Introduction to Arrays

Larry Caretto
Mechanical Engineering 209

Computer Programming for Mechanical Engineers

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California State University Northridge

Outline

- Review midterm
- Array notation and declaration
- Minimum subscript for arrays
- Using arrays in expressions
- For loops and arrays
- Two-dimensional arrays
- Passing arrays to other procedures
- Getting cell data from worksheet
- Programming Assignment Five

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Midterm Results

- Number of students: 25
- Maximum possible score: 125
- Mean score: 67.4
- Median Score: 65
- Standard deviation: 37.8
- Grade distribution:

```
  10  13  18  27  34  37  41  42
43  45  45  46  65  66  71  85  85
 105 105 108 110 118 120 123 123
```

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Midterm Comments

- Write exponentiation (x^y) as x^y in VBA
- Remember quotes for string constants like Range("A5").Value
  - Can use string variable in the following way
  - Dim c as string : c = "ZX649" : Range(c).Value
- Write $\frac{a}{bc}$ as a/(b*c); a/b*c is $\frac{a}{b}c$
  - Write fractions on one line (a+b)/(c+d)
  - Write ((a+b)/c) NOT [(a+b)/c]

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Midterm Comments II

- Two possibilities for simple if statement:

```
If a = b Then c = 0 Else c = 1
If a = b Then
   c = 0
Else
   c = 1
End If
```

First form only works for a single statement in both blocks (can omit else statement)

- Precedence rules for exponentiation and unary minus differ between VBA (–1^2 = –1) and worksheet (–1^2 = 1)
  - Can always use (-1)^n to be sure

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Function Basics (Problem 2)

```
Function LoanPayment(P As Double, _
     i As Double, N As Integer) As Double
          LoanPayment = P * i / _
                    (1 - (1 + i) ^ (-N))
End Function
```

- Input data from arguments, not from Range.Value statements
- Output value through function name

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More midterm comments

- Be careful tracking code with loops and If statements
- Use information sheet
- Problem 3 solution

```
If n Mod 2 = 0 Then
    t = 0
Else
    t = -2 * Cos((2 * n + 1) * PI _
          * x / L) / (2 * n + 1)
End If
```

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Select Case Alternative to If 1

```
Function getValue(color As String)
    If color = "black" Then
        getValue = 0
    ElseIf color = "brown" Then
        getValue = 1
    ElseIf color = "red" Then
        getValue = 2
    ElseIf color = "orange" Then
        getValue = 3
    ElseIf color = "yellow" Then
        getValue = 4
```

Continued next slide

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Select Case Alternative to If 2

```
    ElseIf color = "green" Then
        getValue = 5
    ElseIf color = "blue" Then
        getValue = 6
    ElseIf color = "violet" Then
        getValue = 7
    ElseIf color = "gray" Then
        getValue = 8
    ElseIf color = "white" Then
        getValue = 9
    End If
End Function
```

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Select Case Alternative to If 3

```
Function getValue2(color As String)
    Select Case color
        Case "black"
            getValue2 = 0
        Case "brown"
            getValue2 = 1
        Case "red"
            getValue2 = 2
        Case "orange"
            getValue2 = 3
        Case "yellow"
            getValue2 = 4
```

Continued next slide

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Select Case Alternative to If 4

```
        Case "green"
            getValue2 = 5
        Case "blue"
            getValue2 = 6
        Case "violet"
            getValue2 = 7
        Case "gray"
            getValue2 = 8
        Case "white"
            getValue2 = 9
    End Select
End Function
```

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Date	Assignment	Date	Assignment
April 11		April 13	
April 18	Assignment 4 Due	April 20	Quiz 4
April 25	Assignment 5 Due	April 27	
May 2	Quiz 5	May 4	
May 9	Assignment 6 Due	May 11	Programming Exam
		May 18	Final Exam 12:45 to 2:45 pm

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Why Arrays

Run	Data
1	12.3
2	14.4
3	11.8
4	12.5
5	13.2
6	14.1

- Consider a set of experimental data with several runs
- How do we represent the data in such a way that we can easily process these results with similar results for any number of data points?

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Why Arrays II

Run, i	x_i Data
1	x_1
2	x_2
3	x_3
4	x_4
5	x_5
6	x_6

- x_i is technical notation for several values of similar data
  - Letter represents identity of variable and subscript gives a particular value
  - Ten values of pressure would be labeled from p_1 to p_{10}

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Why Arrays III

i	Stress Data	Strain Data
1	σ_1	ε_1
2	σ_2	ε_2
3	σ_3	ε_3
4	σ_4	ε_4
5	σ_5	ε_5
6	σ_6	ε_6

- Example of stress (σ_i) and strain (ε_i) data
- Calculate modulus $E_i = \sigma_i/\varepsilon_i$ for each run
- Find statistics

$$\bar{\sigma} = \frac{1}{N}\sum_{i=1}^{N}\sigma_i$$

$$s^2 = \frac{1}{N-1}\sum_{i=1}^{N}(\sigma_i - \bar{\sigma})^2$$

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General Calculations

- We could use a set of variables like s1, s2, s3, etc. and compute the mean as (s1+s2+s3+s4+s5+s6)/6
- We would like to have a more general approach so that we can use the same code to compute a mean as the size of the sample or identity of the variable changes
- We use arrays to do this

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VBA Arrays

Math	VBA
x_1	x(1)
x_2	x(2)
x_3	x(3)
x_4	x(4)
x_5	x(5)
x_6	x(6)

- Math notation, x_i, is replaced by VBA notation x(i)
  - i is called a subscript
  - View this one-dimensional array as one row or one column of data
  - Can have arrays of any size, but have to declare maximum array size

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Arrays Represent Data Sets

- Any program variable name can be used as an array name
  - Array name u(i) replaces the mathematical notation u_i
  - stress(i), strain(i), pressure(k), V(j)
- We can refer to particular data items
  - stress(2), strain(2), pressure(14), V(65)
- How do we declare variables as arrays and how do we use them in calculations

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Declaring Arrays

- We use the same Dim statement that we have been using, but we have to add the size of the array to the Dim
  - Usual variables: Dim x as Double
  - Array variable: Dim x(200) as Double
  - The declaration shown here specifies the **maximum subscript** for the array x
    - The Dim statement for an array sets the storage area for the array
    - What is the minimum subscript for an array?

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VBA Minimum Array Subscript

- The default minimum array subscript in VBA is zero
- You can change this default to one with the following option statement
  - `Option Base 1`
    - Like all option statements, this goes before the first procedure in the module
- You can also set a separate minimum subscript for each array you declare

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How Many Elements in Array?

```
Option Base 0  'Default, not required
Sub test()
    Dim x(17) As Double
    Dim r(32) As String
    Dim model(1985 To 2040) As Integer
    Dim stress(1 To 12) As Double
    Dim strain(12) As Double
    Dim modulus(0 To 12) As Double
```

18 33 56 12 13 13

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How Many Elements in Array?

```
Option Base 1
Sub test()
    Dim x(17) As Double
    Dim r(32) As String
    Dim model(1985 to 2040) As Integer
    Dim stress(1 to 12) As Double
    Dim strain(12) As Double
    Dim modulus(0 to 12) As Double
```

17 32 56 12 12 13

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Using Array Data

- We can use individual array elements like any other programming variable
  - E = stress(3)/strain(3)
  - k = 3 : E = stress(k)/strain(k)
  - For k = 1 To N : sum = sum + x(k) : Next k
  - j = 2 : power(j) = current(j) * voltage(j)
  - Dim pressure(1 to 10) as Double
    meanPressure = Application. _
    Worksheetfunction.Average(pressure)

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Array Statement Quiz

Array	Data
x(1)	360
x(2)	40
x(3)	40
x(4)	80
x(5)	120
x(6)	72

- Give results of state-ments below (k = 3)

x(k) = 40 x(3) = 40

x(k+1) = 2 * x(k) x(4)=2*x(3)=80

x(7-2*k) = 32 x(1) = 32

x(k-1) = x(4) – x(3) x(2) = 80 - 40 = 40

x(5) = x(k) + x(k+1)

x(5) = x(3)+x(4)=40+80 =120

x(k-2) = 3 * x(k+2)

x(1) = 3*x(5)=360

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Using Array Data II

- We can use a variable or a constant for an array subscript
  - A variable must be assigned a value before it is used as an array subscript
- Write array expressions for the following
  - $x_3 = \cos(3\pi+1)$ x(3) = cos(3*PI+1)
  - $P_4 = mRT_4/V_4$ P(4) = m*R*T(4) / V(4)
  - $f_k = f_{k-1} + f_{k-2}$ f(k) = f(k-1) + f(k-2)
  - power = I_kV_j power = I(k)*V(j)

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For Loops and Arrays

- A common application of arrays uses for loops to set elements in an array

```
For k = 1 To 10
    x(k) = cos(k*PI/10)
Next k
```

- Can sum all or (some) elements in an array

```
sum = x(1)
For k = 2 To NX
    sum = sum + x(k)
Next k
```

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For Loops and Arrays II

- Process all data in a data set

```
For k = first To last
  power(k) = amps(k) * volts(k)
Next k
```

- Find mean of computed result

```
sumP = 0
For k = first To last
  sumP = sumP + amps(k) * volts(k)
Next k
meanP = sump / (last – first + 1)
```

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Dimensions vs. Elements

- Dim statement sets maximum array size
- Not all possible elements may be used
  - Elements not assigned values are zero
  - In example below x(6) to x(10) are zero
  - Where do we get values of x(1) to x(5)?

```
Dim x(1 To 10) As Double
For k = 1 to 5
   x(k) = cells(1,k).Value
Next k
```

x(1) to x(5) are values in range A1:E1 of active worksheet

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Two-dimensional Arrays

The efficiency, e, of an electromechanical device measured over six levels of current and four levels of voltage. The data at each combination of current and voltage can be represented by arrays as shown below. e(k,j) is a *two-dimensional* array.

	I(1)	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**
V(1)	e(1,1)	e(1,2)	e(1,3)	e(1,4)	e(1,5)	e(1,6)
V(2)	e(2,1)	e(2,2)	e(2,3)	e(2,4)	e(2,5)	e(2,6)
V(3)	e(3,1)	e(3,2)	e(3,3)	e(3,4)	e(3,5)	e(3,6)
V(4)	e(4,1)	e(4,2)	e(4,3)	e(4,4)	e(4,5)	e(4,6)

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Two-dimensional Arrays II

- The two-dimensional array in VBA is a representation of the data on an Excel worksheet
- It represents **discrete data** from a function of two variables f(x,y) where we have data at certain values x_i and y_j
- The math notation f_{ij} represents $f(x_i, y_j)$
- The VBA notation for f_{ij} is f(i,j) the two-dimensional array

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Two-dimensional Arrays III

- The Dim statement for a two-dimensional array has to declare the maximum size of each dimension

```
Dim e(1 To 4, 1 To 6) As Double
```

- Can use the upper bound only, but the lower limit may be 0 or 1
  - How many elements in arrays below

```
Dim e(4,6) As Double
```
24 or 35

```
Dim e(3,5) As Double
```
15 or 24

First result for Option Explicit 1, second for Option Explicit 0

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Two-dimensional Arrays IV

- Two-way table from two-dimensional arrays and nested for loops
  - Need to define P(k) and T(j) arrays prior to executing this code

```
For k = 1 to 10
  For j = 1 to 20
    rho(k,j) = M*P(k) / (R*T(j))
  Next j
Next k
```

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Worksheets and Arrays

- Can use cells method to get known amount of worksheet data into an array

```
Const NX As Long = 10, NY As Long = 20
Dim row As Long, col as Long
Dim x(1 to NX, 1 To NY)
For row = 1 To NX
   For col = 1 To NY
      x(row,col)=Cells(row,col).Value
   Next col
Next row
```

Note use of Const for array bounds and for loop limits. Changes to NX or NY can be done by changing Const values

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LBound and UBound

- These VBA functions get lower and upper bounds for array dimensions
  - Recall arrays can have more than one dimension, e.g. p(k,m)
- The arguments are (<array Name>, <dimension>) where dimension = 1, 2, etc. for the first, second, etc. dimension
  - Only look at one- and two-dimensional arrays in this course
  - If <dimension> is omitted it has a value of 1

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Passing Arrays to Procedures

- When passing arrays to procedures it is not necessary to Dim the array
- Instead, the argument to handle an array is written with empty parentheses

```
Function mean(x() as Double) As Double
  Dim k as Long
  mean = 0
  For k = LBound(x) To UBound(x)
     mean = mean + x(k)
  Next k
  mean = mean /(UBound(x) -LBound(x) + 1)
End Function
```

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Use of Mean Function

- Mean function shown on previous slide must be called from other VBA code
  - Cannot be called from worksheet
  - Example of VBA code that calls mean

```
Dim x(1 To 10) As Double
For k = 1 To 10
  x(k) = rnd()   'Random number
Next k
msgBox "Mean = " & mean(x)
```

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