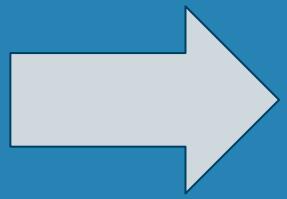
# SPDS: A Scalable Solution for Static Analysis

As presented by:
Bjorn Prollius, Levi Stevenson, and Favour Akinloye

# Porting SPDS to SWAN

SPDS

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lgs@ualberta.ca
tgakinlo@ualberta.ca

# Benefits of porting SPDS to SWAN

**Quickly fix issues without having to wait for the author to fix them**

Use sensible structures for representing the SPDS IR

Eventually wrap the Boomerang solving code with proper exception handling

Increase overall ease of development

prollius@ualberta.ca
lgs@ualberta.ca
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prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# SPDS

**S**ynchronized

**P**ush

**D**own

**S**ystems

Solves the issue of creating an analysis that is flow, context, and field sensitive

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Context Sensitivity

```
Main(){

    x = 0;
c1: x = id(x);

    x = 1;
c2: x = id(x);
}
```

```
id(y){
    z = y;
    return y;
}
```

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Context Sensitivity

Impractical to store every callsite, especially for recursive programs.

We resort to k-limiting

K-limiting is a source of imprecision

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Field Sensitivity

```
a = source();

while(true){
    b = new DS();
    b.f = a;
    a = b;
}
sink(d);
```

The number of field accesses potentially grows beyond manageability

prollius@ualberta.ca
lqs@ualberta.ca
tqakinlo@ualberta.ca

# Combining flow, context and field

A highly precise analysis ideally combines all 3 sensitivities

HOWEVER

Tracking all 3 sensitivities is not scalable.

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Context, Field, and Flow-sensitive

Stored information:

EVERY program statement

prollius@ualberta.ca
lqs@ualberta.ca
tqakinlo@ualberta.ca

# Context, Field, and Flow-sensitive

Stored information:

EVERY program statement

EVERY calling context

prollius@ualberta.ca
lqs@ualberta.ca
tqakinlo@ualberta.ca

# Context, Field, and Flow-sensitive

Stored information:

EVERY program statement

EVERY calling context

For different combinations of field accesses.

prollius@ualberta.ca
lqs@ualberta.ca
tqakinlo@ualberta.ca

# SPDS

Does not resort to k-limiting

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# SPDS

Does not resort to k-limiting

Reduces complexity:
from $|\mathbf{F}|^{3k} \Rightarrow |\mathbf{S}||\mathbf{F}|^2$

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

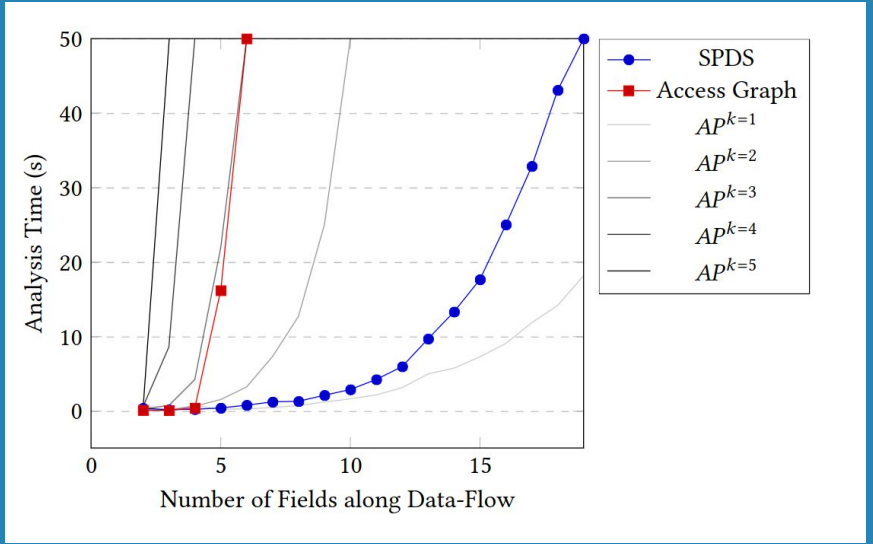
# SPDS

Does not resort to k-limiting

Reduces complexity:
from $|\mathbf{F}|^{3k} \Rightarrow |\mathbf{S}||\mathbf{F}|^2$

Scales similar to:

k=1 with precision of k=∞

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lqs@ualberta.ca
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# Undecidability

False positives exposed only when:

Context-insensitive data-flow path coincides with field-sensitive data-flow

OR

Context-sensitive data-flow coincides with field-insensitive data-flow

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Undecidability

False positives exposed only when:

Context-insensitive data-flow path coincides with field-sensitive data-flow

OR

Context-sensitive data-flow coincides with field-insensitive data-flow

**These corner cases are very rare in practice**

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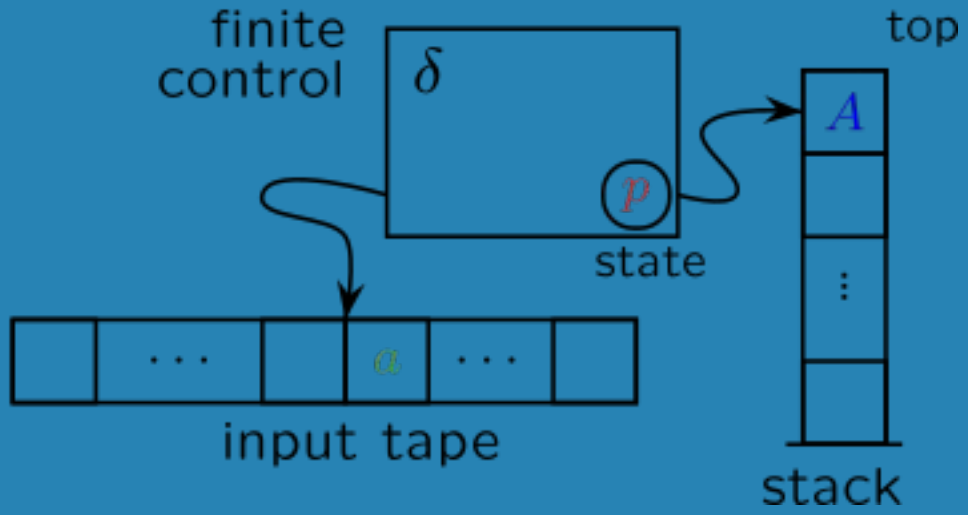
# What is a pushdown system?

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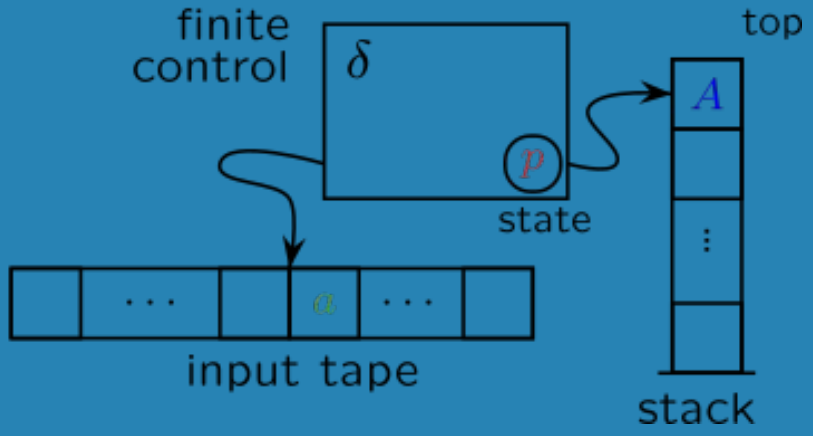
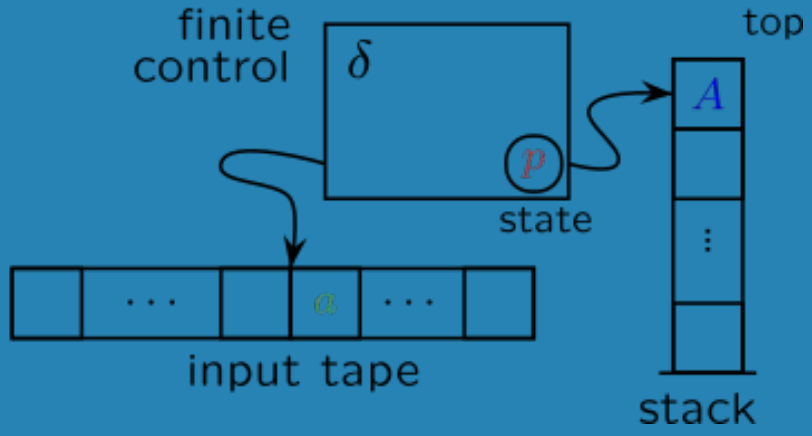
# What is a Synchronized Pushdown System?

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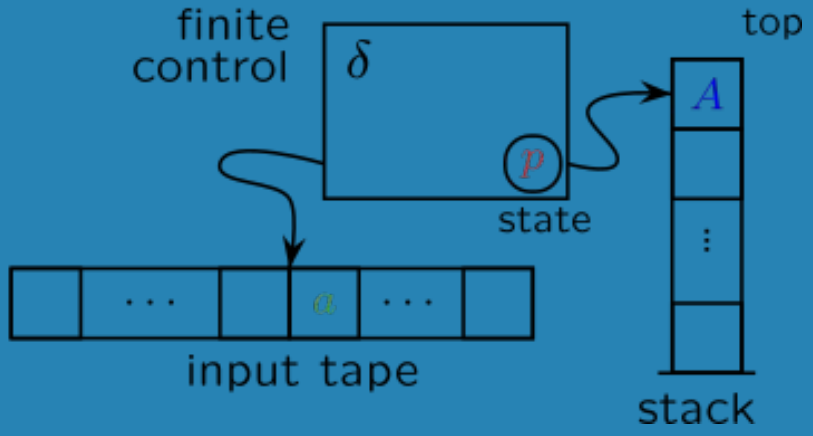


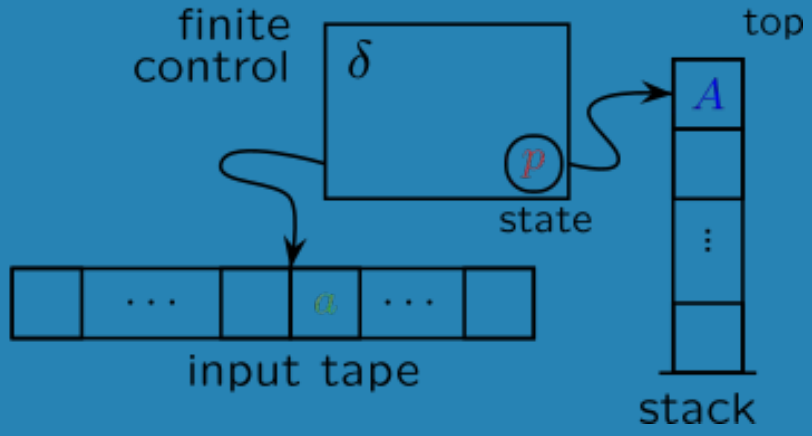


**Context** and **Flow** sensitive Automata

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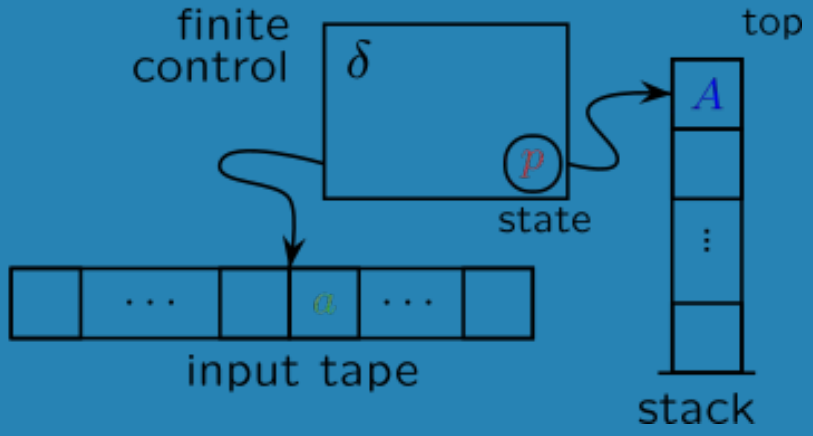


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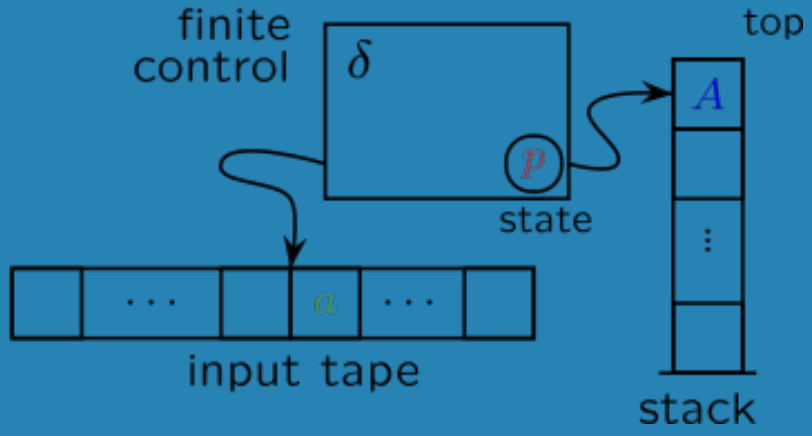


**Field** and **Flow** sensitive Automata

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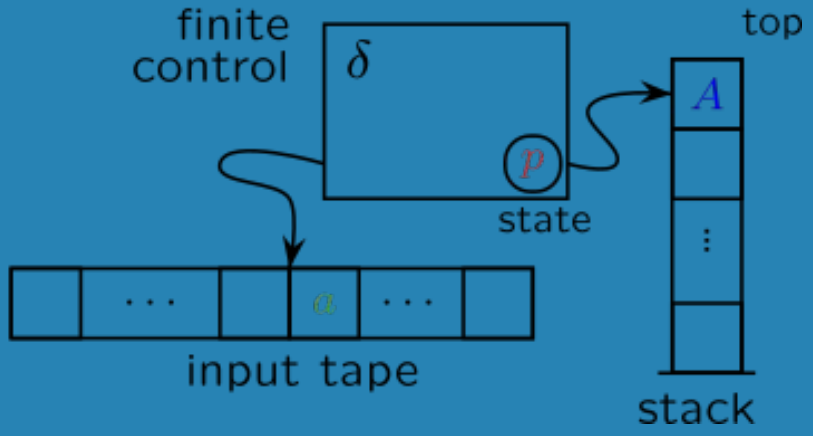


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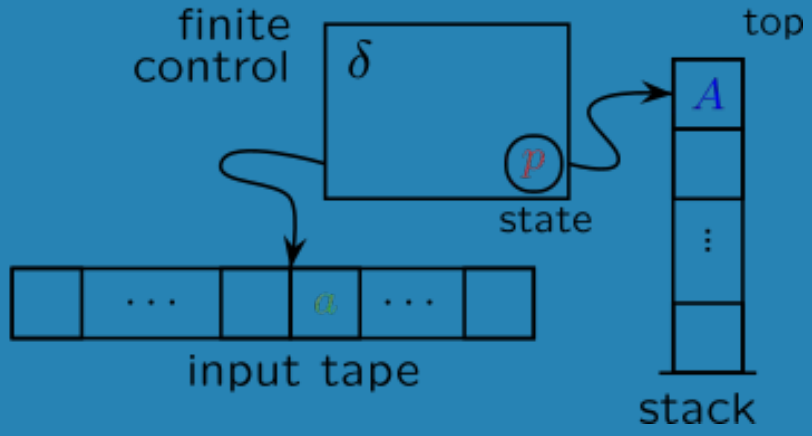


**Field** and **Flow** sensitive Automata

**SYNC POWERS ACTIVATE**

prollius@ualberta.ca
lgs@ualberta.ca
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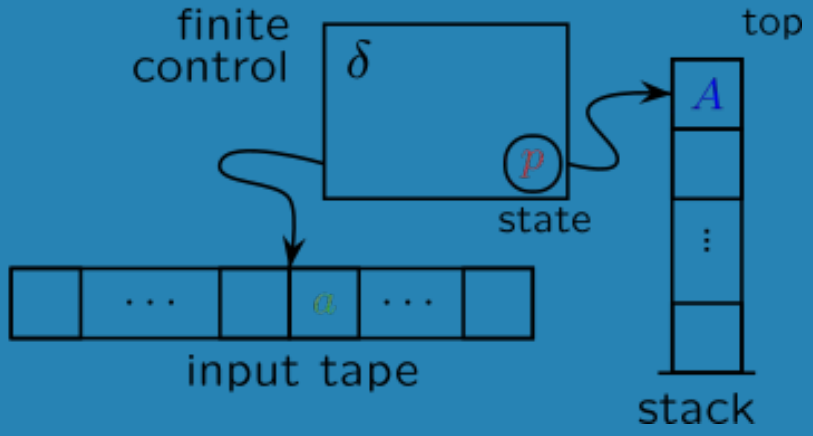
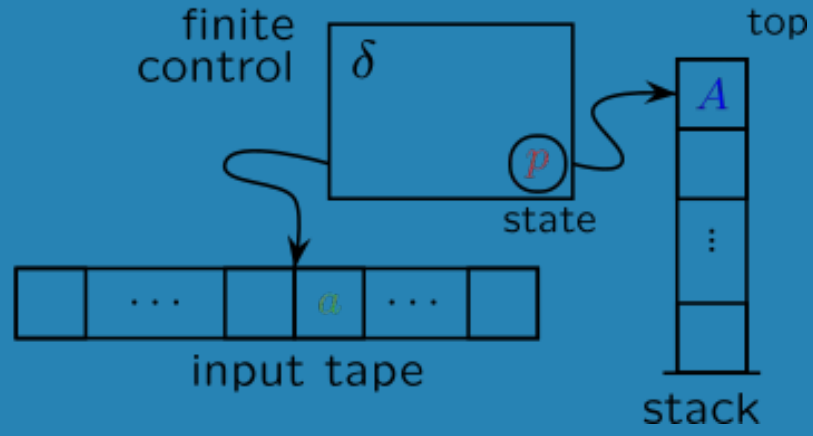
# What is a Synchronized Pushdown System?




**Context** and **Flow** sensitive Automata

Decidable

Context-Sensitive




**Field** and **Flow** sensitive Automata

Field-Sensitive

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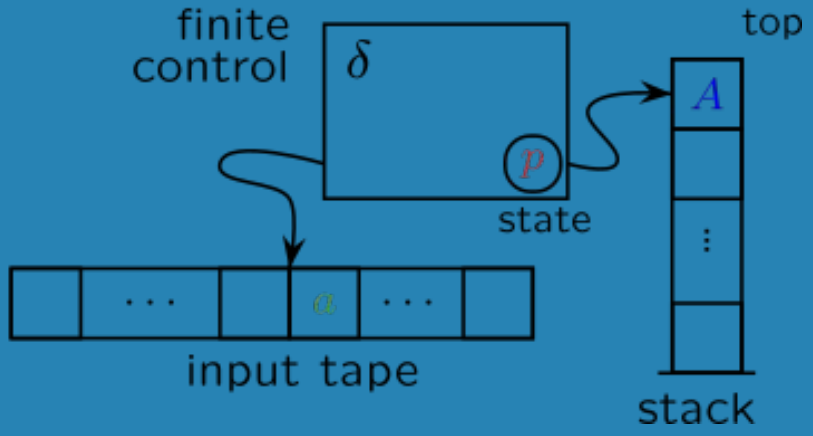
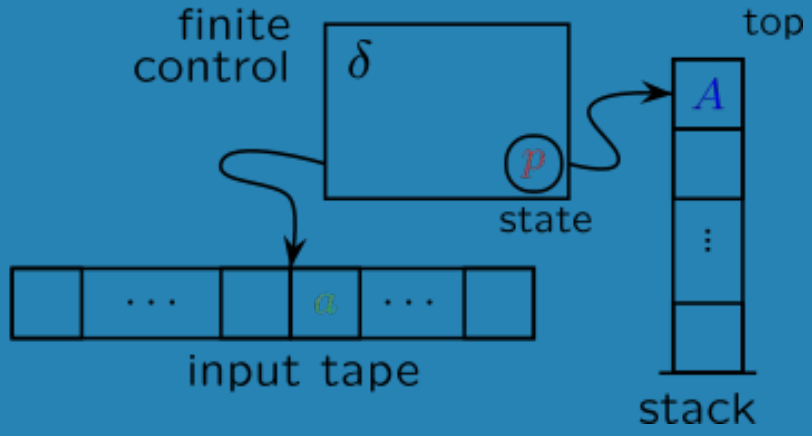
lgs@ualberta.ca
tgakinlo@ualberta.ca

# How does a PDS work?




**Context** and **Flow** sensitive Automata




**Field** and **Flow** sensitive Automata

prollius@ualberta.ca
lqs@ualberta.ca
tqakinlo@ualberta.ca

# Examples!

```
23 main(){
24   A u = new A();
25   A v = u;
26   A w = foo(v);
27 }
```

```
28 foo(A a){
29   if(...){
30     return a;
31   }
32   b = foo(a);
33   return b;
34 }
```

| Normal Rules (main) |
| --- |
| $\langle\!\langle u,24 \rangle\!\rangle \rightarrow \langle\!\langle u,25 \rangle\!\rangle$ |
| $\langle\!\langle u,24 \rangle\!\rangle \rightarrow \langle\!\langle v,25 \rangle\!\rangle$ |
| $\langle\!\langle u,25 \rangle\!\rangle \rightarrow \langle\!\langle u,26 \rangle\!\rangle$ |

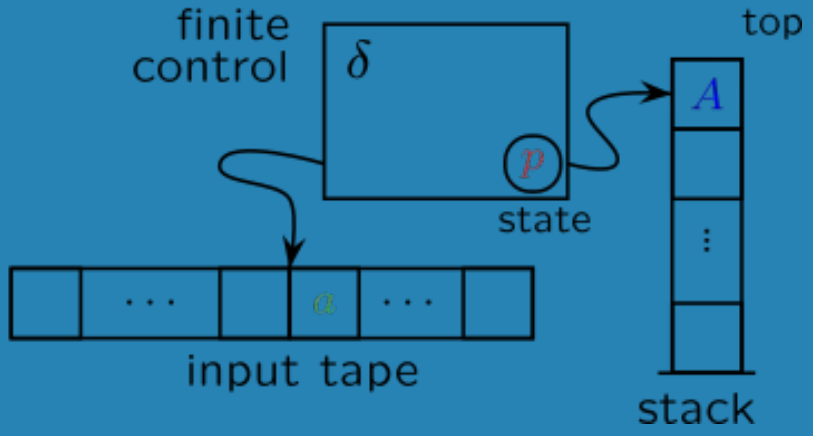
| Normal Rules (foo) |
| --- |
| $\langle\!\langle a,28 \rangle\!\rangle \rightarrow \langle\!\langle a,29 \rangle\!\rangle$ |
| $\langle\!\langle a,29 \rangle\!\rangle \rightarrow \langle\!\langle a,30 \rangle\!\rangle$ |
| $\langle\!\langle a,29 \rangle\!\rangle \rightarrow \langle\!\langle a,31 \rangle\!\rangle$ |
| $\langle\!\langle a,32 \rangle\!\rangle \rightarrow \langle\!\langle a,33 \rangle\!\rangle$ |
| $\langle\!\langle b,32 \rangle\!\rangle \rightarrow \langle\!\langle b,33 \rangle\!\rangle$ |

| Push Rules |
| --- |
| $\langle\!\langle v,25 \rangle\!\rangle \rightarrow \langle\!\langle a,28 \cdot 26 \rangle\!\rangle$ |
| $\langle\!\langle a,31 \rangle\!\rangle \rightarrow \langle\!\langle a,28 \cdot 32 \rangle\!\rangle$ |

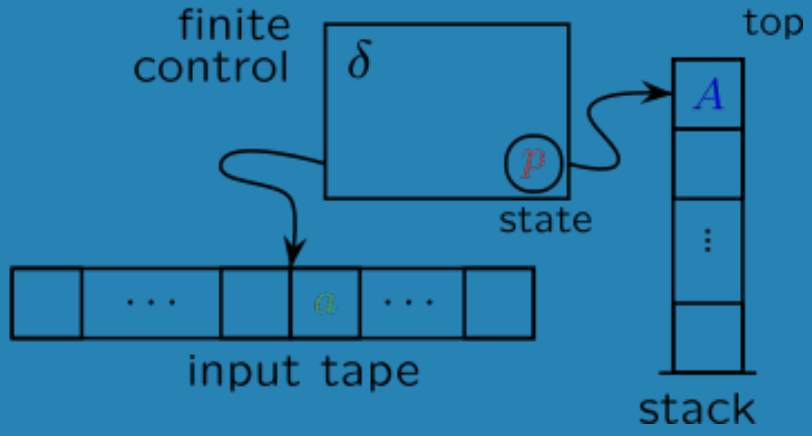
| Pop Rules |
| --- |
| $\langle\!\langle a,30 \rangle\!\rangle \rightarrow \langle\!\langle a,\epsilon \rangle\!\rangle$ |
| $\langle\!\langle a,30 \rangle\!\rangle \rightarrow \langle\!\langle v,\epsilon \rangle\!\rangle$ |
| $\langle\!\langle a,33 \rangle\!\rangle \rightarrow \langle\!\langle a,\epsilon \rangle\!\rangle$ |
| $\langle\!\langle a,33 \rangle\!\rangle \rightarrow \langle\!\langle v,\epsilon \rangle\!\rangle$ |
| $\langle\!\langle b,33 \rangle\!\rangle \rightarrow \langle\!\langle w,\epsilon \rangle\!\rangle$ |
| $\langle\!\langle b,33 \rangle\!\rangle \rightarrow \langle\!\langle b,\epsilon \rangle\!\rangle$ |

Späth, Johannes, Karim Ali, and Eric Bodden. "Context-, flow-, and field-sensitive data-flow analysis using synchronized pushdown systems." Proceedings of the ACM on Programming Languages 3.POPL (2019): 1-29.

# How does a PDS work?




**Context** and **Flow** sensitive Automata



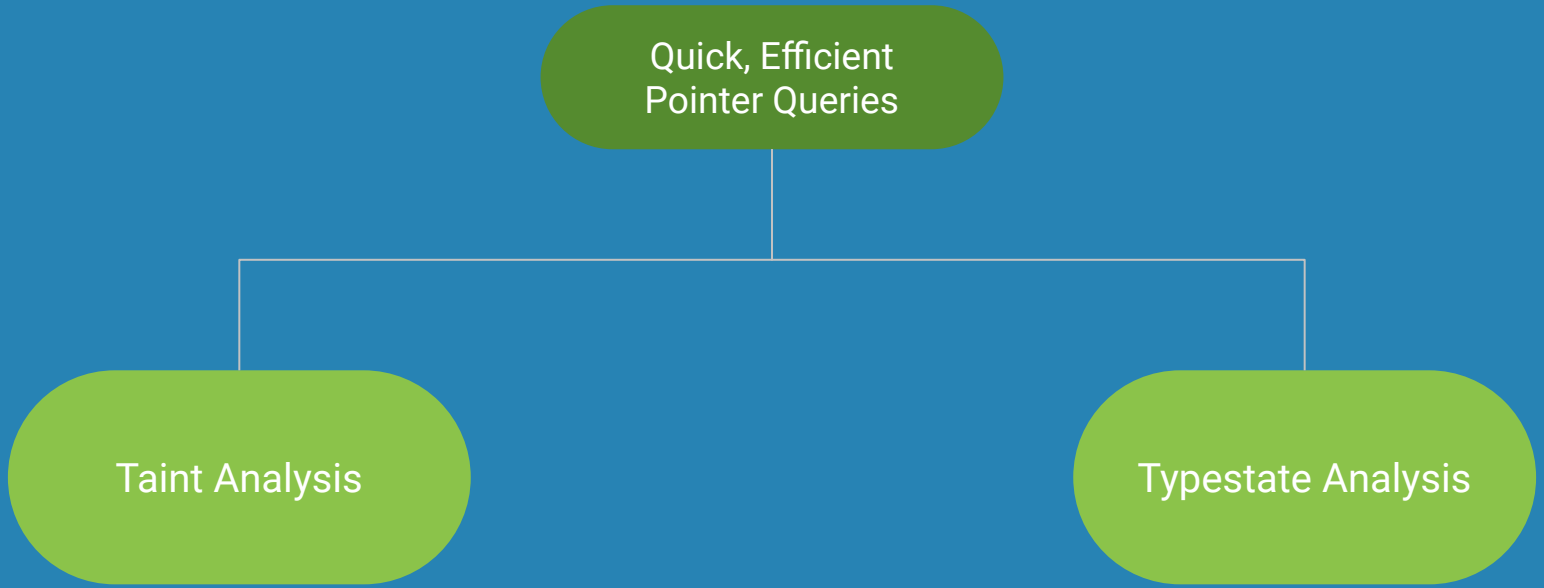

**Field** and **Flow** sensitive Automata

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Why are they used in static analyses like SWAN?

For exactly the reason that they are decidable, context and field sensitive and lets us avoid k-limiting issues in recursive programs.

# SPDS in SWAN: Developer uses

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lqs@ualberta.ca
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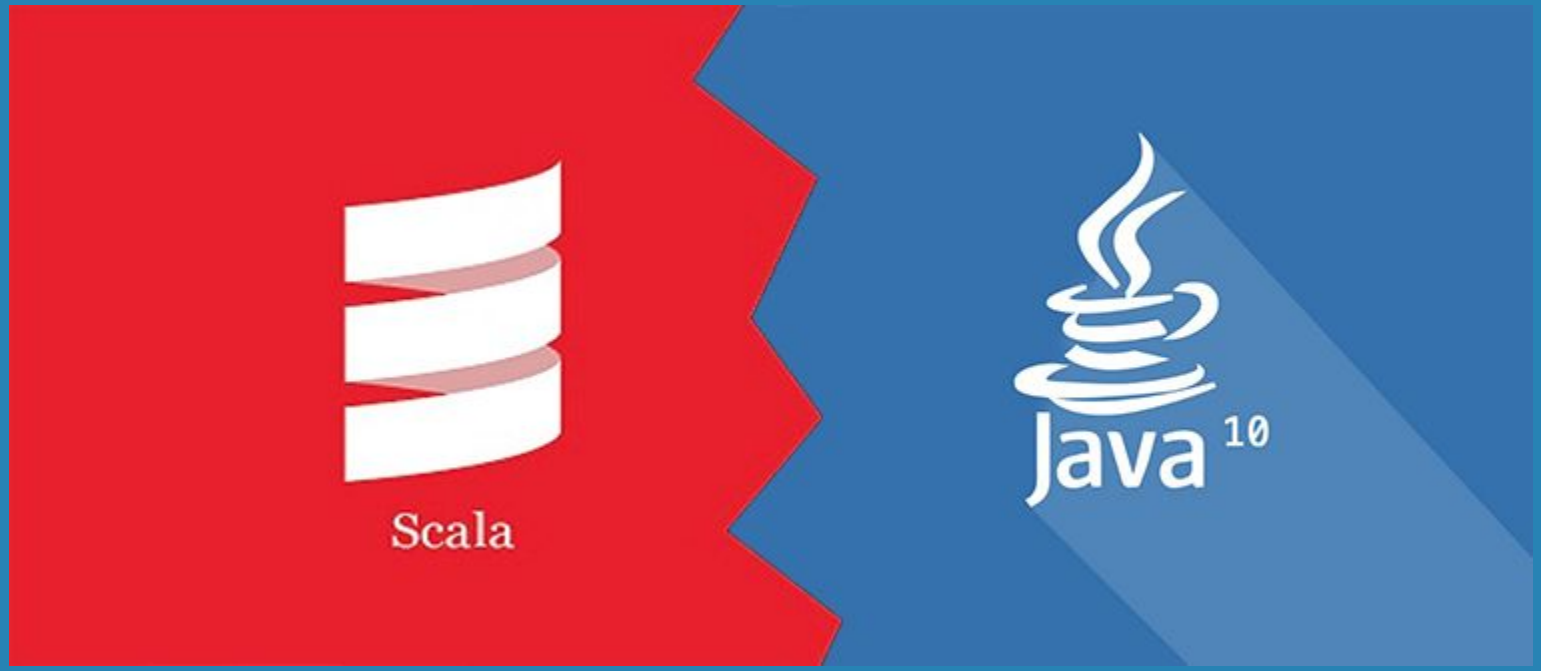
# What benefits are there to using scala over java?




prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

- While Scala has static typing like Java, it integrates type inference, eliminating the need for explicit declaration of variable types and allowing for better code streamlining.

- Scala streamlines concurrent and parallel programming through its actor model and Akka framework, simplifying the development of scalable and efficient programs compared to Java's less effective thread-based model.

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

- Scala seamlessly interoperates with Java, enabling the use of existing Java frameworks and libraries concurrently with Scala programming.

- This encourages a smooth transition from Java to Scala or the concurrent use of both languages within a project.

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

- Additionally, Scala includes advanced language features like pattern matching, high-order functions, and case classes, leading to neater, better-maintained code and aiding in bug resolution.

- We can see this in a small example of a program that determines if a person(class) is an adult or not, written in both Java and Scala

- The Next 3 slides feature the classes used/required of the adult_filter program in Java and Scala

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

Filter.java

```java
import java.util.ArrayList;
import java.util.List;

class Filter {
    static <T> List<T> filter(List<T> list, Predicate<T> predicate) {
        List<T> result = new ArrayList<>();
        for (T item : list) {
            if (predicate.test(item)) {
                result.add(item);
            }
        }
        return result;
    }
}
```

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

Person.java

```java
class Person {
    String name;
    int age;

    Person(String name, int age) {
        this.name = name;
        this.age = age;
    }
}
```

Predicate.java

```java
interface Predicate<T> {
    boolean test(T t);
}
```

# What benefits are there to using scala over java?

adult_filter.scala

```scala
case class Person(name: String, age: Int)

def isAdult(person: Person): Boolean = {
  person.age >= 18
}

val people = List(
  Person("Alice", 25),
  Person("Bob", 17),
  Person("Charlie", 30)
)

val adults = people.filter(isAdult)

adults.foreach {
  case Person(name, _) => println(s"$name is an adult.")
}

```

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

main.scala | adult_filter.scala

main.scala > Main > main > ...

```scala
object Main {
  def main(args: Array[String]): Unit = {
    // Define a case class representing a person
    case class Person(name: String, age: Int)

    // Function to check if a person is an adult
    def isAdult(person: Person): Boolean = {
      person.age >= 18
    }

    // List of people
    val people = List(
      Person("Alice", 25),
      Person("Bob", 17),
      Person("Charlie", 30)
    )

    // Filter adults using a high-order function and pattern matching
    val adults = people.filter(isAdult)

    adults.foreach {
      case Person(name, _) => println(s"$name is an adult.")
    }
  }
}
```

Main.java | Filter.java | Person.java | Predicate.java

Main.java

```java
import java.util.ArrayList;
import java.util.List;
import java.util.function.Predicate;

class Main {
    // Function to check if a person is an adult
    static boolean isAdult(Person person) {
        return person.age >= 18;
    }
    public static void main(String[] args) {
        // List of people
        List<Person> people = new ArrayList<>();
        people.add(new Person("Alice", 25));
        people.add(new Person("Bob", 17));
        people.add(new Person("Charlie", 30));
        // Filter adults using the Filter class and the isAdult predicate
        List<Person> adults = Filter.filter(people, Main::isAdult);
        // Print the names of adults
        for (Person person : adults) {
            System.out.println(person.name + " is an adult.");
        }
    }
}
```

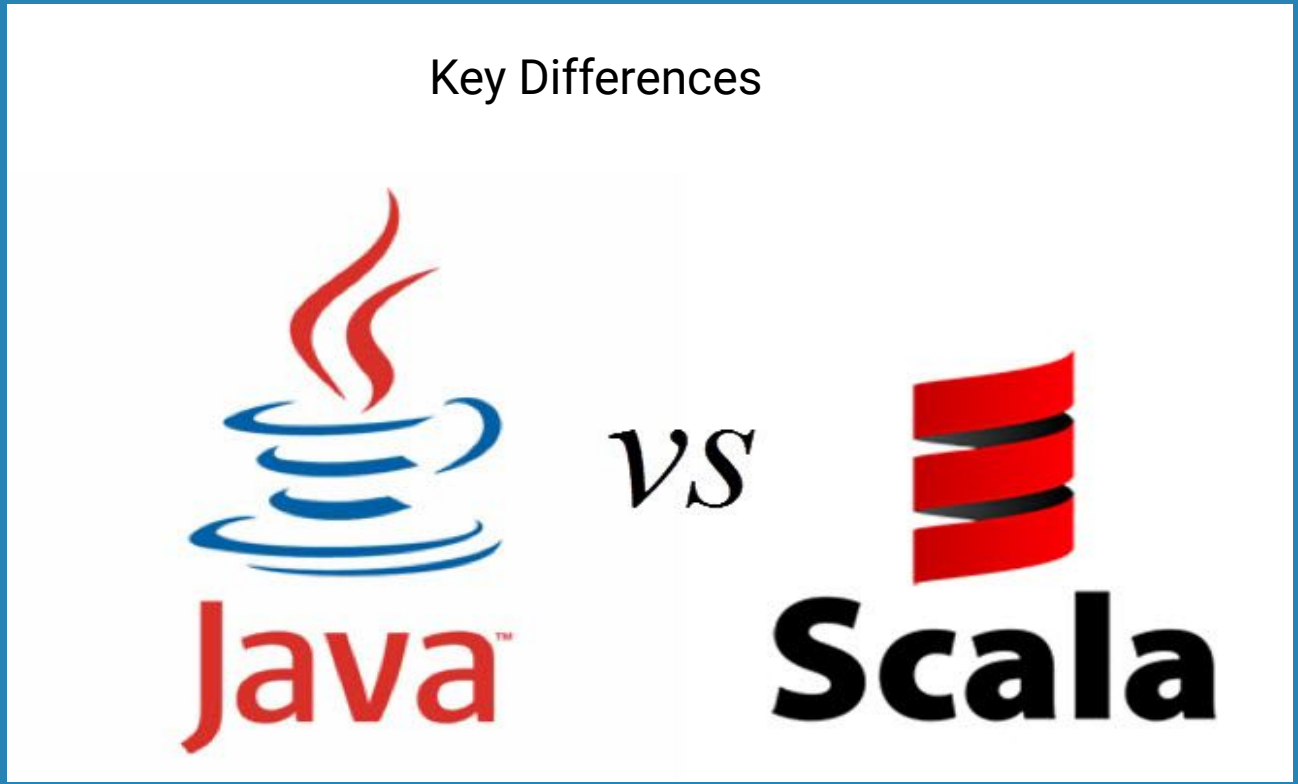
Console | Shell

Run

```
Alice is an adult.
Charlie is an adult.
```

prollius@ualberta.ca
los@ualberta.ca
tgakinlo@ualberta.ca

# What benefits are there to using scala over java?

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lgs@ualberta.ca
tgakinlo@ualberta.ca

# How are each of these contributing to improving the project

- Overall, Scala is more suitable for complex algorithms and intricate data flow analysis, such as the case of SPDS (assuming it refers to some specific domain or application).

- As a hybrid functional and object-oriented language, Scala supports functional programming paradigms that align with the mathematical and algorithmic nature of SPDS.

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Current Progress

All files within the SPDS project have been fully translated

Now working on ironing out some compatibility issues that arose during translation

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca

# Questions?

prollius@ualberta.ca
lgs@ualberta.ca
tgakinlo@ualberta.ca