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Operating Systems

Internals and Design Principles

Ninth Edition 2017

Readers/Writers Problem, Ver. 2

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```
rdr_wrt_msg_v1.pml (1/7)
```

```
$ cat -n rdr_wrt_msg_v1.pml | expand
                                           Simplificamos el modelo
                                           creando un solo código para los
     1 #define NRDRS
                                           procesos de Readers y Writers.
     2 #define NWRTS
       #define MAXRDRO 20
        #define MAXWRRQ 20
        chan readrequest = [MAXRDRQ] of { byte, chan }
        chan writerequest = [MAXWRRQ] of { byte, chan }
        chan finished
                          = [MAXRDRO+MAXWRRO] of { byte }
        chan mbox[NRDRS+NWRTS+1] = [MAXRDRQ+MAXWRRQ] of { bool }
    10
    11
        byte count = 100
       mtype = { reader, writer }
    12
        byte nr = 0, nw = 0
    14
```

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```
rdr_wrt_msg_v1.pml (2/7)
```

```
proctype ReaderWriter(byte i; mtype who) {
15
        chan ch
16
17
        :: who == reader -> ch = readrequest
18
        :: else -> ch = writerequest
19
20
        fi
21
        ch ! i,mbox[i]
22
23
        atomic {
24
            mbox[i] ?
            printf("%e %d\n",who,i)
25
26
```

rdr_wrt_msg_v1.pml (3/7)

```
27
        if
28
        :: who == reader -> nr++
29
        :: else -> nw++
30
        fi
31
        assert(nw < 2)
        assert((nw > 0 && nr == 0) || (nw == 0 && nr > 0))
32
        atomic {
33
34
35
            :: who == reader -> nr--
            :: else -> nw--
36
37
38
            finished! i
39
40
41
```

```
rdr_wrt_msg_v1.pml (4/7)
                                                                                 rdr_wrt_msg_v1.pml (5/7)
        proctype Controller() {
    42
                                                                                     61
                                                                                                   :: empty(finished) && empty(writerequest) && nempty(readrequest) ->
             byte p
                                                                                     62
                                                                                                            atomic {
    43
    44
                                                                                     63
                                                                                                                 readrequest ? p
                                                                                                                printf("request from Reader %d\n",p)
    45
        end:
                                                                                     64
                                                                                     65
    46
             do
             :: count > 0 ->
    47
                                                                                     66
                                                                                                            count - -
    48
                  if
                                                                                     67
                                                                                                            atomic {
    49
                  :: nempty(finished) ->
                                                                                     68
                                                                                                                mbox[p] ! true
    50
                           atomic {
                                                                                     69
                                                                                                                printf("OK to Reader %d\n",p)
                               finished ? p
                                                                                     70
    51
    52
                               printf("finished %d\n",p)
                                                                                     71
                                                                                                   fi
    53
                                                                                     72
                                                                                               :: count == 0 ->
    54
                           count++
                                                                                     73
                                                                                                        atomic {
    55
                  :: empty(finished) && nempty(writerequest) ->
                                                                                     74
                                                                                                            mbox[p] ! true
                                                                                     75
    56
                           atomic {
                                                                                                            printf("OK to Writer %d\n",p)
    57
                               writerequest ? p
                                                                                     76
    58
                               printf("request from Writer %d\n",p)
                                                                                     77
                                                                                                       atomic {
                                                                                     78
    59
                                                                                                            finished ? p
                                                                                     79
                                                                                                            printf("finished Writer %d\n",p)
    60
                           count = count - 100
                                                                                     80
                                                                                     81
                                                                                                        count = 100
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                                                                                    INF646 Métodos Formales
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rdr_wrt_msg_v1.pml (6/7)
                                                                                 rdr_wrt_msg_v1.pml (7/7)
    82
             :: count < 0 ->
                                                                                     91 init {
                      atomic {
                                                                                     92
    83
                                                                                              byte i
                           finished ? p
                                                                                     93
    84
                           printf("finished Writer %d\n",p)
    85
                                                                                     94
                                                                                              atomic {
    86
                                                                                     95
                                                                                                   for (i : 1 .. NRDRS+NWRTS) { /* R1,R2,W3,R4,W5,R6,R7 */
    87
                      count++
                                                                                     96
    88
             od
                                                                                     97
                                                                                                        :: i == 3 || i == 5 ->
    89
                                                                                     98
                                                                                                                run ReaderWriter(i,writer)
    90
                                                                                     99
                                                                                                        :: else ->
                                                                                    100
                                                                                                                run ReaderWriter(i,reader)
                                                                                                        fi
                                                                                    101
                                                                                    102
                                                                                                   run Controller()
                                                                                    103
                                                                                    104
                                                                                    105 }
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                                                                          7
                                                                                    INF646 Métodos Formales
                                                                                                                 VK, 2017 - Readers/Writers, v2
```

```
Simulation: seed 0 (1/2)
                                                                              Simulation: seed 0 (2/2)
$ spin -n0 -B rdr wrt msq v1.pml | expand
                                         request from Writer 5
                                                                                                                       request from Reader 2
                                         OK to Writer 5
                                                                                                                       OK to Reader 2
                            writer 5
                                                                                             reader 2
                                         finished Writer 5
                                                                                                                       finished 4
                                                                                                                       finished 2
                                         request from Writer 3
                                         OK to Writer 3
                                                                                                                       request from Reader 1
                                                                                                                       OK to Reader 1
                   writer 3
                                         finished Writer 3
                                                                                        reader 1
                                         request from Reader 7
                                                                                                                       finished 1
                                         OK to Reader 7
                                                                                    timeout
                                     reader 7
                                         request from Reader 6
                                         OK to Reader 6
                                reader 6
                                         finished 7
                                         finished 6
                                                                                  seed 0:
                                                                                              W5, W3, (R7+R6), (R4+R2), R1.
                                         request from Reader 4
                                         OK to Reader 4
                        reader 4
. . .
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                                                                       9
                                                                                INF646 Métodos Formales
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                                                                                                                                                     10
Verification: 1 error
                                                                              Error trail
$ spin -run rdr_wrt_msg_v1.pml | expand
pan:1: missing pars in receive (at depth 43)
                                                                              $ spin -t -s -r -B rdr_wrt_msg_v1.pml | expand
pan: wrote rdr wrt msg v1.pml.trail
                                                                              using statement merging
                                                                                      proc 7 (ReaderWriter:1) rdr_wrt_msg_v1.pml:22 Send 7,9 ->
(Spin Version 6.4.6 -- 2 December 2016)
                                                                               42:
Warning: Search not completed
                                                                              queue 1 (ch)
        + Partial Order Reduction
                                                                              44: warning: missing params in next recv
                                                                                     proc 8 (Controller:1) rdr_wrt_msg_v1.pml:63 Recv 7,0
Full statespace search for:
                                                                              queue 1/(readrequest)
        never claim
                                   - (none specified)
                                                                                                                       request from Reader
        assertion violations
                                                                              spin: trail ends after 44 steps
        cycle checks
                                  - (disabled by -DSAFETY)
        invalid end states
                                                                                 Just "warning"?
State-vector 620 byte, depth reached 43, errors: 1
                                                                                                          Realmente no necesitamos este parámetro.
. . .
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```

```
rdr_wrt_msg_v2.pml (1/7)
                                                                                rdr_wrt_msg_v2.pml (2/7)
                                                                                        proctype ReaderWriter(byte i; mtype who) {
$ cat -n rdr_wrt_msg_v2.pml | expand
                                                      Versión 2 del modelo
                                                                                             chan ch
                                                                                    16
                                                      (código unificado para
        #define NRDRS
                                                                                    17
                                                                                             if
                                                      Readers/Writers)
                                                                                             :: who == reader -> ch = readrequest
     2 #define NWRTS
                                                                                    18
                                                                                             :: else -> ch = writerequest
        #define MAXRDRQ 20
                                                                                    19
        #define MAXWRRQ 20
                                                                                    20
                                                                                             fi
                                                                                    21
        chan readrequest = [MAXRDRQ] of { byte }
                                                                                             ch! i
                                                                                    22
         chan writerequest = [MAXWRRQ] of { byte }
                                                                                    23
                                                                                             atomic {
        chan finished
                             = [MAXRDRQ+MAXWRRQ] of { byte }
                                                                                    24
                                                                                                 mbox[i] ? _
        chan mbox[NRDRS+NWRTS+1] = [MAXRDRQ+MAXWRRQ] of { bool }
                                                                                                 printf("%e %d\n",who,i)
                                                                                    25
    10
                                                                                    26
    11 byte count = 100
                                                                                . . .
        mtype = { reader, writer }
        byte nr = 0, nw = 0
    14
. . .
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                                                                                  INF646 Métodos Formales
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                                                                                                                                                        14
rdr_wrt_msg_v2.pml (3/7)
                                                                                rdr_wrt_msg_v2.pml (4/7)
                                                                                        proctype Controller() {
                                                                                    42
    27
             if
                                                                                    43
                                                                                             byte p
             :: who == reader -> nr++
                                                                                    44
    28
             :: else -> nw++
                                                                                    45
                                                                                        end:
    30
             fi
                                                                                    46
                                                                                             do
    31
             assert(nw < 2)
                                                                                    47
                                                                                             :: count > 0 ->
    32
             assert((nw > 0 && nr == 0) || (nw == 0 && nr > 0))
                                                                                    48
                                                                                                 if
             atomic {
    33
                                                                                    49
                                                                                                 :: nempty(finished) ->
    34
                 if
                                                                                    50
                                                                                                          atomic {
    35
                  :: who == reader -> nr--
                                                                                    51
                                                                                                              finished?p
                                                                                                              printf("finished %d\n",p)
    36
                  :: else -> nw--
                                                                                    52
    37
                                                                                    53
    38
                 finished! i
                                                                                    54
                                                                                                          count++
                                                                                    55
                                                                                                 :: empty(finished) && nempty(writerequest) ->
    39
    40
                                                                                    56
                                                                                                          atomic {
    41
                                                                                    57
                                                                                                              writerequest ? p
                                                                                    58
                                                                                                              printf("request from Writer %d\n",p)
                                                                                    59
                                                                                    60
                                                                                                          count = count - 100
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                                                                                  INF646 Métodos Formales
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                                                                                                                                                        16
```

```
rdr_wrt_msg_v2.pml (5/7)
                                                                                rdr_wrt_msg_v2.pml (6/7)
                                                                                    82
                                                                                              :: count < 0 ->
    61
                  :: empty(finished) && empty(writerequest) && nempty(readrequest) ->
    62
                          atomic {
                                                                                    83
                                                                                                       atomic {
    63
                               readrequest ? p
                                                                                    84
                                                                                                           finished ? p
                                                                                                           printf("finished Writer %d\n",p)
                               printf("request from Reader %d\n",p)
                                                                                    85
    64
    65
                                                                                    86
    66
                          count - -
                                                                                    87
                                                                                                      count++
    67
                          atomic {
                                                                                    88
                                                                                             od
    68
                               mbox[p] ! true
                                                                                    89
                               printf("OK to Reader %d\n",p)
                                                                                    90
    69
    70
    71
                 fi
    72
             :: count == 0 ->
    73
                      atomic {
    74
                          mbox[p] ! true
    75
                          printf("OK to Writer %d\n",p)
    76
    77
                      atomic {
    78
                          finished ? p
    79
                          printf("finished Writer %d\n",p)
    80
    81
                      count = 100
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                                                                                   INF646 Métodos Formales
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                                                                                                                                                         18
rdr_wrt_msg_v2.pml (7/7)
                                                                                Verification: 1 error
    91 init {
                                                                                $ spin -run rdr_wrt_msg_v2.pml | expand
    92
             byte i
                                                                                pan:1: invalid end state (at depth 165)
    93
                                                                                pan: wrote rdr wrt msg v2.pml.trail
    94
             atomic {
    95
                 for (i : 1 .. NRDRS+NWRTS) { /* R1,R2,W3,R4,W5,R6,R7 */
                                                                                (Spin Version 6.4.6 -- 2 December 2016)
    96
                                                                                Warning: Search not completed
                      :: i == 3 || i == 5 ->
                                                                                         + Partial Order Reduction
    97
    98
                               run ReaderWriter(i,writer)
    99
                      :: else ->
                                                                                Full statespace search for:
   100
                               run ReaderWriter(i,reader)
                                                                                         never claim
                                                                                                                    - (none specified)
                      fi
                                                                                         assertion violations
   101
                                                                                                                    - (disabled by -DSAFETY)
   102
                                                                                         cycle checks
                 run Controller()
                                                                                         invalid end states
   103
   104
   105 }
                                                                                State-vector 572 byte, depth reached 166, errors: 1
                                                                                . . .
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                                                                         19
                                                                                   INF646 Métodos Formales
                                                                                                                VK, 2017 - Readers/Writers, v2
                                                                                                                                                         20
```

```
Invalid End State Error trail (1/3)
                                                                                Invalid End State Error trail (2/3)
$ spin -t rdr_wrt_msg_v2.pml | expand
                                                                                                                          finished Writer 3
                                                                                                                          request from Reader 2
                                        request from Reader 7
                                          OK to Reader 7
                                                                                                                          OK to Reader 2
                                      reader 7
                                                                                               reader 2
                                          finished 7
                                                                                                                          finished 2
                                          request from Reader 6
                                                                                                                          request from Reader 1
                                                                                                                          OK to Reader 1
                                          OK to Reader 6
                                 reader 6
                                                                                           reader 1
                                          finished 6
                                                                                                                          finished 1
                                          request from Writer 5
                                                                                spin: trail ends after 166 steps
                                          OK to Writer 5
                                                                                #processes: 9
                             writer 5
                                                                                                  queue 1 (readrequest): -
                                                                                                                                              Colas vacías
                                                                                                  queue 3 (writerequest):
                                          finished Writer 5
                                                                                                 queue 2 (finished):
                                          request from Reader 4
                                          OK to Reader 4
                                                                                                  queue 4 (mbox[0]):
                                                                                                 queue 5 (mbox[1]):
                        reader 4
                                                                                                 queue 6 (mbox[2]):
                                          finished 4
                                                                                                 queue 7 (mbox[3]):
                                          request from Writer 3
                                          OK to Writer 3
                                                                                                  queue 8 (mbox[4]):
                                                                                                 queue 9 (mbox[5]):
                    Writer 3
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                                                                                  INF646 Métodos Formales
                                                                                                               VK. 2017 - Readers/Writers. v2
                                                                                                                                                         22
Invalid End State Error trail (3/3)
                                                                                rdr_wrt_msg_v3.pml (4/7 only)
. . .
                                                                                        proctype Controller() {
                  queue 10 (mbox[6]):
                                                            Invalid end state
                 queue 11 (mbox[7]):
                                                                                    43
                                                                                             byte p
                                                                                                                                      Versión 3 del modelo
                 count = 100
                                                                                    44
                                                                                                                                      (end label correct place)
                 nr = 0
                                                                                    45
                                                                                             do
                 nw = 0
                                                                                    46
                                                                                             :: count > 0 ->
       proc 8 (Controller:1) rdr_wrt_msg_v2.pml:48 (state 20)
166:
                                                                                    47
                                                                                        end:
                                                                                                 if
166:
       proc 7 (ReaderWriter:1) rdr wrt msg v2.pml:40 (state 27) <valid end state>
                                                                                    48
                                                                                                  :: nempty(finished) ->
```

```
proc 6 (ReaderWriter:1) rdr wrt msg v2.pml:40 (state 27) <valid end state>
166:
       proc 5 (ReaderWriter:1) rdr wrt msg v2.pml:40 (state 27) <valid end state>
166:
       proc 4 (ReaderWriter:1) rdr wrt msg v2.pml:40 (state 27) <valid end state>
166:
       proc 3 (ReaderWriter:1) rdr wrt msg v2.pml:40 (state 27) <valid end state>
166:
166:
       proc 2 (ReaderWriter:1) rdr wrt msg v2.pml:40 (state 27) <valid end state>
       proc 1 (ReaderWriter:1) rdr_wrt_msg_v2.pml:40 (state 27) <valid end state>
166:
       proc 0 (:init::1) rdr wrt msg v2.pml:105 (state 17) <valid end state>
166:
9 processes created
```

End label is misplaced: **45** → **48**

23

```
49
                    atomic {
50
                        finished ? p
                        printf("finished %d\n",p)
51
52
53
                    count++
54
            :: empty(finished) && nempty(writerequest) ->
55
                    atomic {
                        writerequest ? p
56
                        printf("request from Writer %d\n",p)
57
58
59
                    count = count - 100
```

```
Verification: 1 error
                                                                               Invalid End State Error trail (1/3)
$ spin -run rdr_wrt_msg_v3.pml | expand
                                                                               $ spin -t rdr_wrt_msg_v3.pml | expand
pan:1: invalid end state (at depth 138)
                                                                                                                         request from Reader 7
pan: wrote rdr wrt msg v3.pml.trail
                                                                                                                         OK to Reader 7
                                                                                                                    reader 7
(Spin Version 6.4.6 -- 2 December 2016)
                                                                                                                         finished 7
Warning: Search not completed
                                                                                                                         request from Reader 6
        + Partial Order Reduction
                                                                                                                         OK to Reader 6
                                                                                                                reader 6
Full statespace search for:
                                                                                                                         finished 6
        never claim
                                   - (none specified)
                                                                                                                         request from Writer 5
        assertion violations
                                                                                                                         OK to Writer 5
        cvcle checks
                                     (disabled by -DSAFETY)
                                                                                                           writer 5
        invalid end states
                                                                                                                         finished Writer 5
                                                                                                                         request from Reader 4
State-vector 572 byte, depth reached 166, errors: 1
                                                                                                                         OK to Reader 4
                                                                                                       reader 4
                                                                                                                         finished 4
                                                                                                                         request from Reader 2
                                                                                                                         OK to Reader 2
                                                                                                                         request from Writer 3
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Invalid End State Error trail (2/3)
                                                                               Invalid End State Error trail (3/3)
spin: rdr wrt msg v3.pml:59, Error: value (-1->255 (8)) truncated in assignment
               reader 2
                                       finished 2
                                                                                                                                            Invalid end state
spin: rdr wrt msg v3.pml:53, Error: value (256->0 (8)) truncated in assignment
                                         OK to Writer 2
                                                            Esto es lo más
spin: trail ends after 139 steps
                                                            preocupante
#processes: 9
                                                                                        proc 8 (Controller:1) rdr_wrt_msg_v3.pml:76 (state 28)
                                                                               139:
                 queue 1 (readrequest): [1]
                                                                                      proc 7 (ReaderWriter:1) rdr_wrt_msg_v3.pml:40 (state 27) <valid end state>
                                                                               139:
                 queue 3 (writerequest):
                                                                                      proc 6 (ReaderWriter:1) rdr wrt msg v3.pml:40 (state 27) <valid end state>
                                                                               139:
                                                                                      proc 5 (ReaderWriter:1) rdr_wrt_msg_v3.pml:40 (state 27) <valid end state>
                 queue 2 (finished):
                                                                               139:
                                                            Tambien colas
                                                                                      proc 4 (ReaderWriter:1) rdr wrt msg v3.pml:40 (state 27) <valid end state>
                                                                               139:
                 queue 4 (mbox[0]):
                                                            no procesadas
                                                                               139:
                                                                                        proc 3 (ReaderWriter:1) rdr wrt msg v3.pml:23 (state 10)
                 queue 5 (mbox[1]):
                                                                               139:
                                                                                      proc 2 (ReaderWriter:1) rdr wrt msg v3.pml:40 (state 27) alid end state>
                 queue 6 (mbox[2]): [1]
                                                                                        proc 1 (ReaderWriter:1) rdr wrt msg v3.pml:23 (state 10)
                                                                               139:
                 queue 7 (mbox[3]):
                                                                                      proc 0 (:init::1) rdr_wrt msg v3.pml:104 (state 17) salid end state>
                 queue 8 (mbox[4]):
                                                                               9 processes created
                 queue 9 (mbox[5]):
                 queue 10 (mbox[6]):
                                                                                                                        Invalid end state
                                                                                                                                            Invalid end state
                 queue 11 (mbox[7]):
                 count = 0
                 nr = 0
```

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nw = 0

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Observaciones

Se suponía que el algoritmo garantiza el procesamiento prioritario de las solicitudes de los *Writers*. Para este propósito sirve la variable **count**. Pero parece que su manejo no es correcto.

No nos queda otra cosa que encontrar el error y desarrollar la siguiente versión del modelo: rdr_wrt_msg_v4.pml.

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