Conditional Estimation of Vector Patterns

in Remote Sensing and GIS

Final Report

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Conditional Estimation of Vector Patterns in Remote Sensing and GIS

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Abstract

Within this project report we provide the mathematical theory for the extraction of primary topographic vectors using Bayesian statistical models. In particular, this effort documents the mathematical foundations for the algorithms used within the C, C++, and JAVA computer languages, and further describes the related mathematical techniques for the vector model and class structure. This final report also contains the remaining C-code elements for the processing of digital (raster) data into a composite vector model. While this research includes only the working prototypes and sample code elements, it is anticipated that Corps researchers will use these examples to refine their respective methods for use in water control, digital elevation modeling, and land use analysis.
1. Title

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Final Report

2. Abstract

Within this project report we provide the mathematical theory for the extraction of primary topographic vectors using Bayesian statistical models. In particular, this effort documents the mathematical foundations for the algorithms used within the C, C++, and JAVA computer languages, and further describes the related mathematical techniques for the vector model and class structure. This final report also contains the remaining C-code elements for the processing of digital (raster) data into a composite vector model. While this research includes only the working prototypes and sample code elements, it is anticipated that Corps researchers will use these examples to refine their respective methods for use in water control, digital elevation modeling, and land use analysis.

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4. Introduction

A statement of the vector conversion model to be used will be made using traditional statistical notation. It is assumed that there exists two statistical environments called pattern class $c_1$ and pattern class $c_2$. For the purpose of this discussion, let $c_1$ be the background image (in raster), and let $c_2$ be the "potential" vector class that requires "identification" and "conversion".

Each environment is also characterized by a constant $c$, but unknown probability distribution exists over the $n$ discrete values of the pattern measurement variable $x$. 
Namely, \( P(x_i \mid c_1) \) is the probability of measurement value \( x_i \) occurring in environment \( c_1 \) (background) for \( i = 1, 2, \ldots, n \) image samples. Similarly, the unknown distribution \( P(x_i \mid c_2) \) characterizes \( x \) under the second environment \( c_2 \) (the new vector class). Vector measurements will be discussed following our introduction to the formal mathematical model.

By unknown, it is meant that no prior information whatever is given on the \( 2n \) scalars \( P(x_i \mid c_1) \).

Any pair of distributions is equally likely a priori. Sample pattern data from the environments is to be measured to estimate the actual \( P(x_i \mid c_1) \) existing in any specific recognition problem (the sample relative frequencies will be used).

Hence, the only constraints are that all probabilities be non-negative with closure to unit probability. This may be formally stated as:

\[
h_1 < P(x_i \mid c_1) > = h_1 < P(x_i \mid c_2) > = 1 \tag{1}
\]

A prospective vector is admitted to the proper set if the incremental increase in scalar measure satisfies a well-defined statistical test of significance (error probability measure). The \( J \) measure shown in Equation (2) is an excellent basis criteria since it varies with the squared distance between the means of the two classes normalized by the combined covariance matrices:

\[
J = (\mu - \mu_0)^T x (\Lambda_1 + \Lambda_2)^{-1} (\mu - \mu_0) \tag{2}
\]

and 
\( \mu \) and \( \Lambda \) denote the mean and covariance respectively.

Whenever a measurement \( x \) is made, there is a known prior class probability \( P(c_1) \) that class \( c_1 \) is in effect and \( P(x_i \mid c_1) \) applies. With the complementary probability \( P(c_2) = 1 - P(c_1) \), class \( c_2 \) and \( P(x_i \mid c_2) \) are in effect. However, the particular class in effect for a pattern is not known; only the value \( x \), extracted from the multispectral data set. Indeed, even the number of bands within this data set may vary.

The vector identification problem is to design a recognition rule to predict (recognize) the pattern class most likely to be in effect for each of the \( n \) possible measurement
values of \( x_i \). Its theoretic solution is known to be a maximal class recognition accuracy using Bayes Rule.

Specifically, this rule is to:

\[
\text{Predict } c_i \text{ when } x_i \text{ occurs if } P(c_i \mid x_i) > P(c_i \mid x_j); \\
\text{and Predict } c_j \text{ otherwise.}
\]

The superficially simple rule states to choose the more probable class, given the measurement value \( x_i \) which has occurred. The resultant correct recognition probability accuracy is then:

\[
P_{c_j}(n, P_{c_i}) = S_j < \max_{x_j} P(c_i \mid x_i) \mid P(x_i) >
\]

Where

\[ h_i < \max_{x_i} P(c_i \mid x_i) \text{ and } h_j < \max_{x_j} P(x_i \mid c_j) P_{c_j} > \]

Note that no assumption of measurable statistical independence is made. Please recall from our earlier development within Interim Report 4, that the independence was required to derive the C-code and related statistical libraries.

Within this new context, a vector of \( r \) discrete measurements, each having \( n_k \) values \((k=1,2, \ldots, r)\) is clearly evident to a single measurement with:

\[
n = n_1 n_2 \ldots n_r.
\]

Although the unknown probabilities \( P(x_i \mid c_j) \) must actually be statistically estimated from the finite pattern sets (carefully selected from within the original raster data set), the limiting case of known probabilities \((m = \infty)\) may be developed to show asymptotic properties for larger data sets (raster or vector).

5. Performance Criteria

A standard procedure for evaluating the performance of a probability model is the expected or mean Bayes recognition accuracy over all possible environmental probabilities \( P(x_i \mid c_j) \). Namely, no prior information on each scalar \( P(x_i \mid c_j) \) is assumed before the sample pattern data are measured. Any set of \( 2n \) positive real
probability values is equally likely provided the condition in Equation (2) is met. If any such set were made more likely than another, then the criterion would emphasize the accuracy of that particular recognition problem (for example band collinearity). Instead, the criterion is to weigh equally all recognition problems having given values of \( P(c_i) \) and \( n \).

It should be remarked that \((Pc_c)\) is explicitly exhibited as a parameter because recognition rule performance should be judged against a minimum accuracy of \( \max_j (Pc_1, 1 - Pc_i) \) using no prior measurements. If \( Pc_1 \) lies near zero or unity, then any recognizer should have nearly 100 percent accuracy.

Hence, the Bayes accuracy of: \( h_i < \max_j P(x_i \mid c_j) Pc_j \) is a statistic, in that it is a function of the random variables (extracted from the image plane):

\[
u_i = P(x_i \mid c_i) \text{ and } v_i = P(x_i \mid c_2) \quad i = 1, 2, \ldots n
\]  

(6)

To compute its mean or expected value, first note that the \( u_i \) and \( v_i \) are uniformly distributed due to the "equally likely" assumption of the model:

\[
dP(u_1, u_2, \ldots, u_n, v_1, v_2, \ldots, v_n) = N du_1 du_2 \ldots du_n dv_1 dv_2 \ldots dv_n
\]

(7)

Where only 2\((n-1)\) differentials appear on the right of Equation (7) because the two normalizing constraints in Equation (1) fix \( u_n \) and \( v_n \) in terms of the other remaining elements.

Now, the boundaries of the \((n-1)\) order distribution of the \( u_i \) alone are given by the intersection of the hypercube \( 0 \cdot u_i \cdot 1, i = 1, 2, \ldots n-1 \), and the symmetric orthogonal hyperplane:

\[
h_i < u_i > = 1; \quad \text{such that}
0 \cdot u_i \cdot 1, i = 1, 2, \ldots n-1
\]

(8)

Note that the constraining Equation (8) is a direct result of Equation (1). An identical boundary structure holds for the \( v_i \), so that the normalizing constant \( N \) in Equation (7) is obtained from:

\[
1 = N \left\{ \int_{0,1} du_1 \int_{0,1-a} du_2 \int_{0,1-a\cdot u_2} du_3 \cdots \int_{0,1-a\cdot u_2 \cdots u_n} du_n \right\} \times
\left\{ \int_{0,1} dv_1 \int_{0,1-a\cdot v_1} dv_2 \int_{0,1-a\cdot v_1 \cdot v_2} dv_3 \cdots \int_{0,1-a\cdot v_1 \cdot v_2 \cdots v_n} dv_n \right\}
\]

(9)
However, the two iterated integrals may be easily evaluated giving

\[ N = [(n-1)!]^2 \]  \hspace{1cm} (10)

As shown, Equation (10) is a very simple factorial model that is quickly coded as a C-code element for row and matrix estimation:

```c
s[lm1] = Fact_j.colnrm2_j(n-l+1,x,lm1,lm1);
if (s[lm1] != 0.0) {
    if (x[lm1][lm1] != 0.0) s[lm1] = Fact_j.sign_j(s[lm1],x[lm1][lm1]);
    Fact_j.colscal_j(n-l+1,1.0/s[lm1],x,lm1,lm1);
    x[lm1][lm1]++;
}

s[lm1] = -s[lm1];
for (j = l; j < p; j++) {
    if ((j <= nct) && (s[lm1] != 0.0)) {
        t = -Fact_j.coldot_j(n-l+1,x,lm1,lm1,j)/x[lm1][lm1];
        Fact_j.colaxpy_j(n-l+1,t,x,lm1,lm1,j);
    }
```

7
6. Vector Recognition Accuracy

Equation (9) is the recognition accuracy given \( u_i \) and \( v_i \) and is multiplied by Equation (7) to obtain a joint probability. This is integrated over the \( u_i, v_i \) range to get the mean accuracy. After careful simplification, we find that:

\[
P_c = n [(n-1)!]^2 \int_{0,1} \int_{0,1} (1-u)^{x^2} (1-v)^{y^2} \max (P_{c_1} u_i, P_{c_2} v_j) du_i dv_i
\]  

(11)

By requiring that \( P_{c_1} \cdot P_{c_2} \) without loss of generality, the \( v_1 \) integral in Equation (11) may be broken into two ordinary integrals:

a. Over the range \( 0 \cdot v_1 \cdot P_{c_1} u_1 / P_{c_2} \)

and

b. All remaining regions outside \( v_1 \).

The region defined by item (b) requires an integration by parts. The \( u_1 \) integral may be evaluated as a beta function plus a second, somewhat cumbersome integral whose integrand may be expanded by the binomial theorem and integrated term by term giving:

\[
P_c = P_{c_1} + P_{c_2} (n-1) \left( P_{c_1} / P_{c_2} \right)^{h_j} \\
\text{for } P_{c_1} \cdot P_{c_2}
\]

(12)

And, for the common case where \( P_{c_1} = P_{c_2} = 0.5 \), Equation (13) reduces to the specific form

\[
P_c (n, 0.5) = 3n-2 / 4n-2
\]

(13)

Note that each recognition accuracy begins at \( \max( P_{c_1}, 1 - P_{c_1} ) \) for \( n=1 \) in that a single measurement value must always occur and therefore imparts no information (it simply increases with the complexity of each measurement).
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The algorithm shown in Equation (12) is near asymptotic maximum recognition accuracy for all \( n > 2 \). The ordinal value is significantly less than 100 percent unless \( P(c_i) \) is near zero or unity. The inflection occurs near \( n = n_c \) as the number of pattern classes defined increases within the image volume. The asymptotic maximum accuracy of this algorithm is obtained by letting \( n \) approach infinity in Equation (11) yielding:

\[
P_c \ (n = \infty, \ P_{c_i}) = P_{c_1} + P_{c_2} = P_{c_1} + P_{c_2} = 1 - P_{c_1} P_{c_2}
\]  
(14)

7. Simulation Code

The mathematical results shown in Equation (14) have been tested using C-language models for pattern recognition and vector extraction. A cube is defined as described in Equation (8), namely \( h_i < u_i = 1 \); such that \( 0 \leq u_i \leq 1 \), \( i = 1, 2, \ldots, n-1 \). Classes are selected, reduced, and combined using the geometric “spinning” of vectors in \( n \)-space. This procedure is used to randomize the input elements (as a Monte-Carlo simulation). The vector cubes are tested using conditional probability measures as described in Equation (13). Equation (14) is applied when class probabilities are equal to 0.5. The complete simulation engine is programmed for Sun Solaris (Unix) applications.

```c
// *******************************************************************************

* FUNCTION: UNIX_XArg_Main

* INPUTS: hXARG_ - XARG_ module handle
          dwReason - reason being called (e.g. process attaching)
          lpReserved - reserved

* RETURNS: TRUE if initialization passed, or FALSE if initialization failed.

* COMMENTS: On XARG_PROCESS_ATTACH registers the VECTORCUBECLASS

          XARG_initialization serialization is guaranteed within a
          process (if multiple threads then XARG_entry points are
          serialized), but is not guaranteed across processes.

          When synchronization objects are created, it is necessary
          to check the return code of GetLastError even if the create
          call succeeded. If the object existed, ERROR_ALREADY_EXISTED
          will be returned.

          If your XARG_ uses any C runtime functions then you should
          always call _CRT_INIT so that the C runtime can initialize
          itself appropriately. Failure to do this may result in
          indeterminate behavior. When the XARG_ entry point is called
          for XARG_PROCESS_ATTACH & XARG_THREAD_ATTACH circumstances,
```
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* _CRT_INIT should be called before any other initialization
* is performed. When the XARG_entry point is called for
* XARG_PROCESS_DETACH & XARG_THREAD_DETACH circumstances,
* _CRT_INIT should be called after all cleanup has been
* performed, i.e. right before the function returns.
*

/*********************************************************************/

BOOL UNIX_XArg_Main (HANDLE hXARG_, DWORD dwReason, LPVOID lpReserved)
{
    ghMod = hXARG_;
    switch (dwReason)
    {
    case XARG_PROCESS_ATTACH:
        
        WNDCLASS wc;
        
        if (!_CRT_INIT (hXARG_, dwReason, lpReserved))
        
            return FALSE;
        
        wc.style = CS_HREDRAW | CS_VREDRAW | CS_DBLCLKS | CS_OWNDC | 
            CS_GLOBALCLASS;
        
        wc.lpfnWndProc = (WNDPROC) VectorcubeWndProc;
        
        wc.cbClsExtra = 0;
        
        wc.cbWndExtra = VECTORCUBE_EXTRA;
        
        wc.hInstance = hXARG_;
        
        wc.hIcon = NULL;
        
        wc.hCursor = LoadCursor (NULL, IDC_ARROW);
        
        wc.hbrBackground = NULL;
        
        wc.lpszMenuName = (LPSTR) NULL;
        
        wc.lpszClassName = (LPSTR) VECTORCUBECLASS;
        
        if (!RegisterClass (&wc))
        
            MessageBox (NULL,
                (LPCTSTR) "XArg_Main(): RegisterClass() failed",
                    (LPCTSTR) "Err! - VECTORCUBE XARG_",
                MB_OK | MB_ICONEXCLAMATION);
            
            return FALSE;
        
        break;
    }
    
    case XARG_PROCESS_DETACH:
    {
        if (!_CRT_INIT (hXARG_, dwReason, lpReserved))
        
            return FALSE;
        
        if (!UnregisterClass ((LPSTR) VECTORCUBECLASS, hXARG_))
        
            MessageBox (NULL,
                (LPCTSTR) "XArg_Main(): UnregisterClass() failed",
                    (LPCTSTR) "Err! - VECTORCUBE XARG_",
                MB_OK | MB_ICONEXCLAMATION);
            
            return FALSE;
        
        break;
    }
}
default:
    if (!_CRT_INIT (hXARG_, dwReason, lpReserved))
        return FALSE;
    break;
}
return TRUE;

/*********************************************/

BOOL UNIX_MOTIF_CRT_INIT (HWND hXARG_, DWORD dwReason, LPVOID lpReserved);

    // Declared below are the module's 2 exported variables.
    //
    // gNumVectorcubes. This Process is an instance variable that contains
    // the number of (existing) Vectorcube controls created by the
    // current process.
    //
    // gNumVectorcubesAllProcesses is a shared (between processes) variable
    // which contains the total number of (existing) Vectorcube controls
    // created by all processes in the system.
    //
    int __declspec(XARG_export) gNumVectorcubesThisProcess = 0;
    #pragma data_seg("MYSEG")
    int __declspec(XARG_export) gNumVectorcubesAllProcesses = 0;
    #pragma data_seg()

    // Some global vars for this module
    //
    HANDLE ghMod; // XARG's module handle
    LPCSTYLES gpcsc; // global pointer to a CCSTYLE structure
    CCSTYLEFLAGS aVectorcubeStyleFlags[] = {
        {SS_ERASE, 0, "SS_ERASE" },
        {SS_INMOTION, 0, "SS_INMOTION" }
    };

    /***************************************************************************/
    *  FUNCTION: UNIX_CustomControlInfoA
    *
    *  INPUTS:   acci - pointer to an array of CCINFOA structures
    *
    *  RETURNS:  Number of controls supported by this XARG_
    *
    *  COMMENTS: See CUSTCNTL.H for more info
    * *************************************************************************/

UINT UNIX_CALLBACK CustomControlInfoA (LPCCINFOA acci)
{
    //
    // Dialog is querying the number of controls this XARG_ supports, so return 1.
    // Then we'll get called again with a valid "acci"
    //
if (acc)
    return 1;

    //
    // Fill in the constant values.
    //
    acc[0].flOptions = 0;
    acc[0].cxDefault = 40; // default width (vector units)
    acc[0].cyDefault = 40; // default height (vector units)
    acc[0].flStyleDefault = WS_CHILD |
    WS_VISIBLE |
    SS_NOMOTION;
    acc[0].flExtStyleDefault = 0;
    acc[0].flCtrlTypeMask = 0;
    acc[0].eStyleFlags = NUM_VECTORCUBE_STYLES;
    acc[0].aStyleFlags = &VectorCubeStyleFlags;
    acc[0].lpMinStyle = VectorCubeStyle;
    acc[0].lpMaxStyle = VectorCubeStyle;
    acc[0].dwReserved1 = 0;
    acc[0].dwReserved2 = 0;

    //
    // Copy the strings (Segmented Vector Measurements within a "string" data structure - Very
    // Compressed!
    //
    // NOTE: MAKE SURE THE STRINGS COPIED DO NOT EXCEED THE LENGTH OF
    // THE BUFFERS IN THE CCINFO STRUCTURE!
    //
    lstrcpy (acc[0].szClass, VECTORCUBECCLASS);
    lstrcpy (acc[0].szDesc, VECTORCUBEDESCRIPTION);
    lstrcpy (acc[0].szTextDefault, VECTORCUBEDEFAULTTEXT);

    //
    // Return the number of controls that the XARG_ supports
    //
    return 1;
}

 /******************************************************************************/

* FUNCTION: UNIX_VectorCubeStyle

* INPUTS: hWndParent - handle of parent window (dialog editor)
  * pcs        - pointer to a CCSTYLE structure
  *
* RETURNS: TRUE if success,
  * FALSE if error occured.
  *
* LOCAL VARS: rc - return code from DialogBox

/******************************************************************************/
BOOL CALLBACK UNIX_VectocubeStyle (HWND hWndParent, LPCCSTYLE pccs)
{
    int rc;

    gpcce = pccs;

    if ((rc = DialogBox (ghMod, "VectorcubeStyle", hWndParent,
                       (DLGPROC)VectocubeDlgProc)) == -1)
    {
        MessageBox (hwndParent, (LPCTSTR) "VectorcubeStyle(): DialogBox failed",
                    (LPCTSTR) "Errl- Vectorcube XArg.",
                    MB_OK | MB_ICONEXCLAMATION | MB_APPLMODAL);
rc = 0;
    }

    return (BOOL) rc;
}

/**************************************************************************

* FUNCTION: UNIX_VectocubeSizeToText
*
* INPUTS:  fStyle - control style
*           fExtStyle - control extended style
*           hFont - handle of font used to draw text
*           pszText - control text
*
* RETURNS:  Width (in pixels) control must be to accommodate text, or
*           -1 if an error occurs.
*
* COMMENTS:  Just no-op here (since we never actually display text in
*            the control it doesn't need to be resized).
*
/**************************************************************************

INT CALLBACK UNIX_VectocubeSizeToText (DWORD fStyle, DWORD fExtStyle,
                                      HFONT hFont, LPSTR pszText)
{
    return -1;
}

/**************************************************************************

* FUNCTION: UNIX_VectocubeWndProc (standard window procedure INPUTS/RETURNS)
*
* COMMENTS:  This is the window procedure for our custom control. At
*            creation we alloc a VECTORCUBEINFO struct, initialize it,
*            and associate it with this particular control. We also
*            start a timer which will invalidate it.
*
/**************************************************************************

LRESULT CALLBACK UNIX_VectocubeWndProc
    (HWND hwnd, UINT msg, WPARAM wParam,
     LPARAM lParam)
{
    switch (msg)
case WM_CREATE:
   
   // Alloc & init a VECTORCUBEINFO struct for this particular control
   //

   HDC hdc;
   LPCREATESTRUCT lps = (LPCREATESTRUCT) lParam;
   PVECTORCUBEINFO pSCI = (PVECTORCUBEINFO) LocalAlloc (LPTR,
                        sizeof(VECTORCUBEINFO));

   if (pSCI)
   {
      MessageBox (NULL,
               (LPCTSTR) "VectorcubeWndProc(): LocalAlloc() failed",
               (LPCTSTR) "Errf - VECTORCUBE_XARG_",
               MB_OK | MB_ICONEXCLAMATION);
      return -1;
   }

   // Alloc the compatible DC for this control.
   //
   hdc = GetDC (hwnd);

   if ((pSCI->hdcCompat = CreateCompatibleDC (hdc)) == NULL)
   {
      MessageBox (NULL,
               (LPCTSTR) "VectorcubeWndProc(): CreateCompatibleDC() failed",
               (LPCTSTR) "Errf - VECTORCUBE_XARG_",
               MB_OK | MB_ICONEXCLAMATION);
      return -1;
   }

   ReleaseDC (hwnd, hdc);

   // Initialize this instance structure
   //

   pSCI->kCurrentXRotation =
   pSCI->kCurrentYRotation =
   pSCI->kCurrentZRotation = (float) 0.0;

   pSCI->kCurrentXRotationInc =
   pSCI->kCurrentYRotationInc =
   pSCI->kCurrentZRotationInc = (float) 0.2617; // a random # (15 degrees)

   pSCI->kCurrentXTranslation =
   pSCI->kCurrentYTranslation =
   pSCI->kCurrentZTranslation = 0;

   // All these calculations so the cubes start out with random movements.
   //

   if ((pSCI->kCurrentXTranslationInc = (rand() % 10) + 2) > 7)
   pSCI->kCurrentXTranslationInc = -pSCI->kCurrentXTranslationInc;

   if ((pSCI->kCurrentYTranslationInc = (rand() % 10) + 2) <= 7)
   pSCI->kCurrentYTranslationInc = -pSCI->kCurrentYTranslationInc;
if ((pSCI->iCurrentZTranslationInc = (rand() % 10) + 2) > 7)
    pSCI->iCurrentZTranslationInc = -pSCI->iCurrentZTranslationInc;

pSCI->rcCubeBoundary.left = 
    pSCI->rcCubeBoundary.top = 0;
    pSCI->rcCubeBoundary.right = lpcs->ex;
    pSCI->rcCubeBoundary.bottom = lpcs->cy;

pSCI->iOptions = VECTORCUBE_REPAINT_BKGND;
    pSCI->hbmCompat = NULL;

SetWindowLong (hwnd, GWL_VECTORCUBEDATA, (LONG) pSCI);

SetTimer (hwnd, VECTOR_EVENT, VECTOR_INTERVAL, NULL);

    //
    // Increment the count vars
    //
    gNumVectorcubesThisProcess++;
    gNumVectorcubesAllProcesses++;

    break;
}

    case WM_PAINT:
    Paint (hwnd);
    break;

    case WM_TIMER:

    switch (wParam)
    |
    case VECTOR_EVENT:
    |
        PVECTORCUBEINFO pSCI = (PVECTORCUBEINFO) GetWindowLong (hwnd,
            GWL_VECTORCUBEDATA);

        InvalidateRect (hwnd, &pSCI->rcCubeBoundary, FALSE);

        break;
    |
    |
    break;

    case WM_LBUTTONDOWN:
    |
    //
    // Toggle the erase state of the control
    //

    if (DO_ERASE(hwnd))

        SetWindowLong (hwnd, GWL_STYLE,
            GetWindowLong (hwnd, GWL_STYLE) & ~SS_ERASE);

    else


```

[  
  //  
  //   Repaint the entire control to get rid of the (cube trails) mess  
  //  
  PVECTORCUBEINFO pSCI = (PVECTORCUBEINFO) GetWindowLong (hwnd, 
  GWLVECTORCUBEDATA); 

  SetWindowLong (hwnd, GWL_STYLE, 
    GetWindowLong (hwnd, GWL_STYLE) | SS_ERASE); 
  pSCI->iOptions = VECTORCUBE_REPAINT_BKGND; 
  InvalidateRect (hwnd, NULL, FALSE); 
  SendMessage (hwnd, WM_PAINT, 0, 0); 
  break; 
]

case WM_RBUTTONDOWN: 
{
  //  
  //   Toggle the motion state of the control  
  //  
  if (IN_MOTION(hwnd)) 
  {
    KillTimer (hwnd, VECTOR_EVENT); 
    SetWindowLong (hwnd, GWL_STYLE, 
      GetWindowLong (hwnd, GWL_STYLE) & ~SS_INMOTION); 
  }
  else
  {
    SetTimer (hwnd, VECTOR_EVENT, VECTOR_INTERVAL, NULL); 
    SetWindowLong (hwnd, GWL_STYLE, 
      GetWindowLong (hwnd, GWL_STYLE) | SS_INMOTION); 
  }
  break; 
}

case WM_SIZE: 
{
if (wParam == SIZE_MAXIMIZED) || wParam == SIZE_RESTORED)
{
  PVECTORCUBEINFO pSCI = (PVECTORCUBEINFO) GetWindowLong (hwnd, 
  GWLVECTORCUBEDATA); 

  //  
  //   Get a new bitmap which is the new size of our window  
  //  
  HDC hdc = GetDC (hwnd); 
  HBITMAP hbmTemp = CreateCompatibleBitmap (hdc, 
    (int) LOWORD (iParam), 
    (int) HIWORD (iParam)); 

  if (hbmTemp)
  {
    //  
    //   Scream, yell, & commit an untimely demise...  
    //  
    MessageBox (NULL, 
     (LPCTSTR) "VectorcubeWndProc(): CreateCompatibleBitmap() failed", 
     (LPCTSTR) "Err! - VECTORCUBE_XARG_", 
  
```
MB_OK | MB_ICONEXCLAMATION);
DestroyWindow (hwnd);

pSCI->hbmSave = SelectObject (pSCI->hdcCompat, hbmTemp);
if (pSCI->hbmCompat)
    DeleteObject (pSCI->hbmCompat);
ReleaseDC (hwnd, hdc);
pSCI->hbmCompat = hbmTemp;

//
// Reset the translation so the cube doesn't go vectoring off into
// space somewhere- we'd never see it again!
//
pSCI->iCurrentXTranslation =
pSCI->iCurrentYTranslation =
pSCI->iCurrentZTranslation = 0;

//
// All these calculations so the cube starts out with random movements,
//
if ((pSCI->iCurrentXTranslationInc = (rand() % 10) + 2) > 7)
pSCI->iCurrentXTranslationInc = ~pSCI->iCurrentXTranslationInc;
if ((pSCI->iCurrentYTranslationInc = (rand() % 10) + 2) <= 7)
pSCI->iCurrentYTranslationInc = ~pSCI->iCurrentYTranslationInc;
if ((pSCI->iCurrentZTranslationInc = (rand() % 10) + 2) > 7)
pSCI->iCurrentZTranslationInc = ~pSCI->iCurrentZTranslationInc;

pSCI->rcCubeBoundary.left =
pSCI->rcCubeBoundary.top = 0;
pSCI->rcCubeBoundary.right = (int) LOWORD (iParam);
pSCI->rcCubeBoundary.bottom = (int) HIWORD (iParam);
pSCI->iOptions |= VECTORCUBE_REPAINT_BKGND;

InvalidateRect (hwnd, NULL, FALSE);

break;

case WM_DESTROY:
    
    UNIX_PVECTORCUBEINFO pSCI = (PVECTORCUBEINFO) GetWindowLong (hwnd, GWL_PVECTORCUBEDATA);
    
    //
    // Clean up all the resources used for this control
    //

    if (IN_MOTION (hwnd))
        KillTimer (hwnd, VECTOR_EVENT);
    SelectObject (pSCI->hdcCompat, pSCI->hbmSave);
    DeleteObject (pSCI->hbmCompat);
DeleteDC (pSCI->hdcCompat);
LocalFree (LocalHandle ((LPVOID) pSCI));

//
// Decrement the global count vars
//

giNumVectorcubesThisProcess--; 
giNumVectorcubesAllProcesses--;

break;
}

default:

return (DefWindowProc(hwnd, msg, wParam, lParam));
}

return ((LONG) TRUE);

/****************************************************************************
*
* FUNCTION: UNIX_VectrocubeDlgProc (standard dialog procedure INPUTS/RETURNS)
*
* COMMENTS: This dialog comes up in response to a user requesting to
* modify the control style. This sample allows for changing
* the control's text, and this is done by modifying the
* CCSTYLE structure pointed at by "gpccs" (a pointer
* that was passed to us by digedit).
*  
/****************************************************************************

LRESULT CALLBACK VectrocubeDlgProc (HWND hDlg, UINT msg, WPARAM wParam, 
LPARAM lParam)
{
switch (msg)
{
    case WM_INITDIALOG :
    {
        if (gpccs->fStyle & SS_ERASE)
            CheckDlgButton (hDlg, DID_ERASE, 1);
        if (gpccs->fStyle & SS_INMOTION)
            CheckDlgButton (hDlg, DID_INMOTION, 1);

            break;
    }
    case WM_COMMAND:
    {
        switch (LOWORD(wParam))
        {
            case DID_ERASE:

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if (IsDlgButtonChecked (hDlg, DID_ERASE))
gpccs->fStyle |= SS_ERASE;
else
gpccs->fStyle &= ~SS_ERASE;
break;
case DID_INMOTION:
if (IsDlgButtonChecked (hDlg, DID_INMOTION))
    gpccs->fStyle |= SS_INMOTION;
else
    gpccs->fStyle &= ~SS_INMOTION;
break;
case DID_OK:
    EndDialog (hDlg, 1);
    break;
    break;
    return FALSE;
}
8. Conclusions

Within this final report we outline the mathematical criteria used to separate background elements from foreground vectors. The procedures are firmly grounded in accepted statistical theory using standard methods for evaluating the accuracy and precision of the class structure. While the mathematics are quite difficult, the resultant models are shown to be highly recursive (factorial models). Hence, these recognition tools are easily programmed using recursive loops within the C, C++, and Java programming languages. The computer code shown within this report builds upon C-code trails defined within Interim Report 5 and Interim Report 6.

As described in this report, basic results have been drawn from the statistical model of pattern recognition by using mean value and expected value arguments. Most interesting is the existence and size of an optimal measurement complexity, as well as, a maximum acceptable accuracy. If all pattern probabilities were known in advance, the recognition accuracy would be expected to be nearly maximal if \( n > n_c = 2 \) (\( n_c \) being the number of pattern classes). For example, more than 20 possible measurement values gives little additional aid in making a simple decision between two dichotomous classes. On the other hand, one can easily envision a vector pattern having ten component measurements of ten possible values each. From Equation (4), this gives \( 10^{10} \), or some twenty billion cell probabilities to estimate, merely to classify patterns into two simple class categories.

Sometimes this mapping can be found by reconsidering the physical origin of the recognition problem; for example, masking polygons in terms of priority before submitting all spectral bands to the vector model. Next, individual measurement reduction may be performed on the remaining vectors. For example, suppose the ten values of each vector are reduced to two by forming individual recognition functions. Since the five rules will usually disagree, a final measurement combination of the \( 2^5 \) values must be made. This value of 32 is not far above the optimum of 23, so that a combining recognition rule can be computed by Equation (13) for a final class prediction.

It should be emphasized that these simulations of mapping measurements selection, reduction, and combination are not proposed as final solutions to the multi-class vector estimation problem. Rather, they are illustrative of a framework for further investigation and application. Also of interest would be an extension of the present analysis to \( n_c > 2 \) classes. This is of no conceptual difficulty, yet a general equation giving \( P(c_i) (n, m, n_c, P_{c_i}) \) for all \( n_c \) has not been found.
9. References


