Validating Library Usage Interactively

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Outline

1. **Motivation**
2. Problem definition
3. Technique and experiments

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1. Motivation

3. Technique and experiments

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1. Motivation

Developers Often Optimize Library Usage

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In a previous study (*Understanding and Detecting Real-World Performance Bugs*, Jin et. al., PLDI '12), of 109 bug patches:

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42

caused by

"an inefficient function call sequence composed of efficient individual functions"

Developers Often Optimize Library Usage

In a previous study (*Understanding and Detecting Real-World Performance Bugs*, Jin et. al., PLDI '12), of 109 bug patches:

34

caused by

"calling functions that conduct unnecessary work given the calling context"

Developers Often Optimize Library Usage *Concisely*

In a previous study (*Understanding and Detecting Real-World Performance Bugs*, Jin et. al., PLDI '12), of 109 bug patches:

42

contained ≤ 5 lines of code,
and median size was 8 lines

The Case for Verification

Opportunities to improve practice: optimizations...

- are discussed extensively
- validated by testing only

Why its feasible: optimizations...

- use a clean interface
- are small

The Case for Verification

Opportunities to improve practice: optimizations...

- are discussed extensively
- validated by testing only

Why its feasible: optimizations...

- use a clean interface
- are small

Why its hard: optimizations implicitly rely on subtle library properties

Mozilla Bug #409961

Original

```
DbList dbnewList;
Card card;
for (pos=1;pos<=numAddrs;pos++)
  card = CreateCard(user(pos));
  dbnewList = DbList();
  AddAddrToList(dbnewList,card);
return card;
```

Optimized

Mozilla Bug #409961

Original

```
DbList dbnewList;
Card card;
for (pos=1;pos<=numAddrs;pos++)
  card = CreateCard(user(pos));
  dbnewList = DbList();
  AddAddrToList(dbnewList,card);
return card;
```

Optimized

Mozilla Bug #409961

$\forall$ x, y, z.

`AddAddressToList[arg2]`(x, y)

= `AddAddressToList[arg2]`(z, y)

Original

```
DbList dbnewList;
Card card;
for (pos=1;pos<=numAddrs;pos++)
  card = CreateCard(user(pos));
  dbnewList = DbList();
  AddAddrToList(dbnewList,card);
return card;
```

Optimized

MySQL Bug #38769

Original

```
for (n=0; n < 256; ++n) {
  Snapshot_info* i = at(info, n);
  if (!i) continue;
  process_snapshot(i);
}
```

Optimized

MySQL Bug #38769

Original

```
for (n=0; n<< 256; ++n) {    ;++n){
  Snapshot_info* i = at(info, n);
  if (!i) continue;
  process_snapshot(i);
}
```

Optimized

MySQL Bug #38769

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```
for (n=0; n<< 256; ++n) {    ;++n){
  Snapshot_info* i = at(info, n);
  if (!i) continue;
  process_snapshot(i);
}
```

Optimized

```
snap_count(info)
```

MySQL Bug #38769

$$\forall\, x.\ \texttt{snap\_count}(x) < 256$$

$$\forall\, x, y.\ \texttt{snap\_count}(x) \leq y \Rightarrow \texttt{at}(x, y) = \text{NULL}$$

Original

```
for (n=0; n<< 256; ++n) {    ;++n){
  Snapshot_info* i = at(info, n);
  if (!i) continue;
  process_snapshot(i);
}
```

Optimized

```
snap_count(info)
```

Apache Bug #34464

Original

```
string sb := “”;
while (!is_sub(sb, s)) {
  app(sb, get());
}
return sb;
```

Optimized

Apache Bug #34464

Original

```
string sb := “”;
while (!is_sub(sb, s)) {
  app(sb, get());
}
return sb;
```

Optimized

```
int pos := -len(s);
       pos < 0
       ||          sub(   pos),

   pos := len(sb) - len(s);
```

Apache Bug #34464

$$\texttt{len}(\text{“”}) = 0$$

$$\forall\, x, y.\ \texttt{len}(x) > \texttt{len}(y) \Rightarrow \neg\texttt{is\_sub}(x, y)$$

$$\forall\, x, y, z.\ \neg\texttt{is\_sub}(x, y) \Rightarrow$$

$$\texttt{is\_sub}(\texttt{app}(x, z), y) \Leftrightarrow$$

$$\texttt{is\_sub}(\texttt{sub}(\texttt{app}(x, z), \texttt{len}(\texttt{app}(x, z)) - \texttt{len}(y)), y)$$

Original

```
string sb := “”;
while (!is_sub(sb, s)) {
  app(sb, get());
}
return sb;
```

Optimized

```
int pos := -len(s);
      pos < 0
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Outline

1. Motivation

2. Problem definition
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3. Technique and experiments

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1. Problem definition

Apache Bug #34464

Org.

```
string sb := “”;
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```
string sb := “”;
int pos = -len(s);
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chklibs

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||

chklibs

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User

chklibs

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∀ x, y. is_sub(x, y)

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chklibs

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∀ x, y. is_sub(x, y)
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string sb := “”;
while (!is_sub(sb,
  app(sb, get());
}
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Invalid

```
string sb := “”;
int pos = -len(s);
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chklibs

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∀ x, y. is_sub(x, y)

string sb := “”;
while (!is_sub(sb,
  app(sb, get());
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return sb;
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Invalid

Opt.

```
∀ x, y. len(x) > len(y) ⇒
  ¬is_sub(x, y)   ";
int pos = -len(s);
while (pos < 0 ||
    !is_sub(sub(sb, pos), s)){
  app(s
  pos
}
return sb;
```

b) - len(s);

User

Org. ≈ Opt
assuming
∀ x, y. `len`(x) > `len`(y) ⇒
¬`is_sub`(x, y)
...

`chklibs`

Org.

∀ x, y. `is_sub`(x, y)

```
string sb := "";
while (!is_sub(sb,
  app(sb, get());
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∀ x, y. `len`(x) > `len`(y) ⇒
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```
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int pos = -len(
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}
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```

...

Valid

User

`chklibs`
Requirements

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1. Relative soundness

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1. Relative soundness

1. Non-redundant queries

2. Queries on properties of the library only

`chklibs` Requirements

1. Non-redundant queries

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Inputs

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string sb := "";
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chklibs 

User 

1. Non-redundant queries

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chklibs 

∀ x, y. `len`(x) > `len`(y) ⇒

`is_sub`(x, y)

User 

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chklibs

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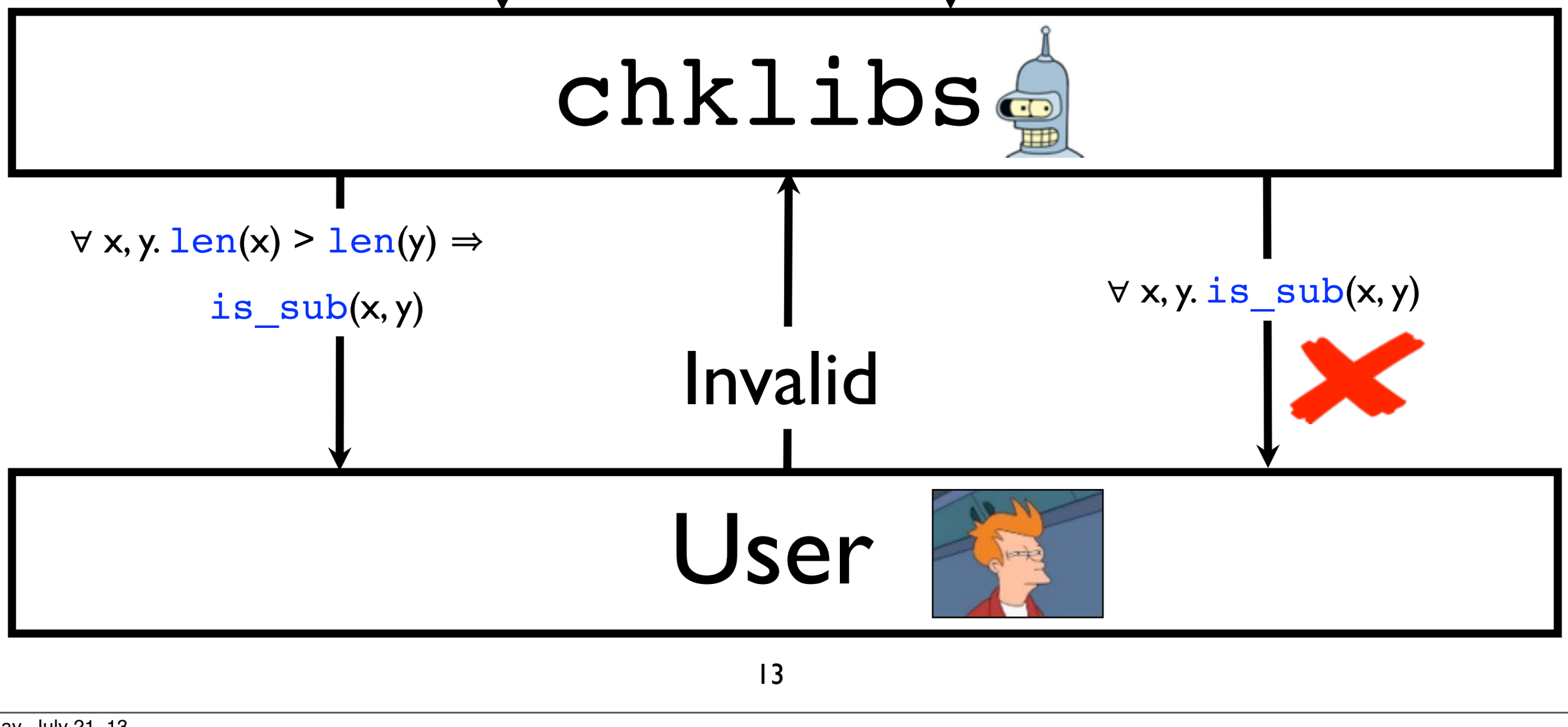

1. Queries on properties of the library only

Inputs

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chklibs 

User 

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chklibs 

$\forall$ x, y. `len`(x) > `len`(y) $\Rightarrow$

$\neg$`is_sub`(x, y)

User 

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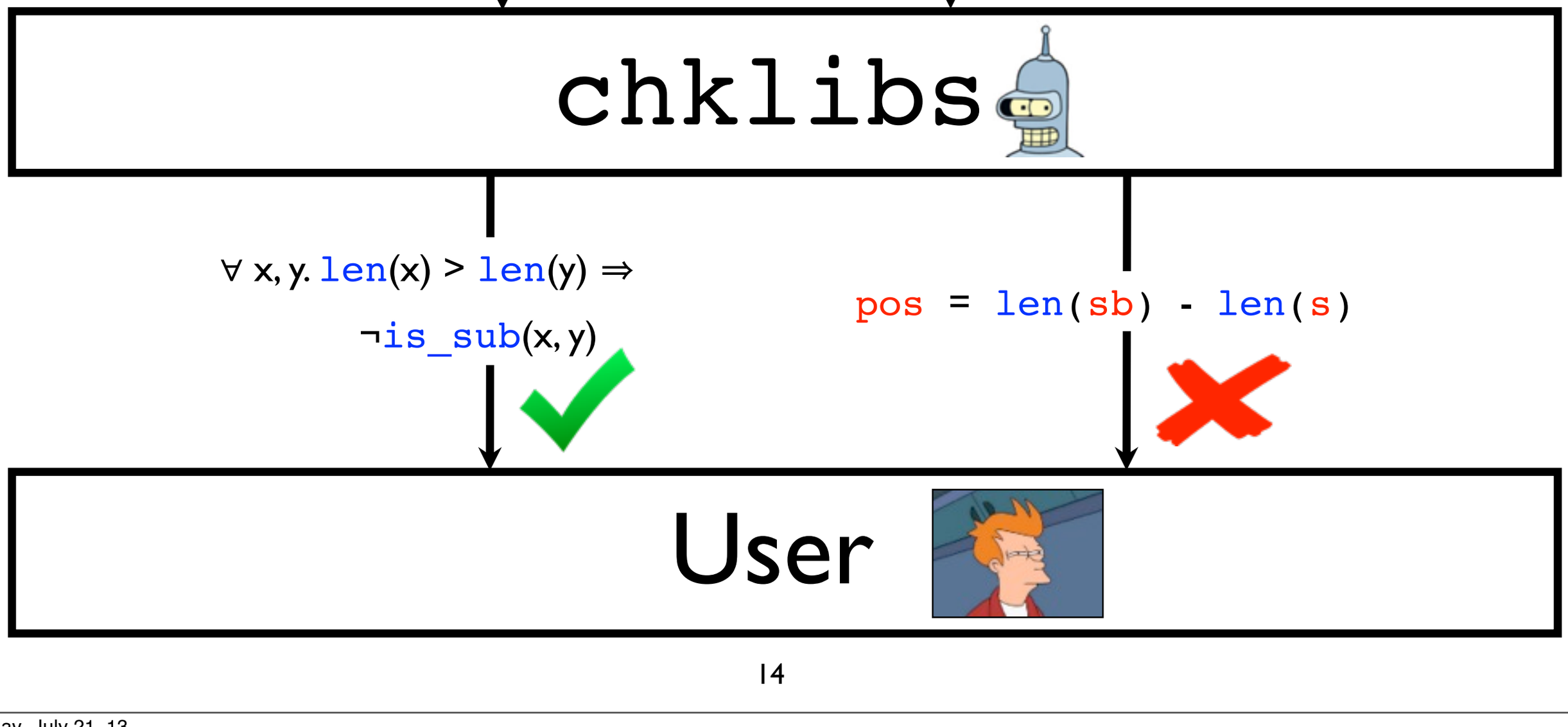

Why involve the user?

- Libraries may be difficult to analyze
- Do small optimizations contain specifications of big callees?

Outline

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2. Problem definition
3. **Technique** and experiments

Outline

2. Problem definition

3. **Technique** and experiments

Outline

B. **Technique** and experiments

Outline

1. Technique and experiments

Technique

- Based on known translation-validation algorithm (Necula, PLDI '00)
- Key difference: simultaneously find formula in simulation relation and supporting library property over predicates in post

```
L0:
string sb := “”;
L1:
while (!is_sub(sb, s)) {
  app(sb, get());
}
L2:
return sb;
```

```
L0’:
string sb := “”;
int pos = -len(s);
L1’:
while (pos < 0 ||
       !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
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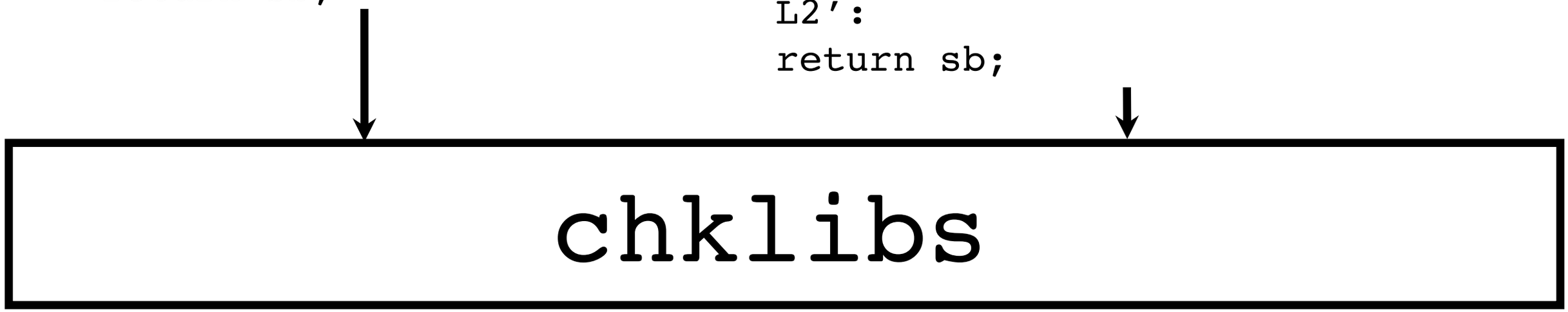
L2’:
return sb;
```



User

chklibs

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L0’:
string sb := “”;
int pos = -len(s);
L1’:
while (pos < 0 ||
       !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
}
L2’:
return sb;
```

validated Lib. property: True

User

chklibs

```
L0:
string sb := “”;
L1:
while (!is_sub(sb, s)) {
  app(sb, get());
}
L2:
return sb;
```

```
L0’:
string sb := “”;
int pos = -len(s);
L1’:
while (pos < 0 ||
       !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
}
L2’:
return sb;
```

validated Lib. property: True

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chklibs

```
                                  s = s'
                                  L0':
L0:                               string sb := "";
string sb := "";                  int pos = -len(s);
L1:                               L1':
while (!is_sub(sb, s)) {          while (pos < 0 ||
  app(sb, get());                        !is_sub(sub(sb, pos), s)){
}                                   app(sb, get());
L2:                                 pos := len(sb) - len(s);
return sb;                        }
                                  L2':
                                   return sb;
```

validated Lib. property: True

User

chklibs

s = s'

```
L0:
string sb := "";
L1:
while (!is_sub(sb, s)) {
  app(sb, get());
}
L2:
return sb;
```

sb = sb'

```
L0':
string sb := "";
int pos = -len(s);
L1':
while (pos < 0 ||
         !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
}
L2':
return sb;
```

validated Lib. property: True

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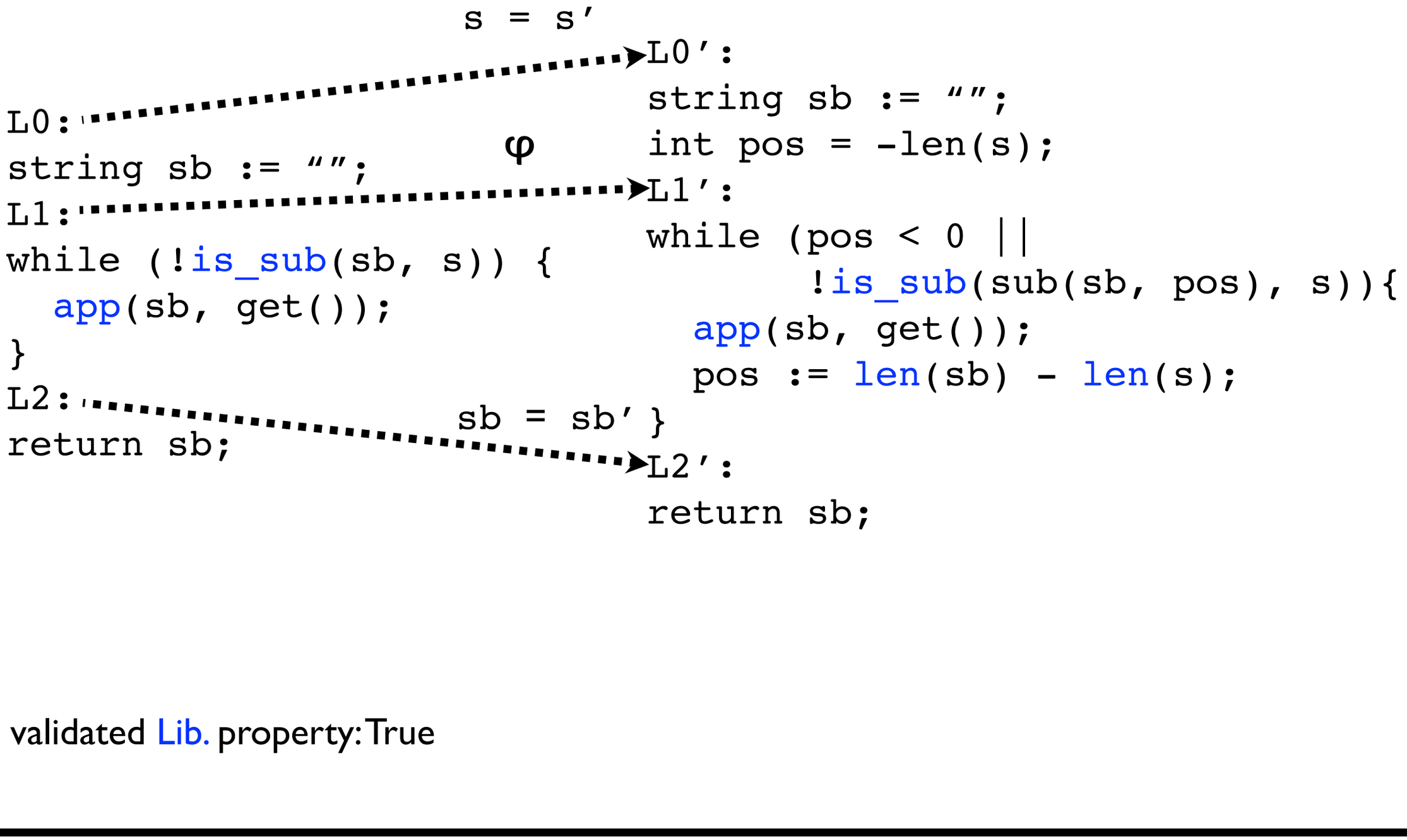
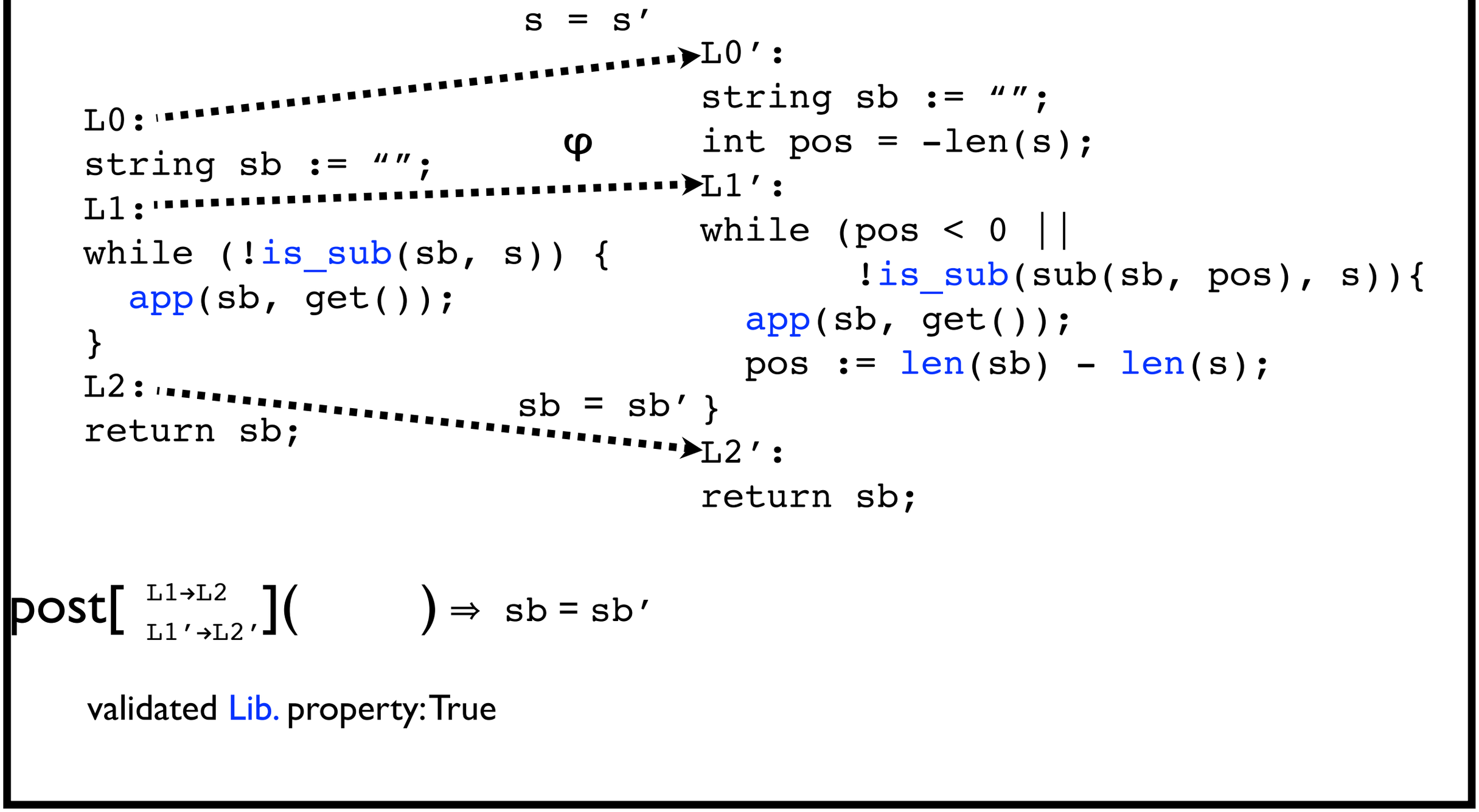
chklibs



validated Lib. property: True

User

chklibs



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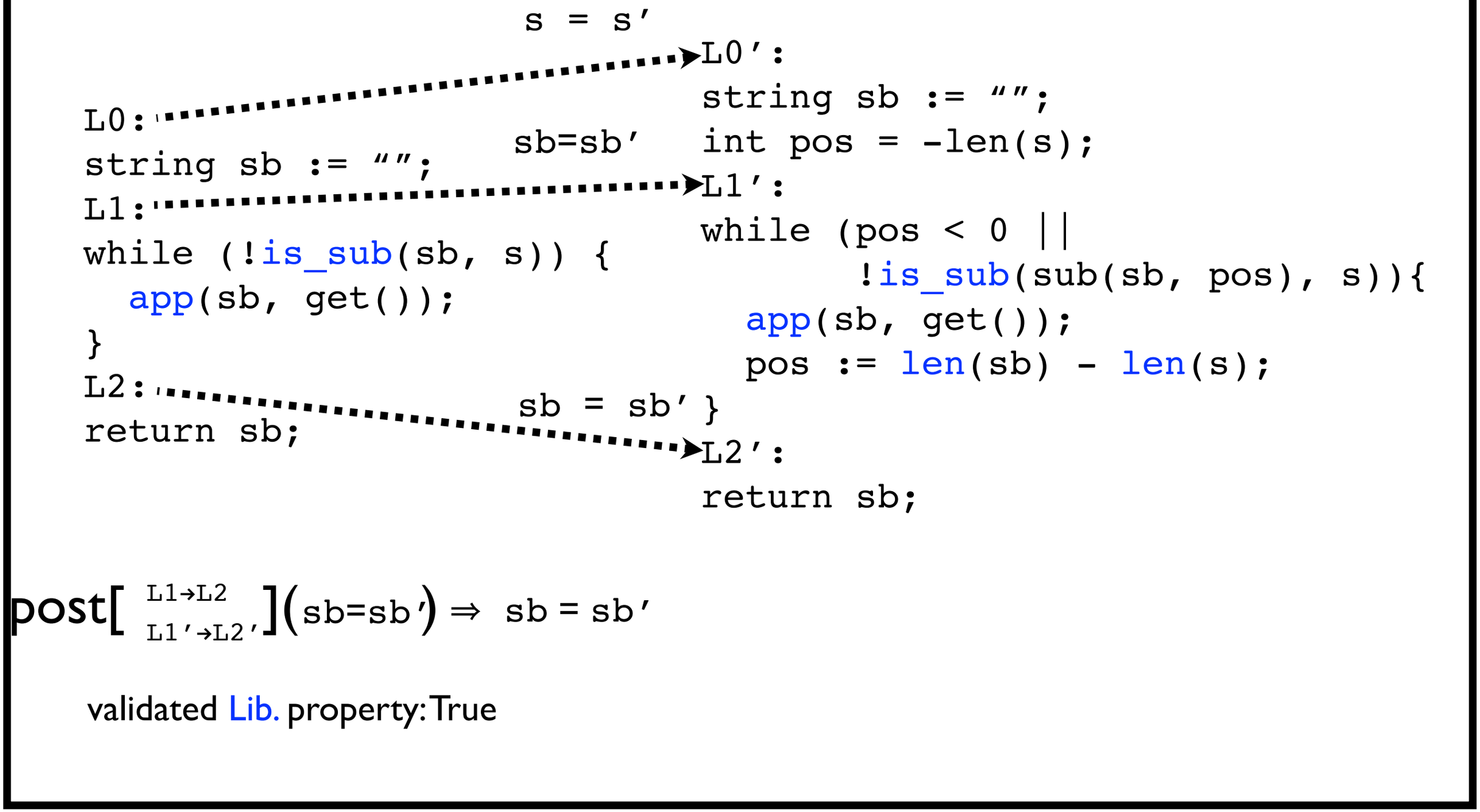
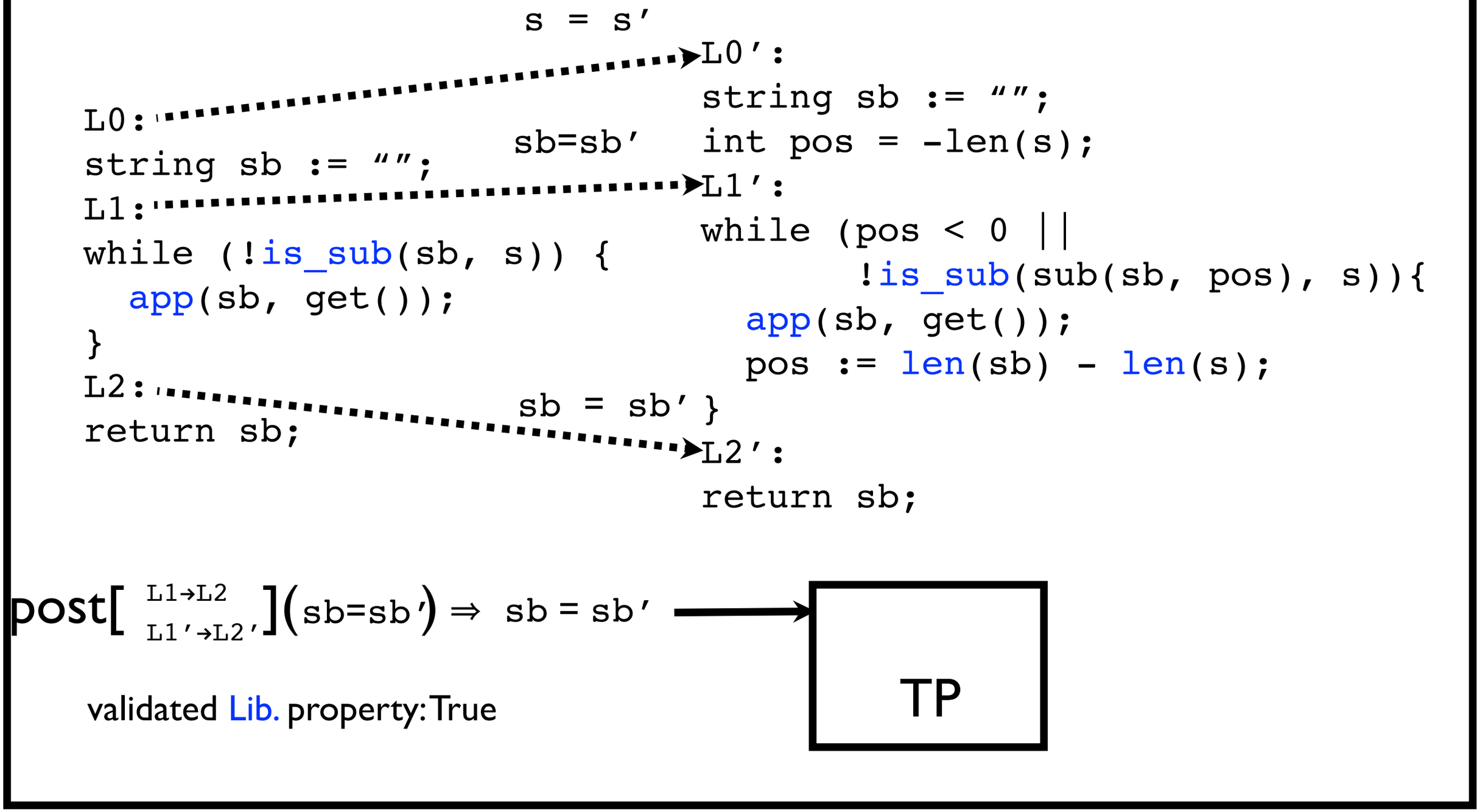
chklibs



User

chklibs



User

chklibs

s = s′

sb=sb′

sb = sb′

```
L0:
string sb := "";
L1:
while (!is_sub(sb, s)) {
  app(sb, get());
}
L2:
return sb;
```

```
L0':
string sb := "";
int pos = -len(s);
L1':
while (pos < 0 ||
          !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
}
L2':
return sb;
```

$\text{post}[\,{}^{L1 \to L2}_{L1' \to L2'}\,](sb = sb') \Rightarrow sb = sb'$ → TP → Invalid

validated Lib. property: True

User

chklibs

```
L0:
string sb := “”;
L1:
while (!is_sub(sb, s)) {
  app(sb, get());
}
L2:
return sb;
```

s = s′ (L0 → L0′)

sb=sb′ (L1 → L1′)

sb = sb′ (L2 → L2′)

```
L0′:
string sb := “”;
int pos = -len(s);
L1′:
while (pos < 0 ||
        !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
}
L2′:
return sb;
```

$\text{post}\left[\begin{smallmatrix}\texttt{L1}\to\texttt{L2} \\ \texttt{L1'}\to\texttt{L2'}\end{smallmatrix}\right](\texttt{sb=sb'}) \Rightarrow \texttt{sb = sb'}$ → TP

validated Lib. property: True

User

chklibs

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sb = sb′

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}
L2':
return sb;
```

$\mathrm{post}\left[\begin{smallmatrix} L1 \to L2 \\ L1' \to L2' \end{smallmatrix}\right](sb = sb') \Rightarrow sb = sb'$ → Lib.-Abd. TP

validated Lib. property: True → Lib.-Abd. TP

User

chklibs

```
L0:                          s = s'        L0':
string sb := "";                           string sb := "";
                             sb=sb'        int pos = -len(s);
L1:                                        L1':
while (!is_sub(sb, s)) {                   while (pos < 0 ||
  app(sb, get());                                !is_sub(sub(sb, pos), s)){
}                                            app(sb, get());
                                             pos := len(sb) - len(s);
L2:                          sb = sb'      }
return sb;                                 L2':
                                           return sb;
```

post[L1→L2 / L1'→L2'](sb=sb') ⇒ sb = sb' → **Lib.-Abd. TP** → ∀x, y. find(x, y)

validated Lib. property: True → **Lib.-Abd. TP**

User

chklibs

```
L0:
string sb := “”;
L1:
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  app(sb, get());
}
L2:
return sb;
```

s = s′ · sb=sb′ · sb = sb′

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L0′:
string sb := “”;
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while (pos < 0 ||
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  app(sb, get());
  pos := len(sb) - len(s);
}
L2′:
return sb;
```

post[L1→L2 / L1′→L2′](sb=sb′) ⇒ sb = sb′

validated Lib. property: True

Lib.-Abd. TP

∀x, y. find(x, y)

User

Experimental Highlights

- Ran tool on 11 performance-bug patches from Apache, Mozilla, and MySQL
- On average, found supporting conditions
  - in < 1 second
  - with < 10 queries (0 - 7 invalid)

Thanks for your attention!

Questions?

```
string sb := “”;
while (!is_sub(sb, s)) {
  app(sb, get());
}
return sb;
```

```
string sb := “”;
int pos = -len(s);
while (pos < 0 ||
       !is_sub(sub(sb, pos), s)){
  app(sb, get());
  pos := len(sb) - len(s);
}
return sb;
```

chklibs 

User 

Questions?

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while (!is_sub(sb, s)) {
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return sb;
```

Org. ≈ Opt
assuming
∀ x, y. `len`(x) > `len`(y) ⇒
¬`is_sub`(x, y)
…

`chklibs`

∀ x, y. `is_sub`(x, y)

Invalid

∀ x, y. `len`(x) > `len`(y) ⇒
¬`is_sub`(x, y)

…

Valid

User

Extra Slides

Apache Bug #19101

Original

```
vector<BuildListener> ls =
getBuildListeners();
for (i=0; i < size(ls); i++) {
  BuildListener l = at(ls, i);
  l.startTask();
}
```

Optimized

Apache Bug #19101

Original

```
vector<BuildListener> ls =
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vector<BuildListener> ls =
getBuildListeners();
for (i=0; i < size(ls); i++) {
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}
```

Optimized

```
int sz =          ;
sz
```

Apache Bug #19101

$\forall$ x, y. `size`(`at[arg0]`(x, y)) = `size`(x)

Original

```
vector<BuildListener> ls =
getBuildListeners();
for (i=0; i < size(ls); i++) {
  BuildListener l = at(ls, i);
  l.startTask();
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```

Optimized

```
int sz =          ;
sz
```

1. Non-redundant

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string sb := “”;
while (!find(sb, s)) {
  app(sb, get());
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string sb := “”;
int pos = -len(s);
while (pos < 0
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  pos := len(sb) - len(s);
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chklibs

User

1. Non-redundant

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∀ x, y. len(x) > len(y) ⇒

¬find(x, y)

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