IMAGE PATTERN RECOGNITION BY QUAD STRING ARRAY APPROACH

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Abstract

How to use one-chip processor and small size memory to recognize the shape of object is the most important topic in modern industrial application. Usually, it is impossible to get the front view of fast flying object, the image taken at the view direction are called plane projection images. The plane projection image is composed of "object" and "background", that is what we say pixel recursion image. The image processing by the using of pixel recursion is the most simple and fast approach. The pixel recursion image can be achieved by the scanning, and the image after size and orientation normalization can be recognized by the Quad String Array (QSA) approach.

The size normalization can be achieved by the scanning device and the orientation normalization can be handled by the Circular Layer String method. In the orientation normalization, the principle axis of unknown image is achieved by rotation and compared with the standard patterns which are pre-estimation. The unknown image can be divided into several subimage and each subimage is coded by the Vertical String Array. By the using of Vertical String Array, the shape of unknown object can be described precisely. In this paper, the experiment results of Vertical String Array, Random Walk and Gauss-Markov-R-process are also discussed.

I. INTRODUCTION

The statistical approach was commonly used in the 1960's to process the 2-D or 3-D image patterns. The recognition was achieved by storing the sample data of a pattern in the memory which were then compared with the random input pattern. A Markov approach [1,2,3] was adopted to recognize the 2-D pattern into 10 layers structured as a pyramid. The variation of each mesh was represented by a transfer function.[4] describes the circular layer method to implement the orientation, [5] [6] used the complexity to recognize the image.

II. KOLMOGOROV COMPLEXITY

The digital picture point method is a general approach for image recognition. Each pixel is expressed by the brightness level ranged from 0 to 256.

Assumption 2-1:

The length, the area, even the size of any pattern in arbitrary direction are all finite. Therefore, the string array of pixels can be used for recognizing any feature of a 2-D image picture.

Definition 2-1:

Let $(0,1)^*$ express an optimal binary string of finite length. The first n terms of input pattern sequence are denoted as $X(n)$, where

$$X(n) = (x_1, x_2, \dots, x_n) \quad (2-1)$$

Let A be an automaton which can transfer the random input into an optimally logical output string array, such that

$$A : (0,1)^* \times N \rightarrow (0,1)^* \quad (2-2)$$

where N is the number of extracted features.

Definition 2-2: Complexity production

A binary data representation has the complexity if it can be expressed as follows

$$\{x \in \{0,1\}^* : K(X) = k\} < 2^k \quad (2-3)$$

where $K(X)$ is called Kolmogorov complexity program.

Rule 2-2: The production of Kolmogorov complexity program

Let $\ell(X)$ be the length of the sequence $X(m)$ and $X(m)/n$ be a probability of the occurrence of pixel in a string of length n . $X(m)$ represents the total number of appearances of pixels.

$K(X)$ can be expressed by $\ell(X)$, as follows

$$K[X(m/n)] = \min_{A(p,n)=X(m)} \ell(p), \quad (2-4)$$

where $m = 1, 2, \dots, n$ and p is the probability of successful appearance of the image pixels. $A(p,n)$ means that the automaton can convert the successful event among total number of features n with probability p into. $\ell(p)$ represents the length of the string where object pixels occurred.

III. STRING QUAD ARRAY ANALYSIS

$$\text{Define: } s \in S, s = 1, 2, \dots, S. \quad (3-1)$$

where s is the number of string components.

Definition 4-1:

The object in "pixel recursion" is defined as "1" and the background in "pixel recursion" is defined as "0".

Definition 3-2:

The area of pseudo Quad plane in scanning process is similar to discrimination function, in this paper, is defined as "Recognition Potential function" or "Quad-Array function".

Definition 3-3:

The pixel number of horizontal scanning line is m and the pixel number of vertical scanning line is n , where $m = 1, 2, \dots, M, 1 < M < \infty; n = 1, 2, \dots, N, 1 < N < \infty$.

Definition 3-4:

the number of vertical pixel n and horizontal pixel m are decided by the real edge of object image, such that the Quad plane potential function $Q_s(m,n)$ is a function of (m,n) .

(1) Object image edge is monodescending sense in right hand side of topmost point.

Definition 3-5:

Object image edge is monodescending scene as show in Fig.3. The raster line on the right side of topmost point is divided into S stages, Q_s is the area between S -th stage raster and corresponding object image edge W_s . The potential function sequence is defined as Q ,

$$Q_i = [Q_1, Q_2, \dots, Q_s, \dots, Q_S]. \quad (3-2)$$

This potential function as called as Quad String Array

Corollary 3-1:
As shown in Fig.3, if object edge is monodecreasing, no matter it is linear or not, we can divide the raster line in equal division m . But the vertical pixel number of Q is decided by the shape of object edge, and the length sequence is N ,

$$N = (N_1, N_2, \dots, N_s, \dots, N_S) \quad (3-3)$$

Then

$$Q_1 = R_1(0,0) + T_1(m, n_1);$$

$$Q_2 = R_2(m, n_1) + T_2(m, n_2 - n_1)$$

⋮

$$Q_s = R_s(m, n_{s-1}) + T_s(m, n_s - n_{s-1}) \quad (3-4)$$

where $R(\cdot)$ is the rectangular quad; $T(\cdot)$ is the triangle quad and $R(0,0) = 0$, $T(0,0) = 0$.

(2) Object image edge as fluctuating wave form.

Corollary 3-2:

As show in Fig. 4, the fluctuating wave form is another form of monodecreasing and monoincreasing wave form.

Definition 3-6:

The Quad String Array shown in Fig. 4 is defined as Q ,

$$\tilde{Q}_{II} = [Q_1, Q_2, \dots, Q_s, \dots, Q_S] \quad (3-7)$$

The horizontal interval of Q_s is decided by the interval between the valley point V_s and the neighbor top point P_{s-1} . The intervals between each quads may not be equal.

Corollary 3-3:

each quad of fluctuant edge can be divided into equal M 's divisions horizontally. The quad Q_{1m} is in monodecreasing sense for odd 1, and is in monoincreasing sense for 1. Then

$$Q_1 = \sum_{m=1}^{M1} Q_{1m}; Q_2 = \sum_{m=1}^{M2} Q_{2m}; \dots; Q_s = \sum_{m=1}^{Ms} Q_{sm} \quad (3-6)$$

where

$$Q_{1m} = R_1(m, n_{m-1}) + T(m, n_m - n_{m-1}), \quad 1 < m < M$$

$$Q_{2m} = R_2(m, n_{m-1}) + T(m, n_m - n_{m-1}), \quad 1 < m < M$$

$$\vdots \quad \vdots \quad \vdots \quad (3-7)$$

$$Q_{sm} = R_s(m, n_{m-1}) + (-1)^{s+1} T(m, n_m - n_{m-1}), \quad 1 < m < M$$

and $m \in M$, $s = 1, 2, \dots, S$; $N = (N_1, N_2, \dots, N_{s-1}, N_s, \dots, N_S)$. The sign of triangular quad is plus for the edge in monodecreasing scene and minus for the edge in monocreasing scene.

IV. RECOGNITION ALGORITHM

Assumption 4-1:

If the object image edges are divided into small partitions then each interval will be linear no matter how shape the original edges are.

Assumption 4-2:

If the object image edges are an irregular fluctuant wave form, then the quad plane domain will be convexity. The quad domain will be convex if edge fluctuates downward and be concave if edge fluctuates upward.

Assumption 5-3:

The String QUAD Sequence Array $\tilde{Q}_{II}$

$$\tilde{Q}_{II} = (Q_1, Q_2, \dots, Q_s, \dots, Q_S) \quad (3-5)$$

Q_s is the s -th stage Quad Potential Function.

$$n = (W_1, W_2, \dots, W_s, \dots, W_S) \quad (4-1)$$

Definition 4-1:

The sample space of Quad Potential Function sequence is Q sample, then

$$\tilde{Q}^{s\text{amp}} = (Q_1^{s\text{amp}}, Q_2^{s\text{amp}}, \dots, Q_s^{s\text{amp}}, \dots, Q_S^{s\text{amp}}) \quad (4-2)$$

Lemma 4-1:

The Quad Potential Function Sequence of new input flying object image is Q , then

$$\tilde{Q} = (Q_1, Q_2, \dots, Q_s, \dots, Q_S) \quad (4-3)$$

The error sequence between unknown object and standard pattern is e , then e can be defined as following,

$$\text{where } \tilde{e} = (e_1, e_2, \dots, e_s, \dots, e_S) \quad (4-4)$$

$$\text{or } e_1 = Q_1 - Q_1^{s\text{amp}} \quad (4-5)$$

$$e_1 = |Q_1 - Q_1^{s\text{amp}}| \quad (4-6)$$

The Risk Function of Quad Potential Function Sequence is:

$$E = (|e_1|, |e_2|, \dots, |e_s|, \dots, |e_S|) = \# \left| e_s \right|, \quad (4-7)$$

where $\#$ is defined as the String Connection Function. The minimum Risk Function (or Performance index) be defined as J ,

$$J = \min_s E = \min_s (|e_1|, |e_2|, \dots, |e_s|, \dots, |e_S|) \quad (4-8)$$

The object edge W_s is one side of the right-triangular potential function $T_s(m, n_s - n_{s-1})$ and W_s may be nonlinear.

If the unknown object image is similar or resemble to the standard pattern then it must satisfied the following optimum threshold condition.

$$e_s < Th^*(s) = T_s^{s\text{amp}}(m, n_s - n_{s-1}) \quad (4-9)$$

where $Th^*(s)$ is the optimum threshold in s -th quad.

Theorem 4-1:

The scanning raster is begin at the topmost edge point and scanning from left to right, the horizontal interval m can be counted by the pixel number. The optimum threshold in eq. 5-9 approximates to object edge in Q_s , if the pixel number is very small. Such that,

$T_s^{s\text{amp}}(m, n_s - n_{s-1})$ is the necessary condition. By eq. 5-6

$$\begin{aligned} |e_s| &= |Q_s - Q_s^{s\text{amp}}| \\ &= |R_s(m, n_{s-1}) + T(m, n_s - n_{s-1}) - R_s^{s\text{amp}}(m, n_{s-1}) - T_s^{s\text{amp}}(m, n_s - n_{s-1})| \end{aligned} \quad (4-10)$$

and the optimum threshold in the s -th Quad is defined as $Th^*(s)$ where

$$Th^*(s) = T_s^{s\text{amp}}(m, n_s - n_{s-1})$$

i.e., $T_s^{s\text{amp}}(m, n_s - n_{s-1})$ is the maxi variance between two similar edges. If there are more than two quads in the Quad String Array then the minimum optimum threshold string $Th^*(s)$ can be used as standard threshold.

$$Th^*(s) = \#_{s=1}^s Th^* = \#_{s=1}^s T_s^{s\text{amp}}(m, n_s - n_{s-1})$$

$$= [T_1^{s\text{amp}}(m, n_1 - n_0), T_2^{s\text{amp}}(m, n_2 - n_1), \dots, T_s^{s\text{amp}}(m, n_s - n_{s-1})] \quad (4-11)$$

where "#" is the string connection as defined in eq. (4-7), in eq.(4-11), it is the representation of optimum threshold string. There is an identification mapping ϵ , which may not be defined on the all ranges of Z , then

$$\epsilon : \{ e_s < T_s^{s\text{amp}}(m, n_s - n_{s-1}) \} \rightarrow W \quad (4-12)$$

$$Z : \{ E = \#_{s=1}^s |e_s| < \#_{s=1}^s (T_s^{s\text{amp}}(m, n_s - n_{s-1})) \} \rightarrow \Omega \quad (4-13)$$

where $\Omega = \{ W_1, W_2, \dots, W_s, \dots, W_S \}$; "---->" is a mapping relation.

Lemma 4-2:

By the definition of Q_s , the vertical pixel number for standard sample image and unknown image are $N_s^{s\text{amp}}$ and N_s respectively.

$$\text{If } |N_s - N_s^{s\text{amp}}| < 2T_s/m \quad (4-14)$$

m : horizontal pixel number

$$\text{then } \epsilon : Q_s \rightarrow W_s \text{ where } W_s \in \Omega \quad (4-15)$$

Proof:

m, n are very small and finite; $T_s = 1/2 m, n$; $n = 2T_s/m$ and $n = n_s - n_{s-1}$.

Corollary 4-1:

If the length of horizontal and vertical string are m, n respectively which are positive real number, then the slope of image edge is determined by the following equation.

$$\begin{aligned} \text{slope} &<= |1| \text{ as } m > n \\ \text{slope} &<= |1| \text{ as } m < n \end{aligned} \quad (4-16)$$

Lemma 4-3:

By the definition of Q_s , $m = n$, m, n are positive real number. If m is constant for both input and sample pattern and

$$|n_i - n_i^{s\text{amp}}| < n_s - n_{s-1}, \quad s = 1, 2, \dots, S, \quad i = 1, 2, \dots, N, \quad (4-17)$$

$$\text{Then } \epsilon : Q_s \rightarrow W_s \text{ where } W_s \in \Omega \quad (4-18)$$

Lemma 4-4: Markovian Matching Block function

The horizontal coordinate of Markovian matching block

function is $(\tilde{m}_1, \tilde{m}_2, \dots, \tilde{m}_s)$ which is the horizontal segmentation sequence. It is not necessary for $\tilde{m}_s$ equal to $\tilde{m}_{s-1}$ as the object image edge is convex & concave scene. If the object image edge is monodecreasing, for simplicity, the horizontal segmentation can be $0m_1 = m_1m_2 = m_2m_3 \dots$ and $0m_1 = m_1, m_1m_2 = m_2, \dots, m_{s-1}m_s = \tilde{m}_s$. The vertical coordinate of matching function can be segmented in the same process and the sequence is $\{\tilde{n}_1, \tilde{n}_2, \dots, \tilde{n}_s\}$. We have the following relation:

$$1/2 \tilde{n}_s \tilde{m}_s = T_s^{s\text{amp}} \quad (4-19)$$

where $T_s^{s\text{amp}}$ is the triangular area in $Q_s^{s\text{amp}}$, it may be finite fixed value. Such that we can rewrite eq. 4-19 eq. 4-20

$$\tilde{n}_s = 2T_s^{s\text{amp}} / \tilde{m}_s \quad (4-20)$$

and $T_s^{s\text{amp}}$ is the maxi variance in Quad s for Markovian matching block.

In Fig.5, suppose the curve C is divided into three Quads Q_1, Q_2 and Q_3 . By the eq.(3-4):

$$\begin{aligned} Q_1 &= R_1 + T_1 = 0 + T_1 \\ Q_2 &= R_2 + T_2 \\ Q_3 &= R_3 + T_3 \end{aligned}$$

The basic assumption is that " $T_s^{s\text{amp}}$ " is the maxi variance for Quad s , that is, in Quad Q_1 , T_1 is the maxi tolerance and T_2 is the maxi tolerance for Q_2 etc. The curve C_1 in Quad Q_1 and Q_2 is similar to C , iff $|C_1 - C| < TH^*(s)$.

By eq. (4-10) and (4-11):

$$|C_1 - C| = \#_{i=1}^2 |e_i| = [T_s^{s\text{amp}}, A_1 + T_2^{s\text{amp}}, -A_2] \quad (4-22)$$

if $A_1 = A_2$ then $|C_1 - C| < [T_1^{s\text{amp}}, T_2^{s\text{amp}}] = TH^*(s)$ then we can say " C_1 is similar to C ".

In the other case if the tolerance is negative, then by Fig.6 :

$$C_2 - C = -[T_1, (A_1' + T_2' - A_2')]$$

where $T_1 = T_1^{s\text{amp}}$

$$t_2 = T_2^{s\text{amp}}$$

$$\text{and if } A_1' = A_2',$$

$$(4-23)$$

$$\text{then } |C_2 - C| = [T_1^{s\text{amp}}, T_2^{s\text{amp}}] = TH^*(s)$$

that is, C_2 is similar to C . The above two cases are the extreme condition for similarity, and any curve lays between these two extreme conditions can be recognized as similar curve for C . The Markovian matching block function is sketched as following: Fig.7.

L is the histogram of $\tilde{n}_s \tilde{m}_s$ for standard curve C

L_1 is the histogram of $\tilde{n}_s \tilde{m}_s$ for standard curve C_1

L_2 is the histogram of $\tilde{n}_s \tilde{m}_s$ for standard curve C_2

Now, we process the above algorithms to Quad Q_2 and Q_3

,and suppose the tolerance in Q_1 will not influence the variance in Q_2 and Q_3 then we can sketch the Markovian matching block from Q_2 again. The Markovian matching block function is shown as Fig.8.

We combine Fig.7 and Fig.8 together then we get the following result and shown in fig.9.

Any curve lays inside the block area shown in Fig.8 is similar to curve C. There is an another example shown in Fig.9, the curve in that example is divided into 6 Quads. If the histogram of $\tilde{n}_s \tilde{m}_s$ for any unknown curve is laid inside the Markovian matching block of C, then we can say that the unknown curve is similar to the standard curve C.

$\Sigma : \{ \text{Histogram of } \tilde{n}_s \tilde{m}_s \text{ for unknown object lay inside the normalized Markovian matching block} \} \rightarrow n(4-24)$

By the equation 4-20, $\tilde{n}_s$ is variable and the histogram of $\tilde{n}_s \tilde{m}_s$ segments is defined as histogram function which is the recognition threshold in String Quad Array.

The optimum threshold $Th(s)$ is defined as the boundary distance of matching block in each stage s.

If the histogram $\tilde{n}_s \tilde{m}_s$ of unknown object is laid inside the matching block of standard pattern, then these two objects are similar each other.

Corollary 4-2: Defined $W(T)$ as the domain of the Markovian matching block, and " $\Rightarrow$ " is the representation of "within the matching function threshold" then

$$\Sigma : \tilde{Q} \xrightarrow{s=1} [\text{Histogram of } \tilde{n}_s \tilde{m}_s \Rightarrow W(T)] \rightarrow n \quad (4-25)$$

V. RANDOM WALK APPROACH

Random walk technique is further discussed by the view points of vertical pixels recursion string approach and vertical recursion Quad string method. By the analysis of Pseudo Quad Potential function array which is shown in Fig.11.

$$\tilde{Q} = \{ Q_1, Q_2, \dots, Q_s, \dots, Q_S \} \quad (4-3)$$

It is not necessary for $\tilde{m}_{s-1} = \tilde{m}_s$ and $\tilde{n}_{s-1} = \tilde{n}_s$.

In Fig.11, every Quad Q_s is the combination of pixel cell array, every rectangular and triangular in Q_s can be expressed by a pixel cell. By eq. 3-7, every odd Quad is convex and concave for every even Quad.

By the using of Q_s , there are two recognition approaches, one is vertical Quad string the other is vertical pixel string, the former has less recognition time but low recognition rate, the latter has high recognition rate.

Assumption 5-1:

As shown in Fig.11, Quad Q_s is the combination of rectangulars and triangulars. Every rectangular and triangular are expressed by a pixel set, but the rectangular area is far away from the object image. Such that, the shape of object image edge can be expressed by the triangular pixel cell approximately.

Definition 5-1:

Usually, the shape of object edge is irregular fluctuating, the monodecreasing or monoincreasing can be defined by the equations 5-1 and 5-2.

$$(Q_{2s-1}; s = 1, 2, \dots, s/2) \rightarrow \text{convex scene} \quad (5-1)$$

$$(Q_{2s}; s = 1, 2, \dots, s/2) \rightarrow \text{convex scene} \quad (5-2)$$

where convex scene is the representation of monodecreasing edge and convex scene is the representation of monoincreasing edge.

Definition 5-2:

Ω is defined as the image edge string of every Quad. then $\Omega = (W_1, W_2, \dots, W_s, \dots, W_S)$ (4-1)

The shape of edge mapping by Q_{2s-1} and Q_{2s} are different. ie,

$$(Q_{2s-1}; s = 1, 2, \dots, s/2) \xRightarrow{*} (W_{2s-1}; s = 1, 2, \dots, s/2) \quad (5-3)$$

$$(Q_{2s}; s = 1, 2, \dots, s/2) \xRightarrow{*} (W_{2s}; s = 1, 2, \dots, s/2) \quad (5-4)$$

where " $\xRightarrow{*}$ " is the representation of edge "similarity"

Lemma 5-1:

By the equation 3-7, edges mapping by Q_{2s-1} and Q_{2s} is monodecreasing and monoascending respectively. By the assumption 5-1, Quad is the combination of R_s and T_s where R is the representation of background and T is the neighborhood representation of object edge. Due to the change of monodecreasing and monoascending, the sign variance of T is defined by equation 5-5 and 5-6.

$$(T_{2s-1}; s = 1, 2, \dots, s/2) \xrightarrow{*} +1 \quad (5-5)$$

$$(T_{2s}; s = 1, 2, \dots, s/2) \xrightarrow{*} -1 \quad (5-6)$$

where "+" is the vertical downward movement of one cell and "-" is the vertical upward movement of one cell. That is, what R_s is known, then the progress of T_s is a kind of Vertical Binary Random Walk.

where " $\xrightarrow{*}$ " is the direction of random walk.

Lemma 5-2: For every Q_{2s-1} and Q_{2s} which are fit for the matching block function threshold defined in Lemma 4-4 can be classified into feasible region. The decision mapping E is defined by eq. 5-7 and 5-8 corresponding to eq.(5-5) and (5-6) respectively.

$$[Q_{2s-1}; s = 1, 2, \dots, s/2 \Rightarrow W(T)] \rightarrow n_{2s-1} \quad (5-7)$$

$$[Q_{2s}; s = 1, 2, \dots, s/2 \Rightarrow W(T)] \rightarrow n_{2s} \quad (5-8)$$

where " $\Rightarrow W(T)$ " is the representation of "within the matching function threshold", as defined in corollary 5-2 and it can be proved by eq. 6-3 and 6-4.

Lemma 5-3: Quad Q_s referred is shown in Fig. 12.

The pixel cell of Q_s can be divided by eq. 6-9 and 6-10

$$m_s = (m_{s1}, \dots, m_{sr}, \dots, m_{sr'}), \quad r = 1, 2, \dots, R \quad (5-9)$$

$$n_s = (n_{s1}, n_{s2}, \dots, n_{sr}, \dots, n_{sr'}), \quad r = 1, 2, \dots, R' \quad (5-10)$$

$$\text{where } m_{s1} = M_{s-1}, m_{sr} = M_s, n_{sr} = N_{s-1}, n_{sr'} = N_s$$

$$\Sigma : [Q_s(m_{sr}, n_{sr}); r=1, 2, \dots, R \Rightarrow W(T)] \rightarrow W_s \quad (5-11)$$

$$\Sigma : [Q_s(m_{sr}, n_{sr}); r=1, 2, \dots, R \Rightarrow W(T)] \rightarrow n_Q \quad (5-12)$$

where $r = 1, 2, \dots, R$ and $r' = 1, 2, \dots, R'$ and $Q_s(m_{sr}, n_{sr'})$ is the pixel cell quad array of Q_s .

Theorem 5-1:

By the algorithm of Random Walk, system recognition

can be implemented by the vertical binary random walk. If the unknown object fits for eq. 5-7, 5-8, 5-11 and 5-12 then following equation is existed.

$$: [Q_{2s-1}; s=1, \dots, s/2 \text{ (monodecending scene)} \Rightarrow W(T)]$$

$$\rightarrow Q_{2s-1} \quad (5-13)$$

$$: [Q_{2s}; s=1, 2, \dots, s/2 \text{ (monoascending scene)} \Rightarrow W(T)]$$

$$\rightarrow Q_{2s} \quad (5-14)$$

This can be proved by Lemma 5-2 and Lemma 5-3.

Theorem 5-2:

$P[(m_{sr}, n_{sr}) | (m_{s(r-1)}, n_{s(r-1)})]$ is defined as the probability which transferred from the pixel $[m_{s(r-1)}, n_{s(r-1)}]$ to the pixel $[m_{sr}, n_{sr}]$.

If $P(m_{sr}, n_{sr}) = 1$,

then $Z : (Q_{2s-1} \cup Q_{2s}) \rightarrow \Omega$

where $s = 1, 2, \dots, S$, $r = 1, 2, \dots, R$, $r' = 1, 2, \dots, R'$. This can be proved by Lemma 5-3 and theorem 5-1.

VI. EXPERIMENT RESULTS

As discussing in section III and IV, there are three different types object used in this experiment, these objects are handtool, human face and aircraft. The Vertical String Array, Random Walk recognition algorithms are applied on these test objects respectively. The experiment results are shown as the following tables.

Table 1:

Correct Recognition	Vertical String Array approach	Random Walk approach
H.a	0.93	0.95
H.b	0.90	0.93
H.c	0.90	0.93
H.d	0.90	0.96

Table 2:

Correct Recognition	Vertical String Array approach	Random Walk approach
Face A	0.62	0.70
Face B	0.55	0.67

Table 3:

Correct Recognition	Vertical String Array approach	Random Walk approach
F-16	0.80	0.90
Mig-25	0.85	0.89

VII. CONCLUSIONS

1. The recognition algorithms discussed in this paper utilize the object background Quad as the basic elements. the recognition process is beginning the topmost point of object edge, and it is especially useful in real-time recognition.
2. The object images are different as the view direction changed. The aircraft is viewed at upward and face to face direction, the variance between two continuous image is also stored in the computer memory.
3. The matching of principal axis direction between unknown object image and standard pattern is implemented by the Circular Layer Code techniques.
4. It is better to normalize the object image within the scanner device, this can be done by hardware or software such that memory size as well as the processing time of main processor can be reduced to minimum.
5. The edge of input image will be stepalized by the String Quad Array approach, the variance between step form edge and analog edge is the major factor for misrecognition.
6. For the hollow object, the algorithm can apply on it and the object can be recognized within one frame's scanning.

7. It is not necessary to rotated the object image in Pseudo Quad plane, if we modified the associated software program.

8. The major error of recognition is due to the not matching of principle axis between standard pattern and unknown object.

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Fig. 1 Classification block.

Fig. 2. Pseudo Quad Plane.

Fig. 3. monodecreasing quad plane.

Fig. 4. monodecending and monoascending

Fig. Positive variance for two similar curves

Fig. Negative variance for two similar curves

Fig.7 Markovian matching block function for two quads curve

Fig.8 Markovian matching block function for secondary quad.

Fig.9 Markovian matching function for three quads curves

Fig.10 Markovian matching block function and its' relative curve

Fig. 11 Image of fluctuating edge.

Fig. 12. Pixel maps of handtools.

Fig. 13. Pixel maps of human faces.

Fig. 14. Pixel maps of aircraft F-16 and Mig-25.