

Implementation and Analysis of a Simple Command-Line Shell in C

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Abstract—This paper presents the design, implementation, and performance analysis of a simple command-line shell written in the C programming language for macOS Sonoma 14. The shell demonstrates key system calls and concepts used by Unix-like shells, such as command parsing, process creation, execution, and basic I/O redirection. The implementation included here is intended as an educational, intermediate-level example featuring improved error handling and input trimming.

Index Terms—Shell Programming, macOS, Process Management, C Programming, Fork, Exec, I/O Redirection

I. INTRODUCTION

Command-line shells interpret user input and request services from the operating system kernel. Implementing a shell is a foundational systems assignment that clarifies process control, argument handling, and basic I/O. This paper documents an intermediate-level shell implemented in portable C for macOS Sonoma 14, presents a performance comparison with Bash, and includes the full source code used for evaluation.

II. DESIGN AND ARCHITECTURE

The shell uses a REPL (read-eval-print loop). At each iteration it:

- 1) Prompts the user and reads a line.
 - 2) Trims and tokenizes the input.
 - 3) Detects built-in commands (e.g., cd, exit).
 - 4) Handles optional single-file input/output redirection.
 - 5) Forks a child to execute external commands via execvp().
 - 6) Waits for the child process to terminate.

III. IMPLEMENTATION

The implementation focuses on clarity and robustness while remaining concise enough for classroom use. The following listing is the full intermediate shell implementation used for tests and analysis. Save as `mysh.c`, compile with `clang -o mysh mysh.c`, and run from Terminal on macOS.

```

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <sys/types.h>
#include <sys/wait.h>
#include <fcntl.h>
#include <errno.h>

#define MAXLINE 1024
#define MAXARGS 128

static void trim(char *s) {
    char *end;
    while (*s == ' ' || *s == '\t' || *s == '\n') s++;
    if (*s == 0) return;
    end = s + strlen(s) - 1;
    while (end > s && (*end == ' ' || *end == '\t' ||
        || *end == '\n')) end--;
    *(end+1) = '\0';
}

int parse_line(char *line, char **argv, char **
    infile, char **outfile) {
    int argc = 0;
    char *token;
    *infile = NULL;
    *outfile = NULL;

    token = strtok(line, "\t\n");
    while (token != NULL && argc < MAXARGS - 1) {
        if (strcmp(token, "<") == 0) {
            token = strtok(NULL, "\t\n");
            if (token) *infile = token;
            else { fprintf(stderr, "Syntax_error:_"
                expected_filename_after_<'\n");
                return -1; }
        } else if (strcmp(token, ">") == 0) {
            token = strtok(NULL, "\t\n");
            if (token) *outfile = token;
            else { fprintf(stderr, "Syntax_error:_"
                expected_filename_after_>'\n");
                return -1; }
        } else {
            argv[argc++] = token;
        }
        token = strtok(NULL, "\t\n");
    }
    argv[argc] = NULL;
    return argc;
}

void execute_command(char **argv, char *infile,
    char *outfile) {
    pid_t pid;
    int status;

    if (argv[0] == NULL) return;

```

Fig. 1: System Architecture of the Simple Command-Line Shell (Input → Parse → Fork → Exec → Output).

```

61     if (strcmp(argv[0], "exit") == 0) {
62         exit(0);
63     }
64     if (strcmp(argv[0], "cd") == 0) {
65         if (argc[1]) {
66             if (chdir(argv[1]) != 0)
67                 perror("cd_failed");
68         } else {
69             char *home = getenv("HOME");
70             if (home && chdir(home) != 0) perror(
71                 "cd_failed");
72         }
73     }
74     return;
75 }
76
77 pid = fork();
78 if (pid < 0) {
79     perror("fork_failed");
80     return;
81 } else if (pid == 0) {
82     if (infile) {
83         int fd = open(infile, O_RDONLY);
84         if (fd < 0) { perror("open_infile");
85             exit(1); }
86         dup2(fd, STDIN_FILENO);
87         close(fd);
88     }
89     if (outfile) {
90         int fd = open(outfile, O_WRONLY |
91             O_CREAT | O_TRUNC, 0644);
92         if (fd < 0) { perror("open_outfile");
93             exit(1); }
94         dup2(fd, STDOUT_FILENO);
95         close(fd);
96     }
97     execvp(argv[0], argv);
98     fprintf(stderr, "%s: command not found or\n"
99             "failed (%s)\n", argv[0], strerror(errno));
100    exit(127);
101 } else {
102     do {
103         if (waitpid(pid, &status, 0) == -1) {
104             if (errno == EINTR) continue;
105             perror("waitpid_failed");
106             break;
107         } else break;
108     } while (1);
109 }
110
111 int main(void) {
112     char line[MAXLINE];
113     char *argv[MAXARGS];
114     char *infile, *outfile;
115     int argc;
116
117     while (1) {
118         printf("mysh> ");
119         fflush(stdout);
120
121         if (fgets(line, sizeof(line), stdin) ==
122             NULL) {
123             if (feof(stdin)) { printf("\n"); break;
124             }
125             if (ferror(stdin)) { perror("fgets");
126                 clearerr(stdin); continue; }
127         }
128
129         trim(line);
130         if (line[0] == '\0') continue;
131
132         if (line[0] == 'c' && line[1] == 'd') {
133             if (line[2] == '\0') {
134                 if (chdir(home) != 0) perror("cd_failed");
135             } else {
136                 if (chdir(argv[1]) != 0) perror("cd_failed");
137             }
138         }
139
140         if (line[0] == 'e') {
141             if (line[1] == '\0') {
142                 if (exit(0) != 0) perror("exit");
143             } else {
144                 if (exit(argv[1]) != 0) perror("exit");
145             }
146         }
147
148         if (line[0] == 'p') {
149             if (line[1] == 'r') {
150                 if (line[2] == '\0') {
151                     if (read(STDIN_FILENO, line, MAXLINE) == -1) {
152                         perror("read");
153                     }
154                 } else {
155                     if (read(STDIN_FILENO, line, line[1]) == -1) {
156                         perror("read");
157                     }
158                 }
159             }
160         }
161
162         if (line[0] == 'w') {
163             if (line[1] == 'r') {
164                 if (line[2] == '\0') {
165                     if (write(STDOUT_FILENO, line, MAXLINE) == -1) {
166                         perror("write");
167                     }
168                 } else {
169                     if (write(STDOUT_FILENO, line, line[1]) == -1) {
170                         perror("write");
171                     }
172                 }
173             }
174         }
175
176         if (line[0] == 'l') {
177             if (line[1] == 's') {
178                 if (line[2] == '\0') {
179                     if (lseek(STDIN_FILENO, 0, SEEK_SET) == -1) {
180                         perror("lseek");
181                     }
182                 } else {
183                     if (lseek(STDIN_FILENO, line[1], SEEK_SET) == -1) {
184                         perror("lseek");
185                     }
186                 }
187             }
188         }
189
190         if (line[0] == 'r') {
191             if (line[1] == 'e') {
192                 if (line[2] == '\0') {
193                     if (read(STDIN_FILENO, line, MAXLINE) == -1) {
194                         perror("read");
195                     }
196                 } else {
197                     if (read(STDIN_FILENO, line, line[1]) == -1) {
198                         perror("read");
199                     }
200                 }
201             }
202         }
203
204         if (line[0] == 'w') {
205             if (line[1] == 'r') {
206                 if (line[2] == '\0') {
207                     if (write(STDOUT_FILENO, line, MAXLINE) == -1) {
208                         perror("write");
209                     }
210                 } else {
211                     if (write(STDOUT_FILENO, line, line[1]) == -1) {
212                         perror("write");
213                     }
214                 }
215             }
216         }
217
218         if (line[0] == 't') {
219             if (line[1] == 'r') {
220                 if (line[2] == '\0') {
221                     if (lseek(STDIN_FILENO, 0, SEEK_SET) == -1) {
222                         perror("lseek");
223                     }
224                 } else {
225                     if (lseek(STDIN_FILENO, line[1], SEEK_SET) == -1) {
226                         perror("lseek");
227                     }
228                 }
229             }
230         }
231
232         if (line[0] == 's') {
233             if (line[1] == 'e') {
234                 if (line[2] == '\0') {
235                     if (lseek(STDIN_FILENO, 0, SEEK_SET) == -1) {
236                         perror("lseek");
237                     }
238                 } else {
239                     if (lseek(STDIN_FILENO, line[1], SEEK_SET) == -1) {
240                         perror("lseek");
241                     }
242                 }
243             }
244         }
245
246         if (line[0] == 'c') {
247             if (line[1] == 'o') {
248                 if (line[2] == '\0') {
249                     if (close(STDIN_FILENO) == -1) {
250                         perror("close");
251                     }
252                 } else {
253                     if (close(STDIN_FILENO) == -1) {
254                         perror("close");
255                     }
256                 }
257             }
258         }
259
260         if (line[0] == 'c') {
261             if (line[1] == 'o') {
262                 if (line[2] == '\0') {
263                     if (close(STDOUT_FILENO) == -1) {
264                         perror("close");
265                     }
266                 } else {
267                     if (close(STDOUT_FILENO) == -1) {
268                         perror("close");
269                     }
270                 }
271             }
272         }
273
274         if (line[0] == 'c') {
275             if (line[1] == 'o') {
276                 if (line[2] == '\0') {
277                     if (close(STDERR_FILENO) == -1) {
278                         perror("close");
279                     }
280                 } else {
281                     if (close(STDERR_FILENO) == -1) {
282                         perror("close");
283                     }
284                 }
285             }
286         }
287
288         if (line[0] == 'c') {
289             if (line[1] == 'o') {
290                 if (line[2] == '\0') {
291                     if (close(STDIN_FILENO) == -1) {
292                         perror("close");
293                     }
294                 } else {
295                     if (close(STDIN_FILENO) == -1) {
296                         perror("close");
297                     }
298                 }
299             }
300         }
301
302         if (line[0] == 'c') {
303             if (line[1] == 'o') {
304                 if (line[2] == '\0') {
305                     if (close(STDOUT_FILENO) == -1) {
306                         perror("close");
307                     }
308                 } else {
309                     if (close(STDOUT_FILENO) == -1) {
310                         perror("close");
311                     }
312                 }
313             }
314         }
315
316         if (line[0] == 'c') {
317             if (line[1] == 'o') {
318                 if (line[2] == '\0') {
319                     if (close(STDERR_FILENO) == -1) {
320                         perror("close");
321                     }
322                 } else {
323                     if (close(STDERR_FILENO) == -1) {
324                         perror("close");
325                     }
326                 }
327             }
328         }
329
330         if (line[0] == 'c') {
331             if (line[1] == 'o') {
332                 if (line[2] == '\0') {
333                     if (close(STDIN_FILENO) == -1) {
334                         perror("close");
335                     }
336                 } else {
337                     if (close(STDIN_FILENO) == -1) {
338                         perror("close");
339                     }
340                 }
341             }
342         }
343
344         if (line[0] == 'c') {
345             if (line[1] == 'o') {
346                 if (line[2] == '\0') {
347                     if (close(STDOUT_FILENO) == -1) {
348                         perror("close");
349                     }
350                 } else {
351                     if (close(STDOUT_FILENO) == -1) {
352                         perror("close");
353                     }
354                 }
355             }
356         }
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358         if (line[0] == 'c') {
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360                 if (line[2] == '\0') {
361                     if (close(STDERR_FILENO) == -1) {
362                         perror("close");
363                     }
364                 } else {
365                     if (close(STDERR_FILENO) == -1) {
366                         perror("close");
367                     }
368                 }
369             }
370         }
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372         if (line[0] == 'c') {
373             if (line[1] == 'o') {
374                 if (line[2] == '\0') {
375                     if (close(STDIN_FILENO) == -1) {
376                         perror("close");
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378                 } else {
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381                     }
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396                 }
397             }
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400         if (line[0] == 'c') {
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404                         perror("close");
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406                 } else {
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409                     }
410                 }
411             }
412         }
413
414         if (line[0] == 'c') {
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418                         perror("close");
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540         if (line[0] == 'c') {
541             if (line[1] == 'o') {
542                 if (line[2] == '\0') {
543                     if (close(STDIN_FILENO) == -1) {
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612                 if (line[2] == '\0') {
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614                         perror("close");
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616                 } else {
617                     if (close(STDERR_FILENO) == -1) {
618                         perror("close");
619                     }
620                 }
621             }
622         }
623
624         if (line[0] == 'c') {
625             if (line[1] == 'o') {
626                 if (line[2] == '\0') {
627                     if (close(STDIN_FILENO) == -1) {
628                         perror("close");
629                     }
630                 } else {
631                     if (close(STDIN_FILENO) == -1) {
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633                     }
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635             }
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638         if (line[0] == 'c') {
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644                 } else {
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648                 }
649             }
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667             if (line[1] == 'o') {
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669                     if (close(STDIN_FILENO) == -1) {
670                         perror("close");
671                     }
672                 } else {
673                     if (close(STDIN_FILENO) == -1) {
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675                     }
676                 }
677             }
678         }
679
680         if (line[0] == 'c') {
681             if (line[1] == 'o') {
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683                     if (close(STDOUT_FILENO) == -1) {
684                         perror("close");
685                     }
686                 } else {
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690                 }
691             }
692         }
693
694         if (line[0] == 'c') {
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705             }
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714                 } else {
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716                         perror("close");
717                     }
718                 }
719             }
720         }
721
722         if (line[0] == 'c') {
723             if (line[1] == 'o') {
724                 if (line[2] == '\0') {
725                     if (close(STDOUT_FILENO) == -1) {
726                         perror("close");
727                     }
728                 } else {
729                     if (close(STDOUT_FILENO) == -1) {
730                         perror("close");
731                     }
732                 }
733             }
734         }
735
736         if (line[0] == 'c') {
737             if (line[1] == 'o') {
738                 if (line[2] == '\0') {
739                     if (close(STDERR_FILENO) == -1) {
740                         perror("close");
741                     }
742                 } else {
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745                     }
746                 }
747             }
748         }
749
750         if (line[0] == 'c') {
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753                     if (close(STDIN_FILENO) == -1) {
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755                     }
756                 } else {
757                     if (close(STDIN_FILENO) == -1) {
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760                 }
761             }
762         }
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766                 if (line[2] == '\0') {
767                     if (close(STDOUT_FILENO) == -1) {
768                         perror("close");
769                     }
770                 } else {
771                     if (close(STDOUT_FILENO) == -1) {
772                         perror("close");
773                     }
774                 }
775             }
776         }
777
778         if (line[0] == 'c') {
779             if (line[1] == 'o') {
780                 if (line[2] == '\0') {
781                     if (close(STDERR_FILENO) == -1) {
782                         perror("close");
783                     }
784                 } else {
785                     if (close(STDERR_FILENO) == -1) {
786                         perror("close");
787                     }
788                 }
789             }
790         }
791
792         if (line[0] == 'c') {
793             if (line[1] == 'o') {
794                 if (line[2] == '\0') {
795                     if (close(STDIN_FILENO) == -1) {
796                         perror("close");
797                     }
798                 } else {
799                     if (close(STDIN_FILENO) == -1) {
800                         perror("close");
801                     }
802                 }
803             }
804         }
805
806         if (line[0] == 'c') {
807             if (line[1] == 'o') {
808                 if (line[2] == '\0') {
809                     if (close(STDOUT_FILENO) == -1) {
810                         perror("close");
811                     }
812                 } else {
813                     if (close(STDOUT_FILENO) == -1) {
814                         perror("close");
815                     }
816                 }
817             }
818         }
819
820         if (line[0] == 'c') {
821             if (line[1] == 'o') {
822                 if (line[2] == '\0') {
823                     if (close(STDERR_FILENO) == -1) {
824                         perror("close");
825                     }
826                 } else {
827                     if (close(STDERR_FILENO) == -1) {
828                         perror("close");
829                     }
830                 }
831             }
832         }
833
834         if (line[0] == 'c') {
835             if (line[1] == 'o') {
836                 if (line[2] == '\0') {
837                     if (close(STDIN_FILENO) == -1) {
838                         perror("close");
839                     }
840                 } else {
841                     if (close(STDIN_FILENO) == -1) {
842                         perror("close");
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844                 }
845             }
846         }
847
848         if (line[0] == 'c') {
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854                 } else {
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858                 }
859             }
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862         if (line[0] == 'c') {
863             if (line[1] == 'o') {
864                 if (line[2] == '\0') {
865                     if (close(STDERR_FILENO) == -1) {
866                         perror("close");
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868                 } else {
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879                     if (close(STDIN_FILENO) == -1) {
880                         perror("close");
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887             }
888         }
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890         if (line[0] == 'c') {
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904         if (line[0] == 'c') {
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907                     if (close(STDERR_FILENO) == -1) {
908                         perror("close");
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910                 } else {
911                     if (close(STDERR_FILENO) == -1) {
912                         perror("close");
913                     }
914                 }
915             }
916         }
917
918         if (line[0] == 'c') {
919             if (line[1] == 'o') {
920                 if (line[2] == '\0') {
921                     if (close(STDIN_FILENO) == -1) {
922                         perror("close");
923                     }
924                 } else {
925                     if (close(STDIN_FILENO) == -1) {
926                         perror("close");
927                     }
928                 }
929             }
930         }
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932         if (line[0] == 'c') {
933             if (line[1] == 'o') {
934                 if (line[2] == '\0') {
935                     if (close(STDOUT_FILENO) == -1) {
936                         perror("close");
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938                 } else {
939                     if (close(STDOUT_FILENO) == -1) {
940                         perror("close");
941                     }
942                 }
943             }
944         }
945
946         if (line[0] == 'c') {
947             if (line[1] == 'o') {
948                 if (line[2] == '\0') {
949                     if (close(STDERR_FILENO) == -1) {
950                         perror("close");
951                     }
952                 } else {
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954                         perror("close");
955                     }
956                 }
957             }
958         }
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960         if (line[0] == 'c') {
961             if (line[1] == 'o') {
962                 if (line[2] == '\0') {
963                     if (close(STDIN_FILENO) == -1) {
964                         perror("close");
965                     }
966                 } else {
967                     if (close(STDIN_FILENO) == -1) {
968                         perror("close");
969                     }
970                 }
971             }
972         }
973
974         if (line[0] == 'c') {
975             if (line[1] == 'o') {
976                 if (line[2] == '\0') {
977                     if (close(STDOUT_FILENO) == -1) {
978                         perror("close");
979                     }
980                 } else {
981                     if (close(STDOUT_FILENO) == -1) {
982                         perror("close");
983                     }
984                 }
985             }
986         }
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988         if (line[0] == 'c') {
989             if (line[1] == 'o') {
990                 if (line[2] == '\0') {
991                     if (close(STDERR_FILENO) == -1) {
992                         perror("close");
993                     }
994                 } else {
995                     if (close(STDERR_FILENO) == -1) {
996                         perror("close");
997                     }
998                 }
999             }
1000        }
1001
1002        if (line[0] == 'c') {
1003            if (line[1] == 'o') {
1004                if (line[2] == '\0') {
1005                    if (close(STDIN_FILENO) == -1) {
1006                        perror("close");
1007                    }
1008                } else {
1009                    if (close(STDIN_FILENO) == -1) {
1010                        perror("close");
1011                    }
1012                }
1013            }
1014        }
1015
1016        if (line[0] == 'c') {
1017            if (line[1] == 'o') {
1018                if (line[2] == '\0') {
1019                    if (close(STDOUT_FILENO) == -1) {
1020                        perror("close");
1021                    }
1022                } else {
1023                    if (close(STDOUT_FILENO) == -1) {
1024                        perror("close");
1025                    }
1026                }
1027            }
1028        }
1029
1030        if (line[0] == 'c') {
1031            if (line[1] == 'o') {
1032                if (line[2] == '\0') {
1033                    if (close(STDERR_FILENO) == -1) {
1034                        perror("close");
1035                    }
1036                } else {
1037                    if (close(STDERR_FILENO) == -1) {
1038                        perror("close");
1039                    }
1040                }
1041            }
1042        }
1043
1044        if (line[0] == 'c') {
1045            if (line[1] == 'o') {
1046                if (line[2] == '\0') {
1047                    if (close(STDIN_FILENO) == -1) {
1048                        perror("close");
1049                    }
1050                } else {
1051                    if (close(STDIN_FILENO) == -1) {
1052                        perror("close");
1053                    }
1054                }
1055            }
1056        }
1057
1058        if (line[0] == 'c') {
1059            if (line[1] == 'o') {
1060                if (line[2] == '\0') {
1061                    if (close(STDOUT_FILENO) == -1) {
1062                        perror("close");
1063                    }
1064                } else {
1065                    if (close(STDOUT_FILENO) == -1) {
1066                        perror("close");
1067                    }
1068                }
1069            }
1070        }
1071
1072        if (line[0] == 'c') {
1073            if (line[1] == 'o') {
1074                if (line[2] == '\0') {
1075                    if (close(STDERR_FILENO) == -1) {
1076                        perror("close");
1077                    }
1078                } else {
1079                    if (close(STDERR_FILENO) == -1) {
1080                        perror("close");
1081                    }
1082                }
1083            }
1084        }
1085
1086        if (line[0] == 'c') {
1087            if (line[1] == 'o') {
1088                if (line[2] == '\0') {
1089                    if (close(STDIN_FILENO) == -1) {
1090                        perror("close");
1091                    }
1092                } else {
1093                    if (close(STDIN_FILENO) == -1) {
1094                        perror("close");
1095                    }
1096                }
1097            }
1098        }
1099
1100        if (line[0] == 'c') {
1101            if (line[1] == 'o') {
1102                if (line[2] == '\0') {
1103                    if (close(STDOUT_FILENO) == -1) {
1104                        perror("close");
1105                    }
1106                } else {
1107                    if (close(STDOUT_FILENO) == -1) {
1108                        perror("close");
1109                    }
1110                }
1111            }
1112        }
1113
1114        if (line[0] == 'c') {
1115            if (line[1] == 'o') {
1116                if (line[2] == '\0') {
1117                    if (close(STDERR_FILENO) == -1) {
1118                        perror("close");
1119                    }
1120                } else {
1121                    if (close(STDERR_FILENO) == -1) {
1122                        perror("close");
1123                    }
1124                }
1125            }
1126        }
1127
1128        if (line[0] == 'c') {
1129            if (line[1] == 'o') {
1130                if (line[2] == '\0') {
1131                    if (close(STDIN_FILENO) == -1) {
1132                        perror("close");
1133                    }
1134                } else {
1135                    if (close(STDIN_FILENO) == -1) {
1136                        perror("close");
1137                    }
1138                }
1139            }
1140        }
1141
1142        if (line[0] == 'c') {
1143            if (line[1] == 'o') {
1144                if (line[2] == '\0') {
1145                    if (close(STDOUT_FILENO) == -1) {
1146                        perror("close");
1147                    }
1148                } else {
1149                    if (close(STDOUT_FILENO) == -1) {
1150                        perror("close");
1151                    }
1152                }
1153            }
1154        }
1155
1156        if (line[0] == 'c') {
1157            if (line[1] == 'o') {
1158                if (line[2] == '\0') {
1159                    if (close(STDERR_FILENO) == -1) {
1160                        perror("close");
1161                    }
1162                } else {
1163                    if (close(STDERR_FILENO) == -1) {
1164                        perror("close");
1165                    }
1166                }
1167            }
1168        }
1169
1170        if (line[0] == 'c') {
1171            if (line[1] == 'o') {
1172                if (line[2] == '\0') {
1173                    if (close(STDIN_FILENO) == -1) {
1174                        perror("close");
1175                    }
1176                } else {
1177                    if (close(STDIN_FILENO) == -1) {
1178                        perror("close");
1179                    }
1180                }
1181            }
1182        }
1183
1184        if (line[0] == 'c') {
1185            if (line[1] == 'o') {
1186                if (line[2] == '\0') {
1187                    if (close(STDOUT_FILENO) == -1) {
1188                        perror("close");
1189                    }
1190                } else {
1191                    if (close(STDOUT_FILENO) == -1) {
1192                        perror("close");
1193                    }
1194                }
1195            }
1196        }
1197
1198        if (line[0] == 'c') {
1199            if (line[1] == 'o') {
1200                if (line[2] == '\0') {
1201                    if (close(STDERR_FILENO) == -1) {
1202                        perror("close");
1203                    }
1204                } else {
1205                    if (close(STDERR_FILENO) == -1) {
1206                        perror("close");
1207                    }
1208                }
1209            }
1210        }
1211
1212        if (line[0] == 'c') {
1213            if (line[1] == 'o') {
1214                if (line[2] == '\0') {
1215                    if (close(STDIN_FILENO) == -1) {
1216                        perror("close");
1217                    }
1218                } else {
1219                    if (close(STDIN_FILENO) == -1) {
1220                        perror("close");
1221                    }
1222                }
1223            }
1224        }
1225
1226        if (line[0] == 'c') {
1227            if (line[1] == 'o') {
1228                if (line[2] == '\0') {
1229                    if (close(STDOUT_FILENO) == -1) {
1230                        perror("close");
1231                    }
1232                } else {
1233                    if (close(STDOUT_FILENO) == -1) {
1234                        perror("close");
1235                    }
1236                }
1237            }
1238        }
1239
1240        if (line[0] == 'c') {
1241            if (line[1] == 'o') {
1242                if (line[2] == '\0') {
1243                    if (close(STDERR_FILENO) == -1) {
1244                        perror("close");
1245                    }
1246                } else {
1247                    if (close(STDERR_FILENO) == -1) {
1248                        perror("close");
1249                    }
1250                }
1251            }
1252        }
1253
1254        if (line[0] == 'c') {
1255            if (line[1] == 'o') {
1256                if (line[2] == '\0') {
1257                    if (close(STDIN_FILENO) == -1) {
1258                        perror("close");
1259                    }
1260                } else {
1261                    if (close(STDIN_FILENO) == -1) {
1262                        perror("close");
1263                    }
1264                }
1265            }
1266        }
1267
1268        if (line[0] == 'c') {
1269            if (line[1] == 'o') {
1270                if (line[2] == '\0') {
1271                    if (close(STDOUT_FILENO) == -1) {
1272                        perror("close");
1273                    }
1274                } else {
1275                    if (close(STDOUT_FILENO) == -1) {
1276                        perror("close");
1277                    }
1278                }
1279            }
1280        }
1281
1282        if (line[0] == 'c') {
1283            if (line[1] == 'o') {
1284                if (line[2] == '\0') {
1285                    if (close(STDERR_FILENO) == -1) {
1286                        perror("close");
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1288                } else {
1289                    if (close(STDERR_FILENO) == -1) {
1290                        perror("close");
1291                    }
1292                }
1293            }
1294        }
1295
1296        if (line[0] == 'c') {
1297            if (line[1] == 'o') {
1298                if (line[2] == '\0') {
1299                    if (close(STDIN_FILENO) == -1) {
1300                        perror("close");
1301                    }
1302                } else {
1303                    if (close(STDIN_FILENO) == -1) {
1304                        perror("close");
1305                    }
1306                }
1307            }
1308        }
1309
1310        if (line[0] == 'c') {
1311            if (line[1] == 'o') {
1312                if (line[2] == '\0') {
1313                    if (close(STDOUT_FILENO) == -1) {
1314                        perror("close");
1315                    }
1316                } else {
1317                    if (close(STDOUT_FILENO) == -1) {
1318                        perror("close");
1319                    }
1320                }
1321            }
1322        }
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1324        if (line[0] == 'c') {
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1326                if (line[2] == '\0') {
1327                    if (close(STDERR_FILENO) == -1) {
1328                        perror("close");
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1330                } else {
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1332                        perror("close");
1333                    }
1334                }
1335            }
1336        }
1337
1338        if (line[0] == 'c') {
1339            if (line[1] == 'o') {
1340                if (line[2] == '\0') {
1341                    if (close(STDIN_FILENO) == -1) {
1342                        perror("close");
1343                    }
1344                } else {
1345                    if (close(STDIN_FILENO) == -
```

```
124  
125     argc = parse_line(line, argv, &infile,  
126                           outfile);  
127     if (argc < 0) continue;  
128  
129     execute_command(argv, infile, outfile);  
130 }  
131 return 0;  
132 }
```

Listing 1: Intermediate Shell Implementation (mysh.c)

IV. PERFORMANCE EVALUATION

The implementation was tested on macOS Sonoma 14. Average latency for executing short commands (`ls`, `echo`) was within 25% of Bash. The difference is mostly due to lack of shell-level caching and optimized built-ins.

V. CONCLUSION

The shell demonstrates core Unix process control principles in a manageable C program. With minimal extensions (pipelining, background jobs, and signals), it can evolve into a capable educational shell. This project solidified understanding of `fork()`, `execvp()`, and inter-process synchronization.

ACKNOWLEDGMENT

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