CS738: Advanced Compiler Optimizations

Points-to Analysis using Types

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Reference Papers

- Bjarne Steensgaard: Points-to Analysis in Almost Linear Time. POPL 1996
- Manuvir Das: Unification-based pointer analysis with directional assignments. PLDI 2000

Language

$$S \quad ::= \quad x = y$$

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\begin{array}{lcl}
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  & | & x = \&y
\end{array}
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\end{array}
$$

Language

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\begin{array}{lcl}
S & ::= & x = y \\
  & \mid & x = \&y \\
  & \mid & x = *y \\
  & \mid & x = \text{allocate}(y)
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Steensgaard's Analysis

- Non standard Types

$$s \in \text{Symbols}$$

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$$\begin{array}{rcl} s & \in & \text{Symbols} \\ \tau & \in & \text{Locations} ::= (\varphi, \alpha) \end{array}$$

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\alpha & \in & \text{Values} ::= \bot \mid \text{ptr}(\tau)
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$$

A denotes type environment.

Steensgaard's Analysis

- Partial Order

$$\alpha_1 \trianglelefteq \alpha_2 \quad \Leftrightarrow \quad (\alpha_1 = \bot) \vee (\alpha_1 = \alpha_2)$$

Steensgaard's Analysis: Typing Rules

$$\frac{A \vdash x : (\varphi, \alpha) \qquad A \vdash y : (\varphi', \alpha') \qquad \alpha' \trianglelefteq \alpha}{A \vdash \text{welltyped}(x = y)}$$

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$$\frac{A \vdash x : (\varphi, \alpha) \qquad A \vdash y : (\varphi', \text{ptr}(\varphi'', \alpha'')) \qquad \alpha'' \trianglelefteq \alpha}{A \vdash \text{welltyped}(x = *y)}$$

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$$\frac{A \vdash x : \tau}{A \vdash \mathrm{welltyped}(x = \mathrm{allocate}(y))}$$

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- Function Definitions

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$$A \vdash x : (\tau_1 \ldots \tau_n) \rightarrow \tau$$
$$\forall i \in \{1 \ldots n\}. A \vdash f_i : \tau_i$$

Steensgaard's Analysis

- Function Definitions
- Need a new type value: $(\tau_1 \ldots \tau_n) \to \tau$

$$\frac{A \vdash x : (\tau_1 \ldots \tau_n) \to \tau \quad \forall i \in \{1 \ldots n\}.A \vdash f_i : \tau_i \quad A \vdash r : \tau}{}$$

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- Need a new type value: $(\tau_1 \ldots \tau_n) \rightarrow \tau$

$$
\begin{gathered}
A \vdash x : (\tau_1 \ldots \tau_n) \rightarrow \tau \\
\forall i \in \{1 \ldots n\}. A \vdash f_i : \tau_i \\
A \vdash r : \tau \\
\forall s \in S^*. A \vdash \text{welltyped}(s)
\end{gathered}
$$

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- Function Calls

$$A \vdash x : \tau \qquad \qquad \tau = (\varphi, \alpha)$$

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$$A \vdash x : \tau \qquad \tau = (\varphi, \alpha)$$
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Steensgaard's Analysis

- Function Calls

$$\begin{array}{ll} A \vdash x : \tau & \tau = (\varphi, \alpha) \\ A \vdash \mathrm{p} : (\tau_1 \ldots \tau_n) \rightarrow \tau' & \tau_i = (\varphi_i, \alpha_i) \\ \forall i \in \{1 \ldots n\}. A \vdash y_i : \tau'_i & \tau'_i = (\varphi'_i, \alpha'_i) \end{array}$$

Steensgaard's Analysis

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A \vdash x : \tau & \tau = (\varphi, \alpha) \\
A \vdash \mathrm{p} : (\tau_1 \ldots \tau_n) \rightarrow \tau' & \tau_i = (\varphi_i, \alpha_i) \\
\forall i \in \{1 \ldots n\}. A \vdash y_i : \tau_i' & \tau_i' = (\varphi_i', \alpha_i') \\
\alpha_i' \trianglelefteq \alpha_i & \alpha' \trianglelefteq \alpha
\end{array}
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Steensgaard's Analysis

- Function Calls

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Manuvir Das's *One-level Flow-based* Analysis

$$\alpha_1 \le \alpha_2 \quad \Leftrightarrow \quad \mathsf{ptr}(\tau_1) \le \mathsf{ptr}(\tau_2)$$

Manuvir Das's *One-level Flow-based* Analysis

$$\begin{aligned} \alpha_1 \leq \alpha_2 &\Leftrightarrow \mathsf{ptr}(\tau_1) \leq \mathsf{ptr}(\tau_2) \\ &\Leftrightarrow \mathsf{ptr}((\varphi', \alpha')) \leq \mathsf{ptr}((\varphi, \alpha)) \end{aligned}$$

Manuvir Das's *One-level Flow-based* Analysis

$$
\begin{aligned}
\alpha_1 \leq \alpha_2 &\Leftrightarrow \mathsf{ptr}(\tau_1) \leq \mathsf{ptr}(\tau_2) \\
&\Leftrightarrow \mathsf{ptr}((\varphi', \alpha')) \leq \mathsf{ptr}((\varphi, \alpha)) \\
&\Leftrightarrow (\varphi' \subseteq \varphi) \wedge (\alpha' = \alpha)
\end{aligned}
$$

One-level Flow-based Analysis

- Replace $\trianglelefteq$ by $\leq$ in Steensgaard's analysis

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- Replace $\trianglelefteq$ by $\leq$ in Steensgaard's analysis
- Keeps "top" level pointees separate!