MIAT方法論系統設計案例

**ADPHE\_SHE影像增強演算法軟體高階合成**

學生：104522065張翔珳

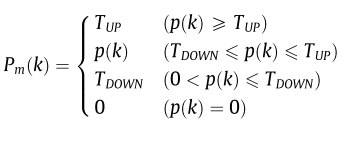
指導教授：陳慶瀚教授

**1.影像增強演算法ADPHE\_SHE**

　　A new adaptive contrast enhancement algorithm for infrared images based on double plateaus histogram equalization[1]，一種自適應雙門檻直方圖均勻化的方法，並將它和SHE[3]方法結合，進而解決最低值和最高值灰階數量過高，最後以此兩篇論文方法練習GRAFCET建模，將其軟體高階合成[2]，驗證輸出結果。

**2. ADPHE\_SHE演算法說明**

利用上界和下界去過濾直方圖[1]，pseudo code如下



P(k): 直方圖灰階k的出現次數

Tup: 上界

Tdown: 下界

Pm: 修改後的直方圖

Tup上界門檻值是取直方圖所有local maximum的平均值，而local maximum是利用一維遮罩去過濾直方圖，當遮罩中心值為最大值時，便將它納入local maximum的group。

Tdown下界公式如下所示

Tdown = min(Ntotal, Tup \* L)/M

其中M為灰階數量256, Ntotal為原始影像像素數量, L為直方圖像素非零值的數量。

上界可以確保影像不會over-equalization，而下界則可以確保不會損失影像細節，不會將過低的灰階給納入合併成相同灰階，進而降低影像品質

**3.演算法的離散事件建模**

整體影像增強IDEF0系統架構可分為四個模組，一為從鍵盤輸入檔案名稱，二為讀取輸入影像，三為影像增強演算法，四為輸出影像至檔案系統。並使用MIAT方法論對系統建模，如下圖所示。



影像增強系統top Grafcet如下圖所示：



灰階數量M=256，1維遮罩大小WIN\_SIZE=9，WIN\_SIZE\_2=WIN\_SIZE>>1



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| 狀態 | 動作 | 功能說明 |
| 20 | //Initial histogram bin to zero  for(int z=0;z < M;z++)bin[z]=0  i=j=0 | 直方圖和影像座標初始化 |
| 21 | //read image pixels  pixel = ima(i, j)  if(j == nc - 1) i++, j=0; else j++; | 取得影像對應座標像素  座標遞增 |
| 22 | //statistics histogram  bin[pixel]++ | 統計直方圖 |
| 23 | first\_one = last\_two = last\_one = -1;  bi=255; fi=0; head=0;  for(z = 0;z < WIN\_SIZE;z++)  　buf[i] = 0;  nz\_cnt=0;  max\_sum=0; max\_cnt=0; | 各項參數初始化：  SHE參數  ADPHE參數 |
| 24 | if(bin[bi]&&last\_one<0)  last\_one=bi;  elsif(bin[bi]&&last\_two<0) last\_two=bi;  bi--; | 找直方圖最後一個和倒數第二個非零的灰階索引值 |
| 25 | if(bin[fi] && first\_one < 0) first\_one=fi; | 找直方圖第一個  非零的灰階索引值 |
| 26 | //get local max sum  buf[head]=bin[fi];  max\_sum+=lmax(buf);  max\_cnt+=(buf[WIN\_SIZE\_2] >= max) ? 1 : 0;  head=(head+1)%WIN\_SIZE; | 計算直方圖的  區域最大值平均值 |
| 27 | //non-zero count  if(bin[fi++]) nz\_cnt++; | 統計直方圖出現次數  非零的數量 |
| 28 | //threshold calculation  Tup=max\_sum/(max\_cnt+1)  Tdown=min(nr \* nc, Tup\*nz\_cnt)/(M<<1)  index=1; N=0; i=0; j=0;  bin[first\_one]=0; bin[last\_one]=bin[last\_two]; | 計算  自適應上界、下界門檻值  取代第一個出現的灰階次數為0  將倒數第一個的數量取代為倒數第二個的數量 |
| 29 | //threshold histogram  z:=index; temp:=bin[z];  if(bin[z] >=Tup)  　temp:=Tup;  elsif(bin[z]==0) temp:=0;  elsif (bin[z]<=Tdown)  　temp:=Tdown; | 根據上界、下界  門檻化直方圖 |
| 210 | //accumulative  bin[z]=temp + bin[z-1];  N+=temp;  index++; | 累加直方圖出現次數 |
| 211 | //LUT output  bima[i][j]=bin[ima[i][j]] \* (M-1) / N;  if(j == nc - 1){  i++; j = 0;  }else j++; | 以輸入影像對  直方圖查表數值  至輸出影像 |
| 212 | NULL | 上層模組轉移空狀態 |

**4.軟體高階合成**

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| **#include <iostream>**  **#include "stdlib.h"**  **#include "bmp.h"**  **#define M 256**  **#define WIN\_SIZE 9**  **#define WIN\_SIZE\_2 (WIN\_SIZE >> 1)**  **using namespace std;**  **//global variable**  **int bin[M];**  **unsigned char \*\*ima, \*\*bima;**  **int nr, nc;//image height and width**  **int fi, i, j;**  **int index, N;**  **char filename[128];**  **bool isvalid;**  **//state**  **int x0 = 1, x1, x2, x3, x4;**  **int x20 = 1,x21 ,x22 ,x23 ,x24 ,x25 ,x26 ,x27 ,x28 ,x29 ,x210 ,x211, x212;**  **void grafcet0();**  **void action0();**  **void grafcet1\_ADPHE\_SHE();**  **void action1();**  **int main(int argc, char\*\* argv) {**    **while(x4 != 1) grafcet0();**  **system("PAUSE");**  **return 1;**  **}**  **void grafcet0(){**    **action0();**  **if(x0 == 1){ x0 = 0; x1 = 1;}**  **else if(x1 == 1){ x1 = 0; x2 = 1;}**  **else if(x2 == 1 && x212 == 1){ x2 = 0; x3 = 1;}**  **else if(x3 == 1){ x3 = 0; x4 = 1;}**  **else if(x4 == 1){ x4 = 0; x0 = 1;}**  **}**  **void action0(){**  **if(x0 == 1){**  **isvalid = false;**  **//read bmp image from file**  **cout << "Enter input filename:";**  **cin >> filename;**  **}**  **else if(x1 == 1){**  **isvalid = Read\_BMP(filename, ima, nr, nc);**  **if (!isvalid) exit(1);**  **bima=UC2D(nr, nc);**  **Write\_BMP\_8bits("ima.bmp", ima, nr, nc);**  **}**  **else if(x2 == 1){ grafcet1\_ADPHE\_SHE(); }**  **else if(x3 == 1){ Write\_BMP\_8bits("ADPHE\_SHE.bmp", bima, nr, nc); }**  **}**  **void grafcet1\_ADPHE\_SHE(){**  **action1();**  **if(x20 == 1){x20 = 0; x21 = 1; x22 = 1;}**  **else if(x21 == 1 && x22 == 1 && i == nr){x21 = 0; x22 = 0; x23 = 1;}**  **else if(x23 == 1){x23 = 0; x24 = 1; x25 = 1; x26 = 1; x27 = 1;}**  **else if(x24 == 1 && x25 == 1 && x26 == 1 && x27 == 1 && fi == M){x24 = 0; x25 = 0; x26 = 0; x27 = 0; x28 = 1;}**  **else if(x28 == 1){x28 = 0; x29 = 1; x210 = 1;}**  **else if(x29 == 1 && x210 == 1 && index == M){x29 = 0; x210 = 0; x211 = 1;}**  **else if(x211 == 1 && i == nr){x211 = 0; x212 = 1;}**  **else if(x212 == 1){x212 = 0; x20 = 1;}**  **}**  **void action1(){**  **static int first\_one, last\_two, last\_one, head, nz\_cnt, max\_sum, max\_cnt, bi;**  **static int Tup, Tdown;**  **static int buf[WIN\_SIZE];**  **int z, temp;**  **int pixel;**    **if(x20 == 1){ i = j = 0; for(int index = 0;index < M;index++) bin[index] = 0;}**  **if(x21 == 1){ pixel = ima[i][j]; if(j == nc - 1) i++, j=0; else j++;}**  **if(x22 == 1){ bin[pixel]++;}**  **if(x23 == 1){**  **for(int z = 0;z < WIN\_SIZE;z++) buf[z] = 0;**  **first\_one = last\_two = last\_one = -1; head = fi = nz\_cnt = max\_sum = max\_cnt = 0;**  **bi = M - 1;**  **}**  **if(x24 == 1){**  **if(bin[bi] && last\_one < 0) last\_one = bi;**  **else if(bin[bi] && last\_two < 0) last\_two = bi;**  **bi--;**  **}**  **if(x25 == 1){**  **if(bin[fi] && first\_one < 0) first\_one = fi;**  **}**  **if(x26 == 1){**  **buf[head] = bin[fi];**  **//lmax**  **int max = buf[0];**  **for(int z = 1;z < WIN\_SIZE;z++)**  **if(max < buf[z]) max = buf[z];**  **max\_sum += ((buf[WIN\_SIZE\_2] >= max) ? buf[WIN\_SIZE\_2] : 0);**  **max\_cnt += ((buf[WIN\_SIZE\_2] >= max) ? 1 : 0);**    **head = (head + 1) % WIN\_SIZE;**  **}**  **if(x27 == 1){**  **if(bin[fi]) nz\_cnt++;**  **fi++;**  **}**  **if(x28 == 1){**  **Tup = max\_sum/(max\_cnt+1);**  **int temp1, temp2;**  **temp1 = nr \* nc; temp2 = Tup \* nz\_cnt;**  **Tdown = ((temp1 > temp2) ? temp2 : temp1) / (M << 1);**  **index = 1; N = i = j = 0;**  **bin[first\_one] = 0; bin[last\_one] = bin[last\_two];**  **}**  **if(x29 == 1){**  **z = index; temp = bin[z];**  **if(bin[z] >= Tup) temp = Tup;**  **else if(bin[z] == 0) temp = 0;**  **else if(bin[z] <= Tdown) temp = Tdown;**  **}**  **if(x210 == 1){**  **bin[z] = temp + bin[z - 1];**  **N += temp;**  **index++;**  **}**  **if(x211 == 1){**  **bima[i][j] = bin[ima[i][j]] \* (M - 1) / (N);**  **if(j == nc - 1){ i++, j = 0;}**  **else j++;**  **}**  **if(x212 == 1){ /\*no operation\*/ }**    **}** |

**5.實驗結果**

　　透過實驗數張影像發現Tdown的公式導致Tdown數值過高，容易造成直方圖均勻化時沒有效果，所以可改為除2，如下所示

Tdown = min(Ntotal, Tup \* L)/(2\*M)

HE(Standard Histogram equalization)

ADPHE(Adaptive Double plateau histogram equalization)[1]

SHE(A simple histogram modification scheme for contrast enhancement)[3]

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| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Position3_8bit.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Position3_8bit-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Position3_8bit-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Position3_8bit-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular1_8bit.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular1_8bit-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular1_8bit-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular1_8bit-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular4_8bit.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular4_8bit-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular4_8bit-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Rectangular4_8bit-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Surrounded_8bit.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Surrounded_8bit-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Surrounded_8bit-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\Surrounded_8bit-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\TestTube001_8bit.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\TestTube001_8bit-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\TestTube001_8bit-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\TestTube001_8bit-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\UniSiegen_8bit.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\UniSiegen_8bit-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\UniSiegen_8bit-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\ADLink_with_Tdown\UniSiegen_8bit-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\CR.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\CR-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\CR-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\CR-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\dark.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\dark-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\dark-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\dark-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\DPHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\DPHE-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\DPHE-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\DPHE-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\explosion.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\explosion-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\explosion-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\explosion-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\FigP0438(left).bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\FigP0438(left)-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\FigP0438(left)-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\FigP0438(left)-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\hands3.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\hands3-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\hands3-processed.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\hands3-SHE.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |
| C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\women.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\women-HE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\women-SHE.bmp | C:\Users\MIAT\Desktop\MIAT\1051master\Embedded_vision\HW1\DevC++\women-processed.bmp |
| 原圖 | HE | SHE | ADPHE and SHE |

**6.實驗討論**

自適應雙門檻直方圖均勻化主要是為了解決雙門檻直方圖均勻化效果不明顯的問題，而雙門檻直方圖均勻化是為了解決傳統**直方圖均勻化過曝**和**影像細節損失**的問題。

**以直方圖統計數量高低討論**

自適應雙門檻直方圖均勻化一方面能夠以上界限制較高統計值，可以避免直方圖統計數值過高時，產生較大的空隙擠壓其他灰階，而是以均勻的方式去拉伸直方圖，如圖(d)，另一方面，可保留低於下界的統計值，以確保影像細節不被合併成相同灰階，如圖(h)所示，但為了保留影像細節而產生的副作用則是對比增強效果不明顯，如圖(d)。

|  |  |
| --- | --- |
| (a)原圖 | (b)HE |
| (c)SHE | (d)ADPHE\_SHE |

|  |  |
| --- | --- |
| (e)原圖 | (f)HE |
| (g)SHE | (h)ADPHE\_SHE |

**以直方圖動態範圍高低討論**

觀察直方圖結果後發現，對於動態範圍高的影像，一般直方圖均勻化方法會增加相同灰階被合併的數量，而ADPHE\_SHE被合併的數量則會降低，如圖(l)所示。動態範圍低的影像對於ADPHE\_SHE來說並不會產生過曝現象，如上圖(p)所示。

|  |  |
| --- | --- |
| (i)原圖 | (j)HE |
| (k)SHE | (l)ADPHE\_SHE |
| (m)原圖 | (n)HE |
| (o)SHE | (p)ADPHE\_SHE |

**7.參考資料**

[1] Liang et al. “A new adaptive contrast enhancement algorithm for infrared images based on double plateaus histogram equalization”

[2] 陳慶瀚教授 “MIAT技術文件\_微程式控制器設計與硬體合成”

[3] Chang et al. “A simple histogram modification scheme for contrast enhancement”