The 2nd Verified Software Competition
Experience Report

Jean-Christophe Filliâtre   Andrei Paskevich   Aaron Stump

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Previous Competitions

- on-site competitions
  - VSTTE 2010 / 2 hours / 5 problems
    (Peter Müller, Natarajan Shankar)
  - FoVeOOS 2011 / 2.5 hours / 3 problems
    (Marieke Huisman, Vladimir Klebanov, Rosemary Monahan)
- long-term challenges
  - VACID-0 / 5 problems
    (Rustan Leino, Michał Moskal)

And Now for Something Completely Different

inspired by the ICFP programming contest

- more challenging problems
- over a short period (2/3 days)

but

- algorithm is given
- solution = specification + mechanized proof

a completely different evaluation process

- adequacy of a specification cannot be judged mechanically

Competition Format

- first announcement on Sep 30
  - second call on Oct 7
  - last call on Nov 1 ("one week to go")
- competition from Nov 8 15:00 UTC to Nov 10 15:00 UTC
  - problems put on the web
  - solutions sent by email
- winner(s) private notification on Dec 12

Rules

- team work is allowed
  (only teams up to 4 members are eligible for the first prize)
- any software used in the solutions should be freely available for noncommercial use to the public
- software must be usable on x86 Linux or Windows
- participants can modify their tools during the competition

Problems

find a balance between

- purely applicative vs imperative style
- data structures vs algorithms
- easy vs difficult

5 independent problems

Pentathlon

1. Two-Way Sort (50 points)

   sort an array of Boolean values

2. Combinators (100 points)

   call-by-value reduction of SK-terms

3. Ring Buffer (150 points)

   queue data structure in a circular array

4. Tree Reconstruction (150 points)

   build a binary tree from a list of leaf depths

5. Breadth-First Search (150 points)

   search for a shortest path in a directed graph

Participants

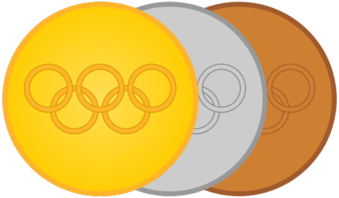
Participants

- 29 submissions
- 79 participants
  - 8 teams of size 1
  - 6 teams of size 2
  - 4 teams of size 3
  - 10 teams of size 4
  - 1 team of size 9

- ACL2 (1)
- Agda (3)
- ATS (1)
- B (2)
- BLAST (1)
- CBMC (1)
- Coq (7)
- Dafny (6)
- Escher (1)
- Guru (1)
- HIP (1)
- Holfoot (1)
- Isabelle (2)
- KeY (1)
- KIV (1)
- PAT (1)
- PML (1)
- PVS (3)
- Socos (1)
- VCC (2)
- VeriFast (1)
- Ynot (1)

a group of excellent submissions with tied scores

$\Rightarrow$ we opted for 6 medalists: 2 bronze, 2 silver, 2 gold



and they are...

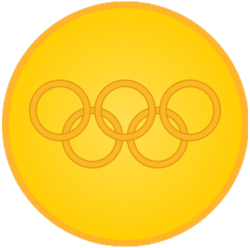
Bronze Medalists (590 points)

- eam (VCC)
  - Ernie Cohen
  - Michał Moskal
- JasonAndNadia (Dafny)
  - Jason Koenig
  - Nadia Polikarpova

Silver Medalists (595 points)

- SRI (PVS)
  - Sam Owre
  - N. Shankar
- LeinoMuller (Dafny)
  - Rustan Leino
  - Peter Müller

Gold Medalists (600 points)



- acl2-dkms
  - Jared Davis
  - Matt Kaufmann
  - J Strother Moore
  - Sol Swords
- KIV
  - Gidon Ernst
  - Gerhard Schellhorn
  - Kurt Stenzel
  - Bogdan Tofan

some feedback from the organizers

Preparation

- a larger set of problems
  - Booth algorithm
  - in-place inversion of a permutation
  - stable counting sort
- solutions in Why3
- beta-testing
  - are the problems too easy / too difficult?
  - make a selection

Organization

- announces on various mailing lists
- web page
  - hosted on the VSTTE web site (Google sites) `https://sites.google.com/site/vstte2012/compet`
- mailing list for the competition
  - Google group `vstte-2012-verification-competition`
- mailbox for submissions
  - `vstte-2012-competition@lri.fr`

Sequence of Events

- before the competition
  - a few discussions on the mailing list or in private
- during the competition
  - “night watch” (2 in Europe, 1 in USA)
  - a few questions on the mailing list
- after the competition
  - we sent acknowledgment emails (was useful)
  - we invited participants to share their solutions
- evaluation process

Evaluation Process

1. proofreading code and specification
2. installing and running tools, inserting errors

Evaluation Process

1. proofreading code and specification
   - what makes it easy
     - Principle of Least Astonishment
   - what makes it hard
     - `ar[i→n(i)]` as a notation for array access
     - non human-readable format
     - code, spec, and proof tangled
2. installing and running tools, inserting errors

Evaluation Process

1. proofreading code and specification
2. installing and running tools, inserting errors
   - what makes it easy
     - packages
     - tool and prover(s) come together
   - what makes it hard
     - installation issues

Conclusion

- we hope to take part in next competitions
- a submission server would be a good idea
- always hire several organizers, on both sides of the Atlantic

Thanks

- beta-testing
  Claude Marché, Duckki Oe
- VSTTE 2012 chairs
  Ernie Cohen, Rajeev Joshi, Peter Müller, Andreas Podelski
- publicity
  Gudmund Grov
- technical support
  LRI's staff

```
two_way_sort(a: array of boolean) :=
  i <- 0;
  j <- length(a) - 1;
  while i <= j do
    if not a[i] then
      i <- i+1
    elseif a[j] then
      j <- j-1
    else
      swap(a, i, j);
      i <- i+1;
      j <- j-1
    endif
  endwhile
```

Problem 1: Two-Way Sort

1. Safety. Verify that every array access is made within bounds.
2. Termination. Prove that function `two_way_sort` always terminates.
3. Behavior. Verify that after execution of function `two_way_sort`, the following properties hold.
   3.1 Array `a` is sorted in increasing order.
   3.2 Array `a` is a permutation of its initial contents.

Problem 2: Combinators

$$\textit{terms} \qquad t ::= \mathsf{S} \mid \mathsf{K} \mid (t\ t)$$

$$\begin{array}{lll} \textit{CBV contexts} & C & ::= \ \Box \mid (C\ t) \mid (v\ C) \\ \textit{values} & v & ::= \ \mathsf{K} \mid \mathsf{S} \mid (\mathsf{K}\ v) \mid (\mathsf{S}\ v) \mid ((\mathsf{S}\ v)\ v) \end{array}$$

$$\begin{array}{rcl} \Box[t] & = & t \\ (C\ t_1)[t] & = & (C[t]\ t_1) \\ (v\ C)[t] & = & (v\ C[t]) \end{array}$$

$$\begin{array}{lcl} C[((\mathsf{K}\ v_1)\ v_2)] & \rightarrow & C[v_1] \\ C[(((\mathsf{S}\ v_1)\ v_2)\ v_3)] & \rightarrow & C[((v_1\ v_3)\ (v_2\ v_3))] \end{array}$$

Problem 2: Combinators

Implementation Task

1. Implement a function `reduction` which, when given a combinator term t as input, returns a term t' such that $t \to^* t'$ and $t' \not\to$, or loops if there is no such term.

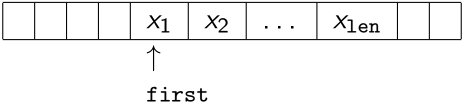
Verification Tasks

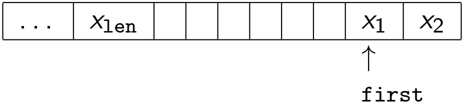
1. Prove that if `reduction`(t) returns t', then $t \to^* t'$ and $t' \not\to$.
2. Prove that function `reduction` terminates on any term which does not contain S.
3. Consider the meta-language function *ks* defined by

$$\begin{array}{lcl} ks\ 0 & = & \mathsf{K} \\ ks\ (n+1) & = & ((ks\ \ n)\ \mathsf{K}) \end{array}$$

Prove that `reduction` applied to the term $(ks\ n)$ returns K when n is even, and (K K) when n is odd.

```
type ring_buffer = record
  data : array of int; // buffer contents
  size : int;          // buffer capacity
  first: int;          // queue head, if any
  len  : int;          // queue length
end
```



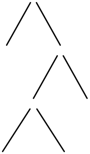


```
create(n: int): ring_buffer :=
  return new ring_buffer(
      data = new array[n] of int;
      size = n; first = 0; len = 0)

clear(b: ring_buffer) :=
  b.len <- 0

head(b: ring_buffer): int :=
  return b.data[b.first]

push(b: ring_buffer, x: int) :=
  b.data[(b.first + b.len) mod b.size] <- x;
  b.len <- b.len + 1

pop(b: ring_buffer): int :=
  r <- b.data[b.first];
  b.first <- (b.first + 1) mod b.size;
  b.len <- b.len - 1;
  return r
```

Problem 3: Ring Buffer

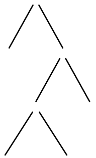
1. Safety. Verify that every array access is made within bounds.
2. Behavior. Verify the correctness of your implementation w.r.t. the first-in first-out semantics of a queue.
3. Harness. The following test harness should be verified.

```
test (x: int, y: int, z: int) :=
  b <- create(2);
  push(b, x);
  push(b, y);
  h <- pop(b); assert h = x;
  push(b, z);
  h <- pop(b); assert h = y;
  h <- pop(b); assert h = z;
```



$1, 3, 3, 2$

Problem 4: Tree Reconstruction



```
type tree
Leaf(): tree
Node(l:tree, r:tree): tree
```

$1, 3, 3, 2$

```
type list
is_empty(s: list): boolean
head(s: list): int
pop(s: list)
```

```
build_rec(d: int, s: list): tree :=
  if is_empty(s) then fail; endif
  h <- head(s);
  if h < d then fail; endif
  if h = d then pop(s); return Leaf();
     endif
  l <- build_rec(d+1, s);
  r <- build_rec(d+1, s);
  return Node(l, r)

build(s: list): tree :=
  t <- build_rec(0, s);
  if not is_empty(s) then fail; endif
  return t
```

Problem 4: Tree Reconstruction

1. Soundness. Verify that whenever function `build` successfully returns a tree the depths of its leaves are exactly those passed in the argument list.
2. Completeness. Verify that whenever function `build` reports failure there is no tree that corresponds to the argument list.
3. Termination. Prove that function `build` always terminates.
4. Harness. The following test harness should be verified:
   - Verify that `build` applied to the list $1, 3, 3, 2$ returns the tree `Node(Leaf, Node(Node(Leaf, Leaf), Leaf))`.
   - Verify that `build` applied to the list $1, 3, 2, 2$ reports failure.

Problem 5: Breadth-First Search

```
bfs(source: vertex, dest: vertex): int :=
  V <- {source}; C <- {source}; N <- {};
  d <- 0;
  while C is not empty do
    remove one vertex v from C;
    if v = dest then return d; endif
    for each w in succ(v) do
      if w is not in V then
        add w to V;
        add w to N;
      endif
    endfor
    if C is empty then
      C <- N;
      N <- {};
      d <- d+1;
    endif
  endwhile
  fail "no path"
```

Problem 5: Breadth-First Search

1. Soundness. Verify that whenever function `bfs` returns an integer n this is indeed the length of the shortest path from `source` to `dest`.

   A partial score is attributed if it is only proved that there exists a path of length n from `source` to `dest`.

2. Completeness. Verify that whenever function `bfs` reports failure there is no path from `source` to `dest`.