A COMPARATIVE ANALYSIS OF TEXTURE ANALYSIS METHODS ON ANT HEAD IMAGES

A Thesis Presented to

The Faculty of the Computer Science Department

by

Noah Gardner

In Partial Fulfillment

of Requirements for the Degree

Master of Science in Computer Science

Kennesaw State University

May 2022

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ABSTRACT

There is a large variety of ant species, and most species are diverse in terms of size, shape, behaviors, and especially skin (cuticle) textures. However, the significance of ant cuticle texture is not widely researched. This research employs modern machine learning methods such as texture analysis and classification with CNN and clustering to automatically group similar ant species to allow for the study of influences cuticle texture on ant ecology.

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To my family

Never fail to have this attitude of mind, go forward without hurry, learn the essence of things through frequent experiences, taking advantage of every occasion. Fight against all kinds of people and be aware of their mind. Follow a road that is a thousand leagues long one step at a time. Be without haste and be convinced that all these practices are the duty of a bushi. Be victorious today over what you were yesterday; tomorrow be victorious over your clumsiness and then also over your skill. Practice in accordance with what I have written without letting your mind deviate from the way.

Miyamoto Musashi [1]

[1] Miyamoto Musashi, The Book of Five Rings

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It is a bit cliche for an author to thank their family. Nevertheless, I would have given up a long time ago without the support of my family. So, I would like to thank my loving family for their support throughout the completion of my graduate degree. I would also like to thank Dr. Chih-Cheng Hung for his mentorship for my thesis and for his guidance in my other research projects. Next, I would like to thank Dr. Zhiling Long for his insights for machine learning and texture analysis. Finally, I would like to thank Dr. Coskun Tekes for providing the Lambda Labs GPU server for my experiments.

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1 CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Introduction

Insects comprise over half of the world's animal biodiversity [1]. Insects are vital to many ecosystem functions, including nutrient recycling, plant propagation, and maintenance of plant and animal communities [2], [3]. As technology advances, systems which can automatically analyze insect-based information are growing in demand by biologists. Due to the extensive number of insect species, manual exploration of insect-based information is difficult and often requires specialized expertise. Therefore, automated entomology is gaining attraction by both biologists and computer scientists and is expected to be a major contribution to the future of insect-based research [4]. One of the most commonly used data types for insect analysis is image data. To develop an image-based system for insect analysis, we can take advantage of existing work in general image processing and texture analysis methods.

Texture is an important feature in many applications, such as image processing, pattern recognition, and computer vision. Analysis of textures can be broken into three main categories: texture classification, texture segmentation, and texture synthesis [5]. The process of classifying a texture into a set of categories and relies on three different approaches. In this paper, we focus on a *model-based approach* which attempts to extract parameters to reveal common patterns and use those parameters to automatically distinguish between different textures [6].

In this work, we explore automated entomology specifically for ants. Although there is some work regarding grouping ants into categories of similar cuticle,

automated categorization has yet to become an active area of research. In general, the goal of automated insect classification methods is species indentification - *i.e.* the identification of species from a set of observations. Due to the large number of different ant species, large scale ant species indentification with standard classification methods is not feasible. Therefore, we must simplify the problem by either other classifying a certain subset of ant species or by applying categories to the entire set of ant species.

In many texture analysis methods, the general goal is to automatically categorize an object into a set of objects with similar texture-based features. The approach of texture analysis to categorize similarly texture-based objects corresponds well to the demands of ant identification. Texture analysis has shown promising results in related fields, such as plant identification [7]. With modern texture analysis methods, the categorization of ants can be automated and the results can be used to study the influence of cuticle texture on ant ecology.

1.2 Research Question

The overarching question that we wish to address by beginning this research is: *how does the texture of ant cuticle affect the ant ecology*? However, to even begin contemplating this question requires a substantial amount of preliminiary research. One point that is necessary to begin this research is to propose a method of group ants by texture. Additionally, due to the sheer number of ant species, an automated effort is necessary to group similar ant species. Therefore, we start our endeavor with a more straightforward research question: *are texture analysis methods able to group similar ant species*? By the end of this research, we will answer this question by demonstrating a variety of texture analysis methods and comparing their results on a custom dataset.

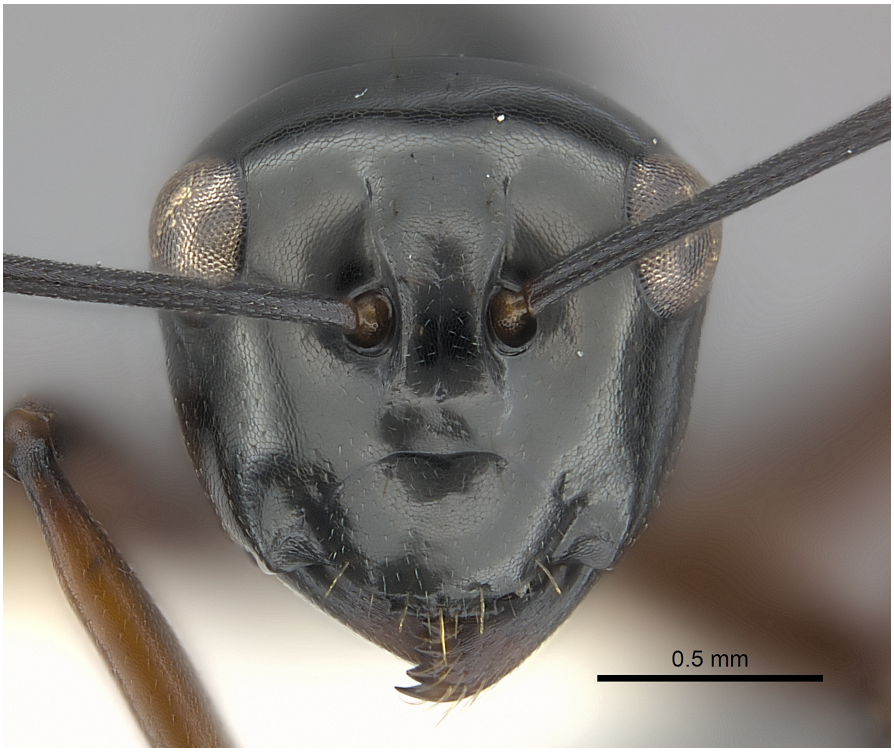

Figure 1: An example ant head image from AntWeb of species *Polyrhachis abbreviata* - specimen CASENT0217419 by Estella Ortega, from AntWeb, is licensed under CC BY 4.0.

1.3 Proposed Approach

In order to group similar ant species, we require mostly uniform images that depict the texture of the ant cuticle. We source our raw images from AntWeb [8], a database of ant head images. An example image is shown in Figure 1. In general, the ant head images are centered in the image, facing the front, and share a similar posture. However, some images may not be centered, show the ant head in a different orientation, or may have a drastically different resolution from the average image. With some data preprocessing methods, these ant head images are suitable for traditional methods of image classification.

1.4 Research Impact

The primary contribution of this research is the development of a unique dataset for ant cuticle texture classification. Additionally, we compare the results of state-of-the-art deep learning and texture analysis methods on our proposed dataset. The secondary contribution is the analysis of the results of these methods and data analysis.

2 CHAPTER 2: LITERATURE REVIEW

2.1 Insect Classification

In this section, we provide an overview of some insect classification methods.

Lim *et al.* apply a CNN-based algorithm for insect classification [9]. Lim *et al.* classify a subset of insect species and families based on the classes available in the ImageNet dataset [10]. ImageNet is a widely used dataset of images labeled by experts with millions of images and thousands of categories [10]. In the ImageNet dataset, there are some categories that specify the class of the insect on a species level, *e.g. monarch butterfly* and *ringlet butterfly* as well as some categories that specify the class of the insect on a family level, *e.g. ant*, *fly*, and *bee* [11]. Lim *et al.* use a modified AlexNet architecture and experiment on how different numbers of kernels affect the performance of the model [9]. Glick *et al.* employ a similar approach by classifying 277 insect classes from ImageNet using a hierarchical CNN [12]. The results from Lim *et al.* and Glick *et al.* suggest that a CNN is capable of differentiating between different hierarchical classes of insects. In our research, we are interested in the classification of ant images of a hierarchical level in-between species and family.

3 CHAPTER 3: METHODOLOGY

4 CHAPTER 4: EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Environment

5 CHAPTER 5: CONCLUSION

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