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Original Article

How I Optimized a Legacy Codebase with Refactoring Techniques

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Abstract - Like renovating an old house, improving a legacy codebase requires maintaining these structural integrity while also making it usable for modern needs and flexible for future expansion. Working on this project, I reworked a huge, archaic, and very complex codebase that had become difficult to maintain, unstable to change, and uncompromising to scalability. Increasing maintainability, improving their performance, ensuring scalability, and increasing system testability were my key goals. I began by spotting architectural restrictions and code smells, then used SOLID ideas and tested-driven development (TDD) to help to implement clean coding techniques. By use of automated refactoring tools, this effort was optimized, human error was reduced, and the process was hastened without endangering stability. The enormous drop in technical debtcode became more understandable, changes no longer felt dangerous, and team members could work with greater confidencehad a major impact. The structural upgrade clearly improved their performance and significantly increased test coverage, therefore supporting our confidence in the implementation of modifications. This change beyond simple code enhancement promoted a more empowered and efficient engineering culture. By means of better design, standardized approaches, and thorough documentation, the team may accelerate onboarding, increase debugging efficiency, and stimulate creativity. This experience made clear that refactoring is an investment in the ongoing well-being of the product and its creators, not merely a technical one.

Keywords - Legacy Code, Refactoring, Code Optimization, Code Smells, Technical Debt, Clean Code, SOLID Principles, Test-Driven Development (TDD), Software Maintainability, Static Code Analysis, Continuous Integration, Software Architecture, Modularization, Code Quality, Automated Testing, Design Patterns, Software Reengineering, System Modernization, Developer Productivity, Software Scalability.

1. Introduction

All engineers eventually face legacy code a convoluted, entwined system of logic and dependencies either inherited from previous teams or produced during a very different period of a company's existence. Legacy code is software that is typically without any proper documentation or automated testing, outdated in design, and badly maintained. Though it still serves its original purpose, it does so ineffectively, dangerously, and in ways that inhibit development. Although interacting with such code may be risky, arduous, and frustrating, it is an unavoidable feature of modern software development.

Older code offers various difficulties. Mostly, there is usually a lack of paperwork. Opening a file full of overly complicated procedures, unclear variable names, and these multiple lines of dubious reasoning might quickly overwhelm one. Not knowing the original goal or structure, even little changes might have unexpected effects. Inadequate modularizing raises serious issues. Many other legacy systems were developed before best practices such the single responsibility principle and separation of concerns were generally accepted or understood. Business logic is so commonly entwined with UI code, data access is hidden behind utility classes, and duplicate logic is scattered throughout modules.

Many legacy systems also rely on their out-of-date technologies and frameworks. You might come across models of libraries that have been out of date for years or frameworks devoid of security enhancements. This not only leaves prospective weaknesses but also makes it rather difficult to integrate the latest tools or features. Legacy codebases often have hidden flaws anomalies and temporary fixes difficult to spot resulting from inadequate knowledge of their original implementation.

The project I worked on modernized a significant legacy system a monolithic application developed over 12 years ago combining PHP 5 with jQuery. For a mid-sized logistics company, the application helped with internal operations including everything from invoicing to cargo tracking. Comprising more than 200,000 lines spread across many other PHP files, the codebase lacked any modern MVC architecture or object-oriented design techniques. It observed many cases of developer churn,

each adding unique coding styles, fixes, and unresolved issues. Given the fragile nature of the system, implementing a single feature or fixing an issue would routinely take weeks.

Acknowledging that cost and schedule constraints made a total overhaul unworkable, I proposed a deliberate and progressive reworking strategy. While the software runs well for the end users, the goal was not to redesign the system suddenly but rather to methodically improve the code, increase its modularity, and reduce technical debt.

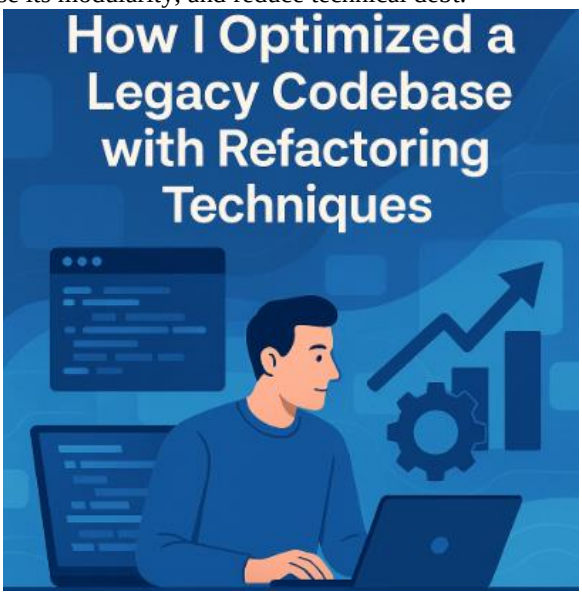


Figure 1. How Optimized a Legacy Codebase with Refactoring Techniques

Refactoring was very essential in this environment not just for improving code readability and efficiency but also for ensuring long-term maintainability and business agility. Improving the structure of the code without changing its outward capability might reduce their future expansion expenses, solve issues, and help new engineers to be onboarded. This was a strategic investment in the longevity of the program rather than merely a technical one.

The most important and problematic areas of the program especially those related to user identification, data entry processes, and reporting were evaluated as part of the optimization endeavor. Our goals were to reduce duplication,, where practical, apply automated testing, update API usage, and explain basic reasoning. We improved the clarity and resilience of a once-fragile and opaque system over many months via constant feedback from consumers and stakeholders. This article describes the exact refactoring techniques used, the difficulties faced, and the actual world learning from close interaction with a legacy codebase.

2. Understanding the Legacy Codebase

Before making any major codebase improvements, I had to be fully aware of the current architecture. Years of upgrades, input from missing developers, and limited documentation are just a few of the complexity legacy systems may provide. I began with a careful review of the present system to help with the challenge of responsible refactoring.

2.1. Synopsis of Systems

The monolithic program I inherited had one, huge codebase covering all tasks including user authentication, backend data processing, and front-end delivery. Though at its inception this architectural method was more effective, scaling, maintenance, and test over time became more difficult. Java 8 was used in development together with Spring Boot 1.x. Java 8 included streams and lambda expressions, two functional programming capabilities, but their use in the current code was negligible. Mostly constructed in a procedural manner typical of pre-Java 8 programming, the application was using an Oracle Database, the solution closely integrated SQL searches directly contained in the code with application logic. Without an abstraction layer like JPA or Hibernate, bare JDBC calls proliferated across the codebase, rendering database-related changes dangerous and work intensive. Maven was the build and deployment toolchain utilized; Jenkins oversaw builds and a fragile CI/CD pipeline kept under maintenance utilizing these custom shell scripts and workarounds. Though restricted to a few modules, tests were available; most business logic remained untested, which raised questions about future refactoring projects.

2.2. Initial Inspection

I began a stationary code analysis using SonarQube and PMD in order to get clarity. These instruments provide a general picture of the technical debt of the system, pointing out various defects like more complex methods, duplicated blocks, missing JavaDocs, and unreachable code. Tools, therefore, only tell a part of the story. I started hand-guided code walks with experienced engineers with knowledge in history. These sessions were very illuminating. Developers shared codes judged "off-limits," communal knowledge, and tacit rules. We worked through the key componentsthe user administration module, the invoicing system, and the audit logging tool. Making use of both technology and human knowledge, I produced a set of important conclusions:

- Code redundancy: Many other services repeated the same standard logicthat which included error formatting and input validation.
- Some classes have grown to hundreds of lines of code, doing far more operations than required.
- Significant components have less than 10% unit test coverage; others no tests at all.
- Many libraries were outdated and no longer maintained, therefore exposing security and compatibility issues.

These results enabled the prioritizing of action sites and gave a complete knowledge of the weakness of the system.

2.3. Realized Difficulties

Apart from the code, the architectural choices and these design patterns showed degradation. Many other developers have hurriedly added functionality over years, usually opting for quick fixes over long-term solutions. Many codes smelled bad and anti-patterns followed from this.

The ongoing challenges comprised:

- Modules showed notable dependency at close proximity. Changing a technique in one class might begin a chain of these related changes all over the system.
- Static variables controlled configuration settings and shared state, therefore creating hidden dependencies and making unit testing quite challenging.
- Inadequately arranged inheritance: Debugging with huge inheritance hierarchies may be rather than difficult. Often without a clear contract, subclasses overrule methods leading to inconsistent behavior.
- Feature envy and shotgun surgery: Techniques would mostly edit the information of any other objects rather than their own, thereby requiring minor changes that require changes in many sites.
- God objects: Specific utility classes controlled file I/O and email validation, therefore violating the Single Responsibility Principle.
- One rather problematic tendency was the way services were presented. Direct invocations across modules replaced fully specified interfaces or service contracts with hard-coded dependencies. This fibrous character made even little changes dangerous.

The development team complained about deployments. In the lack of automated testing and with limited recording, a single issue may take hours sometimes days to find and fix in a manufacturing setting.

3. Refactoring Strategy and Techniques

When initially optimizing a legacy codebase, I discovered it would not need significant rework or instantaneous changes. Legacy systems are not destroyed; they are more like old buildings. You keep good components, update out-of-date features, and apply careful improvements to avoid structural problems. Refactoring is a methodical, deliberate process that improves the fundamental framework of code while maintaining their data's outer use.

3.1. Refactoring Concepts

Early on, one of the most important things I learned was to treat refactoring like one would approach a surgical operation: exact, careful, and safe. One major component of my approach was Martin Fowler's catalog of refactoring these techniques. His idea of making little, safe changes became my compass. Every change, no matter how little, was meant to help the next one to be made. This approach depends critically on the use of automated testing. Tests serve as a safety net, giving one confidence to carry out improvements free from concern about generating downstream problems. When a test came up short, I quickly found the cause. This reduced speculation and greatly improved my productivity. I covered the procedure as a whole with continuous integration (CI). Every refactoring branch connected CI pipelines to ensure that every change tested right away upon commitment. Especially considering a sensitivity by legacy codebase, this quick feedback system was really too vital.

3.2. Methodologies for Stratified Refactoring

I looked at the program piecemeal, beginning with little elements and working toward more significant architectural concerns. Dealing with everything at once would have been more difficult and more dangerous.

- Level of Refactorizing: Function: At the most detailed level, I focused on accuracy and cleanliness. This includes renaming variables for improved descriptiveness, cutting long logic blocks into succinct helper methods, and deleting out-of-date code not used for years. It's amazing how powerful these little changes can be; the code starts to clear right away.
- Level Class Refactoring: I moved up to the class level as individual tasks got reasonable. Some classes were very longone contained almost 2,000 lines of code. Beginning the use of the Single Responsibility Principle (SRP), every class has to serve one only purpose. This sometimes meant breaking down huge courses into smaller, more focused groups. I used clear interfaces and limited direct reliance to try to reduce these tight coupling.
- Refactoring inside the Module Level: The layer at last was module and package level. I broke up unrelated tasks into separate modules and reorganized directories to precisely depict domain boundaries. For example, it was common practice to combine business logic with database access code, which helped to define different issues thus facilitating testing and updating.

Also crucial was decoupling tightly linked components. I used a basic event-driven framework to enable module-wise interaction free from direct dependence. This encouraged greater modular development and more freedom.

3.3. Application of SOLID Ideas

The SOLID ideas of object-oriented design acted as my compass throughout the refactoring process. This shows how every element influences the developments.

- S: One Responsibility Principle: One data processor class I came across was assigned loading, validating, modifying, and database publishing of this information. I split them up into numerous groups, each charged with a certain task. Testing became much more controllable, and putting improvements into effect no longer appeared risky.
- O: Open/ Closed Idea: I begin planning classes for extensibility instead of always changing them to fit the latest features. For example, I created a basic DataSource interface and carried out separate implementations for every data sourceCSV, API, Databasewhile handling many other data sources. The main reasoning just used the interface techniques, ignoring the specific source in issue.
- L: Liskov substitution principle: This concept told me to be careful building class hierarchies. I found a subclass that changed a method such that its behavior was greatly altered and mistakes followed when the parent class was expected. I rearranged it so that the subclass followed the parent's specifications, therefore preserving a strong and predictable system.
- I: principle of interface segregation: Some classes were forced to adopt these interfaces unrelated to their intended use. For example, a reporting class had to include exporting and logging techniques it had never used. I broke up the interfaces into smaller, more relevant ones so that classes could choose only what they needed, hence reducing these side effects and clutter.
- D: Inversibility of Dependency Principle: I then finally took care of important dependencies. Many other courses were closely associated with certain implementations. I created abstractions interactions and supplied them via dependency injection. This not only made code testing easier but also less likely bad consequences from component replacement.

3.4. Tooling and Automation

Helped to enable a more safe and quick process. Manual refactoring is prone to mistakes, especially in huge scale codesbases; consequently, I mostly rely on their automation.

- Integrated Environment Support: For automatic renaming, method extraction, and class dependency analysis, I made great use of IntelligJ IDEA. These qualities saved many hours and helped to stop issues from arising all through the reorganizing process.
- Analyzers for Codes and Formatters: For the Java parts of the system, I used Checkstyle; for the JavaScript components, ESLint and Prettier. These instruments followed consistent style rules and found troublesome code smells, therefore maintaining readability throughout changes.
- Git techniques: Another very important component was the branching method. For every refactoring goal, I set separate branches and always avoided combining unrelated changes. Every branch had a different goal, say "extract-user-service" or "remove-legacy-utils." Often using interactive rebase to hone the commit history before merging, I performed succinct, clear, descriptive commits, each serving a single function.

Rollback safety came first always. Should a modification fail, Git enabled the reversionthat is, selective implementation of a few chosen changes without affecting others. This gave me the freedom to explore free from concern about permanent damage.

4. Testing and Validation

It was clear when the initial reworking began that the optimization entailed restoring faith in the system rather than just code rewriting. Testing and validation acted as the link between bold ideas and these consistent outcomes in a legacy environment marked by close coupling and out-of-date processes. This is my approach to handle this important phase.

4.1. Benchmark Establishing

Before beginning structural changes or code improvement, I must have an understanding of the operational dynamicsor lack thereof. This entailed laying a strong basis for utility as well as their performance. Regardless of their obsolescence, I carefully went over a set of pre-existing tests and noted their findings. The primary goal was to get a picture of system behavior before changes. I noted necessary application procedures, error logs, and execution times. For performance measures, this step was vital as knowing the length of important events helped to find more hotspots that refactorizing may affect.

Calculating code coverage was just as important. I established the degree of codebase coverage attained by the current test suite using many other basic instrumentation methods. The numbers were, understandably, quite bad. While some fundamental modules received 20–30% coverage, others were not tested at all. This gave me a clear goal: improve test coverage while advanced refactoring is in progress. Not only was recording this data a documentation choreography. It was a commitment to transparency that let every team member observe the initial benchmarks and track development by these over time.

4.2. Improving Test Coverage

One major challenge with any older codebases is their often lack of design for testability. Creation of meaningful tests is difficult due to monolithic functions, close coupling, and hidden many other side effects. I used what I call "refactor-to-test" to improve coverage.Finding areas of the code that may be split into smaller, independent bits was part of the refactor-to- test. For instance, comprehensive utility techniques handling more numerous tasks were broken down into these single-purpose uses. This clarified their objective and helped them to test alone.

Then imitation dependencies followed. Other systems databases, APIs, and outside SDKs weaved much of the business logic. I used mocking libraries to help avoid brittle, integration-intensive tests. Java codebases depend on tools like Mockito absolutely. They let me create dependable tests, segregate functionality, and duplicate dependencies.

The basis of the latest suite came from testing systems like JUnit. We effectively arranged and scaled tests using JUnit's methodical annotations and test runners. Coverage improved gradually as the base was laid. Previously test-free modules now included many other evaluations, frequently covering edge scenarios and failure types neglected for years. The ultimate goal was not test coverage; rather, it was a useful tool for exposing weaknesses and fostering confidence among ongoing changes.

4.3. Ongoing Integration and Distribution

Refactoring has hazards, especially if done gradually over long stretches, say weeks or months. Maintaining order therefore required the combining of Continuous Integration (CI) and Continuous Development (CD) pipelines. I set up a simple CI/CD system wherein every commit carried out automated testing. This assured that no effort at refactorizing interfered with current functioning without any instant notice. In case of any errors, the build servers performed tests, obtained the most latest codes, and delivered alerts.

We have also set up regular runs of the regression tests. These were particularly important after major refactors as even apparently unrelated modules might be affected. For stakeholders as well as programmers, the promise to say, "we modified X and all other components remain functional," was powerful. The pipelines changed during time. We guaranteed consistency using style enforcers, linting checks, and static analysis. It was about preserving the code to a higher quality at every level, not merely about passing tests. Faster iterations were possible using the CI/CD method. Developers were free from waiting for hand-made validations. Automated gates built allow transitions from development to staging to happen with confidence.

4.4. Standard Measures of Performance

Saying that a codebase is "superior" post-refactoring is very easy; however, what evidence may support this assertion? Quality measurements become crucial here. SonarQube helped us track measures like maintainability index, cyclomatic complexity, and code duplication. The dashboard begins off with red signals. Commonly occurring were functions displaying complexity levels exceeding 30, duplicated logic across more modules and maintainability alarms.

We kept these measures as a scorecard throughout the refactoring process. Every reduction of complexity and code smell correction showed obvious results. With SonarQube's historical visualizations, we tracked improvements over time and found great satisfaction in the trend line going from more critical to clean. One last gauge of progress was cyclomatic complexity. We simplified the reasoning by dissecting complex conditionals and loops, thereby improving the comprehensibility, testability, maintainability, and logical consistency. Analogous continuous improvement was shown by the maintainability index, a composite measure generated from many code characteristics. This was more than just a surface measure; it also represented a decrease in flaws, faster new engineer onboarding, and more predictable future changes.

5. Case Study: Real-World Application

5.1. Problematic Module: "Invoice Processing Engine"

Among the most dated parts of our backend system was the "Invoice Processing Engine". Built more than 10 years ago, it has developed into a complex mix of more than 6,000 lines of closely linked code. Assuming invoice data from more multiple sources, checking entries, calculating taxes and discounts, and finally begins the payment and reporting processes fell to this module. Still, its design suggested its age. Managed inside a single huge class, all operations were hampered by procedural codes and overloaded methods. Maintenance became therefore a difficult task. Even small changes threatened the operation of more unrelated features.

- Responsibility creep turned the module into a god-class covering file processing, business logic, and outside API connections.
- Years of ad hoc fixes combined with these inadequate abstractions have resulted in technical debt.
- Developer morale dropped since interaction with this section of the system seemed like negotiating a dangerous scenario.

The look of the original code is succinctly summarized here:

With over 300 lines in this long switch-case structure basically a chain of if-elif-else statements adding the latest invoice type was a work intensive and error-filled task.

5.2. Methodical Editing

Rewording code was simply one aspect of refactoring this historical module; another understood the system's purpose, its justification, and how to keep that logic while improving their maintainability.

5.2.1. Disaggregation into Modular Services

The next step was breaking up the "Invoice Processing Engine" into precisely defined responsibilities. We followed the Single Responsibility Principle quite closely. This is our breakdown technique:

- Manages file parsing CSV, XML, etc. using Parser Service.
- Verifies required information, forms, and adherence to business policies under validator service.
- TaxCalculator Service: follows invoice classification-based tax rules.
- Discount Service: Figures perks or discounts.
- Directs the final invoice to next systems via Invoice Routing.

Every service developed into a separate class assessed alone with well specified inputs and outputs. This gave more freedom and the ability to independently swap or upgrade offerings.

5.2.2. Following the Strategy Pattern

The code's most egregious feature was its switch-case logic for invoice kinds. Every new invoice category required involvement with this area. This was a perfect use of the Strategy Pattern. We designed a suite of strategy classes instead of adding extra conditionals:

- Processor for domestic invoices
- Global Invoice Processor
- Processor for Nonprofit Invasions
- Et cetera....
- Each ran on a common interface: process (invoice).

Then, depending on the kind of invoice, we selected the suitable processor using a simple factory or register. Just the application of the latest strategy class will be enough to introduce a new type without any necessary changes to the basic logic.

5.2.3. Moving from Procedural to Object-Oriented Design

First procedural codes set data from behavior apart. Under the new paradigm, invoices were complicated objects with combined features. For example, we right into the Invoice class inserted applyTax() and markAsPaid(). This included the business rationale and helped to enable a more natural representation of actual processes. We made an additional advantage of polymorphism. Many invoice forms, for instance, originated from a basic Invoice class and altered certain characteristics. This completely eliminated the necessity for branching logic. Value objects for repeated domain concepts such as Currency, Tax Rate, and Invoice Item helped to reduce low-level issues and improve type safety.

5.3. Findings

After weeks of painstaking reorganization, the results surpassed the employment intensive investment.

5.3.1. Legislative Legibility of Codes

The new module now seems to be a well-organized story. Every lesson has one goal and clear instructions. Instead of weeks, new developers may integrate in these days. Discrete domains with low intersection define logic. We standardized formatting and incorporated thorough inline comments to enable code navigation and group reviews.

5.3.2. Improvement of Test Coverage

Unit tests were absent from the preceding module; most testing was done manually or via rigorous end-to---course exams. Every service fits the latest design for unit testing.

- We created around a hundred more test cases covering fault paths and edge conditions.
- Test coverage rose from 23% to 85%, therefore greatly boosting our confidence in the reliability of the system.
- This made early identification of flaws in continuous integration pipelines possiblea feat hitherto unthinkable.

5.3.3. Forty percent reduction in bug fixing time

The improved modularity and coverage greatly speeded the problem discovery and repair. What used to call for a day or two of debugging might now be done in a few hours. For our support workers, this was very crucial as processing invoices is a fundamental business operation. Faster fixes produced fewer escalations and more happy consumers.

5.3.4. Stakeholder Involvement

Originally concerned about refactoring as it may compromise product availability, the business team & their viewpoint changed, nevertheless, in view of the post-refactor stability and speed.

- Stakeholders underlined the need of lowering invoice reporting errors.
- Faster response times for feature requestssuch as adding more invoice kinds for seasonal campaignsthat call for seasonal discounts.
- Because code and logic are more transparent, developers and business analysts are better cooperating.

"We feel in control of our invoice system rather than being limited by it, for the first time in years," a product owner remarked.

6. Outcomes and Lessons Learned

6.1. Key Wins

Reworking the old program produced the most satisfying result: a significant drop in these defects and support issues. Historically, even little changes in features often led to unanticipated behavior or the latest difficulties. After the revamp, the system showed substantially improved stability, which helped to lower late-night support calls and urgent hotfixes. The result amply demonstrated how effective it was to try to simplify and tidy the code.

Improving the new developers' onboarding procedure was a major accomplishment. Even seasoned engineers would require weeks to get trust in the codebase before the redesign; they frequently struggled with unclear logic or negotiated difficult edge conditions. The better structure, better interfaces, and better documentation have greatly lowered the learning curve such that newly hired team members may contribute meaningfully in days instead of weeks.

Our deployment process showed a notable change. Better and more consistent releases came from improved modularity, thorough testing, and predictable code. The team's confidence grew, so we stopped seeing deployments as high-risk events. On the other hand, we began to see them as methodical, under control stages of our development.

6.2. Difficulties Observed

Still, the journey had some challenges despite the successes. Inside resistance was one of the initial challenges. Some team members were understandably more nervous about changing code that, despite the messy layout, was working. Conveying the long-term advantages of the adjustments to all the engaged stakeholders depends on patience and regular communication.

Managing business logic that was closely entwined with unrecorded historical events proved too difficult. Sometimes the only way to find out a system's intended usage was to speak with users or stakeholders. These situations brought complexity and risk as we had to keep behavior even when we cannot completely understand its original intent. One absolute constraint was time. Originally just a "clean-up" project, its scope quickly expanded. As we dug further, we encountered more severe problems that required a careful balance between improvement and refactor fatigue avoidance.

6.3. Acts I Would Change

Looking back, I would underline the requirement of beginning any refactored code with first-rate documentation or user shadowing. Understanding the reasoning behind certain procedures would have helped to reduce pointless conjecture and changes. I also would make more frequent use of feature flags. Significant changes might be dangerous; yet, flags provide teams the flexibility to use gradually and undo securely if needed. This is a basic yet efficient way to reduce anxiety amid big changes.

7. Conclusion

When one considers the effort of rebuilding a legacy codebase, one finds that the process is as about attitude as it is about the method. From a complex entanglement of complicated logic, outdated approaches, and brittle dependencies, what began as a challenging entanglement of ideas gradually became a more simplified, controllable, performance-oriented system. This was accomplished without any major overhaul or radical change. Instead it resulted from methodical, intentional, slow changes addressing one function, one module, and one dependent sequence.

The basic lesson is that little changes within huge systems could have significant results. In complex applications, trying to solve all these problems at once usually causes frustration and ineffectiveness. But you begin to build momentum by using a technique of constant refactoringaddressing technical debt in manageable chunks. Every little triumph increases confidence, fixes the system, and lays the groundwork for further development. This is a green way to update programs without disturbing the surroundings.

Older systems also lead to another conclusion: they are not fundamentally bad. Usually built under different constraints and aims, they are the result of years of work. Their need is nurturing, not desertion. An old codebase may evolve easily with suitable maintenance. Refactoring helps to improve the lifetime and value of the product as well as to optimize it.

Engineers running similar problems should consider refactoring as an ongoing activity rather than as a one-time effort. Plan it into your daily schedule. Improve the code slightly above its initial condition. Share it with your staff. Gradual improvements might lead to a codebase that not only runs more effectively but also makes maintainers proud and trusting.

Reworking ultimately reflects the core of workmanship rather than just code. It shows a commitment to sustainability, excellence, and the ongoing welfare of the systems we design. More than any one strategy, this one is what really makes a difference.

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