University of Johannesburg

Masters Dissertation

A NEAT Inspired GEP Algorithm

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in the

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Academy of Computer Science and Software Engineering

> “It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is most adaptable to change. In the struggle for survival, the fittest win out at the expense of their rivals because they succeed in adapting themselves best to their environment.”
>
> — Charles Darwin

Acknowledgements

I would like to sincerely thank my supervisor, Prof Coulter, for his guidance and support throughout this research. His expertise and feedback were invaluable.

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1. Introduction

Charles Darwin, an English naturalist, geologist, and biologist theorized the evolution by natural selection suggesting that all life on Earth evolved from common ancestors through a process of adaption and survival of the fittest. Put simply, organisms and animals go through generational mutations and adaptations to survive in the environment they are placed in. Through millions of years of evolution, the human brain began to form which consists of thousands of neurons, small building blocks which act as thresholds to fire signal within the brain. Combining these signals allows complex logic and have evolved to be the development of intelligent brain cognitive function. The computer sicence field has taken these principles and represetned them mathematically, that being, in terms of evolution, evolutionary computing has become a popular field whereby evolutionary processes are mimiced in order to solve optimzation tasks, whereas twith regards to the brain, peceptrons have designed as the model of neurons to simulate cognitave ability which has introduced the world of neural networks.

There are two concepts which this paper is based on, namely gene expression programming (GEP) and the Neuroevolution of augmenting toploiges (NEAT). GEP is an evolutionary algorithm whereby expression trees are represented in a meaningful expression string and undergo generations of adaptations in order to solve an optimzation task. NEAT on the other hand is a architectural search mechanism whereby cancdidate solutions representing a neural netorks topology are evolved through generations to create an optimal neural netowrk to solve a particular task. This research paper proposes a new algorithm, GEP-

NEAT which combines the aspects of GEP and GEP-NEAT in an attempt to create an algorithm that obtains strengths from both. Importantly, GEP-NEAT introduces new novelty, which is the representation of innovation numbers as sub-tree configurations. In addition to this, this paper seeks to find a meaninufl way to make use of this representation in the hope to create some powerful metric to be used wtihin the algorithm.

1.1 Publications Resulting from this Work

A peer-reviewed conference paper derived from this research was published in the proceedings of the **8th International Conference on Information Science and Systems (ICISS 2025)**. As an established forum in its eight iteration, ICISS maintains rigorous academic standards through its double-blind peer review process, where both author and reviewer identities are concealed to remove bias and ensure impartial evaluation based solely on scholarly merit. The conference brings together leading researchers across ten interdisciplinary tracks spanning artificial intelligence, data science, and information systems.

The accepted paper, which contributes to the Machine Learning and Artificial Intelligence track, presents the algorithm GEP-NEAT with its innovation number novelty, showcasing the ability to solve the XOR and Cart Pole problem effectively. ICISS 2025 facilitated valuable scholarly exchange through keynote presentations by field leaders, technical workshops, and interdisciplinary discussion bridging academic and real-world application. The conference proceedings are to be published into **Communications in Computer and Information Sicence (Electronic ISSN: 1865-0937 & Print ISSN: 1865-0929)** as a proceedings book volume and indexed by EI Compendex, Scopus, INSPEC, SCImago and other databases.

1.2 Research Questions

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1.3 Research Methodology

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2. Sectioning Examples

2.1 Section Title

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2.1.1 Subsection Title

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Unnumbered Section

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Unnumbered Subsubsection

3. In-text Element Examples

3.1 Referencing Publications

This statement requires citation [1]; this one is more specific [2, page 162].

3.2 Link Examples

This is a URL link: LaTeX Templates. This is an email link: example@example.com. This is a monospaced URL link: `https://www.LaTeXTemplates.com`.

3.3 Lists

Lists are useful to present information in a concise and/or ordered way.

3.3.1 Numbered List

1. First numbered item
    a. First indented numbered item
    b. Second indented numbered item
        i. First second-level indented numbered item
2. Second numbered item
3. Third numbered item

3.3.2 Bullet Point List

- First bullet point item
  - First indented bullet point item
  - Second indented bullet point item
    - First second-level indented bullet point item
- Second bullet point item
- Third bullet point item

3.3.3 Descriptions and Definitions

Name Description

Word Definition

Comment Elaboration

3.4 International Support

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3.5 Ligatures

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Part Two Title

4. Mathematics

4.1 Theorems

4.1.1 Several equations

This is a theorem consisting of several equations.

Theorem 4.1 — Name of the theorem. In $E = \mathbb{R}^n$ all norms are equivalent. It has the properties:

$$\big| ||\mathbf{x}|| - ||\mathbf{y}|| \big| \leq ||\mathbf{x} - \mathbf{y}|| \tag{4.1}$$

$$||\sum_{i=1}^{n} \mathbf{x}_i|| \leq \sum_{i=1}^{n} ||\mathbf{x}_i|| \quad \text{where } n \text{ is a finite integer} \tag{4.2}$$

4.1.2 Single Line

This is a theorem consisting of just one line.

Theorem 4.2 A set $\mathscr{D}(G)$ in dense in $L^2(G)$, $|\cdot|_0$.

4.2 Definitions

A definition can be mathematical or it could define a concept.

Definition 4.1 — Definition name. Given a vector space E, a norm on E is an application, denoted $||\cdot||$, E in $\mathbb{R}^+ = [0, +\infty[$ such that:

$$||\mathbf{x}|| = 0 \Rightarrow \mathbf{x} = \mathbf{0} \tag{4.3}$$

$$||\lambda\mathbf{x}|| = |\lambda| \cdot ||\mathbf{x}|| \tag{4.4}$$

$$||\mathbf{x}+\mathbf{y}|| \leq ||\mathbf{x}|| + ||\mathbf{y}|| \tag{4.5}$$

4.3 Notations

■ **Notation 4.1** Given an open subset G of $\mathbb{R}^n$, the set of functions φ are:

1. Bounded support G;
2. Infinitely differentiable;

a vector space is denoted by $\mathscr{D}(G)$.

4.4 Remarks

This is an example of a remark.

R The concepts presented here are now in conventional employment in mathematics. Vector spaces are taken over the field $\mathbb{K} = \mathbb{R}$, however, established properties are easily extended to $\mathbb{K} = \mathbb{C}$.

4.5 Corollaries

Corollary 4.1 — Corollary name. The concepts presented here are now in conventional employment in mathematics. Vector spaces are taken over the field $\mathbb{K} = \mathbb{R}$, however, established properties are easily extended to $\mathbb{K} = \mathbb{C}$.

4.6 Propositions

4.6.1 Several equations

Proposition 4.1 — Proposition name. It has the properties:

$$\big|||\mathbf{x}|| - ||\mathbf{y}||\big| \leq ||\mathbf{x}-\mathbf{y}|| \tag{4.6}$$

$$||\sum_{i=1}^{n} \mathbf{x}_i|| \leq \sum_{i=1}^{n} ||\mathbf{x}_i|| \quad \text{where } n \text{ is a finite integer} \tag{4.7}$$

4.6.2 Single Line

Proposition 4.2 Let $f,g \in L^2(G)$; if $\forall \varphi \in \mathscr{D}(G)$, $(f,\varphi)_0 = (g,\varphi)_0$ then $f = g$.

4.7 Examples

4.7.1 Equation Example

■ **Example 4.1** Let $G = \{x \in \mathbb{R}^2 : |x| < 3\}$ and denoted by: $x^0 = (1,1)$; consider the function:

$$f(x) = \begin{cases} \mathrm{e}^{|x|} & \text{si } |x - x^0| \leq 1/2 \\ 0 & \text{si } |x - x^0| > 1/2 \end{cases} \tag{4.8}$$

The function f has bounded support, we can take $A = \{x \in \mathbb{R}^2 : |x - x^0| \leq 1/2 + \varepsilon\}$ for all $\varepsilon \in]0; 5/2 - \sqrt{2}[$. ■

4.7.2 Text Example

■ **Example 4.2 — Example name.** Aliquam arcu turpis, ultrices sed luctus ac, vehicula id metus. Morbi eu feugiat velit, et tempus augue. Proin ac mattis tortor. Donec tincidunt, ante rhoncus luctus semper, arcu lorem lobortis justo, nec convallis ante quam quis lectus. Aenean tincidunt sodales massa, et hendrerit tellus mattis ac. Sed non pretium nibh. Donec cursus maximus luctus. Vivamus lobortis eros et massa porta porttitor. ■

4.8 Exercises

Exercise 4.1 This is a good place to ask a question to test learning progress or further cement ideas into students' minds. ■

4.9 Problems

Problem 4.1 What is the average airspeed velocity of an unladen swallow?

4.10 Vocabulary

Define a word to improve a students' vocabulary.

■ **Vocabulary 4.1 — Word.** Definition of word.

5. Presenting Information and Results with a Long Chapter Title

5.1 Table

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Treatments	**Response 1**	**Response 2**
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

Table 5.1: Table caption.

Referencing Table 5.1 in-text using its label.

5.2 Figure

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Treatments	**Response 1**	**Response 2**
Treatment 1	0.0003262	0.562
Treatment 2	0.0015681	0.910
Treatment 3	0.0009271	0.296

Table 5.2: Floating table.

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Figure 5.1: Figure caption.

Referencing Figure 5.1 in-text using its label.

Figure 5.2: Floating figure.

Bibliography

Articles

[1] A. B. Jones and J. M. Smith. “Article Title”. In: *Journal title* 13.52 (Mar. 2022), pages 123–456. DOI: 10.1038/s41586-021-03616-x (cited on page 17).

Books

[2] J. M. Smith and A. B. Jones. *Book Title*. 7th. Publisher, 2021 (cited on page 17).

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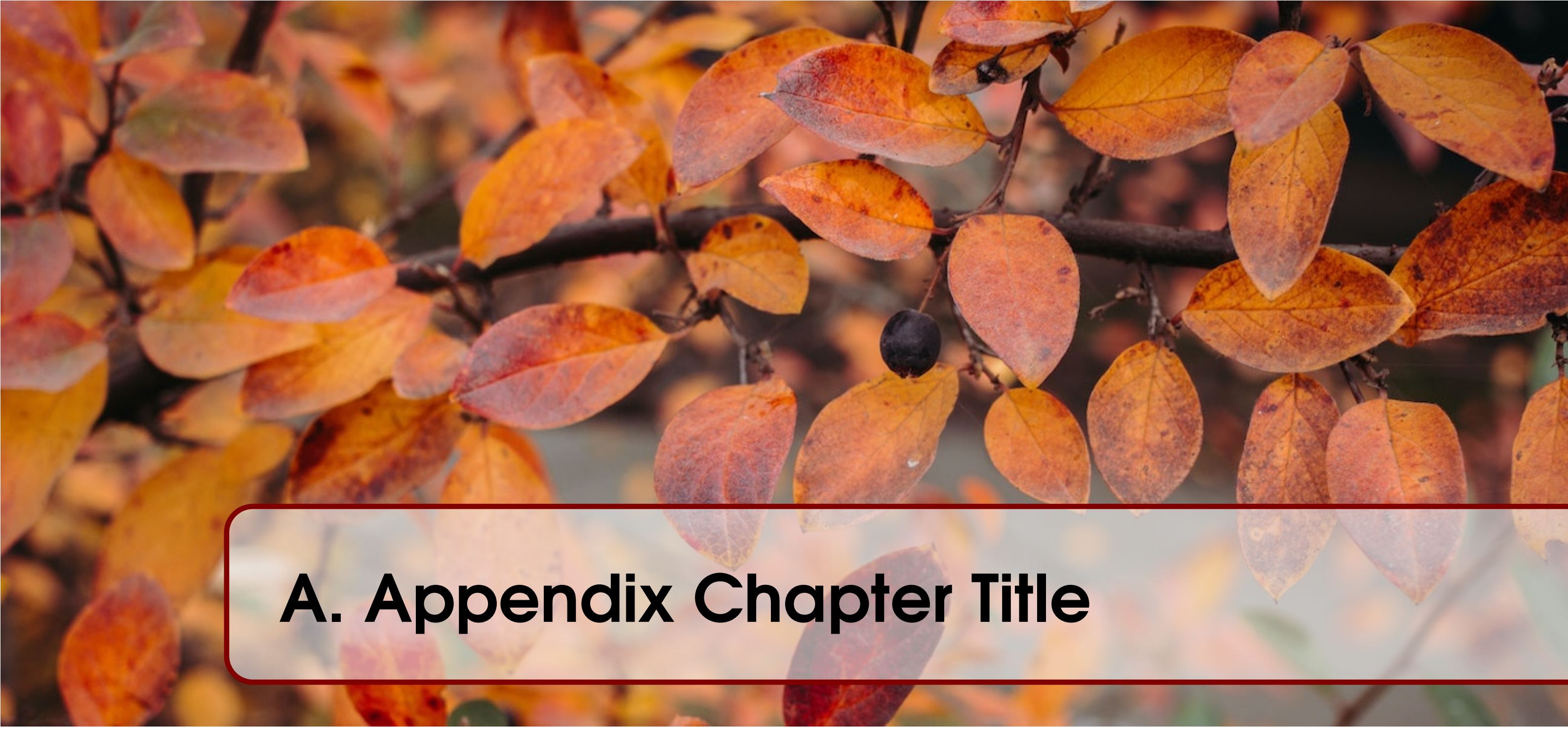

A. Appendix Chapter Title

A.1 Appendix Section Title

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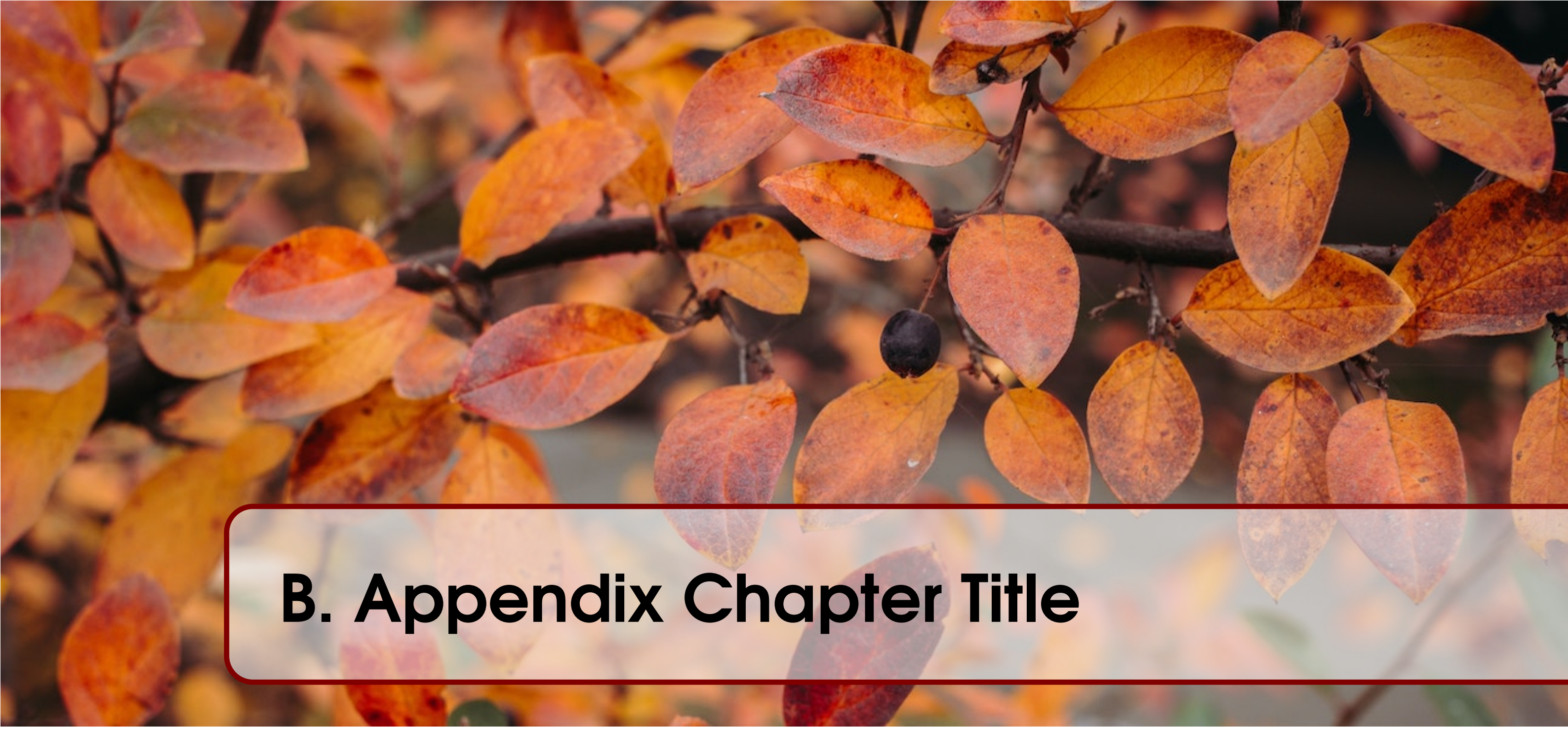

B. Appendix Chapter Title

B.1 Appendix Section Title

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