## Coming up: Project Final Presentations

- December 12, 10AM-11:15AM
- CS 150 (in the CS building)
- Think of this as a science fair.
- Each team will get an easel. Bring a poster or printed slides. And laptop for demo.
- Describe and discuss the solution, and demo the implementation.
- Will see (at least) 2 separate judges.
- Chance to see other projects too!

## In-Class Exercise: Reasoning About Mutants

- Today we'll learn how to use Z3, a formal theorem prover
- And we'll use it to help us create tests

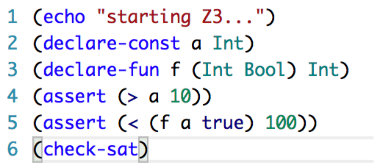
## Z3

- Online interface: https://rise4fun.com/Z3
- Tutorial: https://rise4fun.com/Z3/tutorial/guide
- In-class assignment: https://people.cs.umass.edu/~rjust/courses/2017Fall/CS520/inclass4/inclass4.pdf

## Z3's language

- Z3 uses a a kind of programming language
- Can declare variables and functions, define constraints, print things to the screen, etc.

## Z3’s language



```
(echo "starting Z3...")
(declare-const a Int)
(declare-fun f (Int Bool) Int)
(assert (> a 10))
(assert (< (f a true) 100))
(check-sat)
```

This code prints “starting Z3…” to the screen,

declares a constant a

declares a function Int f (Int Bool)

makes 2 assertions: a > 10 and  f(a, true) < 100

asks “is this possible?”

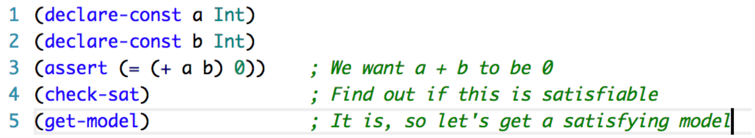
## Encoding programs in constraints

Given a program **P** and a question about **P**, encode them into constraints and ask Z3 to answer the question!

**P**:

```
int P(int a, int b){
    return a + b;
}
```

Question: Can **P** ever return 0?



```
(declare-const a Int)
(declare-const b Int)
(assert (= (+ a b) 0))      ; We want a + b to be 0
(check-sat)                 ; Find out if this is satisfiable
(get-model)                 ; It is, so let's get a satisfying model
```

## Modeling Control Flow

```
int doesStuff(int a, int b, int c){
    if (c == 0    ) return 0;
    if (c == 4    ) return 0;
    if (a + b < c ) return 1;
    if (a + b > c ) return 2;
    if (a * b == c) return 3; // Does this ever happen??
    return 4;
}
```

To ask if doesStuff ever returns 3, encode:

!(c == 0)    !(c == 4)    !(a + b < c)

!(a + b > c)    (a*b==c)

## Modeling Control Flow

```
int doesStuff(int a, int b, int c){
    if (c == 0    ) return 0;
    if (c == 4    ) return 0;
    if (a + b < c ) return 1;
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    if (a * b == c) return 3; // Does this ever happen??
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```
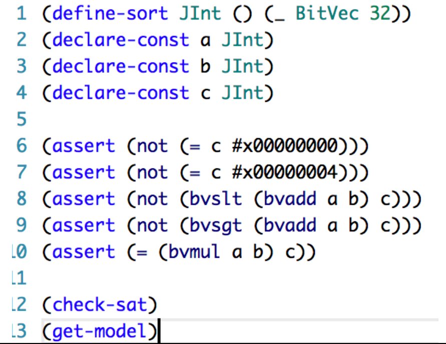
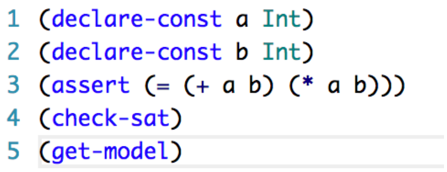



```
(define-sort JInt () (_ BitVec 32))
(declare-const a JInt)
(declare-const b JInt)
(declare-const c JInt)

(assert (not (= c #x00000000)))
(assert (not (= c #x00000004)))
(assert (not (bvslt (bvadd a b) c)))
(assert (not (bvsgt (bvadd a b) c)))
(assert (= (bvmul a b) c))

(check-sat)
(get-model)
```

# Z3 for Mutation Testing

```
int normal_sum(int a, int b){
     return a + b;
}

int mutant_sum(int a, int b){
     return a * b;
}
```

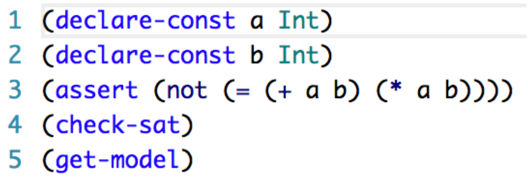


```
(declare-const a Int)
(declare-const b Int)
(assert (= (+ a b) (* a b)))
(check-sat)
(get-model)
```

# We have to frame the question in terms of "Does there exist an input such that…"

- If two functions are identical, then for all inputs, they act the same.
- We can ask if two functions are **NOT** identical.

"Does there exist an input for which they differ?''



```
(declare-const a Int)
(declare-const b Int)
(assert (not (= (+ a b) (* a b))))
(check-sat)
(get-model)
```

# Now, you drive!

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- Online Z3 interface: https://rise4fun.com/Z3
- Tutorial: https://rise4fun.com/Z3/tutorial/guide