Finding Incorrect Compositions of Atomicity

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Seminar Presentation

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Problem Statement

- Concurrent APIs provide atomic operations.
- User composes APIs to new atomic functionality.

```
1: x = pos.getX();
2: y = pos.getY();
// (x, y) only valid if called atomically
```

- Problematic interleaving:

```
P1: pos = new Pos(0, 0);
P1: x = pos.getX();
P2: pos.move(5, 5);
P1: y = pos.getY(); // P1 sees (0, 5)
```

- Problem: Identify compositions and find out whether they need to be implemented atomically.

Contributions

- Identify the problem of **incorrect compositions of atomic library APIs**.
- **Automatic** approach to find incorrect compositions.
- **Extensive evaluation** of the approach.

Algorithm

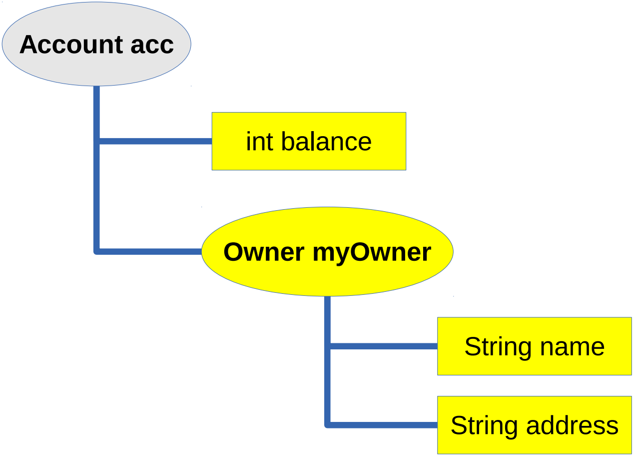
1. Inferring atomic sets.
2. Identifying library and client using atomic sets.
3. Inferring atomic compositions.
4. Exhibiting synchronization errors.

Atomic Sets

- Definition in the paper:
  "In object-oriented programs, where objects form reference hierarchies via field references, an atomic set is a set of instance fields, each of which is reachable from the root object along a field chain."
- Atomic sets are inferred statically for each synchronized block or method.
- Sets that share fields are merged.

Atomic Sets

- Example:



- $\{acc.balance, acc.myOwner, acc.myOwner.name, \cdots\}$

Library Example

```
public class Account {
  private int balance;
  private Owner myOwner;

  public synchronized void deposit() {
    /* ... */
  }

  public synchronized int
          withdraw(int amount) {
    /* ... */
  }

  public synchronized int getBalance() {
    return balance;
  }
}
```

Client Example

```
public class Client {
  private Account account;

  /* Uses atomic APIs withdraw and
   * getBalance from Account library. */
  public static void main(String[] args) {
    int balance, cash;
    balance = account.checkBalance();
    cash = account.withdraw(100);
  }
}
```

Library and Client

- Library module: Classes which declare the fields in the atomic set.
  Example: $\{Account, Owner\}$
- Client module: The class of which the methods invoke the atomic methods of the library module.
  Example: class *Client*
- Library and client are inferred **statically**.

Atomic Compositions

- **Atomic API**: Methods that use fields of the atomic set in a synchronized block.
- **Atomic Composition**: Using multiple atomic APIs in a single method.
- Does not always need to be atomic:

```
cash = someAccount.withdraw(100);
otherAccount.deposit(cash);
```

- Which compositions **need to be atomic**?

USE Symptom

- If a program dependence exists between two atomic calls, they should be called atomically.
- Example:

```
// withdraw everything if balance < 100
int balance, cash;
balance = account.checkBalance();
if (balance < 100) {
  cash = account.withdraw(balance);
}
```

Complementation Symptom

- If two invocations **dominate** and **post-dominate** each other, they should be called atomically.
- Example:

```
/* withdraw 100 after checking the
 * balance */
int balance, cash;
balance = account.checkBalance();
cash = account.withdraw(100);
```

Dynamic Checking

- Uses existing atomicity violation detection analyses to find **buggy interleavings**.
- Monitor a normal run (trace) and then try to find violating interleavings.
- Prunes a lot of false positives.
- For example: If a composition is only executed by one thread, it does not need to be atomic.

The Big Picture

1. **Infer atomic sets.**
   Simple in our example:
   $\{Account.balance, Account.owner, Account.owner.name, \cdots\}$.
2. **Identify library and client.**
   Library: $\{Account, Owner\}$.
   Clients: *main* method in class *Client*.
3. **Infer atomic compositions.**
   For example:

   ```
   balance = account.checkBalance();
   cash = account.withdraw(balance);
   ```

4. **Find buggy interleavings (dynamic checking).**
   E.g. bug if another thread can withdrow from my account in between calls.

Evaluation

- Exhaustive evaluation with various programs. Most notably: Tomcat.
- Compare with state of the art approach: MUVI (statistics based).
- Static part: Number of compositions found comparable to MUVI.
- Dynamic checking: Prunes most compositions.
- Case study with Tomcat: Inspect reported violations and (try to) determine if they are true/false positives.

Remarks: What I did not like

- Some explanations not very detailed.
- Evaluation seems to leave out "uncomfortable" data.
- Some statements in the evaluation are a bit vague and/or useless.
  - *"Our evaluation on a set of large scale applications shows, the static analysis finds up to 391 atomic compositions for an application, while half would be missed by the previous statistic-based approach."*
- Poor documentation of the provided program.
- Dynamic checking not included in provided program.

Remarks: What I did like

- First half (algorithm description) well written and easy to understand.
- Impressive results (e.g. 5 of 12 compositions in Tomcat were actual bugs).
- The tool can be useful in practice.
  - Few actual reports (less than 20 in each of their cases).
  - But: Execution time may be an issue with larger project.