1. Problem: Generate enough predicates for invariants \( \{ \delta \} \) while \( \rho \) do \( S \) end \( \epsilon \)

Invariants must satisfy the following conditions:

(A) \( \delta \Rightarrow I \)  
(B) \( I \land \rho \Rightarrow \text{Pre}(I, S) \)  
(C) \( I \land \neg \rho \Rightarrow \epsilon \)

Atomic predicates from annotated loop:

\[
\begin{align*}
\text{precondition} \delta & : n \geq 0 \land x = n \land y = n \\
\text{loop guard} \rho & : \text{while } x > 0 \text{ do } \\
& \{ \text{x := x - 1; } \\
& \{ \text{y := y - 1; } \\
& \text{end } \\
\text{postcondition} \epsilon & : x + y = 0
\end{align*}
\]

Invariant: \( x \geq 0 \land x = y \)

2. Idea: Use Craig’s interpolation theorem

We can always find an interpolation \( I \) from \( A \Rightarrow B \):

(A) \( A \Rightarrow I \)  
(B) \( I \Rightarrow B \)  
(C) \( \text{Var}(I) \subseteq \text{Var}(A) \cup \text{Var}(B) \)

Generating new predicates:

\[
\begin{align*}
\text{Interpolant} & : x = y \land 0 \leq y \\
\text{New predicates} & : x > 0 \land x + y = 0
\end{align*}
\]

3. Solution: Implementing a Teacher both to Answer Queries and Generate Predicates

Overview

From incorrect conjectures

Equivalence query asks whether a conjecture \( \theta \) is equivalent to an invariant

1. Interpolating over-approximation \( \theta \land \rho \Rightarrow \text{Pre}(I, S) \)  
2. Interpolating under-approximation \( I \land \rho \Rightarrow \text{Pre}(\theta, S) \)

From conflicting abstract counterexamples

Two distinct valuation can have the same abstract valuation because of the coarse abstraction

4. Experimental Result

```
<table>
<thead>
<tr>
<th>case</th>
<th>SIZE</th>
<th>PREVIOUS (VMCIT 09)</th>
<th>CURRENT</th>
<th>BLAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>ide-re.sml</td>
<td>16</td>
<td>0.01</td>
<td>1.5</td>
<td>2.98</td>
</tr>
<tr>
<td>riva</td>
<td>29</td>
<td>0.51</td>
<td>2.5</td>
<td>2.29</td>
</tr>
<tr>
<td>cas</td>
<td>9</td>
<td>0.01</td>
<td>2.0</td>
<td>0.59</td>
</tr>
<tr>
<td>sub-message</td>
<td>18</td>
<td>0.01</td>
<td>1.1</td>
<td>0.32</td>
</tr>
<tr>
<td>vpr</td>
<td>14</td>
<td>0.01</td>
<td>0.0</td>
<td>0.23</td>
</tr>
</tbody>
</table>
```

5. Conclusion

* Novel approach to invariants generation.  
* Fully automated with new predicate generation technique.  
* We are currently working on its extension supporting quantified invariants.