Mike Staunton

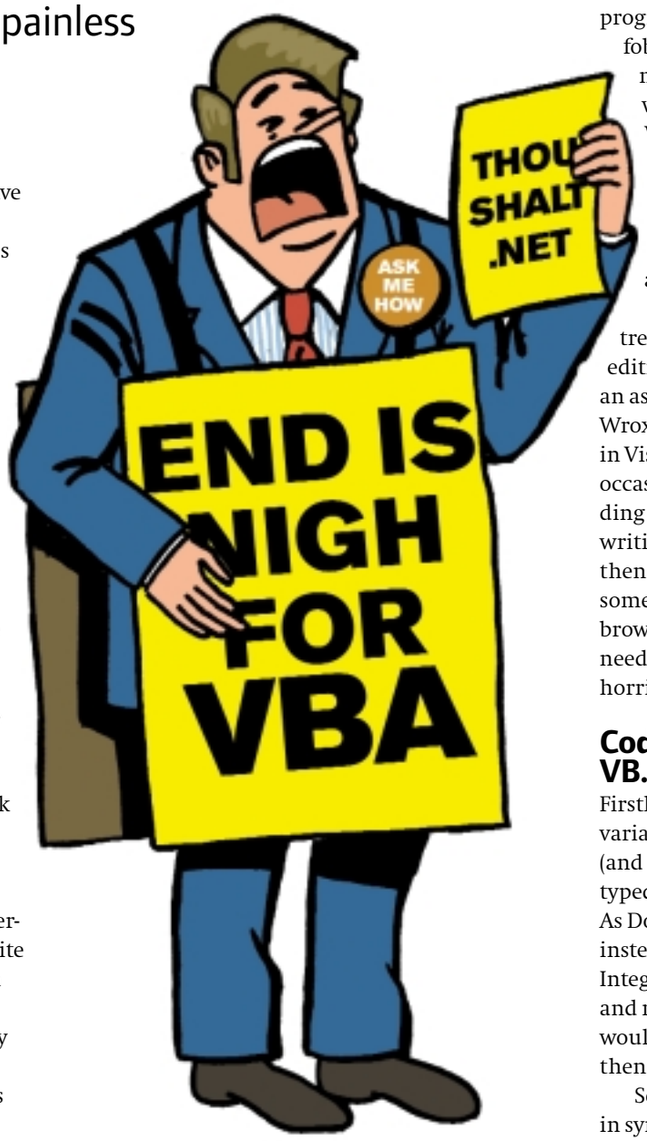
From VBA to VB .NET and back

Ushering in a new era in as painless a way as possible

Those of you who walk down London's Oxford Street might have encountered the odd individual standing still amongst the hordes of passing shoppers displaying a sign with the words "The end is nigh". Well, the same could be said of Excel's programming language since 1993, Visual Basic for Applications (VBA), as bookshops throughout the world are groaning under the weight of enormous .NET tomes. Except that, fortunately for us poor souls still wedded to VBA, the language can readily be adapted to live within the new .NET world.

Perhaps I'd better clarify the precise meaning of what I'm aiming to do in this column. Within my world of VBA, I write large numbers of user-defined functions, pausing occasionally to use some macros and know nothing about user forms (or whatever they're called), and would be hard pushed to give a coherent explanation of objects, methods or properties. Gosh, and I have the supreme cheek to allow myself to be called an expert!

In a similar fashion, my embracing of the VB.NET world will ignore subroutines, object-oriented programming (whatever that is), inheritance and polymorphism. But I will aim to write program code for functions that can run, with tiny alterations, in both VBA and VB.NET. The functions can be saved in a VB.NET class library and, just to show how soft I'm getting, I might even mention the new user interface known as Windows Forms.



Visual Studio Tools for Office 2003

I'm sorry but I just don't get the point behind Visual Studio Tools for Office (VSTO). The VBA language is somewhat of an orphan since Microsoft has pledged to support it only for this year's new version of Excel and the next updated version in a couple of years' time. Obviously it will then be replaced by a more .NET-friendly programming language. In the meantime, we're fobbed off with VSTO that allows .NET style macro code that can run in conjunction with events in Excel 2003 spreadsheets and Word 2003 documents. Well, I forked out my $20 for the grandly titled *Office System Beta 2 Kit 2003* and was intimidated by the complex sequence required to install everything complete with primary interop assemblies and the like.

So instead, I first spent £80 or so and treated myself to a copy of the standard edition of *Visual Basic.NET 2003* and then bought an assorted collection of VB.NET books from Wrox, O'Reilly et al. The programming front-end in Visual Studio is rather overwhelming (and on occasions irritating) compared to the corresponding VBA interface. There's nothing to stop you writing your code in a simple text editor but then you'd be missing out on the vast and sometimes useful help documents, the object browser and intellisense. The changes that I needed to make to my VBA code were less horrible than I feared.

Code changes between VBA and VB.NET

Firstly, I had to embrace the strong typing of variables in those that I had left without a type (and thus ended up as Variant by default) were typed as double (well I eventually tired of typing As Double and used the shorthand character # instead, along with the % character to replace As Integer). Everything else, predominantly vectors and matrices, were left as Variants so that they would stick out like sore thumbs in .NET and then in due course be typed as Objects.

Secondly, I wanted to allow for the changes in syntax for some of the mathematical and associated functions. For instance, the Sqrt command in Excel was represented by Sqr in VBA and now by Math.Sqrt in VB.NET. As another example, the Max command in Excel was represented by WorksheetFunction.Max in VBA and

VBA CODE

```
Shared Function BarrierOutOptionTian#(ByVal iopt%, ByVal _
        idu%,    ByVal S#, ByVal K#, ByVal H#, ByVal Rb#, ByVal _
        r#, ByVal q#, ByVal tyr#, ByVal sigma#, ByVal nb%, _
        ByVal ns%)
        '   Values the discretely-sampled Out Barrier Option
        '   Based on Tian (1997)
        Dim vo#, delt#, deltb#, erdt#, rmqdt#, lam0#, eta0#
        Dim lamd#, lnstep#, etad#, pudt#, pmdt#, pddt#, _
                Si#, ibarr#, jbarr#
        Dim i%, j%, kb%
        Dim vvec() As Object
        ReDim vvec(2 * ns)
        delt = tyr / ns
        deltb = tyr / nb
        erdt = Exp(r * delt)
        rmqdt = (r - q - 0.5 * sigma * sigma) * Sqrt(delt)
        lam0 = Sqrt(1.5)
        eta0 = Log(S / H) / (lam0 * sigma * Sqrt(delt))
        lamd = eta0 * lam0 / (0.5 + Int(eta0))
        lnstep = lamd * sigma * Sqrt(delt)
        etad = Log(S / H) / (lamd * sigma * Sqrt(delt))
        pudt = (1 / (2 * lamd * lamd) + rmqdt / _
                (2 * lamd * sigma)) / erdt
        pmdt = (1 - 1 / (lamd * lamd)) / erdt
        pddt = (1 / (2 * lamd * lamd) - rmqdt / _
                (2 * lamd * sigma)) / erdt
        j = ns
        ibarr = j + etad
        Si = Log(S) + (ns + 1) * lnstep
        For i = 0 To 2 * j
            Si = Si - lnstep
            If (Sign(ibarr - i) * idu) < 0 Then
                vvec(i) = Rb
            Else
                vvec(i) = Max(iopt * (Exp(Si) - K), 0)
            End If
        Next i
        kb = nb - 1
        For j = ns - 1 To 1 Step -1
            ibarr = j + etad
            jbarr = Abs(j * delt - kb * deltb)
            If jbarr >= delt Then
                For i = 0 To 2 * j
                    vvec(i) = pudt * vvec(i) + _
                            pmdt * vvec(i + 1) + pddt * vvec(i + 2)
                Next i
            Else
                For i = 0 To 2 * j
                    If (Sign(ibarr - i) * idu) < 0 Then
                        vvec(i) = Rb
                    Else
                        vvec(i) = pudt * vvec(i) + pmdt * _
                            vvec(i + 1) + pddt * vvec(i + 2)
                    End If
                Next i
                kb = kb - 1
            End If
        Next j
        Return pudt * vvec(0) + pmdt * vvec(1) + pddt * vvec(2)
End Function
```

now by Max in VB.NET. It would be relatively straightforward to use Search and Replace on the program code to handle cases such as these but I have chosen another approach. What I've done is to write functions in VBA with the same names as the VB.NET functions (so Sqrt) and so there will be no need to alter the calls to these functions in my program code.

Thirdly, the ability to start counting arrays in VBA from one via the Option Base command has not survived the transition to VB.NET. Instead, all arrays in VB.NET start counting their elements from zero. Although my binomial trees and the like from VBA are safe, this is probably the most time-consuming of the syntax changes.

Fourthly, parameters that are passed by reference as the default in VBA will now be passed by value as the default in VB.NET. You will see that ByVal is added in VB.NET as a prefix to all parameters that come, as mine do, with no prefixes from their VBA code. For the occasional parameters that you wish to pass by reference, you should prefix them with ByRef in your VBA code.

The changes that I needed to make to my VBA code were less horrible than I feared

Above is my VB.NET code for Tian's trinomial tree to value discretely-sampled barrier options. I would need to make only a couple of very minor changes before the code could be copied back to VBA and work perfectly.

Working in the VB.NET world

Slowly, day by day, I'm building up my tolerance to working in the .NET environment but frequently there are still times of frustration. I've learnt how to assemble some forms, complete with text boxes, list boxes and some even more exotically named controls (see, even some of the object-oriented terminology is sticking). There is very little relevant material comparing the numerical performance between VBA and VB.NET but some tentative suggestions are that there's little difference in run time but that the ability to compile VB.NET code can give time savings of over 30 per cent.

I'd be very interested to hear from other more experienced users of the .NET environment on different approaches to converting code and on performance comparisons between code written in different languages. Please feel free to email mstaunton@london.edu with your thoughts.

Mike Staunton

Sharpen Up

This month, I will show how VBA code previously converted to VB.NET can be translated into Microsoft's highly favored new C#.NET language

The differences between VB and C# are substantial and worthwhile enough for O'Reilly to publish a pocket reference guide to converting between the two languages. Fortunately most of the differences (lower or mixed case, declaration of vectors and matrices, line termination characters, comments, variable declaration, if statements, loops) can be handled in an automated fashion by commercial software programs such as InstantCSharp. That leaves just a few small of wrinkles for us to consider.

The first wrinkle is that C# lacks the exponentiation (^) character. In my VBA code, my need for the ^ character is limited by my preference for alternatives such as Sqrt(x) instead of x^0.5 as well as x*x (for x^2) and x*x*x (for x^3). When needed, the ^ character can be replaced by using the Pow function from the System.Math class in the .NET framework. In VBA, one can create a user-defined function that handles exponentiation and hence allow any function calls in VB.NET to work as well.

The second wrinkle also concerns the System.Math class of numeric functions. For instance, the Power function can be called as Math.Pow or just Pow if used in conjunction with the Using System.Math statement at the top of one's program code in VB.NET. But, in C#, the corresponding imports statement cannot refer to mere classes (such as System.Math) but only to namespaces (such as System). Thus we need to use the fuller Math.Pow rather than just Pow if we wish to allow our code to work across both VB and C#.

The third wrinkle is that the Int function that is part of both Excel and VBA carries through to the Visual Basic side of .NET but not to C#. The Int function is a strange hybrid that rounds positive numbers towards zero (as does Floor) but rounds negative numbers away from zero (as does Ceiling). The Floor and Ceiling functions are not part of VBA but are Excel functions and also members of the .NET Math Class. Thus it is not possible to use the Int function across VBA, VB.NET and C#.NET.

VB. NET CODE

```
Shared Function VBBarrierOutOptionTian#(ByVal iopt%, _
     ByVal idu%, ByVal S#, ByVal K#, ByVal H#, ByVal Rb#, _
     ByVal r#, ByVal q#, ByVal tyr#, ByVal sigma#, _
     ByVal nb%, ByVal ns%)
   '   Values the discretely-sampled Out Barrier Option
   '   Based on Tian (1997)
   Dim vo#, delt#, deltb#, erdt#, rmqdt#, lam0#, eta0#
   Dim lamd#, lnstep#, etad#, pudt#, pmdt#, pddt#, _
     Si#, ibarr#, jbarr#
   Dim i%, j%, kb%
   Dim vvec() As Object
   ReDim vvec(2 * ns)
   delt = tyr / ns
   deltb = tyr / nb
   erdt = Math.Exp(r * delt)
   rmqdt = (r - q - 0.5 * sigma * sigma) * Math.Sqrt(delt)
   lam0 = Math.Sqrt(1.5)
   eta0 = Math.Log(S / H) / (lam0 * sigma * Math.Sqrt(delt))
   lamd = eta0 * lam0 / (0.5 + Int(eta0))
   lnstep = lamd * sigma * Math.Sqrt(delt)
   etad = Math.Log(S / H) / (lamd * sigma * Math.Sqrt(delt))
   pudt = (1 / (2 * lamd * lamd) + rmqdt / _
     (2 * lamd * sigma)) / erdt
   pmdt = (1 - 1 / (lamd * lamd)) / erdt
   pddt = (1 / (2 * lamd * lamd) - rmqdt / _
     (2 * lamd * sigma)) / erdt
   j = ns
   ibarr = j + etad
   Si = Math.Log(S) + (ns + 1) * lnstep
   For i = 0 To 2 * j
      Si = Si - lnstep
      If (Math.Sign(ibarr - i) * idu) < 0 Then
         vvec(i) = Rb
      Else
         vvec(i) = Math.Max(iopt * (Math.Exp(Si) - K), 0)
      End If
   Next i
   kb = nb - 1
   For j = ns - 1 To 1 Step -1
      ibarr = j + etad
      jbarr = Math.Abs(j * delt - kb * deltb)
      If jbarr >= delt Then
         For i = 0 To 2 * j
            vvec(i) = pudt * vvec(i) + pmdt * _
            vvec(i + 1) + pddt * vvec(i + 2)
         Next i
      Else
         For i = 0 To 2 * j
            If (Math.Sign(ibarr - i) * idu) < 0 Then
               vvec(i) = Rb
            Else
               vvec(i) = pudt * vvec(i) + pmdt *
                   vvec(i + 1) + pddt * vvec(i + 2)
            End If
         Next i
         kb = kb - 1
      End If
   Next j
   Return pudt * vvec(0) + pmdt * vvec(1) + pddt * vvec(2)
End Function
```

Comments on the converted C# code

In C#, the variables are explicitly initialized with zero values (this is done within the Dim statement in VB). In C#, the object vvec has 2*ns+1 elements – this is equivalent to defining the upper bound as 2*ns in the base 0 VB.NET world. VB and VB.NET's Int function translates into the Microsoft.VisualBasic.Conversion.Int function. In C#, temporary variables such as Temp1 are created to replace the use of loop maximum values such as 2*j that are not fixed. And ... that's it. You're welcome to look amongst other translation programs but the single free program that I found could not handle the numbering of elements in vectors and matrices. InstantCSharp comes as either a free version that will translate limited code snippets, a $59 version for unlimited code snippets or the full $159 version that will convert both snippets and whole projects from VB.NET to C#.NET. And the people at InstantCSharp are so helpful - when I first pointed out that the program did not cope properly with type-declaration characters such as # and % it took them only a few hours to correct their code and make available a new version for me to download.

You're welcome to look amongst other translation programs but the single free program that I found could not handle the numbering of elements in vectors and matrices.

Getting back to VB.NET

I'm much less concerned with translation from C# to VB but there is a recent article in msdn magazine by John Robbins. From my brief experience with the free conversion utilities mentioned, one small snag is that they create arrays in VB.NET with one more element than strictly

REFERENCES

http://www.tangiblesoftwaresolutions.com/
http://msdn.microsoft.com/msdnmag/issues/04/08/EndBracket/default.aspx

CONVERTED C#.NET CODE

```
public static double VBBarrierOutOptionTian(int iopt, int idu,
     double S, double K, double H, double Rb, double r, double
     q, double tyr, double sigma, int nb, int ns)
{
     //  Values the discretely-sampled Out Barrier Option
     //  Based on Tian (1997)
     double vo = 0;
     double delt = 0;
     double deltb = 0;
     double erdt = 0;
     double rmqdt = 0;
     double lam0 = 0;
     double eta0 = 0;
     double lamd = 0;
     double lnstep = 0;
     double etad = 0;
     double pudt = 0;
     double pmdt = 0;
     double pddt = 0;
     double Si = 0;
     double ibarr = 0;
     double jbarr = 0;
     int i = 0;
     int j = 0;
     int kb = 0;
     object[] vvec = null;
     vvec = new object[2*ns + 1];
     delt = tyr / ns;
     deltb = tyr / nb;
     erdt = Math.Exp(r * delt);
     rmqdt = (r - q - 0.5 * sigma * sigma) * Math.Sqrt(delt);
     lam0 = Math.Sqrt(1.5);
     eta0 = Math.Log(S / H) / (lam0 * sigma * Math.Sqrt(delt));
     lamd = eta0 * lam0 / (0.5 +
            Microsoft.VisualBasic.Conversion.Int(eta0));
     lnstep = lamd * sigma * Math.Sqrt(delt);
     etad = Math.Log(S / H) / (lamd * sigma * Math.Sqrt(delt));
     pudt = (1 / (2 * lamd * lamd) + rmqdt /
            (2 * lamd * sigma)) / erdt;
     pmdt = (1 - 1 / (lamd * lamd)) / erdt;
     pddt = (1 / (2 * lamd * lamd) - rmqdt /
            (2 * lamd * sigma)) / erdt;
     j = ns;
     ibarr = j + etad;
     Si = Math.Log(S) + (ns + 1) * lnstep;
     int ForTemp1 = 2 * j;
     for (i = 0; i <= ForTemp1; i++)
     {
            Si = Si - lnstep;
            if ((Math.Sign(ibarr - i) * idu) < 0)
            {
                   vvec[i] = Rb;
            }
            else
            {
                   vvec[i] = Math.Max(iopt *
                   (Math.Exp(Si) - K), 0);
            }
     }
     kb = nb - 1;
     for (j = ns - 1; j >= 1; j--)
     {
            ibarr = j + etad;
            jbarr = Math.Abs(j * delt - kb * deltb);
            if (jbarr >= delt)
            {
                   int ForTemp2 = 2 * j;
                   for (i = 0; i <= ForTemp2; i++)
                   {
                          vvec[i] = pudt *
                          vvec[i] + pmdt * vvec[i + 1]
                          + pddt * vvec[i + 2];
                   }
            }
            else
            {
                   int ForTemp3 = 2 * j;
                   for (i = 0; i <= ForTemp3; i++)
                   {
                          if ((Math.Sign(ibarr - i) *
                                 idu) < 0)
                          {
                                 vvec[i] = Rb;
                          }
                          else
                          {
                                 vvec[i] = pudt * vvec[i]
                                 + pmdt * vvec[i + 1] +
                                 pddt * vvec[i + 2];
                          }
                   }
                   kb = kb - 1;
            }
     }
     return pudt * vvec[0] + pmdt * vvec[1] + pddt * vvec[2];
}
```

THE ORIGINAL VBA FUNCTIONS from Excel

```
Const Log2# = 0.693147180559945
Const twoPI# = 6.28318530717959

Function vaBermPutCONV(S#, K#, r#, q#, Tyr#, vol#, nStepT&, nPower2&) As Double
    Dim dT#, erdT#, vol2#, rnmudT#, SqrV#, dy#, ydisc#, yeps#, du#, crfi#, cifi#
    Dim xdisc#, xeps#, xShift#, crecfi#, ciecfi#
    Dim delta&, i&, iBase&, id&, iSwitch&, j&
    Dim a1vec
    Dim c1vec

    Dim bgvec() As Double
    Dim ciavec() As Double
    Dim cicfvec() As Double
    Dim cilncfvec() As Double
    Dim ciaecfvec() As Double
    Dim cravec() As Double
    Dim crcfvec() As Double
    Dim crlncfvec() As Double
    Dim craecfvec() As Double
    Dim cvec() As Double
    Dim evec() As Double
    Dim uvec() As Double
    Dim vvec() As Double
    Dim vwtwvec() As Double
    Dim wtwvec() As Double
    Dim wvec() As Double
    Dim xvec() As Double
    Dim yvec() As Double
    Dim zerovec() As Double
    ReDim bgvec(nPower2 - 1)
    ReDim ciavec(nPower2 - 1)
    ReDim cicfvec(nPower2 - 1)
    ReDim cilncfvec(nPower2 - 1)
    ReDim ciaecfvec(nPower2 - 1)
    ReDim cravec(nPower2 - 1)
    ReDim crcfvec(nPower2 - 1)
    ReDim crlncfvec(nPower2 - 1)
    ReDim craecfvec(nPower2 - 1)
    ReDim cvec(nPower2 - 1)
    ReDim evec(nPower2 - 1)
    ReDim uvec(nPower2 - 1)
    ReDim vvec(nPower2 - 1)
    ReDim vwtwvec(nPower2 - 1)
    ReDim wtwvec(nPower2 - 1)
    ReDim wvec(nPower2 - 1)
    ReDim xvec(nPower2 - 1)
    ReDim yvec(nPower2 - 1)
    ReDim zerovec(nPower2 - 1)

    iBase = 0
    iSwitch = 1
    delta = 20
    dT = Tyr / nStepT
    erdT = Exp(-r * dT)
    vol2 = vol * vol
    rnmudT = (r - q - 0.5 * vol2) * dT
    SqrV = vol * Sqr(Tyr)
    dy = delta * SqrV / nPower2
    ydisc = Log(K / S)
    yeps = ydisc - vaCeiling(ydisc / dy) * dy
    du = twoPI / (nPower2 * dy)

    For i = 0 To nPower2 - 2 Step 2
        wvec(i) = 1
        wvec(i + 1) = -1
        wtwvec(i) = 1
        wtwvec(i + 1) = -1
    Next i
    wtwvec(0) = 0.5
    wtwvec(nPower2 - 1) = -0.5

    bgvec(0) = -0.5 * nPower2 * dy
    yvec(0) = bgvec(0) + yeps
    uvec(0) = -0.5 * nPower2 * du
    For i = 1 To nPower2 - 1
        bgvec(i) = bgvec(i - 1) + dy
        yvec(i) = bgvec(i) + yeps
        uvec(i) = uvec(i - 1) + du
    Next i
```

```
    For i = 0 To nPower2 - 1
        crfi = -0.5 * vol2 * dT * uvec(i) * uvec(i)
        cifi = rnmudT * uvec(i)
        crcfvec(i) = Exp(crfi) * Cos(cifi)
        cicfvec(i) = Exp(crfi) * Sin(cifi)
        evec(i) = Max(K - S * Exp(yvec(i)), 0)
        vvec(i) = evec(i)
        vwtwvec(i) = vvec(i) * wtwvec(i)
        zerovec(i) = 0
    Next i

    For j = nStepT - 1 To 1 Step -1

        a1vec = vaCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
            cravec(i) = a1vec(i, 0) * crcfvec(i) - a1vec(i, 1) * cicfvec(i)
            ciavec(i) = a1vec(i, 0) * cicfvec(i) + a1vec(i, 1) * crcfvec(i)
        Next i

        c1vec = vaCONVfvec(-1, cravec, ciavec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
            cvec(i) = erdT * wvec(i) * c1vec(i, 0)
            If cvec(i) > evec(i) Then Exit For
        Next i

        id = i
        If id = 0 Then id = 1

        xdisc = (evec(id - 1) - cvec(id - 1)) * yvec(id) - (evec(id) - cvec(id)) * yvec(id - 1)
        xdisc = xdisc / (evec(id - 1) - evec(id) + cvec(id) - cvec(id - 1))
        xeps = xdisc - vaCeiling(xdisc / dy) * dy
        xShift = xeps - yeps

        For i = 0 To nPower2 - 1
            xvec(i) = bgvec(i) + xeps
            evec(i) = Max(K - S * Exp(xvec(i)), 0)
            crecfi = Cos(xShift * uvec(i))
            ciecfi = Sin(xShift * uvec(i))
            craecfvec(i) = cravec(i) * crecfi - ciavec(i) * ciecfi
            ciaecfvec(i) = cravec(i) * ciecfi + ciavec(i) * crecfi
        Next i

        c1vec = vaCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
            cvec(i) = erdT * wvec(i) * c1vec(i, 0)
            vvec(i) = Max(cvec(i), evec(i))
            vwtwvec(i) = vvec(i) * wtwvec(i)
            yvec(i) = xvec(i)
        Next i

        yeps = xeps

    Next j

    xdisc = 0
    xShift = -yeps
    id = 0.5 * nPower2

    a1vec = vaCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase)

    For i = 0 To nPower2 - 1
        crfi = -0.5 * vol2 * dT * uvec(i) * uvec(i)
        cifi = rnmudT * uvec(i)
        crecfi = Exp(crfi) * Cos(cifi + xShift * uvec(i))
        ciecfi = Exp(crfi) * Sin(cifi + xShift * uvec(i))
        craecfvec(i) = a1vec(i, 0) * crecfi - a1vec(i, 1) * ciecfi
        ciaecfvec(i) = a1vec(i, 0) * ciecfi + a1vec(i, 1) * crecfi
    Next i

    c1vec = vaCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase)

    vaBermPutCONV = erdT * wvec(id) * c1vec(id, 0)
End Function

Function vaCONVfvec(iFwdInv&, crfvec, cifvec, nPower2&, iSwitch&, iBase&)
    Dim da#, alpha#, beta#, ar#, ai#, tr#, ti#, dar#, fi#
    Dim nBits&
    Dim blockEndL&, blockSizeL&, iL&, indxL&, jL&, jkL&, nL&
    Dim fvec() As Double
```

```
    ReDim fvec(nPower2 - 1, 1)

    nBits = Log(nPower2) / Log2

    For iL = 0 To nPower2 - 1
        indxL = iL
        jL = 0
        For jkL = 0 To nBits - 1
            jL = (jL * 2) Or (indxL And 1)
            indxL = vaIntL(indxL, 2)
        Next
        fvec(jL, 0) = crfvec(iL + iBase)
        fvec(jL, 1) = cifvec(iL + iBase)
    Next

    blockEndL = 1
    blockSizeL = 2

    Do While blockSizeL <= nPower2
        da = iFwdInv * twoPI / blockSizeL
        alpha = 2 * Sin(0.5 * da) * Sin(0.5 * da)
        beta = Sin(da)

        iL = 0
        Do While iL < nPower2
            ar = 1
            ai = 0

            jL = iL
            For nL = 0 To blockEndL - 1
                jkL = jL + blockEndL
                tr = ar * fvec(jkL, 0) - ai * fvec(jkL, 1)
                ti = ai * fvec(jkL, 0) + ar * fvec(jkL, 1)
                fvec(jkL, 0) = fvec(jL, 0) - tr
                fvec(jL, 0) = fvec(jL, 0) + tr
                fvec(jkL, 1) = fvec(jL, 1) - ti
                fvec(jL, 1) = fvec(jL, 1) + ti
                dar = alpha * ar + beta * ai
                ai = ai - (alpha * ai - beta * ar)
                ar = ar - dar
                jL = jL + 1
            Next

            iL = iL + blockSizeL
        Loop

        blockEndL = blockSizeL
        blockSizeL = blockSizeL * 2
    Loop

    If iSwitch = 1 Then
        For iL = nPower2 / 2 + 1 To nPower2 - 1
            fi = fvec(iL, 0)
            fvec(iL, 0) = fvec(nPower2 - iL, 0)
            fvec(nPower2 - iL, 0) = fi
            fi = fvec(iL, 1)
            fvec(iL, 1) = fvec(nPower2 - iL, 1)
            fvec(nPower2 - iL, 1) = fi
        Next iL
    End If

    If iFwdInv = -1 Then
        For iL = 0 To nPower2 - 1
            fvec(iL, 0) = fvec(iL, 0) / nPower2
            fvec(iL, 1) = fvec(iL, 1) / nPower2
        Next iL
    End If

    vaCONVfvec = fvec
End Function

Function Max(x1#, x2#) As Double
    If x1 >= x2 Then
        Max = x1
    Else
        Max = x2
    End If
End Function

Function vaCeiling(x#) As Double
    If Int(x) = x Then
        vaCeiling = x
```

```
    Else
        vaCeiling = Int(x) + 1
    End If
End Function

Function vaIntL(i1&, i2&) As Long
    vaIntL = Int(i1 / i2)
End Function
```

THE VB.NET FUNCTIONS

```
Const Log2 As Double = 0.693147180559945
Const twoPI As Double = 6.28318530717959

Function vbBermPutCONV(S As Double, K As Double, r As Double, q As Double, Tyr As Double, vol As Double, nStepT As Int32, nPower2 As Int32) As Double
    Dim dT As Double, erdT As Double, vol2 As Double, rnmudT As Double, SqrtV As Double, dy As Double, ydisc As Double, yeps As Double, du As Double, crfi As Double, cifi As Double
    Dim xdisc As Double, xeps As Double, xShift As Double, crecfi As Double, ciecfi As Double
    Dim delta As Int32, i As Int32, iBase As Int32, id As Int32, iSwitch As Int32, j As Int32
    Dim a1vec As Object
    Dim c1vec As Object

    Dim bgvec() As Double
    Dim ciavec() As Double
    Dim cicfvec() As Double
    Dim cilncfvec() As Double
    Dim ciaecfvec() As Double
    Dim cravec() As Double
    Dim crcfvec() As Double
    Dim crlncfvec() As Double
    Dim craecfvec() As Double
    Dim cvec() As Double
    Dim evec() As Double
    Dim uvec() As Double
    Dim vvec() As Double
    Dim vwtwvec() As Double
    Dim wtwvec() As Double
    Dim wvec() As Double
    Dim xvec() As Double
    Dim yvec() As Double
    Dim zerovec() As Double
    ReDim bgvec(nPower2 - 1)
    ReDim ciavec(nPower2 - 1)
    ReDim cicfvec(nPower2 - 1)
    ReDim cilncfvec(nPower2 - 1)
    ReDim ciaecfvec(nPower2 - 1)
    ReDim cravec(nPower2 - 1)
    ReDim crcfvec(nPower2 - 1)
    ReDim crlncfvec(nPower2 - 1)
    ReDim craecfvec(nPower2 - 1)
    ReDim cvec(nPower2 - 1)
    ReDim evec(nPower2 - 1)
    ReDim uvec(nPower2 - 1)
    ReDim vvec(nPower2 - 1)
    ReDim vwtwvec(nPower2 - 1)
    ReDim wtwvec(nPower2 - 1)
    ReDim wvec(nPower2 - 1)
    ReDim xvec(nPower2 - 1)
    ReDim yvec(nPower2 - 1)
    ReDim zerovec(nPower2 - 1)

    iBase = 0
    iSwitch = 1
    delta = 20
    dT = Tyr / nStepT
    erdT = Exp(-r * dT)
    vol2 = vol * vol
    rnmudT = (r - q - 0.5 * vol2) * dT
    SqrtV = vol * Sqrt(Tyr)
    dy = delta * SqrtV / nPower2
    ydisc = Log(K / S)
    yeps = ydisc - vbCeiling(ydisc / dy) * dy
    du = twoPI / (nPower2 * dy)

    For i = 0 To nPower2 - 2 Step 2
        wvec(i) = 1
        wvec(i + 1) = -1
        wtwvec(i) = 1
        wtwvec(i + 1) = -1
    Next i
    wtwvec(0) = 0.5
    wtwvec(nPower2 - 1) = -0.5

    bgvec(0) = -0.5 * nPower2 * dy
    yvec(0) = bgvec(0) + yeps
    uvec(0) = -0.5 * nPower2 * du
    For i = 1 To nPower2 - 1
        bgvec(i) = bgvec(i - 1) + dy
        yvec(i) = bgvec(i) + yeps
        uvec(i) = uvec(i - 1) + du
```

```
    Next i

    For i = 0 To nPower2 - 1
        crfi = -0.5 * vol2 * dT * uvec(i) * uvec(i)
        cifi = rnmudT * uvec(i)
        crcfvec(i) = Exp(crfi) * Cos(cifi)
        cicfvec(i) = Exp(crfi) * Sin(cifi)
        evec(i) = Max(K - S * Exp(yvec(i)), 0)
        vvec(i) = evec(i)
        vwtwvec(i) = vvec(i) * wtwvec(i)
        zerovec(i) = 0
    Next i

    For j = nStepT - 1 To 1 Step -1

        a1vec = vbCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
            cravec(i) = a1vec(i, 0) * crcfvec(i) - a1vec(i, 1) * cicfvec(i)
            ciavec(i) = a1vec(i, 0) * cicfvec(i) + a1vec(i, 1) * crcfvec(i)
        Next i

        c1vec = vbCONVfvec(-1, cravec, ciavec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
            cvec(i) = erdT * wvec(i) * c1vec(i, 0)
            If cvec(i) > evec(i) Then Exit For
        Next i

        id = i
        If id = 0 Then id = 1

        xdisc = (evec(id - 1) - cvec(id - 1)) * yvec(id) - (evec(id) - cvec(id)) * yvec(id - 1)
        xdisc = xdisc / (evec(id - 1) - evec(id) + cvec(id) - cvec(id - 1))
        xeps = xdisc - vbCeiling(xdisc / dy) * dy
        xShift = xeps - yeps

        For i = 0 To nPower2 - 1
            xvec(i) = bgvec(i) + xeps
            evec(i) = Max(K - S * Exp(xvec(i)), 0)
            crecfi = Cos(xShift * uvec(i))
            ciecfi = Sin(xShift * uvec(i))
            craecfvec(i) = cravec(i) * crecfi - ciavec(i) * ciecfi
            ciaecfvec(i) = cravec(i) * ciecfi + ciavec(i) * crecfi
        Next i

        c1vec = vbCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
            cvec(i) = erdT * wvec(i) * c1vec(i, 0)
            vvec(i) = Max(cvec(i), evec(i))
            vwtwvec(i) = vvec(i) * wtwvec(i)
            yvec(i) = xvec(i)
        Next i

        yeps = xeps

    Next j

    xdisc = 0
    xShift = -yeps
    id = 0.5 * nPower2

    a1vec = vbCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase)

    For i = 0 To nPower2 - 1
        crfi = -0.5 * vol2 * dT * uvec(i) * uvec(i)
        cifi = rnmudT * uvec(i)
        crecfi = Exp(crfi) * Cos(cifi + xShift * uvec(i))
        ciecfi = Exp(crfi) * Sin(cifi + xShift * uvec(i))
        craecfvec(i) = a1vec(i, 0) * crecfi - a1vec(i, 1) * ciecfi
        ciaecfvec(i) = a1vec(i, 0) * ciecfi + a1vec(i, 1) * crecfi
    Next i

    c1vec = vbCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase)

    vbBermPutCONV = erdT * wvec(id) * c1vec(id, 0)
End Function

Function vbCONVfvec(iFwdInv As Int32, crfvec As Object, cifvec As Object, nPower2 As Int32, iSwitch As Int32, iBase As Int32) As Object
    Dim da As Double, alpha As Double, beta As Double, ar As Double, ai As Double, tr As Double, ti As Double, dar As Double, fi As Double
    Dim blockEnd As Int32, blockSize As Int32, i As Int32, indx As Int32, j As Int32, jk As Int32, n As Int32, nBits As Int32
```

```
    Dim fvec(,) As Double
    ReDim fvec(nPower2 - 1, 1)

    nBits = Log(nPower2) / Log2

    For i = 0 To nPower2 - 1
        indx = i
        j = 0
        For jk = 0 To nBits - 1
            j = (j * 2) Or (indx And 1)
            indx = vbIntL(indx, 2)
        Next
        fvec(j, 0) = crfvec(i + iBase)
        fvec(j, 1) = cifvec(i + iBase)
    Next

    blockEnd = 1
    blockSize = 2

    Do While blockSize <= nPower2
        da = iFwdInv * twoPI / blockSize
        alpha = 2 * Sin(0.5 * da) * Sin(0.5 * da)
        beta = Sin(da)

        i = 0
        Do While i < nPower2
            ar = 1
            ai = 0

            j = i
            For n = 0 To blockEnd - 1
                jk = j + blockEnd
                tr = ar * fvec(jk, 0) - ai * fvec(jk, 1)
                ti = ai * fvec(jk, 0) + ar * fvec(jk, 1)
                fvec(jk, 0) = fvec(j, 0) - tr
                fvec(j, 0) = fvec(j, 0) + tr
                fvec(jk, 1) = fvec(j, 1) - ti
                fvec(j, 1) = fvec(j, 1) + ti
                dar = alpha * ar + beta * ai
                ai = ai - (alpha * ai - beta * ar)
                ar = ar - dar
                j = j + 1
            Next

            i = i + blockSize
        Loop

        blockEnd = blockSize
        blockSize = blockSize * 2
    Loop

    If iSwitch = 1 Then
        For i = nPower2 / 2 + 1 To nPower2 - 1
            fi = fvec(i, 0)
            fvec(i, 0) = fvec(nPower2 - i, 0)
            fvec(nPower2 - i, 0) = fi
            fi = fvec(i, 1)
            fvec(i, 1) = fvec(nPower2 - i, 1)
            fvec(nPower2 - i, 1) = fi
        Next i
    End If

    If iFwdInv = -1 Then
        For i = 0 To nPower2 - 1
            fvec(i, 0) = fvec(i, 0) / nPower2
            fvec(i, 1) = fvec(i, 1) / nPower2
        Next i
    End If

    vbCONVfvec = fvec
End Function

Function Max(x1 as Double, x2 As Double) As Double
    If x1 >= x2 Then
        Max = x1
    Else
        Max = x2
    End If
End Function

Function vbCeiling(x As Double) As Double
    If Int(x) = x Then
```

```
        vbCeiling = x
    Else
        vbCeiling = Int(x) + 1
    End If
End Function

Function vbIntL(i1 As Int32, i2 As Int32) As Int32
    vbIntL = Int(i1 / i2)
End Function
```

THE VB.NET FUNCTIONS READY FOR EXCELDNA

```
<DnaLibrary>
<![CDATA[

Imports System.Math

Public Module MyFunctions

Const Log2 As Double = 0.693147180559945
Const twoPI As Double = 6.28318530717959

Function vbBermPutCONV(S As Double, K As Double, r As Double, q As Double, Tyr As Double, vol As Double, nStepT As Int32,
nPower2 As Int32) As Double
    Dim dT As Double, erdT As Double, vol2 As Double, rnmudT As Double, SqrtV As Double, dy As Double, ydisc As Double, yeps As
Double, du As Double, crfi As Double, cifi As Double
    Dim xdisc As Double, xeps As Double, xShift As Double, crecfi As Double, ciecfi As Double
    Dim delta As Int32, i As Int32, iBase As Int32, id As Int32, iSwitch As Int32, j As Int32
    Dim a1vec As Object
    Dim c1vec As Object

    Dim bgvec() As Double
    Dim ciavec() As Double
    Dim cicfvec() As Double
    Dim cilncfvec() As Double
    Dim ciaecfvec() As Double
    Dim cravec() As Double
    Dim crcfvec() As Double
    Dim crlncfvec() As Double
    Dim craecfvec() As Double
    Dim cvec() As Double
    Dim evec() As Double
    Dim uvec() As Double
    Dim vvec() As Double
    Dim vwtwvec() As Double
    Dim wtwvec() As Double
    Dim wvec() As Double
    Dim xvec() As Double
    Dim yvec() As Double
    Dim zerovec() As Double
    ReDim bgvec(nPower2 - 1)
    ReDim ciavec(nPower2 - 1)
    ReDim cicfvec(nPower2 - 1)
    ReDim cilncfvec(nPower2 - 1)
    ReDim ciaecfvec(nPower2 - 1)
    ReDim cravec(nPower2 - 1)
    ReDim crcfvec(nPower2 - 1)
    ReDim crlncfvec(nPower2 - 1)
    ReDim craecfvec(nPower2 - 1)
    ReDim cvec(nPower2 - 1)
    ReDim evec(nPower2 - 1)
    ReDim uvec(nPower2 - 1)
    ReDim vvec(nPower2 - 1)
    ReDim vwtwvec(nPower2 - 1)
    ReDim wtwvec(nPower2 - 1)
    ReDim wvec(nPower2 - 1)
    ReDim xvec(nPower2 - 1)
    ReDim yvec(nPower2 - 1)
    ReDim zerovec(nPower2 - 1)

    iBase = 0
    iSwitch = 1
    delta = 20
    dT = Tyr / nStepT
    erdT = Exp(-r * dT)
    vol2 = vol * vol
    rnmudT = (r - q - 0.5 * vol2) * dT
    SqrtV = vol * Sqrt(Tyr)
    dy = delta * SqrtV / nPower2
    ydisc = Log(K / S)
    yeps = ydisc - vbCeiling(ydisc / dy) * dy
    du = twoPI / (nPower2 * dy)

    For i = 0 To nPower2 - 2 Step 2
        wvec(i) = 1
        wvec(i + 1) = -1
        wtwvec(i) = 1
        wtwvec(i + 1) = -1
    Next i
    wtwvec(0) = 0.5
    wtwvec(nPower2 - 1) = -0.5
```

```
bgvec(0) = -0.5 * nPower2 * dy
yvec(0) = bgvec(0) + yeps
uvec(0) = -0.5 * nPower2 * du
For i = 1 To nPower2 - 1
        bgvec(i) = bgvec(i - 1) + dy
        yvec(i) = bgvec(i) + yeps
        uvec(i) = uvec(i - 1) + du
Next i

For i = 0 To nPower2 - 1
        crfi = -0.5 * vol2 * dT * uvec(i) * uvec(i)
        cifi = rnmudT * uvec(i)
        crcfvec(i) = Exp(crfi) * Cos(cifi)
        cicfvec(i) = Exp(crfi) * Sin(cifi)
        evec(i) = Max(K - S * Exp(yvec(i)), 0)
        vvec(i) = evec(i)
        vwtwvec(i) = vvec(i) * wtwvec(i)
        zerovec(i) = 0
Next i

For j = nStepT - 1 To 1 Step -1

        a1vec = vbCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
           cravec(i) = a1vec(i, 0) * crcfvec(i) - a1vec(i, 1) * cicfvec(i)
           ciavec(i) = a1vec(i, 0) * cicfvec(i) + a1vec(i, 1) * crcfvec(i)
        Next i

        c1vec = vbCONVfvec(-1, cravec, ciavec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
           cvec(i) = erdT * wvec(i) * c1vec(i, 0)
           If cvec(i) > evec(i) Then Exit For
        Next i

        id = i
        If id = 0 Then id = 1

        xdisc = (evec(id - 1) - cvec(id - 1)) * yvec(id) - (evec(id) - cvec(id)) * yvec(id - 1)
        xdisc = xdisc / (evec(id - 1) - evec(id) + cvec(id) - cvec(id - 1))
        xeps = xdisc - vbCeiling(xdisc / dy) * dy
        xShift = xeps - yeps

        For i = 0 To nPower2 - 1
           xvec(i) = bgvec(i) + xeps
           evec(i) = Max(K - S * Exp(xvec(i)), 0)
           crecfi = Cos(xShift * uvec(i))
           ciecfi = Sin(xShift * uvec(i))
           craecfvec(i) = cravec(i) * crecfi - ciavec(i) * ciecfi
           ciaecfvec(i) = cravec(i) * ciecfi + ciavec(i) * crecfi
        Next i

        c1vec = vbCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase)

        For i = 0 To nPower2 - 1
           cvec(i) = erdT * wvec(i) * c1vec(i, 0)
           vvec(i) = Max(cvec(i), evec(i))
           vwtwvec(i) = vvec(i) * wtwvec(i)
           yvec(i) = xvec(i)
        Next i

        yeps = xeps

Next j

xdisc = 0
xShift = -yeps
id = 0.5 * nPower2

a1vec = vbCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase)

For i = 0 To nPower2 - 1
        crfi = -0.5 * vol2 * dT * uvec(i) * uvec(i)
        cifi = rnmudT * uvec(i)
        crecfi = Exp(crfi) * Cos(cifi + xShift * uvec(i))
        ciecfi = Exp(crfi) * Sin(cifi + xShift * uvec(i))
        craecfvec(i) = a1vec(i, 0) * crecfi - a1vec(i, 1) * ciecfi
        ciaecfvec(i) = a1vec(i, 0) * ciecfi + a1vec(i, 1) * crecfi
Next i

c1vec = vbCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase)
```

```
    vbBermPutCONV = erdT * wvec(id) * c1vec(id, 0)
End Function

Function vbCONVfvec(iFwdInv As Int32, crfvec As Object, cifvec As Object, nPower2 As Int32, iSwitch As Int32, iBase As Int32) As
Object
    Dim da As Double, alpha As Double, beta As Double, ar As Double, ai As Double, tr As Double, ti As Double, dar As Double, fi As
Double
    Dim blockEnd As Int32, blockSize As Int32, i As Int32, indx As Int32, j As Int32, jk As Int32, n As Int32, nBits As Int32
    Dim fvec(,) As Double
    ReDim fvec(nPower2 - 1, 1)

    nBits = Log(nPower2) / Log2

    For i = 0 To nPower2 - 1
        indx = i
        j = 0
        For jk = 0 To nBits - 1
            j = (j * 2) Or (indx And 1)
            indx = vbIntL(indx, 2)
        Next
        fvec(j, 0) = crfvec(i + iBase)
        fvec(j, 1) = cifvec(i + iBase)
    Next

    blockEnd = 1
    blockSize = 2

    Do While blockSize <= nPower2
        da = iFwdInv * twoPI / blockSize
        alpha = 2 * Sin(0.5 * da) * Sin(0.5 * da)
        beta = Sin(da)

        i = 0
        Do While i < nPower2
            ar = 1
            ai = 0

            j = i
            For n = 0 To blockEnd - 1
                jk = j + blockEnd
                tr = ar * fvec(jk, 0) - ai * fvec(jk, 1)
                ti = ai * fvec(jk, 0) + ar * fvec(jk, 1)
                fvec(jk, 0) = fvec(j, 0) - tr
                fvec(j, 0) = fvec(j, 0) + tr
                fvec(jk, 1) = fvec(j, 1) - ti
                fvec(j, 1) = fvec(j, 1) + ti
                dar = alpha * ar + beta * ai
                ai = ai - (alpha * ai - beta * ar)
                ar = ar - dar
                j = j + 1
            Next

            i = i + blockSize
        Loop

        blockEnd = blockSize
        blockSize = blockSize * 2
    Loop

    If iSwitch = 1 Then
        For i = nPower2 / 2 + 1 To nPower2 - 1
            fi = fvec(i, 0)
            fvec(i, 0) = fvec(nPower2 - i, 0)
            fvec(nPower2 - i, 0) = fi
            fi = fvec(i, 1)
            fvec(i, 1) = fvec(nPower2 - i, 1)
            fvec(nPower2 - i, 1) = fi
        Next i
    End If

    If iFwdInv = -1 Then
        For i = 0 To nPower2 - 1
            fvec(i, 0) = fvec(i, 0) / nPower2
            fvec(i, 1) = fvec(i, 1) / nPower2
        Next i
    End If

    vbCONVfvec = fvec
End Function

Function Max(x1 as Double, x2 As Double) As Double
```

```
    If x1 >= x2 Then
        Max = x1
    Else
        Max = x2
    End If
End Function

Function vbCeiling(x As Double) As Double
    If Int(x) = x Then
        vbCeiling = x
    Else
        vbCeiling = Int(x) + 1
    End If
End Function

Function vbIntL(i1 As Int32, i2 As Int32) As Int32
    vbIntL = Int(i1 / i2)
End Function

End Module

]]>
</DnaLibrary>
```

THE VB.NET FUNCTIONS CONVERTED INTO C#

```
private const double Log2 = 0.693147180559945;
private const double twoPI = 6.28318530717959;

public double csBermPutCONV(double S, double K, double r, double q, double Tyr, double vol, Int32 nStepT, Int32 nPower2)
{
    double dT = 0;
    double erdT = 0;
    double vol2 = 0;
    double rnmudT = 0;
    double SqrtV = 0;
    double dy = 0;
    double ydisc = 0;
    double yeps = 0;
    double du = 0;
    double crfi = 0;
    double cifi = 0;
    double xdisc = 0;
    double xeps = 0;
    double xShift = 0;
    double crecfi = 0;
    double ciecfi = 0;
    Int32 delta = 0;
    Int32 i = 0;
    Int32 iBase = 0;
    Int32 id = 0;
    Int32 iSwitch = 0;
    Int32 j = 0;
    object a1vec = null;
    object c1vec = null;

    double[] bgvec = null;
    double[] ciavec = null;
    double[] cicfvec = null;
    double[] cilncfvec = null;
    double[] ciaecfvec = null;
    double[] cravec = null;
    double[] crcfvec = null;
    double[] crlncfvec = null;
    double[] craecfvec = null;
    double[] cvec = null;
    double[] evec = null;
    double[] uvec = null;
    double[] vvec = null;
    double[] vwtwvec = null;
    double[] wtwvec = null;
    double[] wvec = null;
    double[] xvec = null;
    double[] yvec = null;
    double[] zerovec = null;
    bgvec = new double[nPower2];
    ciavec = new double[nPower2];
    cicfvec = new double[nPower2];
    cilncfvec = new double[nPower2];
    ciaecfvec = new double[nPower2];
    cravec = new double[nPower2];
    crcfvec = new double[nPower2];
    crlncfvec = new double[nPower2];
    craecfvec = new double[nPower2];
    cvec = new double[nPower2];
    evec = new double[nPower2];
    uvec = new double[nPower2];
    vvec = new double[nPower2];
    vwtwvec = new double[nPower2];
    wtwvec = new double[nPower2];
    wvec = new double[nPower2];
    xvec = new double[nPower2];
    yvec = new double[nPower2];
    zerovec = new double[nPower2];

    iBase = 0;
    iSwitch = 1;
    delta = 20;
    dT = Tyr / nStepT;
    erdT = Exp(-r * dT);
    vol2 = vol * vol;
    rnmudT = (r - q - 0.5 * vol2) * dT;
    SqrtV = vol * Sqrt(Tyr);
    dy = delta * SqrtV / nPower2;
    ydisc = Log(K / S);
    yeps = ydisc - csCeiling(ydisc / dy) * dy;
```

```
du = twoPI / (nPower2 * dy);

for (i = 0; i <= nPower2 - 2; i = i + 2)
{
   wvec[i] = 1;
   wvec[i + 1] = -1;
   wtwvec[i] = 1;
   wtwvec[i + 1] = -1;
}
wtwvec[0] = 0.5;
wtwvec[nPower2 - 1] = -0.5;

bgvec[0] = -0.5 * nPower2 * dy;
yvec[0] = bgvec[0] + yeps;
uvec[0] = -0.5 * nPower2 * du;
for (i = 1; i < nPower2; i++)
{
   bgvec[i] = bgvec[i - 1] + dy;
   yvec[i] = bgvec[i] + yeps;
   uvec[i] = uvec[i - 1] + du;
}

for (i = 0; i < nPower2; i++)
{
   crfi = -0.5 * vol2 * dT * uvec[i] * uvec[i];
   cifi = rnmudT * uvec[i];
   crcfvec[i] = Exp(crfi) * Cos(cifi);
   cicfvec[i] = Exp(crfi) * Sin(cifi);
   evec[i] = Max(K - S * Exp(yvec[i]), 0);
   vvec[i] = evec[i];
   vwtwvec[i] = vvec[i] * wtwvec[i];
   zerovec[i] = 0;
}

for (j = nStepT - 1; j >= 1; j--)
{

   a1vec = csCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase);

   for (i = 0; i < nPower2; i++)
   {
      cravec[i] = a1vec(i, 0) * crcfvec[i] - a1vec(i, 1) * cicfvec[i];
      ciavec[i] = a1vec(i, 0) * cicfvec[i] + a1vec(i, 1) * crcfvec[i];
   }

   c1vec = csCONVfvec(-1, cravec, ciavec, nPower2, iSwitch, iBase);

   for (i = 0; i < nPower2; i++)
   {
      cvec[i] = erdT * wvec[i] * c1vec(i, 0);
      if (cvec[i] > evec[i])
      {
        break;
      }
   }

   id = i;
   if (id == 0)
   {
     id = 1;
   }

   xdisc = (evec[id - 1] - cvec[id - 1]) * yvec[id] - (evec[id] - cvec[id]) * yvec[id - 1];
   xdisc = xdisc / (evec[id - 1] - evec[id] + cvec[id] - cvec[id - 1]);
   xeps = xdisc - csCeiling(xdisc / dy) * dy;
   xShift = xeps - yeps;

   for (i = 0; i < nPower2; i++)
   {
      xvec[i] = bgvec[i] + xeps;
      evec[i] = Max(K - S * Exp(xvec[i]), 0);
      crecfi = Cos(xShift * uvec[i]);
      ciecfi = Sin(xShift * uvec[i]);
      craecfvec[i] = cravec[i] * crecfi - ciavec[i] * ciecfi;
      ciaecfvec[i] = cravec[i] * ciecfi + ciavec[i] * crecfi;
   }

   c1vec = csCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase);

   for (i = 0; i < nPower2; i++)
   {
      cvec[i] = erdT * wvec[i] * c1vec(i, 0);
```

```
            vvec[i] = Max(cvec[i], evec[i]);
            vwtwvec[i] = vvec[i] * wtwvec[i];
            yvec[i] = xvec[i];
        }

        yeps = xeps;

    }

    xdisc = 0;
    xShift = -yeps;
    id = 0.5 * nPower2;

    a1vec = csCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase);

    for (i = 0; i < nPower2; i++)
    {
        crfi = -0.5 * vol2 * dT * uvec[i] * uvec[i];
        cifi = rnmudT * uvec[i];
        crecfi = Exp(crfi) * Cos(cifi + xShift * uvec[i]);
        ciecfi = Exp(crfi) * Sin(cifi + xShift * uvec[i]);
        craecfvec[i] = a1vec(i, 0) * crecfi - a1vec(i, 1) * ciecfi;
        ciaecfvec[i] = a1vec(i, 0) * ciecfi + a1vec(i, 1) * crecfi;
    }

    c1vec = csCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase);

    return erdT * wvec[id] * c1vec(id, 0);
}

public object csCONVfvec(Int32 iFwdInv, object crfvec, object cifvec, Int32 nPower2, Int32 iSwitch, Int32 iBase)
{
    double da = 0;
    double alpha = 0;
    double beta = 0;
    double ar = 0;
    double ai = 0;
    double tr = 0;
    double ti = 0;
    double dar = 0;
    double fi = 0;
    Int32 blockEnd = 0;
    Int32 blockSize = 0;
    Int32 i = 0;
    Int32 indx = 0;
    Int32 j = 0;
    Int32 jk = 0;
    Int32 n = 0;
    Int32 nBits = 0;
    double[,] fvec = null;
    fvec = new double[nPower2,2];

    nBits = Log(nPower2) / Log2;

    for (i = 0; i < nPower2; i++)
    {
        indx = i;
        j = 0;
        for (jk = 0; jk < nBits; jk++)
        {
            j = (j * 2) | (indx & 1);
            indx = csIntL(indx, 2);
        }
        fvec[j, 0] = crfvec(i + iBase);
        fvec[j, 1] = cifvec(i + iBase);
    }

    blockEnd = 1;
    blockSize = 2;

    while (blockSize <= nPower2)
    {
        da = iFwdInv * twoPI / blockSize;
        alpha = 2 * Sin(0.5 * da) * Sin(0.5 * da);
        beta = Sin(da);

        i = 0;
        while (i < nPower2)
        {
            ar = 1;
            ai = 0;
```

```
            j = i;
            for (n = 0; n < blockEnd; n++)
            {
                jk = j + blockEnd;
                tr = ar * fvec[jk, 0] - ai * fvec[jk, 1];
                ti = ai * fvec[jk, 0] + ar * fvec[jk, 1];
                fvec[jk, 0] = fvec[j, 0] - tr;
                fvec[j, 0] = fvec[j, 0] + tr;
                fvec[jk, 1] = fvec[j, 1] - ti;
                fvec[j, 1] = fvec[j, 1] + ti;
                dar = alpha * ar + beta * ai;
                ai = ai - (alpha * ai - beta * ar);
                ar = ar - dar;
                j = j + 1;
            }

            i = i + blockSize;
        }

        blockEnd = blockSize;
        blockSize = blockSize * 2;
    }

    if (iSwitch == 1)
    {
        for (i = nPower2 / 2 + 1; i < nPower2; i++)
        {
            fi = fvec[i, 0];
            fvec[i, 0] = fvec[nPower2 - i, 0];
            fvec[nPower2 - i, 0] = fi;
            fi = fvec[i, 1];
            fvec[i, 1] = fvec[nPower2 - i, 1];
            fvec[nPower2 - i, 1] = fi;
        }
    }

    if (iFwdInv == -1)
    {
        for (i = 0; i < nPower2; i++)
        {
            fvec[i, 0] = fvec[i, 0] / nPower2;
            fvec[i, 1] = fvec[i, 1] / nPower2;
        }
    }

    return fvec;
}

public double Max(double x1, double x2)
{
    double tempMax = 0;
    if (x1 >= x2)
    {
        tempMax = x1;
    }
    else
    {
        tempMax = x2;
    }
    return tempMax;
}

public double csCeiling(double x)
{
    double tempcsCeiling = 0;
    if (Microsoft.VisualBasic.Conversion.Int(x) == x)
    {
        tempcsCeiling = x;
    }
    else
    {
        tempcsCeiling = Microsoft.VisualBasic.Conversion.Int(x) + 1;
    }
    return tempcsCeiling;
}

public Int32 csIntL(Int32 i1, Int32 i2)
{
    return Microsoft.VisualBasic.Conversion.Int(i1 / i2);
}
```

THE VB.NET FUNCTIONS CONVERTED INTO C++

```
private:
static const double Log2 = 0.693147180559945;
static const double twoPI = 6.28318530717959;

public:
double cpBermPutCONV(double S, double K, double r, double q, double Tyr, double vol, Int32 nStepT, Int32 nPower2)
{
    double dT = 0;
    double erdT = 0;
    double vol2 = 0;
    double rnmudT = 0;
    double SqrtV = 0;
    double dy = 0;
    double ydisc = 0;
    double yeps = 0;
    double du = 0;
    double crfi = 0;
    double cifi = 0;
    double xdisc = 0;
    double xeps = 0;
    double xShift = 0;
    double crecfi = 0;
    double ciecfi = 0;
    Int32 delta = 0;
    Int32 i = 0;
    Int32 iBase = 0;
    Int32 id = 0;
    Int32 iSwitch = 0;
    Int32 j = 0;
    System::Object ^a1vec = nullptr;
    System::Object ^c1vec = nullptr;

    array<double> ^bgvec = nullptr;
    array<double> ^ciavec = nullptr;
    array<double> ^cicfvec = nullptr;
    array<double> ^cilncfvec = nullptr;
    array<double> ^ciaecfvec = nullptr;
    array<double> ^cravec = nullptr;
    array<double> ^crcfvec = nullptr;
    array<double> ^crlncfvec = nullptr;
    array<double> ^craecfvec = nullptr;
    array<double> ^cvec = nullptr;
    array<double> ^evec = nullptr;
    array<double> ^uvec = nullptr;
    array<double> ^vvec = nullptr;
    array<double> ^vwtwvec = nullptr;
    array<double> ^wtwvec = nullptr;
    array<double> ^wvec = nullptr;
    array<double> ^xvec = nullptr;
    array<double> ^yvec = nullptr;
    array<double> ^zerovec = nullptr;
    bgvec = gcnew array<double>(nPower2);
    ciavec = gcnew array<double>(nPower2);
    cicfvec = gcnew array<double>(nPower2);
    cilncfvec = gcnew array<double>(nPower2);
    ciaecfvec = gcnew array<double>(nPower2);
    cravec = gcnew array<double>(nPower2);
    crcfvec = gcnew array<double>(nPower2);
    crlncfvec = gcnew array<double>(nPower2);
    craecfvec = gcnew array<double>(nPower2);
    cvec = gcnew array<double>(nPower2);
    evec = gcnew array<double>(nPower2);
    uvec = gcnew array<double>(nPower2);
    vvec = gcnew array<double>(nPower2);
    vwtwvec = gcnew array<double>(nPower2);
    wtwvec = gcnew array<double>(nPower2);
    wvec = gcnew array<double>(nPower2);
    xvec = gcnew array<double>(nPower2);
    yvec = gcnew array<double>(nPower2);
    zerovec = gcnew array<double>(nPower2);

    iBase = 0;
    iSwitch = 1;
    delta = 20;
    dT = Tyr / nStepT;
    erdT = Exp(-r * dT);
    vol2 = vol * vol;
    rnmudT = (r - q - 0.5 * vol2) * dT;
    SqrtV = vol * Sqrt(Tyr);
    dy = delta * SqrtV / nPower2;
```

```
ydisc = Log[K / S];
yeps = ydisc - cpCeiling(ydisc / dy) * dy;
du = twoPI / (nPower2 * dy);

for (i = 0; i <= nPower2 - 2; i += 2)
{
   wvec[i] = 1;
   wvec[i + 1] = -1;
   wtwvec[i] = 1;
   wtwvec[i + 1] = -1;
}
wtwvec[0] = 0.5;
wtwvec[nPower2 - 1] = -0.5;

bgvec[0] = -0.5 * nPower2 * dy;
yvec[0] = bgvec[0] + yeps;
uvec[0] = -0.5 * nPower2 * du;
for (i = 1; i < nPower2; i++)
{
   bgvec[i] = bgvec[i - 1] + dy;
   yvec[i] = bgvec[i] + yeps;
   uvec[i] = uvec[i - 1] + du;
}

for (i = 0; i < nPower2; i++)
{
   crfi = -0.5 * vol2 * dT * uvec[i] * uvec[i];
   cifi = rnmudT * uvec[i];
   crcfvec[i] = Exp(crfi) * Cos(cifi);
   cicfvec[i] = Exp(crfi) * Sin(cifi);
   evec[i] = Max(K - S * Exp(yvec[i]), 0);
   vvec[i] = evec[i];
   vwtwvec[i] = vvec[i] * wtwvec[i];
   zerovec[i] = 0;
}

for (j = nStepT - 1; j >= 1; j--)
{

   a1vec = cpCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase);

   for (i = 0; i < nPower2; i++)
   {
      cravec[i] = a1vec(i, 0) * crcfvec[i] - a1vec(i, 1) * cicfvec[i];
      ciavec[i] = a1vec(i, 0) * cicfvec[i] + a1vec(i, 1) * crcfvec[i];
   }

   c1vec = cpCONVfvec(-1, cravec, ciavec, nPower2, iSwitch, iBase);

   for (i = 0; i < nPower2; i++)
   {
      cvec[i] = erdT * wvec[i] * c1vec(i, 0);
      if (cvec[i] > evec[i])
        break;
   }

   id = i;
   if (id == 0)
     id = 1;

   xdisc = (evec[id - 1] - cvec[id - 1]) * yvec[id] - (evec[id] - cvec[id]) * yvec[id - 1];
   xdisc = xdisc / (evec[id - 1] - evec[id] + cvec[id] - cvec[id - 1]);
   xeps = xdisc - cpCeiling(xdisc / dy) * dy;
   xShift = xeps - yeps;

   for (i = 0; i < nPower2; i++)
   {
      xvec[i] = bgvec[i] + xeps;
      evec[i] = Max(K - S * Exp(xvec[i]), 0);
      crecfi = Cos(xShift * uvec[i]);
      ciecfi = Sin(xShift * uvec[i]);
      craecfvec[i] = cravec[i] * crecfi - ciavec[i] * ciecfi;
      ciaecfvec[i] = cravec[i] * ciecfi + ciavec[i] * crecfi;
   }

   c1vec = cpCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase);

   for (i = 0; i < nPower2; i++)
   {
      cvec[i] = erdT * wvec[i] * c1vec(i, 0);
      vvec[i] = Max(cvec[i], evec[i]);
      vwtwvec[i] = vvec[i] * wtwvec[i];
```

```
            yvec[i] = xvec[i];
        }

        yeps = xeps;

    }

    xdisc = 0;
    xShift = -yeps;
    id = 0.5 * nPower2;

    a1vec = cpCONVfvec(1, vwtwvec, zerovec, nPower2, iSwitch, iBase);

    for (i = 0; i < nPower2; i++)
    {
        crfi = -0.5 * vol2 * dT * uvec[i] * uvec[i];
        cifi = rnmudT * uvec[i];
        crecfi = Exp(crfi) * Cos(cifi + xShift * uvec[i]);
        ciecfi = Exp(crfi) * Sin(cifi + xShift * uvec[i]);
        craecfvec[i] = a1vec(i, 0) * crecfi - a1vec(i, 1) * ciecfi;
        ciaecfvec[i] = a1vec(i, 0) * ciecfi + a1vec(i, 1) * crecfi;
    }

    c1vec = cpCONVfvec(-1, craecfvec, ciaecfvec, nPower2, iSwitch, iBase);

    return erdT * wvec[id] * c1vec(id, 0);
}

System::Object ^cpCONVfvec(Int32 iFwdInv, System::Object ^crfvec, System::Object ^cifvec, Int32 nPower2, Int32 iSwitch, Int32 iBase)
{
    double da = 0;
    double alpha = 0;
    double beta = 0;
    double ar = 0;
    double ai = 0;
    double tr = 0;
    double ti = 0;
    double dar = 0;
    double fi = 0;
    Int32 blockEnd = 0;
    Int32 blockSize = 0;
    Int32 i = 0;
    Int32 indx = 0;
    Int32 j = 0;
    Int32 jk = 0;
    Int32 n = 0;
    Int32 nBits = 0;
    array<double, 2> ^fvec = nullptr;
    fvec = gcnew array<double, 2>(nPower2,2);

    nBits = Log[nPower2] / Log2;

    for (i = 0; i < nPower2; i++)
    {
        indx = i;
        j = 0;
        for (jk = 0; jk < nBits; jk++)
        {
            j = (j * 2) | (indx & 1);
            indx = cpIntL(indx, 2);
        }
        fvec[j, 0] = crfvec(i + iBase);
        fvec[j, 1] = cifvec(i + iBase);
    }

    blockEnd = 1;
    blockSize = 2;

    while (blockSize <= nPower2)
    {
        da = iFwdInv * twoPI / blockSize;
        alpha = 2 * Sin(0.5 * da) * Sin(0.5 * da);
        beta = Sin(da);

        i = 0;
        while (i < nPower2)
        {
            ar = 1;
            ai = 0;

            j = i;
            for (n = 0; n < blockEnd; n++)
```

```
            {
                jk = j + blockEnd;
                tr = ar * fvec[jk, 0] - ai * fvec[jk, 1];
                ti = ai * fvec[jk, 0] + ar * fvec[jk, 1];
                fvec[jk, 0] = fvec[j, 0] - tr;
                fvec[j, 0] = fvec[j, 0] + tr;
                fvec[jk, 1] = fvec[j, 1] - ti;
                fvec[j, 1] = fvec[j, 1] + ti;
                dar = alpha * ar + beta * ai;
                ai = ai - (alpha * ai - beta * ar);
                ar = ar - dar;
                j = j + 1;
            }

            i = i + blockSize;
        }

        blockEnd = blockSize;
        blockSize = blockSize * 2;
    }

    if (iSwitch == 1)
    {
        for (i = nPower2 / 2 + 1; i < nPower2; i++)
        {
            fi = fvec[i, 0];
            fvec[i, 0] = fvec[nPower2 - i, 0];
            fvec[nPower2 - i, 0] = fi;
            fi = fvec[i, 1];
            fvec[i, 1] = fvec[nPower2 - i, 1];
            fvec[nPower2 - i, 1] = fi;
        }
    }

    if (iFwdInv == -1)
    {
        for (i = 0; i < nPower2; i++)
        {
            fvec[i, 0] = fvec[i, 0] / nPower2;
            fvec[i, 1] = fvec[i, 1] / nPower2;
        }
    }

    return fvec;
}

double Max(double x1, double x2)
{
    double tempMax = 0;
    if (x1 >= x2)
        tempMax = x1;
    else
        tempMax = x2;
    return tempMax;
}

double cpCeiling(double x)
{
    double tempcpCeiling = 0;
    if (Microsoft::VisualBasic::Conversion::Int(x) == x)
        tempcpCeiling = x;
    else
        tempcpCeiling = Microsoft::VisualBasic::Conversion::Int(x) + 1;
    return tempcpCeiling;
}

Int32 cpIntL(Int32 i1, Int32 i2)
{
    return Microsoft::VisualBasic::Conversion::Int(i1 / i2);
}
```