Pip: Detecting the Unexpected in Distributed Systems

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Problem Statement

- Distributed systems exhibit complex behaviors that can be difficult to debug:
  - Often more difficult than centralized systems.
- Parallel, inter-node activity are difficult to capture with serial, single-node tools:
  - Need something more robust than traditional profilers and debuggers.
Problem Statement

• Once behavior is captured, how do you analyze it?

• Structural bugs:
  – Application processing & communication

• Performance problems:
  – Throughput bottlenecks
  – Consumption of resources
  – Unexpected interdependencies
Pip Overview

• Suite of programs to gather, check, and display the behavior of distributed systems.

• Uses explicit path identifiers and programmer-written expectations to check program behavior.

• Pip compares actual behavior to expected behavior.
System Overview

- Annotation Library
- Declarative Expectations Language
- Trace Checker
- Behavior Explorer GUI

Icon Source: Paul Davey (2007)
Application Annotation

● Pip constructs an application's behavior model from generated events:
  – Manual source code annotations
  – Automatic middleware insertions

● Execution paths are based on:
  – Tasks
  – Messages
  – Notices
Application Annotation

- Set Path ID
- Start/End Task
- Send/Receive message
- Generate Notice

WWW

{Parse HTTP}

{Execute}

{Query}

App Server

Database

time

Received Request

Processed Request

Sent Response

{Send Response}
Expectations

- Declarative language to describe application structure, timing, and resource consumption. Expresses parallelism.
- Accommodates variation in the order and number of events for multiple paths.

```plaintext
validator CGIRequest
task(“Parse HTTP”) limit(CPU_TIME, 100ms);
notice(m/Received Request: .*/);
send(AppServer);
recv(AppServer);
invalidator DatabaseError
notice(m/Database error: .*/);
```
Expectations

• Example: Quorum

```c
validator Request
    recv(Client) limit (SIZE, {=44b});
    task("Read") {
        repeat 3 { send(Peer); }
        repeat 2 {
            recv(Peer);
            task("ReadReply");
        }
        future {
            recv(Peer);
            task("ReadReply");
        }
    }
    send(Client);
```
Expectations

• Recognizers:
  – Description of structural and performance behavior.
  – Matching
  – Matching with performance violations
  – Non-matching

• Aggregates:
  – Assertions about properties of sets of paths.
Trace Checker

- Pip generates a search tree from expectations.
- The trace checker matches results from the path database with expectations.
Behavior Explorer

• Interactive GUI displays:
  – Casual Path Structure
  – Communication Structure
  – Valid/Invalid Paths
  – Resource Usage Graphs
Behavior Explorer

Behavior Explorer

Casual Path Viewer

Executed tasks, messages, and notices

Timing & Resource Properties

Source: Pip web page (2007)
http://issq.cs.duke.edu/pip/
Pip vs. Paradyn

• The Paradyn Configuration Language (PCL) allows programmers to describe expected characteristics of applications.

• “…PCL cannot express the casual path structure of threads, tasks, and messages in a program, nor does Paradyn reveal the program's structure”.
Using Pip in Condor

- No high-level debugging tool is currently used by Condor developers.
- Inner-working knowledge about daemon interactions is either scattered in source code documentations or with a few developers.
Discussion

• Questions?