Funqual - User-Defined, Statically-Checked Call-Tree Constraints in C++

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Masters Thesis Draft

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Abstract

Once upon a time there was a lovely princess. But she had an enchantment upon her of a fearful sort which could only be broken by love's first kiss. She was locked away in a castle guarded by a terrible fire-breathing dragon. Many brave knigts had attempted to free her from this dreadful prison, but non prevailed. She waited in the dragon's keep in the highest room of the tallest tower for her true love and true love's first kiss.

Like that's ever gonna happen. What a load of -

Somebody once told me the world is gonna roll me. I ain't the sharpest tool in the shed. She was lookin' kind of dumb with her finger and her thumb. In the shape of an "L" on her forehead.

The years start comin' and they don't stop comin'. Fed to the rules and hit the ground runnin'. Didn't make sense not to live for fun. Your brain gets smart but your head gets dumb

So much to do so much to see. So what's wrong with takin' the backstreets. You'll never know if you don't go. You'll never shine if you don't glow

Hey, now You're an all-star. Get your game on, go play. Hey, now You're a rock star. Get the show on, get paid

Contents

1   Introduction

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2   Background

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3   Design

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4   Implementation

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5   Methodologies

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6   Analysis

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7   Future Work

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8   Related work

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References

[1] "C2 wiki." [Online]. Available: http://wiki.c2.com/

    Contains witty quotes about almost every computing topic under the sun

[2] "Pypy source," 2018. [Online]. Available: https://bitbucket.org/pypy/pypy/

[3] S. Auhagan, L. Bergstrom, M. Fluet, and J. Reppy, "Garbage collection for multicore numa machines," *ACM Sigplan Workshop on Memory system Performance and Correctness*, June 2011.

    These folks set forth a goal to write a garbage collector that scales to 48 NUMA cores. Part of the challenge with NUMA is that inter-processor communication is very expensive so they added a variety of optimizations to a traditional mark-and-sweep garbage collector so that the cores had to interact as little as possible. Many of these optimizations look like they would strongly benefit Copy on write performance.

[4] Bacon, Cheng, and Rajan, "A unified theory of garbage collection," *OOPSLA*, 2004.

    Very exhaustive survey of garbage collection that provides a theoretical spectrum in which to place every popular modern garbage collection scheme.

[5] T. M. Chilimbi and J. R. Larus, "Using generational garbage collection to implement cache-conscious data placement," *ACM Sigplan*, vol. 34, March 1999.

    A group modifies a copying generational garbage collector to monitor object reference frequency. On copy, the garbage collector co-locates frequently used objects. This reduces cache miss rate significantly. Copying generational garbage collector outperforms traditional mark and sweep in cache performance.

[6] G. et. al., *The Python3 Standard Library*, The Python Software Foundation. [Online]. Available: https://docs.python.org/3/library/gc.html

[7] L. T. et. al., "Linux kernel," 2018. [Online]. Available: https://github.com/torvalds/linux

[8] M. Gorman, *Understanding the Linux Virtual Memory Manager*, 2004.

    Reference manual for the 2.5 Linux kernel Virtual Memory Manager. Kernel 2.5 is pretty old so much of the code is different today but the high level algorithms should have stayed mostly the same.

[9] M. Hertz, Y. Feng, and E. D. Berger, "Garbage collection without paging," *ACM Sigplan*, vol. 40, June 2005.

    A group modifies a mark-and-sweep garbage collector to compactly store all the in- and out-going references in a page of objects when it is swapped out of memory. This prevents memory from needing to be swapped in just to scan during a major garbage collection event.

[10] R. Hudson and E. Moss, "Incremental collection of mature objects." Springer, Berlin, Heidelberg.

    Most generational garbage collectors just do mark and sweep on the oldest generation so as to avoid copying all that memory over again, but this can lead to fragmentation. This paper demonstrates a semispacial mature generation for a generational garbage collector and explains how to make mature collections incremental. It guarantees a cap on collection duration by sacrificing completeness. There is a very interesting analysis section explaining how they reached a good tradeoff between speed and completeness in this garbage collector.

[11] Z. Li. (2017, December) Copy-on-write friendly python garbage collection.

    A team at Instagram edit CPython's mark-and-sweep garbage collector so that it disturbs less memory during garbage collection in order to improve shared memory

[12] K. Sasada. (2014) Incremental gc for ruby interpretor.

Presentation at RubyConf2014 with very detailed description of Ruby's garbage collector and what changes they made to improve the performance in ruby's mark-and-sweep style garbage collector

[13] J. Seligmann and S. Grarup, "Incremental mature garbage collection using the train algorithm," April 2000.

First paper that actually implements the "train" garbage collector. My understanding is that it's like a generational garbage collector except it chunks up the old generation into many train-carts and copies each object several times through the series. Seems sub-optimal but there is a lot of buzz around it.

[14] *Welcome To PyPy*, Software Freedom Conservancy. [Online]. Available: http://doc.pypy.org/en/release-2.4.x

[15] B. Veal and A. Foong, "Performance scalability of a multi-core web server," *ACM/IEEE Symposium on Architecture for networking and communications systems*, December 2007.

Analysis of what system resources are the bottleneck in high-load web-servers. This document found that one of the biggest bottlenecks is on the address bus. Memory in cache was very quick to access, but anything in main memory needed to be fetched and awaited.

[16] C. Wu and M. Ni. (2017, January) Dismissing python garbage collection at instagram.

A team at Instagram Engineering discovered that they can reduce the memory usage of their web tier servers (running Django on CPython) by disabling garbage collection.

[17] B. Zorn, "Comparing mark-and-sweep and stop-and-copy garbage collection," *ACM Conference on LISP and functional programming*, 1990.

In depth comparison of Mark and Sweep vs Generational garbage collection. The paper found that mark-and-sweep has slightly higher cpu overhead but that generational garbage collectors require slightly less memory. This paper didn't reference the problem of memory fragmentation that occurs with a mark-and-sweep garbage collector.