Get Started with Open Source Formal Verification

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What is Formal Verification?

the act of proving or disproving the correctness of intended algorithms [...] using formal methods of mathematics [1]

[1] https://en.wikipedia.org/wiki/formal_verification

An example

```
y = 10 / (x - 10);
```

An example

```
y = 10 / (x - 10);
```

```
x - 10 != 0
```

An example

```
y = 10 / (x - 10);
```

```
x - 10 != 0
```

```
x != 10
```

An example

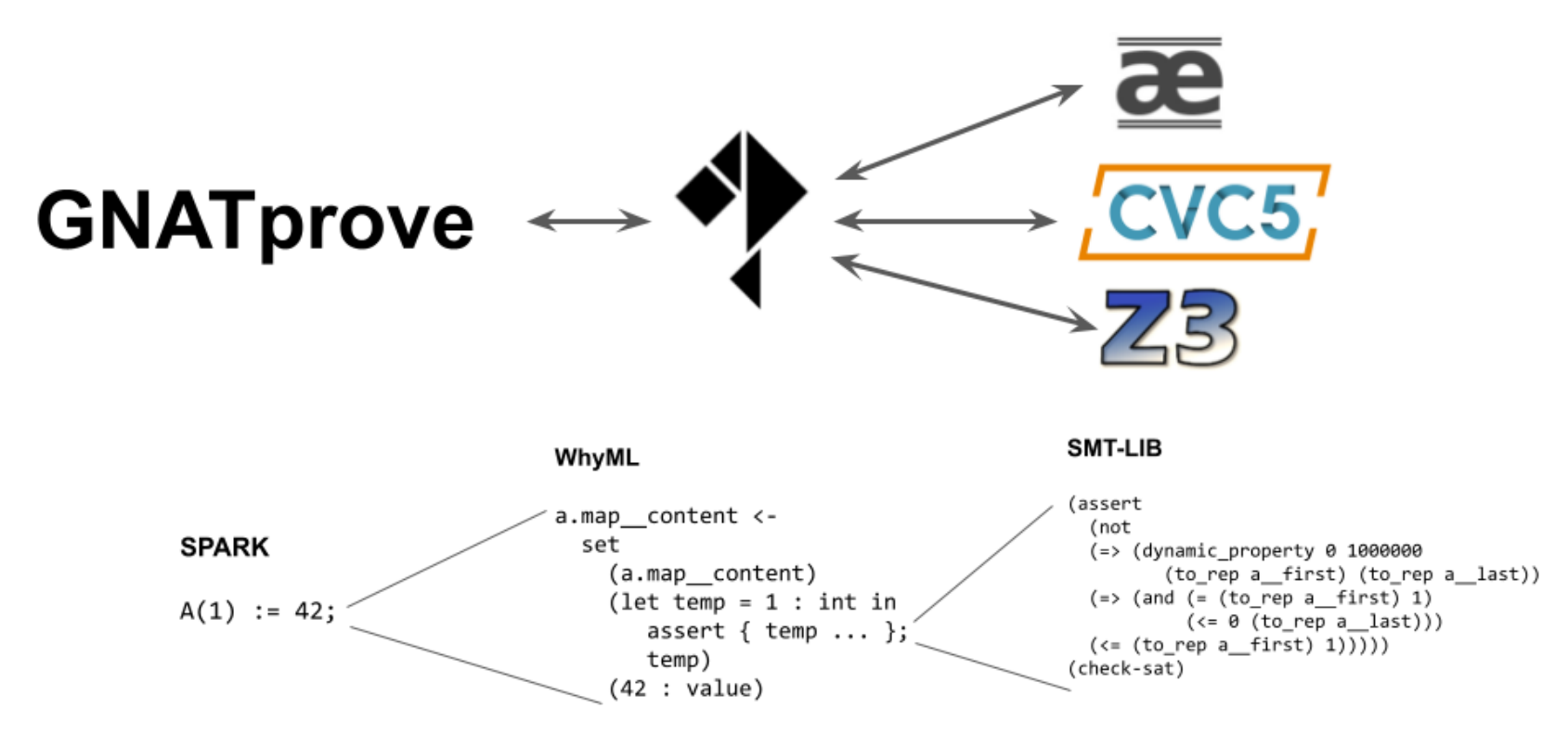
```
if (x != 10) {
  y = 10 / (x - 10);
} else {
  y = 42;
};
```

Spot the bugs

```
float * compute (int * tab, int size) {

   float tab2 [size];
   float * result;

   for (int j = 0; j <= size; ++j) {
       tab [j] = tab2 [j] / 10;
   }

   result = tab2;
   return result;
}
```

SPARK

SPARK - The Automatic Proof Toolkit



SPARK - The language

Why a subset of Ada?

```
type Percentage is new Float range 0.0 .. 1.0;
```

Why a subset of Ada?

```
type Stack is private;

function Is_Empty (S : Stack) return Boolean;
function Is_Full (S : Stack) return Boolean;

procedure Push (S : in out Stack; Value : Natural)
  with Pre  => not Is_Full (S),
       Post => not Is_Empty (S);
```

Why should I care about SPARK?

- No vulnerabilities for **any** possible inputs
- Proof of functional correctness
- Avoid some of the testing efforts

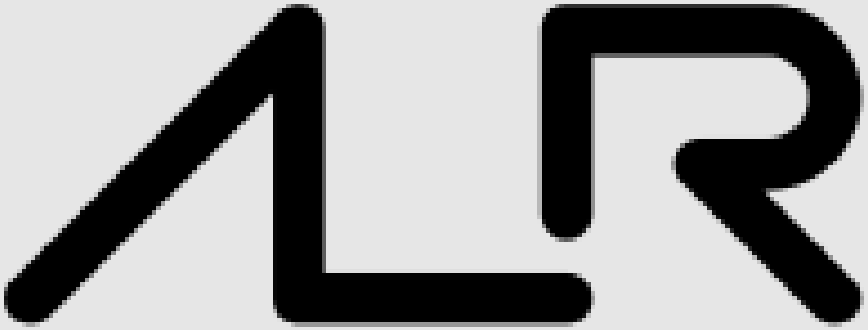
NVIDIA Security Team [2]:

- "Testing security is pretty much impossible"
- "provability over testing as a preferred verification method"
- "let's focus on other areas of security"

[2] https://www.adacore.com/papers/nvidia-adoption-of-spark-new-era-in-security-critical-software-development

Let's prove!

Download and install Alire



Download the Alire package manager from:

`https://alire.ada.dev`

Start a new crate

```
$ alr init --bin lets_prove
lets_prove initialized successfully.
```

```
$ cd lets_prove
```

Add gnatprove dependency

```
$ alr with gnatprove
```

Add some code

In src/lets_prove.adb:

```
with Ada.Text_IO;

procedure Lets_Prove
with SPARK_Mode
is
   X : constant Integer := Integer (Ada.Text_IO.Col);
   Y : Integer;
begin
   Y := 10 / (X - 10);

   Ada.Text_IO.Put_Line (Y'Img);
end Lets_Prove;
```

Run gnatprove

```
$ alr gnatprove
Phase 1 of 2: generation of Global contracts ...
Phase 2 of 2: flow analysis and proof ...

lets_prove.adb:9:12: medium: divide by zero might fail
    9 |   Y := 10 / (X - 10);
      |        ~~~^~~~~~~~~~
Summary logged in gnatprove.out
```

With counter examples

```
$ alr gnatprove --counterexamples=on
Phase 1 of 2: generation of Global contracts ...
Phase 2 of 2: flow analysis and proof ...

lets_prove.adb:9:12: medium: divide by zero might fail
    9 |   Y := 10 / (X - 10);
      |        ~~~^~~~~~~~~~
  e.g. when X = 10
Summary logged in gnatprove.out
```

Fix the code

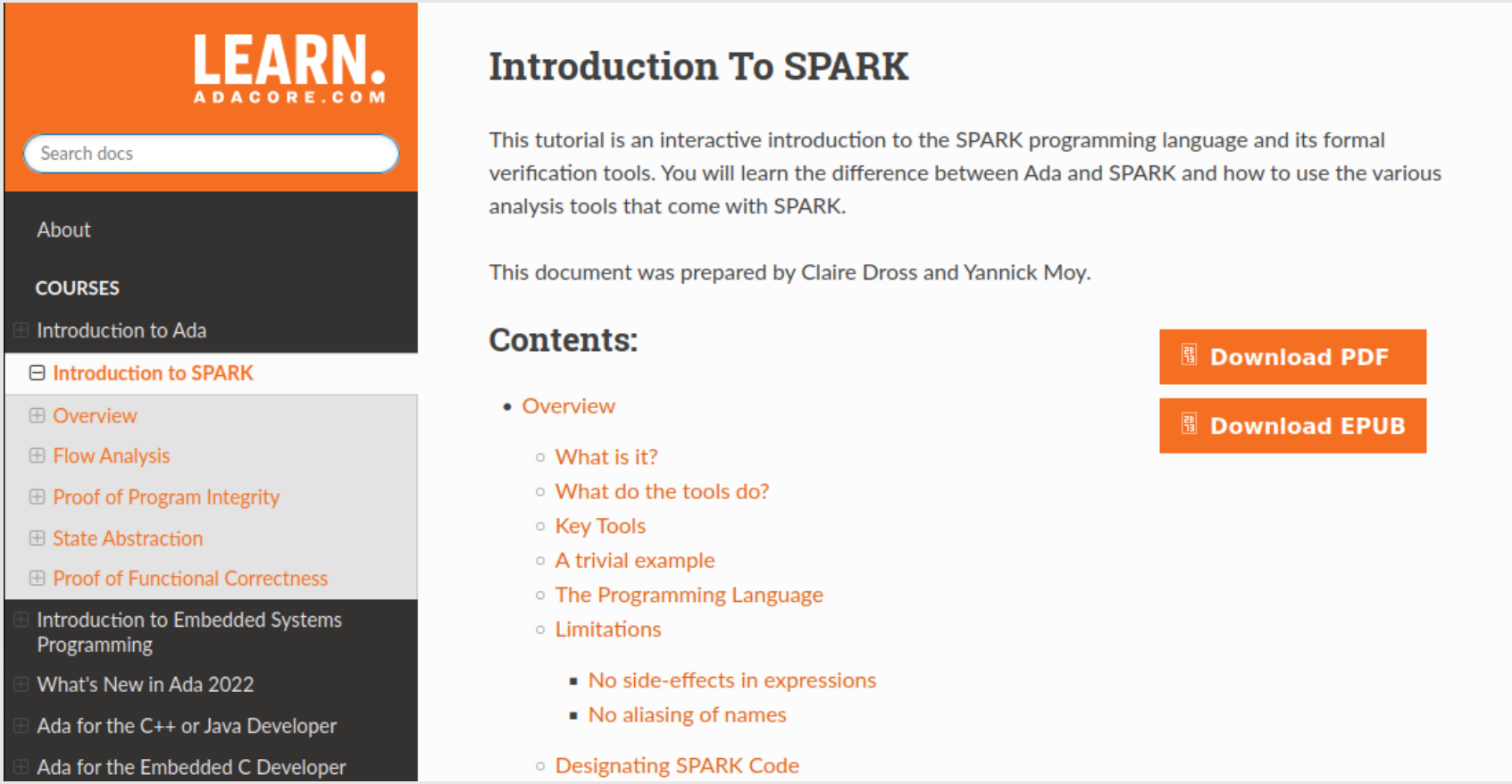
```
with Ada.Text_IO;

procedure Lets_Prove
with SPARK_Mode
is
   X : constant Integer := Integer (Ada.Text_IO.Col);
   Y : Integer;
begin
   if X /= 10 then
      Y := 10 / (X - 10);
   else
      Y := 42;
   end if;

   Ada.Text_IO.Put_Line (Y'Img);
end Lets_Prove;
```

Run gnatprove again

```
$ alr gnatprove
Phase 1 of 2: generation of Global contracts ...
Phase 2 of 2: flow analysis and proof ...
Summary logged in gnatprove.out
```

That's it you just proved your first program!

Resources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Introduction to Embedded Systems Programming
What's New in Ada 2022
Ada for the C++ or Java Developer
Ada for the Embedded C Developer
Introduction To SPARK
This tutorial is an interactive introduction to the SPARK programming language and its formal verification tools. You will learn the difference between Ada and SPARK and how to use the various analysis tools that come with SPARK.
This document was prepared by Claire Dross and Yannick Moy.
Contents:
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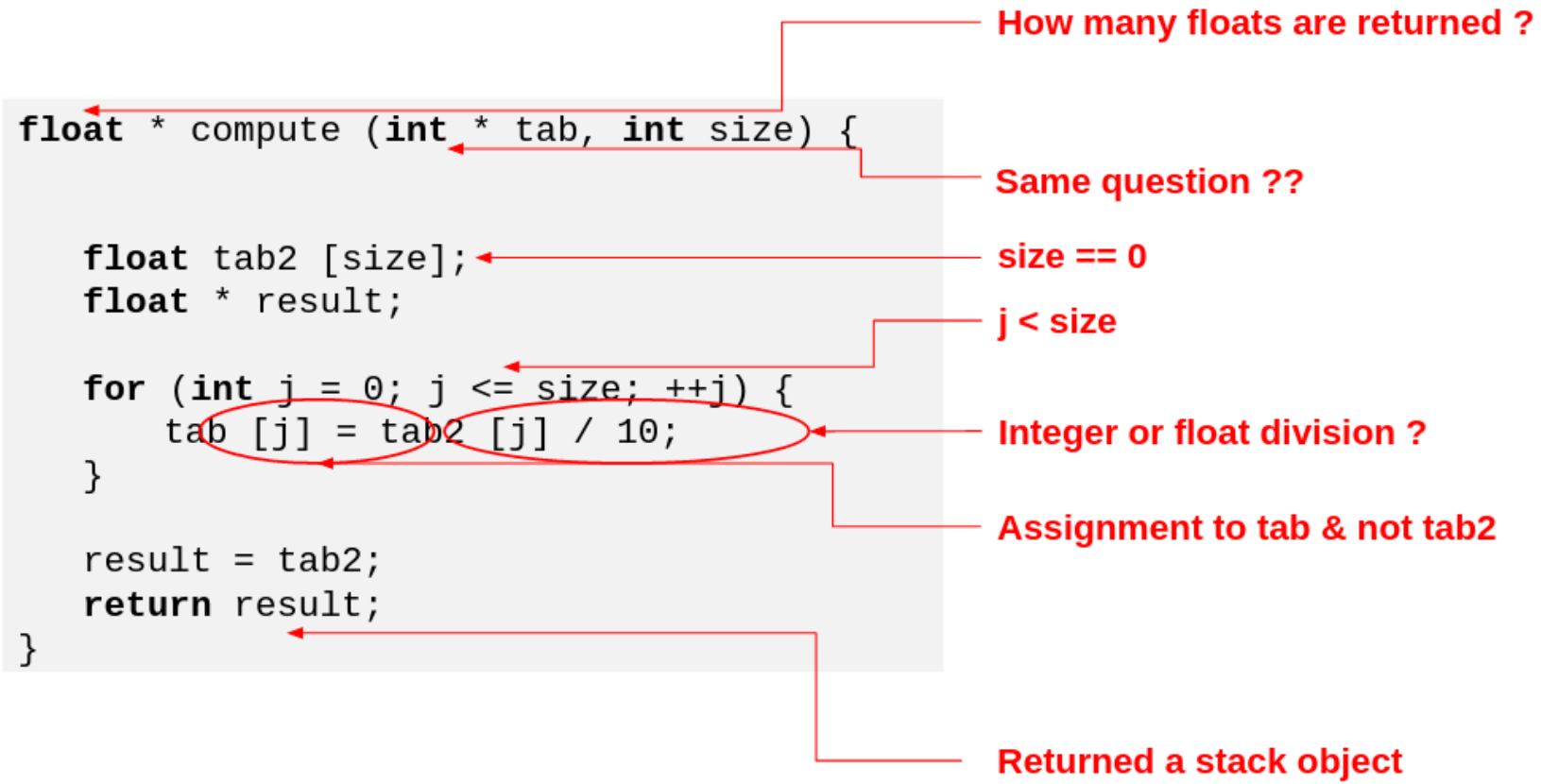
What do the tools do?
Key Tools
A trivial example
The Programming Language
Limitations
No side-effects in expressions
No aliasing of names
Designating SPARK Code

The answer


float * compute (int * tab, int size) {
float tab2 [size];
float * result;
for (int j = 0; j <= size; ++j) {
tab [j] = tab2 [j] / 10;
}
result = tab2;
return result;
}
How many floats are returned ?
Same question ??
size == 0
j < size
Integer or float division ?
Assignment to tab & not tab2
Returned a stack object