Compiler Design
Final Exam

April 28 2006, Open book
All questions carry equal credit
Time: 2 hours

1. Below is an algorithm that uses the SSA form of a program for liveness analysis. Analyze the program and answer the following questions:

   (a) What is the set `M` that is constructed?

   (b) What is the graph constructed in procedure `LiveOutAtStatement`?

   (c) For each variable `v` the algorithm walks backwards from each use. When does it stop?

   (d) Is there any specific feature of the region of the program explored by the algorithm for a variable `v`?

   (e) Does it matter for (d) above whether the program is in SSA form or not?

```
procedure LivenessAnalysis
 begin
  for each variable v
   M = {}
   for each use s of v
    if s is a phi function with v as i^th argument
    then
     p = i^th predecessor of block containing s;
     LiveOutAtBlock(p, v);
    else
     LiveInAtStatement(s, v);
    endif
   endfor
  endfor
 end

procedure LiveOutAtBlock(n, v)
 begin
```

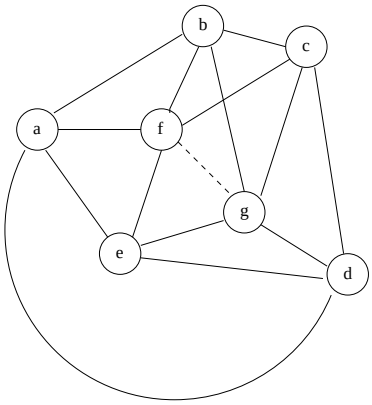
```
  set v to live-out at n;
  if n does not belong to M
  then
   M = M U {n};
   Let s be the last statement in n;
   LiveOutAtStatement(s, v);
  endif
 end

procedure LiveInAtStatement(s, v)
 begin
  set v to live-in at s;
  if s is the first statement of block n
  then
   set v to live-in at n;
   for each predecessor p of n
    LiveOutAtBlock(p, v)
   endfor
  else
   Let s' be the statement preceding s
   LiveOutAtStatement(s', v)
  endif
 end

procedure LiveOutAtStatement(s, v)
 begin
  set v to live-out at s;
  Let W be the set of variables defined at s;
  for each variable w in W-{v}
   add edge (v, w) to graph
  endfor
  if v does not belong to W
   LiveInAtStatement(s, v)
  endif
 end
```

30 marks

2. Consider the graph below where the solid lines represent interferences and the dashed represent a `move` instruction.



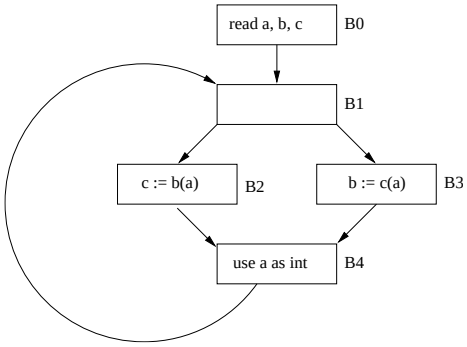
(a) 4-colour the graph without coalescing. Show the colouring stack indicating the order in which you removed nodes. Is there a potential spill? Is there an actual spill?

(b) 4-colour the graph with Briggs coalescing. Is there a potential spill? Is there an actual spill?

potential spill = node of degree $\geq$ k after $\leq$ degree k node removal

20 marks

3. Find the best estimate of the types of each variable in the flowgraph below, using the "*dataflow analysis based type estimation*" algorithm given in the ASU's book. Provide informal arguments for each pass. There is no need to write down the complete trace of all the passes.



15 marks

4. Set up the interprocedural live variable analysis problem (including recursive procedures) and show its working with an example program.

20 marks

5. Find the most general unifier of the type expressions

   (a) $(pointer(\alpha)) \times (\beta \rightarrow \gamma)$

   (b) $\beta \times (\gamma \rightarrow \delta)$

   What happens if the δ in (ii) above where α ? 15 marks