Technische Universität München — *Winter Semester 10/11*
Fakultät für Informatik — *Vesal Vojdani*
Prof. Dr. H. Seidl — *Aleksandr Karbyshev*

Program Optimization

Exercise Sheet 5

Deadline: December 6, at the lecture.

Exercise 1: *(P) Fixpoint solving* — *No Points*

Recall the constraint system of exercise 4 (for Available Expressions analysis) from the Sheet 1 over the domain $\mathbb{D} = 2^{\{a+b, a-b\}}$:

$$\mathcal{A}[1] \sqsupseteq \emptyset$$
$$\mathcal{A}[2] \sqsupseteq \mathcal{A}[1] \cup \{a+b\}$$
$$\mathcal{A}[3] \sqsupseteq \mathcal{A}[2] \cup \{a-b\}$$
$$\mathcal{A}[3] \sqsupseteq \mathcal{A}[5]$$
$$\mathcal{A}[4] \sqsupseteq \mathcal{A}[3] \cup \{a+b\}$$
$$\mathcal{A}[5] \sqsupseteq \mathcal{A}[4] \setminus \{a+b, a-b\}$$
$$\mathcal{A}[6] \sqsupseteq \mathcal{A}[3] \cup \{a+b\}$$

Note that these have been written using the generic lattice operations, rather than the concrete set operations.

a) Give the (vector-)function $F = \langle f_1, \ldots, f_6 \rangle$ we use for fixpoint solving. For example, $f_1(x_1, \ldots, x_6) = \emptyset$ and $f_2(x_1, \ldots, x_6) = x_1 \cup \{a+b\}$.

b) Using Kleene iteration, find the least fixpoint!

Exercise 2: *(P) Live Variables and Friends* — *No Points*

Go to http://www.program-analysis.com and try the PAG/WWW system. The four analyses, Available Expressions, Live Variables, Reaching Definitions, and Very Busy Expressions are data flow analyses that work on sets. Create a table indicating for each analysis: 1) Is it a backward or forward analysis? 2) What are the order and join operation?

Exercise 3: *(H) An Abstract Value Domain* — *15 Points*

a) Define an abstract value domain $\mathbb{D}$ that is ideally suited to answer, whether for an integer value x, the following hold: $x \geq 0$, $x < 0$, x is odd, and x is even. Use a bottom element to represent error values.

b) Define the description relation $\Delta \subseteq \mathbb{Z} \times \mathbb{D}$.

c) Define abstract arithmetic operations for multiplication $n \cdot m$ and integer exponentiation n^m (which returns error for $m < 0$).

d) Show that your operations respect the description relation.

e) Define the domain of a constant propagation analysis based on this value domain and specify the transformation function for the edge $x = e$.