COMPARISON OF GENETIC ALGORITHM TRAINING METHODS AS APPLIED TO Tic-Tac-Toe

A research paper submitted to the
Faculty of the Philippine Science High School –
Cordillera Administrative Region Campus
in fulfillment of the course requirements in
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VASH PATRICK B. ANCHETA
DIEGO SULAYMAN R. PASCUA
RESH VNZI S. TOGUEÑO

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APPROVAL SHEET

In fulfillment of the requirements in Science, Technology, Engineering and Mathematics Research 3 (STR 3), this research entitled, "COMPARISON OF GENETIC ALGORITHM TRAINING METHODS AS APPLIED TO TIC-TAC-TOE" is submitted by Vash Patrick B. Ancheta, Diego Sulayman R. Pascua and Resh Vnzi S. Togueño on 18 May 2020

KAYE MELINA NATIVIDAD B. ALAMAG
Research Adviser

This research paper is hereby accepted by the Research Council.

CONRADO C. ROTOR, Jr., Ph.D.
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MELBA C. PATACSIL
Co-chair

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Member

MARITES P. RIVERA
Member

RICARIDO M. SATURAY, Jr.
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Member

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ABSTRACT

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Adviser: **Kaye Melina Natividad B. Alamag**
According to George Mason University (2020),

> An abstract is a 150- to 250-word paragraph that provides readers with a quick overview of your essay or report and its organization. It should express your thesis (or central idea) and your key points; it should also suggest any implications or applications of the research you discuss in the paper.

George Mason University (2020) also states that the common abstract is divided into such: 25% of space on the purpose and importance of the research (Introduction), 25% of space on what was done (Methods), 35% of space on what was found (Results), and 15% of space on the implications of the research.

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CHAPTER I
INTRODUCTION

Background of the Study

Machine learning (ML) is vast—it is used in different situations such as spam detectors, web search engines, photo tagging applications and game development (Sharma, 2016). There have been researches that are aimed at improving the implementation of ML in various games. A category of games under investigation through ML is the set of *m, n, k* game games, comprised of games where there is an $m \times n$ grid and two players alternate turns trying to earn k pieces adjacent to each other horizontally, vertically or diagonally (Hayes & Loge, 2016). Among the most common examples of *m, n, k* games are Gō, Othello, and Chess. Tic-Tac-Toe, the game under investigation in this study, is an example of an *m, n, k* game. A Tic-Tac-Toe board is composed of three rows and three columns, and requires three adjacent pieces of the same player to render a win, thus it is considered to have a $3, 3, 3$ configuration.

Improvements in ML have lead to the development of artificial intelligence (AI) players that can beat even the most competitive human players around the world. Machine learning methods (MLMs) are algorithms where machines are not explicitly programmed to do what is tasked. Rather, similar to its namesake, MLM-trained machines are capable of performing tasks given its own internal code without any human interference. In short, the machine *learns* (GeeksforGeeks, n.d.). An example of an MLM is the genetic algorithm (GA).

This study aims to develop multiple GAs with different elite preservation methods and compare their performance in Tic-Tac-Toe based on the possible situations.

Objectives of the Study

General Objective

- To compare the effectiveness of trained genetic algorithm (GA) organisms among each other as applied to Tic-Tac-Toe

Specific Objectives

1. To implement known heuristics into Python code
2. To train organisms of an implemented GA using different move generators (MGs)
3. To compare the development of the performance of trained GA organisms among each other within 500 generations

Significance of the Study

This study will contribute to the body of knowledge in ML. Through this study, more can be known about how information gained from one method of AI can be passed on to another mechanism of AI through training. This will shed light on how information from one AI player can be transmitted to an MLM such as GA. This, by extension, can improve the comprehension of how machines can learn strategies in games from one with greater skill.

Scope and Limitations of the Study

This study will focus only on Tic-Tac-Toe and not other games such as Chess or Gō because it is the simplest game to conduct the research on heuristics, namely the training of the GA under different MGs. The complexity of the board game is not relevant to the study because the focus of the research is to compare the effectiveness of trained GA organisms given an *m, n, k* game. Applying these heuristics on other *m, n, k* games however are beyond the time frame of the research. The study will only develop three GAs. The first is a Python implementation of the GA in the work of Bhatt et al. (2008). Using developed AI, the second and third are modified implementations of the same GA. The performance of each GA will be based on how many generations it will take for the GA to find a no-loss first player for Tic-Tac-Toe. This basis for comparison of performance, specifically using the skill of an organism as a first player, is due to the fact that Python is known for being slow. In line with this, indices are 0-based in this paper, as they are in Python.

DEFINITION OF TERMS

***m, n, k* game** – a game where there is an $m \times n$ grid where two players alternate turns trying to earn k pieces adjacent to each other horizontally, vertically or diagonally

Artificial Intelligence (AI) – program that simulates human actions, can simulate a human player in a game.

Allele – the configuration value of a gene given a unique organism

Genetic Algorithm (GA) – algorithm that simulates natural selection and biological reproduction to produce solutions to a problem

Gene – representation of a unique and distinct situation in a game given the game rules

Genome – mapping table of genes with corresponding alleles

Machine Learning (ML) – a heuristic where a program learns rather than strictly follow a given instruction

Machine Learning (MLM) – algorithms used in machine learning

Organism – an algorithm represented by a genome

Probability Valuation (PV) – classical probability of a player winning at a given game state

Tic-Tac-Toe – *m, n, k* game configured as 3,3,3

CHAPTER II
REVIEW OF RELATED LITERATURE

McCombes (2019) lists five (5) important steps in writing an effective literature review: **Search** for relevant literature, **evaluate** sources, **identify** themes, debates and gaps, **outline** the structure, and **write** the literature review itself.

Searching for Relevant Literature

Hardy (2020) provides a proper guide for searching effectively for a literature review. The following ideas are abridged versions of the common search techniques employed when writing an effective literature review. To begin searching, one must perform an analysis of the research topic. This analysis must tackle the main ideas and synonyms, related words and phrases, and concepts and ideas already covered about the research topic. In modern search engines, keywords exist to make searches more efficient such as: **OR** for synonymous terms, **AND** for joining words that make up the main ideas, and **NOT** for exclusion of irrelevant terms (Hardy, 2020).

McCombes (2019) lists the following databases that might aid in the search for related literature:

- Google Scholar (https://scholar.google.com/)
- JSTOR (https://www.jstor.org/)
- EBSCO (https://www.ebsco.com/products/research-databases)
- Project Muse for humanities and social sciences (http://muse.jhu.edu/)
- Medline for life sciences and biomedicine (https://www.nlm.nih.gov/bsd/medline.html)
- EconLit for economics (https://www.aeaweb.org/econlit/)
- Inspec for physics, engineering and computer science (https://www.theiet.org/publishing/inspec/)

The importance of a proper abstract is highlighted during the search for related literature, as the abstract of a work will assist future researchers in selecting the work if they find the abstract to be relevant with their own research (McCombes, 2019).

Evaluating and Selecting Sources

McCombes (2019) emphasizes the fact that one cannot read and digest every single work written about the research topic, therefore each source should be evaluated to filter out the most relevant sources for the study. McCombes (2019) further writes:

"For each publication, ask yourself:

- What question or problem is the author addressing?
- What are the key concepts and how are they defined?
- What are the key theories, models and methods? Does the research use established frameworks or take an innovative approach?
- What are the results and conclusions of the study?
- How does the publication relate to other literature in the field? Does it confirm, add to, or challenge established knowledge?
- How does the publication contribute to your understanding of the topic? What are its key insights and arguments?
- What are the strengths and weaknesses of the research?

Make sure the sources you use are credible, and make sure you read any landmark studies and major theories in your field of research.

The scope of your review will depend on your topic and discipline: in the sciences you usually only review recent literature, but in the humanities you might take a long historical perspective (for example, to trace how a concept has changed in meaning over time)."

The need to take notes and keep track of sources is stressed by McCombes (2019) by mentioning plagiarism. Plagiarism is defined by Merriam-Webster (n.d.) as "[the act of] steal[ing] and pass[ing] off (the ideas or words of another) as one's own : us[ing] (another's production) without crediting the source". Such an act is frowned upon in the academic field, and must be avoided as much as possible.

One may use bibliography management software to keep notes and source information that might be valuable later on in paper writing. Notes that are attached to a bibliographic entry in a bibliography management software can save time later on when one must remember the details of the source listed. Modern bibliography management software such as **Zotero** (https://www.zotero.org/) and **Mendeley** (https://www.mendeley.com/) usually have the capability to maintain and track sources and said notes with the addition of producing citations and bibliographies as well as files for paper-writing software such as LaTeX.

Identifying Themes, Debates, and Gaps

"To begin organizing your literature review's argument and structure, you need to understand the connections and relationships between the sources you've read. Based on your reading and notes, you can look for:

- Trends and patterns (in theory, method or results): do certain approaches become more or less popular over time?
- Themes: what questions or concepts recur across the literature?
- Debates, conflicts and contradictions: where do sources disagree?
- Pivotal publications: are there any influential theories or studies that changed the direction of the field?
- Gaps: what is missing from the literature? Are there weaknesses that need to be addressed?

This step will help you work out the structure of your literature review and (if applicable) show how your own research will contribute to existing knowledge." (McCombes, 2019)

Outlining the Structure of the Literature Review

There are four (4) major principles of organization one may use in writing an effective Literature Review, and these are: Chronological Order or Order of Time, Spatial Order, Climactic Order or Order of Importance, and Topical Order (Friedlander, 2004).

Chronological Order

"Chronological order can suit different rhetorical modes or patterns of exposition. It naturally fits in narration, because when we tell a story, we usually follow the order in which events occur. Chronological order applies to process in the same way, because when we describe or explain how something happens or works, we usually follow the order in which the events occur. But chronological order may also apply to example, description, or parts of any other pattern of exposition." (Friedlander, 2004)

Spatial Order

"In this pattern, items are arranged according to their physical position or relationships. . . . In explaining some political or social problem, I might discuss first the concerns of the East Coast, then those of the Midwest, then those of the West Coast. Describing a person, I might start at the feet and move up to the head, or just the other way around. This pattern might use such transitions as just to the right, a little further on, to the south of Memphis, a few feet behind, in New Mexico, turning left on the pathway, and so on." (Friedlander, 2004)

Climactic Order

"In this pattern, items are arranged from least important to most important. Typical transitions would include *more important*, *most difficult*, *still harder*, *by far the most expensive*, *even more damaging*, *worse yet*, and so on. This is a flexible principle of organization, and may guide the organization of all or part of example, comparison & contrast, cause & effect, and description.

A variation of climactic order is called psychological order. This pattern or organization grows from our learning that readers or listeners usually give most attention to what comes at the beginning and the end, and least attention to what is in the middle. In this pattern, then, you decide what is most important and put it at the beginning or the end; next you choose what is second most important and put it at the end or the beginning (whichever remains); the less important or powerful items are then arranged in the middle. If the order of importance followed 1, 2, 3, 4, 5, with 5 being most important, psychological order might follow the order 4, 3, 1, 2, 5.

Still other principles of organization based on emphasis include:

- general-to-specific order,
- specific-to general order,
- most-familiar-to-least-familiar,
- simplest-to-most-complex,
- order of frequency,
- order of familiarity, and so on.

" This principle of organization is one of the most common. (Friedlander, 2004)

Order of Importance

"[The Order of Importance] refers to organization that emerges from the topic itself. For example, a description of a computer might naturally involve the separate components of the central processing unit, the monitor, and the keyboard, while a discussion of a computer purchase might discuss needs, products, vendors, and service. A discussion of a business might explore product, customer, and location, and so on. Topical order, then, simply means an order that arises from the nature of the topic itself. Transitions in this pattern will be a little vague–things like *another factor*, *the second component*, *in addition*, and so on." (Friedlander, 2004)

Writing the Literature Review

In writing a literature review, one must follow the general structure: introduction, main body, and then conclusion. In the introduction, the central problem of the research must be reiterated and a summary must be provided of the current academic context. Here the timeliness of the topic or the presence of a knowledge gap is highlighted. In the body, subheadings divide major parts that are highlighted in the outline. One must keep in mind the following ideas (McCombes, 2019):

- an overview of the main points of each source must be noted and combined into one coherent whole
- analyses and interpretations must be provided regarding the findings of each source with respect to the research
- the strengths and weaknesses of each source must be stated
- the topic sentence of each paragraph must be clear and the flow between paragraphs must be maintained with transitions

In the conclusion, the key findings of each related literature should be summarized with emphasis on their significance to the research (McCombes, 2019).

CHAPTER III
MATERIALS AND METHODS

Research Design

Labaree (2020) states: "The function of a research design is to ensure that the evidence obtained enables you to effectively address the research problem logically and as unambiguously as possible.". You may use the article by Labaree (2020) to figure out which research design will suit your study the best. In this section of the paper, the research design is described, as well as the independent and dependent variables involved. The description of how identified extraneous variables are held constant is also elaborated in the Research Design section. If the study is developmental in nature, the stages of development may be stated in this section.

Locale of the Study

The places where the study is executed should be stated in the Locale of the Study. The population where samples are taken, as well as the sample size, should be mentioned here. This section must also contain the reasoning for choosing the locale, with respect to the scope and limitations of the study.

Materials and Research Instruments

The materials required in the study as well as any instrumentation to be used should be mentioned in the Materials and Research Instruments. The reasoning may involve any past researches or research-based handbooks that are relevant to the study and are published works (as published works tend to be peer-reviewed). An example of a research-based handbook is Letcher (2017).

Procedures

An elaborate and chronological description of the procedures to be taken is provided in this section. The proper reasoning for each step taken should be stated, as well as what

materials and research instruments are used in each step.

Treatment of Data

Statement of Hypotheses

$$H_0 : \mu = 50$$

$$H_a : \mu > 50$$

Analysis of Data

The statistical tools as well as the significance level to be used is mentioned in this portion of the paper. How the statistical tools will be used should also be detailed in this section.

CHAPTER IV
RESULTS AND DISCUSSION

"The Results section should set out your key experimental results, including any statistical analysis and whether or not the results of these are significant" (SkillsYouNeed.com, 2020).

Cite literature that support your analyses of the results. It is imperative to include relevant results, regardless of support of hypotheses. Brief descriptions of the results should be provided when clarification is needed.

Softening Points

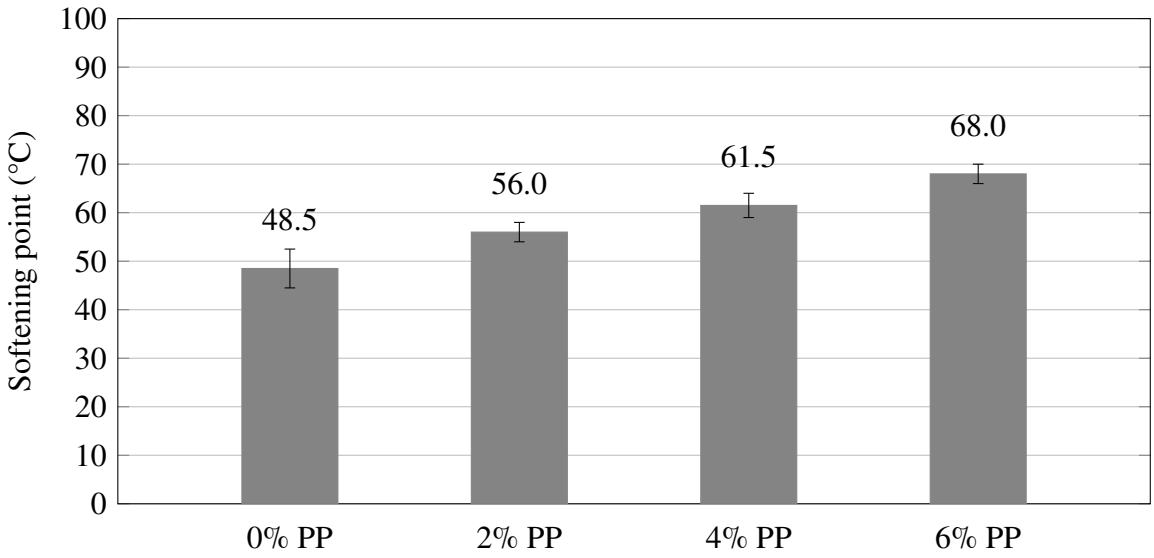

Figure 1. Sample bar graph of softening points.

Table 1. *Characteristics of the Sample*[†]

Variable	Control (n = 45)	Heat & moisture exchanger (n = 49)	Probability
Age (years)[1]	32.7 ± 3.5	36.3 ± 2.7	0.08
Height (m)[1]	1.72 ± 0.60	1.67 ± 0.80	NS
Weight (kg)[1]	76.6 ± 12.8	72.3 ± 16.2	NS
Gender (number of males)[2]	21	26	NS
ASA Physical Status[3]	2 ± 1	2 ± 1	NS
OR room temperature (°C)[1]	21.1 ± 3.6	20.6 ± 2.9	NS

[1] Data is expressed as mean ± one standard deviation. Probability determined using a two-tailed, unpaired Student's t-test.

[2] Data is expressed as number within the sample who possess the characteristic. Probability determined using Chi square (or Fisher's Exact test for 2×2 tables).

[3] Data is expressed as median ± one interquartile range. Probability determined using a Mann-Whitney U test.

[†] Source: Dosch, M. P. (2009, June). *How to write the results and discussion*. Retrieved March 21, 2020, from https://healthprofessions.udmercy.edu/academics/na/agm/htresult.htm

Take advantage of `siunitx` package like so: $(5.67 \pm 0.12) \times 10^6$ A. Take advantage of citations with BibLaTeX like so: The question is posed as to whether or not writing systems influence the associations between phonological awareness, morphological awareness, and reading (Ruan et al., 2018, pp. 180–183). More examples are in the `biblatex-cheatsheet` on CTAN.

$$E^2 = (mc^2)^2 + (pc)^2 \tag{1}$$

$$x(t) = \int_{-B}^{B} X(f) e^{j2\pi ft}\, df \tag{2}$$

One may refer to figures within this section or in the appendix, similar to the following: One may also refer to appendices similar to the following: "Relevant documentation is included in Appendix D."

Analysis/Discussion

" This section has four purposes, it should:

- Interpret and explain your results
- Answer your research question
- Justify your approach
- Critically evaluate your study

The discussion section therefore needs to review your findings in the context of the literature and the existing knowledge about the subject.

You also need to demonstrate that you understand the limitations of your research and the implications of your findings for policy and practice. This section should be written in the present tense.

The Discussion section needs to follow from your results and relate back to your literature review. Make sure that everything you discuss is covered in the results section. ” (SkillsYouNeed.com, 2020)

CHAPTER V
CONCLUSION AND RECOMMENDATIONS

"The Conclusions and Recommendations may be combined or, in long reports, presented in separate sections. If there are no recommendations to be made as a result of the project, just call this section Conclusions.

The Conclusions section sums up the key points of your discussion, the essential features of your design, or the significant outcomes of your investigation. As its function is to round off the story of your project, it should:

- be written to relate directly to the aims of the project as stated in the Introduction
- indicate the extent to which the aims have been achieved
- summarise the key findings, outcomes or information in your report
- acknowledge limitations and make recommendations for future work (where applicable)
- highlight the significance or usefulness of your work.

The conclusions should relate to the aims of the work[.]" (Monash University, 2020)

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APPENDIX A
PROJECT PLAN

Table 2. *Task Lists and Duration*

Task	Task Description	Preceding Tasks	Duration (in days)
A	Development of Tic-Tac-Toe Game Platform and Implementation of Algorithms	—	30
B	Testing, Refinement and Optimization of Implemented Programs	A	31
C	Data Collection	B	60
D	Data Analysis	C	60

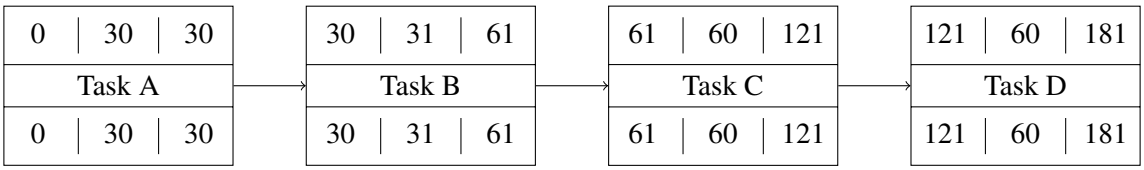

Figure 2. Network chart.

Table 3. *Task Schedule Management and Personnel Assignment Plan*

Task	Task Description	Personnel	Duration (in days)	EST	LST	ECT	LCT
A	Development of Tic-Tac-Toe Game Platform and Implementation of Algorithms	All Personnel	30	NOV 01 2019	NOV 30 2019	NOV 01 2019	NOV 30 2019
B	Testing, Refinement and Optimization of Implemented Programs	All Personnel	31	DEC 01 2019	DEC 31 2019	DEC 01 2019	DEC 31 2019
C	Data Collection	All Personnel	60	JAN 01 2019	FEB 29 2019	JAN 01 2019	FEB 29 2019
D	Data Analysis	All Personnel	61	MAR 01 2019	APR 31 2019	MAR 01 2019	APR 31 2019

Table 4. *Material and Equipment Sourcing Plan*

Protocol	Date/s Needed	Unit	Materials Needed	Potential Source	Remarks
Development of Tic-Tac-Toe Game Platform and Implementation of Algorithm	NOV-01 to 30	1	Laptop with Python	From Home	On Hand
Testing, Refinement and Optimization of Implemented Programs	DEC-01 to 31	1	Laptop with Python	From Home	On Hand
Data Collection and Analysis	JAN-01 to APR-31	1	Laptop with Python and R	From Home	On Hand

Table 5. *Risk Management Plan*

Risk	Safety Measure/Protocol
Development of Carpal Tunnel Syndrome	Frequent 5-minute breaks to relieve muscles
Electrocution	Proper usage of electronic devices
Loss of data	Upload of data into the cloud
Proprietary software trial expiry	Use of free and open-source software

APPENDIX B
RAW DATA

Table 6. *Random Table*

Random	Bits
of	data

APPENDIX C
STATISTICAL TABLES

Table 7. *Example of Organisms Sorted Through a Classifier System*

Aspect	Human	Fish	Bacterium
opposable thumbs	1	0	0
wings	0	0	0
gills	0	1	0
eyes	1	1	0
requires oxygen	1	1	1

APPENDIX D
DOCUMENTATION

(a) We.

(b) Are.

(c) Watching.

(d) You.

Figure 3. We are watching.