Pluggable Type Inference for Free

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- **Pluggable typecheckers** extend a host type system
- Our contribution: a **new approach for type inference** specialized to pluggable typecheckers

Background: Pluggable Types

```
int x
```

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```
@Positive int x
```

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```
@Negative int x
```

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```
@NonConstant int x
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- downside: **manual annotation** of legacy codebases

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Are there other things in typecheckers that are type-system-agnostic?

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Fortress getFort(City city) {
  Fortress result = null;
  if (city != LUXEMBOURG)
      result = fortDB.get(city);
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dataflow detects that `result` is `@Nullable` here ...

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… but `@NonNull` here (assuming `get()` cannot return null)

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Q: Does dataflow **already** know whether the return type is `@NonNull` or `@Nullable`? YES!

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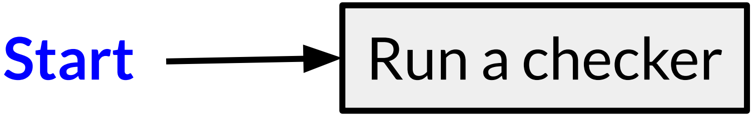

Start

Run a checker

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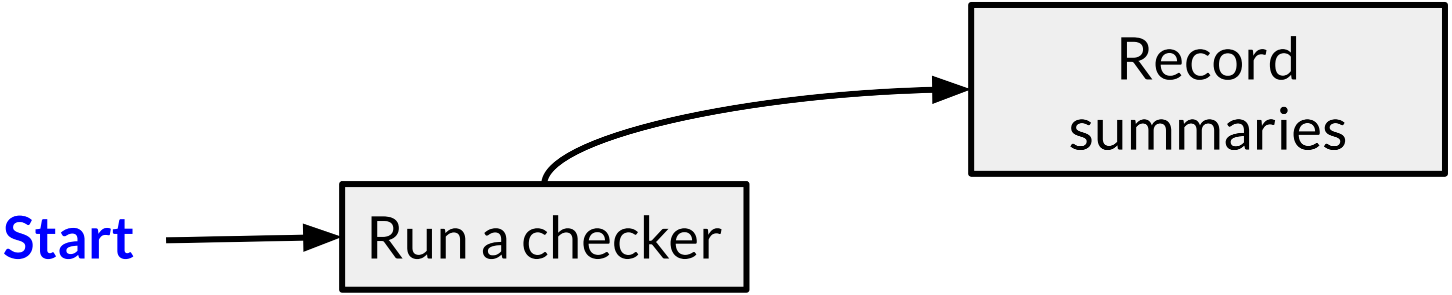

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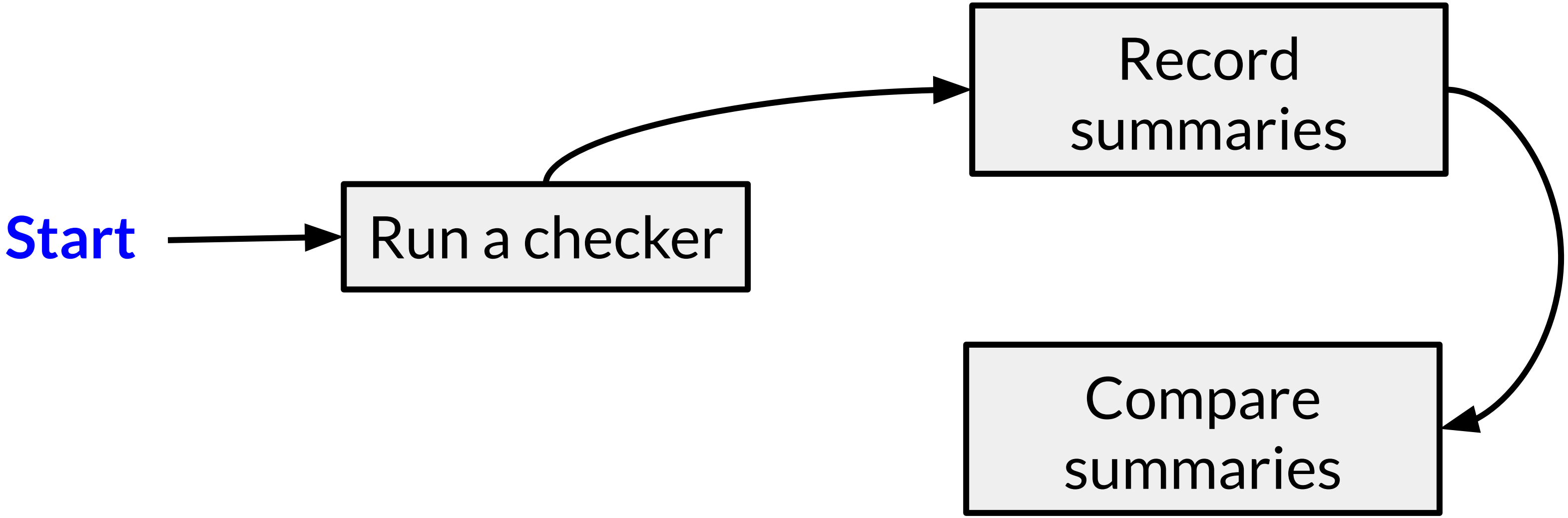

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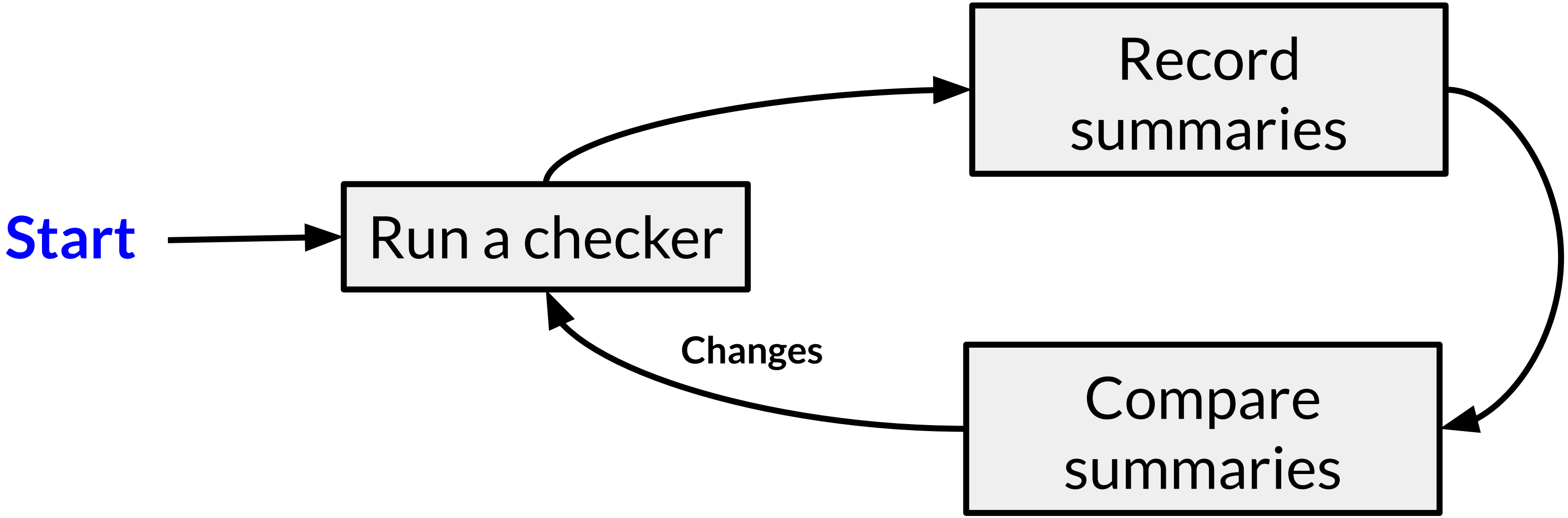

Start

Run a checker

Record summaries

Compare summaries

Changes

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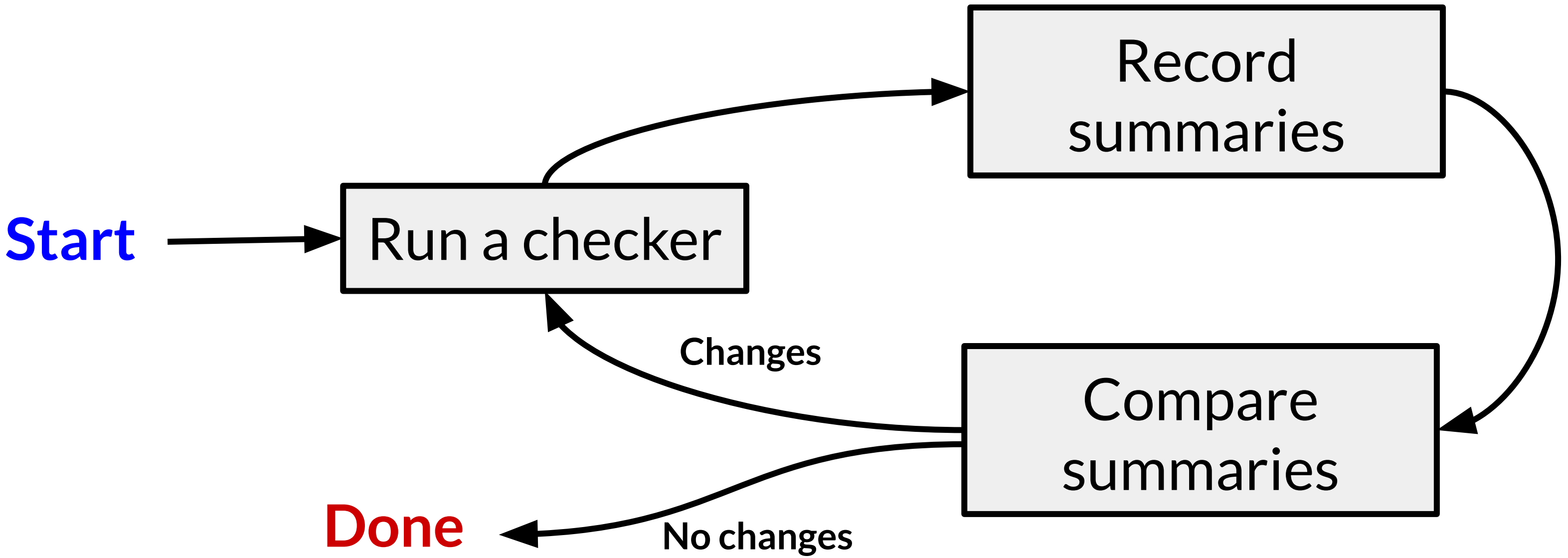

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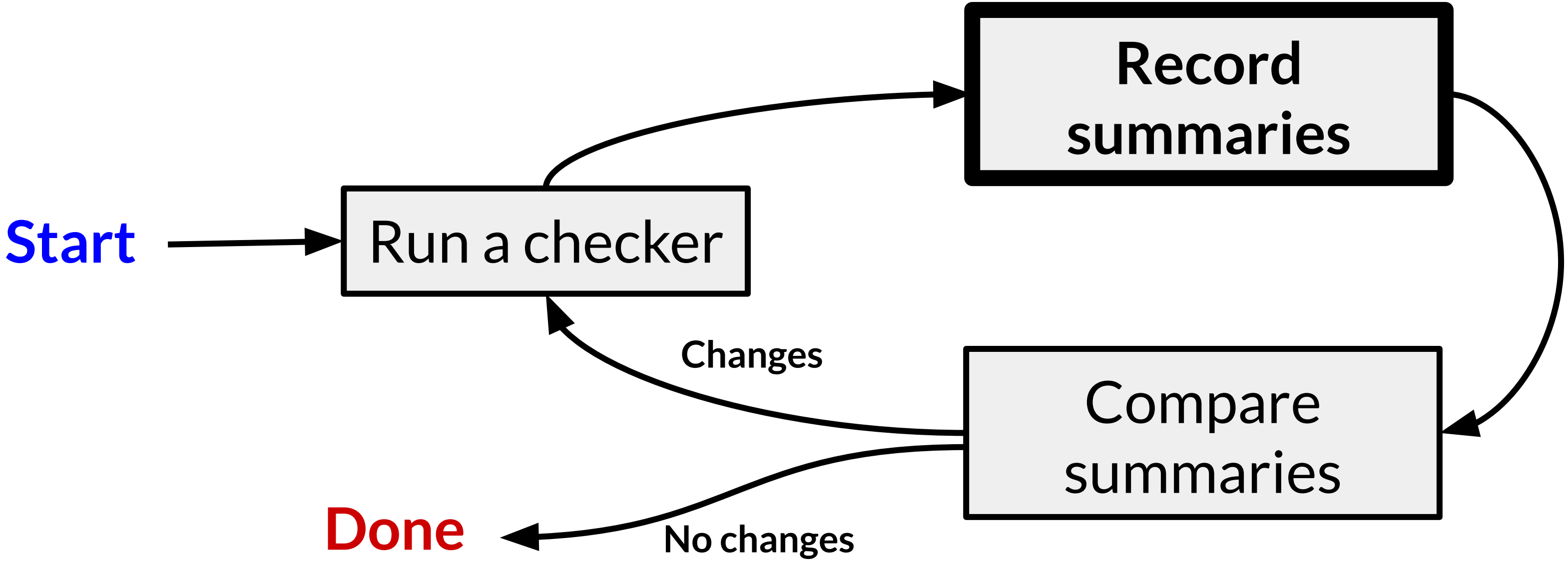
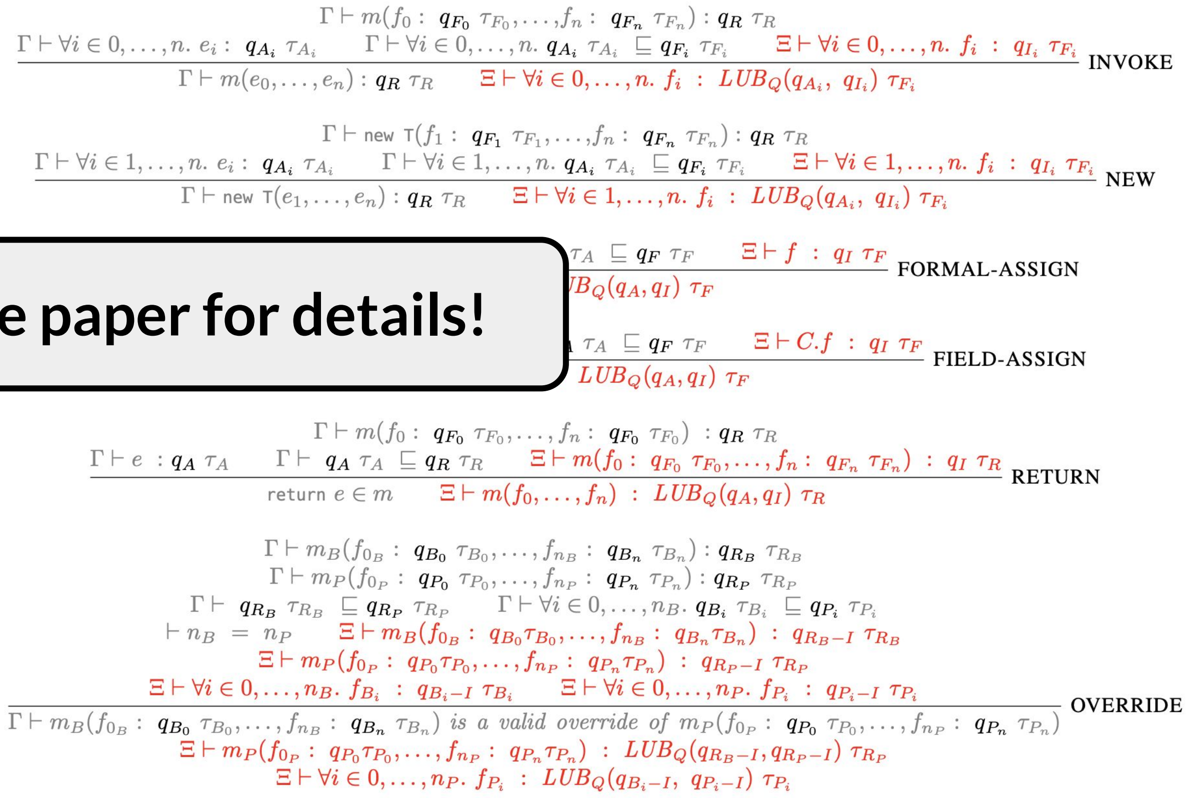


More complicated than it sounds...



$$\frac{\Gamma \vdash m(f_0 :\ q_{F_0}\ \tau_{F_0}, \ldots, f_n :\ q_{F_n}\ \tau_{F_n}) : q_R\ \tau_R \qquad \Gamma \vdash \forall i \in 0, \ldots, n.\ e_i :\ q_{A_i}\ \tau_{A_i} \quad \Gamma \vdash \forall i \in 0, \ldots, n.\ q_{A_i}\ \tau_{A_i} \sqsubseteq q_{F_i}\ \tau_{F_i} \quad \Xi \vdash \forall i \in 0, \ldots, n.\ f_i\ :\ q_{I_i}\ \tau_{F_i}}{\Gamma \vdash m(e_0, \ldots, e_n) : q_R\ \tau_R \quad \Xi \vdash \forall i \in 0, \ldots, n.\ f_i\ :\ LUB_Q(q_{A_i},\ q_{I_i})\ \tau_{F_i}}\ \text{INVOKE}$$

$$\frac{\Gamma \vdash \mathsf{new}\ \mathsf{T}(f_1 :\ q_{F_1}\ \tau_{F_1}, \ldots, f_n :\ q_{F_n}\ \tau_{F_n}) : q_R\ \tau_R \qquad \Gamma \vdash \forall i \in 1, \ldots, n.\ e_i :\ q_{A_i}\ \tau_{A_i} \quad \Gamma \vdash \forall i \in 1, \ldots, n.\ q_{A_i}\ \tau_{A_i} \sqsubseteq q_{F_i}\ \tau_{F_i} \quad \Xi \vdash \forall i \in 1, \ldots, n.\ f_i\ :\ q_{I_i}\ \tau_{F_i}}{\Gamma \vdash \mathsf{new}\ \mathsf{T}(e_1, \ldots, e_n) : q_R\ \tau_R \quad \Xi \vdash \forall i \in 1, \ldots, n.\ f_i\ :\ LUB_Q(q_{A_i},\ q_{I_i})\ \tau_{F_i}}\ \text{NEW}$$

Read the paper for details!

$$\frac{\tau_A \sqsubseteq q_F\ \tau_F \qquad \Xi \vdash f\ :\ q_I\ \tau_F}{B_Q(q_A, q_I)\ \tau_F}\ \text{FORMAL-ASSIGN}$$

$$\frac{A\ \tau_A \sqsubseteq q_F\ \tau_F \qquad \Xi \vdash C.f\ :\ q_I\ \tau_F}{LUB_Q(q_A, q_I)\ \tau_F}\ \text{FIELD-ASSIGN}$$

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$$\frac{\begin{array}{c} \Gamma \vdash m_B(f_{0_B} :\ q_{B_0}\ \tau_{B_0}, \ldots, f_{n_B} :\ q_{B_n}\ \tau_{B_n}) : q_{R_B}\ \tau_{R_B} \\ \Gamma \vdash m_P(f_{0_P} :\ q_{P_0}\ \tau_{P_0}, \ldots, f_{n_P} :\ q_{P_n}\ \tau_{P_n}) : q_{R_P}\ \tau_{R_P} \\ \Gamma \vdash\ q_{R_B}\ \tau_{R_B} \sqsubseteq q_{R_P}\ \tau_{R_P} \qquad \Gamma \vdash \forall i \in 0, \ldots, n_B.\ q_{B_i}\ \tau_{B_i} \sqsubseteq q_{P_i}\ \tau_{P_i} \\ \vdash n_B\ =\ n_P \qquad \Xi \vdash m_B(f_{0_B} :\ q_{B_0}\tau_{B_0}, \ldots, f_{n_B} :\ q_{B_n}\tau_{B_n})\ :\ q_{R_B - I}\ \tau_{R_B} \\ \Xi \vdash m_P(f_{0_P} :\ q_{P_0}\tau_{P_0}, \ldots, f_{n_P} :\ q_{P_n}\tau_{P_n})\ :\ q_{R_P - I}\ \tau_{R_P} \\ \Xi \vdash \forall i \in 0, \ldots, n_B.\ f_{B_i}\ :\ q_{B_i - I}\ \tau_{B_i} \qquad \Xi \vdash \forall i \in 0, \ldots, n_P.\ f_{P_i}\ :\ q_{P_i - I}\ \tau_{P_i} \end{array}}{\begin{array}{c} \Gamma \vdash m_B(f_{0_B} :\ q_{B_0}\ \tau_{B_0}, \ldots, f_{n_B} :\ q_{B_n}\ \tau_{B_n})\ \textit{is a valid override of}\ m_P(f_{0_P} :\ q_{P_0}\ \tau_{P_0}, \ldots, f_{n_P} :\ q_{P_n}\ \tau_{P_n}) \\ \Xi \vdash m_P(f_{0_P} :\ q_{P_0}\tau_{P_0}, \ldots, f_{n_P} :\ q_{P_n}\tau_{P_n})\ :\ LUB_Q(q_{R_B - I}, q_{R_P - I})\ \tau_{R_P} \\ \Xi \vdash \forall i \in 0, \ldots, n_P.\ f_{P_i}\ :\ LUB_Q(q_{B_i - I},\ q_{P_i - I})\ \tau_{P_i} \end{array}}\ \text{OVERRIDE}$$

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All these details (and more) in the paper!

Implementation

- Implemented as part of the Checker Framework (our tool is called "Whole Program Inference" or "WPI") for Java
    - automatically works with all checkers built on the framework
- Scripts automate it for Maven and Gradle projects
- You can try it out:

https://checkerframework.org/manual/#whole-program-inference

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These metrics are proxies for human effort to verify an unannotated codebase

Experimental Results

- Dataset of 12 projects (88,680 NCNB LoC total)
    - **11** distinct typecheckers (median 3.5 checkers/project)
    - **803** human-written annotations
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Significant reduction in human effort

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- Long tail of other causes, none greater than 5%

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