

# Termination Analysis with Algorithmic Learning

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(joint work with Bow-yaw Wang and Kwangkeun Yi)

## Tasks

Go to MSN home page

E-mail inbox (868 new messages)

View Windows Live

Send an instant mes

● Available

Busy

Away

Appear offline

Sign out from here

Windows Live Messe

Unpin this program

Close all windows

## Windows Explorer

### Windows Explorer is not responding

If you restart or close the program, you might lose information.

➔ Restart the program

➔ Close the program

➔ Wait for the program to respond

Non-termination is annoying

**Non-termination leaks  
resources silently**





**We want to prove termination**

```
while (i > 0 && j > 0) {  
    if (*) i--; else j--;  
}
```

$$i > 0 \wedge j > 0 \wedge (i > i' \vee j > j')$$

Transition Invariant as Termination Proof

# Transition Invariants (Podelski et al., LICS'04)

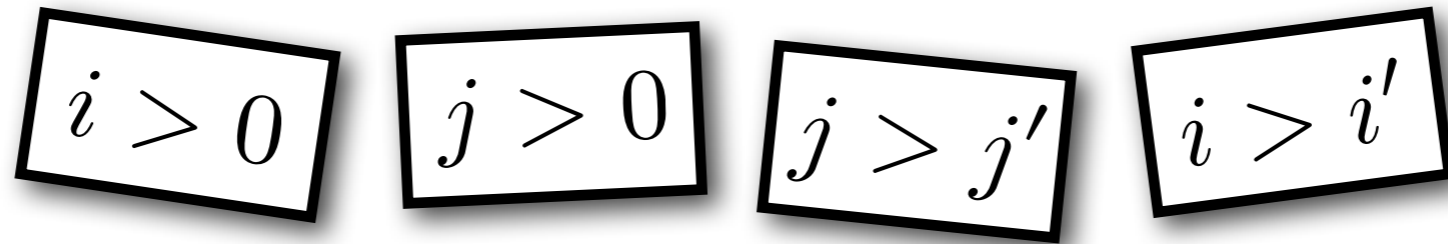
```
while (i > 0 && j > 0) {  
    if (*) i--; else j--;  
}
```

$$\frac{i > 0 \wedge j > 0}{\text{bound}} \wedge \frac{(i > i' \vee j > j')}{\text{progress}}$$

Transition Invariant as Termination Proof

# How we compute transition invariants

## Atomic Predicates



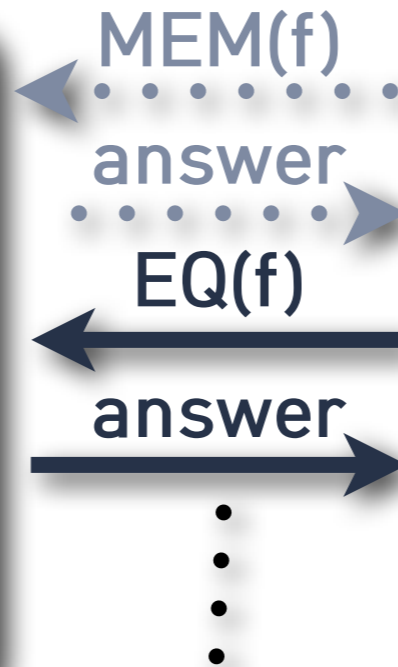
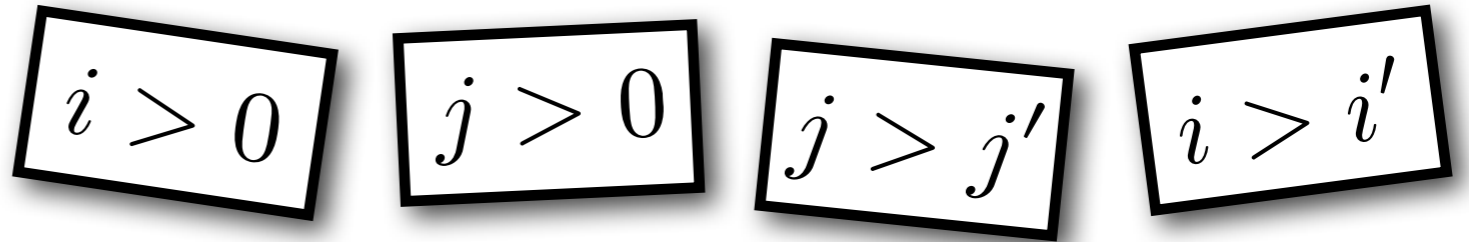
## Transition Invariant

# How we compute transition invariants

## Program

```
while (i > 0 && j > 0) {  
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}
```

## Atomic Predicates



$$i > 0 \wedge j > 0 \wedge (i > i' \vee j > j')$$

## Transition Invariant

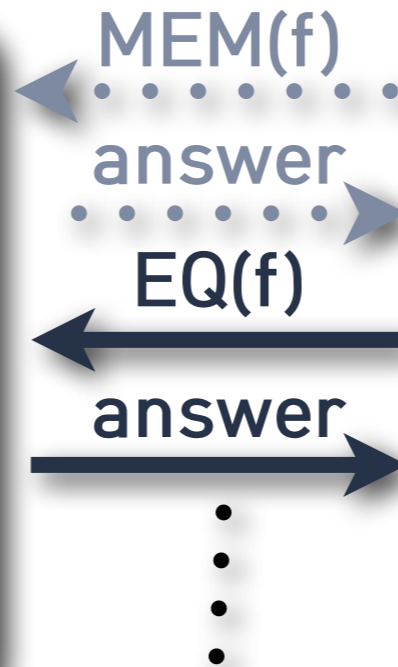
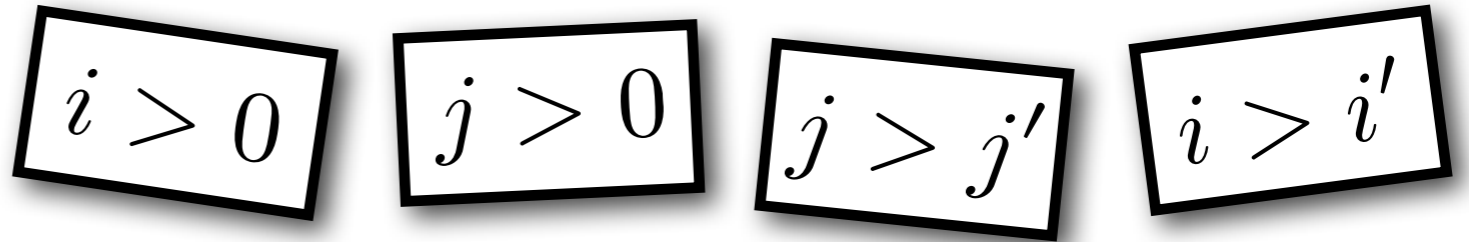


# How we compute transition invariants

## Program

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while (i > 0 && j > 0) {  
  if (*) i--; else j--;  
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## Atomic Predicates

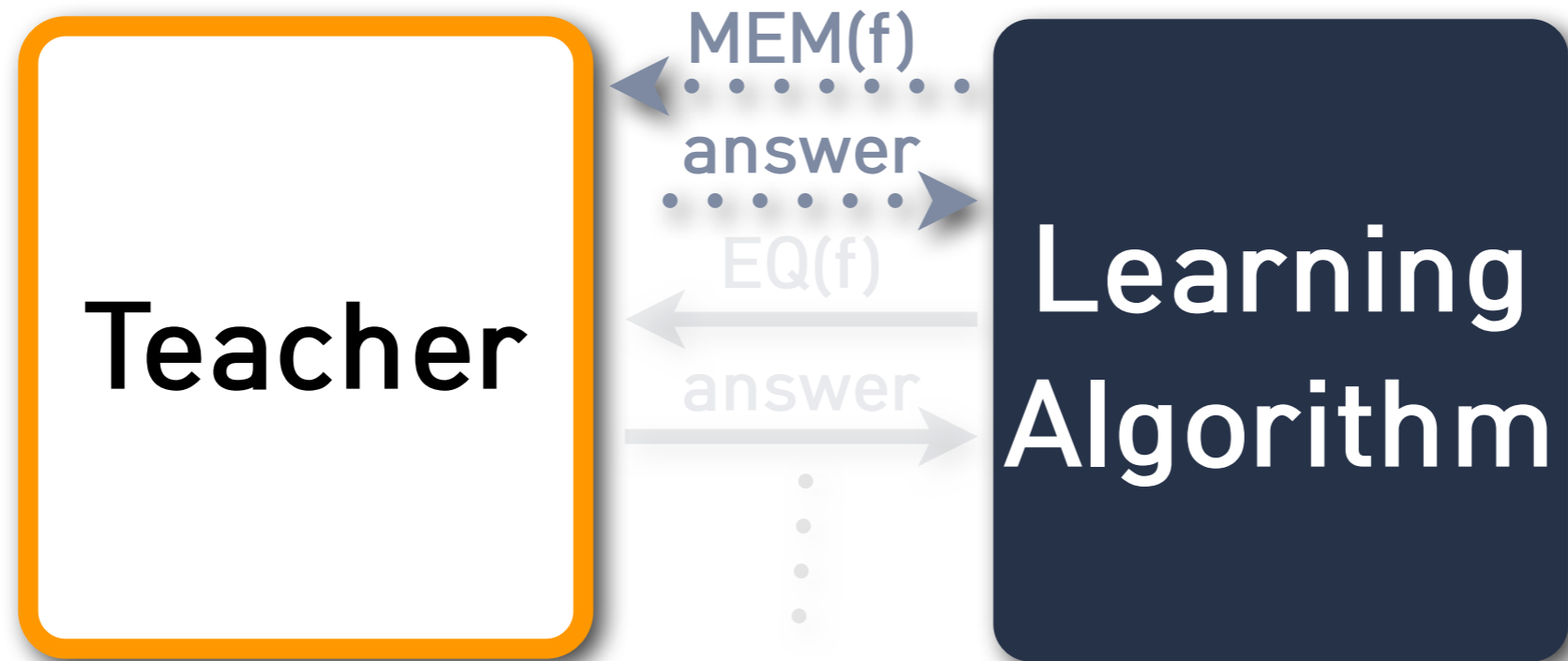


*we should make this!*

$$i > 0 \wedge j > 0 \wedge (i > i' \vee j > j')$$

## Transition Invariant

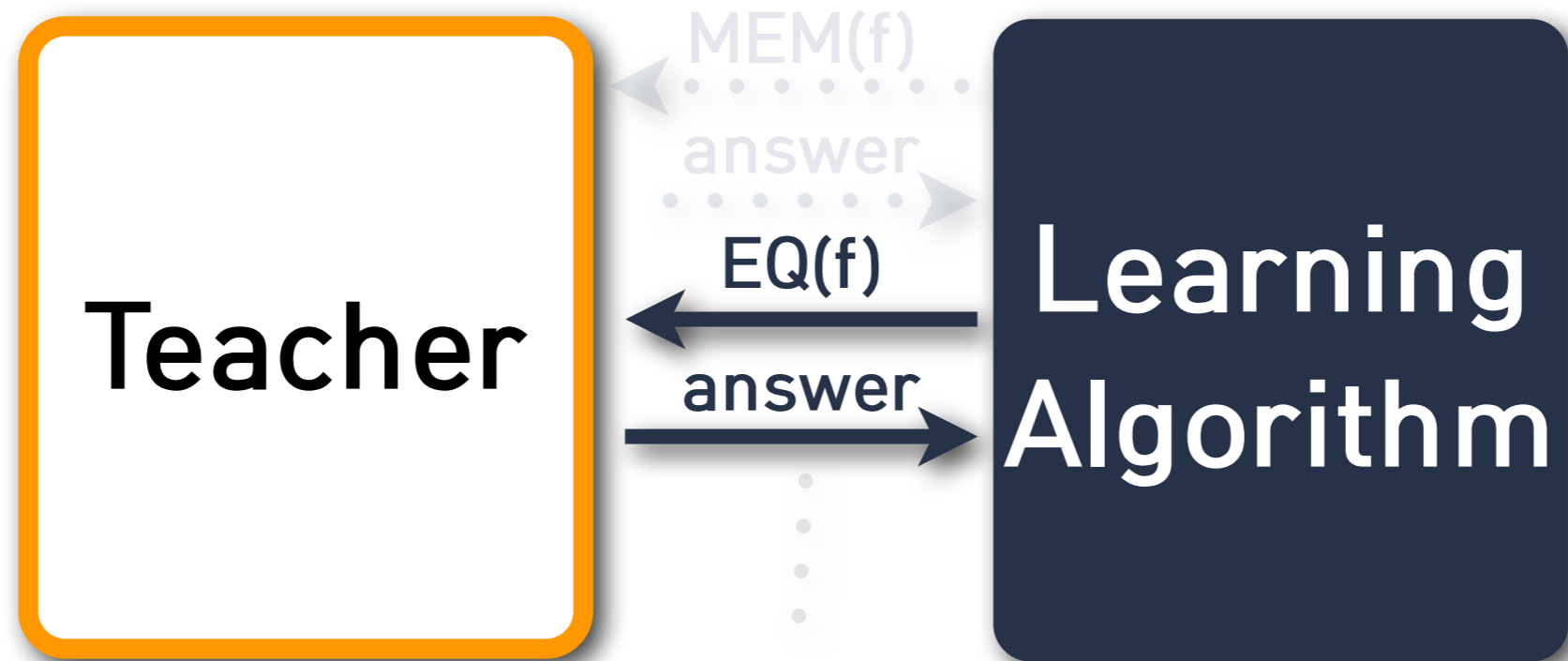
# What teacher should answer



1) Membership Query  $\text{MEM}(f)$ :  
is  $f$  a part of invariant?  $\Rightarrow$  YES/NO

$$\text{MEM}( \boxed{i > 0} \wedge \boxed{j > 0} \wedge \boxed{i > i'} ) \Rightarrow \text{YES}$$

# What teacher should answer



2) Equivalence Query  $EQ(f)$ :  
is  $f$  an invariant?  $\Rightarrow$  YES/CEX

$$EQ( \boxed{i > 0} \wedge \boxed{j > 0} \wedge \boxed{j > j'} )$$
$$\Rightarrow \{i : 1, j : 1, \underline{i' : 0}, j' : 1\}$$

**For more details:**

<http://ropas.snu.ac.kr/~wclee>

- paper on this work
- other paper on learning-based approach

**Thank you!**