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An Investigation Into the Use of Haskell for Dynamic Programming

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Abstract [[Insert abstract of about 150 words]]

Keywords Haskell · C · Java · Functional Programming · Dynamic Programming · Language Comparison

1 Introduction

Over the last decade the speed of computers has increased by many orders of magnitude but the speed of the typical programmer has not. In many cases it is far more important to quickly produce correct and robust code than to optimise code for performance, and as computers continue to become more powerful, while humans will essentially remain the same this is ultimately going to become the norm. We argue that prototyping new heuristics and algorithms for combinatorial optimisation is one area where speed of development of correct code is already more important than absolute performance.

We use Haskell to implement standard dynamic programming algorithms, including bounded and unbounded knapsack, and column generation. Then we compare with implementations in Java and C in terms of speed, conciseness, modularity, as well as ease of parallelisation, refactoring, debugging and reasoning. To make the

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comparisons fair we keep the structure of the code similar across languages, except when taking advantage of specific language features (e.g., pointers, objects or laziness). The implementations are idiomatic and representative of an 'average' user, without non-portable micro-optimisations. In particular, standard libraries are used throughout for data structures, mathematics and floating-point arithmetic with as little as possible implemented by hand.

TODO: talk about reasoning about code

2 Preliminary Results

Our preliminary results (unbounded knapsack in C and Haskell) show that while the C code is about four times faster, using Haskell for prototyping indeed offers significant advantages in terms of speed of development and eliminating certain classes of errors, without incurring a performance penalty that is unacceptable for a prototype.

3 Abstraction Of Common Patterns

As an example, there was a high profile case recently[1] in which a software bug has caused erroneous results to be published, and to possibly influence European policy[1]. Amongst other things, a cause of error was a range-indexing mistake in the spreadsheet which caused several countries to be excluded from the analysis.

Consider the simplified example of summing a collection of numbers: in a high level programming language like Haskell one passes the name of a collection of numbers (whether an array, a list or otherwise) to the *sum* function which will, behind the scenes and opaque to the user, index each element and add them together thus completely eliminating that class of errors. In most spreadsheet software however one has to manually select the cells (e.g. "C3:C100")[2] which is error-prone as well as being non-trivial to later expand to include additional data.

Consider the following examples from the unbounded knapsack implementations to find the Greatest Common Divisor (gcd) of an array of n weights, $\mathbf{W}$, and the initial capacity c. The function *gcd* (which takes two integers and returns the largest integer which cleanly divides both of them) is associative, so

$$gcd(c, \mathbf{W}_0, \ldots, \mathbf{W}_{n-1}) = gcd(gcd(\cdots gcd(gcd(c, \mathbf{W}_0), \mathbf{W}_1)\cdots), \mathbf{W}_{n-1})$$

and the code needs to apply *gcd* pairwise to the capacity and each weight, reducing them to a single integer after n calls to *gcd*. The basic algorithm is demonstrated in the C implementation2 - there exists an accumulator variable *gcd_all* which is initialised to *capacity* and then *gcd*'d with each weight. Note that it was necessary to manually specify the bounds of the loop, index each element separately and then update the accumulator variable manually with the result of *gcd* for each new $\mathbf{W}_i$.

[1] `www.bbc.co.uk/news/magazine-22223190`

[2] While named ranges do exist they still have to be manually specified which just pushes the problem elsewhere.

```c
int gcds (int capacity, size_t n, int weights[n]) {
        int i, gcd_all = capacity;
        for (i = 0; i < n; i++) {
                gcd_all = gcd (gcd_all, weights[i]);
        }
        return gcd_all;
}
```

Fig. 1: C99

```java
public int gcds (int capacity, int[] weights) {
        int gcd_all = capacity;
        for (int weight : weights) {
                gcd_all = gcd (gcd_all, weight);
        }
        return gcd_all;
}
```

Fig. 2: Java 7

```haskell
gcds :: Int -> Vector Int -> Int
gcds capacity weights = foldl' gcd capacity weights
```

Fig. 3: Haskell

In Java the task of iterating over each element has been abstracted into the *for-each* loop. This avoids the problem of having to manually specify the bounds of the loop or index into the array at the cost of some flexibility. As shown in the Java implementation of gcds2, a for-each loop reduces the boilerplate that the user needs to type and hence the number of places that an error can appear.

In Haskell the idiom of updating an accumulator variable with each element of a list using a binary function is abstracted over using the function foldl ' as shown in the Haskell definition2, thus avoiding the need for the programmer to manually specify the range of the loop or how the accumulator should be updated and further reducing the places in which an error can appear.

TODO: make this way shorter

TODO: Graph of knapsack results here? gcc -O2 vs ghc-O2

References

1. Herndon, T., Ash, M., Pollin, R.: Does high public debt consistently stifle economic growth? a critique of reinhart and rogoff. Cambridge Journal of Economics (2013). DOI 10.1093/cje/bet075. URL `http://cje.oxfordjournals.org/content/early/2013/12/17/cje.bet075.abstract`