

Turning Manual Concurrent Memory Reclamation into Automatic Reference Counting

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Abstract

Safe memory reclamation (SMR) schemes are an essential tool for lock-free data structures and concurrent programming. However, manual SMR schemes are notoriously difficult to apply correctly, and automatic schemes, such as reference counting, have been argued for over a decade to be too slow for practical purposes. A recent wave of work has disproved this long-held notion and shown that reference counting can be as scalable as hazard pointers, one of the most common manual techniques. Despite these tremendous improvements, there remains a gap of up to 2x or more in performance between these schemes and faster manual techniques such as epoch-based reclamation (EBR).

In this work, we first advance these ideas and show that in many cases, automatic reference counting can in fact be as fast as the fastest manual SMR techniques. We generalize our previous Concurrent Deferred Reference Counting (CDRC) algorithm to obtain a method for converting any standard manual SMR technique into an automatic reference counting technique with a similar performance profile. Our second contribution is extending this framework to support weak pointers, which are reference-counted pointers that automatically break pointer cycles by not contributing to the reference count, thus addressing a common weakness in reference-counted garbage collection.

Our experiments with a C++ library implementation show that our automatic techniques perform in line with their manual counterparts, and that our weak pointer implementation outperforms the best known atomic weak pointer library by up to an order of magnitude on high thread counts. All together, we show that the ease of use of automatic memory management can be achieved without significant cost to practical performance or general applicability.

CCS Concepts: • Computing methodologies → Concurrent algorithms.

Keywords: automatic memory reclamation, concurrency, smart pointers, lock-free

1 Introduction

Manually managing memory for concurrent programs is notoriously difficult and prone to errors. One solution is to

only work in fully garbage-collected languages but this is not always possible, and comes with its own performance problems, often yielding no control to the user. On the other hand, manually managing memory can be challenging even for sequential programs, but the concurrent setting makes it significantly more difficult. In particular, concurrent programs can suffer from read-reclaim races [12] with potentially disastrous results. For example, one thread could overwrite a location containing a pointer to an object, and then reclaim the memory for that object since it is not being referred to anymore. Another thread executing concurrently could read the location just before it is overwritten. It could then access the contents of the object, which by now might have been reclaimed and perhaps even been reallocated for another use, or returned to the operating system.

Over the past two decades, researchers have developed a broad set of techniques to avoid such read-reclaim races. The goal of these techniques is to delay the destruction and reclamation on an object until it can be ensured that no thread can still access the object. These techniques are generally referred to as *safe memory reclamation* (SMR), and include approaches such as read-copy-update (RCU) [10], epoch-based-reclamation (EBR) [8], hazard-pointers [19], pass-the-back [13], pass-the-pointer [4], interval-based reclamation (IBR) [30], Hyaline [25], and others [2, 27]. All these approaches replace the destruction of an object with a retire operation, which delays the actual destruction until it is safe.

The SMR approaches differ in how they ensure the reclamation and destruction is safe. The approaches can be partitioned broadly into two classes. *Protected-region techniques*, such as RCU, EBR, IBR, and hyaline, protect regions of code, while *protected-pointer techniques*, such as hazard-pointers, pass-the-back, and pass-the-pointer, are based on protecting individual pointers. The protected-region techniques tend to be faster since they only need a memory fence on every critical region instead of every read, but require more space due to longer delays between a retire and reclamation. Both classes of manual techniques, however, are difficult to use and can lead to subtle and hard to reproduce bugs. As evidence, Anderson et al. [1] noted several instances where manual techniques of both kinds were applied incorrectly to concurrent data structures.

An alternative approach for memory management in languages without built-in garbage collection (or even with)

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Turning A Manual Into An Automatic

VM Jensen



Turning A Manual Into An Automatic:

Technical Manual United States. War Department,1959 Boiler Operator's Handbook, Second Edition P.E. Heselton,2020-11-26 This book was written specifically for boiler plant operators and supervisors who want to learn how to lower plant operating costs as well as how to operate plants of all types and sizes more wisely It is newly revised with guidelines for HRSGs combined cycle systems and environmental effects of boiler operation Also included is a new chapter on refrigeration systems that addresses the environmental effects of inadvertent and intentional discharges of refrigerants Going beyond the basics of keeping the pressure up the author explains in clear terms how to set effective priorities to ensure optimal plant operation including ensuring safety and continuity of operations preventing damage managing environmental impact training replacement plant operators logging and preserving historical data and operating the plant economically **CNC Control Setup for Milling and Turning** Peter Smid,2010 This unique reference features nearly all of the activities a typical CNC operator performs on a daily basis Starting with overall descriptions and in depth explanations of various features it goes much further and is sure to be a valuable resource for anyone involved in CNC Boiler Operator's Handbook Carl Buzzuto,2021-12-28 With the increased interest in climate impacts sustainability and efficiency more responsibility is being placed on boiler operators to help improve performance and reduce emissions This third edition of the Boiler Operator s Handbook is intended to help such operators in the quest for improved operability and performance of their boilers and their plants The theme of this book is to operate wisely The goal is to instill not only know how but know why The main details have been provided by the original author Mr Ken Heselton This updated version has been somewhat expanded to include a wider range of examples and some of the more recent environmental requirements To illustrate these points topics include multi boiler operations understanding the plant load maintenance issues and controls Every plant is different However it is hoped that with the information provided in this book the wise operator will be able to address the various unique issues posed by the specific plant and provide timely solutions to meet the present day requirements

Managing Computer Numerical Control Operations Mike Lynch,1995 Provides the ideas guidelines and techniques you need to capture the full potential of your CNC equipment Nearly every aspect of CNC operations is addressed and the book is organized so you can use it as a step by step guide to efficient CNC utilization or as a shop floor reference for continuous improvement Hundreds of specific utilization boosting techniques are detailed AF Manual United States. Department of the Air Force,1964 Lloyd's Register Technical Association Session 1985-1986 Lloyd's Register Foundation,1985-01-01 The Lloyd s Register Technical Association LRTA was established in 1920 with the primary objective of sharing technical expertise and knowledge within Lloyd s Register Publications have consistently been released on a yearly basis with a brief interruption between 1938 and 1946 These publications serve as a key reference point for best practices and were initially reserved for internal use to maximise LR s competitive advantage Today the LRTA takes a fresh approach focusing on

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MacOS High Sierra: The Missing Manual David Pogue,2018-01-31 With High Sierra Apple has taken its macOS operating system to new heights From Apple s efficient new file system to improved video streaming and support for virtual reality this latest macOS version provides features improve your experience And once again David Pogue brings his humor and expertise to the 1 bestselling Mac book Whether you re a developer or a home user this guide offers a wealth of detail on Apple s macOS 10 13 operating system this new edition covers everything High Sierra has to offer Perfect for newcomers Get crystal clear jargon free introductions to the best and brightest macOS apps including Siri Safari iCloud FaceTime and AirDrop Get the whole picture

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Manual, Valve Repair and Maintenance for Naval Service United States. Navy Department. Bureau of Ships,1949

iMovie '09 and iDVD: The Missing Manual David Pogue,Aaron Miller,2009-04-17 Bursting with new features Apple s iMovie 09 is vastly more usable and complete than iMovie 08 amazing right out of the box But the box doesn t include a good user s guide so learning these applications is another matter iMovie 09 and iDVD The Missing Manual gets you up to speed on everything you need to turn raw digital footage into highly creative video projects You get crystal clear jargon free explanations of iMovie s new video effects slow fast motion advanced drag drop video stabilization and more Author and New York Times tech columnist David Pogue uses an objective lens to scrutinize every step of process including how to Organize your videos just like your photos and precisely edit with ease Work on multiple iMovie projects at once and drag drop clips among them Integrate with other iLife programs to use songs photos and an original sound track Output your creation to a blog its own web page or as a video podcast with iWeb Understand basic film techniques to improve the quality of the video you bring to iMovie From choosing and using a digital camcorder to burning the finished work onto DVDs posting it online or creating versions for iPod and iPhone iMovie 09 iDVD The Missing Manual helps you zoom right in on the details

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Table of Contents Turning A Manual Into An Automatic

1. Understanding the eBook Turning A Manual Into An Automatic
 - The Rise of Digital Reading Turning A Manual Into An Automatic
 - Advantages of eBooks Over Traditional Books
2. Identifying Turning A Manual Into An Automatic
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Turning A Manual Into An Automatic
 - User-Friendly Interface
4. Exploring eBook Recommendations from Turning A Manual Into An Automatic
 - Personalized Recommendations
 - Turning A Manual Into An Automatic User Reviews and Ratings
 - Turning A Manual Into An Automatic and Bestseller Lists
5. Accessing Turning A Manual Into An Automatic Free and Paid eBooks
 - Turning A Manual Into An Automatic Public Domain eBooks
 - Turning A Manual Into An Automatic eBook Subscription Services

- Turning A Manual Into An Automatic Budget-Friendly Options
- 6. Navigating Turning A Manual Into An Automatic eBook Formats
 - ePub, PDF, MOBI, and More
 - Turning A Manual Into An Automatic Compatibility with Devices
 - Turning A Manual Into An Automatic Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Turning A Manual Into An Automatic
 - Highlighting and Note-Taking Turning A Manual Into An Automatic
 - Interactive Elements Turning A Manual Into An Automatic
- 8. Staying Engaged with Turning A Manual Into An Automatic
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Turning A Manual Into An Automatic
- 9. Balancing eBooks and Physical Books Turning A Manual Into An Automatic
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Turning A Manual Into An Automatic
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Turning A Manual Into An Automatic
 - Setting Reading Goals Turning A Manual Into An Automatic
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Turning A Manual Into An Automatic
 - Fact-Checking eBook Content of Turning A Manual Into An Automatic
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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