

MSCS Comprehensive Exam: Spring 2002

Answer five of the six problems.

1. Turing Records is putting together a CD music collection, featuring the top hits of musicians and bands like Britney Knuth, the Backstreet Karpis, and Seymour “Puffy” Cray. There are a number of songs, each that lasts a certain number of seconds. Let S_1, S_2, \dots, S_n be n songs that we can choose from, and we’ll want a subset of these for a single compact disk. Song S_i lasts t_i seconds, and the capacity of the disk is T seconds total, where $T < \sum_{i=1}^n t_i$. We want to maximize the number of songs on the CD; give an optimal greedy algorithm to do this, and prove that the algorithm is correct.

Now, suppose we want to release a box set of all the songs, and minimize the number of disks in the collection. Can we do this efficiently? Why, or why not?

2. We are given the plumbing diagram for a large building; there are many interconnected pipes, each with a known water carrying capacity (in gallons per minute). Sketch an algorithm to determine how much water can be carried from the pipes that connect directly to the city water supply to the city sewer system. There may be many pipes that connect to the supply, or to the sewer; find the *maximum total* number of gallons per minute that can pass through the system. *Give algorithm details; don’t just say what the algorithm is called.*

If we need to increase capacity, how would you determine where to add more pipe?

3. (a) The granularity of protecting objects in the virtual address space is a page. Consider a D-cache and an I-cache that use physical tags and virtual address indices. Assume that the caches are set-associative. Show how the cache designs can be modified to protect memory objects at the level of a line. Show explicitly the nature of the entry for each line in a cache frame. Assume that the access rights permitted are read, write and execute-only. What information does the CPU need to provide to the cache (& TLB) for accessing the caches? (Hint: consider how the TLB checks for access rights!)

(b) Does your design impose any restriction on sharing a common physical line between two processes with different access rights? If so, is there any way to generalize your design to remove this restriction?

(c) What can the Operating System and the architecture do to speed up transfers of control and/or data between an application and the kernel?

4. (a) Recall that there are three types of data dependencies: true (or flow) dependency, anti-dependency and output dependency. Explain how the register renaming mechanism addresses these dependencies in the process of exploiting ILP.

(b) What can a compiler/post-processor do to improve the performance of a modern pipelined processor? Explain at least two techniques that a compiler/post-processing module can use in this respect.

5. (a) Describe the steps taken by a machine to implement a high-level language procedure (or function) call. Describe the roles and use of (at least) the stack, activation record, registers, program counter, return value, and return address; and describe how they are used to implement a call.

(b) What extra steps are needed to handle nested procedures, where the scope of the nested procedure is entirely inside some enclosing procedure.

(c) Some implementations of languages with nested procedures have used more than one register to provide references to the more than one activation record in the stack. What are the benefits and disadvantages of using these extra registers?

(d) Does the D-cache employed in most modern machine help or hinder the implementation of procedure/function calls and returns? Explain your result.

6. Describe the differences between ways objects (instances of classes) can be created in a C++ program and the different locations they can be stored in memory during execution. Compare the more limited model of Java. What is meant by garbage and automatic garbage collection? Why is garbage collection in Java relatively simple and garbage collection in C++ very hard or impossible?