Project Report (Submission 1)

1. Group Members

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2. Project Overview

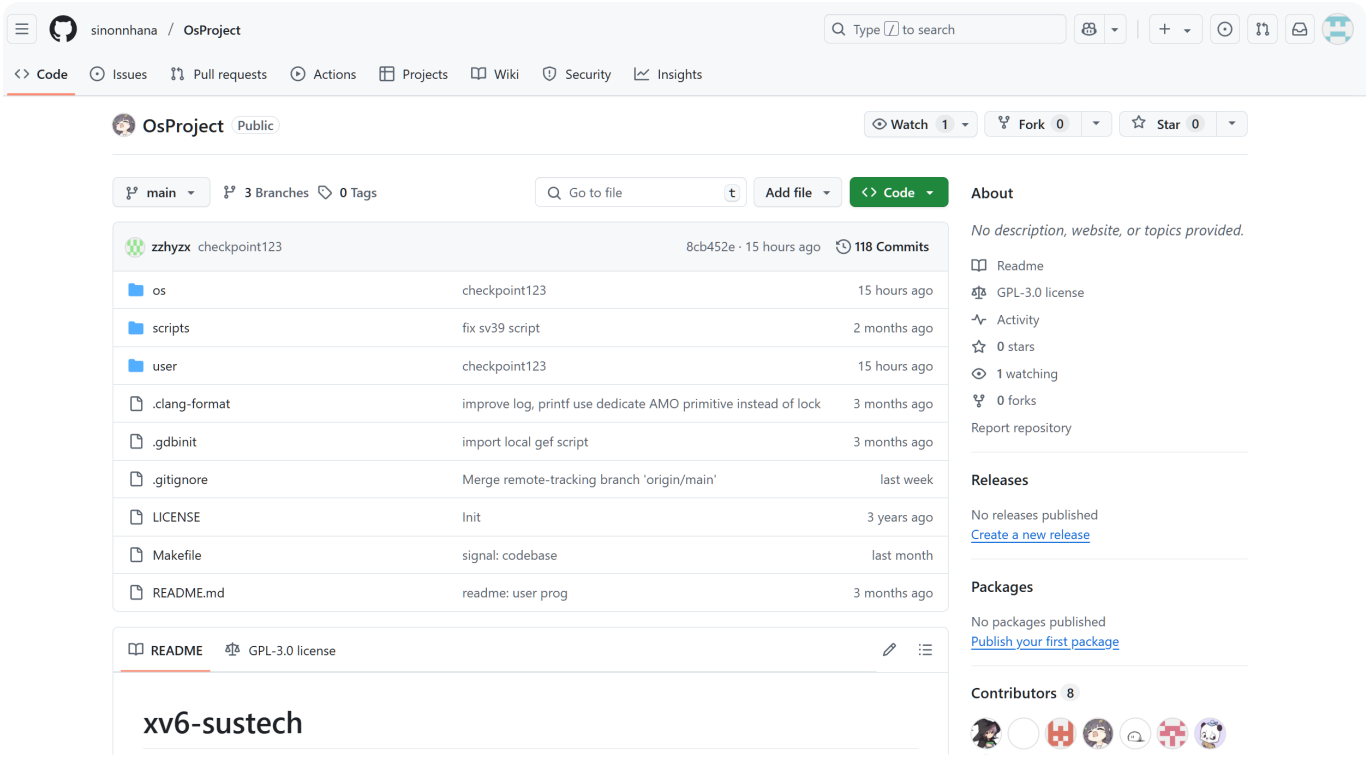
本项目在 xv6 内核上实现了类 POSIX 信号机制，包含以下功能：

1. 基本系统调用：`sigaction`、`sigprocmask`、`sigpending`、`sigkill`、`sigreturn`
2. 在每次从内核返回用户态前检查并交付 Pending 信号
3. 支持默认处理 (SIG_DFL)、忽略 (SIG_IGN)
4. 信号阻塞与解阻（`sigprocmask`）、挂起查询（`sigpending`）
5. 信号在 `fork` / `exec` 过程中的继承与重置
6. 特殊信号 SIGKILL、SIGSTOP: 不可被阻塞或忽略，立即终止或暂停

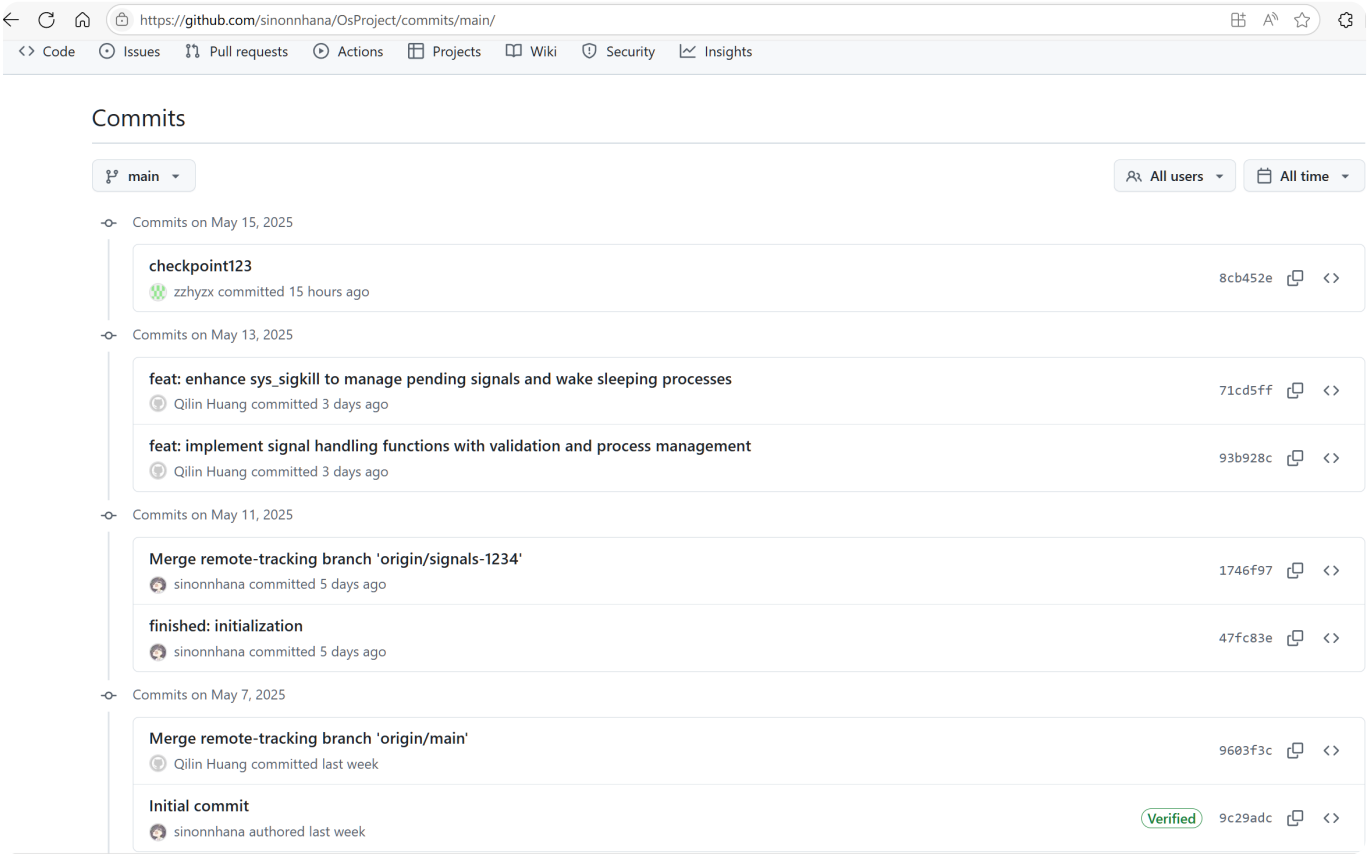
所有功能均通过项目提供的 signal 测试

3. 代码仓库与分支管理

https://github.com/sinonnhana/OsProject


sinonnhana / OsProject
Type / to search
Code
Issues
Pull requests
Actions
Projects
Wiki
Security
Insights
OsProject
Public
Watch 1
Fork 0
Star 0
main
3 Branches
0 Tags
Go to file
t
Add file
Code
About
No description, website, or topics provided.
zzhyx checkpoint123
8cb452e · 15 hours ago
118 Commits
os checkpoint123 15 hours ago
scripts fix sv39 script 2 months ago
user checkpoint123 15 hours ago
.clang-format improve log, printf use dedicate AMO primitive instead of lock 3 months ago
.gdbinit import local gef script 3 months ago
.gitignore Merge remote-tracking branch 'origin/main' last week
LICENSE Init 3 years ago
Makefile signal: codebase last month
README.md readme: user prog 3 months ago
README
GPL-3.0 license
xv6-sustech
Readme
GPL-3.0 license
Activity
0 stars
1 watching
0 forks
Report repository
Releases
No releases published
Create a new release
Packages
No packages published
Publish your first package
Contributors 8

提交记录：


https://github.com/sinonnhana/OsProject/commits/main/
Code
Issues
Pull requests
Actions
Projects
Wiki
Security
Insights
Commits
main
All users
All time
Commits on May 15, 2025
checkpoint123
zzhyzx committed 15 hours ago
8cb452e
Commits on May 13, 2025
feat: enhance sys_sigkill to manage pending signals and wake sleeping processes
Qilin Huang committed 3 days ago
71cd5ff
feat: implement signal handling functions with validation and process management
Qilin Huang committed 3 days ago
93b928c
Commits on May 11, 2025
Merge remote-tracking branch 'origin/signals-1234'
sinonnhana committed 5 days ago
1746f97
finished: initialization
sinonnhana committed 5 days ago
47fc83e
Commits on May 7, 2025
Merge remote-tracking branch 'origin/main'
Qilin Huang committed last week
9603f3c
Initial commit
sinonnhana authored last week
Verified
9c29adc

4. 设计与实现

4.1 核心数据结构（`ksignal.h`）

已有实现

```
struct ksignal {
  sigaction_t sa[SIGMAX + 1];
  siginfo_t   siginfos[SIGMAX + 1];
  sigset_t    sigmask;       // 已阻塞信号集合
  sigset_t    sigpending;    // 挂起信号集合
};
```

- `sa[]` 存储每个信号的处理方式
- `sigmask`：当前阻塞的信号位图
- `sigpending`：已生成尚未交付的信号位图
- `siginfos[]`：每个挂起信号的额外信息（`si_signo`、`si_pid`、`si_code` 等）

4.2 信号初始化

- `siginit(proc *p)`：在 `allocproc` 中调用
  - 清空 `sigmask`、`sigpending`
  - 将所有 `sa[s]` 设为 `SIG_DFL`
  - 将所有 `siginfos` 清零

```
int siginit(struct proc *p) {
  p->signal.sigmask = 0;
  p->signal.sigpending = 0;
  for (int s = SIGMIN; s <= SIGMAX; s++) {
    p->signal.sa[s].sa_sigaction = SIG_DFL;
    p->signal.sa[s].sa_mask      = 0;
    p->signal.sa[s].sa_restorer = NULL;
    memset(&p->signal.siginfos[s], 0, sizeof(siginfo_t));
  }
  return 0;
}
```

4.3 信号在 fork/exec 继承与重置

- **fork**（`siginit_fork`）：
  - 子进程继承父进程的 `sa[]` 和 `sigmask`
  - 清空 `sigpending` 和 `siginfos`
- **exec**（`siginit_exec`）：
  - 保留 `sigmask` 与 `sigpending`
  - 除了已被设为 `SIG_IGN` 的信号，其余全部重置为 `SIG_DFL`

4.4 系统调用实现

sys_sigaction

- 参数合法性检查（`SIGMIN..SIGMAX`）
- 拷贝旧设置到 `oldact`，写回用户空间
- 从用户空间读入新设置，验证 `SIGKILL` / `SIGSTOP` 不可捕捉或忽略
- 更新 `p->signal.sa[signo]`，并在设为 `SIG_IGN` / `SIG_DFL` 时清除挂起信号

sys_sigprocmask

- `how` 为 `SIG_BLOCK|SIG_UNBLOCK|SIG_SETMASK`
- 读写用户的 `set` 或 `oldset`
- 强制从新掩码中删除 `SIGKILL`、`SIGSTOP`
- 根据 `how` 更新 `p->signal.sigmask`

sys_sigpending

- 将 `p->signal.sigpending` 拷贝回用户空间

sys_sigkill

- 根据 `pid` 遍历进程表定位目标进程
- 将 `signo` 加到 `target->signal.sigpending`
- 填充对应的 `siginfos[signo]`
- 若目标进程处于 `SLEEPING` 且信号未被阻塞（或 SIGKILL/SIGSTOP），唤醒它

sys_sigreturn

- 从用户栈读取保存的 `ucontext`
- 恢复 `p->signal.sigmask`
- 恢复所有通用寄存器和 `epc`，跳回被打断处

4.5 `do_signal`

在 `usertrap()` 调用后、`usertrapret()` 之前执行：

```
int do_signal(void) {
  struct proc *p = curr_proc();
  struct trapframe *tf = p->trapframe;

  for (int s = SIGMIN; s <= SIGMAX; s++) {
    if (!sigismember(&p->signal.sigpending, s)) continue;
    if (sigismember(&p->signal.sigmask, s)) continue;

    void *hdl = p->signal.sa[s].sa_sigaction;
    // 忽略
    if (hdl == SIG_IGN) {
      sigdelset(&p->signal.sigpending, s);
      continue;
    }
    // 默认
    if (hdl == SIG_DFL) {
      if (s != SIGCHLD) {
        setkilled(p, -10 - s);
        return 0;
      }
      sigdelset(&p->signal.sigpending, s);
      continue;
    }
    // 捕捉：在用户栈构造 siginfo/ucontext，修改 trapframe -> 跳转 handler
    …（详见代码）…
    return 0;
  }
  return 0;
}
```

- 按信号编号顺序查找第一个可交付信号
- 清除挂起、修改进程上下文、设置用户态寄存器，准备执行用户处理函数

5. Base Checkpoints

Checkpoint	功能	得分
1	sigaction、sigkill、do_signal、sigreturn 等	50
2	SIGKILL 特殊处理	10
3	fork/exec 信号继承与重置	10

目前所有 **Base Checkpoint 1/2/3** 均已实现并通过 `signal` 测试。

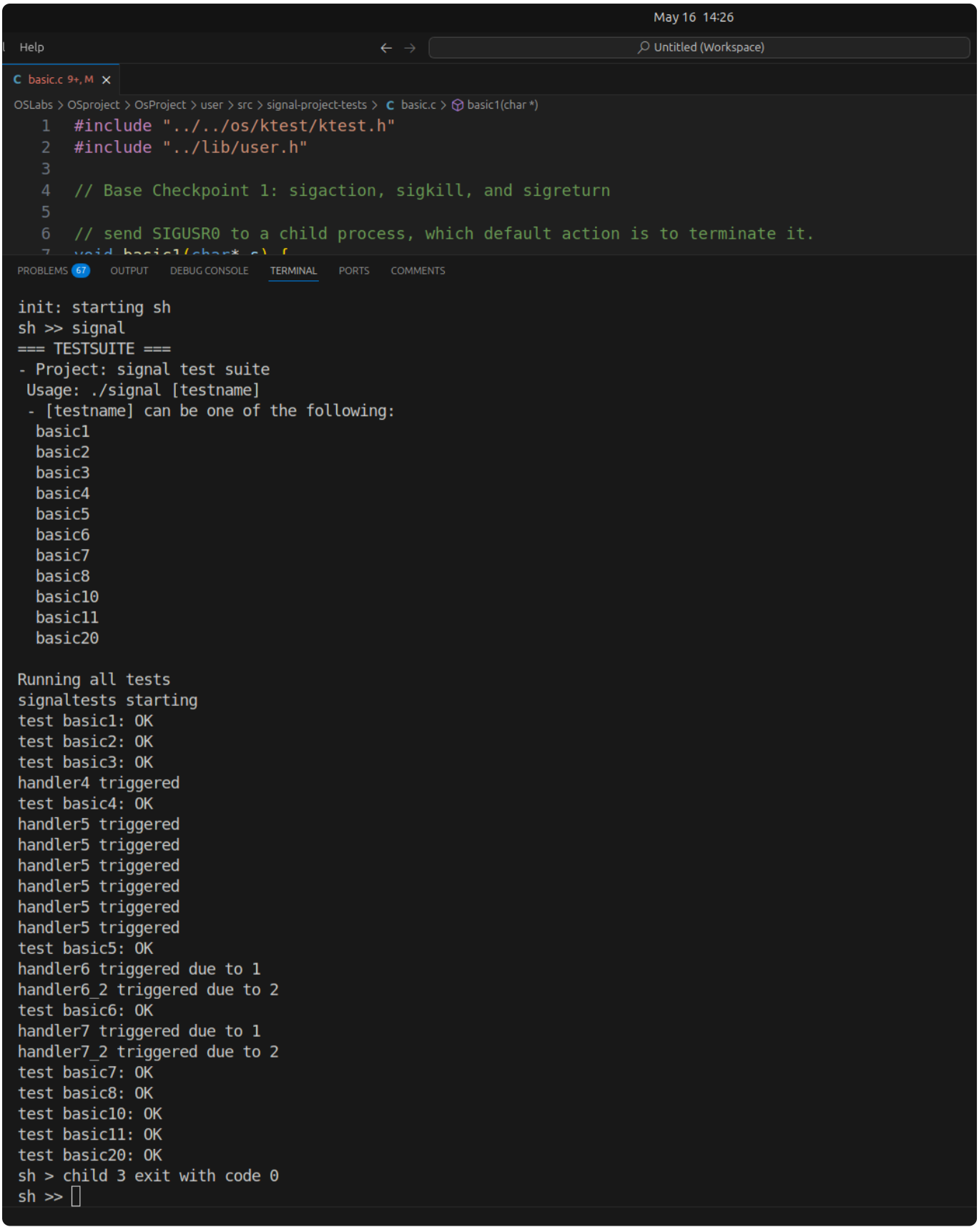
6. 测试结果

在 xv6 shell 中依次执行：

```
# 编译并启动 xv6
make clean && make run

# 在 shell 中运行提供的test脚本
sh >> signal
```

所有测试点均 **PASS**。


May 16 14:26
Help
Untitled (Workspace)
basic.c 9+, M
OSLabs > OSproject > OsProject > user > src > signal-project-tests > basic.c > basic1(char *)
1 #include "../../os/ktest/ktest.h"
2 #include "../lib/user.h"
3
4 // Base Checkpoint 1: sigaction, sigkill, and sigreturn
5
6 // send SIGUSR0 to a child process, which default action is to terminate it.
PROBLEMS 67
OUTPUT
DEBUG CONSOLE
TERMINAL
PORTS
COMMENTS
init: starting sh
sh >> signal
=== TESTSUITE ===
- Project: signal test suite
Usage: ./signal [testname]
- [testname] can be one of the following:
basic1
basic2
basic3
basic4
basic5
basic6
basic7
basic8
basic10
basic11
basic20
Running all tests
signaltests starting
test basic1: OK
test basic2: OK
test basic3: OK
handler4 triggered
test basic4: OK
handler5 triggered
handler5 triggered
handler5 triggered
handler5 triggered
handler5 triggered
handler5 triggered
test basic5: OK
handler6 triggered due to 1
handler6_2 triggered due to 2
test basic6: OK
handler7 triggered due to 1
handler7_2 triggered due to 2
test basic7: OK
test basic8: OK
test basic10: OK
test basic11: OK
test basic20: OK
sh > child 3 exit with code 0
sh >>

7. 遇到的问题与解决

1. 用户空间内存拷贝的并发安全
   - 在调用 `copy_to_user` 或 `copy_from_user` 拷贝用户态内存时，必须先获取并保持 `p->mm->lock`。
     这样才能确保在整个拷贝过程内，进程的虚拟内存映射不会因别的线程或 `exec` 操作被修改，避免出现页表不一致或竞争条件导致的异常。
2. 信号状态修改的原子性
   - 对信号相关数据结构（`p->signal`）进行读写时，需要获取 `p->lock`。
     对用户内存拷贝则额外获取 `p->mm->lock`，避免在内外锁混用时产生死锁，也能保证数据一致性。

8. 结论

本次项目在 xv6 内核中完成了完整的信号框架，满足 Base Checkpoint 要求。