CSCE 747 Software Testing and Quality Assurance

Lecture 10 – Integration Testing

Last Time

- Integration & System Testing Part III
- Levels of Testing Ch 12, pp 181-199

Today

- Integration & System Testing Part III
- Integration Testing Ch 13, pp 201-227

Table 13.1 SATM Units

Table 13.1 SATM Units and Abbreviated Names

Unit Number	*Level Number*	*Unit Name*
1	1	SATM System
A	1.1	Device Sense & Control
D	1.1.1	Door Sense & Control
2	1.1.1.1	Get Door Status
3	1.1.1.2	Control Door
4	1.1.1.3	Dispense Cash
E	1.1.2	Slot Sense & Control
5	1.1.2.1	WatchCardSlot
6	1.1.2.2	Get Deposit Slot Status
7	1.1.2.3	Control Card Roller
8	1.1.2.4	Control Envelope Roller
9	1.1.2.5	Read Card Strip
10	1.2	Central Bank Comm.
11	1.2.1	Get PIN for PAN
12	1.2.2	Get Account Status
13	1.2.3	Post Daily Transactions
B	1.3	Terminal Sense & Control
14	1.3.1	Screen Driver
15	1.3.2	Key Sensor
C	1.4	Manage Session
16	1.4.1	Validate Card
17	1.4.2	Validate PIN
18	1.4.2.1	GetPIN
F	1.4.3	Close Session
19	1.4.3.1	New Transaction Request
20	1.4.3.2	Print Receipt
21	1.4.3.3	Post Transaction Local
22	1.4.4	Manage Transaction
23	1.4.4.1	Get Transaction Type
24	1.4.4.2	Get Account Type
25	1.4.4.3	Report Balance
26	1.4.4.4	Process Deposit
27	1.4.4.5	Process Withdrawal

SATM Functional Decomposition

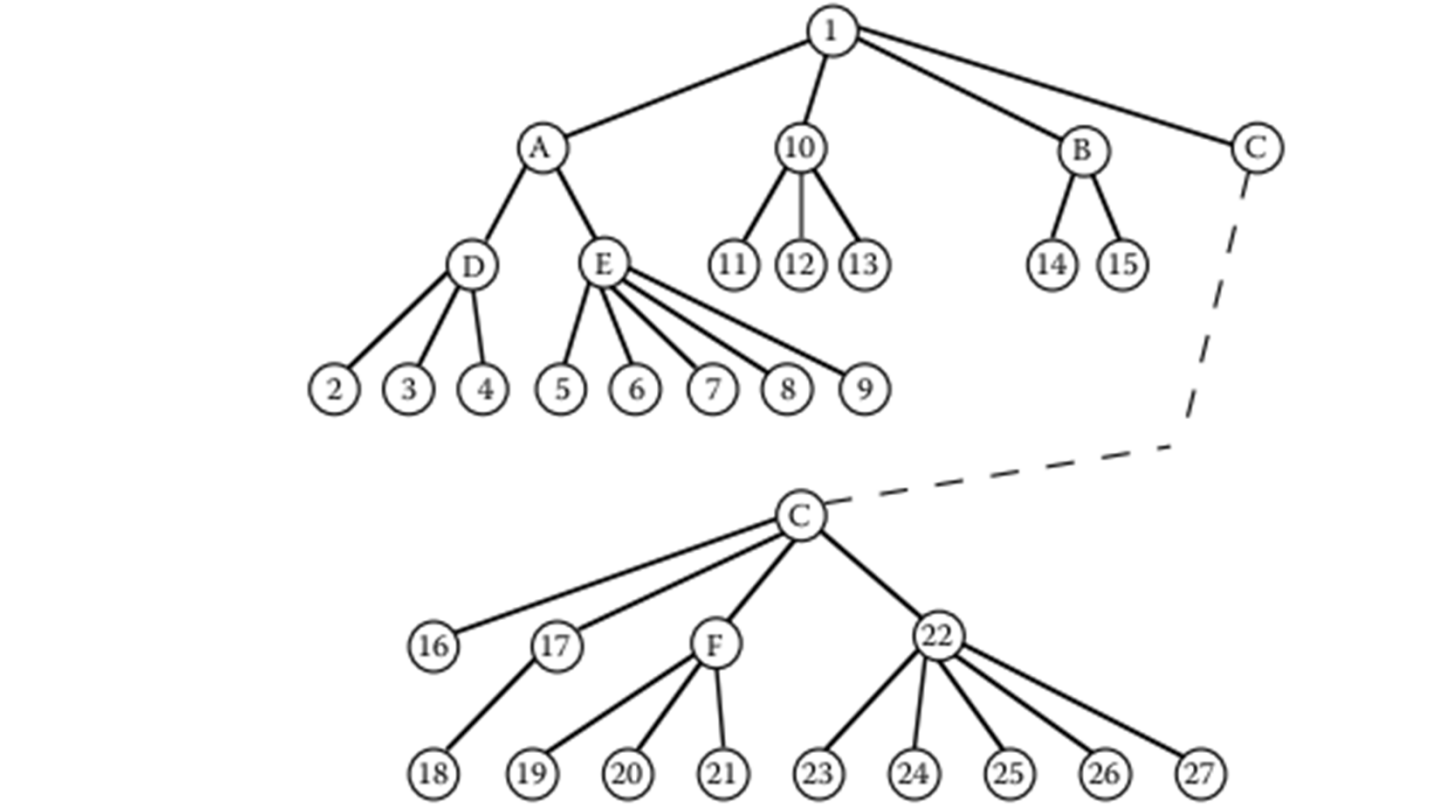
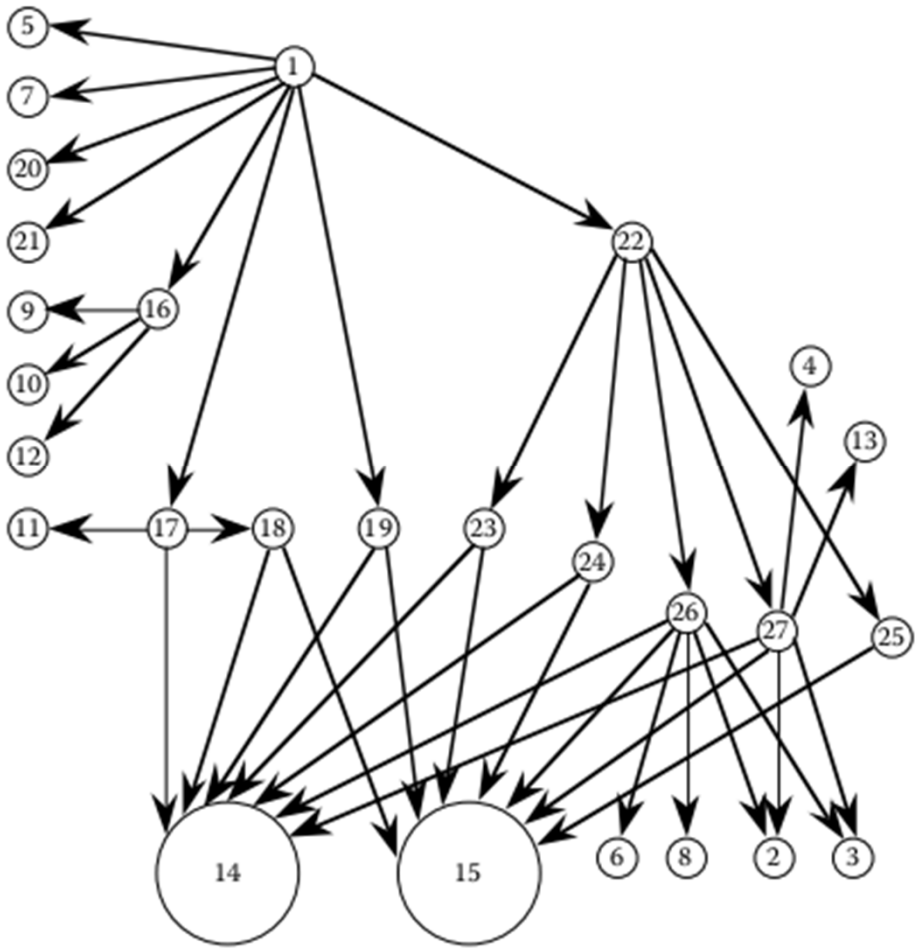


Figure 13.1 SATM functional decomposition tree.

Table 13.2 Adjacency Matrix for the SATM Call Graph

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1				X		X									X	X		X	X	X	X					
2																										
3																										
4																										
5																										
6																										
7																										
8																										
9																										
10																										
11																										
12																										
13																										
14																										
15																										
16								X	X		X															
17										X			X				X									
18													X	X												
19													X	X												
20																										
21																										
22																						X	X	X	X	X
23													X	X												
24													X	X												
25														X												
26	X	X			X		X						X	X												
27	X	X	X		X		X					X	X	X												

SATM Call Graph



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Stubs for Top Down Integration

```
Procedure GetPINforPAN(PAN, ExpectedPIN) STUB
If PAN = '1123' Then ExpectedPIN = '8876'
If PAN = '1234' Then ExpectedPIN = '8765'
If PAN = '8746' Then ExpectedPIN = '1253'
End

Procedure KeySensor(KeyHit) STUB
data: KeyStrokes STACK OF '8'. '8', '7', 'cancel'
KeyHit = POP (KeyStrokes)
End
```

Figure 13.3 Top-down Integration

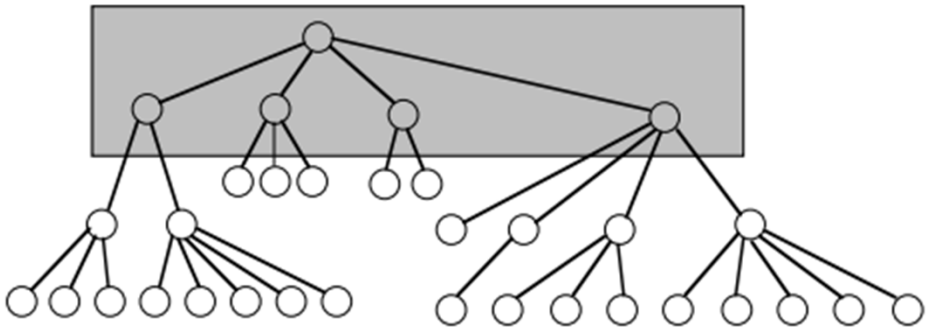


Figure 13.3 Top-down Integration

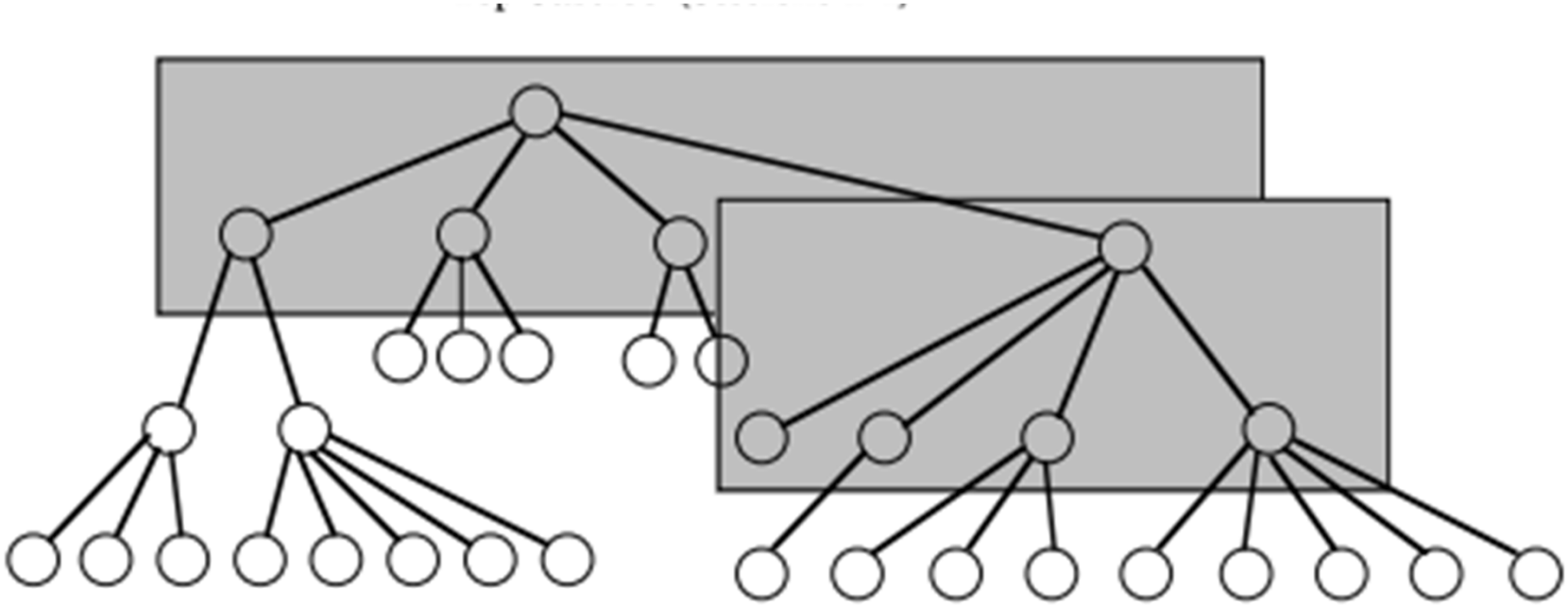
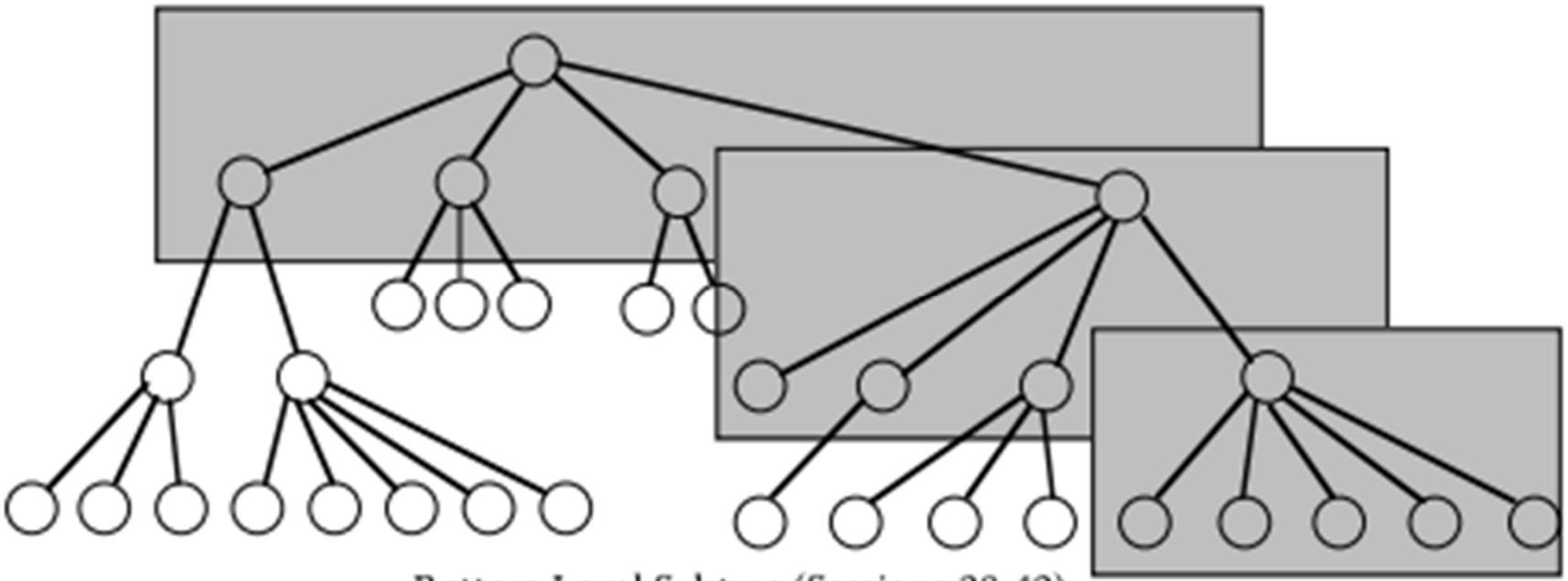
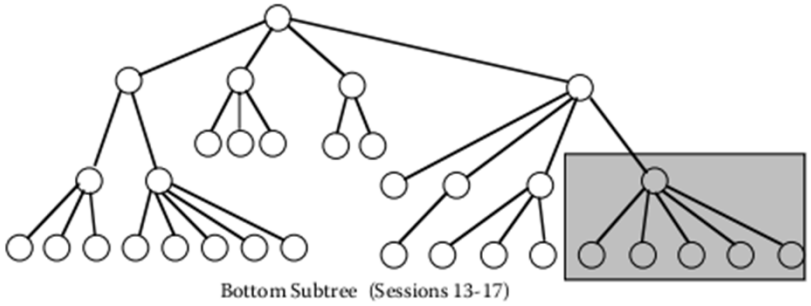
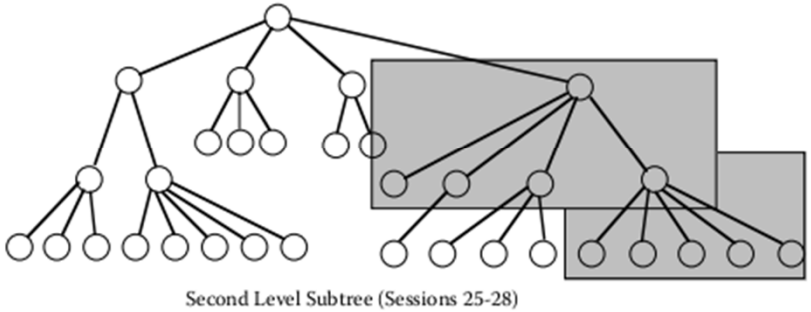


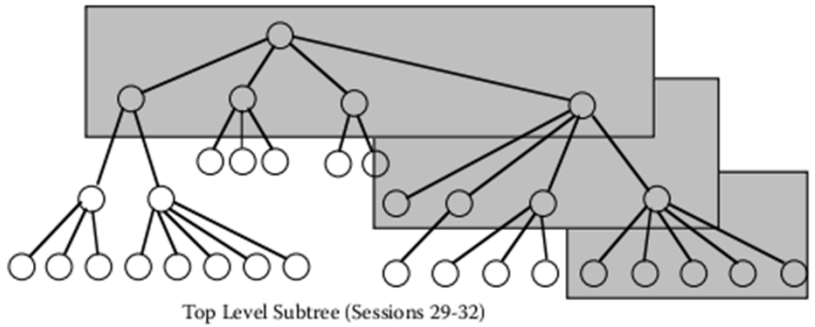
Figure 13.3 Top-down Integration



Bottom-Up Integration







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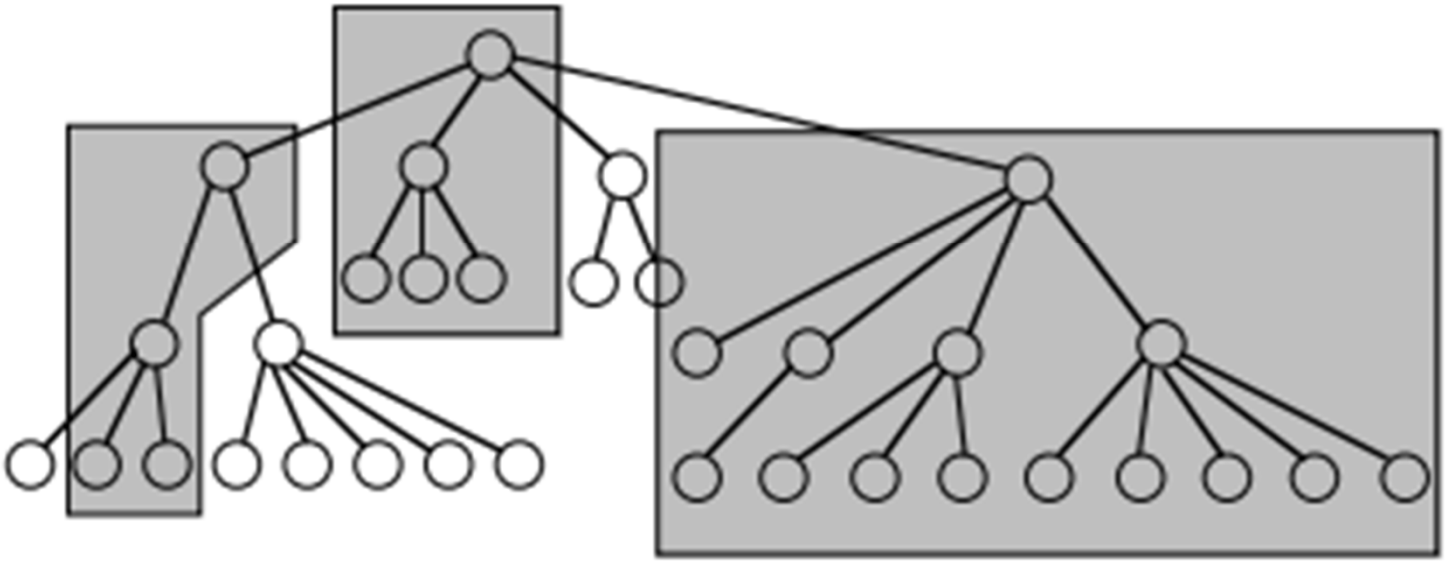
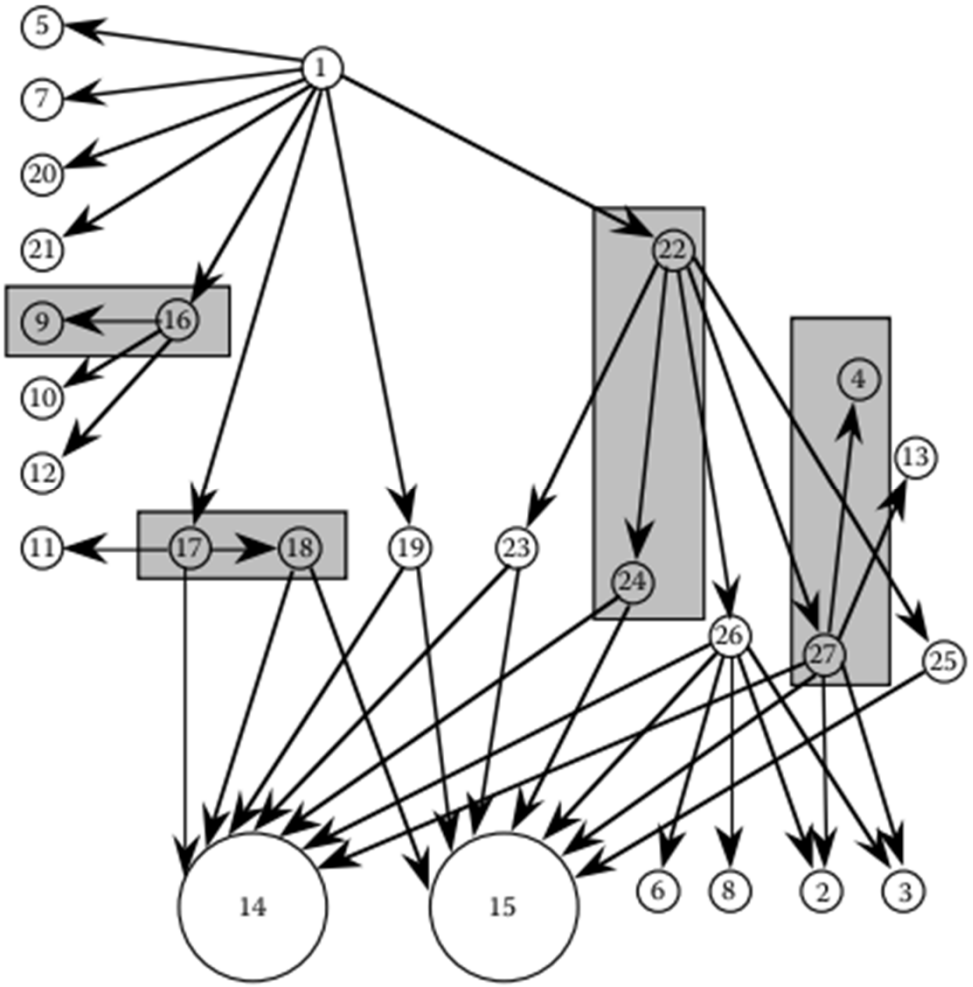
Sandwich Integration

- John Montagu, 4th Earl of Sandwich



Call Based Graph Integration

- Pairwise integration
- Neighborhood integration
  - InteriorNodes = nodes – sources – sinks
  - Neighborhoods
    - Interior+source node



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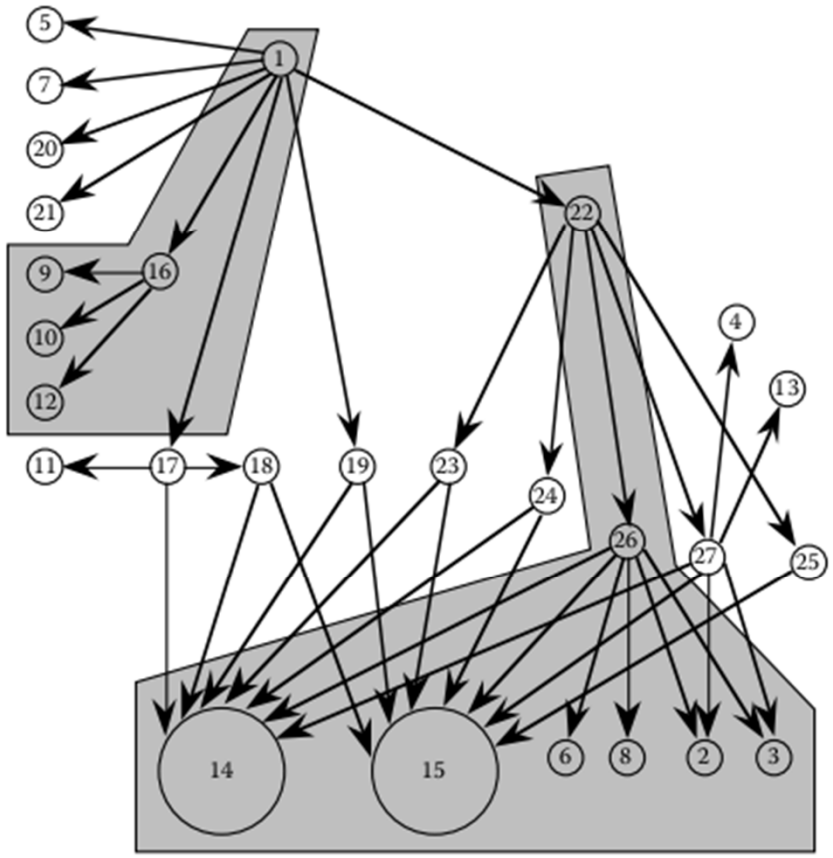
Neighborhood Integration

Table 13.3 SATM Neighborhoods

Node	Predecessors	Successors
16	1	9, 10, 12
17	1	11, 14, 18
18	17	14, 15
19	1	14, 15
23	22	14, 15
24	22	14, 15
26	22	14, 15, 6, 8, 2, 3
27	22	14, 15, 2, 3, 4, 13
25	22	15
22	1	23, 24, 26, 27, 25
1	n/a	5, 7, 2, 21, 16, 17, 19, 22



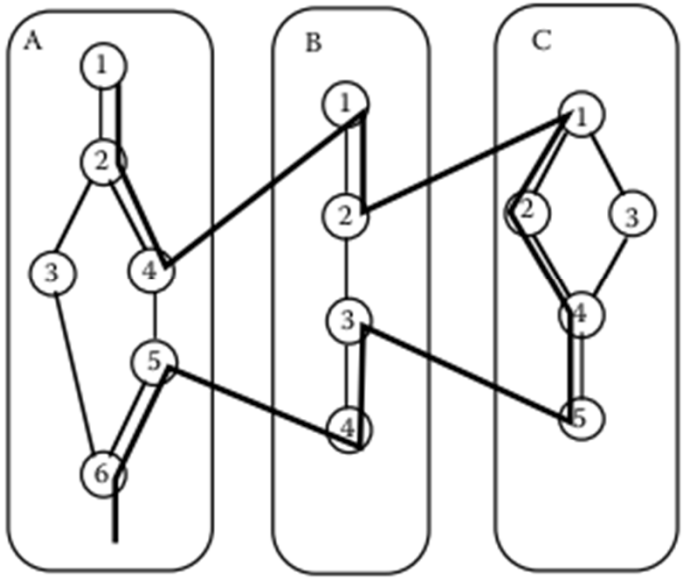
Path Based Integration

New and Extended Concepts

- Definition: A **source node** in a program is a statement at which program execution begins or resumes.
- Definition: A **sink node** in a program is a statement at which program execution stops.
- Definition: A **module execution path** is a sequence of statements that begins with a source node and ends with a sink node, with no intervening sink nodes.

- **Definition: A message is a programming language mechanism by which one unit transfers control to another unit.**
- **Definition: An MM-Path is an interleaved sequence of module execution paths and messages.**

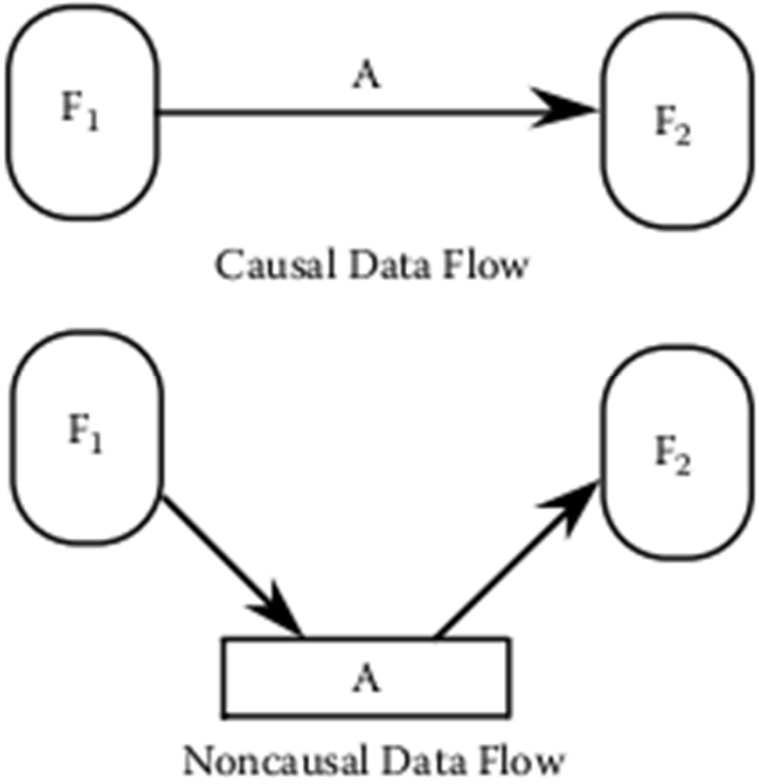
Fig 13.8 MM-Paths across three Units



MEP(A,1) = <1, 2, 3, 6>
MEP(A,2) = <1, 2, 4>
MEP(A,3) = <5, 6>
MEP(B,1) = <1, 2>
MEP(B,2) = <3, 4>
MEP(C,1) = <1, 2, 4, 5>
MEP(C,2) = <1, 3, 4, 5>

- **Definition: Given a set of units, their MM-Path graph is the directed graph in which nodes are module execution paths and edges correspond to messages and returns from one unit to another.**

Figure 13.10 Data Quiescence



SATM code

```
1.  Main Program
2.  State = AwaitCard
3.  Do              'Main loop
4.  Case State
5.    Case 1:     AwaitCard
6.                ScreenDriver(1, null)                    msg1
7.                WatchCardSlot(CardSlotStatus)            msg2
8.                Do While CardSlotStatus is Idle
9.                     WatchCardSlot(CardSlotStatus)       msg3
10.               End While
11.               ControlCardRoller(accept)                msg4
12.               ValidateCard(CardOK, PAN)                msg5
13.               If CardOK
14.                    Then State = AwaitPIN
15.                    Else ControlCardRoller(eject)       msg6
16.               EndIf
17.               State = AwaitCard
18.   Case 2: AwaitPIN
19.               ValidatePIN(PINok, PAN)                  msg7
```

```
20.              If PINok
21.                   Then ScreenDriver(2, null)          msg8
22.                        State = AwaitTrans
23.                   ElseScreenDriver(4, null)           msg9
24.                        State = AwaitCard
25.              EndIf
26.   Case 3: AwaitTrans
27.              ManageTransaction                        msg10
28.              State = CloseSession
29.   Case 4: CloseSession
30.              If NewTransactionRequest
31.                   Then State = AwaitTrans
32.                   ElsePrintReceipt                    msg11
33.              EndIf
34.              PostTransactionLocal                     msg12
35.              CloseSession                             msg13
36.              ControlCardRoller(eject)                 msg14
37.              State = AwaitCard
38. End Case (State)
39. Until 'Forever
```

```
40. End. (Main program SATM)
41. Procedure ValidatePIN(PINok, PAN)
42. GetPINforPAN(PAN, ExpectedPIN)                          msg15
43. Try = First
44. Case Try of
45.   Case 1: First
46.         ScreenDriver(2, null)                           msg16
47.         GetPIN(EnteredPIN, CancelHit)                   msg17
48.         If EnteredPIN = ExpectedPIN
49.               Then PINok = True
50.               Else ScreenDriver(3, null)                msg18
51.                     Try = Second
52.               EndIf
53.         Case 2: Second
54.               ScreenDriver(2, null)                     msg19
55.               GetPIN(EnteredPIN,CancelHit)              msg20
56.               If EnteredPIN = ExpectedPIN
57.                     Then PINok = True
58.                     Else ScreenDriver(3, null)          msg21
59.               EndIf
60.               Try = Third
```

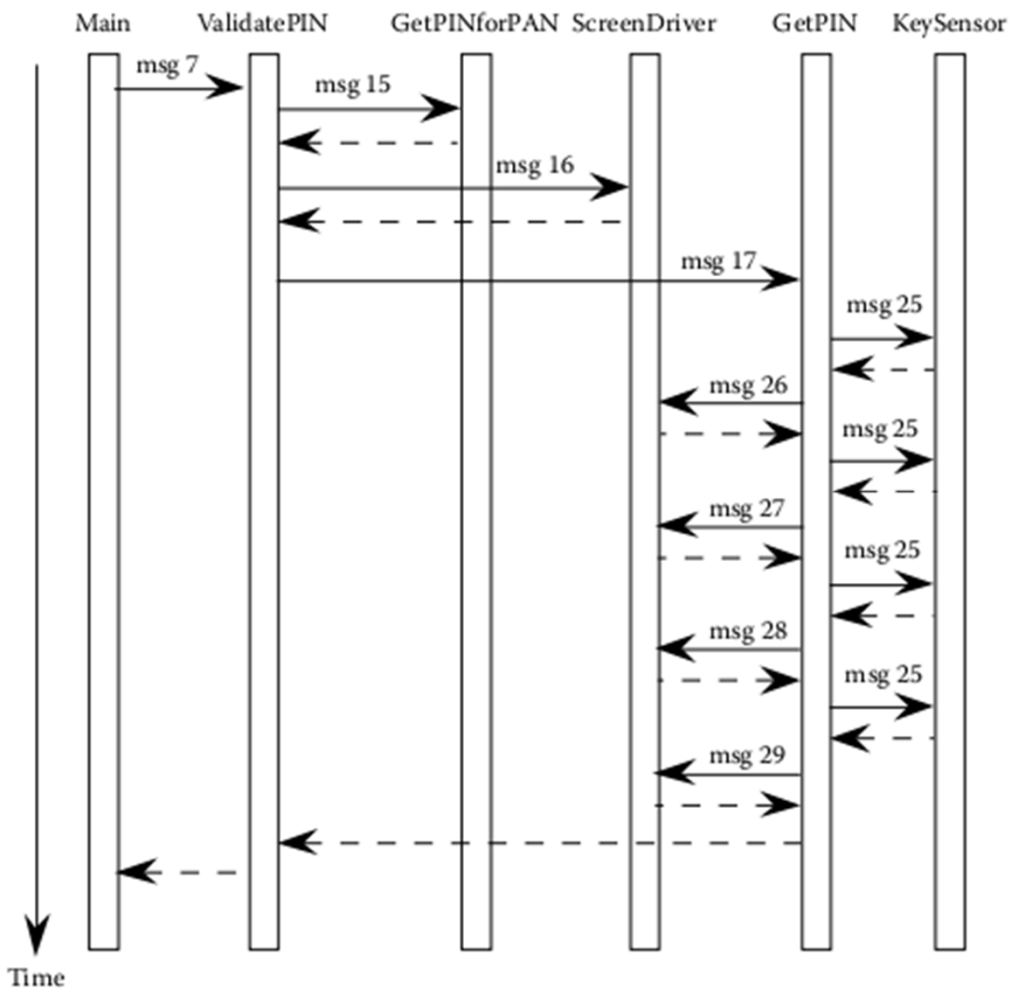
```
60.                Try = Third
61.          Case 3: Third
62.                ScreenDriver(2, null)                    msg22
63.                GetPIN(EnteredPIN, CancelHit)            msg23
64.                If EnteredPIN = ExpectedPIN
65.                      Then PINok = True
66.                      Else  ScreenDriver(4, null)        msg24
67.                            PINok = False
68.                EndIf
69.    EndCase (Try)
70.    End.          (Procedure ValidatePIN)


71.    Procedure GetPIN(EnteredPIN, CancelHit)
72.    Local Data: DigitKeys = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
73.    CancelHit = False
74.    EnteredPIN = null string
75.    digitsRcvd=0
76.    Do While NOT(DigitsRcvd=4 OR CancelHit)
77.          KeySensor(KeyHit)msg25
78.          If KeyHit IN DigitKeys
79.                Then
80.                      EnteredPIN = EnteredPIN + KeyHit
81.                      digitsRcvd = digitsRcvd + 1
82.                      If digitsRcvd = 1
83.                        Then ScreenDirver (2, 'X---')   msg26
84.                      EndIf
```

```
85.                    If digitsRcvd = 2
86.                      Then ScreenDirver (2, 'XX--')    msg27
87.                    EndIf
88.                    If digitsRcvd = 3
89.                       Then ScreenDirver (2, 'XXX-')  msg28
90.                    EndIf
91.                    If digitsRcvd = 4
92.                      Then ScreenDirver (2, 'XXXX')   msg29
93.                    EndIf
94.              Else
95.                    CancelHit = True
96.         EndIf
97.   End While
98.   End.  (Procedure GetPIN)
```

```
Main (1, 2, 3, 18, 19)
msg 7
ValidatePIN (41, 42)
msg 15
GetPINforPAN (no pseudo-code given)
ValidatePIN (43, 44, 45, 46)
msg 16
ScreenDriver (no pseudo-code given)
ValidatePIN (47)
msg 17
GetPIN(71, 72, 73, 74, 75, 76, 77)
msg 25
KeySensor (no pseudo-code given)   'first digit
GetPIN (78, 79, 80, 81, 82, 83)
msg 26
ScreenDriver (no pseudo-code given)
GetPIN (84, 85, 87, 88, 90, 91, 93, 96, 97, 76, 77)
```

```
msg 25
KeySensor (no pseudo-code given) )       'second digit
GetPIN (78, 79, 80, 81, 82, 84, 85, 86)
msg 27
ScreenDriver (no pseudo-code given)
GetPIN (87, 88, 90, 91, 93, 96, 97, 76, 77)
msg 25
KeySensor (no pseudo-code given) )       'third digit
GetPIN (78, 79, 80, 81, 82, 84, 85, 87, 88, 89)
msg 28
ScreenDriver (no pseudo-code given)
GetPIN (90, 91, 93, 96, 97, 76, 77)
msg 25
KeySensor (no pseudo-code given) )       'fourth digit
GetPIN (78, 79, 80, 81, 82, 84, 85, 87, 88, 90, 91, 92)
msg 29
ScreenDriver (no pseudo-code given)
GetPIN (93, 96, 97, 76, 98)
ValidatePIN (48, 49, 52, 69, 70)
Main(20)
```

UML Sequence Diagram a sample MM-Path



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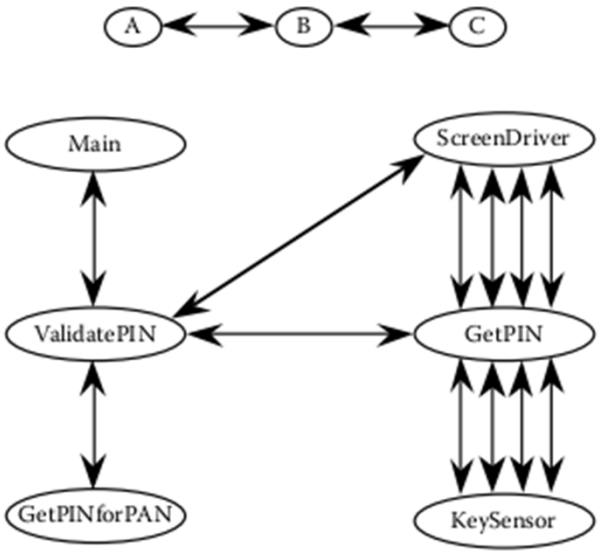
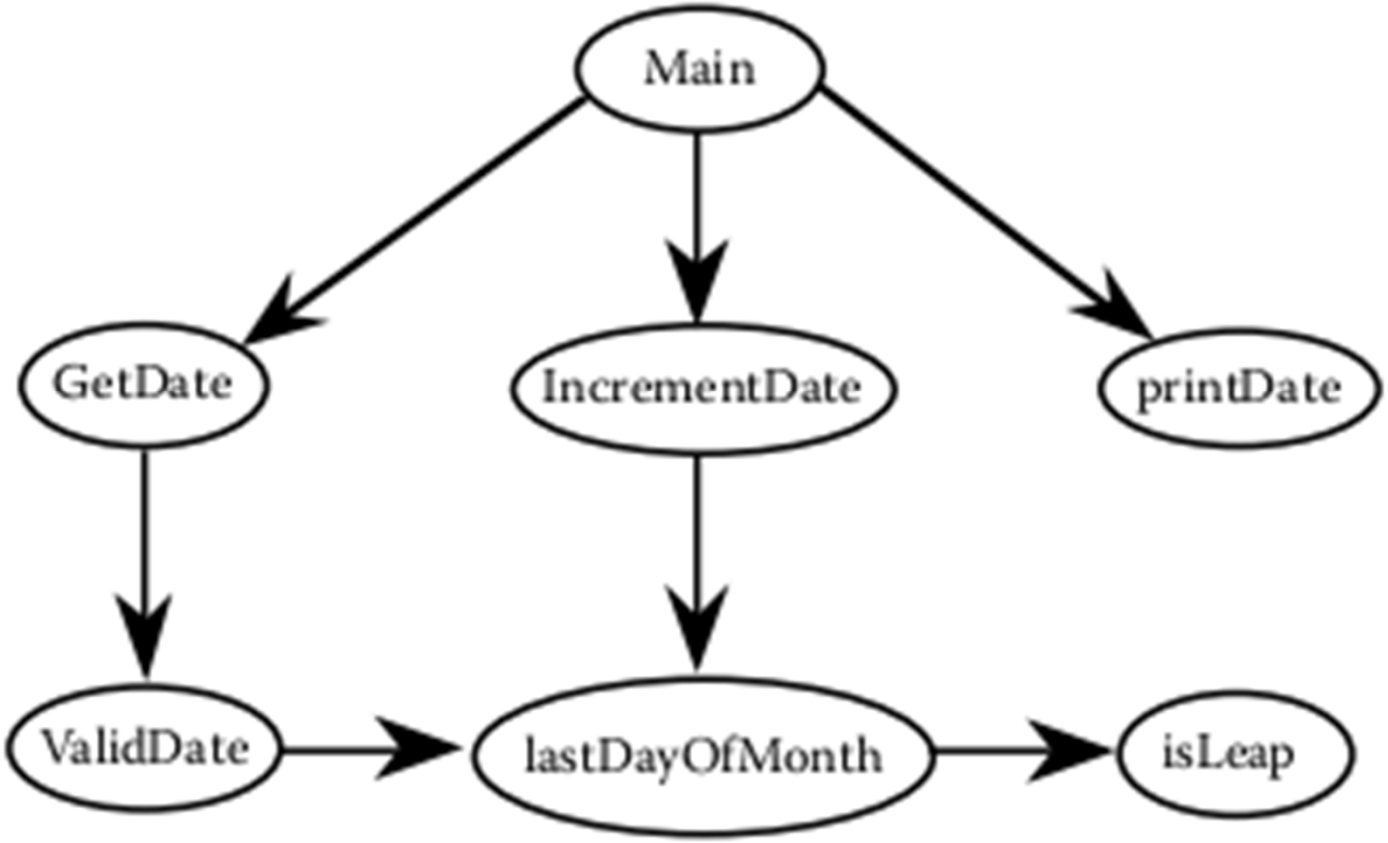
MM-Path directed graphs



Call Graph of "Integration" Version



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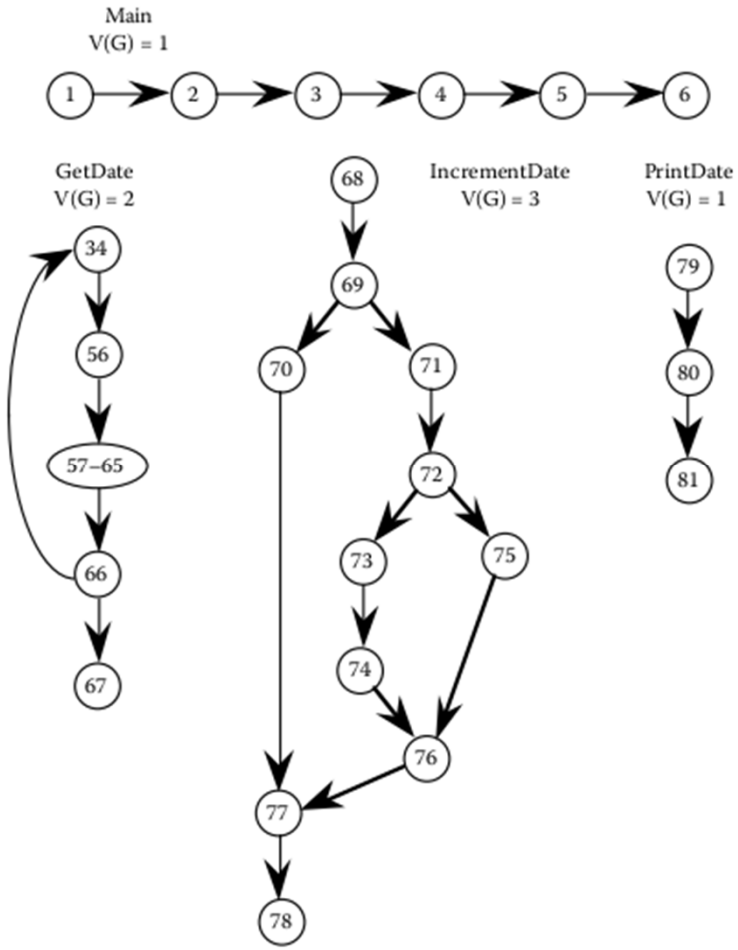
SATM Integration Version

- **Function**
  - **isLeapYear(year)**
  - **lastDayOfMonth( )**
  - **getDate()**



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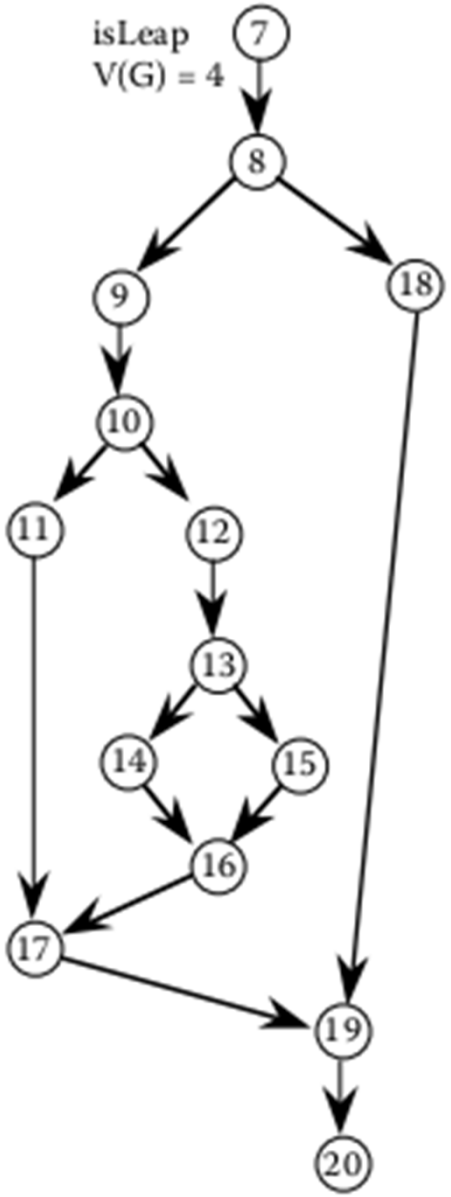
isLeap()



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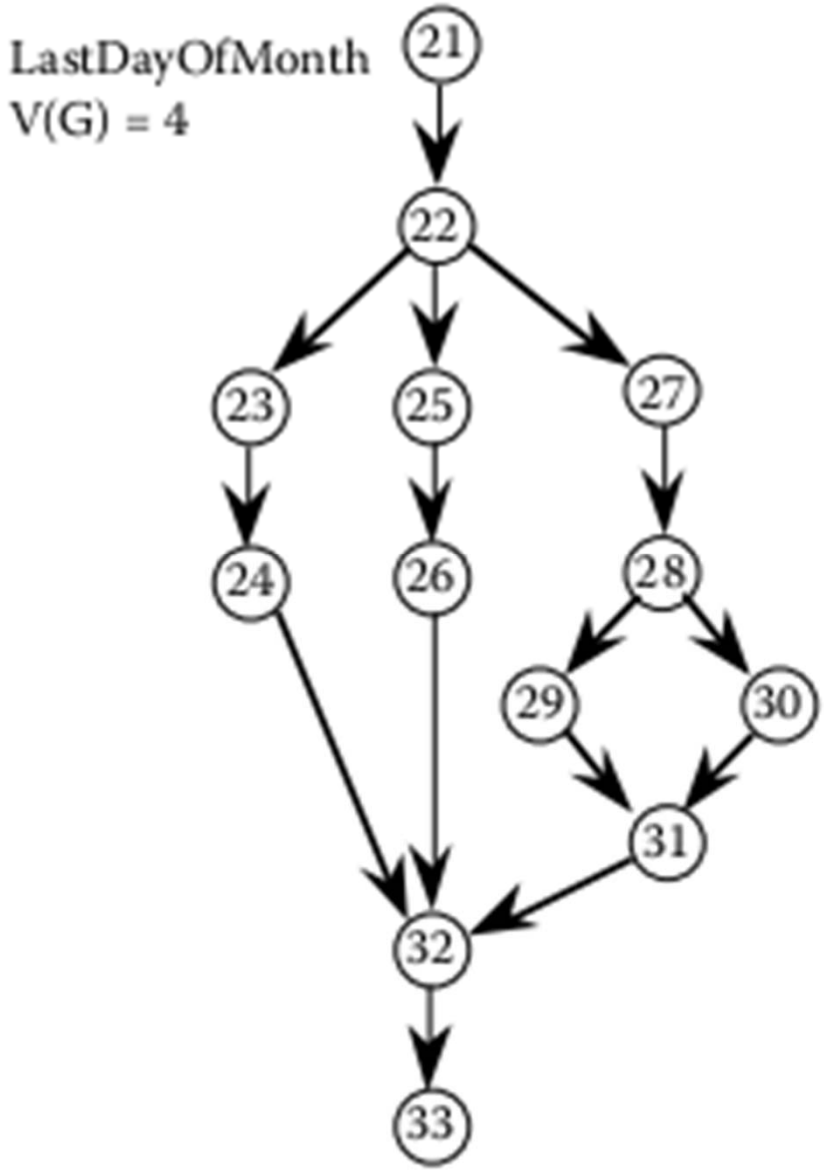
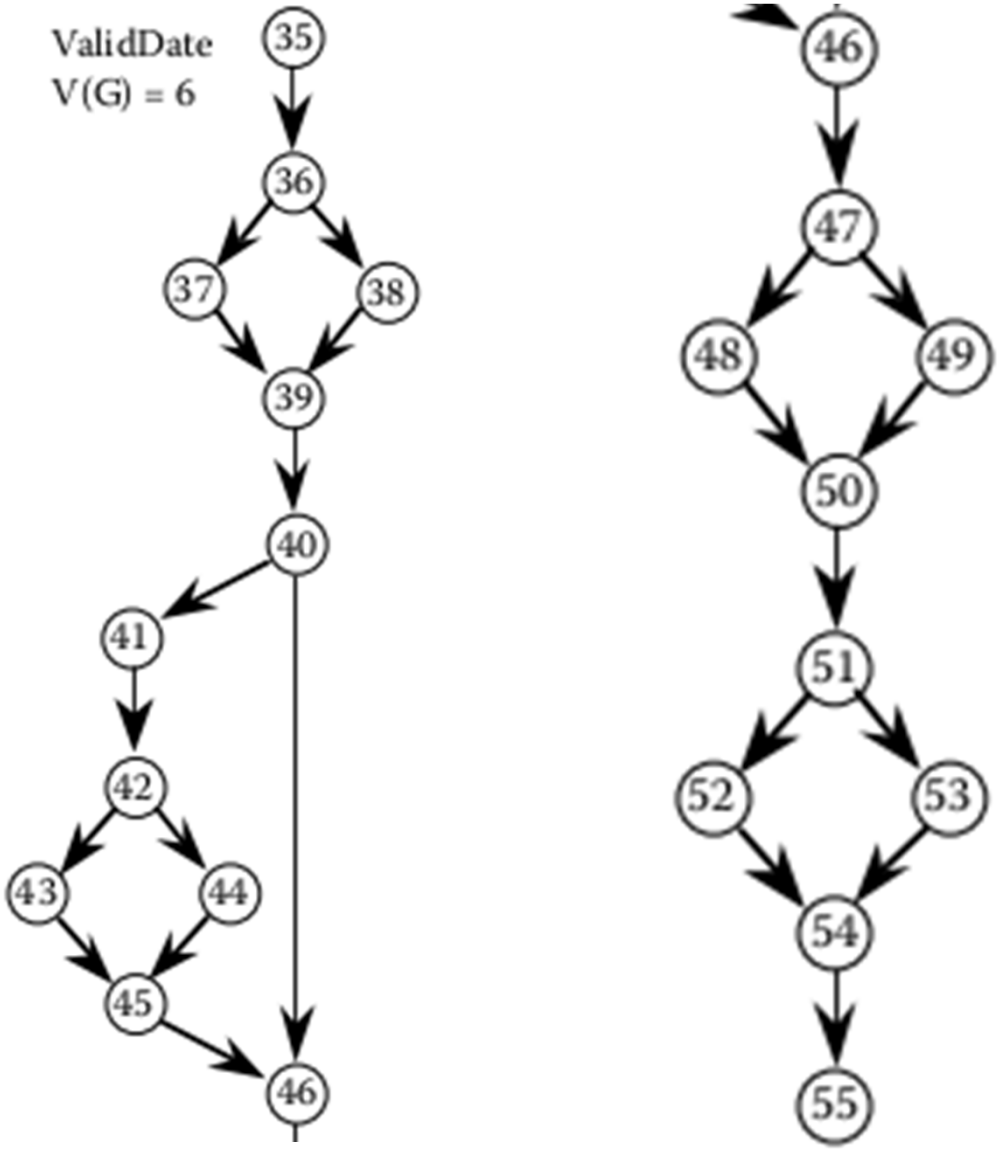
lastDayOfMonth



validDate()



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Decomposition Based Integration

Call Graph Based Integration

MM-Path-Based Integration

```
Main (1, 2)
      msg1
      GetDate (34, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66)
            msg7
            ValidDate (35, 36, 37, 39, 40, 41, 42))
                  msg6
                  lastDayOfMonth (21, 22, 23, 24, 32, 33)
                                                  'point of
                  message quiescence
            ValidDate (43, 45, 46, 47, 48, 50, 51, 52, 54, 55)
      GetDate (67)
Main (3)
```

Table13.4 Comparison of Integration Testing Strategies

Strategy Basis	*Ability to Test Interfaces*	*Ability to Test Co-Functionality*	*Fault Isolation Resolution*
Functional decomposition	Acceptable but can be deceptive	Limited to pairs of units	Good, to faulty unit
Call graph	Acceptable	Limited to pairs of units	Good, to faulty unit
MM-Path	Excellent	Complete	Excellent, to faulty unit execution path

References

Deutsch, M.S., *Software Verification and Validation-Realistic Project Approaches*, Prentice-Hall, Englewood Cliffs, NJ, 1982.

Fordahl, M., Elementary Mistake Doomed Mars Probe, Associated Press, October 1, 1999, www.fas.org/mars/991001/-mars01.htm.

Hetzel, B., *The Complete Guide to SOFTWARE TESTING*, 2nd ed., QED Information Sciences, Inc., Wellesley, MA, 1988.

Jorgensen, P.C., The Use of MM-Paths in Constructive Software Development, Ph.D. dissertation, Arizona State University, Tempe, 1985.

Jorgensen, P.C. and Erickson, C., Object-oriented integration testing, *Communications of the ACM*, September 1994.

Kaner, C., Falk, J., and Nguyen, H.Q., *Testing Computer Software*, 2nd ed., Van Nostrand Reinhold, New York, 1993.

Mosley, D.J., *The Handbook of MIS Application Software Testing*, Yourdon Press, Prentice-Hall, Englewood Cliffs, NJ, 1993.