Compiler Optimisation
4-from-ssa – Conversion from SSA (addendum)

Hugh Leather
IF 1.18a
hleather@inf.ed.ac.uk

Institute for Computing Systems Architecture
School of Informatics
University of Edinburgh

2019
Things to watch out for when converting from SSA.

- Effect of optimisation
- Critical edges
- Lost copy problem
- Swap problem
Effect of Optimisation

Optimisations can prevent conversion by just merging variables

<table>
<thead>
<tr>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a = x + y$</td>
</tr>
<tr>
<td>$b = x + y$</td>
</tr>
<tr>
<td>$a = 17$</td>
</tr>
<tr>
<td>$c = x + y$</td>
</tr>
</tbody>
</table>

Just a basic block
Effect of Optimisation

Optimisations can prevent conversion by just merging variables

Example

\begin{align*}
a_0 &= x_0 + y_0 \\
b_0 &= x_0 + y_0 \\
a_1 &= 17 \\
c_0 &= x_0 + y_0
\end{align*}

Convert to SSA.
Note that \( b_0 \) and \( c_0 \) are copies of \( a_0 \)
Effect of Optimisation

Optimisations can prevent conversion by just merging variables

Example

\[ a_0 = x_0 + y_0 \]
\[ b_0 = a_0 \]
\[ a_1 = 17 \]
\[ c_0 = a_0 \]

Optimise the redundant expressions. What will happen if we merge variables now?
Effect of Optimisation

Optimisations can prevent conversion by just merging variables

Example

\[
\begin{align*}
a &= x + y \\
b &= a \\
a &= 17 \\
c &= a \ (x+y)
\end{align*}
\]

If we merge \(a_0\) and \(a_1\) back into \(a\), then \(c\) gets the wrong value

So, keep variables, use copies in predecessors of \(\phi\) nodes\(^1\)

\(^1\)As in lecture-3.
Critical Edges

Copies on predecessors difficult with *critical edges*.

**Critical Edge**
A CFG edge whose destination has multiple predecessors and whose source has multiple successors.

**Example**

*Source has multiple successors*: a copy in the source means all of its successors get the copy. If the copy is live into them then potential semantics change.

*Destination has multiple predecessors*: If there was only one, we could put the copy in the destination and probably wouldn’t need the phi node anyway.
Lost copy problem

- Most SSA algorithms *split* critical edges
- Next example shows necessary splitting to prevent lost copy
Lost copy problem

Example

A simple loop

Convert to SSA
Lost copy problem

Example

\[ i_0 = 1 \]

\[ i_1 = \varphi (i_0, i_2) \]

\[ y_0 = i_1 \]

\[ i_2 = i_1 + 1 \]

\[ z_0 = y_0 + \ldots \]

Converted to SSA

\( y_0 \) now redundant

Optimisation: Replace uses with \( i_1 \) and remove definition
Lost copy problem

Example

\[ i_0 = 1 \]

\[ i_1 = \varphi(i_0, i_2) \]

\[ i_2 = i_1 + 1 \]

\[ z_0 = i_1 + \ldots \]

\[ y_0 \text{ removed} \]

Try to convert from SSA

Place copies without splitting
Lost copy problem

Example

\[ i_0 = 1 \]
\[ i_1 = i_0 \]
\[ i_1 = \varphi(i_0, i_2) \]
\[ i_2 = i_1 + 1 \]
\[ i_1 = i_2 \]
\[ z_0 = i_1 + \ldots \]

Copies placed

Now remove \( \varphi \)
Lost copy problem

Example

\[ i_0 = 1 \]
\[ i_1 = i_0 \]
\[ i_2 = i_1 + 1 \]
\[ i_1 = i_2 \]
\[ z_0 = i_1 + \ldots \]

Note: Back edge is critical and \( i_1 \) is live in to loop exit

Does \( z_0 \) use the same version of \( i_1 \) as before the copy?

Instead, split loop’s back edge
Lost copy problem

Example

\[
\begin{align*}
  i_0 &= 1 \\
  i_1 &= i_0 \\
  i_2 &= i_1 + 1 \\
  z_0 &= i_1 + \ldots \\
  i_1 &= i_2
\end{align*}
\]

Edge split keeps semantics

Extra jump can be expensive inside hot loops

Instead, use temporaries to remember correct values
Lost copy problem

Example

\[
\begin{align*}
i_0 &= 1 \\
i_1 &= i_0 \\
i_2 &= i_1 + 1 \\
t &= i_1 \\
i_1 &= i_2 \\
z_0 &= t + ..
\end{align*}
\]

Extra temporary in place
Swap problem

- \( \phi \) nodes execute simultaneously in parallel
  - i.e. All read their operands at once, before any assignments
- Copies do not
  - Naive conversion with copies can cause incorrect behaviour

**Example**

<table>
<thead>
<tr>
<th>Simultaneous phis, swap values</th>
<th>Naive copy, swap lost(^2)</th>
<th>Temporary inserted</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_1 = \phi(x_0, y_1) )</td>
<td>( x_1 = y_1 )</td>
<td>( t = x_1 )</td>
</tr>
<tr>
<td>( y_1 = \phi(y_0, x_1) )</td>
<td>( y_1 = x_1 )</td>
<td>( y_1 = t )</td>
</tr>
</tbody>
</table>

\(^2\)Assume \( x_1 = x_0 \), \( y_1 = y_0 \) placed in another block.
The biggest revolution in the technological landscape for fifty years
Now accepting applications! Find out more and apply at:
pervasiveparallelism.inf.ed.ac.uk

• 4-year programme: MSc by Research + PhD

• Research-focused: Work on your thesis topic from the start

• Collaboration between:
  ▶ University of Edinburgh’s School of Informatics
    ✴ Ranked top in the UK by 2014 REF
  ▶ Edinburgh Parallel Computing Centre
    ✴ UK’s largest supercomputing centre

• Research topics in software, hardware, theory and application of:
  ▶ Parallelism
  ▶ Concurrency
  ▶ Distribution

• Full funding available

• Industrial engagement programme includes internships at leading companies

The biggest revolution in the technological landscape for fifty years

Now accepting applications! Find out more and apply at:
pervasiveparallelism.inf.ed.ac.uk