CS 201
Exam-I
October 31, 2018

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1. (40 points: 7+4+4+10+15) For the control flow graph given below: (a) provide the dominator tree; (b) identify the loop back edges using dominator information; (c) identify the loops corresponding to each loop back edge; (d) provide the dominance frontier sets; and (e) provide the corresponding SSA-form.

(a) Dominator tree

(b) Loop back edges
\[ 5 \rightarrow 1 \]
\[ 6 \rightarrow 5 \]

(c) Loops
\[ \{1, 2, 3, 4, 5, 6\} \]
\[ \{5, 6\} \]
(d) Dominance Frontiers

DF(0) = \emptyset

DF(1) = 1

DF(2) = 1, 7

DF(3) = 5

DF(4) = 5

DF(5) = 1, 5, 7

DF(6) = 5, 7

DF(7) = \emptyset

(e) SSA-form
2. (30 points) **Constant Propagation (CP)** Apply constant propagation to the following code and provide the solutions at marked entry and exit points of various basic blocks.
3. (30 points) Given a variable $X$, develop a single data flow analysis that classifies $X$ at each program point $p$ as being: (a) **DefinitelyInitialized (DI)** – if $X$ is defined along all paths leading to $p$; (b) **DefinitelyUninitialized (DU)** – if $X$ is not initialized along any path leading to $p$. (c) **Either (E)** – if $X$ is defined along some paths and undefined along some paths leading to $p$;

Your solution must provide the following: (i) the information set $L$ (ii) the meet operator $\land$, also identify the top and bottom elements; (iii) the pictorial representation of the partial order relation; (iv) the transfer function; (v) the data flow equations; and (vi) the initialization of data flow values.

(a) $L = \{ UNDEF, DI, DU, E \}$

(b) $T = UNDEF$

(c) $E = D$

(iii) $T = UNDEF$

\[ D \rightarrow DI \rightarrow DU \]

\[ E = T \]

(iv) $f_s(X) = \begin{cases} DU & \text{if } s \text{ assigns to } X \\ \bot & \text{otherwise} \end{cases}$

(v) $IN_{[n, x]} = \bigwedge_{p \in \text{pred}(n)} f_n(IN_{[p, x]})$

(vi) $IN_{[s_0, x]} = DU \ \ s_0 - \text{start node}$

$IN_{[n, x]} = UNDEF \ \forall n \in N - \{s_0\}$