Lightweight Verification of Array Indexing

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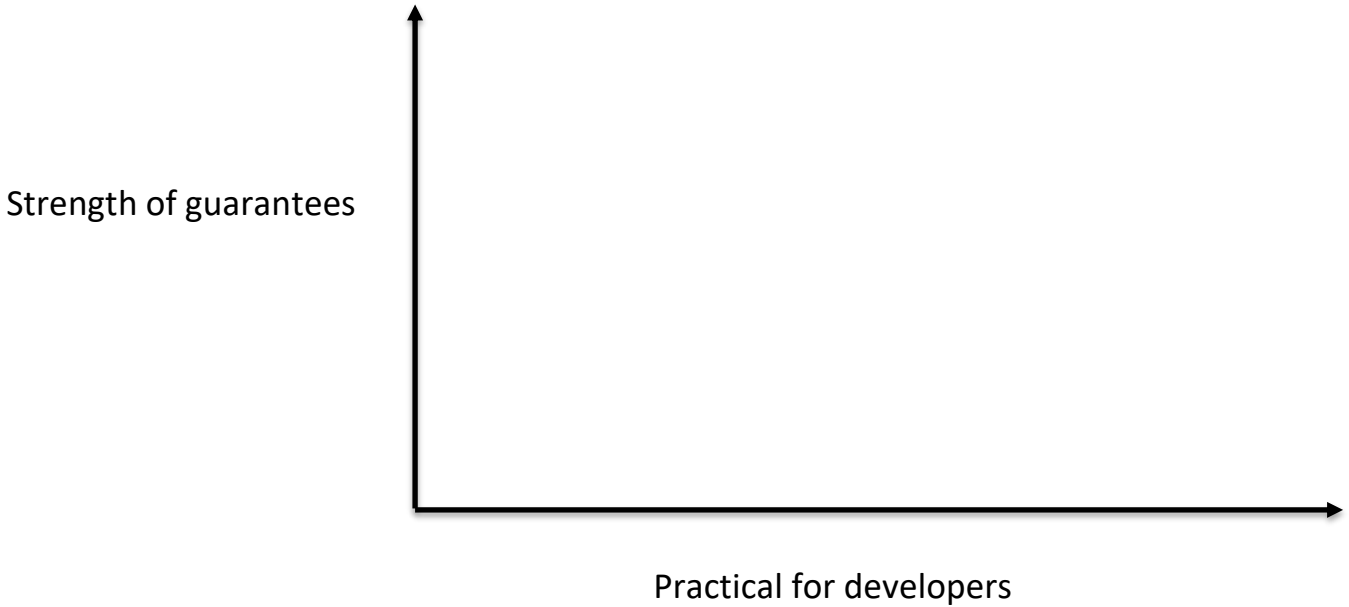
The problem: unsafe array indexing

- In unsafe languages (C): buffer overflow!
- In managed languages (Java, C#, etc.): exception, program crashes

The state of the art



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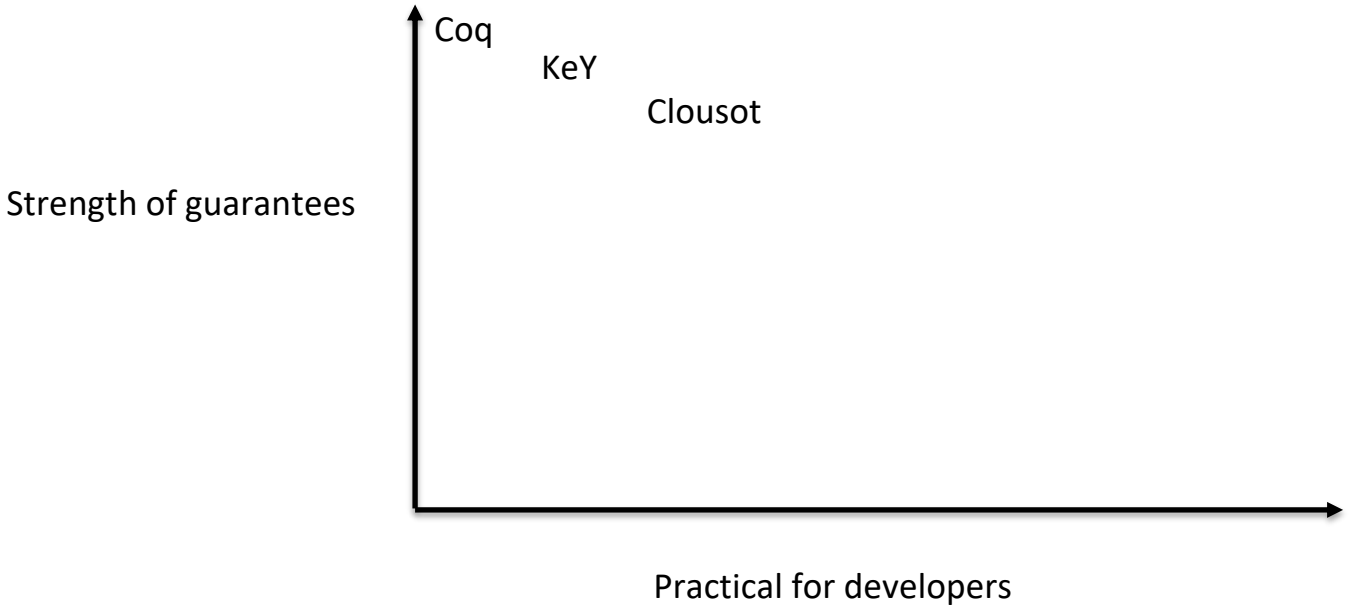

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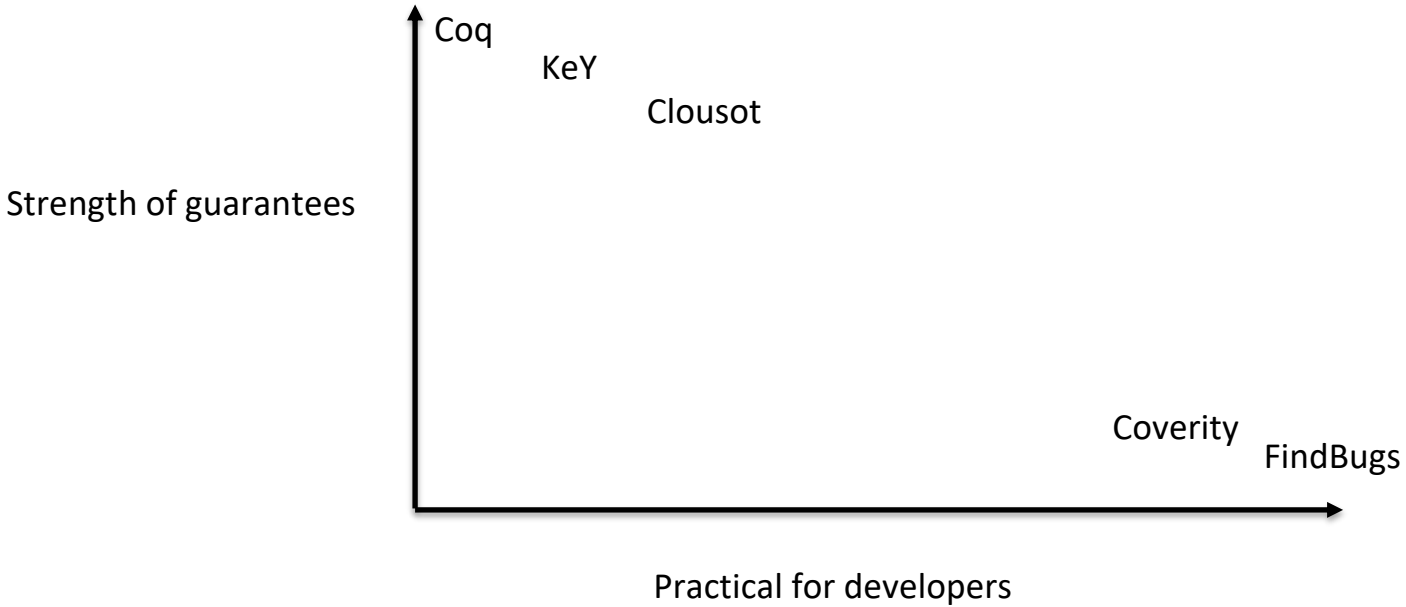

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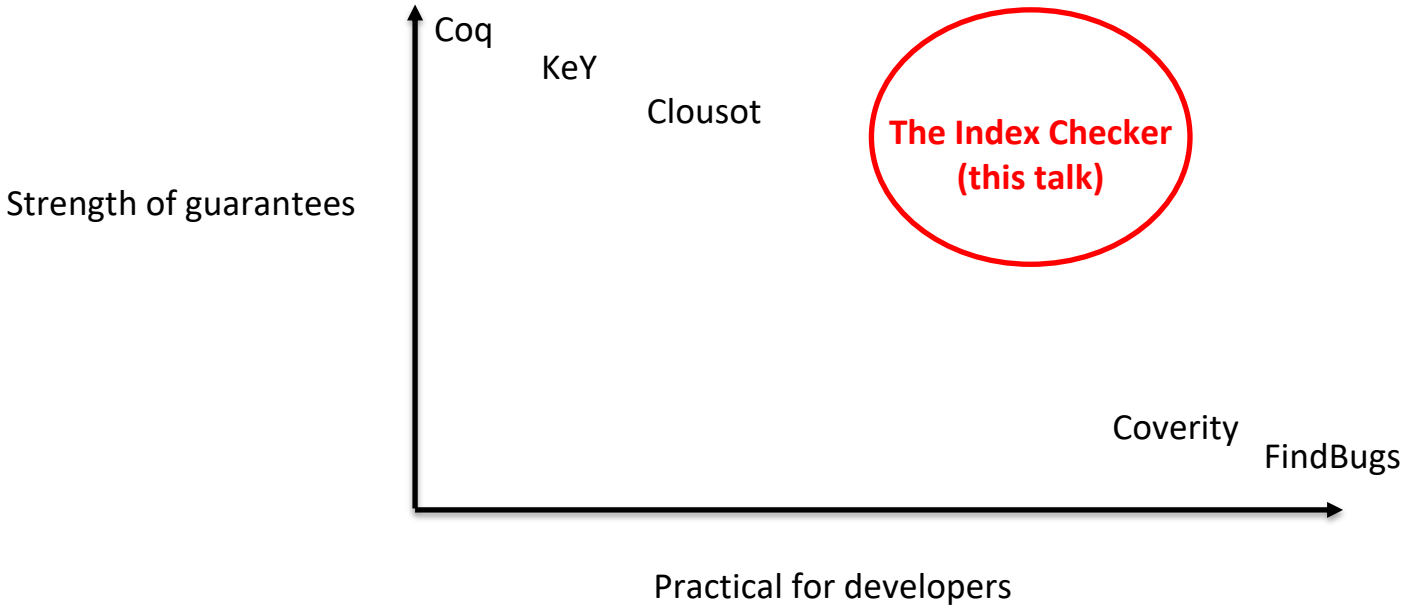

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    - **complex analysis** → harder to implement
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- annotation burden
    - **complex analysis** → complex annotations

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Insight:

Fundamental problem is complex analyses!

Cooperating simple analyses

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- **simpler analysis → simpler to predict**

Proving an array access safe

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T[] a = …;
int i = …;
... a[i] ...
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- i ≥ 0
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T[] a = …;
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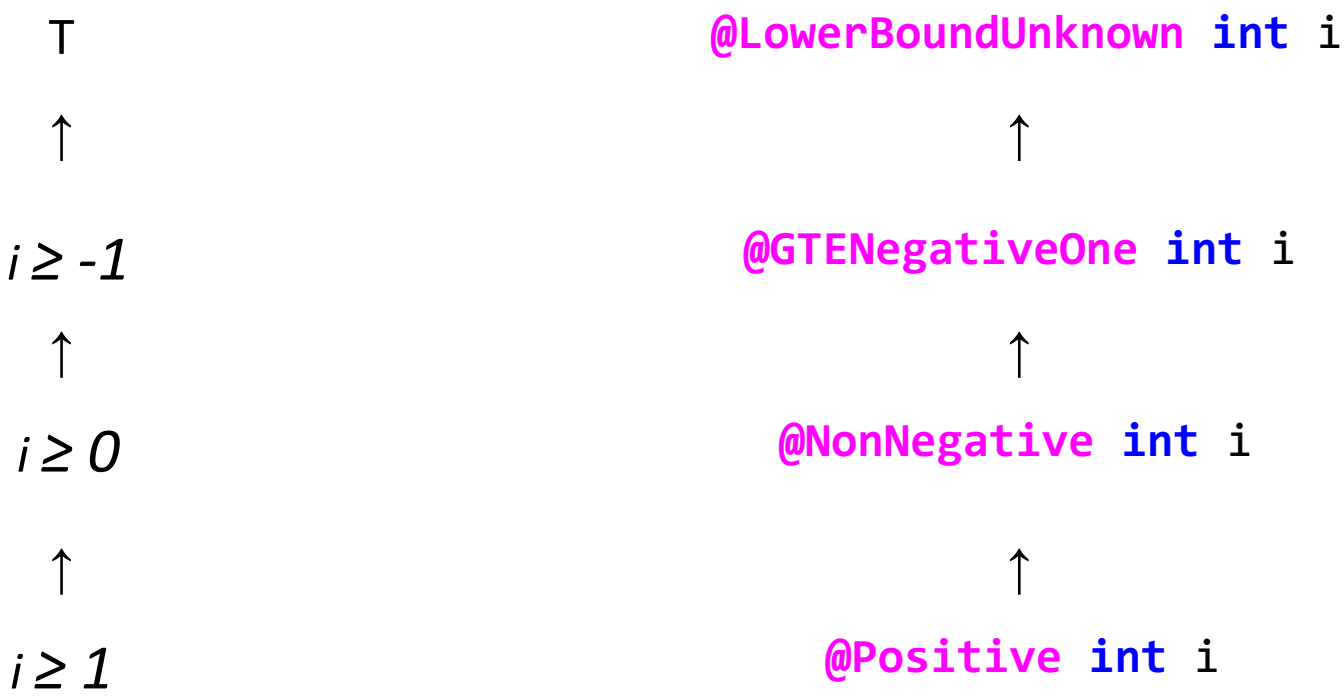
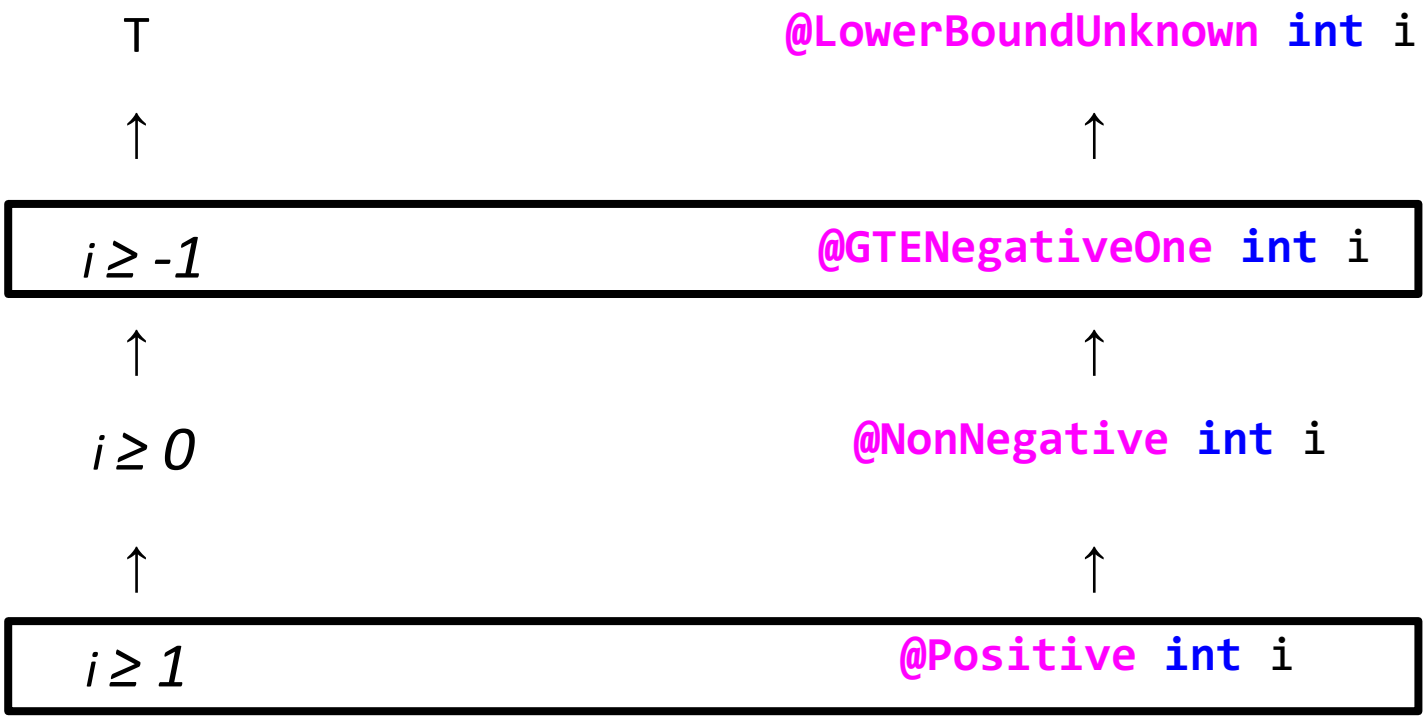
We need to show that:

- ~~`i` is an index for `a`~~
- `i ≥ 0` ← A lower bound on `i`
- `i < a.length` ← An upper bound on `i`

A type system for lower bounds



A type system for lower bounds



A type system for upper bounds

```
if (i >= 0 && i < a.length) {
        a[i] = ...
}
```

A type system for upper bounds

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if (i >= 0 && i < a.length) {
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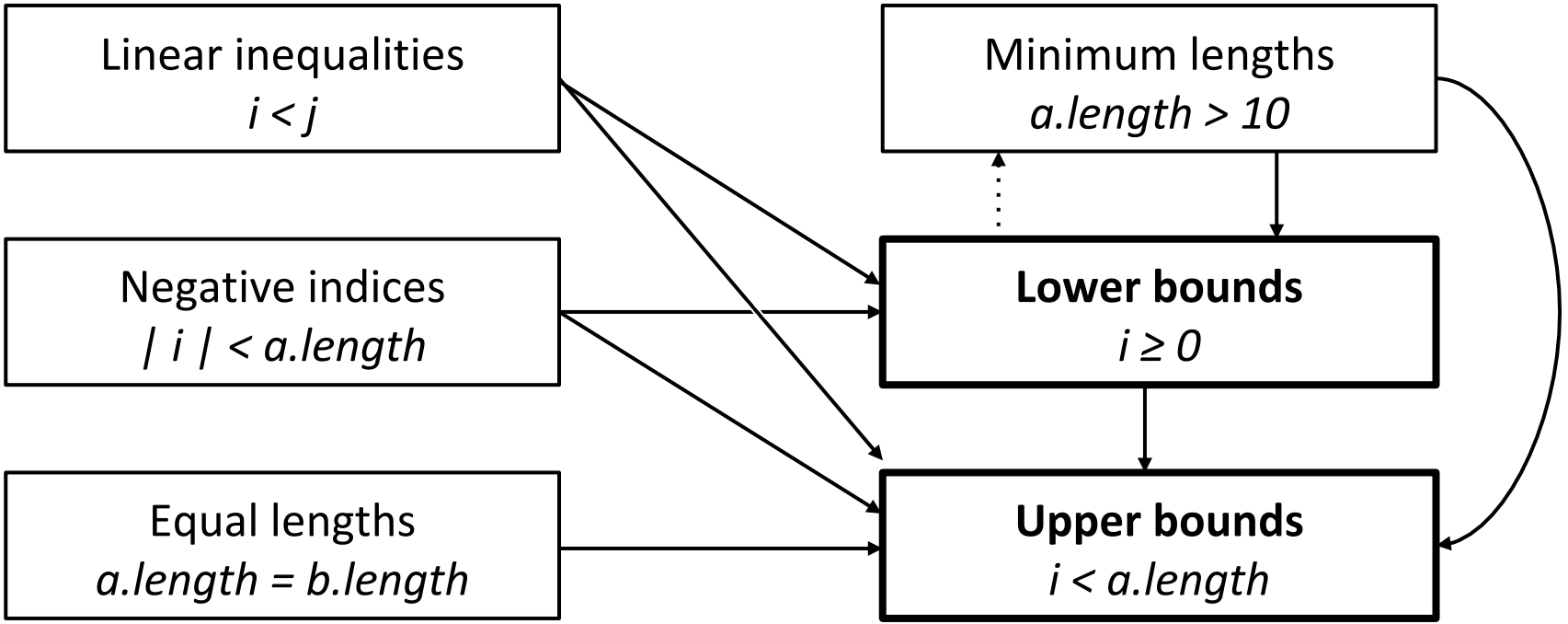
```

i < a.length

```
@LTLengthOf("a") int i
```

Type systems



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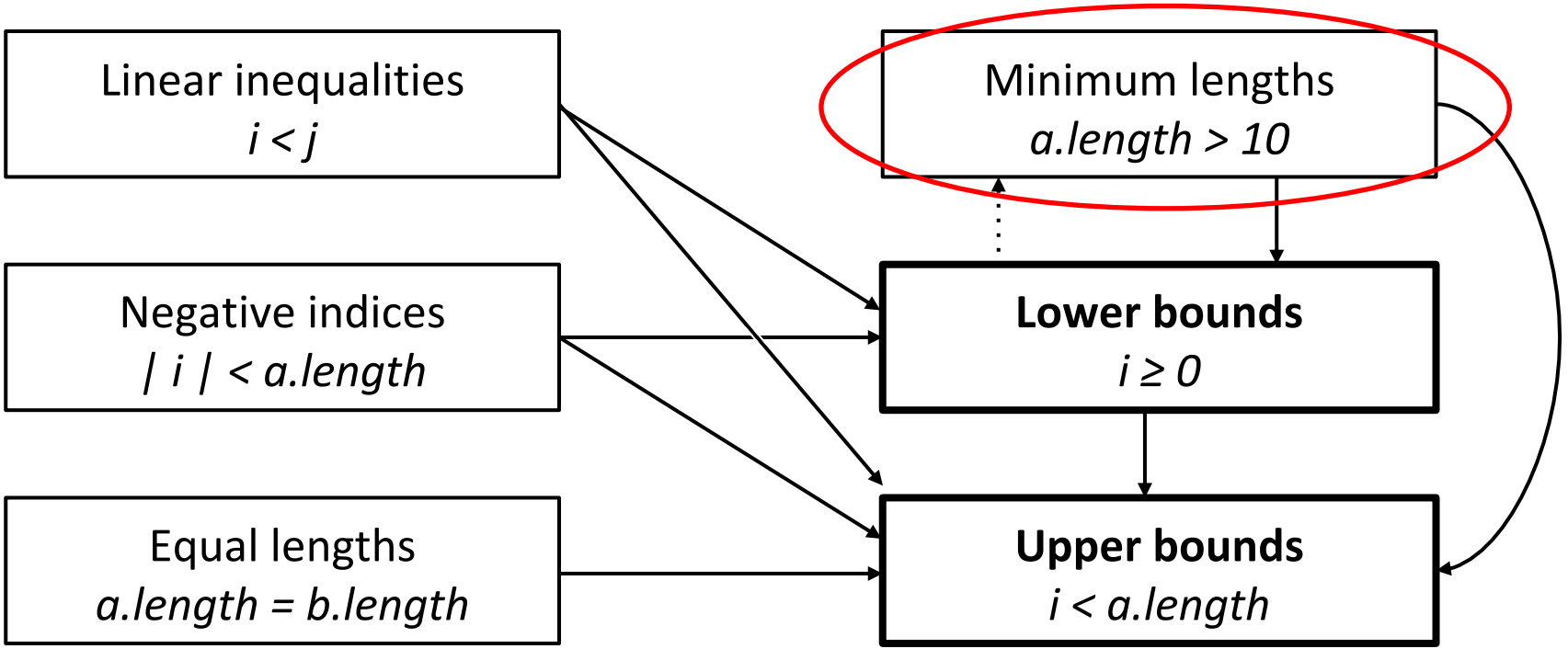

A type system for minimum array lengths

```
if (a.length >= 3) {
        a[2] = ...;
}
```

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```

a.length ≥ i

```
T @MinLen(i) [] a
```

Evaluation

Three case studies:

- **Google Guava (two packages)**
- **JFreeChart**
- **plume-lib**

Comparison to existing tools:

- **FindBugs, KeY, Clousot**

Case Studies

	Guava	JFreeChart	plume-lib	Total
Lines of code	10,694	94,233	14,586	119,503
Bugs found	5	64	20	89
Annotations	510	2,938	241	3,689
False positives	138	386	43	567
Java casts	222	2,740	219	3,181

Comparison to other tools: confirmed bugs

Approach	Types	Bug finder	Verif. w/ solver	Abs. interpret.
Tool	**Index Checker**	**FindBugs**	**KeY**	**Clousot**
True Positives				
False Negatives				
Time (100k LoC)				

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Tool	**Index Checker**	**FindBugs**	**KeY**	**Clousot**
True Positives	18/18	0/18	9/18	16/18
False Negatives	0/18	18/18	1/18	2/18
Time (100k LoC)	~10 minutes	~1 minute	cannot scale	~200 minutes

Using the Index Checker

- Distributed with Checker Framework

www.checkerframework.org

Contributions

- A methodology: simple, cooperative type systems
- An analysis: abstractions for array indexing
- An implementation and evaluation for Java
- Verifying the absence of array bounds errors in real codebases (and finding bugs in the process!)