

Pointer Analysis

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CS6843 Program Analysis
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Dead Code Elimination

```
a = s1.arr;
b = s2.ptr;
q = &a[ii];
p = &b[jj];

if (p == q) {
    x = 10;
    y = 100;
} else {
    x = 20;
    y = 30;
}
```

To check the condition, we need to test if

- $p == q$
- $a + ii * \text{sizeof} == b + jj * \text{sizeof}$
- $s1.arr + ii * \text{sizeof} == s2.ptr + jj * \text{sizeof}$

This needs to be tested statically

Outline

- Introduction
- Pointer analysis as a DFA problem
- Design decisions
- Andersen's analysis, Steensgaard's analysis
- Pointer analysis as a graph problem
 - Optimizations
- Applications
- Parallelization
 - Constraint based
 - Replication based
 - Graph rewrite rules

Common Subexpression Elimination

```
q = s1.arr;
p = s1.ptr;

if (p + i == q + j) {
    x = 10;
    y = 100;
} else {
    x = 20;
    y = 30;
}
```

To identify if the expression is common

- $p + i == q + j$
- $s1.arr + i * \text{sizeof}_i == s1.ptr + j * \text{sizeof}_j$

This needs to be computed statically

Applications

- Dead-code elimination
- Common subexpression elimination
- Parallelization
- Escape analysis

Parallelization

```
f() {
    *p = 10;
}
g() {
    *q = 20;
}
main() {
    ...
    f();
    g();
}
```

To identify if the functions are parallelizable, check if

- $!alias(*p, *q)$

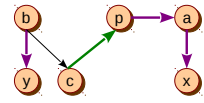
Escape Analysis

```
f() {
    *p = 10;
}
```

- To identify if the definition escapes function f , check
- if p points-to any global / heap variable
 - $\text{pointsto}(p, x)$ where $x \in \text{globals}$ or $x \in \text{heap-allocated}$

Graph Rewrite Rules

Program	Andersen's
$a = \&x;$	$a \rightarrow \{x, y\}$
$b = \&y;$	$b \rightarrow \{y\}$
$p = \&a;$	$c \rightarrow \{y\}$
$c = b;$	$p \rightarrow \{a\}$
$*p = c;$	



copy rule



load rule



store rule

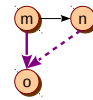
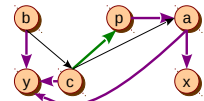
→ Store
→ Points-to
→ Copy
→ Load

Parallel Pointer Analysis

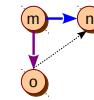
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Graph Rewrite Rules

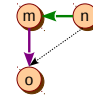
Program	Andersen's
$a = \&x;$	$a \rightarrow \{x, y\}$
$b = \&y;$	$b \rightarrow \{y\}$
$p = \&a;$	$c \rightarrow \{y\}$
$c = b;$	$p \rightarrow \{a\}$
$*p = c;$	



copy rule



load rule



store rule

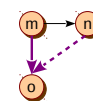
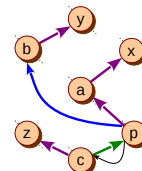
→ Store
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→ Copy
→ Load

Pointer Analysis as Graph Rewrite Rules

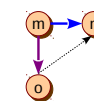
- Initially: **Constraint-based**: pointers and associated points-to sets
- Later: **Graph problem**: pointers as nodes, subset relation forms edges, points-to set with each node
- Now: **Graph rewrite rules**: variables as nodes, all relations form edges, points-to set defined using edges

Classwork

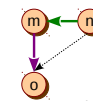
Program
$*p = c;$
$b = \&y;$
$b = *p;$
$p = \&a;$
$a = \&x;$
$*p = c;$
$c = p;$
$c = \&z;$



copy rule



load rule



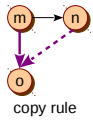
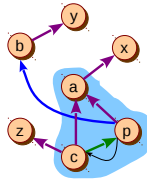
store rule

→ Store
→ Points-to
→ Copy
→ Load

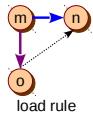
Classwork

Program

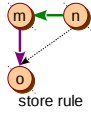
```
*p = c;
b = &y;
b = *p;
p = &a;
a = &x;
*p = c;
c = p;
c = &z;
```



copy rule



load rule



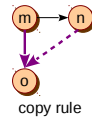
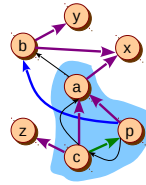
store rule



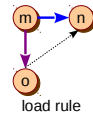
Classwork

Program

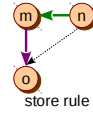
```
*p = c;
b = &y;
b = *p;
p = &a;
a = &x;
*p = c;
c = p;
c = &z;
```



copy rule



load rule



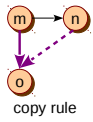
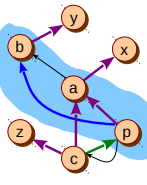
store rule



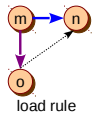
Classwork

Program

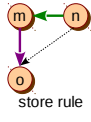
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*p = c;
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b = *p;
p = &a;
a = &x;
*p = c;
c = p;
c = &z;
```



copy rule



load rule



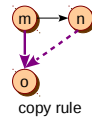
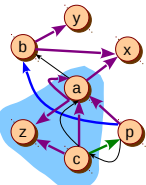
store rule



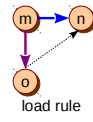
Classwork

Program

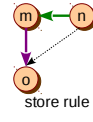
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*p = c;
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b = *p;
p = &a;
a = &x;
*p = c;
c = p;
c = &z;
```



copy rule



load rule



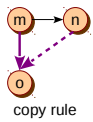
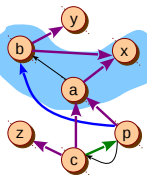
store rule



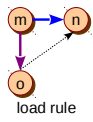
Classwork

Program

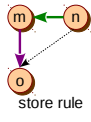
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*p = c;
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c = p;
c = &z;
```



copy rule



load rule



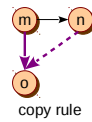
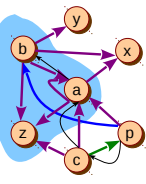
store rule



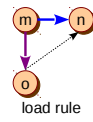
Classwork

Program

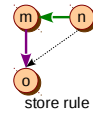
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copy rule



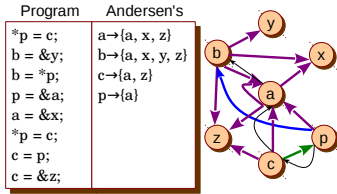
load rule



store rule

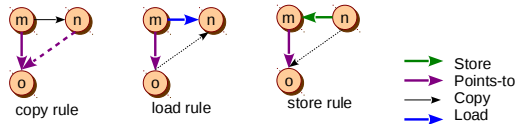


Classwork

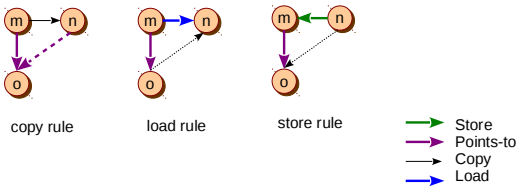
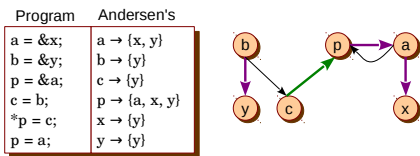


Parallel Graph Rewrite Rules

- *Open*: How to order rule evaluation?
- *Open*: How to combine rules for better efficiency?



Parallel Graph Rewrite Rules



Parallel Graph Rewrite Rules

