行政院國家科學委員會專題研究計畫　期中進度報告

數位相機之影像處理：自動白平衡，自動曝光，自動聚焦 (1/2)

計畫類別：個別型計畫
計畫編號：NSC93-2213-E-002-073-
執行期間：93 年 08 月 01 日至 94 年 07 月 31 日
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計畫主持人：傅楸善

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行政院國家科學委員會專題研究計畫成果報告

數位相機之影像處理：自動白平衡，自動曝光，自動聚焦(1/2)

Image Processing for Digital Cameras: Auto White Balance, Auto Exposure, Auto Focus (1/2)

計畫編號：NSC 93-2213-E-002 -073-
執行期限：93 年 8 月 1 日至 94 年 7 月 31 日
主持人：傅楸善　台灣大學資訊工程系

一、中文摘要

本計畫為期三年，目的是研究利用電腦視覺與數位影像處理方法，進行數位相機自動白平衡、自動曝光、自動聚焦之研究。在計畫執行期間，我們將探討最佳的攝影機與光源和環境及景物的互動，第一年研究最佳色彩反應之自動白平衡方法；第二年控制最適當的光圈大小及快門速度並且考慮閃光燈的影響以完成自動曝光；第三年研究各種聚焦感測模組及方法，以發展自動聚焦程式及演算法，以突破日本及美國在這三方面的專利及技術障礙，提高我國的數位靜態相機及視訊攝影機在國際市場的競爭力。

關鍵詞：自動白平衡、自動曝光、自動聚焦、電腦視覺、數位影像處理

Abstract

This is a three-year project to use computer vision and digital image processing methods for auto white balance, auto exposure, and auto focus of digital cameras. We will study the best camera, light source, environment, and scene interaction. In the first year, we will develop the auto white balance method for optimum color response. In the second year, we will control the optimum aperture size and shutter speed and the influence of flash to achieve auto exposure. In the third year, we will research various auto focus sensing modules and methods to develop programs and algorithms for auto focus. We would like to break the patent and technology barriers of Japanese and American companies and to enhance and competitiveness of Taiwan companies in international markets.

Keywords: Auto White Balance, Auto Exposure, Auto Focus, Computer Vision, Digital Image Processing

二、緣由與目的

數位靜態相機 (Digital Still Camera) 及視訊攝影機 (Digital Video Camcorder) 將大部份取代現有的軟片相機，相機是很大的市場，國外在美國有柯達 (Kodak)；日本有 Nikon, Canon, Minolta, Sony, Panasonic, Fujifilm, Konica, … 等；歐洲有 Leica, Zeiss, Hasselblad, Agfa, … 等。台灣只要在數位相機方面佔一席之地，可以造就出像柯達的國際大廠。

數位相機目前用的感應器在中低階大部份用的是互補式金屬氧化物半導體 (CMOS: Complementary Metal Oxide Semiconductor)，高階相機則大部份用電荷耦合裝置 (CCD: Charge-Coupled Device) [26]。 國內已有廠商發展到兩百萬像素 CMOS 感應器，CCD 感應器則全部操縱在美日廠商的手上。國內如凌陽，聯詠…等廠商，已發展出 Sunplus 533, 536, 5000 等數位靜態相機使用的數位處理器 (DSP: Digital Signal Processing) 晶片，可以和美國德州儀器的 DM320 或以色列 Zoran 的 COACH (Camera On A Chip) 7 競爭。其中最關鍵的技術就是自動白平衡，自動曝光，自動聚焦等技術。

國外史丹福大學有一個很大的可程式數位相機計畫 (Programmble Digital

Camera Project, http://isl.stanford.edu/~abbas/group/) 有 Canon, Kodak, Hewlett-Packard, Agilent Technolgies 等工業界合作廠商。本實驗室希望能與他們並駕齊驅, 目前已和光寶科技, 智基科技, 英華達, 致伸科技, 建興電子, 聚興科技, 全譜電腦合作。

第二年, 我們研究自動曝光。自動曝光主要調整三個參數: 光圈孔徑的大小 (Aperture f-number), 快門的速度 (Shutter Speed) 或曝光時間的長短, 和自動增益控制 (Automatic Gain Control) [29]。因為曝光量就是光亮度和曝光時間長度的乘積。場景往往包括不同的亮度區域, 因此構成場景亮度比 (SLR: Subject Luminance Ratio), 可以分成非常高 (2048:1), 高 (512:1), 平均 (128:1), 低 (32:1), 和非常低 (8:1) 。場景亮度比會影響到曝光值 (EV: Exposure Value) 。曝光值每差一, 曝光量就差 2 倍; 例如: 快門設在 1/500 秒, 光圈設在 f/8, 則曝光值為 15; 光圈大小不變在 f/8, 快門設在 1/1000 秒, 則曝光值為 16, 此時曝光量為原來的一半。

若快門設在 1/500 秒, 光圈設在 f/11, 則曝光值為 16, 此時曝光量為原來的一半。光圈 f-number 每格差 1.4= 倍是因為它是焦距和光圈孔徑的直徑比, 因此, 直徑差 1.4 倍, 面積就差 2 倍。

眩光 (Flare or Glare) 是透鏡間或相機機體中的不要的多餘的反射的光; 眩光也會影響到自動曝光, 因為眩光會影響到影像照明比例 (IIR: Image Illumination Ratio) 。如何適當克服或因應眩光以達到最佳的自動曝光是我們研究的方向之一。

測光計 (Light Meter or Exposure Meter) 是自動曝光的重要工具, 有些是獨立的, 有些是外接的, 有些是內建的 [28]。柯達所出版的灰卡是測光的重要工具之一 [30], 它的白面的反射率是 90%; 灰面的反射率是 18%, 也就是大部份場景的平均反射率。在測光時, 我們將使用灰卡以更精確測光。如何打光是攝影學的一大課題, 我們將嘗試從攝影師如何打光的觀點, 反推如何做好自動曝光 [3, 5, 23, 39, 40]。

測光計牽涉到光度學 (Photometry) 和輻射能測量學 (Radiometry) [25, 48,]。有時因為場景中人或物在運動或其他因素必需要先固定光圈大小或快門速度; 例如: 有人物在快速運動時, 快門速度必須快, 使得曝光時間短, 以避免人物模糊, 稱為快門優先 (Shutter-Priority); 有時為了景深或構圖等因素, 必須固定光圈大小, 稱為光圈優先 (Aperture-Priority) 。決定何時用快門優先, 何時用光圈優先, 也是我們要研究的。此外, 當使用者決定要用快門優先時, 如何決定最適當的光圈大小; 或者, 當使用者決定要用光圈優先時, 如何決定最適當的快門速度, 是自動曝光最主要的研究課題。我們希望綜合不同測光法的優點, 想辦法避免它們的缺點, 提出我們原創性的貢獻, 希望我們的新方法比現有的測光法能又快又準做好自動曝光。

測光的方法有很多種 [12], 例如: 點測光 (Spot Metering) [17, 47, 49], 中央權重測光 (Center-Weighted Metering), 矩陣測光 (Matrix Metering) … 等。目前廣泛應用的曝光計算與方法之一即是區域系統 (Zone System) [11, 18, 22, 27], 我們將仔細研究其細節並改進它。

Nikon 的 F5 相機有用三度空間彩色矩陣測光 (3D Color Matrix Meter) [4], 我們將先瞭解它的工作原理後, 嘗試研究發展新的自動曝光方法, 達到更佳的性能與更多的功能。例如: Nikon 宣稱它的資料庫有 30,000 張不同的曝光資料, 我們可以分析場景的亮度, 對比, 選擇的焦距, 距離資訊, 和場景的顏色特性, … 等, 建立更完整的自動曝光資料庫也是我們要研究的。

閃光燈是自動曝光的重要研究課題 [24]。在戶內或光源較暗時, 往往需要閃光燈, 它的頻譜功率分佈會影響到自動白平衡。它每次放電時的時間長短與功率更影響光圈大小及快門速度的設定, 如何避免曝光不足 (Under-Saturation) 或過度曝光 (Over-Saturation), 是我們的研究重心之一; 我們將先研究現有的最先進的閃光燈, 例

如: Nikon SB-27 AF Flash Unit 可以做三度空間多感測器補助光線閃光 (Three-Dimensional Multi-Sensor Fill-in Flash) 考慮到距離; 它也有自動聚焦輔助光束 (Auto Focus Assist Beam), 我們也將嘗試搭配散光板 (Diffuser), 使得近拍時也可以用閃光燈. 如何將快門與閃光燈的放電時間同步也是一大學問, 先進的閃光燈有後同步 (Rear Synchronization) 功能…等, 也是我們努力的方向。

剛開始時我們以 Nikon 的 AMP (Automatic Multi-Pattern) [54, 55]為基礎, 根據專業攝影師的經驗, 將場景按氣候分為五類: 場景包括太陽 (Scenes Involving the Sun), 戶外的好天氣 (Outdoors in Fine Weather), 一般戶外場景 (General Outdoor Scenes), 朝陽或夕陽 (Sunset/Twilight Scenes), 室內和夜景(Dark Night Scenes)。場景的背景也分為五個層次: 平緩對比 (Flat Contrast),某些對比 (Some Contrast), 中等對比 (Medium Contrast), 強烈對比 (Strong Contrast) 和非常強烈對比 (Very Strong Contrast), 如下圖:

此時可以用不同的方法從事自動曝光, 例如: 中央權重測光 (CW: enter-Weighted metering), 亮光權重測光 (BH: Bright-light weighted metering), 平均測光 (AV: Averaged metering), 和暗光權重測光 (BL: Dim-light weighted metering) 。

三、結果與討論

我們把拍攝的天氣, 亮度對, 主體和背景分開來討論, 並運用模糊的方式使得這些狀況之間平滑轉換. 我們的方法所得到的照片亮度對比清楚, 明暗層次分明. 比其他方法有獨特良好的性能。

我們也定了一個簡單評估函數來評估相同景在不同的曝光參數下, 那張照片的曝光是最好的. 實驗結果顯示此函數的結果和使用者的主觀選擇相當接近。

四、成果自評

1. 自動曝光系統之設計流程與參數設定.
2. 自動曝光與閃光燈分析與處理程式。
3. 結案報告。
4. 詳細報告請見附件論文。

五、參考文獻

[1] R. M. Adams II and J. B. Weisberg, *The GATF Practical Guide to Color Management,* GATF, Pittsburgh, PA, 1998.

[2] R. S. Berns, *Billmeyer and Saltzman's Principles of Color Technology,* 3rd Ed., Wiley, New York, 2000.

[3] J. Bidner, *The Lighting Cookbook,* Amphoto, New York, 1997.

[4] P. Braczko, *Complete Nikon System: An Illustrated Equipment Guide,* Silver Pixel Press, Rochester, NY, 2000.

[5] R. Caputo, *National Geographic Photography Field Guide: People & Portraits,* National Geographic, Washington, D.C. 2002.

[6] Y. C. Cheng, W. H. Chan, and Y. Q. Chen, "Automatic White Balance for Digital Still Camera," *IEEE Transactions on Consumer Electronics,* Vol. 41, pp. 460-466, 1995.

[7] D. Cohen, "Automatic Focus Control: The Astigmatic Lens Approach," *Applied Optics,* Vol. 23, p. 565, 1984.

[8] G. Crawley, "Canon Autofocus Zoom," *British Journal of Photography,* Vol. 128, p. 804, 1981.

[9] G. Crawley, "Canon EOS-1---Predictive Autofocus," *British Journal of Photography,* Vol. 137, pp. 13-15, 1990.

[10] G. Crawley, "Minolta Dynax 9xi---Predictive Autofocus," *British Journal of Photography,* Vol. 139, p. 19, 1992.

[11] P. Davis, *Beyond the Zone System,* 4th Ed., Focal Press, Boston, 1999.

[12] I. Davydkin, "Solving the Exposure Measurement Proglem in Photography," *Soviet Journal of*

Optical Technology, Vol. 48, p. 113, 1981.
[13] H. Denstman, "Autofocus Technologies," *Professional Photographer,* Vol. 20, No. 9, p. 92, 1980.
[14] A. V. Durg and O. Rashkovskiy, "Global White Point Detection and White Balance for Color Images," U.S. Patent #6069972, 2000.
[15] L. Eiseman, *Pantone Guide to Communicating with Color,* Grafix Press, 2000.
[16] M. D. Fairchild, *Color Appearance Models,* Addison Wesley, Reading, MA, 1998.
[17] B.Farzad, *The Confused Photographer's Guide to On-Camera Spotmetering,* Confused Photographer's Guide Books, Birmingham, AL, 2001.
[18] B.Farzad, *The Confused Photographer's Guide to Photographic Exposure and the Simplified Zone System,* Confused Photographer's Guide Books, Birmingham, AL, 2001.
[19] M. Fedor, "Approaches to Color Balancing," PSYCH221/EE362 Course Project, Department of Psychology, Stanford University, 1998.
[20] E. J. Giorgianni and T. E. Madden, *Digital Color Management: Encoding Solutions,* Addison Wesley, Reading, MA, 1998.
[21] N. Goldberg, "Inside Autofocus," *Popular Photography,* Vol. 89, No. 2, p. 77, 1982.
[22] C. Graves, *The Zone System for 35mm Photographers,* 2nd Ed., Focal Press, Boston, 1997.
[23] R. Hicks and F. Schultz, *Learning to Light: A Practical Guide to Photographic Lighting for the Amateur,* Amphoto, New York, 1998.
[24] T. Hogan, *Nikon Flash Guide,* Silver Press, Rochester, NY, 2001.
[25] J. Holm, "A System for Exposure Determination and Tone Reproduction Control in Black and White Photography," *Kodak Tech Bits,* No. 3, 23-28, 1990.
[26] G. C. Holst, *CCD Arrays, Cameras, and Displays,* 2nd Ed., JCD Publishing, Winter Park, FL, 1998.
[27] C. Johnson, *The Practical Zone System,* 3rd Ed., Focal Press, Boston, 1999.
[28] K. Kazuo, "Light Measuring System for Minolta 9000," *Minolta Techno Report Special,* pp. 85-91, 1986.
[29] H. Koch and K. Gfeller, "Selective Exposure Control for Large Format Still Cameras," *Journal of Imaging Technology,* Vol. 10, p. 87, 1984.
[30] E. Kodak Company, *Kodak Gray Cards,* Silver Pixel Press, Rochester, NY, 1999.
[31] E. Kodak Company, *Kodak Photographic Filters Handbook,* Eastman Kodak, Rochester, NY, 1990.
[32] E. Kodak Company, *Using Filters (The Kodak Workshop Series),* Silver Pixel Press, Rochester, NY, 2002.
[33] M. Y. Lu and P. B. Denyer, "Method and Apparatus for Controlling Color Balance of a Video Signal," U.S. Patent #5504524, 1994.
[34] A. Mannheim, "Pentax ME-F TTL Autofocus," *British Journal of Photography,* Vol. 128, p. 1214, 1981.
[35] H. Masataka and N. Toshio, "Autofocus Technology for Minolta," *Minolta Techno Report,* No. 6, pp. 36-44, 1989.
[36] R. Mitkin and V. Karpushin, "Automatic Camera Lens Focusing Systems," *Soviet Journal of Optical Technology,* Vol. 49, p. 453, 1982.
[37] N. Motohiro and M. Yukari, "Multi-Beam Autofocus," *Minolta Techno Report,* No. 6, pp. 45-52, 1989.
[38] M. Motonobu, "Autofocus with a Position Sensor Applying 'Cross-Talk'," *Minolta Techno Report,* No. 1, pp. 22-29, 1984.
[39] F. Patterson, *Photography and the Art of Seeing,* Key Porter, Toronto, 1989.
[40] B. Peterson, *Understanding Exposure,* Amphoto, New York, 1990.
[41] B. M. Peterson, *Magic Lantern Guide to Nikon Lenses,* 2nd Ed., Silver Pixel Press, Rochester, NY, 2000.
[42] S. F. Ray, *Applied Photographic Optics,* 3rd Ed., Focal Press, Oxford, 2002.

[43] S. F. Ray, *Scientific Photography and Applied Imaging,* Focal Press, Oxford, 1999.
[44] K. Taniguehi and K. Kanamori, "Apparatus for Calculating a Degree of White Balance Adjustment for a Picture," U.S. Patent #5619347, 1997.
[45] K. Toshihiko, "AF Sensor Module," *Minolta Techno Report Special,* pp. 40-48, 1986.
[46] M. Uno, "A CMOS Linear Image Sensor for Passive Autofocusing Systems," *Journal of Society of Photographic Science and Technology Japan,* Vol. 60, pp. 98-102, 1997.
[47] G. Wakefield, "Spot Metering," *British Journal of Photography,* Vol. 134, p. 1071, 1987.
[48] G. Wakefield, "The Weston Exposure Meter," *British Journal of Photography,* Vol. 137, pp. 16-17, 1990.
[49] G. Wakefield, "Gossen Spot-Master," *British Journal of Photography,* Vol. 140, p. 27.
[50] G. Wakefield, "Color Temperature and a Modern Meter," *British Journal of Photography,* Vol. 135, pp. 10-11, 1988.
[51] B. A. Wandell, *Foundations of Vision,* Sinauer, Sunderland, MA, 1995.
[52] E. Wildi, *Photographic Lenses,* Amherst Media, 2001.
[53] G. Wyszecki and W. S. Stiles, *Color Science: Concepts and Methods, Quantitative Data and Formulae,* 2nd Ed., Wiley, New York, 2000.
[54] T. Takagi, "Three-Dimensional-Multi-Pattern Photo-Metering Apparatus," United States Patent #4,951,082, 1990.
[55] "AMP Pattern Classification Table," http://www.kenrockwell.com/nikon/matrix05.htm, 2003.
[56] N. K. Chern, N. P. A. Neow, and M. H. Ang, Jr., "Practical Issues in Pixel-Based Autofocusing for Machine Vision," *Proceedings of the IEEE International Conference on Robotics and Automation*, Seoul, Vol. 3, pp. 2791-2796, 2001.

附件：封面格式

行政院國家科學委員會補助專題研究計畫成果報告

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※　數位相機之影像處理：自動白平衡，自動曝光，自動聚焦　※
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共同主持人：
計畫參與人員：黃彥嵐, 王博民, 陳坤毅

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□國際合作研究計畫國外研究報告書一份

執行單位：台灣大學資訊工程系

中　華　民　國　94　年　5　月　2　日

Automatic Exposure with Fuzzy Control

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ABSTRACT

In this paper, we will present an automatic exposure method based on Nikon's method [9] and AMP (Automatic-Multiple-Pattern) [7]. Our method will add the fuzzy control into the AMP to get smooth transition effect and subject growing function to classifies subject and background to get a better exposure. We also implement an easy evaluative function to estimate what is a well exposed picture in the same scene with different exposure parameters. The experiment results show that our evaluative function selects the best exposed picture similar to most people's selection.

1. INTRODUCTION

Nikon disclosed a patent *"Three-Dimensional Multi-Pattern Photo-Metering Apparatus"* on August 21, 1990 [9]. The sensor is divided into five areas as shown in *Figure 1*.

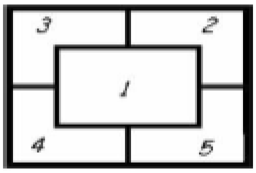

Figure 1: The CCD is divided into five segments.

The method based on the professional photographers' experience under various weather conditions. AMP [7] is similar to [9], however, it does not take flash into account and it is only two-dimensional. AMP classified weather into five different conditions (*W1~W5*), and contrast is also classified into five conditions (*C1~C5*). We can construct a two-dimensional reference table as shown in *Figure 2*.

	W1	*W2*	*W3*	*W4*	*W5*
C1	Metering Method				
C2					
C3					
C4					
C5					

Figure 2: Reference table, W1~W5 is from bright weather to dark weather, and C1~C4 is from flat contrast to strong contrast. (W1: Scene involves the sun, W2: Outdoors in fine weather, W3: General outdoor scenes, W4: Sunset/twilight scenes, W5: Dark night scenes. C1: Flat contrast, C2: Some contrast, C3: Medium contrast, C4: Strong contrast, C5: Very strong contrast

When weather, contrast, and distance information are decided, a mapping metering method is selected. In this paper, we extend the concept of [9] and [7], and apply fuzzy control and subject growing function to get a better result.

2. PROBLEMS OF AMP AND IMPROVEMENT

2.1 SUBJECT CONDITION

In [7] and [9], the CCD is divided to five segments as shown in *Figure 1*. Center segment is treated as the subject. Is it always this way? When we photograph, our subject is usually in the center, but not always. Sometimes, it may slight near right, left, top or bottom. [7] and [9] fixes the subject in center, it is suitable for most conditions, however, when subject shifts (not in the middle center), the contrast between foreground and background may wrong.

2.2 SMOOTH TRANSITION

AMP [7] does not mention how they handle the transition between two weather or contrast conditions, if our table is fine enough to cover all conditions, there is no problem for smooth transitions. However, if we do not have a fine reference table, apply fuzzy function to achieve smooth transition is necessary.

2.3 IMPROVEMENT OF AMP

In this paper, we define three reference tables for different foreground and background contrast. Fuzzy control is applied to achieve smooth transition and subject growing function is implemented to guess where subject is.

3. OUR AUTOMATIC EXPOSURE METHOD

Unfortunately, most metering methods are hardware dependent. For example, the three-dimensional matrix-metering [9] need special lens with a chip to detect the subject's distance. In this paper, we focus on the metering method without additional hardware support. We will extend the Nikon's AMP metering method and append fuzzy control and subject growing function to smooth the transition between conditions and guess the subject.

3.1 FUZZY WEATHER

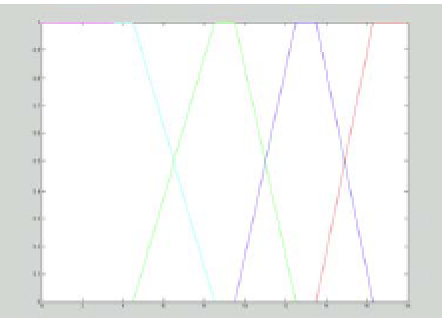

Figure 3.3: Membership functions of different weather conditions and x-axis is LV (Light Value), and y-axis is probability.

The membership functions of the five different weather conditions are shown in *Figure 3.3*. Red line represents *W1*; blue line represents *W2*; green line represents *W3;* cyan line represents *W4;* and magenta represents *W5*. If *BMAX* (luminance of the brightest segment in *Figure 3.1*) >= LV 16.3, it means the probability of *W1* is 1. If LV 13.5>=*BMAX* >= LV 12.5, it means the probability of *W2* is 1. If LV 9.5>=*BMAX* >= LV 8.5, it means the probability of *W3* is 1. If LV 4.5>=*BMAX* >= LV 3.5, it means the probability of *W4* is 1. If LV *BMIN* (luminance of the darkest segment in *Figure 3.1*) <= LV 3.5, it means the probability of *W5* is 1. When *BMAX* or *BMIN* does not fall into the range that exactly belongs to any one weather condition, in other words, they fall into the gradient line segments (gray zones). Camera will take the combination of the two different weather conditions according to their probabilities. For example, if program selects bright table (*Figure 3.6*) as reference table and *BMAX* falls into the gray zone between *W1* and *W2*. If probability of *W1* is 0.3 and probability of *W2* is 0.7, the fuzzy weather will return 0.3*(AV or BL) +0.7*CW (assume contrast is flat). The priority of the five weather conditions is: *W1* > *W5* > *W2* > *W3* > *W4*. This is because *W1* is extremely bright weather condition and it may lead to under-exposure. W5 is extremely dark and it may result in over-exposure.

3.2 FUZZY CONTRAST

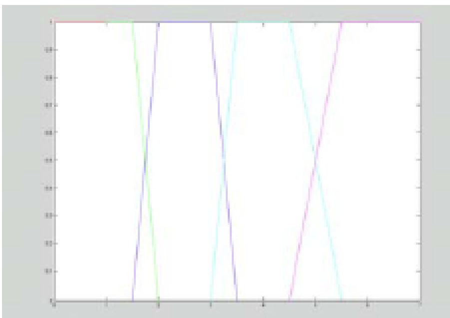

Figure 3.4: Membership functions for different contrast

levels (red: C1, green: C2, blue: C3, cyan: C4, magenta: C5) and x-axis is LV (Light Value), and y-axis is probability.

Let *C=BMAX-BMIN*, (*BMAX* and *BMIN* is the maximum and minimum *LV* of the five segments shown in *Figure 3.1*)

Probability of very strong contrast is 1 when *C>=5.5*.

Probability of strong contrast is 1 when *4.5>=C>=3.5*.

Probability of medium contrast is 1 when *3>=C>=2*.

Probability of some contrast is 1 when *1.5>=C>1*.

Probability of flat contrast is 1 when *C<=1*

When *C* falls into gray zone, it is similar to fuzzy weather.

3.3 FUZZY SUBJECT

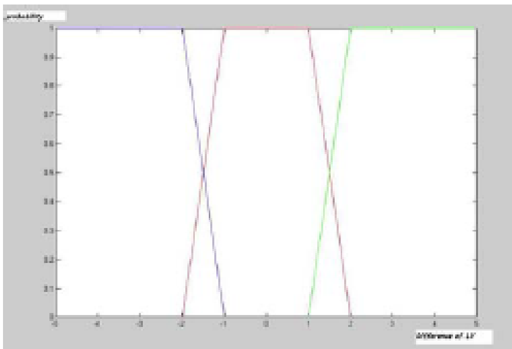

Figure 3.5: Membership functions for different subject conditions (red: moderately bright subject, green: bright subject, blue: dark subject).

When we photograph, we usually have a subject to emphasize. In this paper, we assume subject is not fixed in center. We construct three reference tables for different subject conditions, bright subject, moderately bright subject and dark subject. These tables are shown as *Figure 3.6*, *Figure 3.7*, and *Figure 3.8*:

Weather / Contrast	Scene involves the sun	Outdoors in fine weather	General outdoor scenes	Sunset/twilight scenes	Dark night scenes
Flat contrast	AV	CW	CW	CW	CW & BL
Some contrast	AV	CW	CW	CW	CW & BL
Medium contrast	BL	CW	CW & BH	CW & BH	CW & BH
Strong contrast	BL	CW	CW & BH	CW & BH	CW & BH
Very strong contrast	BL	CW	CW & BH	CW & BH	CW & BH

Figure 3. 6: Reference table for bright subject.

Weather / Contrast	Scene involves the sun	Outdoors in fine weather	General outdoor scenes	Sunset/twilight scenes	Dark night scenes
Flat contrast	AV	CW	CW	CW	CW & BL
Some contrast	AV	CW	CW	CW	CW & BL
Medium contrast	BL	BL	CW	CW	CW
Strong contrast	BL	BL	CW	CW	CW
Very strong contrast	BL	BL	CW	CW	CW

Figure 3.7: Reference table for moderately bright subject.

Weather / Contrast	Scene involves the sun	Outdoors in fine weather	General outdoor scenes	Sunset/twilight scenes	Dark night scenes
Flat contrast	BL	CW	CW	CW	CW & BL
Some contrast	BL	CW	CW	CW	CW & BL
Medium contrast	BL	BL	BL	BL	BL
Strong contrast	BL	BL	BL	BL	BL
Very strong contrast	BL	BL	BL	BL	BL

Figure 3.8: Reference table for dark subject.

BL: Dim light metering

BH: Bright light metering

CW: Center weighted

AV: Average metering

After introducing the three fuzzy models (fuzzy subject, fuzzy weather, and fuzzy contrast), it shows when the light condition of a scene falls into gray zones of all the three models. We need to take a combination of eight metering methods.

3.3 SUBJECT GROWING

When photograph, subject is what we want to emphasize. In *Figure 3.1*, subject is assumed in the center. In fact, when we photograph, subject is not always in the center. Maybe subject is in the center near left, right, bottom or top, therefore, the assumption is incorrect. In this paper, subject information is important for us to support correct contrast between foreground and background. In AMP, some scenes may fool it, because subject location is fixed.

In the section, we assume parts of the subject would in the center as *Figure 3.9*:

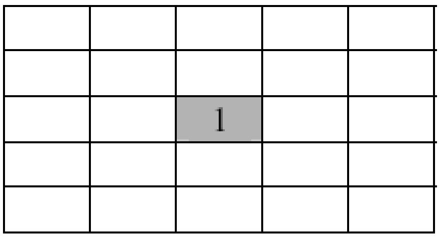

Figure 3.9: In initial state, segment 1 is assumed part of subject (In our experiment camera, CCD is divided into 25 segments)..

In initial state, only segment 1 is the subject. We extend subject by combine the segments (connected component of segment 1) according to the luminance. If the differences of luminance of other segments and segment 1 are less than 2.0 LV, then the segments are appended to subject. If the number of member segments of the growing connected component is less than 6 or greater than 20, the subject is defined as default setting as shown in *Figure 3.1*.

After subject growing process, we can get a vague foreground and vague background, therefore, more precise contrast between foreground and background could be obtained. Therefore, a suitable reference table could be selected.

4. OPTIMAL EXPOSURE SELECTION

If there are two or more pictures only different in exposure, and which one is preferred by most people? There is no tool for the decision making. It is intuitive for people. However, different people may prefer different pictures. In this section, we develop an easy method for the decision making according to histogram distribution, hue, saturation, intensity, and entropy.

4.1 IMAGE SEGMENTATION AND IMAGE INFORMATION RETRIEVAL

Picture is divided into 8x8 segments as shown in *Figure 3.10*. Subject is assumed to contain cyan region. Few people photograph too bright and flat subject. Thus, if intensity of cyan region is greater than 220, program will shift the cyan region to find an optimal 2x2 region as the new subject in yellow region. When cyan region is found, the growing process is similar to subject growing in Section 3.3

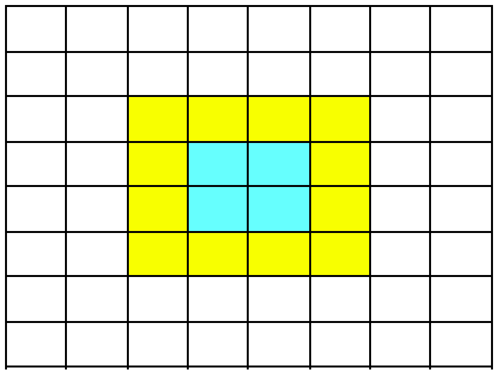

Figure 3.10: Subject is assumed to contain cyan region (In computer simulation, we divide a picture into 8x8 segments).

Step 1: Subject is extended based on the cyan region according to hue and CrCb distance. After Step 1, the rough subject region would be marked.

Step 2: Calculate means, standard deviations, hue, saturation, intensity, and intensity entropy of subject region and global image.

Mean:

We know the closer the mean value is to 128, the higher probability people may prefer it. If the mean value is near 0 or 255, the picture may be under-exposed or over-exposed. In this paper, we divide the range of 0 to 255 into 12 zones. *Figure 3.11* shows zone numbers and their relative gray values and points and *Figure 3.12* shows curve of weight function.

Zone	0	1	2	3	4	5
Gray value	0	48	97	108	120	134
Pts	0	1	3	5	7	9
Zone	6	7	8	9	10	11
Gray value	149	166	185	206	229	255
Pts	10	6	4	3	1	0

Figure 3.11.: Table of zone numbers and their relative gray values and points.

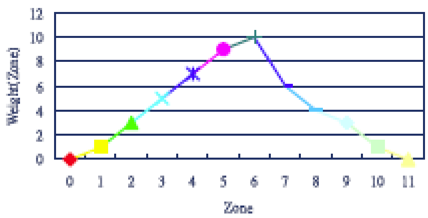

Figure 3.12: Curve of weight function.

Standard Deviation and Entropy:

The larger the intensity standard deviation, the higher probability of high contrast of the picture may be. The larger the intensity entropy is, the more uniform distribution of gray values is. Histogram equalized images have the highest intensity entropy. We need to take standard deviation and entropy into account at the same time, because they are dependent. The maximum entropy of gray values in an image is 8 and the maximum standard deviation is 128.

Colorful

Most people like colorful image. In application, YCrCb color space is preprocessed by hardware. Y represents the luminance information. We can distinguish subject is colorful easily from Cr and Cb information.

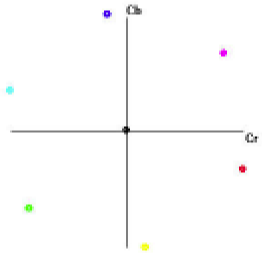

Figure 3.13: Red (340 degree), green (220 degree), blue (100 degree), cyan (160 degree), yellow (280 degree), and magenta (40 degree) showed on CrCb plane.

The more CrCb distance from the origin, the colorful they are.

4.2 DECISION MAKING

In this section, we will count the points of mean, standard deviation, and HSI. After subject growing, a virtual subject emerges, hence, we have subject mean, standard deviation, HSI, global mean, standard deviation, and HSI. We will put more weight in subject information.

- Subject Mean (*SM*): *R* pts.
- Subject Entropy and Standard Deviation (*SED*): *R* pts.
- Subject vivid (*SH*). *R* pts.
- Global Mean (*GM*): *R/2* pts.
- Global Entropy and Standard Deviation (*GED*): *R/2* pts.

SM=weight(zone of subject). (*Figure 3.12*)

*GM=1/2*weight(zone of global image).*

SED=R/2(Entropy/8 + Standard_Deviation/127.5).*

GED=R/4(Entropy/8 + Standard_Deviation/127.5).*

SH=R(distance/133).*

Total points=SM+SED+GM+GED+SH

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5. EXPERIMENT RESULT

In the section, we compare three experiment results and show their scored points given by optimal exposure selection function (select by computer), and votes that voting from different people (select by human).

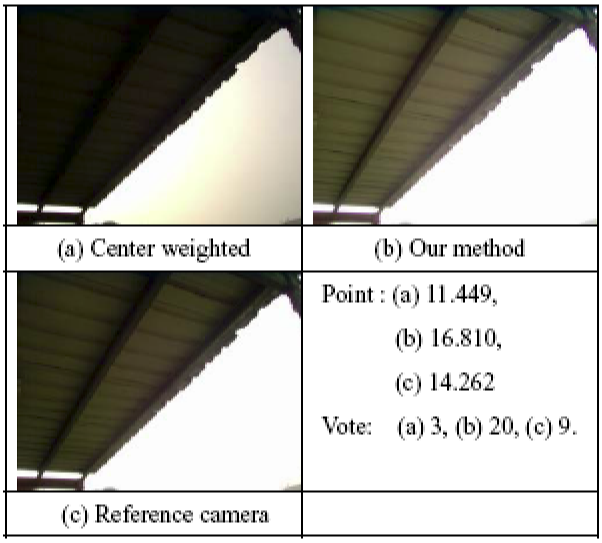


FIGURE 3.14: experiment result.

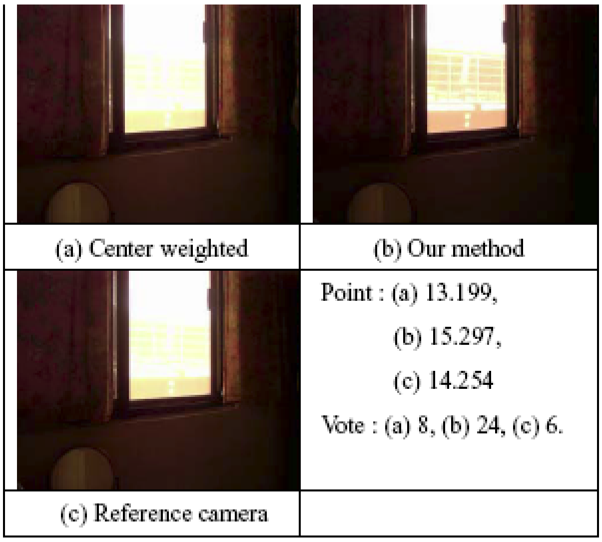


FIGURE 3.15: Experiment result.

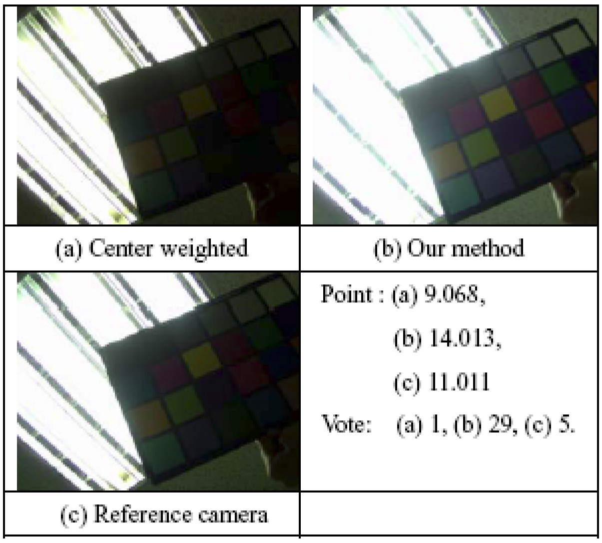


FIGURE 3.16: Experiment result.

	
(a) Center weighted	(b) Our method
	Point : (a) 9.913, (b) 15.558, (c) 9.526 Vote: (a) 1, (b) 27, (c) 5.
(c) Reference camera	

FIGURE 3.17: Experiment result.

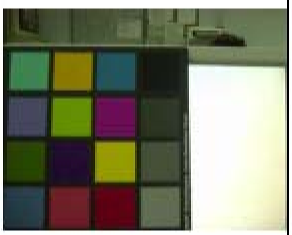
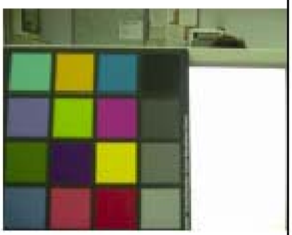
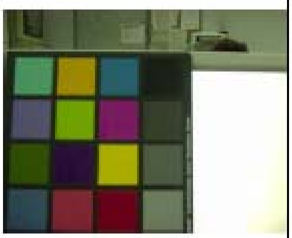
	
(a) Center weighted	(b) Our method
	Point : (a) 11.423, (b) 14.602, (c) 12.618 Vote: (a) 4, (b) 26, (c) 7.
(c) Reference camera	

FIGURE 3.18: Experiment result.

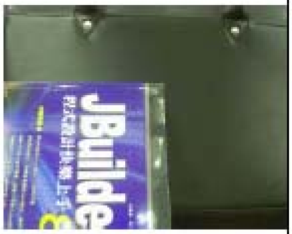
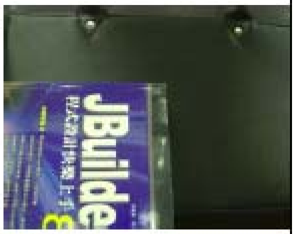
	
(a) Center weighted	(b) Our method
	Point : (a) 18.935, (b) 13.650, (c) 17.262 Vote: (a) 16, (b) 9, (c) 16.
(c) Reference camera	

FIGURE 3.19: Experiment result.

The experiments show our automatic exposure method get more points and votes than the other two methods. It means most voter prefer our exposure method, and our evaluative function (Optimal Exposure Selection) for exposure selection matches human's perceptive.

6. CONCLUSION AND FUTURE WORKS

Our method has good performance under various conditions. Automatic exposure is easily fooled under extreme conditions, and our method performs well under extreme conditions. Our subject growing function can separate foreground and background. In our method, subject is not fixed in the center.

We have experimented for various scenes, and some predictable conditions may fool our method. If subject does not contain the middle center segment, and growing function can not work, our method degrades fixed center metering.

6.1 PROBLEMS STATE

1. Assumption for subject location.

We assume subject always contain the middle center segment. This is not always established.

2. Subject growing criterion:

Subject growing is the key function directing the final exposure. In this paper, the growing criterion is only to restrict LV (light value) difference. We can not get an accurate extended subject by using only LV information. In our implementation, we also try to append color criterion for growing function, however, we can not get accurate color information from our camera. Therefore, we suspend the criterion for now due to color information accuracy.

6.2 FUTURE WORK

In future work, 1. Color compensation, 2. Dynamic subject assumption, and 3. Append Optimal Exposure Selection (OES) to assist automatic exposure can be enhanced.

7. ACKNOWLEDGEMENT

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8. REFERENCE

[1] D. P. Curtin, "Digital Photography, The Textbook, a Free On-Line Course" http://209.196.177.41/, 2004.

[2] S. Hayakawa, "Camera Detecting Luminance from a Plurality of Areas," United States Patent #5,189,460, 1990.

[3] B. Hitchman, "Using the Zone System in the Field" http://www.apogeephoto.com/mag2-6/mag2-7rh.shtml, 2004.

[4] G. J. Klir and B. Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications*, Prentice Hall, Upper Saddle River, N.J., 1995.

[5] S. K. Nayar and T. Mitsunaga, "High Dynamic Range Imaging: Spatially Varying Pixel Exposures," *Proceedings of IEEE Conference on Computer Vision and Pattern Recognition*, Hilton Head Island, South Carolina, Vol. I, pp. 472-479, 2000.

[6] Nikon Corp., "The Nikon F5 Has 1,005 Eyes," http://www.nikon.co.jp/main/eng/society/tec-rep/ccd.htm, 2004.

[7] K. Rockwell, "AMP Pattern Classification Table," http://www.kenrockwell.com/nikon/matrix05.htm, 2003.

[8] K. Rockwell, "What are LV and EV," http://www.kenrockwell.com/tech/ev.htm, 2004.

[9] T. Takagi, "Three-Dimensional-Multi-Pattern Photo-Metering Apparatus," United States Patent #4,951,082, 1990.

[10] G. L. Ward, H. Rushmeier, C. Piatko, "A Visibility Matching Tone Reproduction Operator for High Dynamic Range Scenes," *IEEE Transactions on Visualization and Computer Graphics*, Vol. 3, No. 4, pp. 291-306, 1997.