**Harvard School of Engineering and Applied Sciences — CS 152: Programming Languages**

# Functional Reactive Programming
# Section and Practice Problems

Monday May 4, 2015

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## 1 Functional Reactive Programming

Consider the core calculus for Elm, presented in Lecture 24. Let $i$ be a signal of integers (i.e., $i$ has type **signal int**).

(a) Write a program that computes the factorial of the current value of $i$. That is, the type of your program should be **signal int**, where the current value of the signal should be the factorial of the current value of $i$. (Assume that you have whatever arithmetic operations you need.)

(b) Write a program that computes a signal that is the sum of all of the values of $i$. That is, the type of your program should be **signal int**, where the current value of the signal should be the sum of all values that signal $i$ took on. (Hint: use foldp. Assume that you have whatever arithmetic operations you need.)

(c) Write a program that computes a signal that is the sum of the current and the previous value of $i$. Hint: you may assume that you have pairs.

(d) Write a program that attempts to use a signal of signals of integers. That is, write an expression that should have type **signal signal int**. Check to make sure that this expression is *not* well typed.

(e) Show the first phase evaluation of the following program. Assume that $i$ and $j$ have type **signal int**.

$$
\begin{array}{l}
\mathsf{let}\ mul = \lambda a{:}\mathbf{int}.\ \lambda b{:}\mathbf{int}.\ \lambda c{:}\mathbf{int}.\ a \times (b + c)\ \mathsf{in} \\
\mathsf{let}\ comb = \lambda x{:}\mathbf{signal\ int}.\ \lambda y{:}\mathbf{signal\ int}.\ \mathsf{lift}_2\ (mul\ 2)\ x\ y\ \mathsf{in} \\
\mathsf{let}\ t = comb\ i\ j\ \mathsf{in} \\
\mathsf{let}\ u = \mathsf{foldp}\ (mul\ 3)\ 0\ t\ \mathsf{in} \\
comb\ i\ u
\end{array}
$$

For the final term that is the result of the first phase evaluation of the program, draw a signal graph that shows the signals the program computes.

As a bonus, try the second phase evaluation of the program, assuming that the initial value of $j$ is 1, and input signal $i$ takes on the values 1, 2, 3, 4, ....