 random instances with the fitted log-normal distribution overlaid ( $\mu = -0.748$ ,  $\sigma = 0.183$ ). The log-normal fit demonstrates that CPC follows a log-normal distribution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


## 4 MANUSCRIPT PREPARATION

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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

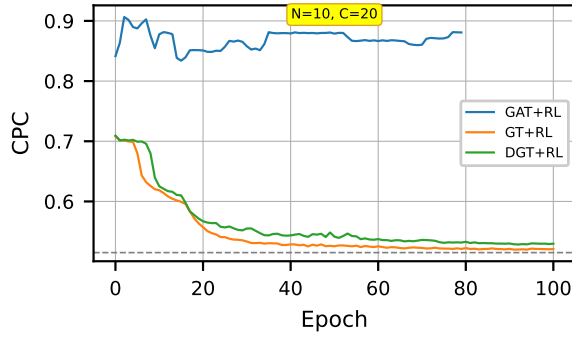


Figure 2: Training batch 75

ning heads) and footers, not even page numbers, because text will be added electronically.

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## 4.1 Manuscript Setup

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- apalike.sty
- article.cls
- scitepress.sty

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- 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:

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- 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.

Parameter	Tiny	Small	Medium	Large	Huge
<b>Problem Configuration</b>					
Number of customers	10	10	20	50	100
Vehicle capacity	20	20	30	40	50
<b>Graph Transformer (GT/DGT) Architecture</b>					
Hidden dimension	128	128	256 <sup>†</sup>	512	512
Number of heads	4 <sup>†</sup>	4 <sup>†</sup>	4 <sup>†</sup>	8	8
Number of layers	3	3	4 <sup>†</sup>	6	8
Transformer dropout	0.1 <sup>†</sup>	0.1 <sup>†</sup>	0.1 <sup>†</sup>	0.15	0.2
Feedforward multiplier	2 <sup>†</sup>	2 <sup>†</sup>	2 <sup>†</sup>	2 <sup>†</sup>	2 <sup>†</sup>
<b>GAT Architecture</b>					
GAT hidden dimension	128	128	256 <sup>†</sup>	512	512
GAT layers	3	3	4 <sup>†</sup>	5	6
GAT dropout	0.6 <sup>†</sup>	0.6 <sup>†</sup>	0.6 <sup>†</sup>	0.5	0.5
GAT edge dimension	16 <sup>†</sup>	16 <sup>†</sup>	16 <sup>†</sup>	16 <sup>†</sup>	16 <sup>†</sup>
GAT negative slope	0.2 <sup>†</sup>	0.2 <sup>†</sup>	0.2 <sup>†</sup>	0.2 <sup>†</sup>	0.2 <sup>†</sup>
<b>Model Parameter Counts</b>					
GAT total parameters	320K	320K	1.28M	6.83M	10.2M
GT total parameters	780K	780K	3.12M	19.9M	31.9M
DGT total parameters	1.77M	1.77M	7.09M	45.3M	72.5M
<b>Training Configuration</b>					
Batches per epoch*	15	1500 <sup>†</sup>	1500 <sup>†</sup>	1500 <sup>†</sup>	1500 <sup>†</sup>
Batch size	64	512 <sup>†</sup>	512 <sup>†</sup>	512 <sup>†</sup>	512 <sup>†</sup>
Number of epochs	100 <sup>†</sup>	100 <sup>†</sup>	100 <sup>†</sup>	100 <sup>†</sup>	100 <sup>†</sup>
Learning rate	10 <sup>-4†</sup>	10 <sup>-4†</sup>	10 <sup>-4†</sup>	10 <sup>-4†</sup>	10 <sup>-4†</sup>
<b>Advanced Training (for Large/Huge)</b>					
Early stopping patience	10 <sup>†</sup>	10 <sup>†</sup>	10 <sup>†</sup>	10 <sup>†</sup>	40
Gradient clip norm	2.0 <sup>†</sup>	2.0 <sup>†</sup>	2.0 <sup>†</sup>	2.0 <sup>†</sup>	1.5

Table 2: Configuration parameters for different problem scales in the Dynamic Graph Transformer RL framework. Values marked with <sup>†</sup> represent default values from `default.yaml`. The tiny configuration uses reduced training data (\*batches per epoch = 15) for rapid experimentation, while other configurations use the full training regime. Model parameter counts are calculated based on the respective architectures: GAT (Graph Attention Network), GT (Graph Transformer), and DGT (Dynamic Graph Transformer).

### 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.

This section must be in two columns.

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.

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

Example: `\section{FIRST TITLE}`

### 4.4.2 Subsection Titles

The heading of a subsection title must be with initial letters capitalized (titlecased).

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Example: `\subsection{First Subtitle}`

### 4.4.3 Sub-Subsection Titles

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Example: `\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: `\begin{table*}`  
`\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.

Table 3: This caption has one line so it is centered.

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

Table 4: This caption has more than one line so it has to be justified.

Example column 1	Example column 2
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Please note that the word "Table" is spelled out.

### 4.4.5 Figures

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

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Figure resolution should be at least 300 dpi.

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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:

$$a = b + c \quad (1)$$

#### 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  $\text{\LaTeX}2\text{e}$  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.
```

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#### 4.4.9 Reference Text and Citations

References and citations should follow the APA (Author, date) System Convention (see the References

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## ACKNOWLEDGEMENTS

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## APPENDIX

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