Hardware & Software Verification

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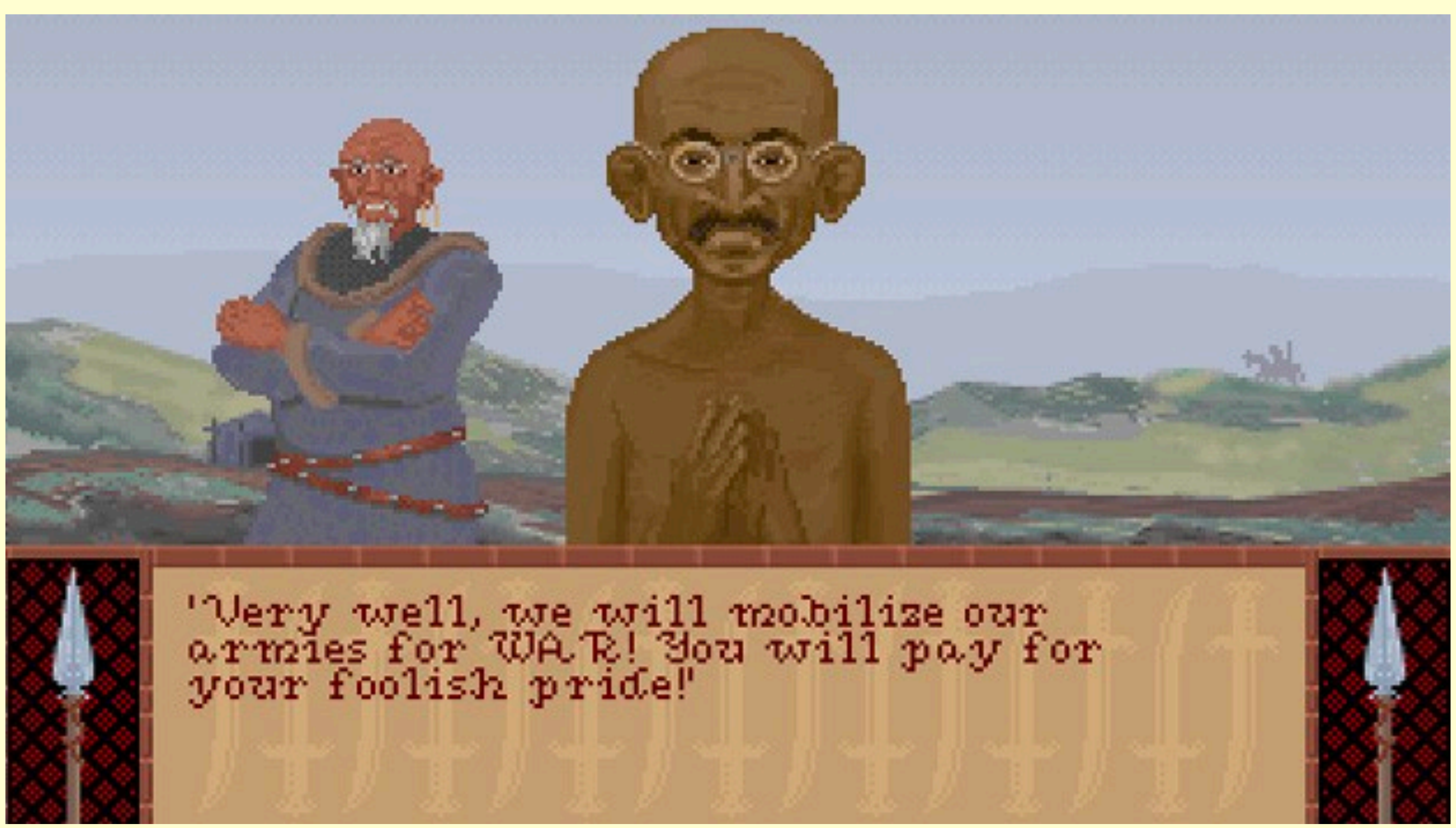
https://github.com/johnwickerson/HSV

Lecture 1
7 October 2025

The correctness problem

```
int main () {
  double a = 4195835;
  double b = 3145727;
  printf ("%f\n", a/b);
}
```



The correctness problem

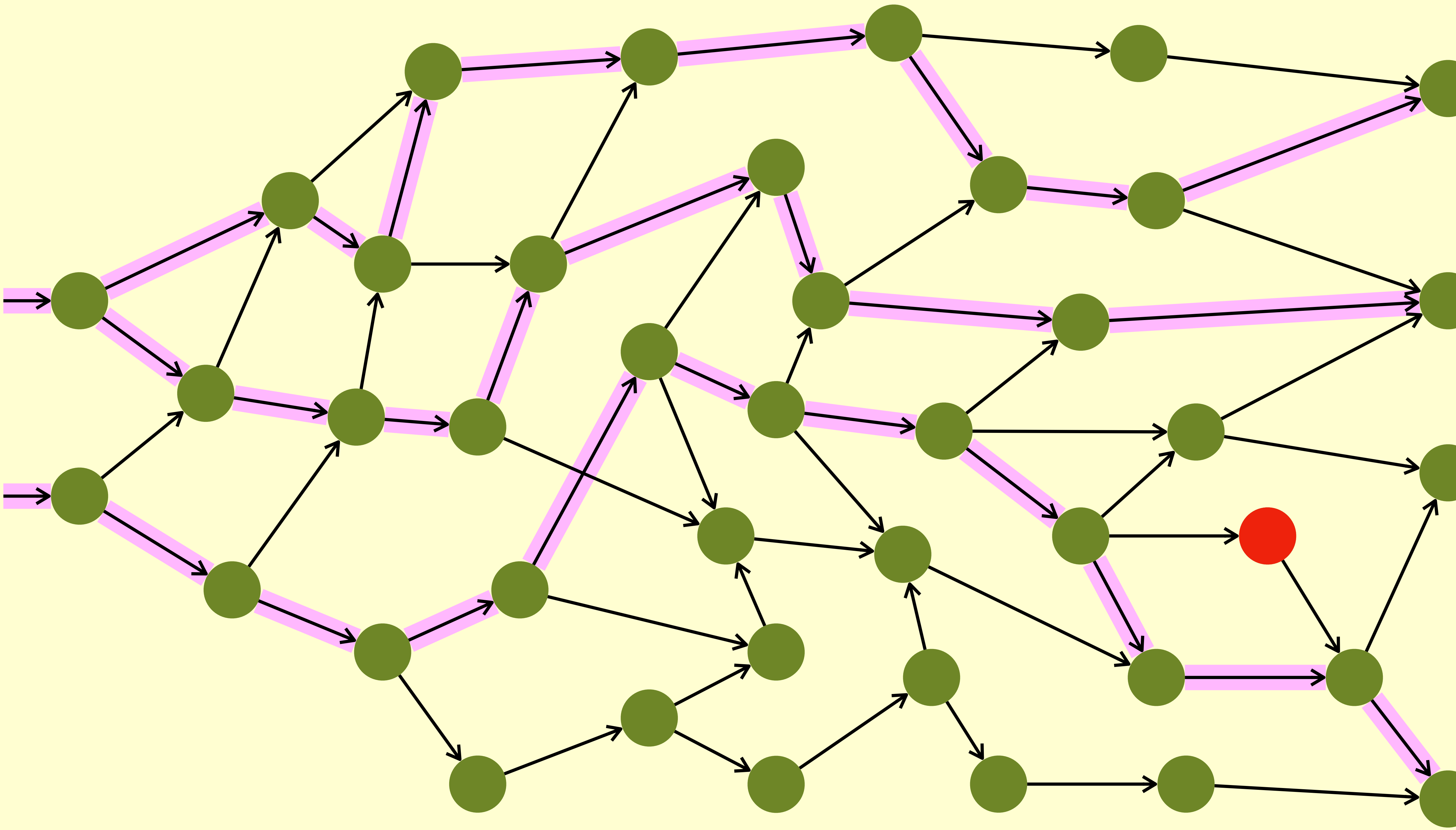
- Computer systems are becoming more **complicated** and more **trusted**.

- This means that being confident that they are correct is increasingly **difficult** and increasingly **important**.

- Traditional **testing** is no longer enough, especially in our manycore era.

- Fortunately there are techniques and tools for **verifying** that a computer system is correct.

The problem with testing



The problem with testing

```
#include <stdlib.h>
#include <stdio.h>

int main(int argc, char **argv) {
  if (argc > 1 && atoi(argv[1]) == 4242) {
    printf ("KABOOM!\n");
    return 1;
  }
}
```

The problem with testing

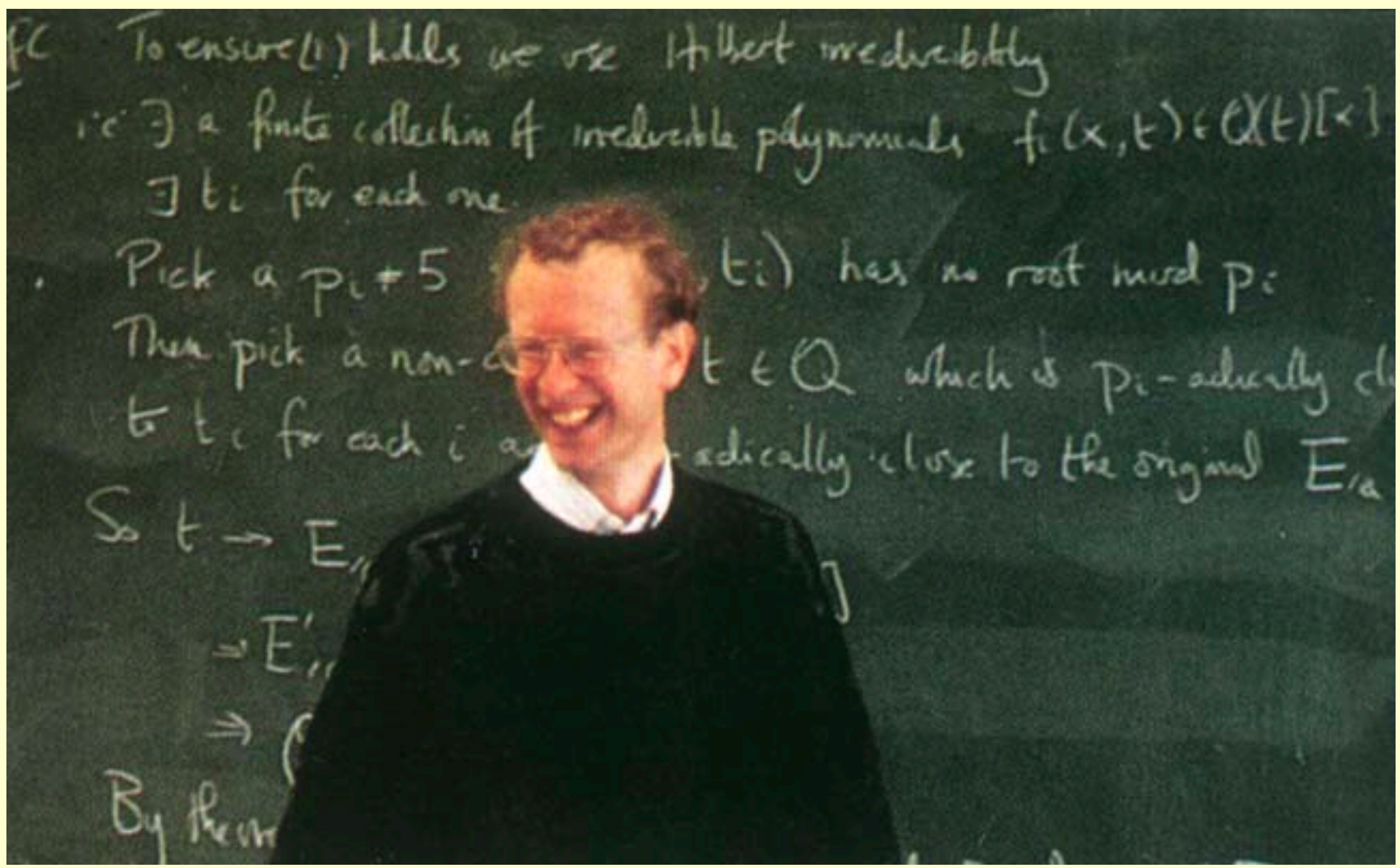
```
int main() {
  int x = 0, y = 0;
  int r1 = 0, r2 = 0;

  x = 1;  ||  r1 = y;
  y = 1;  ||  r2 = x;

  if (r1==1 && r2==0) {
    printf ("KABOOM!\n");
    return 1;
  } else {
    printf ("r1=%d, r2=%d\n", r1, r2);
    return 0;
  }
}
```

- Doesn't cope with **nondeterminism** (e.g. from concurrency).
- Testing results may not be **portable**.

Can we do better?

- Rather than testing on many *particular* inputs, construct a general argument for why the program is correct on *all* inputs.

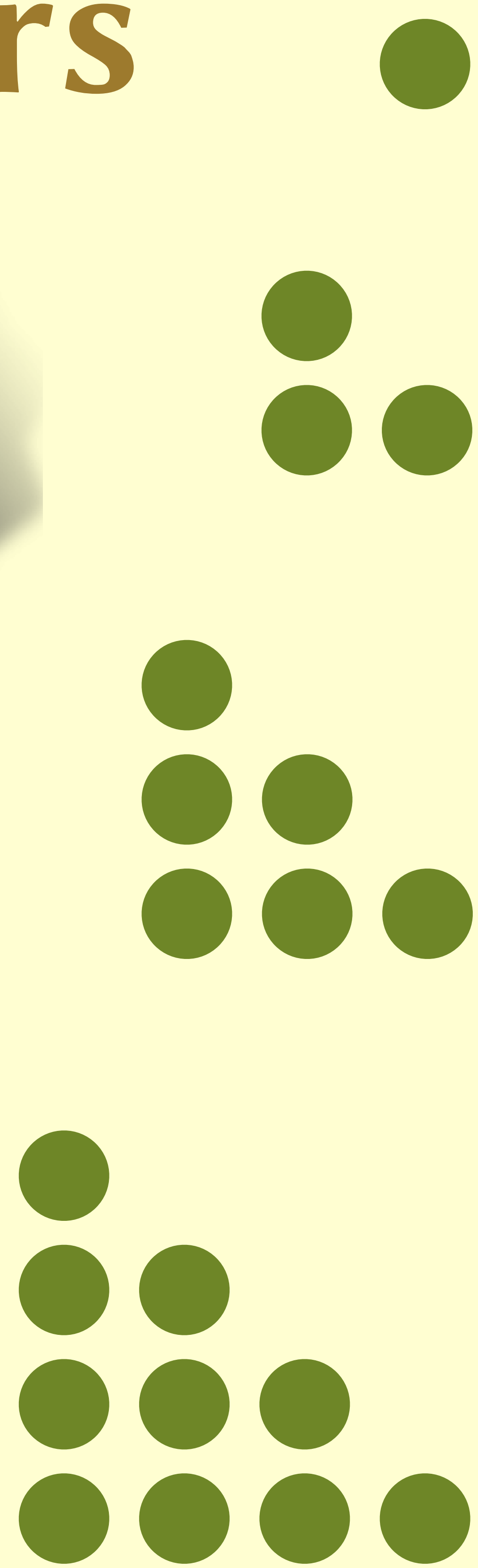
"There is no solution to $a^n + b^n = c^n$ when $n>2$."



Triangle numbers

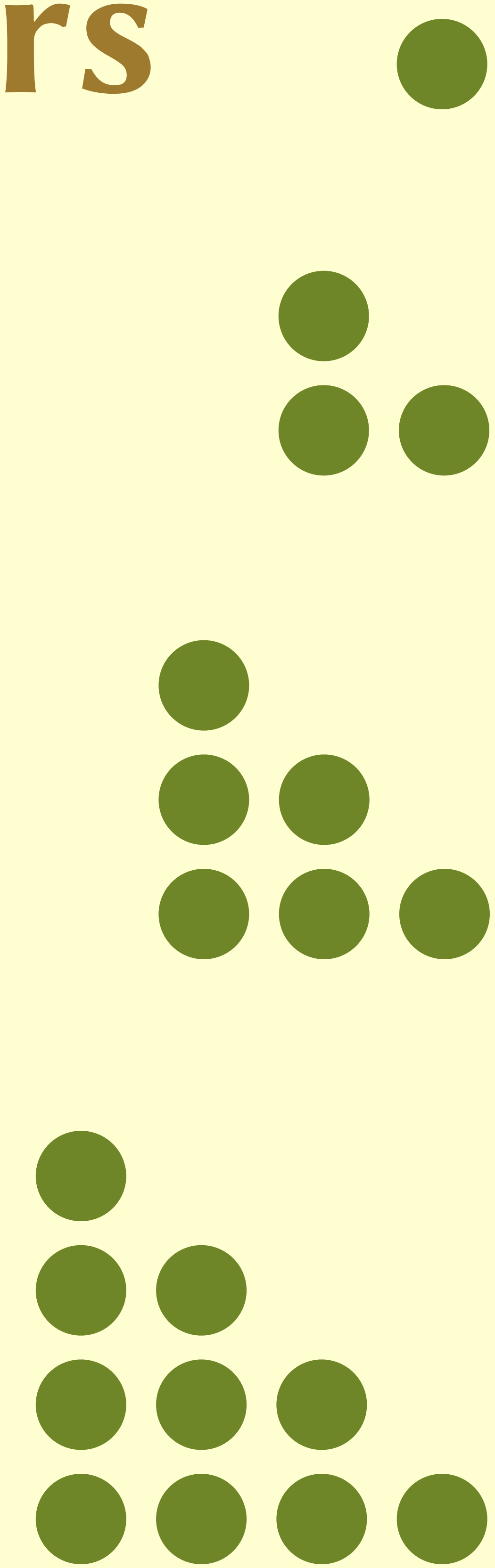
```
#include <stdlib.h>
#include <stdio.h>
#include <assert.h>

int triangle(int n) {
  int t = 0, i = 0;
  while (i < n) {
    i = i+1;
    t = t+i;

  }
  assert(t == n * (n+1) / 2);
  return t;
}

int main(int argc, char **argv) {
  int n = atoi(argv[1]);
  printf("%d\n", triangle(n));
}
```

DEMO



Triangle numbers

```c
#include <stdlib.h>
#include <stdio.h>
#include <assert.h>

int triangle(int n) {
  int t = 0, i = 0;
  while (i < n) {
    i = i+1;
    t = t+i;
    assert(t == i * (i+1) / 2);
  }
  assert(t == n * (n+1) / 2);
  return t;
}

int main(int argc, char **argv) {
  int n = atoi(argv[1]);
  printf("%d\n", triangle(n));
}
```



Dafny

- Developed since 2008 by Rustan Leino and others at Microsoft Research, and nowadays mainly at Amazon.

DEMO

Verifying with Dafny

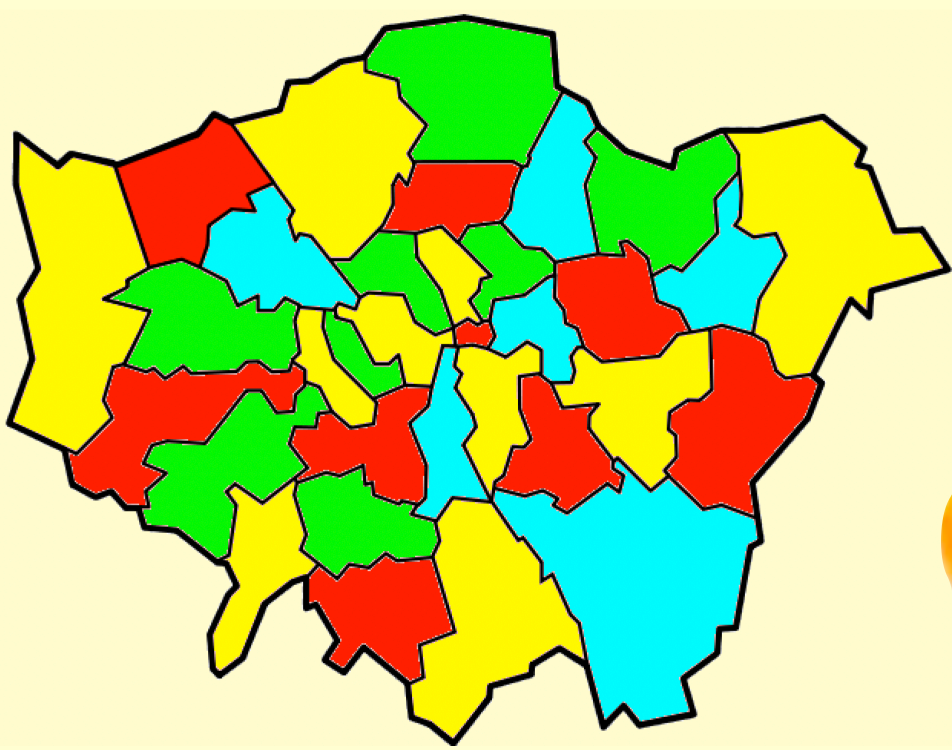
```
method triangle(n:int) returns (t:int)
  requires 0 <= n
  ensures t == n * (n+1) / 2
{
  t := 0;
  var i := 0;
  while i < n
    invariant t == i * (i+1) / 2
    invariant i <= n
  {
    i := i+1;
    t := t+i;
  }
  return t;
}
```

Interactive theorem proving

Rocq

HOL

Isabelle



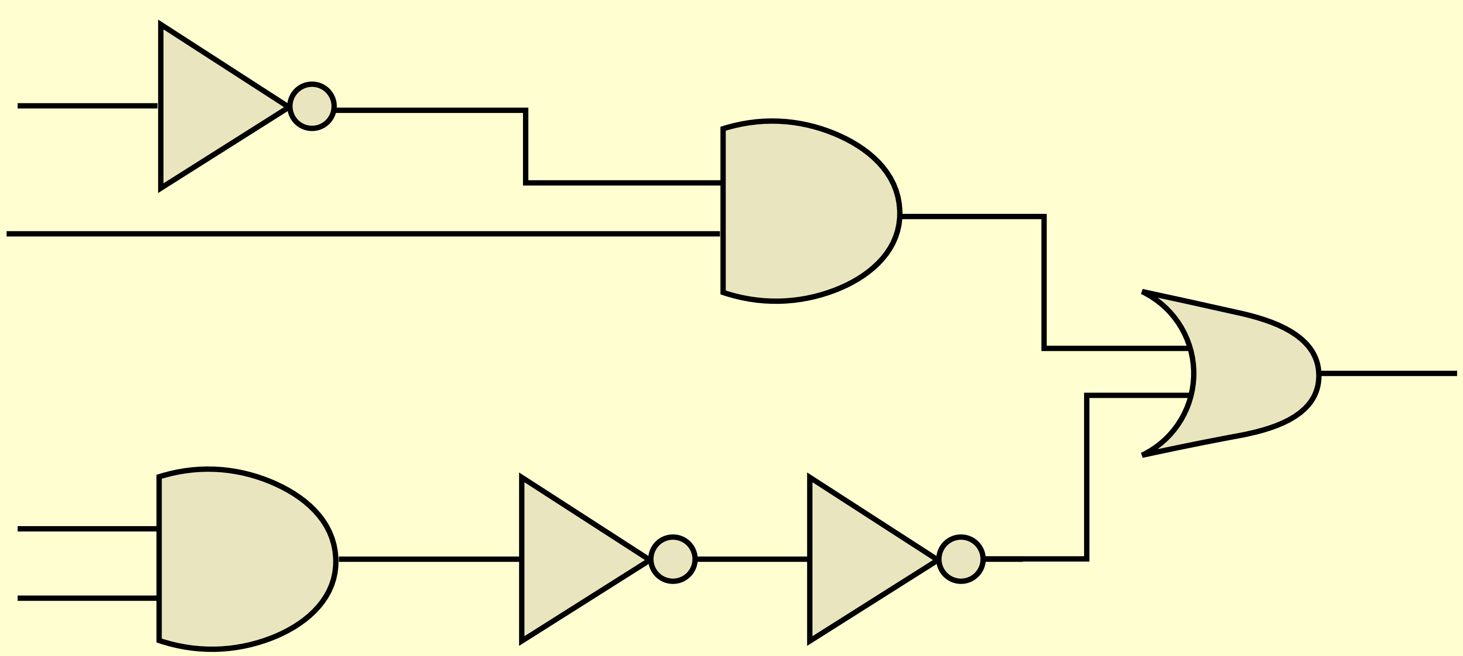
seL4

Security. Performance. Proof.

Interactive theorem proving

- *Your task:* prove a correctness theorem about a little logic synthesiser.

Isabelle



Computer-aided proof

Fully manual — Fully automatic

Rocq	**SymbiYosys**	Facebook Infer
HOL	**Dafny**	Astrée
Isabelle	VCC	Model checking

Aims of the module

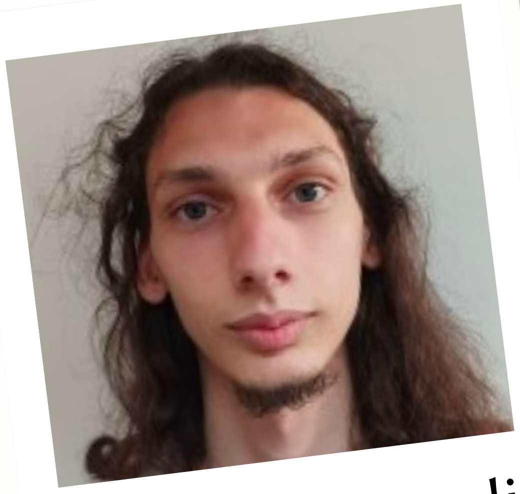
1. Be able to use Dafny to verify simple programs.
    - **Assessment:** I will give you several (increasingly difficult) programs, and you have to verify them using Dafny.
2. Be able to use Isabelle to conduct simple mathematical proofs.
    - **Assessment:** I will give you several (increasingly difficult) theorems, and you have to prove them using Isabelle.
3. Be able to use SymbiYosys to verify simple Verilog designs.
    - **Assessment:** I will give you several (increasingly difficult) Verilog designs, and you have to verify them using SymbiYosys.

Lecture plan

- Introduction
- Proving theorems using Isabelle
- Verifying software using Dafny
- Verifying hardware using SymbiYosys
- Principles of verification
- **Guest lecture from Apple:** Thursday 23 October at 2pm

Teaching support

- **Lectures:** 11am-1pm every Tuesday in room 508.
- **Labs:** 11am-1pm every Thursday in room 403.
- Work in pairs.
- Teaching assistant (from 1 Nov):



Quentin Corradi

A first proof

- **Theorem.** $\sqrt{2}$ is irrational.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