

Holistic Revision Tree: A Better Version Control System for C Programs

Joseph Tessitore

1. Abstract

According to JetBrains's 2023 developer ecosystem survey, 87% of developers use Git to track revisions in their program [1]. While Git's model is powerful, it has a steep learning curve for new users, owing to its complexity. In this paper, we demonstrate the *Holistic Revision Tree* (HRT), an alternative version control system which takes advantage of the C preprocessor to encode multiple versions inline in a single file. We will show how HRT makes you a better programmer by simplifying version control and sharing code with others.

2. Background

While Git's distributed workflow is appealing to many developers [2], it must be acknowledged that a significant factor in Git's ongoing dominance is due to vendor-lock in. Popular software forges and integrated development environments offer built-in tooling for Git, and not for other version control systems. In addition, many developers are already familiar with Git, and are wary of learning a new, complex system. Because of this, many alternative version control systems are *forced* to offer Git compatibility. For any new version control system to challenge Git's tyrannical rule, it must take advantage of universal software features, and have a very shallow learning curve.

2.1. The C Preprocessor

The C preprocessor is a filter applied to C source code files applied before they are compiled [3]. This is most commonly used to include *header files* in a source file with `#include "filename.h"`. More importantly, it can be used to conditionally compile code. The following example will print "TRUE" when compiled and executed, and the else branch will be excluded entirely from the compiled program:

```
#include <stdio.h>

int main() {
    #if 1 + 1 == 2
        printf("TRUE\n");
    #else
        printf("FALSE\n");
    #endif
}
```

Listing 1: Conditionally compiling code with math

This can be taken further by defining variables when compiling. For example, we can define the variable `VERSION` to be equal to 0 or 1 when compiling by using `gcc -DVERSION=0` or `gcc -DVERSION=1` respectively. This definition will cause the respective branch to be compiled, while the other is filtered out. By using this technology, we can store multiple revisions of a program in the same file.

```
#include <stdio.h>

int main() {
    #if VERSION >= 1
        printf("Hello, Universe!\n");
    #else
        printf("Hello, World!\n");
    #endif
}
```

Listing 2: Conditionally compiling code with a variable

To allow users to compile without manually specifying a version, this block can be added to the top of the file:

```
#ifndef VERSION
#define VERSION 1
#endif
```

Listing 3: A version header to specify the latest version

These lines will define `VERSION` to 1 (the latest version) if it is not already defined. By updating

the middle line with each update, it can be insured that users will get the newest version.

By combining these factors, the entire revision history of a C file can be stored with in a single file. While this is powerful, as will be elaborated later, we must accept that editing a program like this is very cumbersome. Thus, we must sacrifice a small amount of our method's ideological purity and actually write code instead of just thinking about it.

3. Introducing HRT

The *Holistic Revision Tree* methodology relies on two core files:

1. *The Tree* – A file containing every revision of the program merged into one file.
2. *The Work File* – A file containing a single revision of the program extracted from the tree, without any conditional compilation.

The program consists of two functionalities:

1. `checkout` - Extract a specific revision from the tree file into a work file.
2. `commit` - Combine a modified revision in a work file back into the tree as a new version.

These functions are named similarly to how they are in Git, to aid in understanding.

4. Methodology

The program uses an *LL parser* [4] to parse some of the relevant preprocessor directives in the C programming language. Thanks to some public domain¹ code from nullprogram.com, the string-handling code necessary was somewhat bearable² [5].

4.1. Checkout

When checking out a revision, the program evaluates any `#if` statement involving the `VERSION`

¹A fact that we *definitely* checked before we based our program off of it

²also aided in memory allocation

³Assuming `VERSION` is on the left-hand side

variable³ to decide whether or not to include a block of code⁴.

4.2. Commit

The commit process first creates a work file from the tree of the latest version, which is determined by the version header (Listing 3). While doing this, the program creates a map⁵ from line numbers in the work file to line numbers in the tree file.

It then calls `diff` to compare the provided and generated work-file, producing a list of changes written by the developer. The output of `diff` is parsed [6], and the changes made to the work file are spliced into the tree by mapping their indexes back.

`diff` can output three different types of changes: Additions, deletions, and changes. The following code is generated for each of the three:

```
...
#if VERSION >= 5
/* Comment added in version 5 */
#endif
```

Listing 4: Code generated for a line addition in version 5

```
#if VERSION < 5
/* Comment removed in version 5 */
#endif
```

Listing 5: Code generated for a line deletion in version 5

```
#if VERSION < 5
/* Comment changed in version 5 */
#else
/* New comment :3 */
#endif
```

Listing 6: Code generated for a line change in version 5

It is important to understand that while two lines of code might be next to each-other in a work file, they might be in different conditional-compilation blocks in the tree. While this doesn't need to be handled for addition like in Listing 4, for removal,

⁴The current version is decided either through a command-line flag or through the version header (Listing 3)

⁵array

it can be handled through recursively parsing conditional-compilation blocks with matching line ranges.

Extra care was required for changes to make sure the new code would not be included multiple times, or so that the wrong lines wouldn't be deleted. The explanation for this process is omitted because I don't fully understand how I fixed it for brevity.

Finally, the program checks the version header shown in Listing 3, and increments it to show the latest version.

5. Usage

Upon obtaining HRT (see Section 7), it can be compiled as follows: `gcc -o hrt hrt.c`⁶. To check out the latest version of a program stored in `tree.c` and save the work file in `work.c`, you can use `hrt checkout < tree.c > work.c`⁷. A specific version, such as version 3, can be checked out by running `hrt checkout -v 3 < tree.c > work.c`.

After editing your file in your favorite text editor, you can commit your changes by running `hrt commit tree.c < work.c > new_tree.c`, with `new_tree.c` intuitively containing the new version of the tree.⁸

However, `hrt` isn't needed to simply compile any version of a program. For example, to compile version 3, one can run `gcc -DVERSION=3 tree.c`. This provides the portability and simplicity that we all so desperately seek.

6. Results

One clear benefit of taking HRT is that it eschews the need for traditional Git forges such as GitHub, since our source tree can be stored wherever a file

can be. This could be provided as a link on a website, stored in a Google Drive, or even provided in its entirety at the end of a paper. The latter is useful because it grants readers a deeper insight into the progression of a paper's core, rather than just its final state. It allows them to see how a program changed over time, including deleted functions, confused comments, and code that was never relevant at any point whatsoever. Changes are also simple to share by either sending a work file, or storing the tree on a shared drive that can be changed by all contributors.⁹

6.1. File Size

HRT also has significant size benefits. Table 1 shows a comparison between how much size the source repository takes as a git bundle [7], a tar archive containing each file, and an HRT tree. It also includes the work files of the final revision in bold.

Method	Bytes
tar archive of revisions	450506
HRT tree	44389
Git bundle	25703
Final work file	24256
tar.gz archive of revisions	17517
HRT tree (gzipped)	8645
Final work file (gzipped)	5791

Table 1: Comparison of file sizes of `hrt` source code

As shown, the HRT tree is the smallest way that every version can be stored with compression. Its compression ratio can be calculated through $\frac{\text{size of all revisions}}{\text{size of HRT tree}}$, yielding 10.15x for an uncompressed tree, and 52.11x for a compressed tree. Other compression systems like Facebook's ZSTD,

⁶Or whatever C compiler you prefer

⁷Standard input and output are used throughout this program because it makes it feel more UNIX-y

⁸Because of how shells work, you can't do `hrt commit tree.c < work.c > tree.c`. You can do `hrt commit tree.c < work.c > new_tree.c && mv new_tree.c tree.c` to accomplish the same thing

⁹`hrt commit` is non-atomic. Careful!

meanwhile, can only offer 5.5x on source-code [8]. Further research is needed to investigate HRT's clear potential as a general purpose compression algorithm.

7. Obtaining HRT

HRT can be obtained either by downloading the source tree from <https://jonot.me/hrt.c>, or by copying the source tree provided at the end of the paper.¹⁰

¹⁰Programmers in the UK must go through a waiting list to make sure that they *really* don't want to use Git instead, and that they're not just pretending.


```

    putchar(' ');
    print_statement_block(b->block);
    putchar(' ');
    print_elif_block(b->next);
    putchar(' ');
}

#endif
typedef struct ElseBlockParse {
#if VERSION >= 9
    Line line;
#endif
    StatementBlockParse *block;
} ElseBlockParse;

#if VERSION < 4
void print_else_block(const ElseBlockParse *b) {
    if (b == NULL) {
        printf("nil");
    } else {
        printf("else ");
        print_statement_block(b->block);
        putchar(' ');
    }
}

#endif
typedef struct IfBlockParse {
    Line line;
#if VERSION >= 2
    Line end_line;
#endif
    StatementBlockParse *statement_block;
    ELIFBlockParse *elif_block;
    ElseBlockParse *else_block;
    StatementBlockParse *next;
} IfBlockParse;

#if VERSION < 4
void print_if_block(const IfBlockParse *b) {
    if (b == NULL) {
        printf("nil");
    } else {
        printf("(if ");
        print_line(b->line);
        putchar(' ');
        print_statement_block(b->statement_block);
        putchar(' ');
        print_elif_block(b->elif_block);
        putchar(' ');
        print_else_block(b->else_block);
        putchar(' ');
        print_statement_block(b->next);
        putchar(' ');
    }
}

#endif
typedef struct {
    Str file;
#if VERSION >= 5
    int lineno;
#endif
} ParserState;

_Bool peek(ParserState *p, Line *out) {
    if (!p->file.len) {
        return 0;
    }
    Cut c = cut(p->file, '\n');
    *out = parse_line(c.head);
    #if VERSION >= 5
    #if VERSION < 9
    out->lineno = p->lineno + 1;
    #else
    out->no = p->lineno + 1;
    #endif
    #endif
    return 1;
}

/* To be called after peek to advance the parser state */
void feed(ParserState *p) {
    Cut c = cut(p->file, '\n');
    #if VERSION >= 5
    p->lineno++;
    #endif
    p->file = c.tail;
}

PlainBlockParse *parse_plain_block(Arena *a, ParserState *p) {
    Line next;
    if (peek(p, &next) && next.line_type == LINE_TYPE_PLAIN) {
        #if VERSION < 5
        PlainBlockParse *ret = new(a, 1, PlainBlockParse);
        #else
        PlainBlockParse *ret = new(a, 1, PlainBlockParse);
        #endif
        feed(p);
        ret->line = next;
        ret->next = parse_plain_block(a, p);
        return ret;
    } else {
        return NULL;
    }
}

IfBlockParse *parse_if_block(Arena *, ParserState *);

StatementBlockParse *parse_statement_block(Arena *a,
ParserState *p) {
    StatementBlockParse *ret = new(a, 1, StatementBlockParse);
    ret->plain_block = parse_plain_block(a, p);

    ret->if_block = parse_if_block(a, p);
    return ret;
}

ELIFBlockParse *parse_elif_block(Arena *, ParserState *);
ElseBlockParse *parse_else_block(Arena *, ParserState *);

IfBlockParse *parse_if_block(Arena *a, ParserState *p) {
    /* (ISCTeS)? */
    Line next;
    if (peek(p, &next) && next.line_type == LINE_TYPE_IF) {
        IfBlockParse *ret = new(a, 1, IfBlockParse);
        feed(p);
        ret->line = next;
        ret->statement_block = parse_statement_block(a, p);
        ret->elif_block = parse_elif_block(a, p);
        ret->else_block = parse_else_block(a, p);
        if (peek(p, &next) && next.line_type == LINE_TYPE_ENDIF) {
            feed(p);
            #if VERSION >= 2
            ret->end_line = next;
            #endif
            ret->next = parse_statement_block(a, p);
            return ret;
        } else {
            /* This is a failed parse actually. TODO maybe do an
            error here? */
            return NULL;
        }
    } else {
        return NULL;
    }
}

ELIFBlockParse *parse_elif_block(Arena *a, ParserState *p) {
    Line next;
    if (peek(p, &next) && next.line_type == LINE_TYPE_ELIF) {
        ELIFBlockParse *ret = new(a, 1, ELIFBlockParse);
        feed(p);
        ret->line = next;
        ret->block = parse_statement_block(a, p);
        ret->next = parse_elif_block(a, p);
        return ret;
    } else {
        return NULL;
    }
}

ElseBlockParse *parse_else_block(Arena *a, ParserState *p) {
    Line next;
    if (peek(p, &next) && next.line_type == LINE_TYPE_ELSE) {
        ElseBlockParse *ret = new(a, 1, ElseBlockParse);
        #if VERSION >= 9
        ret->line = next;
        #endif
        feed(p);
        ret->block = parse_statement_block(a, p);
        return ret;
    } else {
        return NULL;
    }
}

#endif
/* Returns the "turning number" for the line. If opening
something, 1. If closing, -1 */
int parse_turning(Str line) {
    Cut c = cut(line, ' ');
    const Str IF = S("#if");
    const Str IFDEF = S("#ifdef");
    const Str IFNDEF = S("#ifndef");
    const Str ENDIF = S("#endif");
    if (equals(c.head, IF)) {
        return 1;
    }
    if (equals(c.head, IFDEF)) {
        return 1;
    }
    #else
    /* Returns true if the condition deals with the VERSION
    variable */
    _Bool condition_version(const Line *line) {
        const Str version_str = S("VERSION");
        if (!equals(line->variable, version_str)) {
            return 0;
        }
    }
    /* Support that fallback in the file */
    if (line->operator == OP_DEF || line->operator == OP_NDEF) {
        return 0;
    }
    return 1;
}

#endif
/* If VERSION < 9
_Bool evaluate_condition(const Line *line) {
    #else
    #if VERSION < 11
    _Bool evaluate_condition(const Line *line, int version) {
    #else
    _Bool evaluate_condition(const Line *line) {
    #endif
    #endif
    /* Assumes that the variable is VERSION */
    #if VERSION < 9
    const int version = 1;
    #endif
    switch (line->operator) {
        case OP_LT:
            return version < line->value;
        case OP_GT:
            return version > line->value;
        case OP_LE:
            return version <= line->value;
        case OP_GE:
            return version >= line->value;
    }
}

#endif
case OP_EQ:
    return version == line->value;
case OP_NEQ:
    return version != line->value;
default:
    /* These shouldn't be handled here at all */
    return 0;
}
}

#endif
void dump_statement_block(StatementBlockParse *b);
#else
void dump_statement_block(StatementBlockParse *, _Bool);
#endif
void dump_statement_block(FILE *, StatementBlockParse *,
_Bool);
#endif
static int *line_map;
static int current_line;

#if VERSION >= 15
int line_map_reverse(int full_line_number) {
    int *ptr = line_map + 1;
    while (1) {
        if (*ptr == full_line_number) {
            return ptr - line_map;
        }
        ptr++;
    }
}

#endif
void dump_statement_block(FILE *, StatementBlockParse *,
_Bool, int);
#else
static _Bool should_trim = 1;
#endif
#endif
#endif

void dump_plain_block(PlainBlockParse *b) {
    #else
    #if VERSION < 6
    void dump_plain_block(PlainBlockParse *b, _Bool final) {
    #else
    #if VERSION < 10
    void dump_plain_block(FILE *f, PlainBlockParse *b, _Bool
final) {
    #else
    #if VERSION < 11
    void dump_statement_block(FILE *, StatementBlockParse *,
int);
    #else
    void dump_statement_block(FILE *, StatementBlockParse *);
    #endif
    void dump_plain_block(FILE *f, PlainBlockParse *b) {
    #endif
    #endif
    if (b == NULL) {
        return;
    }
    #if VERSION >= 5
    #if VERSION < 6
    printf("%d: ", b->line.lineno);
    #else
    fprintf(f, b->line.span);
    #endif
    #endif
    #if VERSION < 6
    printstr(b->line.span);
    #endif
    #if VERSION < 3
    putchar('\n');
    dump_plain_block(b->next);
    #else
    #if VERSION < 5
    if (!final || b->next != NULL) {
    #else
    #if VERSION < 9
    if (!final || b->next == NULL) {
    #else
    fprintf(f, '\n', f);
    #if VERSION < 10
    line_map[current_line++] = b->line.no;
    #else
    if (should_trim) line_map[current_line++] = b->line.no;
    dump_plain_block(f, b->next);
    #endif
    #endif
    #endif
    #if VERSION < 6
    putchar('\n');
    #else
    #if VERSION < 9
    fprintf(f, '\n', f);
    #endif
    #endif
    #if VERSION < 9
    }
    #endif
}

```



```

#endif
#endif
#endif
#if VERSION < 6
    dump_if_block(b->if_block);
#endif
#endif
}

#if VERSION >= 8
Str read_from_popen(Arena *a, FILE *f) {
    Str ret = {};
    ret.data = a->begin;
    while (!feof(f)) {
        ret.len += fread(ret.data + ret.len, sizeof(char), a->end - (ret.data + ret.len), f);
    }
    ret.len += fread(ret.data + ret.len, sizeof(char), a->end - (ret.data + ret.len), f);
}

#endif
}
a->begin += ret.len;
return ret;
}

#endif
#if VERSION >= 4
#if VERSION < 6
void diff() {
    /* We aren't ready yet */
    return;
    /* Child read, parent write */
    int p1[2];
    /* Parent read, child write */
    int p2[2];
    pipe(p1);
    pipe(p2);
    pid_t pid = fork();
    if (pid == 0) {
        /* Child */
        close(p1[1]);
        close(p2[0]);
        dup2(p1[0], 0);
        dup2(p2[1], 1);
        char *args[] = {"usr/bin/env", "diff", "-./test.c", "-./main.c", NULL};
        if (execv(args[0], args)) {
            printf("Error %d: %s\n", errno, strerror(errno));
        }
    } else {
        /* Parent */
        close(p1[0]);
        close(p2[1]);
        /* Wait for child to exit */
        int status;
        while (1) {
            wait(&status);
            if (WIFEXITED(status)) {
                break;
            }
        }
    }
}

#endif
#if VERSION < 7
void diff(StatementBlockParse *b) {
}
#endif
#if VERSION < 9
void diff(Arena *a, StatementBlockParse *b) {
}
#endif
typedef struct {
    int begin;
    int end;
} DiffLineRange;

DiffLineRange parse_diff_range(Str range) {
    DiffLineRange ret = {};
    Cut c = cut(range, ',');
    if (c.ok) {
        ret.begin = parse_integer(c.head);
        ret.end = parse_integer(c.tail) + 1; /* This might be wrong */
    } else {
        ret.begin = parse_integer(range);
        ret.end = ret.begin + 1;
    }
    return ret;
}

typedef struct {
    DiffLineRange tree;
    DiffLineRange work;
    char mode;
} DiffLine;

DiffLine parse_diff_line(Str line) {
    char mode = 'a';
    Cut c = cut(line, 'a');
    if (!c.ok) {
        mode = 'c';
        c = cut(line, 'c');
    }
    if (!c.ok) {
        mode = 'd';
        c = cut(line, 'd');
    }
}

DiffLine ret = {};
ret.mode = mode;
ret.tree = parse_diff_range(c.head);
ret.work = parse_diff_range(c.tail);
return ret;
}

#endif
#if VERSION < 18
Str skip_lines(Str str, DiffLine line) {
    int lines_to_skip;

```

```

    if (line.mode == 'a') {
        lines_to_skip = line.tree.end - line.tree.begin + 1;
    } else if (line.mode == 'c') {
        lines_to_skip = line.tree.end - line.tree.begin + line.work.end - line.work.begin + 2;
    } else {
        lines_to_skip = line.tree.end - line.tree.begin + 3;
    }
    Cut c = {};
    c.tail = str;
    for (int i = 0; i < lines_to_skip; i++) {
        if (!c.tail.len) {
            break;
        }
    }
}

Str skip_lines(Str str) {
    Cut c = cut(str, '\n');
    while (c.tail.data[0] == '<' || c.tail.data[0] == '>' || c.tail.data[0] == '.') {
    }
}

StatementBlockParse *parse_from_filename(Arena *a, const char *filename) {
    FILE *f = fopen(filename, "r");
    assert(f != NULL);
    ParserState p = {
        .file = read_file(a, f),
    };
    return parse_statement_block(a, &p);
}

#endif
#if VERSION >= 10
#if VERSION < 11
int first_line_if(const IfBlockParse *b);
#endif
#endif
/* Returns the first line number of a statement block */
int first_line_statement(const StatementBlockParse *b) {
    if (b->plain_block) {
        return b->plain_block->line.no;
    }
    return b->if_block->line.no;
}

#endif
#if VERSION >= 12
int last_line_statement(const StatementBlockParse *b) {
    if (b->if_block) {
        if (b->if_block->next) {
            return last_line_statement(b->if_block->next);
        }
        return b->if_block->end_line.no;
    }
    PlainBlockParse *ptr = b->plain_block;
    while (ptr->next) {
        ptr = ptr->next;
    }
    return ptr->line.no;
}

#endif
PlainBlockParse *get_line_range_descend(Arena *a, DiffLineRange range, const PlainBlockParse *b) {
    if (b == NULL || range.end - range.begin == 0) {
        return NULL;
    }
    /* Start cutting */
    if (b->line.no == range.begin) {
        PlainBlockParse *copy = new(a, 1, PlainBlockParse);
        copy->line = b->line;
    }
    if (VERSION >= 13)
        copy->line.no = -1;
    DiffLineRange new_range = range;
    new_range.begin++;
    copy->next = get_line_range_descend(a, new_range, b->next);
    return copy;
}

return get_line_range_descend(a, range, b->next);
}

/* Copies the range of lines from the workfile referred to by the range. Assumes that it doesn't contain any pragmas, which I don't need for the paper anyways. */
PlainBlockParse *get_line_range(Arena *a, DiffLineRange range, const StatementBlockParse *b) {
    /* First check if we need to go deeper into the if block */
    if (b->if_block) {
        if (range.begin > b->if_block->line.no) {
            if (range.begin >= first_line_statement(b->if_block->next)) {
                return get_line_range(a, range, b->if_block->next);
            }
        }
        /* TODO: This path isn't needed for the paper but wow */
        assert(0);
    }
    return get_line_range_descend(a, range, b->plain_block);
}

#endif
#if VERSION < 11

```

```

void diff(Arena *a, StatementBlockParse *tree) {
    const int version = 1;
    #else
    void splice(Arena *a, StatementBlockParse *tree, PlainBlockParse *dna, DiffLineRange range) {
        if (tree->if_block && range.tree.begin >= tree->if_block->line.no) {
            #if VERSION < 21
                /* TODO: Parse into the tree */
            #endif
            if (tree->if_block->next && #if VERSION >= 21 (tree->if_block->next->if_block || tree->if_block->next->plain_block) && #endif range.tree.begin >= first_line_statement(tree->if_block->next)) {
                splice(a, tree->if_block->next, dna, range);
                return;
            }
            if (tree->if_block->else_block && range.tree.begin > tree->if_block->else_block->line.no) {
                splice(a, tree->if_block->else_block->block, dna, range);
                return;
            }
            /* TODO: Elif is completely not handled here. Shouldn't matter, but IDK */
            splice(a, tree->if_block->statement_block, dna, range);
            return;
        }
    }
    PlainBlockParse *prefix = new(a, 1, PlainBlockParse);
    PlainBlockParse *suffix = new(a, 1, PlainBlockParse);
    char *prefix_line_buf = new(a, 32, char);
    sprintf(prefix_line_buf, "#if VERSION >= %d", version + 1);
    prefix->line.span.data = prefix_line_buf;
    prefix->line.span.len = strlen(prefix->line.span.data);
    prefix->next = dna;
    suffix->line.span = S("#endif");
}

#endif
#if VERSION >= 11
PlainBlockParse *ptr = tree->plain_block;
while (ptr) {
    if (ptr->line.no == range.tree.begin) {
        break;
    }
    ptr = ptr->next;
}
PlainBlockParse *dna_ptr = dna;
while (dna_ptr->next) {
    dna_ptr = dna_ptr->next;
}
suffix->next = ptr->next;
ptr->next = prefix;
dna_ptr->next = suffix;
}

#endif
#if VERSION >= 12
void splice_delete(Arena *a, StatementBlockParse *tree, DiffLineRange range) {
    #if VERSION < 13
        assert(range.begin >= first_line_statement(tree) && range.end <= last_line_statement(tree) + 1);
        if (tree->if_block && range.begin > tree->if_block->line.no) {
            if (tree->if_block->next && range.begin > first_line_statement(tree->if_block->next)) {
                return splice_delete(a, tree->if_block->next, range);
            }
            if (tree->if_block->else_block && range.begin > tree->if_block->else_block->line.no) {
                return splice_delete(a, tree->if_block->else_block->block, range);
            }
        }
        #else
        if (tree == NULL) {
            return;
        }
        if (tree->plain_block) {
            PlainBlockParse *ptr = tree->plain_block;
            while (ptr->next) {
                ptr = ptr->next;
            }
            int plain_begin = tree->plain_block->line.no;
            int plain_end = ptr->line.no + 1;
            /* Check for overlap */
            if ((range.begin >= plain_begin && range.begin <= plain_end) || (range.end > plain_begin && range.end <= plain_end)) {
                #if VERSION < 14
                    printf("%d, %d\n", range.begin, range.end, plain_begin, plain_end);
                #endif
                ptr = tree->plain_block;
                PlainBlockParse *parent = NULL;
                while (ptr->line.no == -1 || ptr->line.no < range.begin) {
                    parent = ptr;
                    ptr = ptr->next;
                }
                PlainBlockParse *prefix = new(a, 1, PlainBlockParse);
                char *prefix_line_buf = new(a, 32, char);
                sprintf(prefix_line_buf, "#if VERSION < %d", version + 1);
                prefix->line.span.data = prefix_line_buf;
                prefix->line.span.len = strlen(prefix->line.span.data);
            }

```



```

    prefix->next = ptr;
    if (parent == NULL) {
        tree->plain_block = prefix;
    } else {
        parent->next = prefix;
    }
    PlainBlockParse *back_ptr = ptr;
    while (back_ptr &&
           (back_ptr->line.no == -1 || back_ptr->line.no <
            range.end)) {
        parent = back_ptr;
        back_ptr = back_ptr->next;
    }
    PlainBlockParse *suffix = new (a, 1, PlainBlockParse);
    suffix->line.span = 5("#endif");
    suffix->next = back_ptr;
    parent->next = suffix;
#endif
}
#endif
/* TODO: Again, this doesn't handle elif */
return splice_delete(a, tree->if_block->statement_block,
range);
#endif
}
#endif
if (VERSION < 13)
    PlainBlockParse *ptr = tree->plain_block;
    if (ptr->line.no == range.begin) {
        PlainBlockParse *back_ptr = ptr;
        while (back_ptr->line.no != range.end - 1) {
            back_ptr = back_ptr->next;
        }
        PlainBlockParse *prefix = new (a, 1, PlainBlockParse);
        char *prefix_line_buf = new (a, 32, char);
        sprintf(prefix_line_buf, "#if VERSION < %d", version + 1);
        prefix->line.span.data = prefix_line_buf;
        prefix->line.span.len = strlen(prefix->line.span.data);
        prefix->next = ptr;
        tree->plain_block = prefix;
        PlainBlockParse *suffix = new (a, 1, PlainBlockParse);
        suffix->line.span = 5("#endif");
        suffix->next = back_ptr->next;
        back_ptr->next = suffix;
    }
    #else
    if (!tree->if_block) {
        return;
    }
    #if VERSION < 13
    assert(0);
    #else
    splice_delete(a, tree->if_block->statement_block, range);
    if (tree->if_block->else_block) {
        splice_delete(a, tree->if_block->else_block->block,
range);
    }
    splice_delete(a, tree->if_block->next, range);
#endif
}
}

if (VERSION >= 15)
if (VERSION < 22)
void splice_change(Arena *a, StatementBlockParse *tree, const
StatementBlockParse *work, PlainBlockParse *dna, Diffline
range) {
    #else
    #if VERSION < 23
    void splice_change(Arena *a, StatementBlockParse *tree, const
StatementBlockParse *work, Diffline range, _Bool delete) {
    #else
    static int splice_change_delete;
    void splice_change(Arena *a, StatementBlockParse *tree, const
StatementBlockParse *work, Diffline range) {
    #endif
    #endif
    if (tree == NULL) {
        return;
    }
    if (tree->plain_block) {
        PlainBlockParse *ptr = tree->plain_block;
        while (ptr->next) {
            ptr = ptr->next;
        }
        int plain_begin = tree->plain_block->line.no;
        int plain_end = ptr->line.no + 1;

        /* Check for overlap */
        #if VERSION < 22
        if ((range.tree.begin >= plain_begin && range.tree.begin
< plain_end) ||
            (range.tree.end > plain_begin && range.tree.end <=
plain_end)) {
        #else
        if (((range.tree.begin >= plain_begin && range.tree.begin
< plain_end) ||
            (range.tree.end > plain_begin && range.tree.end <=
plain_end)) || (plain_begin >= range.tree.begin && plain_end
< range.tree.end)) {
        #endif
            ptr = tree->plain_block;
            PlainBlockParse *parent = NULL;
            while (ptr->line.no == -1 || ptr->line.no <
range.tree.begin) {
                parent = ptr;
                ptr = ptr->next;
            }

            PlainBlockParse *prefix = new (a, 1, PlainBlockParse);
            char *prefix_line_buf = new (a, 32, char);
            sprintf(prefix_line_buf, "#if VERSION < %d", version
+ 1);
            prefix->line.span.data = prefix_line_buf;
            prefix->line.span.len = strlen(prefix->line.span.data);
            prefix->next = ptr;

            if (parent == NULL) {
                tree->plain_block = prefix;
            } else {
                parent->next = prefix;
            }
            PlainBlockParse *back_ptr = ptr;
            while (back_ptr &&
                   (back_ptr->line.no == -1 || back_ptr->line.no <
range.tree.end)) {
                parent = back_ptr;
                back_ptr = back_ptr->next;
            }
            PlainBlockParse *interlude = new (a, 1, PlainBlockParse);
            interlude->line.span = 5("#else");
            parent->next = interlude;
            PlainBlockParse *suffix = new (a, 1, PlainBlockParse);
            suffix->line.span = 5("#endif");
            suffix->next = back_ptr;
        #if VERSION >= 22
        #if VERSION < 23
        if (delete) {
            parent->next = suffix;
        }
        #else
        #endif
        #endif
        DifflineRange range_to_get = {
            .begin = line_map_reverse(ptr->line.no) -
line_map_reverse(range.tree.begin) + range.work.begin,
            .end = line_map_reverse(parent->line.no) + 1 -
line_map_reverse(range.tree.begin) + range.work.begin;
        #else
            .begin = line_map_reverse(ptr->line.no) -
line_map_reverse(range.tree.begin)
+ range.work.begin,
        #if VERSION < 23
            range_to_get.end = range_to_get.begin + (range.work.end
- range.work.begin);
            if (range_to_get.end - range_to_get.begin >
range.work.end - range.work.begin) {
        #else
            range_to_get.end =
range_to_get.begin + (range.work.end -
range.work.begin);
            if (range_to_get.begin > splice_change_delete &&
range_to_get.end <= range.work.end) {
                splice_change_delete = range_to_get.end;
                PlainBlockParse *fresh_dna = get_line_range(a,
range_to_get, work);
                if (fresh_dna) {
                    interlude->next = fresh_dna;
                    while (fresh_dna->next) {
                        fresh_dna = fresh_dna->next;
                    }
                    fresh_dna->next = suffix;
                }
                parent->next = suffix;
            }
        #endif
        #endif
        #if VERSION < 23
        PlainBlockParse *fresh_dna = get_line_range(a,
range_to_get, work);
        #endif
        #if VERSION < 22
        interlude->next = fresh_dna;
        while (fresh_dna->next) {
            fresh_dna = fresh_dna->next;
        }
        #else
        if (fresh_dna) {
            if (!delete && range_to_get.end >= range.work.end) {
                delete = 1;
            }
            interlude->next = fresh_dna;
            while (fresh_dna->next) {
                fresh_dna = fresh_dna->next;
            }
        #endif
        #if VERSION < 23
        fresh_dna->next = suffix;
        #else
        } else {
            parent->next = suffix;
        }
        #endif
        #endif
        #if VERSION < 22
        fresh_dna->next = suffix;
        #endif
        if (!tree->if_block) {
            return;
        }
        #if VERSION < 22
        splice_change(a, tree->if_block->statement_block, work,
dna, range);
        #else
        #if VERSION < 23
        splice_change(a, tree->if_block->statement_block, work,
range, delete);
        #else
        if (evaluate_condition(&tree->if_block->line)) {
            splice_change(a, tree->if_block->statement_block, work,
range);
        } else {
            if (tree->if_block->else_block) {
                splice_change(a, tree->if_block->else_block->block,
work, range);
            }
        }
        #endif
        #endif
        StatementBlockParse *work = parse_from_filename(a,
work_file_name);
        while (diff_output.len) {
            Cut c = cut(diff_output, '\n');
            Diffline d = parse_diff_line(c.head);
            #if VERSION < 10
            printf("%c %d %d - %d %d\n", d.mode, d.tree.begin,
d.tree.end, d.work.begin,
d.work.end);
            #else
            #if VERSION < 11
            printf("%c TREE %d %d - WORK %d %d\n", d.mode,
d.tree.begin, d.tree.end,
d.work.begin, d.work.end);
            #endif
            PlainBlockParse *dr = get_line_range(a, d.work, work);

```

```

        should_trim = 0;
        dump_plain_block(stderr, dr);
    #endif
    #endif
    #if VERSION < 12
        if (d.mode != 'a') {
            fprintf(stderr, "Diff mode currently not supported");
            return;
        }
    #endif
    #if VERSION >= 11
        d.tree.begin = line_map[d.tree.begin];
    #if VERSION < 12
        d.tree.end = line_map[d.tree.end];
    #else
    #if VERSION < 22
        d.tree.end = line_map[d.tree.end - 1] + 1;
    #else
        d.tree.end = line_map[d.tree.end - 1] + 1;
        should_trim = 0;
    #endif
    #endif
    #if VERSION < 15
        fprintf(stderr, "[%c] TREE %d %d - WORK %d %d\n", d.mode,
        d.tree.begin, d.tree.end,
        d.work.begin, d.work.end);
    #endif
    #if VERSION < 12
        PlainBlockParse *dna = get_line_range(a, d.work, work);
        should_trim = 0;

        splice(a, tree, dna, d);
        dump_statement_block(stdout, tree);
    #else
        if (d.mode == 'a') {
            PlainBlockParse *dna = get_line_range(a, d.work, work);
        #if VERSION < 17
            should_trim = 0;
            dump_statement_block(stdout, tree);
        #endif
        #if VERSION < 15
            splice(a, tree, dna, d);
            dump_statement_block(stdout, tree);
        #endif
        #if VERSION < 17
            dump_statement_block(stdout, tree);
        #endif
        #if VERSION < 23
            splice_change(a, tree, work, d, 0);
        #else
            splice_change_delete = -1;
            splice_change(a, tree, work, d);
        #endif
    #endif
    #endif
    #if VERSION < 17
        should_trim = 0;
        dump_statement_block(stdout, tree);
    #endif
    #if VERSION < 12
        } else {
            fprintf(stderr, "Diff mode currently not supported\n");
            return;
        }
    #endif
    #if VERSION >= 17
        should_trim = 0;
    #endif
    #endif
    #if VERSION < 12
        #endif
    #if VERSION < 18
        diff_output = skip_lines(diff_output, d);
    #else
        diff_output = skip_lines(diff_output);
    #endif
    }
    #if VERSION >= 17
        update_version_tree(tree);
        dump_statement_block(stdout, tree);
    #endif
    #endif
    #endif
    #if VERSION < 8
    }
    #endif
    #if VERSION < 5
        char buf[200];
    #else
    #if VERSION < 6
        char buf[2000];
    #else
    #if VERSION < 8
        fwrite(outbuf, sizeof(char), r, stdout);
    #endif
    #endif
    #endif
    #if VERSION < 6
        size_t s = read(p2[0], &buf, 200);
        sleep(1);
        buf[s] = '\0';
        printf("Read %ld: %s\n", s, buf);
    #endif
    #if VERSION < 8

```

```

        }
    #endif
    }
    #endif
    #if VERSION < 5
    int main() {
    #else
    void print_usage(const char *name) {
        fprintf(stderr, "Usage: %s checkout\n%s commit <tree-
        file>\n", name, name);
    }

    #if VERSION >= 16
    /* Returns the version number, or -1 if none is given */
    int get_version_args(int argc, char *argv[]) {
        for (int i = 1; i < argc - 1; i++) {
            if (!strcmp(argv[i], "-v")) {
                return atoi(argv[i + 1]);
            }
        }
        return -1;
    }
    #endif

    /* Returns the version number from the block, or -1 if none
    is given */
    int get_version_tree(StatementBlockParse *b) {
        if (!b) {
            return -1;
        }
        if (b->plain_block) {
            return -1;
        }
        if (!b->if_block) {
            return -1;
        }
        if (!equals(b->if_block->line.variable, S("VERSION"))) {
            return -1;
        }
        if (b->if_block->line.operator != OP_NDEF) {
            return -1;
        }
        Str line = b->if_block->statement_block->plain_block-
        >line.span;
        /* Use offset to get the version number alone */
        line.data += 16;
        line.len -= 16;
        return parse_integer(line);
    #if VERSION >= 17
    }

    static char version_tree_buf[32];

    void update_version_tree(StatementBlockParse *b) {
        /* TODO: Add version tree if it doesn't exist */
        sprintf(version_tree_buf, "#define VERSION %d", version
        + 1);
        b->if_block->statement_block->plain_block->line.span.data
        = version_tree_buf;
        b->if_block->statement_block->plain_block->line.span.len =
        strlen(version_tree_buf);
    #endif
    }

    #endif
    int main(int argc, char *argv[]) {
        if (argc < 2) {
            print_usage(argv[0]);
            return 1;
        }
    #endif
    /* Allocate a gigabyte for the whole program */
    ptrdiff_t buf_size = 1024 * 1024 * 1024;
    void *buf = malloc(buf_size);
    Arena a = {
        .begin = buf,
        .end = buf + buf_size,
    };
    Str file_contents = read_file(&a, stdin);
    #else
    #if VERSION < 10
        .begin = buf,
        .end = buf + buf_size,
    #else
        .begin = buf,
        .end = buf + buf_size,
    #endif
    #endif
    #if VERSION < 1
        Cut c = (0);
        c.tail = file_contents;
        while (c.tail.len) {
            c = cut(c.tail, '\n');
            Str line = trimLeft(c.head);
            Line l = parse_line(line);
            printf("%d\n", l.line_type);
        }
    #else
    #if VERSION < 5
        ParserState p = {
            .file = file_contents,
        #endif
        };
    #if VERSION >= 10
        Line_map = new (&a, 1024 * 1024, int);
    #endif
    #if VERSION < 5
        StatementBlockParse *s = parse_statement_block(&a, &p);
    #else
        if (!strcmp("checkout", argv[1])) {
            Str file_contents = read_file(&a, stdin);
            ParserState p = {
                .file = file_contents,
            };

```

```

        StatementBlockParse *s = parse_statement_block(&a, &p);
    #if VERSION < 6
        dump_statement_block(s, 0);
    #else
    #if VERSION < 9
        dump_statement_block(stdout, s, 0);
    #else
    #if VERSION < 16
        /* TODO: Get the version from the program */
    #else
    #if VERSION < 20
        version = get_version_tree(s);
    #else
        version = get_version_args(argc, argv);
        if (version == -1) {
            version = get_version_tree(s);
        }
    #endif
    #endif
    #if VERSION < 11
        const int version = 1;
    #else
        dump_statement_block(stdout, s);
    #endif
    #if VERSION < 10
        dump_statement_block(stdout, s, 0, version);
    #else
    #if VERSION < 11
        dump_statement_block(stdout, s, version);
    #endif
    #endif
    #endif
    } else if (!strcmp("commit", argv[1])) {
        if (argc < 3) {
            print_usage(argv[0]);
            goto end;
        }
        FILE *tree_file = fopen(argv[2], "r");
        Str file_contents = read_file(&a, tree_file);
    #if VERSION >= 6
        ParserState p = {
            .file = file_contents,
        };
        StatementBlockParse *s = parse_statement_block(&a, &p);
    #if VERSION >= 16
        version = get_version_tree(s);
    #endif
    #if VERSION < 7
        diff(s);
    #else
        diff(&a, s);
    #endif
    #endif
    #if VERSION < 2
        print_statement_block(s);
    #else
    #if VERSION < 3
        dump_statement_block(s);
    #else
    #if VERSION < 5
        dump_statement_block(s, 0);
    #endif
    #endif
    #endif
    #if VERSION < 5
        putchar('\n');
    #endif
    #endif
    free(buf);
    #if VERSION >= 4
        diff();
    #else
        return 0;
    #endif
    #endif
    }

```

Bibliography

- [1] JetBrains, “Team Tools - The State of Developer Ecosystem in 2023 Infographic.” [Online]. Available: <https://www.jetbrains.com/lp/devecosystem-2023/team-tools/>
- [2] Linus Torvalds, “Git.” [Online]. Available: <https://git-scm.org/>
- [3] cppreference.com, “Preprocessor.” [Online]. Available: <https://en.cppreference.com/w/c/preprocessor>
- [4] Wikipedia, “LL parser.” [Online]. Available: https://en.wikipedia.org/wiki/LL_parser
- [5] Chris Wellons, “Robust Wavefront OBJ model parsing in C.” [Online]. Available: <https://nullprogram.com/blog/2025/03/02/>
- [6] OpenBSD, [Online]. Available: <https://man.openbsd.org/diff>
- [7] “Git - git-bundle Documentation.” [Online]. Available: <https://git-scm.com/docs/git-bundle>
- [8] Matt Mahoney, “Silesia Open Source Compression Benchmark.” [Online]. Available: <http://mattmahoney.net/dc/silesia.html>