SVMRanker: A General Termination Analysis Framework of Loop Programs via SVM

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Verification

Checking termination is neccessary.

Example

```
assume(True);
int x = 1;
while(x>0) x++;
assertion(x<=0);
```

The assertion can be checked once the loop is terminating.
However theoretically...
In the practice the program return `UNKNOWN` once we cannot prove or disprove the termination.
Our tool: focus on the synthesis ranking function.
What is **ranking function**?

Ranking Function

```
assume(True);
int x = 5;
while(x > 0) x--;
assertion(x<=0);
```

ranking function is the function used for proof of termiation.

$$\Omega(x, x') := x > 0 \wedge x' = x - 1$$

Ranking function:

$$f(x) = x$$

- Informally: $f : S \to \mathbb{R}$ where S is the set of states and $\mathbb{R}$ is a well-founded ordered set.
- strictly decreases at each iteration.
- has a lower bound in the loop state space.

More Powerful Ranking Functions

- Linear ranking function: $f(x) = ax + b$.
- Polynomial ranking function.
- k-phase- nested or multiphase ranking function:

$$\langle f_1, \cdots, f_k \rangle$$

Synthesis of Ranking Function

- Prove the termination is UNDECIDABLE.
- Synthesis of a certain class of ranking function is DECIDABLE.

State-of-the-Art Tools

Termination problem is essential and basic to program verification.
State-of-the-art tools:

- LassoRanker in Ultimate Automizer.
- iRankFinder: A tool for ranking function inferring.
- Loopster: A static loop termination analyzer.
- CPAChecker
- ...

Competition SV-COMP also has a termination track for this problem.

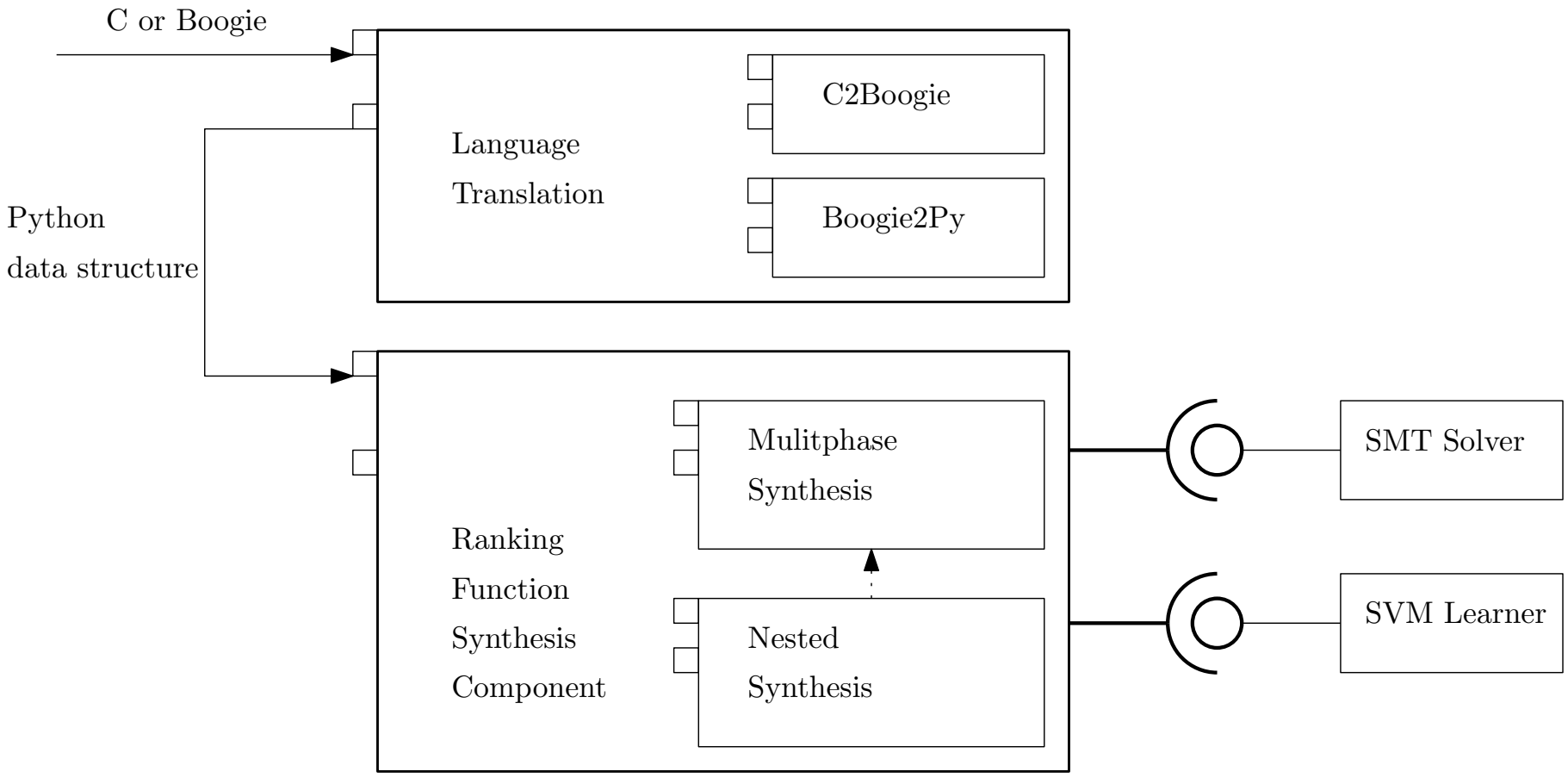
SVMRanker: Synthesize Ranking Function via SVM

Technique previous tools use.

We reduce the synthesis of ranking functions
into the SVM problem.

Advantage? Disadvantage?

SVMRanker: Architecture



Experimental Results: Nonlinear Loops

Cases are adapted from SV-COMP.

Case ID	SVMRanker	iRankFinder	LassoRanker	CPAChecker
116	U	U	U	U
148	Y	U	U	F
149	Y	U	U	U
151	Y	U	U	F
152	Y	U	U	F
153	Y	U	U	F
154	U	U	U	F
155	Y	U	U	F
157	Y	U	U	U
158	Y	U	U	TO
159	Y	U	U	F
160	Y	U	U	TO
161	U	U	U	F
162	Y	U	U	F
163	Y	U	U	F
164	Y	U	U	U
167	Y	U	U	E
171	Y	U	U	E
DoubleNeg	U	U	U	U

Experimental Results: Linear Loops

Draft

Find the derivative of the following function $f(x)$

$$f(x) = 120x - 4x^2$$

$$\begin{aligned}
\frac{df(x)}{dx} &= \lim_{dx \to 0} \frac{f(x+dx) - f(x)}{dx} \\
&= \lim_{dx \to 0} \frac{120(x+dx) - 4(x+dx)^2 - 120x + 4x^2}{dx} \\
&= \lim_{dx \to 0} (120 - 8x - 4dx) \\
&= 120 - 8x
\end{aligned}$$