

# Discrimination between and geolocation of cotton and palmer amaranth using spectral and geometric data

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## ABSTRACT

The discrimination between cotton and the invasive Palmer Amaranth is imperative, as these weeds take precious resources away from cotton, resulting in diminished crop yield. There has been research into the discrimination between species of plants, including cotton and Palmer Amaranth, that focused on the use of aerial imagery and the derived RGB and near-infrared spectral data fed into a machine-learning algorithm to classify these plants based on the measurable differences in their spectral characteristics. We believe that this research can be expanded upon by using geometric data derived from the aerial imagery to classify cotton and non-cotton plants based on their physical characteristics as well as their spectral characteristics. This would also allow for accurate geolocation of the classified weeds for later removal. An autonomous drone with a GPS and two cameras attached, one RGB and the other RGN, will take a predetermined path to scan a crop field, and the resulting videos will be divided into individual frames. From these frames, both the RGBN spectral data and a 3D point cloud can be derived. The RGBN data and the geometric data will be fed into a machine learning algorithm for classification between the cotton and non-cotton plants, and then additional processing will be done to geolocate the weeds. With this additional information for classification, the discrimination between cotton and weeds can be more accurate, and the location of the weeds can be more exact.

**Keywords:** Palmer Amaranth, Cotton, Pigweed, Autonomous, Multi-spectral, Point Cloud, UAV, Machine Learning

## 1. INTRODUCTION

Begin the Introduction below the Keywords. The manuscript should not have headers, footers, or page numbers. It should be in a one-column format. References are often noted in the text and cited at the end of the paper.

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## 2. FORMATTING OF MANUSCRIPT COMPONENTS

This section describes the normal structure of a manuscript and how each part should be handled. The appropriate vertical spacing between various parts of this document is achieved in LaTeX through the proper use of defined constructs, such as `\section{}`. In LaTeX, paragraphs are separated by blank lines in the source file.

At times it may be desired, for formatting reasons, to break a line without starting a new paragraph. This situation may occur, for example, when formatting the article title, author information, or section headings. Line breaks are inserted in LaTeX by entering `\\` or `\linebreak` in the LaTeX source file at the desired location.

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Table 1. Fonts sizes to be used for various parts of the manuscript. Table captions should be centered above the table. When the caption is too long to fit on one line, it should be justified to the right and left margins of the body of the text.

Article title	16 pt., bold, centered
Author names and affiliations	12 pt., normal, centered
Keywords	10 pt., normal, left justified
Abstract Title	11 pt., bold, centered
Abstract body text	10 pt., normal, justified
Section heading	11 pt., bold, centered (all caps)
Subsection heading	11 pt., bold, left justified
Sub-subsection heading	10 pt., bold, left justified
Normal text	10 pt., normal, justified
Figure and table captions	9 pt., normal
Footnote	9 pt., normal
Reference Heading	11 pt., bold, centered
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Table 2. Margins and print area specifications.

Margin	A4	Letter
Top margin	2.54 cm	1.0 in.
Bottom margin	4.94 cm	1.25 in.
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Printable area	17.15 x 22.23 cm	6.75 x 8.75 in.

## 2.1 Title and Author Information

The article title appears centered at the top of the first page. The title font is 16 point, bold. The rules for capitalizing the title are the same as for sentences; only the first word, proper nouns, and acronyms should be capitalized. Avoid using acronyms in the title. Keep in mind that people outside your area of expertise might read your article. At the first occurrence of an acronym, spell it out, followed by the acronym in parentheses, e.g., noise power spectrum (NPS).

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The title and author information is immediately followed by the Abstract. The Abstract should concisely summarize the key findings of the paper. It should consist of a single paragraph containing no more than 250 words. The Abstract does not have a section number. A list of up to eight keywords should immediately follow the Abstract after a blank line. These keywords will be included in a searchable database at SPIE.

## 2.3 Body of Paper

The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material. See Sec. 3 for formatting instructions.

## 2.4 Appendices

Auxiliary material that is best left out of the main body of the paper, for example, derivations of equations, proofs of theorems, and details of algorithms, may be included in appendices. Appendices are enumerated with uppercase Latin letters in alphabetic order, and appear just before the Acknowledgments and References. Appendix A contains more about formatting equations and theorems.

## 2.5 Acknowledgments

In the Acknowledgments section, appearing just before the References, the authors may credit others for their guidance or help. Also, funding sources may be stated. The Acknowledgments section does not have a section number.

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Citations to the references are made using superscript numerals, as demonstrated in the above paragraph. One may also directly refer to a reference within the text, e.g., “as shown in Ref. ? ...”

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Footnotes\* may be used to provide auxiliary information that doesn't need to appear in the text, e.g., to explain measurement units. They should be used sparingly, however.

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\*Footnotes are indicated as superscript symbols to avoid confusion with citations.

### 3. SECTION FORMATTING

Section headings are centered and formatted completely in uppercase 11-point bold font. Sections should be numbered sequentially, starting with the first section after the Abstract. The heading starts with the section number, followed by a period. In LaTeX, a new section is created with the `\section{}` command, which automatically numbers the sections.

Paragraphs that immediately follow a section heading are leading paragraphs and should not be indented, according to standard publishing style.<sup>7</sup> The same goes for leading paragraphs of subsections and sub-subsections. Subsequent paragraphs are standard paragraphs, with 14-pt. (5 mm) indentation. An extra half-line space should be inserted between paragraphs. In LaTeX, this spacing is specified by the parameter `\parskip`, which is set in `spie.cls`. Indentation of the first line of a paragraph may be avoided by starting it with `\noindent`.

#### 3.1 Subsection Attributes

The subsection heading is left justified and set in 11-point, bold font. Capitalization rules are the same as those for book titles. The first word of a subsection heading is capitalized. The remaining words are also capitalized, except for minor words with fewer than four letters, such as articles (a, an, and the), short prepositions (of, at, by, for, in, etc.), and short conjunctions (and, or, as, but, etc.). Subsection numbers consist of the section number, followed by a period, and the subsection number within that section.

##### 3.1.1 Sub-subsection attributes

The sub-subsection heading is left justified and its font is 10 point, bold. Capitalize as for sentences. The first word of a sub-subsection heading is capitalized. The rest of the heading is not capitalized, except for acronyms and proper names.

### 4. FIGURES AND TABLES

Figures are numbered in the order of their first citation. They should appear in numerical order and on or after the same page as their first reference in the text. Alternatively, all figures may be placed at the end of the manuscript, that is, after the Reference section. It is preferable to have figures appear at the top or bottom of the page. Figures, along with their captions, should be separated from the main text by at least 0.2 in. or 5 mm.

Figure captions are centered below the figure or graph. Figure captions start with the figure number in 9-point bold font, followed by a period; the text is in 9-point normal font; for example, “Figure 3. Original image...”. See Fig. 1 for an example of a figure caption. When the caption is too long to fit on one line, it should be justified to the right and left margins of the body of the text.

Tables are handled identically to figures, except that their captions appear above the table.

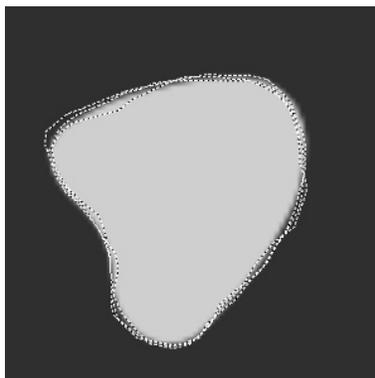


Figure 1. Figure captions are used to describe the figure and help the reader understand its significance. The caption should be centered underneath the figure and set in 9-point font. It is preferable for figures and tables to be placed at the top or bottom of the page. LaTeX tends to adhere to this standard.

## 5. MULTIMEDIA FIGURES - VIDEO AND AUDIO FILES

Video and audio files can be included for publication. See Tab. 3 for the specifications for the multimedia files. Use a screenshot or another .jpg illustration for placement in the text. Use the file name to begin the caption. The text of the caption must end with the text “<http://dx.doi.org/doi.number.goes.here>” which tells the SPIE editor where to insert the hyperlink in the digital version of the manuscript.

Here is a sample illustration and caption for a multimedia file:

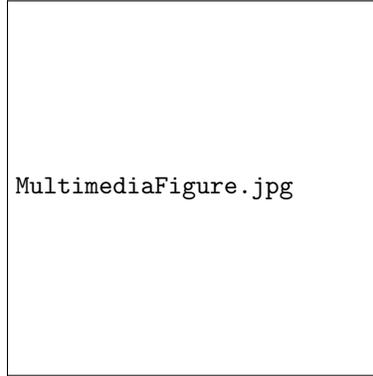


Figure 2. A label of “Video/Audio 1, 2, . . .” should appear at the beginning of the caption to indicate to which multimedia file it is linked . Include this text at the end of the caption: <http://dx.doi.org/doi.number.goes.here>

Table 3. Information on video and audio files that must accompany a manuscript submission.

Item	Video	Audio
File name	Video1, video2...	Audio1, audio2...
Number of files	0-10	0-10
Size of each file	5 MB	5 MB
File types accepted	.mpeg, .mov (Quicktime), .wmv (Windows Media Player)	.wav, .mp3

## APPENDIX A. MISCELLANEOUS FORMATTING DETAILS

It is often useful to refer back (or forward) to other sections in the article. Such references are made by section number. When a section reference starts a sentence, Section is spelled out; otherwise use its abbreviation, for example, “In Sec. 2 we showed...” or “Section 2.1 contained a description...”. References to figures, tables, and theorems are handled the same way.

### A.1 Formatting Equations

Equations may appear in line with the text, if they are simple, short, and not of major importance; e.g.,  $\beta = b/r$ . Important equations appear on their own line. Such equations are centered. For example, “The expression for the field of view is

$$2a = \frac{(b + 1)}{3c}, \quad (1)$$

where  $a$  is the ...” Principal equations are numbered, with the equation number placed within parentheses and right justified.

Equations are considered to be part of a sentence and should be punctuated accordingly. In the above example, a comma follows the equation because the next line is a subordinate clause. If the equation ends the sentence, a period should follow the equation. The line following an equation should not be indented unless it is

meant to start a new paragraph. Indentation after an equation is avoided in LaTeX by not leaving a blank line between the equation and the subsequent text.

References to equations include the equation number in parentheses, for example, “Equation (1) shows ...” or “Combining Eqs. (2) and (3), we obtain...” Using a tilde in the LaTeX source file between two characters avoids unwanted line breaks.

## A.2 Formatting Theorems

To include theorems in a formal way, the theorem identification should appear in a 10-point, bold font, left justified and followed by a period. The text of the theorem continues on the same line in normal, 10-point font. For example,

**Theorem 1.** For any unbiased estimator...

Formal statements of lemmas and algorithms receive a similar treatment.

## ACKNOWLEDGMENTS

This unnumbered section is used to identify those who have aided the authors in understanding or accomplishing the work presented and to acknowledge sources of funding.

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