

# Agricultural Crop Monitoring with Computer Vision

James Ian Burns

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

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

September 11, 2014  
Blacksburg, Virginia

Keywords: Computer Vision, Machine Learning, Agriculture, Multispectral, Automation  
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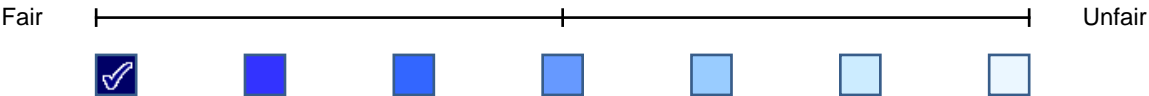
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Leafsnap: A Computer Vision System for Automatic Plant Species Identification
<b>Copyright Holder:</b>	Neeraj Kumar/Springer-Verlag Berlin Heidelberg
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Springer Berlin Heidelberg
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2012
<b>Description of Work:</b>	Reuse of example leaf segmentation image for comparison to other literature.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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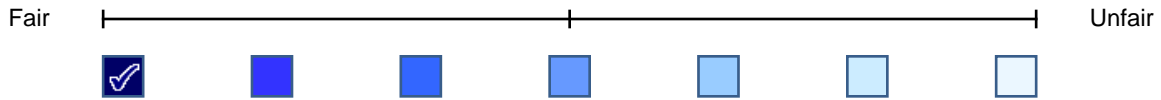
Describe the **Purpose** and Character of Your Intended Use:

[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"  
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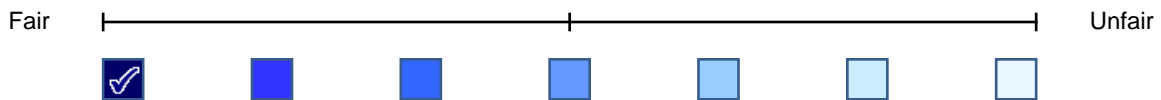
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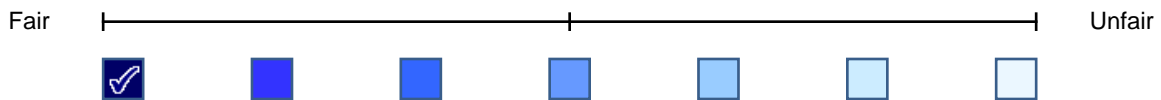
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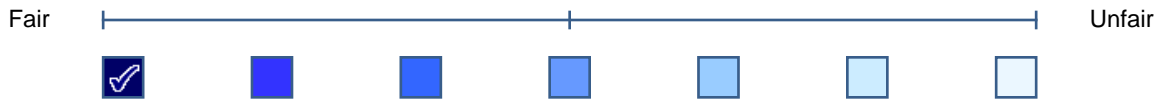
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The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[\[see tool disclaimer for important clarifying information\]:](#)



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

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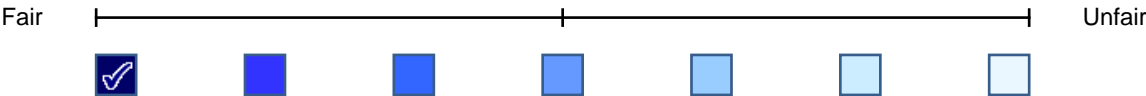
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Neural Networks and Low-Cost Optical Filters for Plant Segmentation
<b>Copyright Holder:</b>	Lessius Mechelen/MIR Labs
<b>Publication Status:</b>	Published
<b>Publisher:</b>	IADIS
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2011
<b>Description of Work:</b>	Reuse of example plant segmentation images for comparison to other literature.
<b>Date of Evaluation:</b>	September 9, 2014
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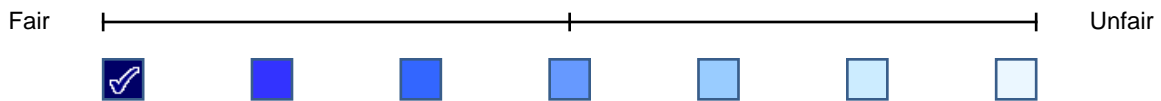
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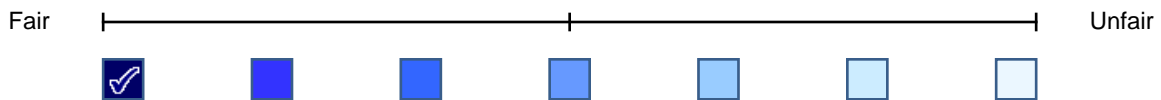
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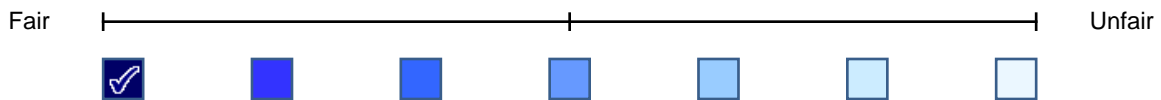
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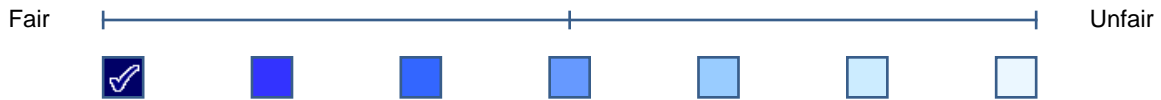
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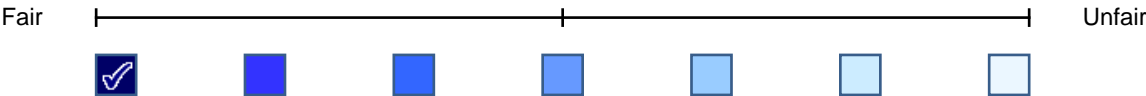
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Segmentation of Plant from Background Using Neural Network Approach
<b>Copyright Holder:</b>	Dev S Shrestha/ASABE
<b>Publication Status:</b>	Published
<b>Publisher:</b>	ASABE
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2003
<b>Description of Work:</b>	Reuse of example plant segmentation images for comparison to other literature.
<b>Date of Evaluation:</b>	September 9, 2014
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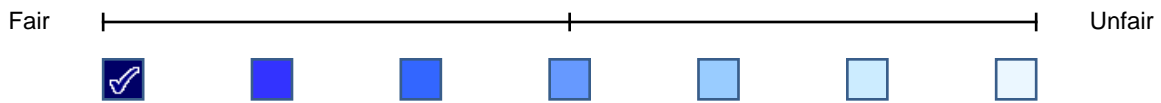
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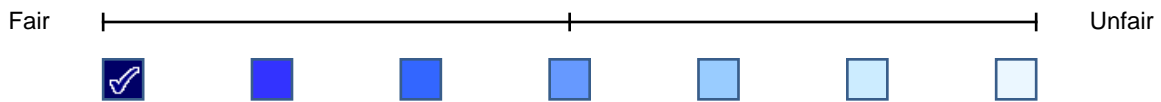
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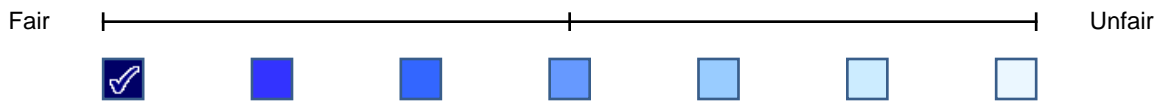
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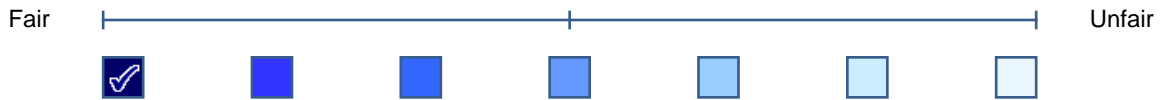
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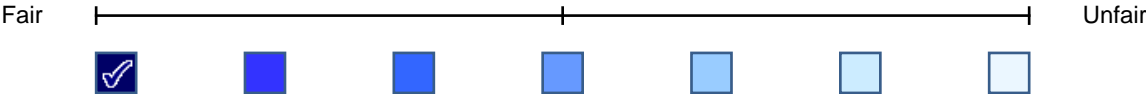
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	An Integrated Image Processing System for Leaf Disease Detection and Diagnosis
<b>Copyright Holder:</b>	Mohammed El-Helly/IICAI
<b>Publication Status:</b>	Published
<b>Publisher:</b>	IICAI
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2003
<b>Description of Work:</b>	Reuse of unhealthy leaf images for examples.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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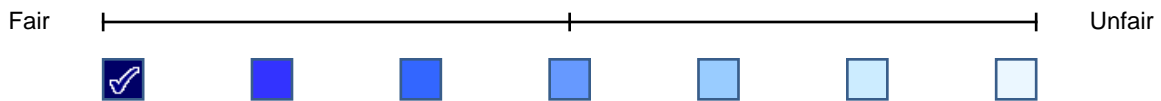
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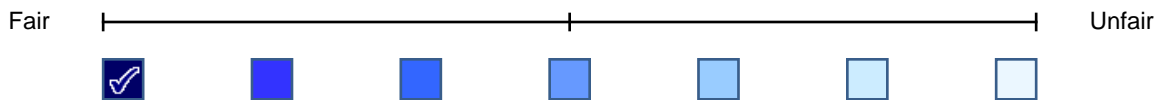
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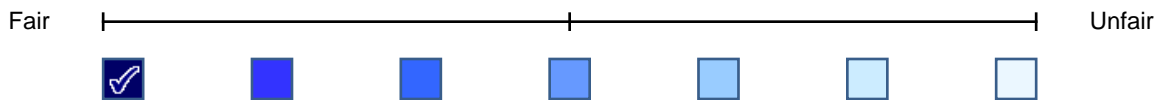
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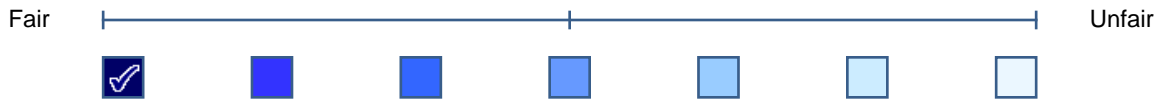
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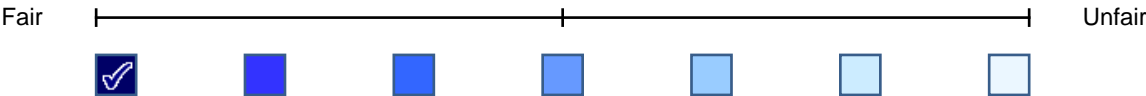
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Identification of citrus disease using color texture features and discriminant analysis
<b>Copyright Holder:</b>	R. Pydipati/Elsevier B.V.
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Elsevier B.V.
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2006
<b>Description of Work:</b>	Reuse of picture of data collection setup for comparison to current work.
<b>Date of Evaluation:</b>	September 9, 2014
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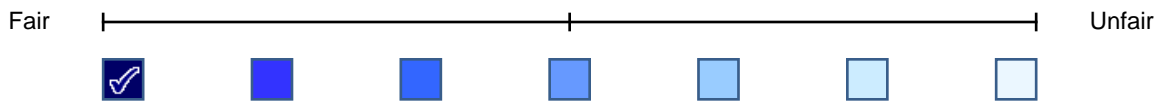
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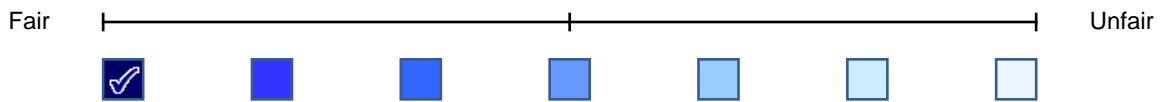
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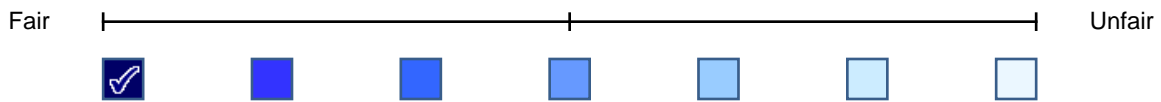
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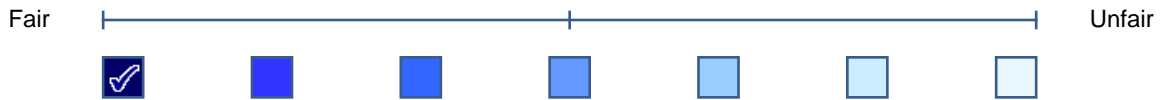
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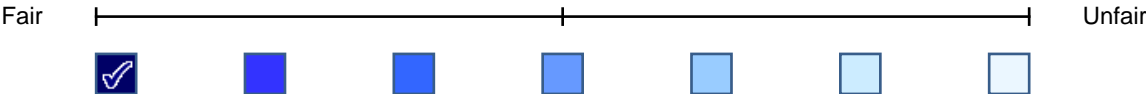
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<b>Title of Work Used:</b>	Bio-inspired feature selection to select informative image features for determining water content of cultured Sunagoke moss
<b>Copyright Holder:</b>	Yusuf Hendrawan/Elsevier B.V.
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Elsevier B.V.
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2011
<b>Description of Work:</b>	Reuse of example plant images for discussion of methods.
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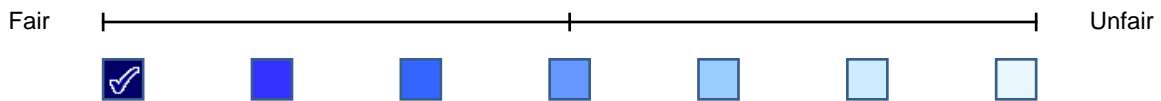
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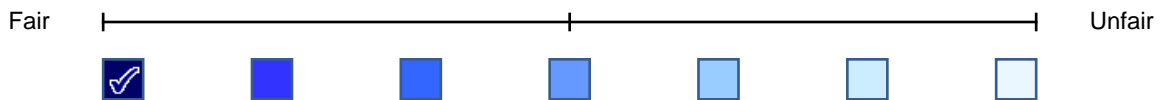
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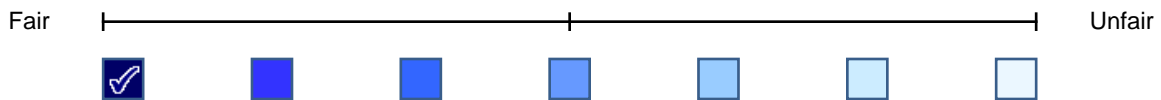
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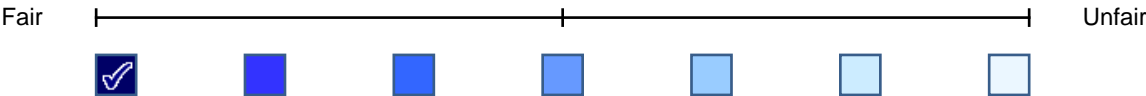
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Hyperspectral image analysis for water stress detection of apple trees
<b>Copyright Holder:</b>	Yunseop Kim/ Elsevier B.V
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Elsevier B.V
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2011
<b>Description of Work:</b>	Reuse of hyperspectral response plots for comparison to current work.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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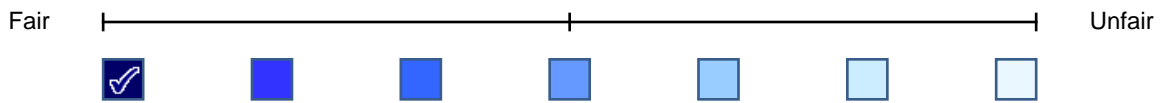
Describe the **Purpose** and Character of Your Intended Use:

[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"  
[+] Use is transformative, i.e. it uses the existing work in a new way (creates an index to the work) or for a new purpose (parody, pastiche, instructional materials, etc.) Transformative works are favored because the purpose of U.S. Copyright Law is to encourage the development and dissemination of new knowledge to benefit the public and thereby advance learning.  
[+] Use is not-for-profit  
[+] Use is clearly defined and is restricted in scope (limited duration, not iterative, restricted access, etc.)



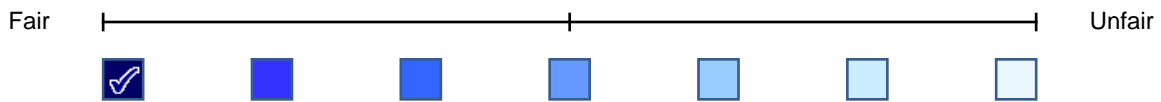
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

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



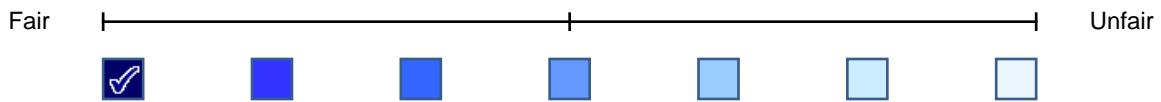
Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

[+] Only limited and reasonable portions will be used  
[+] Only the amount required to achieve the stated, socially-beneficial purpose or objective will be used (be that educational, artistic, scholarly, journalistic, etc.)



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

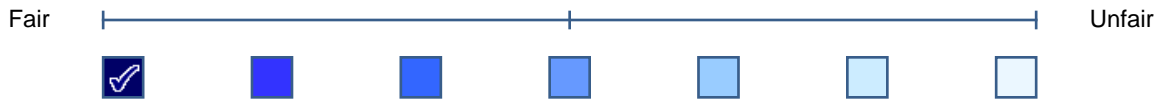
[+] A market for the work as it will be used is absent or is negligible & use of the work will have little or no negative impact on its value or potential value  
[+] Use of the work minimizes the potential for unauthorized use that could impact its value (i.e. steps are taken to ensure the content is not used outside of the stated purpose or audience)  
[+] 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:

[\[see tool disclaimer for important clarifying information\]:](#)



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

Signature: \_\_\_\_\_

Date of Signature: \_\_\_\_\_

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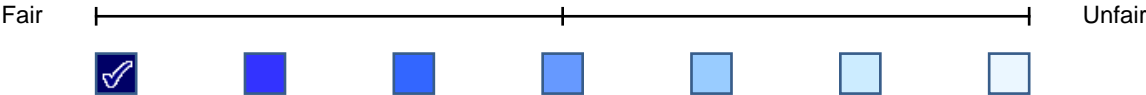
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Support Vector Machines
<b>Copyright Holder:</b>	Bülent Üstün
<b>Publication Status:</b>	Unpublished
<b>Publisher:</b>	
<b>Place of Publication:</b>	
<b>Publication Year:</b>	
<b>Description of Work:</b>	Reusing a nice illustration of support vector machines from his website: <a href="http://www.cac.science.ru.nl/people/ustun/">http://www.cac.science.ru.nl/people/ustun/</a> .
<b>Date of Evaluation:</b>	September 12, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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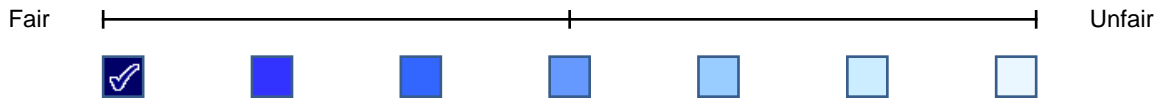
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[+] Use is for "criticism, comment, news reporting, teaching, (including multiple print copies for classroom use), scholarship or research"  
[+] Use is not-for-profit



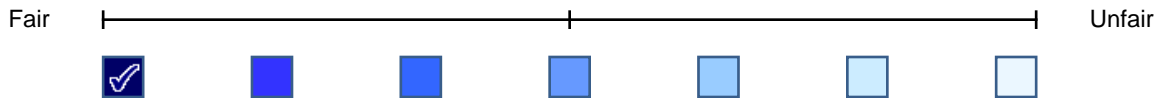
Describe the **Nature** of Your Intended Use of the Copyrighted Work:

[+] Work to be used contains limited new knowledge, content, or creative expression (in relation to previously copyrighted works)  
[+] Work to be used is primarily of a factual nature (non-fiction, collection of facts, etc.)



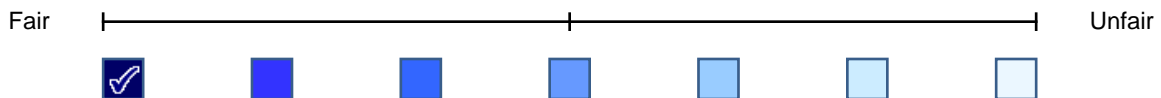
Describe the **Amount** of Your Intended Use in Relation to the Copyrighted Work as a Whole:

[+] Only limited and reasonable portions will be used  
[+] The portion used is not the "heart" of the work (the portion considered most central to the work as a whole)  
[+] Only the amount required to achieve the stated, socially-beneficial purpose or objective will be used (be that educational, artistic, scholarly, journalistic, etc.)



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

[+] Use of the work minimizes the potential for unauthorized use that could impact its value (i.e. steps are taken to ensure the content is not used outside of the stated purpose or audience)  
[+] 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

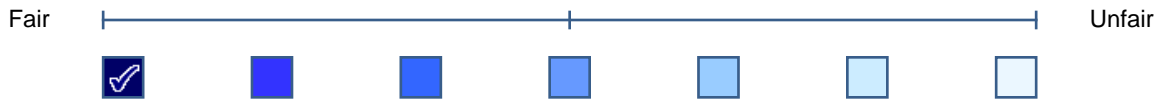




The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[\[see tool disclaimer for important clarifying information\]:](#)



Based on the information and justification I have provided above, I, James Burns, am **UNDECIDED** whether this use is fair under Section 107 of the U.S. Copyright Code.

Signature: \_\_\_\_\_

Date of Signature: \_\_\_\_\_

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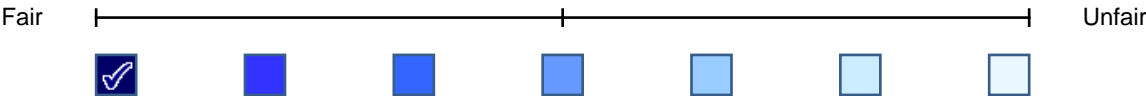
---

<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	AD-080GE Digital 2CCD Progressive Scan Multi-Spectral Camera User's Manual
<b>Copyright Holder:</b>	JAI Ltd.
<b>Publication Status:</b>	Published
<b>Publisher:</b>	JAI Ltd.
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2012
<b>Description of Work:</b>	Reuse of spectral response plots for the cameras that are used in the current work.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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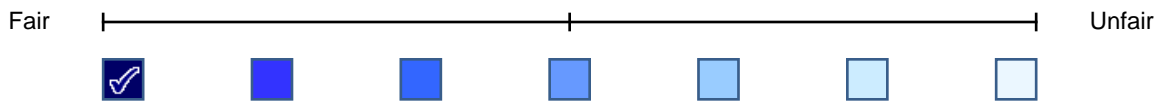
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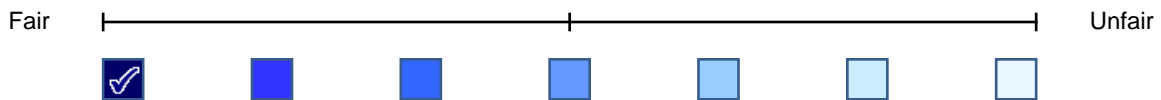
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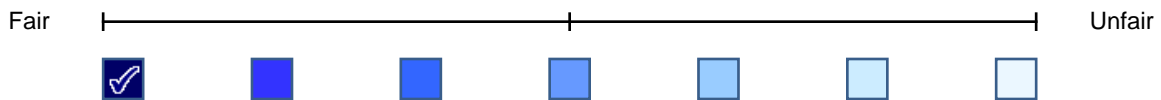
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Describe the **Effect** of Your Intended Use on the Potential Market or Value of the Copyrighted Work:

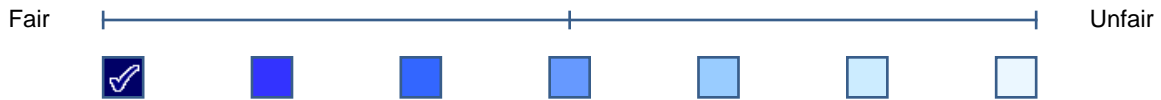
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The Average **"Fairness Level,"** Based on Your Rating of Each of the 4

Factors, Is:

[\[see tool disclaimer for important clarifying information\]:](#)



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

Signature: \_\_\_\_\_

Date of Signature: \_\_\_\_\_

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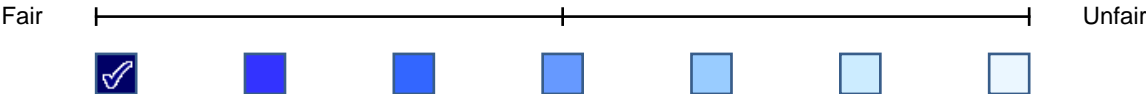
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	SU320HX-1.7RT Mil-Rugged High Sensitivity InGaAs SWIR Camera with Advanced Dynamic Range Enhancements
<b>Copyright Holder:</b>	Sensors Unlimited, Inc.
<b>Publication Status:</b>	Published
<b>Publisher:</b>	UTC Aerospace Systems
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2014
<b>Description of Work:</b>	Reuse of spectral response plots for the cameras that are used in the current work.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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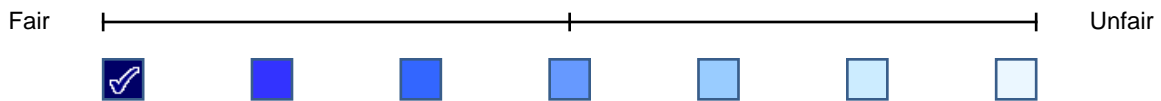
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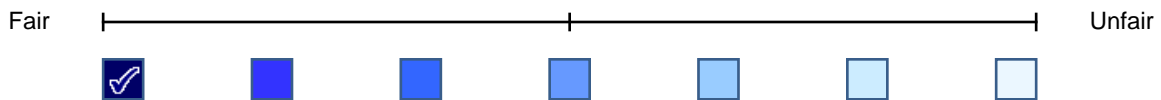
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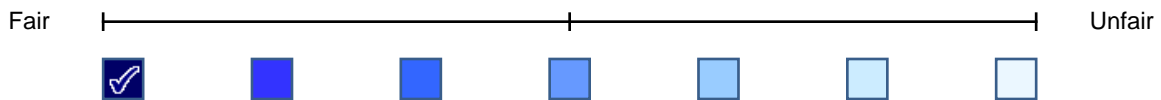
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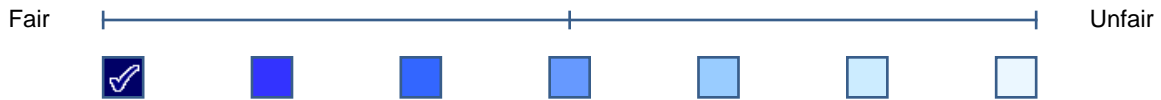
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[\[see tool disclaimer for important clarifying information\]:](#)



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Signature: \_\_\_\_\_

Date of Signature: \_\_\_\_\_

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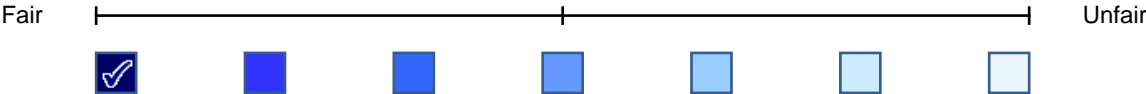
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Gobi-384: Smart and affordable Gobi-384 simplifies the way you work
<b>Copyright Holder:</b>	Xenics
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Xenics
<b>Place of Publication:</b>	
<b>Publication Year:</b>	2008
<b>Description of Work:</b>	Reuse of spectral response plots for the cameras that are used in the current work.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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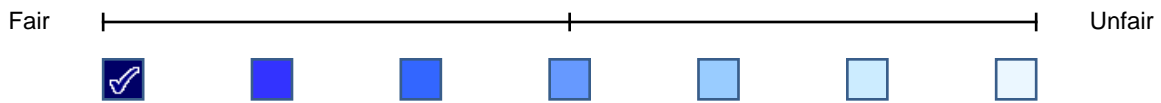
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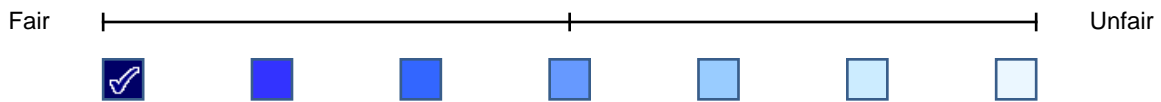
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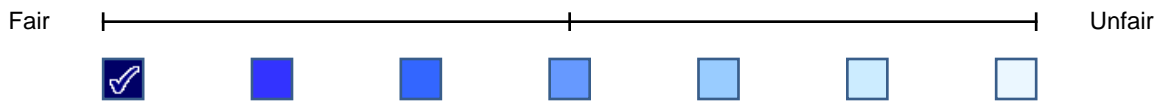
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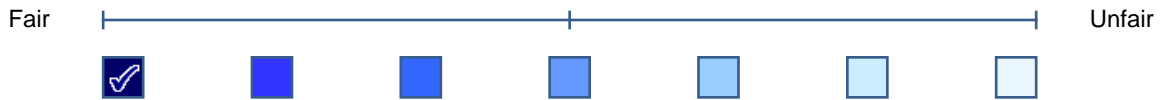
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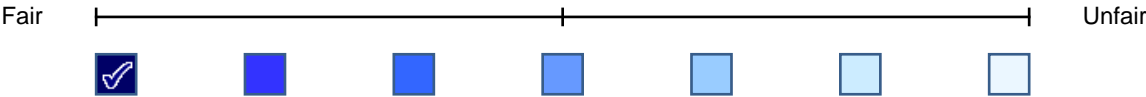
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<b>Name:</b>	James Burns
<b>Job Title:</b>	Graduate Researcher
<b>Institution:</b>	Virginia Polytechnic Institute and State University
<b>Title of Work Used:</b>	Solar Radiation Measurements
<b>Copyright Holder:</b>	Paulescu/Springer-Verlag London
<b>Publication Status:</b>	Published
<b>Publisher:</b>	Springer London
<b>Place of Publication:</b>	London
<b>Publication Year:</b>	2013
<b>Description of Work:</b>	Reuse of spectral measurement plot of sunlight for comparison with the light source of the current work.
<b>Date of Evaluation:</b>	September 9, 2014
<b>Date of Intended Use:</b>	September 11, 2014

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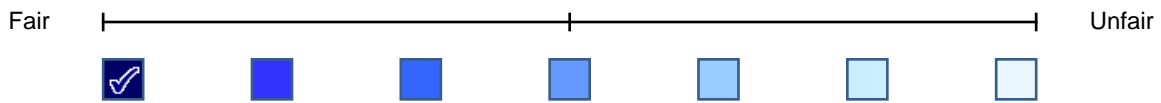
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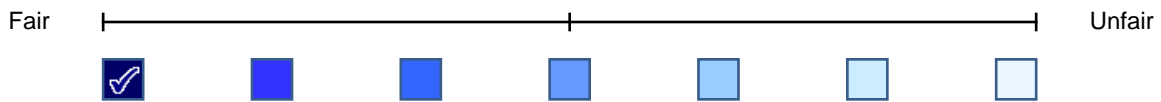
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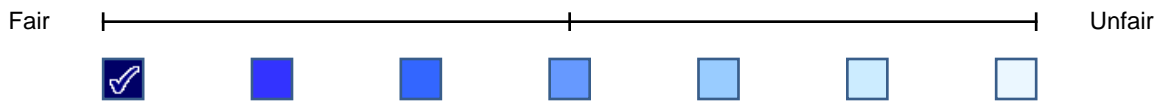
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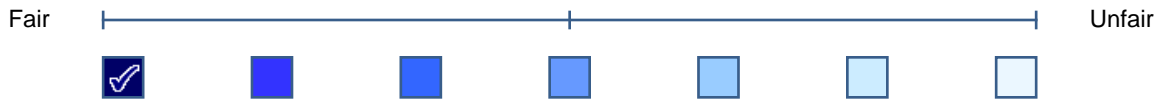
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