

Write your answers on another sheet of paper. Homework assignments are to be completed individually. Hand written submissions are fine, but they must be readable. Due at the beginning of class. Total points: 100, 5% of course grade

1. [20 Points] True or False. If a statement is false, explain why.
 - (a) Memory-dependence profiles enable more flexible register allocation.
 - (b) It is not possible to do full-path, context-sensitive analysis for recursive functions.
 - (c) The third Futamura projection compiles a program.
 - (d) Implementing array accesses for Java only requires generating the address arithmetic. For example, the read reference $A[i]$ (with A being an array of integers) would result in only the following 3-address code:

```
t1 = i*4
t2 = &A + t1
t3 = *t2
```

- (e) Mark and sweep garbage collection can result in cyclic data structures that are not reachable, but can not be collected.
2. [35 Points] Data Dependence Analysis

```
for i = 1 to 6
  for j = i+1 to 8
    A(i,j) = B(i-1, j+2) - 1 + A(j,j+1)
    B(i,j) = A(i+1, j-1) + A(j,i)
```

- (a) Draw the iteration space graph for the above loop. Include the data dependences between iterations.
- (b) Show the data dependence problems for the above loop. Determine if a solution is possible. If so, calculate the dependence distance vector and indicate the dependence type (flow, anti, or output). If it is not possible to calculate a distance vector, then calculate the direction vector.

2. [20 Points] Loop Transformations for Parallelism and Data Locality

```
for i = 1 to 6
  for j = 1 to 6
    for k = 1 to 6
      A(i,j,k) = ...
      ... = A(i,j-2, k+2) + A(i,j,k)
```

- (a) What are the direction vectors for the above dependences?
 - (b) Which loops carry a dependence?
 - (c) Which loops are parallelizable?
 - (d) Specify the unimodular transformation matrix that legally permutes the j and k loops in the above loop nest. It will be necessary to compose skewing with permutation.
 - (e) Rewrite the $A(i,j-2,k+2)$ array access for the transformed loop.
3. [25 Points] Kelly and Pugh transformation framework. Use the Kelly and Pugh transformation framework to answer the following questions.

- (a) What is the anti-dependence relation between the read to $a(i-2)$ and the write to $a(j)$?

```
for i=0,(N-1) do
  for j=0,(N-1) do
    a(j) = a(i-2)
  endfor
endfor
```

- (b) Use the Kelly and Pugh transformation framework to show that fusion is not legal for the following two loops.

```
for i=0,(n-1)
  c(i) = a(i) / 2
endfor
for j=0,(n-1)
  d(j) = 1 / c(j+2)
endfor
```

- (c) Use the Kelly and Pugh transformation framework to specify loop reversal and loop fusion transformations for the above two loops, and show their legality.
4. [10 Extra Points] Describe in one page or less how you could modify the MiniJava compiler to implement inheritance and dynamic binding.