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## Reading

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1. Mitchell, Chapter 8
2. Guy Steele, "Growing A Language",  
<http://homepages.inf.ed.ac.uk/wadler/steele-oopsla98.pdf>  
(Available from the "Links" web page.)

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## Problems

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1. (10 points) ..... ML Modules  
Recall the signature EQ and functor PairEQ from Lecture 29. Please write a functor ListEQ that takes a structure P:EQ and constructs another structure matching signature EQ such that the elements of type t are lists of elements from type P.t, and two elements are equal if they are the same length and corresponding elements are equal according to P.eq.  
Test your functor by applying it to structure IntEQ from lecture 29 to construct a structure named ListIntEQ. Show that that ListIntEQ works properly by building elements of type ListIntEQ and applying the function ListIntEQ.eq to the elements.
2. (15 points) ..... Equivalence of Abstract Data Types  
  
Mitchell, Problem 9.2
3. (20 points) ..... Modularity of Concrete Data Types  
In lecture 19 we discussed an environment-based interpreter for PCF. It is available on-line from the course web page by following the link to "Programs from lecture". In this problem, I would like you to modify that program in order to determine how easy it is to add new features.  
  
(c) Please add a new ML function pretty-print that takes a PCF term and returns a string containing a nice readable version of the term.  
**Note: The datatype term is given in the PCF parser, available from the same programs page. Feel free to copy and paste the definition into PCFEnvinterp.sml and drop the use ... line.**  
The string should contain parentheses to indicate precedence. For example, the term  

```
AST_IF(AST_BOOL true,AST_NUM 5, AST_APP(AST_SUCC, AST_NUM 2))
```

should be pretty-printed as  

```
if true then 5 else (succ 2)
```

whereas  

```
AST_APP(AST_IF(AST_BOOL true,AST_PRED, AST_SUCC), AST_NUM 2)
```

should be pretty-printed as  

```
(if true then pred else succ) 2
```

- (b) Please add a new term to PCF representing sums of integers. I.e., add a new clause to the definition of term of the form `AST_SUM of term * term` so that `AST_SUM a b` represents `a + b`.

Modify the previous program that contains both the `newinterp` function to evaluate terms and `prettyprint` to accommodate the new term.

- (c) I am not asking you to modify the PCF parser code that is available on-line. However, please describe at a high level what would have to be done to modify that code.
- (d) The PCF parser code is presented as a signature and structure. Please take the final code from part b of this question and wrap it in a structure with the appropriate signature so that only the appropriate constructs are publicly available.

*Note: If you wish, you need only turn in the code from the last part of this question plus the description of the modifications to the parser from the previous part. The answers to the first two parts need not be turned in separately.*

#### 4. (25 points) ..... “Growing a Language” Reading

Please read the short paper entitled “Growing a Language” from the auxiliary reading page. The author, Guy Steele, is one of the designers of Java, and this was his keynote talk at the major American conference on object-oriented languages (OOPSLA) in 1998..

This paper includes a discussion of why some items were originally left out of Java when they designed the language, but likely should have been included. It also gives some insight into programming language design in general. The following questions will guide you through the paper:

- (a) What is wrong with designing/using a small language like Lisp?
- (b) What is wrong with designing/using a huge language (C++)?
- (c) What was Steele’s goal in designing Java?
- (d) Why does Steele feel that overloaded operators are important. Contrast this with his conviction (expressed elsewhere) that overloaded methods might have been left out without much harm.
- (e) Discuss why generics might have been left out originally, but why he now feels they are important.

Write a separate paragraph discussing each of these items. A few sentences on each part is sufficient.

We will spend some time discussing these points at the beginning of class on Wednesday.