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The following presentation contains examples of advanced 4Test coding techniques I developed while contracting at Merrill Lynch in New York City. The presentation focuses on real-world examples of how these advanced techniques can be used to simplify 4Test code and to improve test script readability, maintainability and reliability.

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QUEST2001

Advanced 4Test Coding Techniques: Recursion, Threads and Critical Sections

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Objectives



- Become familiar with Recursion, Threads, Semaphores, Critical Resources and Critical Sections
- Learn how to apply these advanced techniques to enhance your test scripts
 - Simplify Code
 - Improve Readability and Maintainability
 - Improve Script Reliability

Recursion



➤ Mathematics

$$- 5! = 5 \times 4!$$

$$5 \times 4 \times 3!$$

$$5 \times 4 \times 3 \times 2!$$

$$5 \times 4 \times 3 \times 2 \times 1!$$

$$\text{FACT}(N) = N * \text{FACT}(N-1)$$

Recursion



➤ Acronyms

– GNU: GNU's Not UNIX

➤ Algorithms

– Binary Trees

➤ Puzzles

– “Tower of Brahma”

Recursive Procedures

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➤ Definition

- A recursive procedure is one that calls itself from within the procedure body
- A recursive call creates a second activation of the procedure, *during the lifetime of the first activation*

Recursive Procedures



➤ Advantages

- Permits more lucid and concise descriptions of algorithms
- Recursive procedures are generally easier to understand

Example 1: Problem



- Test data maintained in an Excel spreadsheet
- Data is saved as CSV file for test execution
- Spreadsheet contains field identifiers, 4Test object names, and one or more rows of input values

Example 1: Problem



- 4Test object names are atomic
 - For example, HtmlTextField5, HtmlPopupList1, etc.
- Object hierarchy is determined at runtime

Example 1: Solution



- **GetObjectHierarchy** function
 - Calls WindowChildren function
 - Loops through list of window children
 - Calls itself (recursion) when window class is BrowserChild or ExtendedBrowserChild

Example 1: Code



```
[+] void GetObjectHierarchy (WINDOW wMain, STRING sWin, out WINDOW wWinFound)
    [] INTEGER i
    [] WINDOW w
    [] LIST OF WINDOW lwChildren
    []
    [] ResOpenList (">> Function::dtcc_GetObjectHierarchy ({wMain}, {sWin}, {wWinFound})")
    []
    [] lwChildren = WindowChildren (wMain)
    [-] for each w in lwChildren
        [-] if (WindowIsDefined (w, sWin))
            [] wWinFound = w.@sWin
            [] Print ("FOUND IT!")
            [] break
        [-] else
            [-] if (ClassOf (w) == @"BrowserChild" || ClassOf (w) ==
                @"ExtendedBrowserChild")
                [] GetObjectHierarchy (w, sWin, wWinFound)
```

Example 1: Window Declaration



```
[+] window Product_Generic MunicipalTrade
  [] parent Browser
  [+] BrowserChild Top
    [+] BrowserChild Branding
      [+] HtmlImage HtmlImage1
      [+] HtmlImage HtmlImage2
    [+] BrowserChild ProdImage
      [+] HtmlImage HtmlImage1
      [+] HtmlHeading MunicipalTrade
  [-] BrowserChild Main
    [+] BrowserChild Top
    [+] BrowserChild TRANSFERINFORMATION
    [-] BrowserChild Bottom
      [+] HtmlPushButton BACK
      [+] HtmlPushButton Submit
      [+] HtmlPushButton Reset
```

Example 1: Results Log



```
>> Function::GetObjectHierarchy (MunicipalTrade, Reset, MunicipalTrade)
  >> Function::GetObjectHierarchy (MunicipalTrade.Top, Reset, MunicipalTrade)
    >> Function::GetObjectHierarchy (MunicipalTrade.Top.Branding, Reset, MunicipalTrade)
      << Function::GetObjectHierarchy
    >> Function::GetObjectHierarchy (MunicipalTrade.Top.ProdImage, Reset, MunicipalTrade)
      << Function::GetObjectHierarchy
    << Function::GetObjectHierarchy
  >> Function::GetObjectHierarchy (MunicipalTrade.Main, Reset, MunicipalTrade)
    >> Function::GetObjectHierarchy (MunicipalTrade.Main.Top, Reset, MunicipalTrade)
      << Function::GetObjectHierarchy
    >> Function::GetObjectHierarchy (MunicipalTrade.Main.TRANSFERINFORMATION, Reset,
      MunicipalTrade)
      << Function::GetObjectHierarchy
  FOUND IT!
  << Function::GetObjectHierarchy
```

Example 1: Results Log



```
>> Function::GetObjectHierarchy (MunicipalTrade.Main_frame, Reset,  
    MunicipalTrade.Main.Bottom.Reset)  
    << Function::GetObjectHierarchy  
    >> Function::GetObjectHierarchy (MunicipalTrade.Top_frame, Reset,  
        MunicipalTrade.Main.Bottom.Reset)  
        >> Function::GetObjectHierarchy (MunicipalTrade.Top_frame.Branding, Reset,  
            MunicipalTrade.Main.Bottom.Reset)  
            << Function::GetObjectHierarchy  
            >> Function::GetObjectHierarchy (MunicipalTrade.Top_frame.ProdImage, Reset,  
                MunicipalTrade.Main.Bottom.Reset)  
                << Function::GetObjectHierarchy  
                >> Function::GetObjectHierarchy (MunicipalTrade.Top_frame.Menubar, Reset,  
                    MunicipalTrade.Main.Bottom.Reset)  
                    << Function::GetObjectHierarchy  
                    << Function::GetObjectHierarchy  
                    << Function::GetObjectHierarchy  
Window is 'MunicipalTrade.Main.Bottom.Reset'
```

Example 2: Code



```
[_] WINDOW GetObjectHierarchy (WINDOW wMain, STRING sWin)
  [] INTEGER i
  [] WINDOW w
  [] WINDOW wWinFound = NULL
  [] LIST OF WINDOW lwChildren
  []
  [] ResOpenList (">> Function::dtcc_GetObjectHierarchy ({wMain}, {sWin})")
  []
  [] lwChildren = WindowChildren (wMain)
  []
  [-] for each w in lwChildren
    [-] if (WindowIsDefined (w, sWin))
      [] wWinFound = w.@sWin
      [] Print ("FOUND IT!")
      [] break
```

Example 2: Code



```
[ ] else
    [ ] if (ClassOf (w) == @"BrowserChild" || ClassOf (w) ==
           @"ExtendedBrowserChild")
        [ ] if (wWinFound == NULL)
            [ ] GetObjectHierarchy (w, sWin, wWinFound)
[ ]
[ ] Print ("<< Function::dtcc_GetObjectHierarchy")
[ ] ResCloseList ()
[ ]
[ ] return (wWinFound)
```


Example 2: Results Log



```
[ ] >> Function::GetObjectHierarchy (MunicipalTrade, Reset)
  [ ] >> Function::GetObjectHierarchy (MunicipalTrade.Top, Reset)
    [ ] >> Function::GetObjectHierarchy (MunicipalTrade.Top.Branding, Reset)
      [ ] << Function::GetObjectHierarchy
    [ ] >> Function::GetObjectHierarchy (MunicipalTrade.Top.ProdImage, Reset)
      [ ] << Function::GetObjectHierarchy
    [ ] << Function::GetObjectHierarchy
  [ ] >> Function::GetObjectHierarchy (MunicipalTrade.Main, Reset)
    [ ] >> Function::GetObjectHierarchy (MunicipalTrade.Main.Top, Reset)
      [ ] << Function::GetObjectHierarchy
    [ ] >> Function::GetObjectHierarchy (MunicipalTrade.Main.TRANSFERINFORMATION, Reset)
      [ ] << Function::GetObjectHierarchy
    [ ] FOUND IT!
      [ ] << Function::GetObjectHierarchy
    [ ] << Function::GetObjectHierarchy
  [ ] MunicipalTrade.Main.Bottom.Reset
```

Example 3: Problem



- Browser application prompts for Certificate selection within a DialogBox
- DialogBox is modal, SysMenu is disabled
- Must dismiss using Cancel or Finish PushButtons

Example 3: Problem



- PushButtons are NOT first-level descendents of the parent window
 - (Default recovery system will not close these windows)

Example 3: Solution



- **CloseObstinateWindow** function
 - Calls `GetChildren` function
 - Loops through list of window children
 - Issue recursive call when window class is `BrowserChild`

Example 3: Solution



- Appends each PushButton found in an lwPushButton variable
- Clicks the appropriate PushButton in lwPushButton

Example 3: Code



```
[_] void CloseObstinateWindow (WINDOW wOW)
  [] LIST OF WINDOW lwChildren
  [] LIST OF WINDOW lwGrandChildren
  [] LIST OF WINDOW lwPushButton
  [] LIST OF WINDOW lwBrowserChild
  [] WINDOW w
  []
  [] ResOpenList (">> Function::CloseObstinateWindow ({wOW})")
  []
  [] lwChildren = wOW.GetChildren ()
  [] wOW.SetActive ()
  [-] for each w in lwChildren
    [-] if (w.Exists ())
      [-] if (w.GetClass () == BrowserChild)
        [] CloseObstinateWindow (w)
      [-] else
        [-] // call another function
```

Example 3: Code



```
[ - ] if (ListCount (lwPushButton) > 0)
    [ - ] for each w in lwPushButton
        [ - ] if (w.Exists ())
            [ - ] if (w.GetCaption () == "Continue" || w.GetCaption () == "Finish")
                [ ] Print ("*--> Continuing window...")
            [ - ] else
                [ - ] if (w.GetCaption () == "Cancel" || w.GetCaption () ==
                    "No" || w.GetCaption () == "OK")
                    [ ] Print ("*--> Dismissing window...")
                [ ] w.Click ()
                [ ] break
        [ ]
    [ ] Print ("<< Function::CloseObstinateWindow")
    [ ] ResCloseList ()
```

Recursion: Summary



- Recursion is a way of expressing a solution to a problem
- Use out or inout function arguments to return values
- Be careful to terminate recursive procedures when using the return statement

Concurrent Coding Techniques

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- Show how to spawn threads in 4Test
 - parallel or spawn/rendezvous statements
- Demonstrate use of semaphores
- Examine situations where mutual exclusion can be used
 - critical statement

Threads



- “Basic unit of computation,” or “a unit of execution”
- A.K.A. process, program, or “task”

Threads



➤ Windows NT context

– “Process is the dynamic invocation of a program along with the system resources required for the program to run”

- Code, data, address space, system resources, at least one *thread of execution*

Threads



➤ Concepts

- A thread is an entity within a process that is scheduled for execution
- Time slicing is used to share the processor among all active threads
- Thread's context consists of processor state, stacks, and private storage area for use by subsystems, RT libraries and DLLs

Threads



➤ Shared Resources

– Critical Resource

- A resource that can only be accessed by one user (thread) at a time

– Critical Section

- A Code region that accesses a critical resource

Threads



➤ Synchronization Techniques

– Semaphore

- The semaphore is a facility that allows threads to block and unblock each other
- Integer variable whose value can only be altered by operations P and V
 - P and V implemented as Acquire and Release in 4Test

Threads



- Binary Semaphore is a semaphore whose maximum value is 1
 - Defined in 4Test using the SEMAPHORE data type
 - » `SEMAPHORE sem1 = 1`

Threads



➤ Mutual exclusion

– A facility which when invoked, prevents any other operation (thread) from executing between the initiation and termination of the invocation

- Implemented in 4Test by critical statement

Example 4: Problem



- Parallel, distributed environment
- A `mach_state.txt` file, resides on the host machine
 - machine name, application name, server, entity, database, current user, current trade info, clearcase view info

Example 4: Problem



- All test scripts running in parallel modify this file at runtime
- File is a critical resource
- Use semaphore to block and unblock threads which execute the block of code which accesses the critical resource (file)

Example 4: Code



```
[+] void MachineConfig_Update (STRING sMachine, MachineAttribute Attr, STRING sNewVal)
    [] //
    [] // Variables and initialization code
    [] //
    [] Acquire (sem1)
    [+] do
        [] HFILE hFile = FileOpen (sTxtFile, FM_READ)
        [] HFILE hNewFile = FileOpen (sNewFile, FM_WRITE)
        []
        [+] while (FileReadLine (hFile, sLine))
            [+] if (GetField (sLine, ",", [INTEGER] MACH) == sMachine)
                [] switch Attr
                []
                [] // case statements
                []
```

Example 4: Code



```
        [] sNewLine = Stuff (sLine, StrPos (GetField (sLine, ",", iPos), sLine),
                               Len (GetField (sLine, ",", iPos)), sNewVal)

    [+] else
        [] sNewLine = sLine
        []
        [] FileWriteLine (hNewFile, sNewLine)
        []
    [] FileClose (hNewFile)
    [] FileClose (hFile)
    []
    [] LocalMachine->SYS_RemoveFile (sTxtFile)
    [] LocalMachine->SYS_CopyFile (sNewFile, sTxtFile)
    [] LocalMachine->SYS_RemoveFile (sNewFile)

[+] except
    [] ExceptPrint ()
    [] LogError ("")

[] Release (sem1)
```

Example 5: Problem



- SUT allows users to login based on a geographical region or entity
- SUT may prompt user with an Entity selection, warning message, password expiration DialogBox or some combination of these

Example 5: Solution



- Spawn two threads
 - Handle Entity Selection
 - Handle Warning and Password Expiration
- Use critical blocks to prevent interleaving
- Timer is used to limit each thread's execution time

Example 5: Code



```
[+] BOOLEAN LoginWithEnt (STRING sUserName, STRING sPassword, STRING sServerName, STRING
                           sEntity, BOOLEAN bShadowEntity optional)

[] Login.Click ()
[] HTIMER hWaitTime = TimerCreate ()
[] TimerStart (hWaitTime)
[]
[+] parallel
    [-] while (TRUE)
        [+] if (EntityDialog_popup.Exists ())
            [+] critical
                [] EntityDialog_popup.Text.TypeKeys (sEntity)
                [] EntityDialog_popup.OK.Click ()
            [] break
        [+] else
            [+] if (TimerValue (hWaitTime) > 30.0)
                [] break
```

Example 5: Code



```
[+] while (TRUE)
    [-] if (Launcher_Question.Exists ())
        [-] if (Launcher_Question.Warning.Exists ())
            [+] critical
                [] HTML_LogWarning (“...”)
                [] Launcher_Question.No.Click ()
            [] break
        [-] else
            [-] if (Launcher_Question.YourPassword.Exists ())
                [-] critical
                    [] Launcher_Question.Yes.Click()
            [] break
    [+] else
        [+] if (TimerValue (hWaitTime) > 30.0)
            [] break
```


Example 6: Problem



- Need to synchronize two events prior to continuing an application's End of Day processing
 - Detect and dismiss an error message
 - Detect when End of Day DialogBox exists

Example 6: Code

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```
[+] parallel
```

```
    [+] if (InfoMessage.Message.Exists (90))
```

```
        [] HTML_LogError (InfoMessage.Message.GetText ())
```

```
        [] InfoMessage.Dismiss.Click ()
```

```
        []
```

```
    [+] while (! this.DialogBox ("Reconciliation").Exists (90))
```

```
        [] sleep (1)
```

SetTrap Alternative



➤ Design

- Use multitestcase to spawn two threads: a function and testcase
- Define a global variable to trigger function
- Set the variable in an appstate
- Reset the variable in TestcaseExit

SetTrap Alternative



➤ Observations

- Extend capability without replacing method
- Must execute continuously
- Script runs noticeably slower
- Code belongs in a critical block
- Can't spawn a thread from a critical block

Concurrency: Summary



- Threads can be spawned as statements, functions or testcases
- Semaphores are used to control access to critical resources
- Mutual exclusion is used to protect “sensitive” areas of code or to minimize interleaving

References



➤ Recursion

- Lorentz, Richard, *Recursive Algorithms*, Ablex, Norwood, New Jersey, 1994.
- Roberts, Eric S., *Thinking Recursively*, John Wiley, New York, 1986.

References



➤ Threads

- Custer, Helen, *Inside Windows NT*, Microsoft Press, Redmond, Washington, 1993.
- Tsichritzis, Dionysios, C. and Bernstein, Philip A., *Operating Systems*, Academic Press, New York, 1974.

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