A generic framework for blackbox components in WCET computation

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introduction
examples of partial analyses
generalization of the approach
experimentation with OTAWA
conclusion
**WCET** computation

WCET computation by static analysis
program control flow analysis
architecture effects analysis
WCET computation \(\rightarrow\) IPET

IPET (Implicit Path Enumeration Technique)
WCET = maximization of \(t_i \times x_i\)
under constraints of an ILP system
program control flow
hardware effects
ILP solver

* Worst Case Execution Time*
blackbox components

WCET computation done on a whole program
program = multiple components
lack of informations on blackbox components
→ no computation
how to handle blackbox component?
partial analysis

* Worst Case Execution Time
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the instruction cache analysis

```c
#define ERR -1
#define OK 0
int status = OK
int fact (int y) {
    int result = 1;
    int i;
    if (y >= 0) {
        for (i = 1; i <= y; i++)
            result *= i;
        status = OK;
    } else status = ERR;
    return result;
}
```

transfer function
state\_after = transfer(state\_before)

summary function
categories = summary(state\_before)
the loop bounds estimation

```c
#define ERR -1
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int status = OK
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    int result = 1;
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    if (y >= 0) {
        for (i = 1; i <= y; i++)
            result *= i;
        status = OK;
    } else status = ERR;
    return result;
}
```

transfer function

\[ \text{state}_{\text{after}} = \text{transfer}(\text{state}_{\text{before}}) \]

summary function

\[ \text{bounds} = \text{summary}(\text{state}_{\text{before}}) \]
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for each analysis

effect: component → main program =
transfer function for each

effect: calling context → ILP parameters =
summary function

for the component

contribution of component = parametrized ILP system
(1) creation of the partial result

each analyzer → transfer 
→ summary

all analyzers → one ILP system
(2) usage of the partial result

with the *transfer* function

do each analysis on the main program

get the component entry state for each analysis
(2) usage of the partial result

with the summary function

apply summaries to get parameter values

instantiate ILP system

solve ILP system
#define ERR -1
#define OK 0
int status = OK
int fact (int y) {
    int result = 1;
    int i;
    if (y >= 0) {
        for (i = 1; i <= y; i++)
            result *= i;
        status = OK;
    } else status = ERR;
    return result;
}

example program

parametrized ILP system

if (p_0=Always_Hit) x^{\text{miss}}_0 = 0
if (p_1=Always_Hit) x^{\text{miss}}_1 = 0
if (p_2=Always_Hit) x^{\text{miss}}_2 = 0
e_{1,1} = p_3 \cdot e_{3,1}

summary

cache summary:
CacheBlock 0, parameter p_0 =
if must(0) < 4 ⇒ Always Hit
else Not Classified
CacheBlock 1, parameter p_1 =
if must(1) < 4 ⇒ Always Hit
else Not Classified
CacheBlock 2, parameter p_2 =
if must(2) < 3 ⇒ Always Hit
else Not Classified

loop bounds summary:
Loop 1, parameter p_3 = 3y

transfer

cache transfer:
ageing (must)
block 0 ⇒ aged 2 times
block 1 ⇒ aged 2 times
inserted blocks (must)
block 2 ⇒ inserted at age 0
loop bounds transfer.
\{x = x + 10\}
Precomputing independent regions

general idea:
pre-compute the WCET of context-independent parts of the component to produce a smaller ILP system.

(we need the summary functions to know which parts are context-independent)
Precomputing independent regions

Single-Entry Single-Exit regions
Constant-WCET regions can be pre-computed
**Precomputing independent regions**

Single-Entry Single-Exit regions

Constant-WCET regions can be pre-computed

The region is now modeled by a single edge.

- basic block
- region

\[
\text{time}_{\text{edge}} = \text{WCET}_{\text{region}}
\]

(the region is now modeled by a single edge)
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experimentation with OTAWA

pessimism increase measurement
average WCET increase: 0.18%

analysis time measurement
average gain: 1.86 times
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Conclusion and future works

blackbox components analysis
handle COTS correctly
speed up WCET computation

future works
finishing branch predictor partial analysis
automate summary/transfer function creation