Currying & Higher Order Functions

**Theory of Currying**

* breaking down a function with multiple parameters into a series of functions that handle the parameters
* or the technique of converting a single function that takes multiple arguments into a series of functions that each take a single argument
* this also allows the creation of ***partially evaluated functions***
  + For example, instead of having a function add(2, 3), you would have a function *add(x)* that would be called twice: add(2)(3)
    - just calling add(2) would create a new function that always adds 2 to whatever argument is passed to it
* **not easily supported in most big languages**
  + **except JavaScript!!**

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| **The visual way of viewing Currying** |
| (this way normally)  (this way using Currying) |

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| **JavaScript Currying Example** |
| JavaScript Functions |
| function **add** (a, b) { return a + b; }  function **curry\_add** (a)  {    return function (b) { return a + b; }  }  function **curry\_factor** (a)  {    return function (b) { return a \* b; }  }  function **curry\_factor** (a) {    return function (b) {      // go through the array and factor      for(i = 0; i <b.length; i++)      { b[i] = b[i] \* a; }      // return the list of a \* b;      return b;    }  } |
| JavaScript “main” |
| print('Hello World');  print ('normal function call --> ' + add(3, 4) ); // returns 7  print ('curried function call --> ' + curry\_add(3)(4));  var add3 = curry\_add(3);  print ('broken up curried function call --> ' + add3(4));  //print ('curried function call --> ' + curry\_add(3)(4)(5));  // so try a curry\_factor example  var factor = curry\_factor(3);  print ('broken up curried function call --> ' + factor([4,6,8]));  print ('curried function call --> ' + curry\_factor(10)([4,6,8])); |
| JavaScript Output |
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| **Other Language Examples** |

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| Scheme | Haskell |
| (define (curry f)    (lambda(x)      (lambda(y)        (f x y))))  (((curry +) 5) 5) | add :: (Num a) => a -> a -> a add first second = first + second  print ((add 5) 5) |

Convert the following Scheme function to a series of functions that only require one input.

(define (sub a b c)

  (- (- a b) c)

 )

(sub 23 13 3)     +> (should look like) 🡺   ((sub 23) 13) 3)

**What are higher order functions?**

* Higher order functions can:
  + take functions as parameters
  + return produce functions
* are used for mapping, filtering, folding, and sorting of lists
* promote modularity of programs
  + Writing higher order functions that are applicable in many cases makes program readable rather than writing recursive functions for individual cases
* Higher-order functions are very common in Haskell/Scheme (and in functional programming).

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| **Higher Order Function Examples** |
| Gambit Scheme |
| (apply **char<?** lst) ; character list  (apply **string<?** lst) ; string list  (apply **<** lst) ; numeric list |
| C++ Version 1 |
| struct CompareNames{    bool operator() (const STUDENT &e1, const STUDENT &e2){      if(e1.Lname == e2.Lname){        return e1.Fname < e2.Fname;      }      return e1.Lname < e2.Lname;    }  }; |
| C++ Version 2 |
| friend bool compare(STUDENT &e1, STUDENT &e2) { return e1.score < e2.score; }  sort(CMSC\_202.begin(), CMSC\_202.end(), **compare**); |

**Theory of Functions as parameters**

* Design of the function is based on the application
* One object could be sorted (in our example) many ways

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| **Function Design by Application** | |
| Version 1 (what could we compare?) | |
| Student 1 | Student 2 |
| Version 2 (what could we compare?) | |
| Student 1 | Lupoli |

In any applications we discussed, what return values would the sample function(s) return?

**Why Are They Useful?**

* Common programming idioms can be encoded as functions within the language itself
* Domain specific languages can be defined as collections of higher-order functions
  + For example, higher-order functions for processing lists.
* Algebraic properties of higher-order functions can be used to reason about programs

**The ugly side of higher-order functions**

* not always built-in
  + versions of Scheme vary widely!!
  + There is **no “filter”** in Gambit Scheme
* if you do not find the higher-order function you need, have to find it!
  + in GAMBIT – had to find them!
* once the code is downloaded, it then needs to be included with your code
  + in this case, we need to add to our Unix server!!

1. In our Unix server, create a directory “higherOrder”.
2. Download/Copy/etc… the files below into the new directory where you will be writing some Scheme code

wget <http://faculty.cse.tamu.edu/slupoli/notes/Scheme/code/apps.scm> .

wget <http://faculty.cse.tamu.edu/slupoli/notes/Scheme/code/sort.scm> .

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| **Loading the custom higher-order functions** |
| (load "sort.scm")  (load "apps.scm")  ;(display (map pow2 '(1 2 3 4))) ;pow2 is not in Gambit  (display (map + '(1 2 3) '(4 5 6))) |

1. Create a file higher.scm with the code above
2. Run the above code to make sure loading works
3. **What did the code do? What did it return?**
4. Add this line below:

(display (map + '(1 2 3) '(4 5 6 ***7***))) => (5, 7, 9)//!7

1. **What did it do? Any change in output? Why? (called type checking)**

**The Map Function**

* The higher-order library function called map applies a function to every element of a list

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| **Scheme Map Function** |
| Syntax |
| (map procedure list1 list2 ...)  ; notice this can be applied to multiple lists at a time |
| Simple |
| (map pow2 '(1 2 3 4)); gsi does not have this function (sadly)  ; Adding each item of '(1 2 3) and '(4 5 6).  (map + '(1 2 3) '(4 5 6))  ⇒ (5 7 9) |
| Complex |
| ; Squaring each item of '(1 2 3)  (map (**lambda** (x) (\* x x)) '(1 2 3))  ⇒ (1 4 9)    ; also had to do this for the basic Gambit-Scheme setup!! It didn’t have pow2!!  Notice how useful lambda is here, since it requires a function!  Also notice this is curried!!  [0] = lambda function (could have been anything!!)  [1] = value |

1. Using the code already created and above, create the function “curve” that will accept a list (you create) and add 10% to the grades. Display your result for proof it worked.
2. Can you change your function slightly to use lambda?
   1. Did data change types? (welcome to type checking)

Answerb:

**The Filter Function**

* The higher-order library function filter selects every element from a list that satisfies a ***predicate***
  + ***the predicate function is a part of the requirements***

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| **Scheme Filter Function** |
| Syntax |
| ; **not in gambit scheme**, why we load sort.scm  (filter predicate-function list1) |
| Simple |
| (filter positive? '(1 -3 4 7 -4))   ⇒ (1 4 7) |

1. Using the Gambit Scheme HTML Manual, find 2 “check” functions (functions with ? at end). You might need to change the data to get it to work, but those are minor changes.
   1. Make sure to include “apps.scm” // apps has filter in it!

**The Sort Function**

* I think you know how this works!
  + ***but the LAST parameter is how you wanted it sorted by!***

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| **Scheme Filter Function** |
| Syntax |
| ; need to (include "sort.scm") for Gambit  (include "sort.scm")  (sort list1 comparison-operator/function) |
| Simple |
| (sort '(7 3 8 2) <) ⇒ (2 3 7 8) |
| Complex |
| 1. Complete a sort on a list of Characters! What comparison function should you use?    1. Make sure to include “sort.scm” 2. Now try Strings! |

**The Apply Function**

* applies a procedure to a list
* the first parameter
  + has to be the function
* last parameters
  + has to be the list
* everything in between is what is applied
  + this part is computed first!

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| **Scheme Apply Function** |
| Syntax |
| (apply **function** optional-values to be applied list1) |
| Simple |
| (apply **max** '(1 3 2))      ⇒   3 |
| Complex |
| (apply **+** 1 2 '(3 4 5))    ⇒  15  (apply **-** 100 '(5 12 17))  ⇒  66  ; **100** – 5 - 12 – 17 = 66 |

**Creating your own higher-order functions**

* the name of the function can be anything you want
* but the first parameter should be a function that will be used to determine the result

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| **Member-If Function** |
| Description |
| returns a sub-list of items that fits the predicate function |
| Code |
| (define (member-if proc ls)    (cond     ((null? ls) #f)     ((proc (car ls)) ls)     (else (member-if proc (cdr ls))))) |
| Results |
| (member-if positive? '(0 -1 -2 3 5 -7))  ⇒  (3 5 -7) ; returns rest of list once it finds a                                                                                    ; positive value |

1. Open <https://raw.githubusercontent.com/jlongster/gambit-iphone-example/master/lib/util/srfi-1.scm> (which is the apps.scm file, but full version).Using Gambit Scheme use 3 more higher functions:
   1. comment what they do
   2. use the higher order function found in the file
   3. display the result

**Answers**

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| **Adding Ten Percent** |
| (display(map (lambda (x) (\* x 1.1)) '(70 85 89))) |

**Sources**

<http://www.shido.info/lisp/scheme8_e.html>

Higher Order Function examples

<http://www.iro.umontreal.ca/~gambit/doc/gambit.html#Scheme-extensions>

Currying

<http://people.cs.aau.dk/~normark/prog3-03/html/notes/higher-order-fu_themes-curry-section.html>

https://stackoverflow.com/questions/36314/what-is-currying

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