Machine Learning Techniques for Gesture Recognition

Carlos Antonio Caceres

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
In
Mechanical Engineering

Alfred L. Wicks, Chair
John P. Bird
Craig A. Woolsey

September 9th, 2014
Blacksburg, VA

Keywords: Gesture Recognition, Smart Prosthetic, Hidden Markov Model, Support Vector Machines, Dynamic Time Warping
Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: Motor Unit Recruitment Strategies During Deep Muscle Pain
Copyright Holder: N. Shapiro
Publication Status: Published
Publisher: The alchemist
Place of Publication:
Publication Year: 2009
Description of Work: Published Research Paper
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

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[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"

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Describe the **Nature** of Your Intended Use of the Copyrighted Work:

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[-] Work to be used has been previously PUBLISHED  
[-] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

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[-] Only limited and reasonable portions will be used

Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

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[-] Use of the work has the potential to create or improve the market for the work  
[-] Proper attribution will be given with the intended use
The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

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**Other Important Criteria:** This fair use form applies to figure 4 on this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

Based on the information and justification I have provided above, I, Carlos Caceres, am asserting this use is **FAIR** under Section 107 of the U.S. Copyright Code.

Signature: ______________________________________

Date of Signature: ________________________________

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### Fair Use Evaluation Documentation

Compiled using the **Fair Use Evaluator** [cc] 2008 Michael Brewer & the Office for Information Technology Policy, [http://librarycopyright.net/fairuse/](http://librarycopyright.net/fairuse/)

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<tr>
<td>Title of Work Used</td>
<td>Soft computing based feature selection for environmental sound classification</td>
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**Describe the Purpose and Character of Your Intended Use:**

- [+] Use is not-for-profit
- [+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"

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Describe the **Nature** of Your Intended Use of the Copyrighted Work:

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The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Fair Unfair

Other Important Criteria: This fair use form applies to figures 16 and 17 of this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

Based on the information and justification I have provided above, I, Carlos Caceres, am asserting this use is FAIR under Section 107 of the U.S. Copyright Code.

Signature: ___________________________
Date of Signature: ___________________

*Disclaimer: This document is intended to help you collect, organize & archive the information you might need to support your fair use evaluation. It is not a source of legal advice or assistance. The results are only as good as the input you have provided by are intended to suggest next steps, and not to provide a final judgment. It is recommended that you share this evaluation with a copyright specialist before proceeding with your intended use.
| **Name:** | Carlos Caceres |
| **Job Title:** | Graduate Research Assistant |
| **Institution:** | Virginia Polytechnic Institute and State University |
| **Title of Work Used:** | The Movement Error Rate for Evaluation of Machine Learning Methods for sEMG-based Hand Movement Classification |
| **Copyright Holder:** | A. Gijsberts, M. Atzori, C. Castellini, H. Muller, and B. Caputo |
| **Publication Status:** | Published |
| **Publisher:** | IEEE |
| **Place of Publication:** | |
| **Publication Year:** | 2014 |
| **Description of Work:** | Published Research Paper. |
| **Date of Evaluation:** | August 25, 2014 |
| **Date of Intended Use:** | September 9, 2014 |

Describe the **Purpose** and Character of Your Intended Use:

[+] Use is not-for-profit
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Describe the **Nature** of Your Intended Use of the Copyrighted Work:

[-] Work to be used has been previously PUBLISHED
[-] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

![Fair Unfair Scale]

Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

[-] Only limited and reasonable portions will be used

![Fair Unfair Scale]

Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

[-] Use of the work has the potential to create or improve the market for the work
[-] Proper attribution will be given with the intended use

![Fair Unfair Scale]
The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Fair | Unfair
---|---
✔️ | ☐
☐ | ☐
☐ | ☐
☐ | ☐
☐ | ☐
☐ | ☐

**Other Important Criteria:** This fair use form applies to figures 13 and 40 of this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

Based on the information and justification I have provided above, I, Carlos Caceres, am asserting this use is **FAIR** under Section 107 of the U.S. Copyright Code.

Signature: ____________________________
Date of Signature: ______________________

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Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: The Sign Language Alphabet
Copyright Holder: HowStuffWorks
Publication Status: Unpublished
Publisher:
Place of Publication:
Publication Year: 2007
Description of Work: Webpage image describing American Sign Language
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the **Purpose** and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"

Fair Use Evaluation Documentation

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Describe the **Nature** of Your Intended Use of the Copyrighted Work:

[+] Work to be used has been previously PUBLISHED  
[+] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

Fair ✅ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | Unfair

Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

[+] Only limited and reasonable portions will be used

Fair ✅ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | Unfair

Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

[+] Use of the work has the potential to create or improve the market for the work  
[+] Proper attribution will be given with the intended use

Fair ✅ | ✇ | ✗ | ✗ | ✗ | ✗ | ☐ | Unfair
The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

| Fair |  |  |  |  |  |  |  |  | Unfair |
|------|---|---|---|---|---|---|---|---|
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Signature: ________________________________

Date of Signature: __________________________

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Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: A decomposition algorithm for surface electrode-array electromyogram
Copyright Holder: G. A. Garcia, R. Okuno, and K. Azakawa
Publication Status: Published
Publisher: IEEE
Place of Publication:
Publication Year: 2005
Description of Work: Published Research Paper
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the **Purpose** and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"

[✔️] Fair [ ][ ][ ][ ][ ][ ] Unfair
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

- [+] Work to be used has been previously PUBLISHED
- [+] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

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Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

- [+] Use of the work has the potential to create or improve the market for the work
- [+] Proper attribution will be given with the intended use
The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Fair [ ] [ ] [ ] [ ] [ ] [ ] [ ] Unfair

Other Important Criteria: This fair use form applies to figure 5 of this thesis.

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Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: An Investigation of Electromyographic (EMG) Control of Dextrous Hand Prostheses for Transradian Amputees
Copyright Holder: A. Hussein Ali
Publication Status: Published
Publisher: IEEE
Place of Publication:
Publication Year: 2013
Description of Work: Published Research Paper.
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the Purpose and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for “criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research”
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

- [+] Work to be used has been previously PUBLISHED
- [+] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

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Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

- [+] Only limited and reasonable portions will be used

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Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

- [+] Use of the work has the potential to create or improve the market for the work
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The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

| Fair | | | | | | | Unfair |

Other Important Criteria: This fair use applies to figure 20 of this thesis.

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Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: Building the Ninapro database: A resource for the biorobotics community
Copyright Holder: M. Atzori, A. Gijsberts, S. Heynen, A. M. Hager, O. Deriaz, P. van der Smagt, C. Castellini, B. Caputo, and H. Muller
Publication Status: Published
Publisher: IEEE
Place of Publication:
Publication Year: 2012
Description of Work: Published Research Paper.
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the **Purpose** and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

- Work to be used has been previously **PUBLISHED**
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**Fair**

![Unfair](image)

Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

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**Fair**

![Unfair](image)

Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

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**Fair**

![Unfair](image)
The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

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**Other Important Criteria:** This fair use form applies to figure 12 on this thesis.

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Signature: ____________________________

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Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: Dynamic Time Warping
Copyright Holder: M. Müller
Publication Status: Published
Publisher: Information Retrieval for Music and Motion
Place of Publication: Berlin
Publication Year: 2007
Description of Work: Published Research Paper.
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the Purpose and Character of Your Intended Use:

[+] Use is not-for-profit
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**Describe the Nature of Your Intended Use of the Copyrighted Work:**

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The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Fair

Unfair

Other Important Criteria: This fair use form applies to figures 8 and 9 of this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

Based on the information and justification I have provided above, I, Carlos Caceres, am asserting this use is FAIR under Section 107 of the U.S. Copyright Code.

Signature: __________________________________________

Date of Signature: __________________________________

*Disclaimer: This document is intended to help you collect, organize & archive the information you might need to support your fair use evaluation. It is not a source of legal advice or assistance. The results are only as good as the input you have provided by are intended to suggest next steps, and not to provide a final judgment. It is recommended that you share this evaluation with a copyright specialist before proceeding with your intended use.
Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: Evaluating the feasibility of EMG and bend sensors for classifying hand gestures
Copyright Holder: S. A. R. Tidwell S. Karlaputi, R. Akl, K. Kavi and D. Struble
Publication Status: Published
Publisher: Proceedings of the International Conference on Multimedia and Human Computer Interaction
Place of Publication:
Publication Year: 2013
Description of Work: Webpage image describing American Sign Language
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the Purpose and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for “criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research”

[ ] [ ] [ ] [ ] [ ] [ ] [ ]
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

- Work to be used has been previously PUBLISHED
- Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

---

**Fair** [✔] [☐] [☐] [☐] [☐] 

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Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

- Only limited and reasonable portions will be used

---

**Fair** [✔] [☐] [☐] [☐] [☐] 

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Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

- Use of the work has the potential to create or improve the market for the work
- Proper attribution will be given with the intended use

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**Fair** [✔] [☐] [☐] [☐] [☐]
The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Fair  |  |  |  |  |  |  | Unfair

**Other Important Criteria:**  This fair use form applies to figure 2 of this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

Based on the information and justification I have provided above, I, Carlos Caceres, am asserting this use is FAIR under Section 107 of the U.S. Copyright Code.

Signature: _____________________________

Date of Signature: _____________________________

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Describe the **Purpose** and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

- [+] Work to be used has been previously PUBLISHED
- [+] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)

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Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

- [+] Only limited and reasonable portions will be used

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Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

- [+] Use of the work has the potential to create or improve the market for the work
- [+] Proper attribution will be given with the intended use

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The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Fair Unfair

Other Important Criteria: This fair use form applies to figure 6 of this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

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Date of Signature: ________________________________

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Name: Carlos Caceres
Job Title: Graduate Research Assistant
Institution: Virginia Polytechnic Institute and State University
Title of Work Used: Gesture Recognition for Musician Computer Interaction
Copyright Holder: N. E. Gillian
Publication Status: Published
Publisher: Queen's University Belfast
Place of Publication: Ireland
Publication Year: 2011
Description of Work: Published Research Paper.
Date of Evaluation: August 25, 2014
Date of Intended Use: September 9, 2014

Describe the **Purpose** and Character of Your Intended Use:

[+] Use is not-for-profit
[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"
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The Average "Fairness Level," Based on Your Rating of Each of the 4 Factors, Is:

[see tool disclaimer for important clarifying information]:

Other Important Criteria: This fair use form applies to figures 7, 10, 11, and 18 of this thesis.

Use of the work is limited to images which help illustrate the specific concepts in Master's Thesis. Said thesis will not be used for any type of financial gains and thus will not take away from the original work.

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Signature: 

Date of Signature: 

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**Name:**  
Carlos Caceres  

**Job Title:**  
Graduate Research Assistant  

**Institution:**  
Virginia Polytechnic Institute and State University  

**Title of Work Used:**  
Hand Gesture Recognition Research Based on Surface EMG Sensors and 2D-accelerometers  

**Copyright Holder:**  

**Publication Status:**  
Published  

**Publisher:**  
Wearable Computers  

**Place of Publication:**  
2007  

**Description of Work:**  
Published Research Paper  

**Publication Year:**  
2007  

**Date of Evaluation:**  
August 25, 2014  

**Date of Intended Use:**  
September 9, 2014

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**The Average "Fairness Level,"
Based on Your Rating of Each of the 4 Factors, Is:**

[see tool disclaimer for important clarifying information]:

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**Other Important Criteria:** This fair use form applies to figure 15 of this thesis.

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Date of Signature: ________________________________

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<td>Virginia Polytechnic Institute and State University</td>
</tr>
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<td>Title of Work Used:</td>
<td>Amputation Rehabilitation and Prosthetic Restoration. From Surgery to Community Reintegration</td>
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<td>Copyright Holder:</td>
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[see tool disclaimer for important clarifying information]:

Fair   Unfair

Other Important Criteria:

This fair use form applies to figure 3 of this thesis.

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Signature: ____________________________
Date of Signature: ____________________________

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