Time Traveling Debugging Queries for Faster Program Exploration

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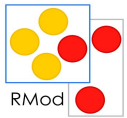


Presentation Agenda

Context
- Debugging, Program Comprehension and Exploration
- Research Question

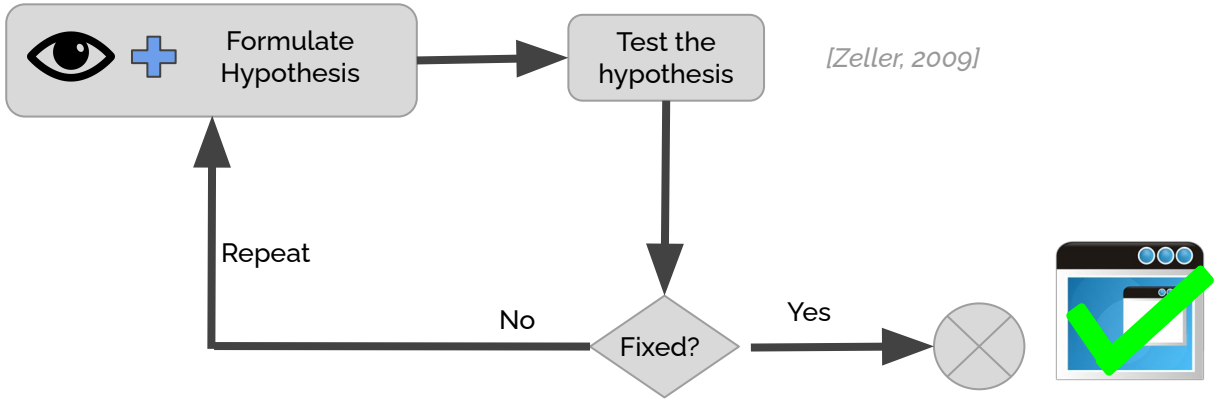
Next

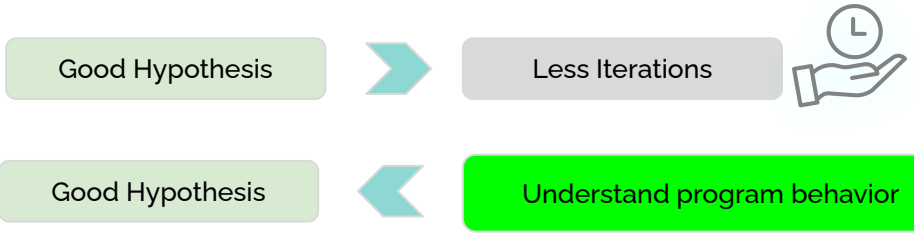
Time-Traveling Queries
- What are they?
- Queries for Program Comprehension

Experiment
- User Study Description
- Results

Context

The Debugging Process

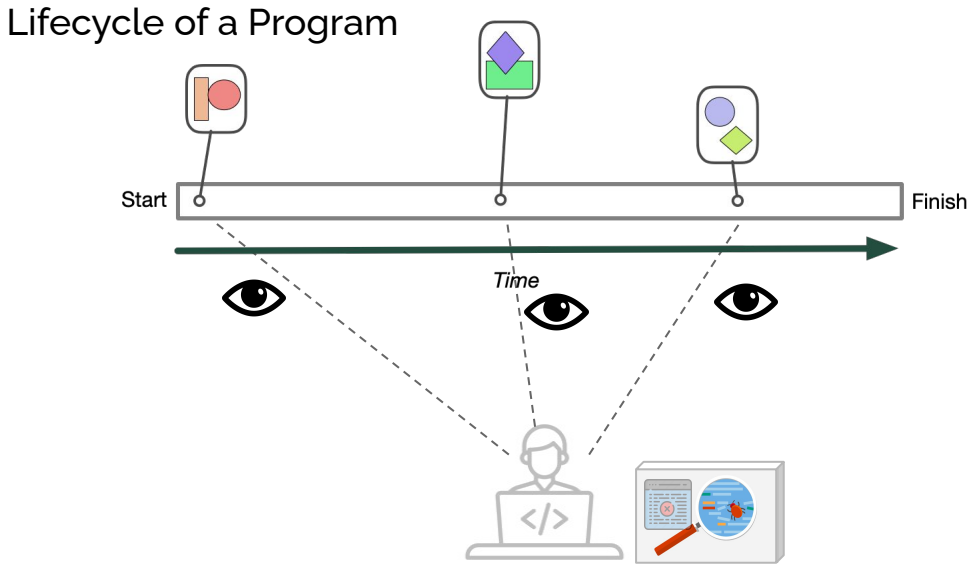




Zeller, 2009: "Why programs fail: a guide to systematic debugging"

Context

Understanding a program behavior

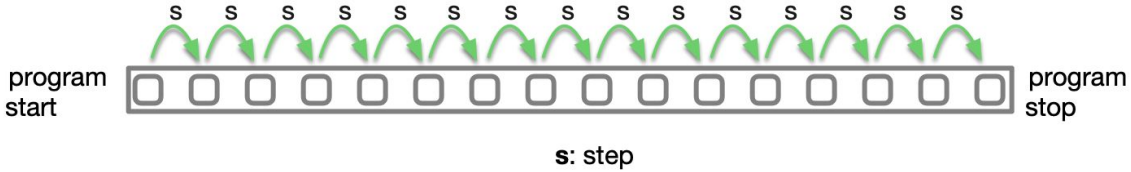


Program Exploration

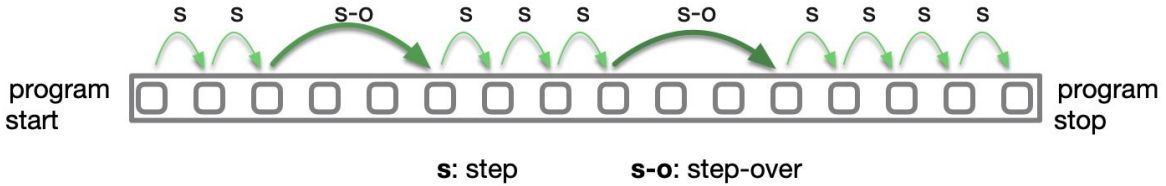
Manually exploring a program execution

Stepping

Step Into



Step Over

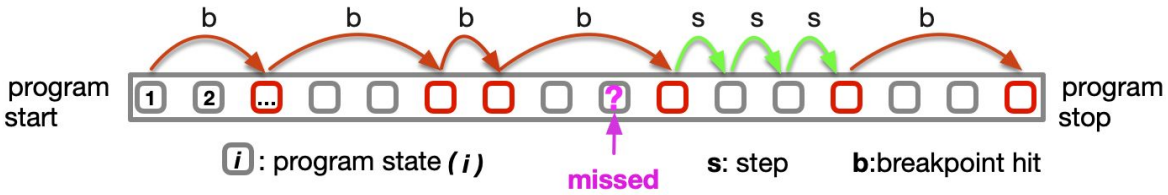


Traverse States Forward in Time

Manual and tedious.

Manually exploring a program execution

Breakpoints

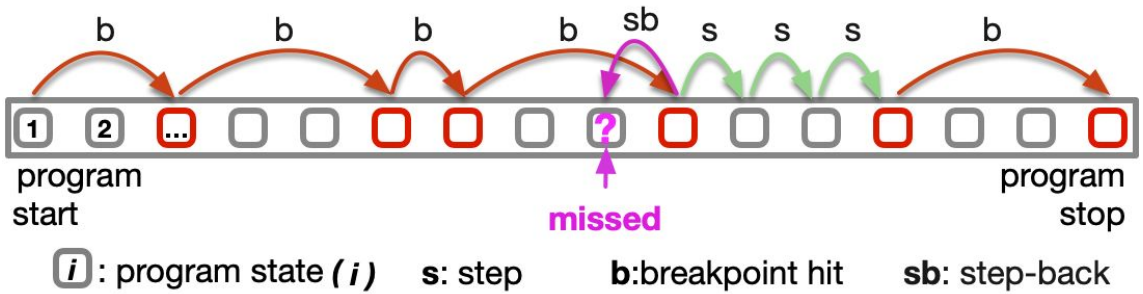


Traverse States Forward in Time

"Missing critical information" problem.

Manually exploring a program execution

Time-Traveling Debuggers



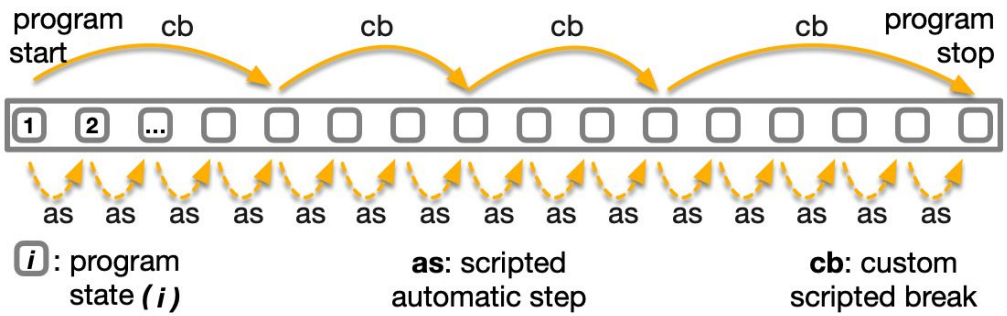
Traverse States Forward and Backward in Time

Helps with the "Missing critical information" problem.

Still tedious.

Exploring a program execution with Scripts

Scriptable Debuggers



They help with tediousness but, require prior knowledge of the execution.

Exploring a program execution...

With basic stepping, breakpoints, scriptable debugger, time-traveling, etc.

Debugging Questions

Difficult to Translate Into

A sequence of debugging actions

Problem Summary

Program Exploration is ...

- Manual/Tedious
- Imprecise and miss critical information
- Translating debugging questions -> debugging actions is difficult

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Research Question

"Can we **express** general program comprehension **questions** as **queries** over programs executions, and does that **improve** program exploration regarding developers' efforts, time spent and precision, **compared to standard debugging tools**?"

Proposed Solution

Time-Traveling Queries

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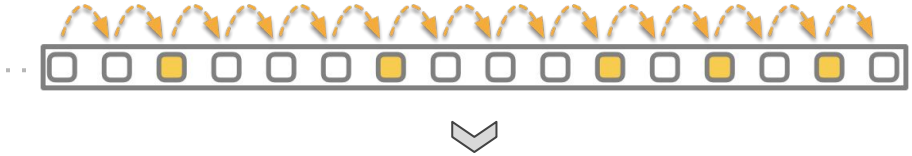
Time-Traveling Queries

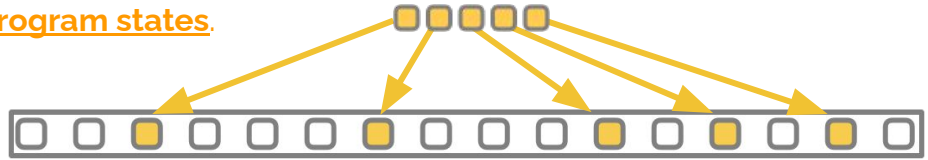
- ➔ Programmatic requests for execution data

- ➔ Automatically traverse program states.



- ➔ Requesting and collecting relevant data.

- ➔ Enabling direct time travel to relevant program states.



Time-Traveling Queries

Key supporting components

1. Time-Traveling Debugger

Advances or restores an execution to any point in time

2. ProgramStates

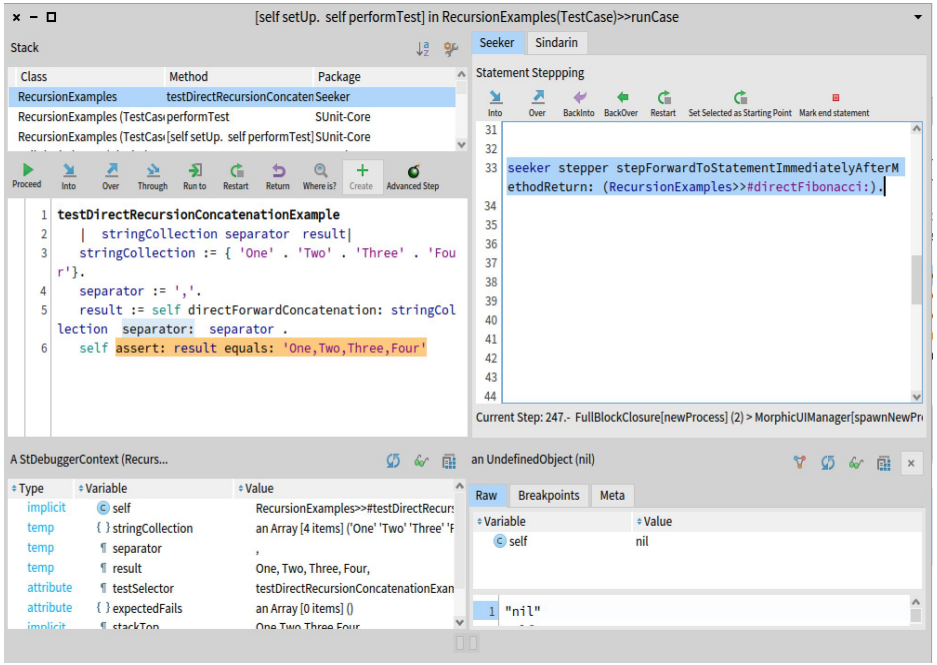
An iterable collection of all the program states

3. Query

A programmatic request of execution data

1. Time-Traveling Debugger

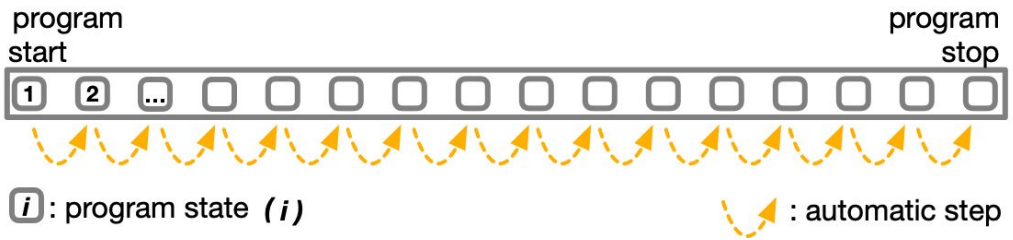
- ➔ As an **extension** of Pharo 9.0 **debugger**
- ➔ Allows to **reverse** a program's execution (step backwards)
- ➔ **Replay**-based Implementation



2. ProgramStates

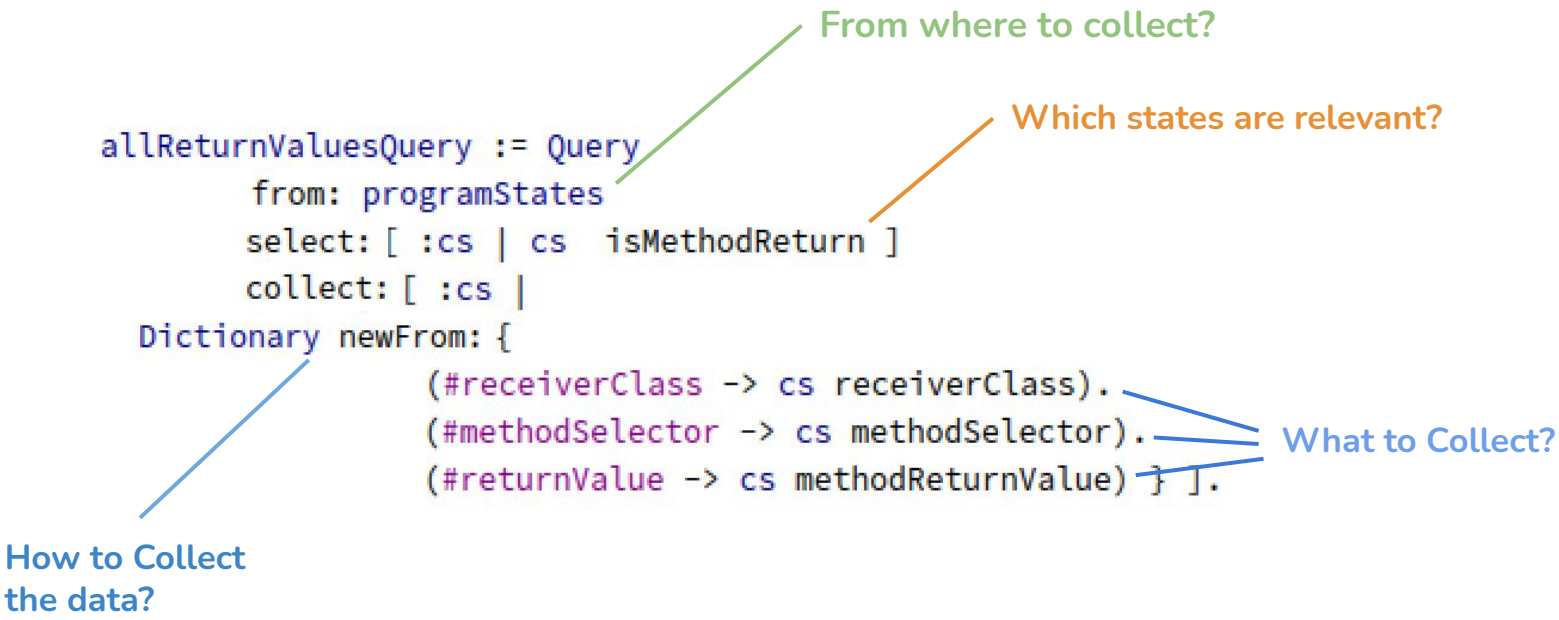
➔ A generator of ProgramState

- Iterable object that exposes an API to retrieve execution data from every state of the program (during its iteration)
- Every iteration of the loop advances execution by one step
- No trace(recording) is required to answer queries.

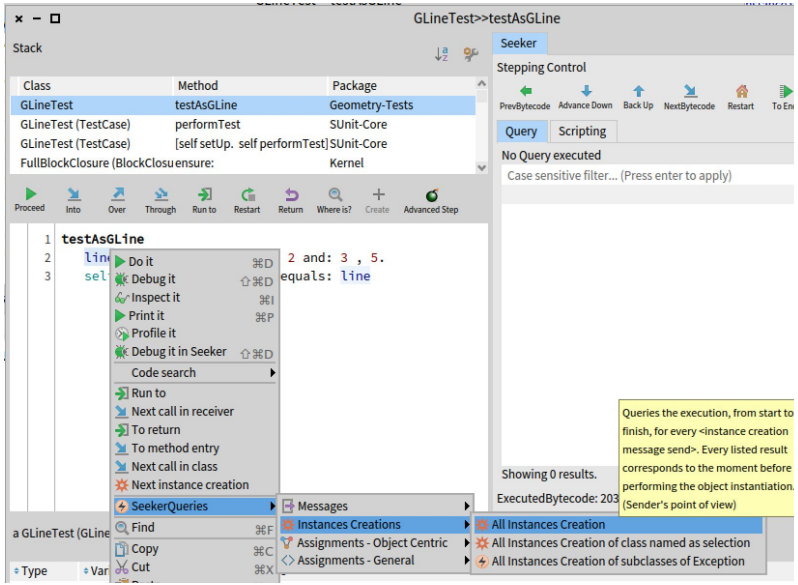


3. Query

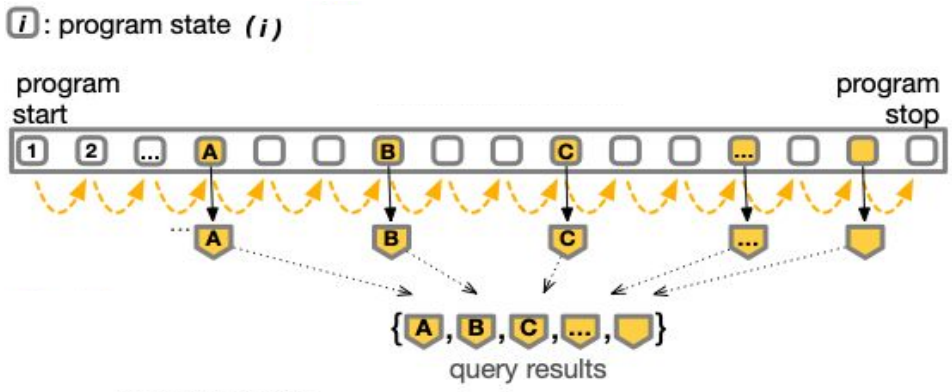
➔ Declared like this



Time-Traveling Queries usage

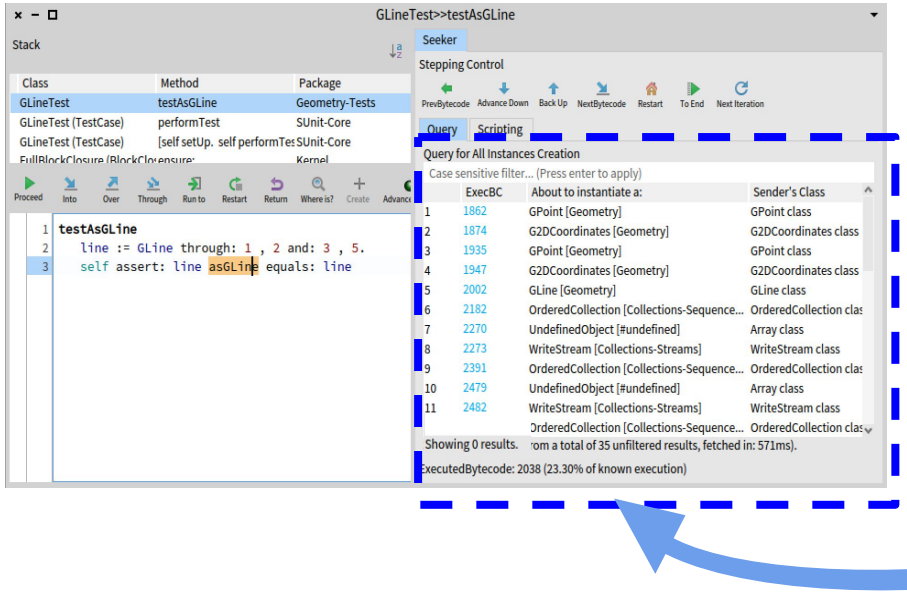


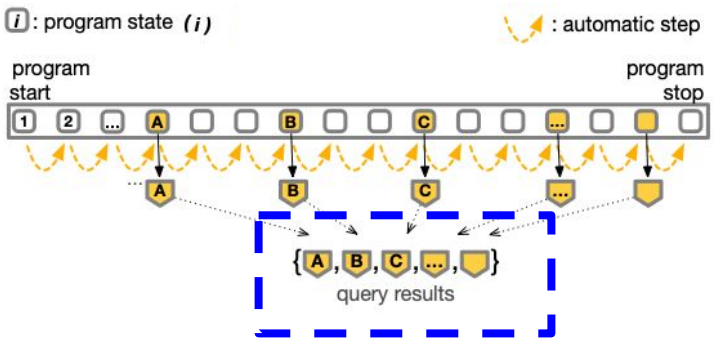
Query from: programStates
select: X
collect: Y



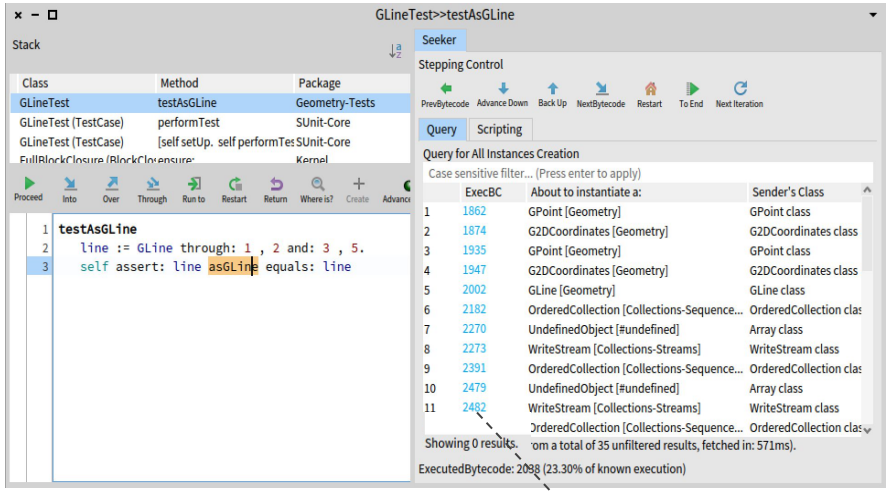
Query results

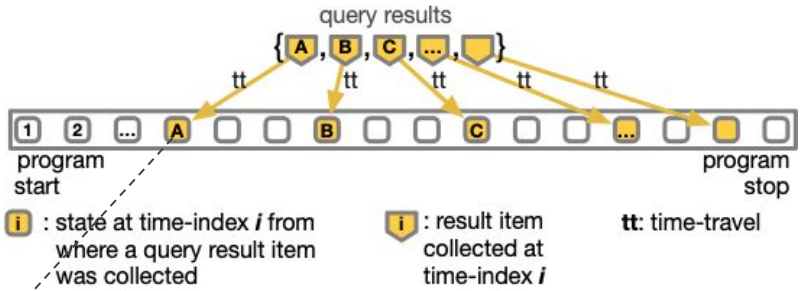
➔ Shown in UI like this





Time-Traveling from results





time-index

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Queries for program comprehension

List of Time-Traveling queries

I	**Messages.**
I.1	Find all messages sent during the execution.
I.2	Find all messages, with a given selector, sent during the execution.
I.3	Find all received messages.
II	**Instances Creation.**
II.1	Find all instance creations.
II.2	Find all instance creations of a class with a given name.
II.3	Find all instance creations of exceptions.
III	**Assignments - Object Centric.**
III.1	Find all assignments of instance variables for the receiver of the currently executed method.
III.2	Find all assignments of instance variables for a particular instance.
III.3	Find all assignments of a given instance variable for the receiver of the currently executed method.
IV	**Assignments - General.**
IV.1	Find all assignments of variables with a given name.
IV.2	Find all assignments of any variable.
IV.3	Find all assignments of instance variables for instances of a given class.

Queries for program comprehension

Based on questions from the literature

[Sillito, 2006]
[Kubelka, 2014]

- [13.] When during the execution is this method called?
- [14.] Where are instances of this class created?
- [15.] Where is this variable or data structure being accessed?
- [19.] What are the values of these arguments at run time?
- [20.] What data is being modified in this code?
- [32.] Under what circumstances is this method called or exception thrown?

Sillito, 2006: “Questions Programmers Ask During Software Evolution Tasks”
Kubelka, 2014: “Asking and Answering Questions during a Programming Change Task in Pharo Language”

How they help?

List of queries → Translation of questions into scripts/steps

Time-Traveling from results → Less “manual and tedious” traversal

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User Study - Queries for Debugging

We evaluated our **Queries** approach **vs Standard** Debugging Techniques, for **program comprehension tasks**:

Do Time Traveling Queries ...

1. Improve **correctness**?
2. Reduce the **employed time**?
3. Reduce the **number of debugging actions**?

(Versus Standard Debugging Tools)

User Study - Experiment Design

- ➔ Quantitative experiment
- ➔ Repeated Measures Design (Within-subject)
- ➔ **34 Participants**.
- ➔ Session of **90 minutes**, solving program comprehension tasks, using:
  - ◆ Time-Traveling Queries.
  - ◆ Standard Debugging Tools
- ➔ Measure the effect of: “TTQs”
  - ◆ On: Participant **Score, Time, Debugging Actions**

- ➔ Followed by Qualitative Survey

Experiment Tasks. From “simpler” ...

- ➔ How many times is the method #atEnd of the object ‘generator’ is called? and from which methods?

```
testAtEnd
    | generator |
    generator := self numbersBetween: 1 and: 3.
    self deny: generator atEnd.
    generator next.
    self deny: generator atEnd.
    generator next.
    self deny: generator atEnd.
    generator next.
    self assert: generator atEnd
```

Experiment Tasks.
To less “simple”...

- ➔ What are the different values of the `pc` instance variable of the first `newContext` object during this test?

```
testSteppingReturnSelfMethod

    |newContext|
    aMethodContext := Context
        sender: thisContext
        receiver: SimulationMock new
        method: (SimulationMock >>#exampleSelfReturnCall)
        arguments: #().

    aMethodContext step.
    aMethodContext stepIntoQuickMethod: true.
    newContext := aMethodContext step.

    "We're in the quick method now, it should be steppable"
    self assert: newContext sender identicalTo: aMethodContext.
    self assert: newContext willReturn.

    newContext := newContext step.
    self assert: newContext identicalTo: aMethodContext
```

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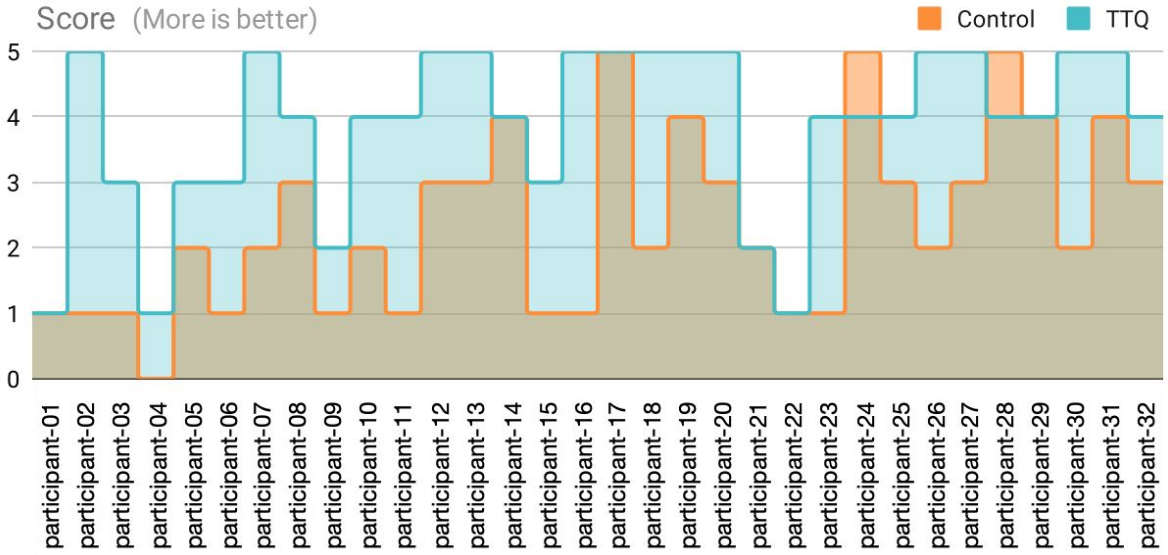
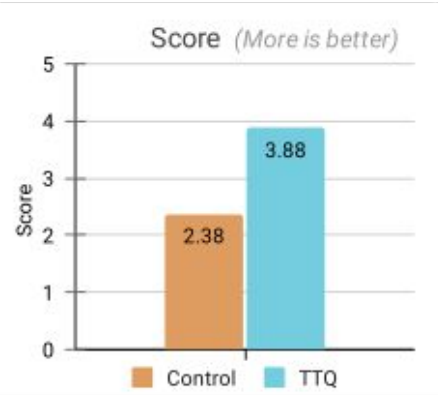
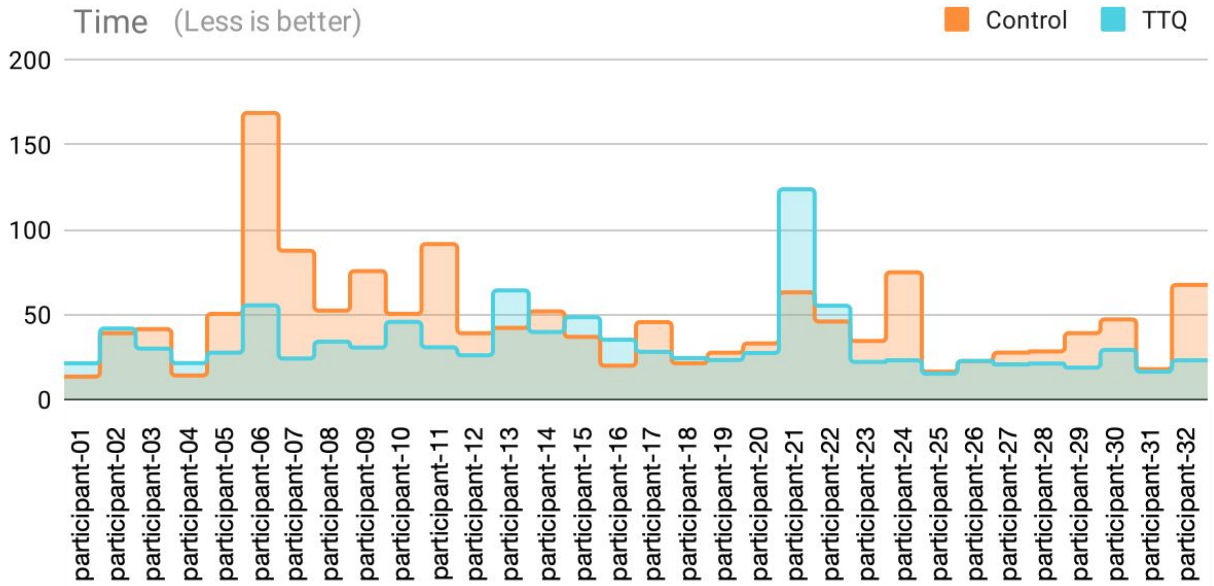
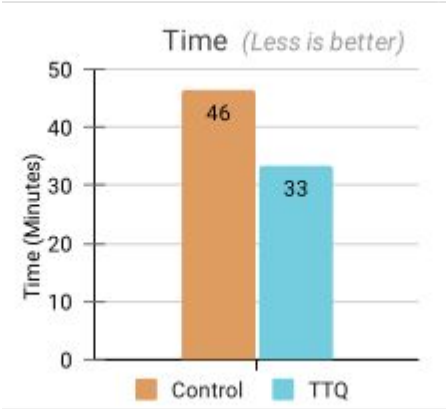
Participants Score





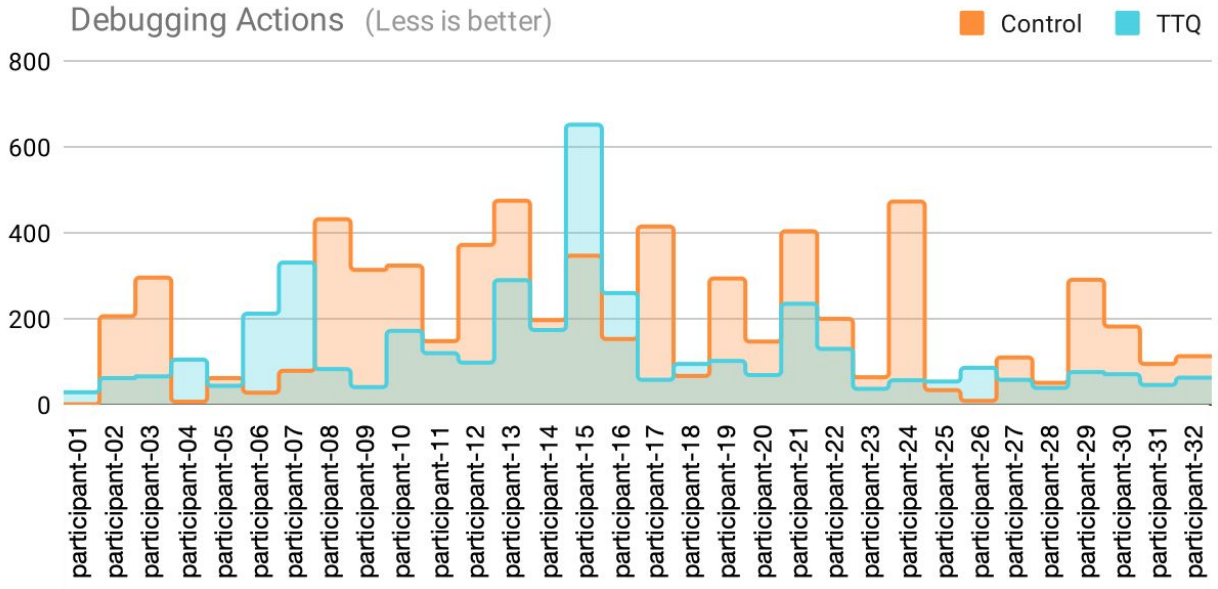
Participants Time

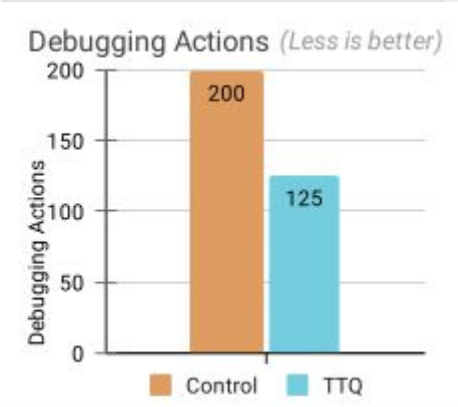




Time to complete all ‘Control’ and ‘TTQs’ tasks.

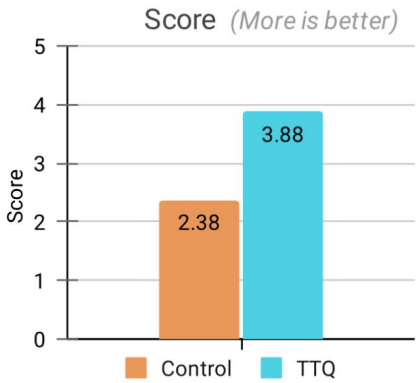
Participants Debugging Actions

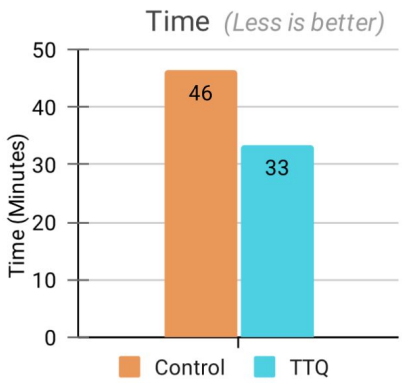


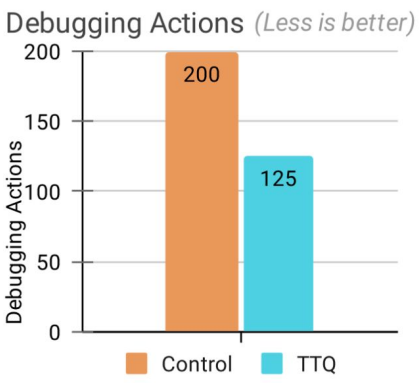


Count of debugging actions of participants

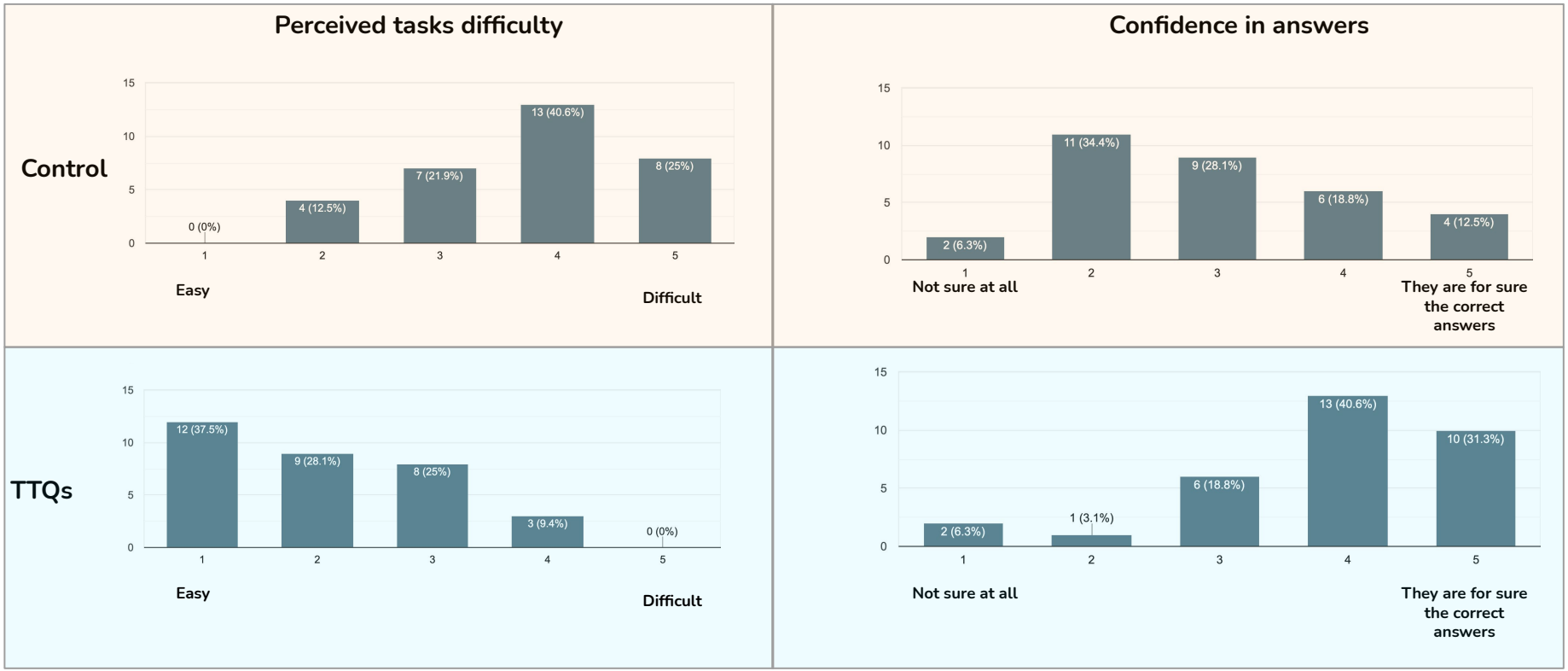
Results Summary





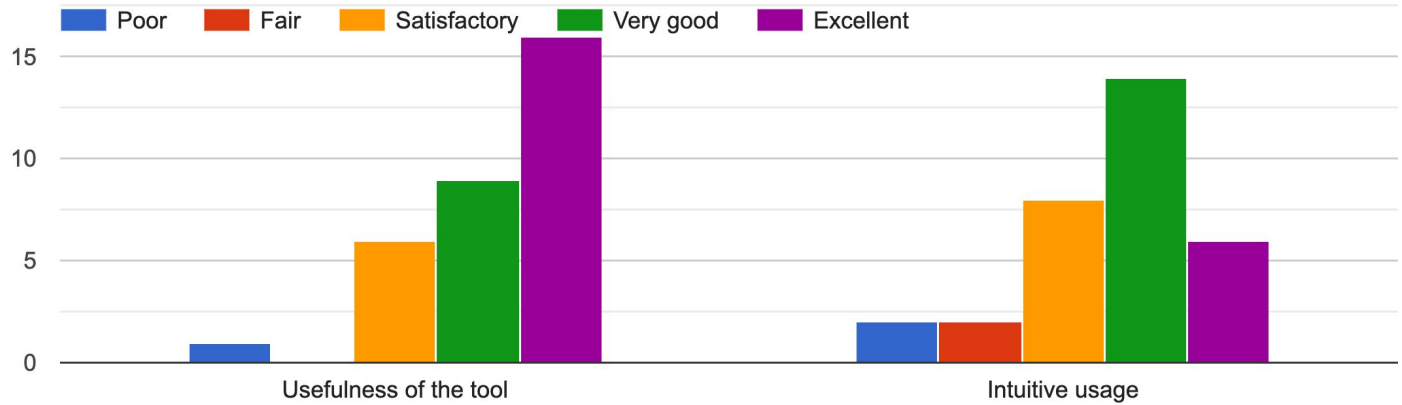


Post-Experiment Survey



Post-Experiment Survey

Time-Traveling Queries evaluation



Experiment Conclusion

- We can express general program comprehension questions as queries over programs executions.
- Results show that TTQs improve program exploration regarding developers' efforts, time spent and precision, compared to standard debugging tools.
- Even with little instruction time for participants, the results were positive.
- Current TTQs don't cover the complete set of problems developers face during their debugging sessions.

Summary

- Different tools and methodologies for program understanding.
- Program exploration using interactive debuggers remains difficult and tedious.
- Proposed TTQs to improve exploration and comprehension.
- Controlled experiment to evaluate our solution.
- With TTQs, developers perform program comprehension tasks more accurately, faster, and with less effort than with standard debugging tools.
- We will continue the Time-Traveling Queries work on:
  - Researching new relevant queries.
  - Researching the supporting infrastructure for TTQs.