`smcgen`: Statistical Model-Checking Generator

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Contents

Chapter 1

smcgen Application

1.1 Main Program

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```
module Main where
import Hack

main :: IO ()
main = hack 3
```

Chapter 2

smcgen Libraries

2.1 Hacking

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```
module Hack where
import Data.List
```

Currently we are hacking ways to generalise `Flash.prism` from having parameter `b` fixed equal to 3.

```
hack b
 | b < 2 = putStrLn "smcgen with b less than two is somewhat pointless"
 | otherwise = writeFile ("Flash"++show b++".prism") $ prismcode b

prismcode b
 = unlines $ intercalate [""]
     [ sem, params b, control
     , mdl b, vars b
     , step1 b, step2 b, step3, step4, step5, step6 b, step7, endm
     , writeable b, dirty b
     , cand b, candidates b, can_erase b
     , diff b, toobig b ]
```

dtmc

```
sem = ["dtmc"]
```

```
const int b=3; // Block Count: Our problematic parameter
const int p; // Pages per Block
const int c; // Number of page writes between wear levelling
const int w; // Maximum wear tolerance (no. of erasures)
const int MAXDIFF; // Maximum desired difference in wear across blocks.
```

```
params b
  = [ "const int b="++show b++"; // Block Count: Our problematic parameter"
    , "const int p; // Pages per Block"
    , "const int c; // Number of page writes between wear levelling"
    , "const int w; // Maximum wear tolerance (no. of erasures)"
    , "const int MAXDIFF; // Maximum desired difference in wear across blocks."
  ]
```

```
// control flow
const int INIT = 1;     // startup
const int WRITE = 2;    // page writes
const int SELECT = 3;   // wear-levelling
const int FINISH = 4;   // done: mempory full or worn out
```

```
control
  = [ "// control flow"
    , "const int INIT = 1;     // startup"
    , "const int WRITE = 2;    // page writes"
    , "const int SELECT = 3;   // wear-levelling"
    , "const int FINISH = 4;   // done: memory full or worn out"
    ]
```

```
module Flash
```

```
mdl b = [ "module Flash"++show b ]
```

```
// fm_clean_i, for i in 1..b - the number of clean pages in block i
fm_clean_1: [0..p];
fm_clean_2: [0..p];
fm_clean_3: [0..p];
// fm_erase_i, i in 1..b, the number of times block i has been erased.
fm_erase_1: [0..w];
fm_erase_2: [0..w];
fm_erase_3: [0..w];
pc: [INIT..FINISH] init INIT; // program counter
i: [0..c] init 0; // number of page writes done since last wear-levelling.
```

```
vars :: Int -> [String]
vars b
  = ( ("// fm_clean_i, for i in 1.."++show b++" - no of clean pages in block i")
    : map (idecl "fm_clean_" ": [0..p]") [1..b] )
    ++
    ( ("// fm_erase_i, i in 1.."++show b++", no of times block i has been erased.")
    : map (idecl "fm_erase_" ":[0..w]") [1..b] )
    ++
    [ "pc: [INIT..FINISH] init INIT; // program counter"
    , "i: [0..c] init 0; // number of writes done since last wear-levelling."
    ]

idecl root typ i = root ++ show i ++ typ
```

```
// Step 1
[] pc=INIT ->
  (fm_clean_1'=p) & (fm_clean_2'=p) & (fm_clean_3'=p) &
  (fm_erase_1'=0) & (fm_erase_2'=0) & (fm_erase_3'=0) &
  (pc'=WRITE);
```

```
step1 b
  =    "// Step 1"
    :  "[] pc=INIT ->"
    :  (map (iinit "  (fm_clean_" "'=p) &") [1..b])
    ++ (map (iinit "  (fm_erase_" "'=p) &") [1..b])
    ++ [ "  (pc'=WRITE);" ]

iinit root val i = root ++ show i ++ val
```

```
// Step 2
[] pc=WRITE & i<c & writeable!=0 ->
  (fm_clean_1>0?1/writeable:0): (fm_clean_1'=fm_clean_1-1) & (i'=i+1) +
  (fm_clean_2>0?1/writeable:0): (fm_clean_2'=fm_clean_2-1) & (i'=i+1) +
  (fm_clean_3>0?1/writeable:0): (fm_clean_3'=fm_clean_3-1) & (i'=i+1);
```

```
step2 b
  =    "// Step 2"
     : "[] pc=WRITE & i<c & writeable!=0 ->"
     : map (iwrite b) [1..b]

iwrite b i
  =      "  (fm_clean_"++show b
      ++ "1>0?1/writeable:0): (fm_clean_"++show b
      ++ "1'=fm_clean_"++show b
      ++ "1-1) & (i'=i+1)"
      ++ iwend b i

iwend b i = if i == b then ";" else " +"
```

```
// Step 3
[] pc=WRITE & i<c & writeable=0 -> (pc'=FINISH);
```

```
step3
  = [ "// Step 3"
    , "[] pc=WRITE & i<c & writeable=0 -> (pc'=FINISH);"
    ]
```

```
// Step 4
[] pc=WRITE & i=c -> (pc'=SELECT);
```

```
step4
  = [ "// Step 4"
    , "[] pc=WRITE & i=c -> (pc'=SELECT);"
    ]
```

```
// Step 5
[] pc=SELECT & (candidates=0 | !can_erase) -> (pc'=FINISH);
```

```
step5
  = [ "// Step 5"
    , "[] pc=SELECT & (candidates=0 | !can_erase) -> (pc'=FINISH);"
    ]
```

```
// Step 6
[] pc=SELECT & candidates!=0 & can_erase ->
  (cand_1_2 ? 1/candidates : 0): (fm_clean_2'=fm_clean_2-dirty_1) &
                                 (fm_clean_1'=p) & (fm_erase_1'=fm_erase_1+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_1_3 ? 1/candidates : 0): (fm_clean_3'=fm_clean_3-dirty_1) &
                                 (fm_clean_1'=p) & (fm_erase_1'=fm_erase_1+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_2_1 ? 1/candidates : 0): (fm_clean_1'=fm_clean_1-dirty_2) &
                                 (fm_clean_2'=p) & (fm_erase_2'=fm_erase_2+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_2_3 ? 1/candidates : 0): (fm_clean_3'=fm_clean_3-dirty_2) &
                                 (fm_clean_2'=p) & (fm_erase_2'=fm_erase_2+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_3_1 ? 1/candidates : 0): (fm_clean_1'=fm_clean_1-dirty_3) &
                                 (fm_clean_3'=p) & (fm_erase_3'=fm_erase_3+1) &
```

```
                                    (i'=0) & (pc'=WRITE) +
  (cand_3_2 ? 1/candidates : 0): (fm_clean_2'=fm_clean_2-dirty_3) &
                                 (fm_clean_3'=p) & (fm_erase_3'=fm_erase_3+1) &
                                 (i'=0) & (pc'=WRITE);
```

```
step6 b
  =    "// Step 6"
    :  "[] pc=SELECT & candidates!=0 & can_erase ->"
    : (map (ierase (3,2)) [(1,2),(1,3),(2,1),(2,3),(3,1),(3,2)])

ierase last (from,to)
```

```
// Step 7
[] pc=FINISH -> true;
```

```
step7
  = [ "// Step 7"
    , "[] pc=FINISH -> true;"
    ]
```

---

endmodule

```
endm = [ "endmodule" ]
```

```
// a block is writeable if it has at least one clean page
// We need to know how many of these there are.
formula writeable = (fm_clean_1!=0 ? 1 : 0) +  (fm_clean_2!=0 ? 1 : 0)
                  + (fm_clean_3!=0 ? 1 : 0);
```

```
writeable b
  = [ "// a block is writeable if it has at least one clean page"
    , "// We need to know how many of these there are."
    , "writeable "++show b++" NYFI"
    ]
```

```
// dirty_i, for i in 1..b - number of dirty pages in block i
formula dirty_1 = p-fm_clean_1;
formula dirty_2 = p-fm_clean_2;
formula dirty_3 = p-fm_clean_3;
```

```
dirty b
  = [ "// dirty_i, for i in 1.."++show b++" - number of dirty pages in block i"
    , "dirty "++show b++" NYFI"
    ]
```

```
// cand_i_j, for i,j in 1..b, i /= j
//  block i is dirty but there is space in block j for its pages
formula cand_1_2 = dirty_1>0 & fm_clean_2 >= dirty_1;
formula cand_1_3 = dirty_1>0 & fm_clean_3 >= dirty_1;
formula cand_2_1 = dirty_2>0 & fm_clean_1 >= dirty_2;
formula cand_2_3 = dirty_2>0 & fm_clean_3 >= dirty_2;
formula cand_3_1 = dirty_3>0 & fm_clean_1 >= dirty_3;
formula cand_3_2 = dirty_3>0 & fm_clean_2 >= dirty_3;
```

```
cand b
  = [ "// cand_i_j, for i,j in 1..b, i /= j"
    , "//  block i is dirty but there is space in block j for its pages"
    , "cand "++show b++" NYFI"
    ]
```

```
// the number of ways in which we can relocate dirty pages from one block
// to another so we can erase (clean) the first block.
formula candidates =
  (cand_1_2?1:0) + (cand_1_3?1:0) + (cand_2_1?1:0) +
  (cand_2_3?1:0) + (cand_3_1?1:0) + (cand_3_2?1:0);
```

```
candidates b
  = [ "// the number of ways in which we can relocate dirty pages from one block"
    , "// to another so we can erase (clean) the first block."
    , "candidates "++show b++" NYFI"
     ]
```

```
// true when it is still possibe to erase ANY block,
// without exceeding the maximum allowable erase operations.
formula can_erase = fm_erase_1<w & fm_erase_2<w & fm_erase_3<w;
```

```
can_erase b
  = [ "// true when it is still possibe to erase ANY block,"
    , "// without exceeding the maximum allowable erase operations."
    , "can_erase "++show b++" NYFI"
     ]
```

```
// diff_i_j , for i,j in 1..b, i /= j
// the difference in number of erasure of blocks i and j
formula diff_1_2 = fm_erase_1-fm_erase_2;
formula diff_1_3 = fm_erase_1-fm_erase_3;
formula diff_2_1 = fm_erase_2-fm_erase_1;
formula diff_2_3 = fm_erase_2-fm_erase_3;
formula diff_3_1 = fm_erase_3-fm_erase_1;
formula diff_3_2 = fm_erase_3-fm_erase_2;
```

```
diff b
  = [ "// diff_i_j, for i,j in 1.."++show b++", i /= j"
    , "// the difference in number of erasure of blocks i and j"
    , "diff "++show b++" NYFI"
     ]
```

```
// true if difference in wear equals some limit.
formula toobig =
  diff_1_2 >= MAXDIFF |
  diff_1_3 >= MAXDIFF |
  diff_2_1 >= MAXDIFF |
  diff_2_3 >= MAXDIFF |
  diff_3_1 >= MAXDIFF |
  diff_3_2 >= MAXDIFF;
```

```
toobig b
  = [ "// true if difference in wear equals some limit."
    , "toobig "++show b++" NYFI"
     ]
```

Chapter 3

smcgen Tests

```
module Main where

import Test.HUnit
import Test.Framework as TF (defaultMain, testGroup, Test)
import Test.Framework.Providers.HUnit (testCase)

import Hack

main = defaultMain tests

tests :: [TF.Test]
tests
 =  [ testCase "1+1=2" (1+1 @?= 2)
    ]
```

Chapter 4

Model Files

4.1 Flash Prism Model

The original model developed by Jim Woodcock and Andrew Butterfield in March 2018 in TCD. Here the `b` parameter was fixed at 3, as the number of terms in some commands depend on this value.

dtmc

```
const int b=3; // Block Count: Our problematic parameter

const int p; // Pages per Block
const int c; // Number of page writes between wear levelling
const int w; // Maximum wear tolerance (no. of erasures)
const int MAXDIFF; // Maximum desired difference in wear across blocks.

// control flow
const int INIT = 1;    // startup
const int WRITE = 2;   // page writes
const int SELECT = 3;  // wear-levelling
const int FINISH = 4;  // done: memory full or worn out

module Flash

// fm_clean_i, for i in 1..b - the number of clean pages in block i
fm_clean_1: [0..p];
fm_clean_2: [0..p];
fm_clean_3: [0..p];

// fm_erase_i, i in 1..b, the number of times block i has been erased.
fm_erase_1: [0..w];
fm_erase_2: [0..w];
fm_erase_3: [0..w];

pc: [INIT..FINISH] init INIT;

// count the number of page writes done since last wear-levelling.
i: [0..c] init 0;

// Step 1
[] pc=INIT ->
  (fm_clean_1'=p) & (fm_clean_2'=p) & (fm_clean_3'=p) &
  (fm_erase_1'=0) & (fm_erase_2'=0) & (fm_erase_3'=0) &
  (pc'=WRITE);
// Step 2
[] pc=WRITE & i<c & writeable!=0 ->
  (fm_clean_1>0?1/writeable:0): (fm_clean_1'=fm_clean_1-1) & (i'=i+1) +
```

```
  (fm_clean_2>0?1/writeable:0): (fm_clean_2'=fm_clean_2-1) & (i'=i+1) +
  (fm_clean_3>0?1/writeable:0): (fm_clean_3'=fm_clean_3-1) & (i'=i+1);
// Step 3
[] pc=WRITE & i<c & writeable=0 -> (pc'=FINISH);
// Step 4
[] pc=WRITE & i=c -> (pc'=SELECT);
// Step 5
[] pc=SELECT & (candidates=0 | !can_erase) -> (pc'=FINISH);
// Step 6
[] pc=SELECT & candidates!=0 & can_erase ->
  (cand_1_2 ? 1/candidates : 0): (fm_clean_2'=fm_clean_2-dirty_1) &
                                 (fm_clean_1'=p) & (fm_erase_1'=fm_erase_1+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_1_3 ? 1/candidates : 0): (fm_clean_3'=fm_clean_3-dirty_1) &
                                 (fm_clean_1'=p) & (fm_erase_1'=fm_erase_1+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_2_1 ? 1/candidates : 0): (fm_clean_1'=fm_clean_1-dirty_2) &
                                 (fm_clean_2'=p) & (fm_erase_2'=fm_erase_2+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_2_3 ? 1/candidates : 0): (fm_clean_3'=fm_clean_3-dirty_2) &
                                 (fm_clean_2'=p) & (fm_erase_2'=fm_erase_2+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_3_1 ? 1/candidates : 0): (fm_clean_1'=fm_clean_1-dirty_3) &
                                 (fm_clean_3'=p) & (fm_erase_3'=fm_erase_3+1) &
                                 (i'=0) & (pc'=WRITE) +
  (cand_3_2 ? 1/candidates : 0): (fm_clean_2'=fm_clean_2-dirty_3) &
                                 (fm_clean_3'=p) & (fm_erase_3'=fm_erase_3+1) &
                                 (i'=0) & (pc'=WRITE);
// Step 7
[] pc=FINISH -> true;

endmodule

// a block is writeable if it has at least one clean page
// We need to know how many of these there are.
formula writeable = (fm_clean_1!=0 ? 1 : 0) +  (fm_clean_2!=0 ? 1 : 0)
                  + (fm_clean_3!=0 ? 1 : 0);

// dirty_i, for i in 1..b - number of dirty pages in block i

formula dirty_1 = p-fm_clean_1;
formula dirty_2 = p-fm_clean_2;
formula dirty_3 = p-fm_clean_3;

// cand_i_j, for i,j in 1..b, i /= j
//  block i is dirty but there is space in block j for its pages

formula cand_1_2 = dirty_1>0 & fm_clean_2 >= dirty_1;
formula cand_1_3 = dirty_1>0 & fm_clean_3 >= dirty_1;
formula cand_2_1 = dirty_2>0 & fm_clean_1 >= dirty_2;
formula cand_2_3 = dirty_2>0 & fm_clean_3 >= dirty_2;
formula cand_3_1 = dirty_3>0 & fm_clean_1 >= dirty_3;
formula cand_3_2 = dirty_3>0 & fm_clean_2 >= dirty_3;

// the number of ways in which we can relocate dirty pages from one block
// to another so we can erase (clean) the first block.
formula candidates =
  (cand_1_2?1:0) + (cand_1_3?1:0) + (cand_2_1?1:0) +
  (cand_2_3?1:0) + (cand_3_1?1:0) + (cand_3_2?1:0);

// true when it is still possibe to erase ANY block,
// without exceeding the maximum allowable erase operations.
```

```
formula can_erase = fm_erase_1<w & fm_erase_2<w & fm_erase_3<w;

// diff_i_j , for i,j in 1..b, i /= j
// the difference in number of erasure of blocks i and j
formula diff_1_2 = fm_erase_1-fm_erase_2;
formula diff_1_3 = fm_erase_1-fm_erase_3;
formula diff_2_1 = fm_erase_2-fm_erase_1;
formula diff_2_3 = fm_erase_2-fm_erase_3;
formula diff_3_1 = fm_erase_3-fm_erase_1;
formula diff_3_2 = fm_erase_3-fm_erase_2;


// true if difference in wear equals some limit.
formula toobig =
  diff_1_2 >= MAXDIFF |
  diff_1_3 >= MAXDIFF |
  diff_2_1 >= MAXDIFF |
  diff_2_3 >= MAXDIFF |
  diff_3_1 >= MAXDIFF |
  diff_3_2 >= MAXDIFF;
```

4.2 Flash Prism Properties

```
!E [ F "deadlock" ];
E [ F toobig ];
P =? [ F toobig ];
```

Bibliography