Lecture 7: Shell

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COP 4610 Operating Systems

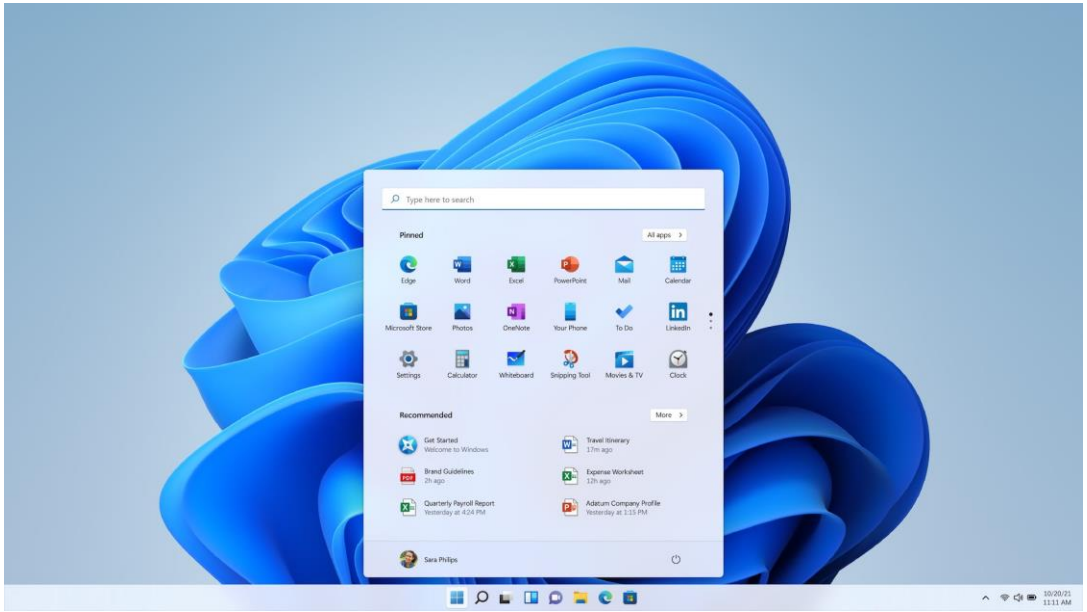
What Have We Learned?

- Building the World of Computer Systems
  - Hardware: Starts executing instructions (computation and I/O) from CPU Reset.
  - Firmware: Loads the operating system.
  - Operating System: The manager of state machines.
  - Initializes the first process (state machine).
    - Executes system calls.

- In the Entire System, Only One Program is Needed
  - **Docker/Virtual Machine**: A single program that can execute various applications.
  - Examples: vim (editor), dosbox (emulator), xeyes (GUI), etc.

•Wrapping the OS API for Users

- We need a program that "users can directly operate" to manage OS objects.
- This is the Shell
  - Kernel provides system calls; Shell provides the user interface.
  - The First Program to Directly Interact with Humans
  - Helps users create/manage processes (applications) and data files.



UNIX Shell

- The Great Design of the "Terminal" Era
  - The pinnacle of the Command-Line Interface (CLI).
- The Shell is a programming language that "translates user commands into system calls".
  - man sh (recommended reading!), bash, etc.
    - Examples: Q5 in HW3
  - We've always been programming, until the emergence of Graphical Shells (GUI).
    - Examples: Windows, Gnome, Symbian, Android.

1970

2020

The Quirky World of UNIX

- "Unix is user-friendly; it's just choosy about who its friends are."

- But if you think of the shell as a programming language, being "hard to use" doesn’t seem like much of a problem.

- After all, have you ever seen a programming language that’s "easy to use"?

A UNIX Shell

- Supported Basic Features:
  - Command execution: ls
  - Redirection: ls > a.txt
    - Using File Descriptors: A "pointer" to an open file
  - Piping: ls | wc -l
  - Background execution: ls &
  - Command combination: (echo a ; echo b) | wc –l

- The Shell Programming Language
  - Core Concept: Text Substitution
  - Building fast workflows based on text substitution
    - Redirection: cmd > file < file 2> /dev/null
    - Sequential execution: cmd1; cmd2, cmd1 && cmd2, cmd1 || cmd2
    - Piping: cmd1 | cmd2
    - Preprocessing: $(), <()
    - Variables/Environment Variables, Control Flow, etc.

Project 1 Hints

- Test code individually

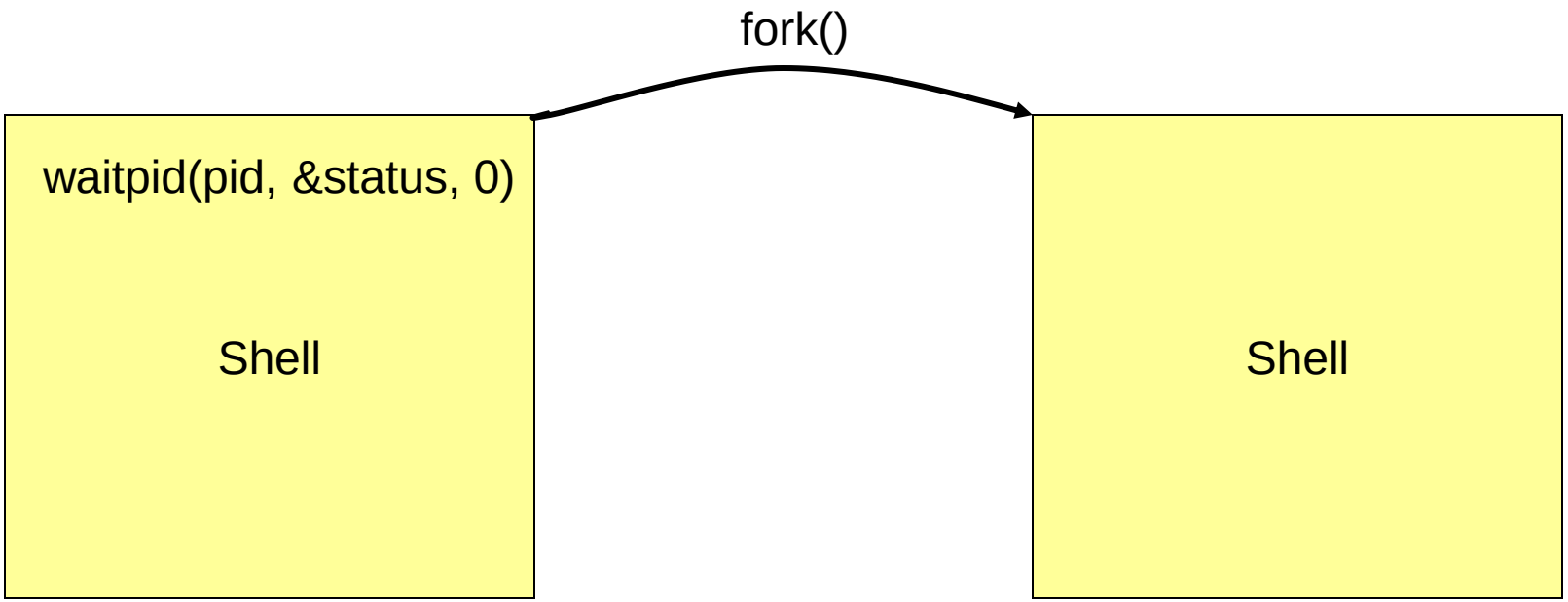
```
#ifdef TEST_PROMPT
        int main() {
        // Your test code for propt.c }
#endif
```

gcc -DTEST_PROMPT -o test_prompt src/prompt.c -Iinclude/ && ./test_prompt

- If your code relies on other codes:
  gcc -DTEST_EXPAND_TOKENS -o test_expand_tokens src/expand_tokens.c src/lexer.c -Iinclude && ./test_expand_tokens

- You should create a Makefile for the whole project.

Foreground Execution



Type “xeyes” in your terminal

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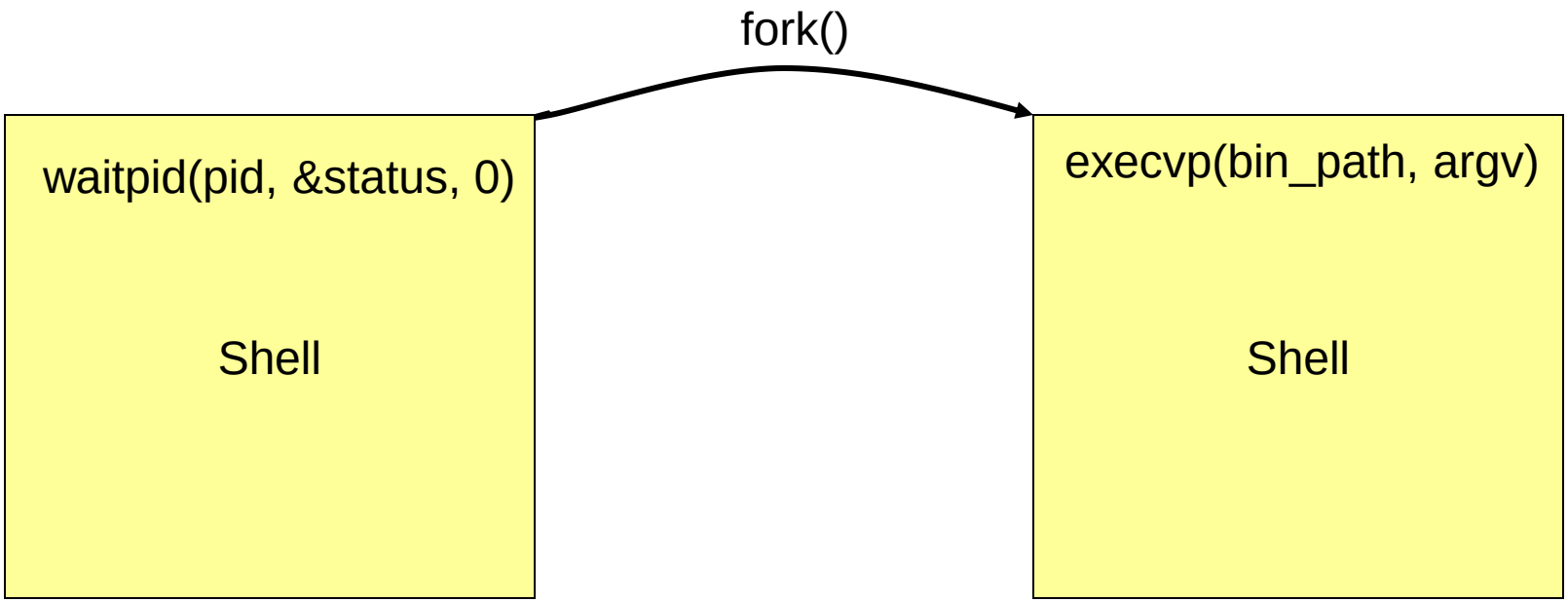

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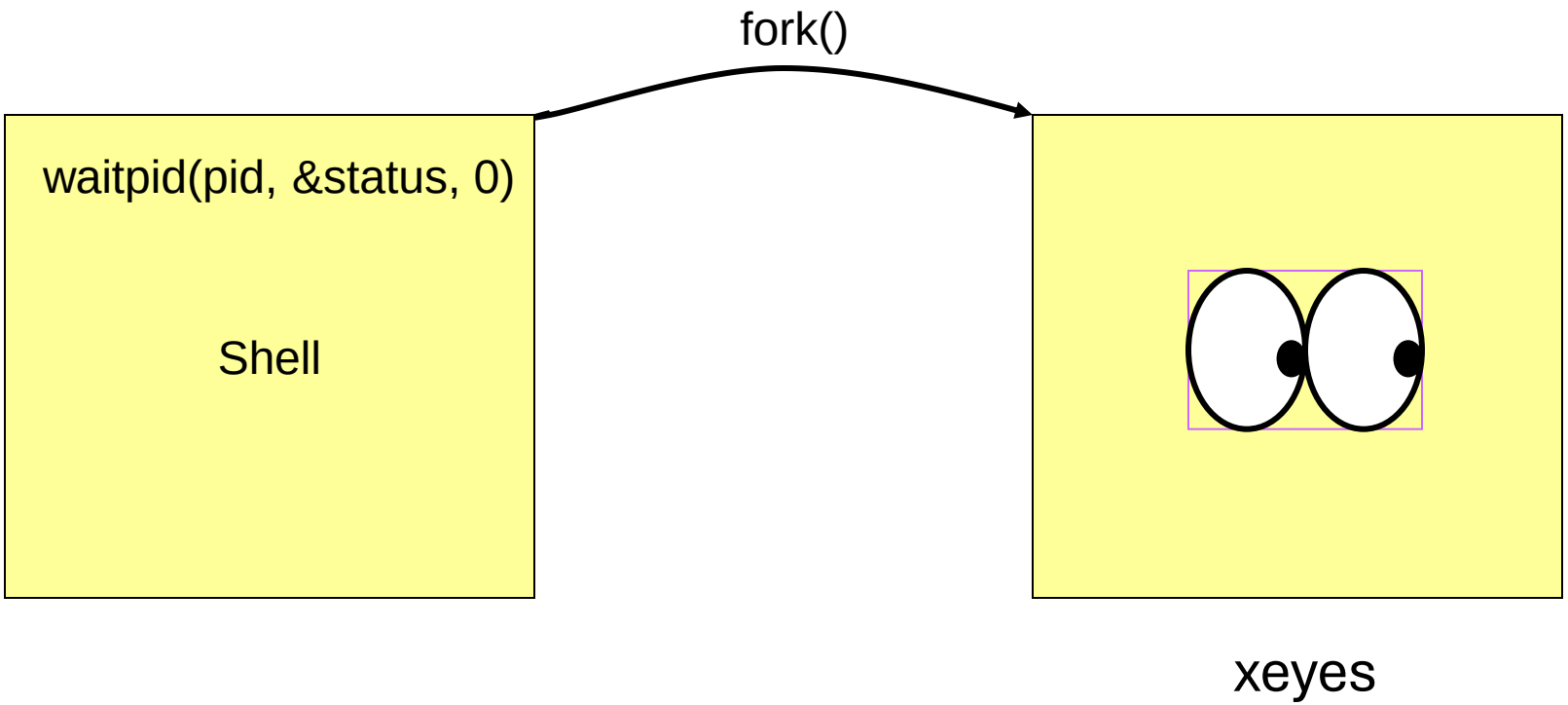
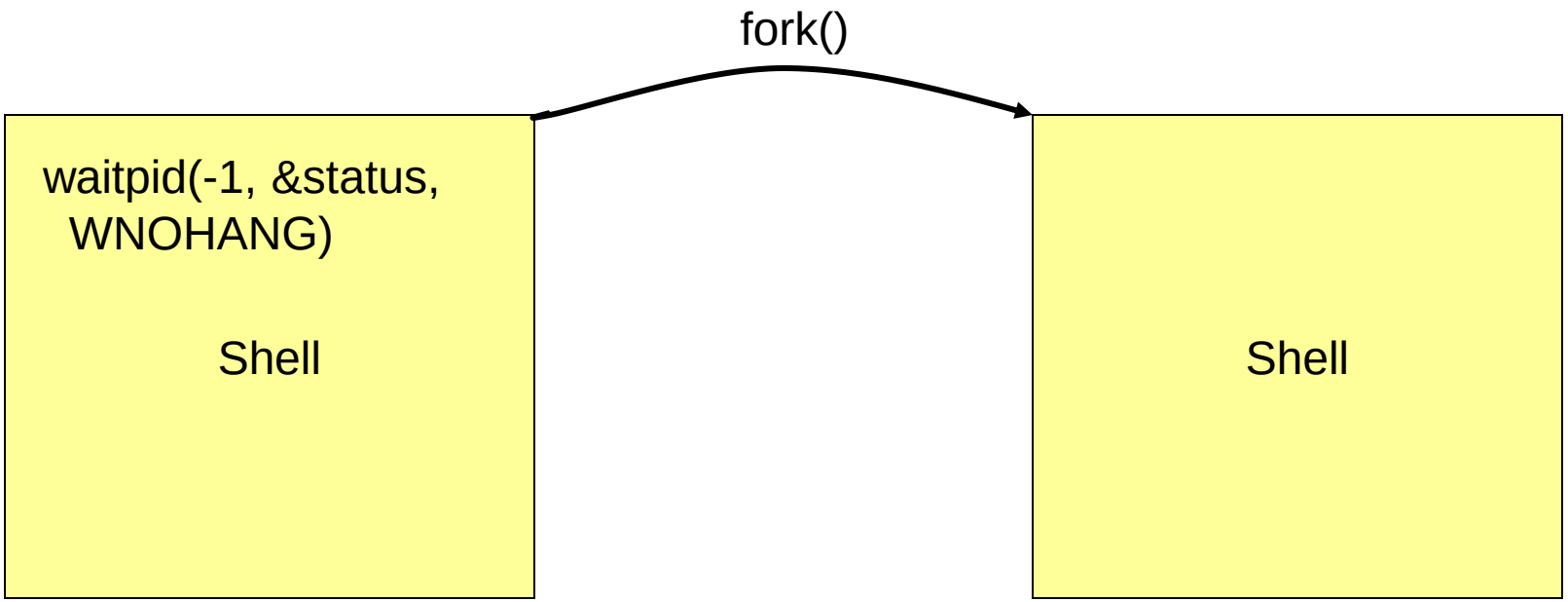


Background Execution



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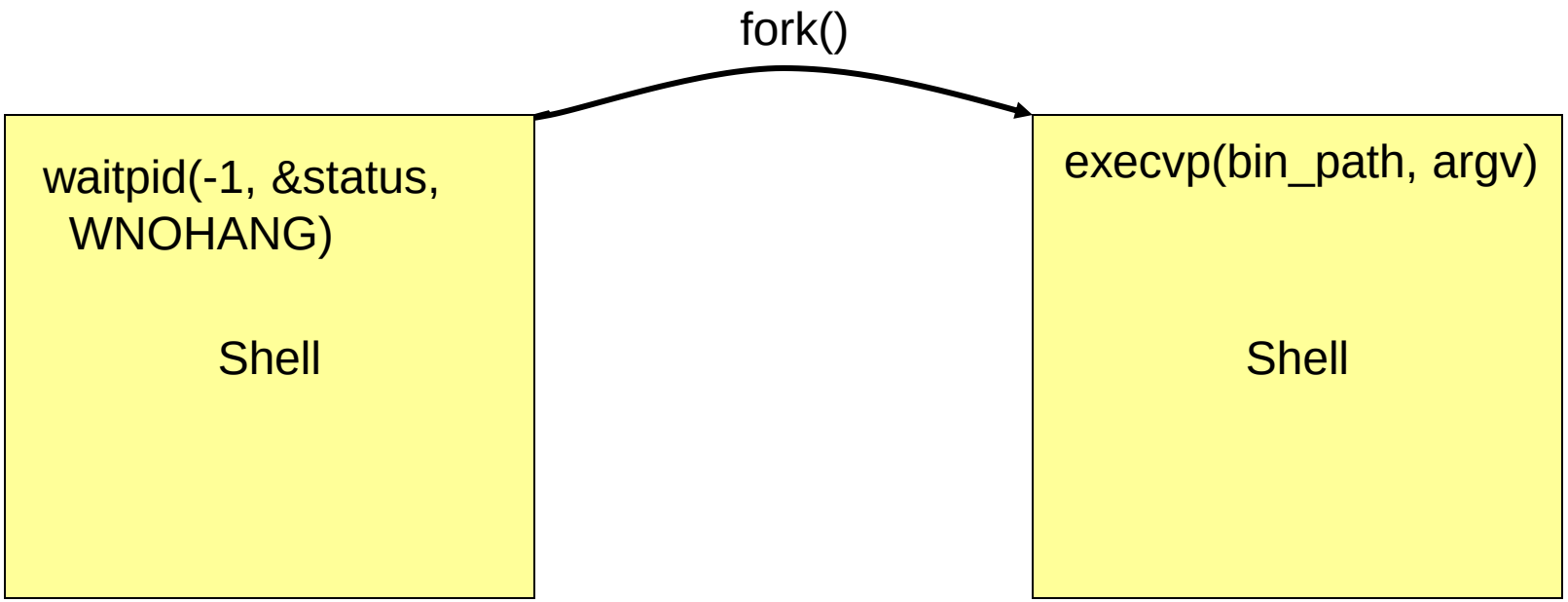

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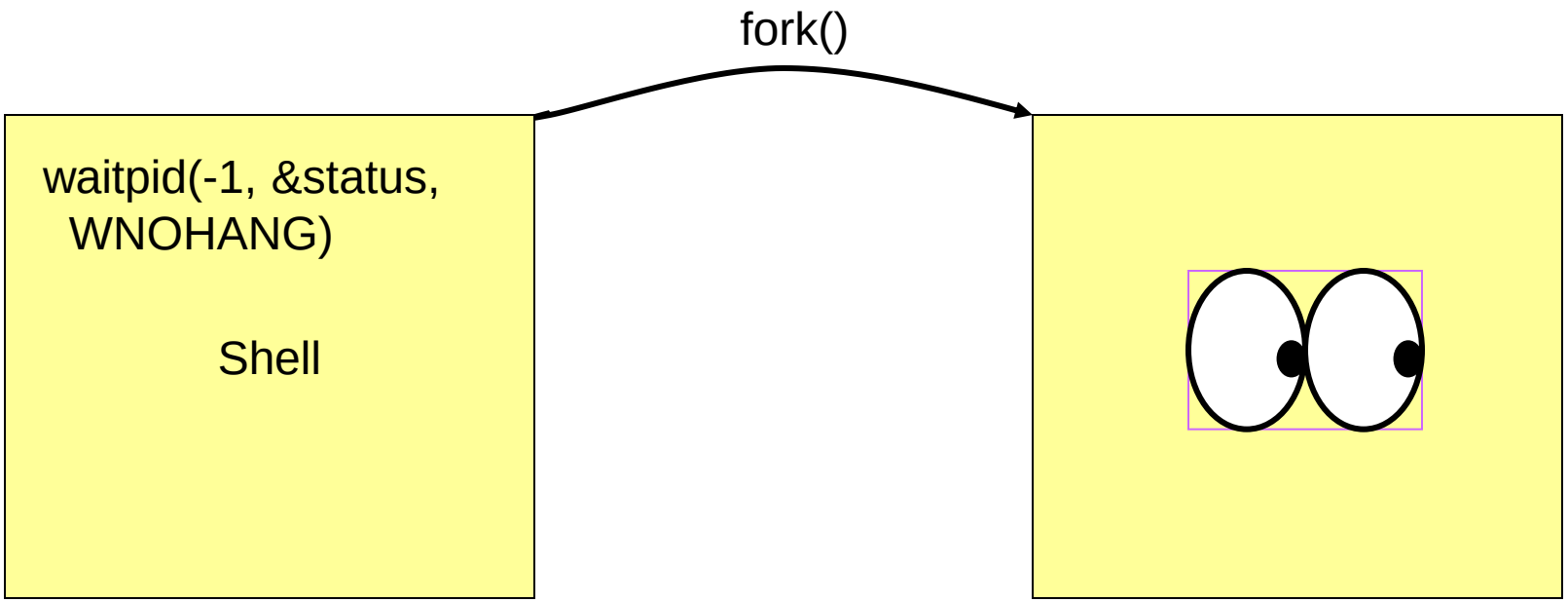

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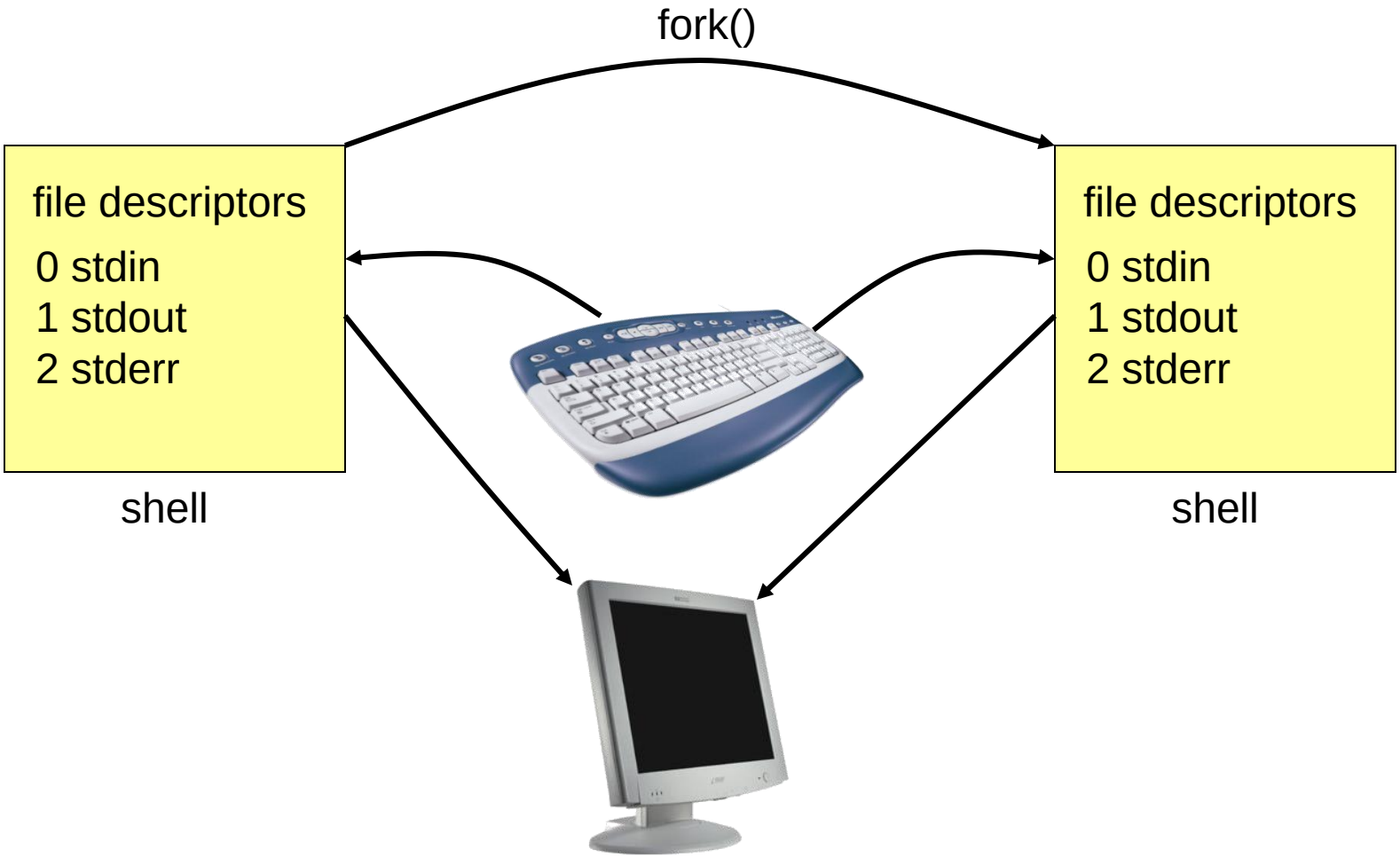

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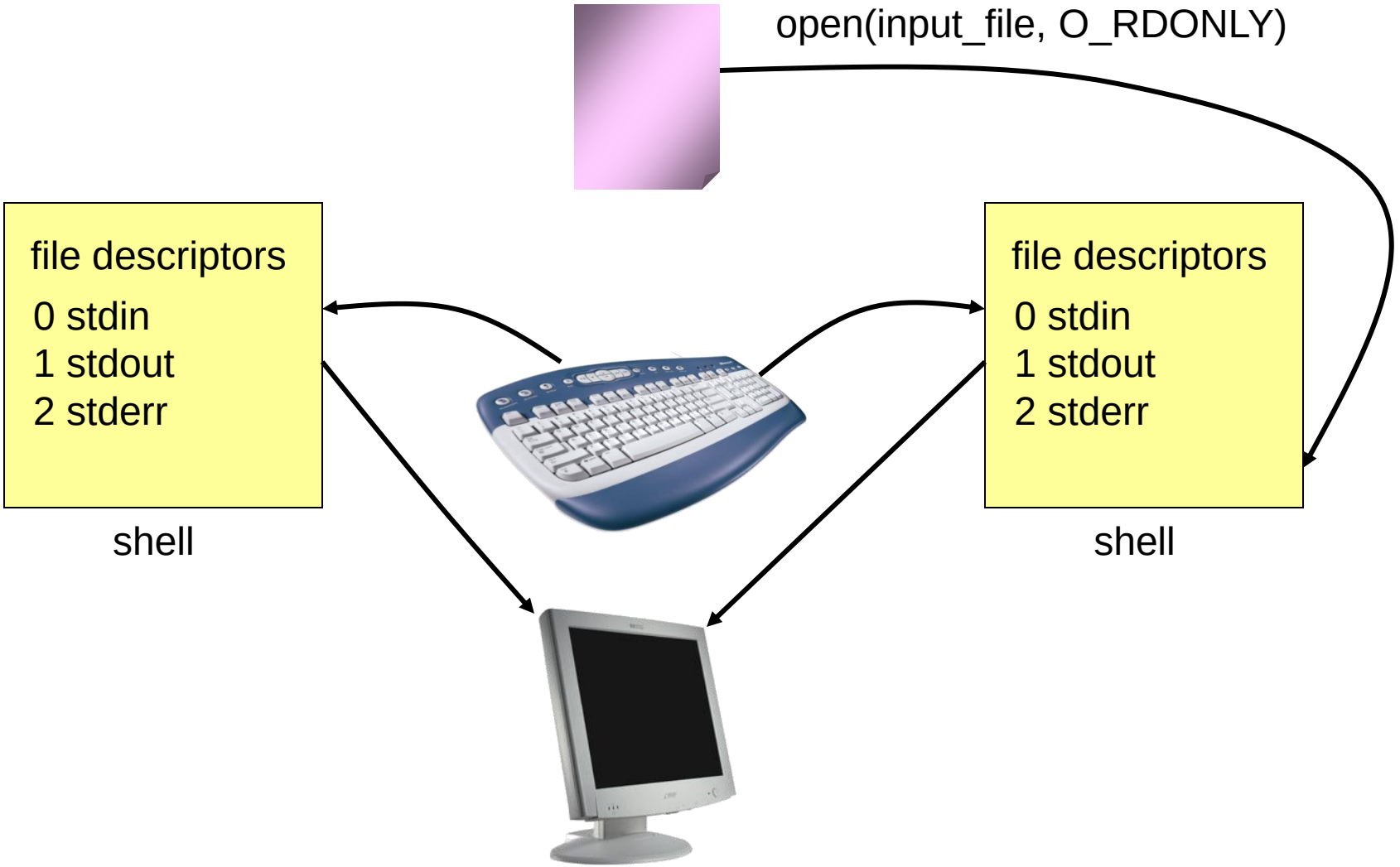

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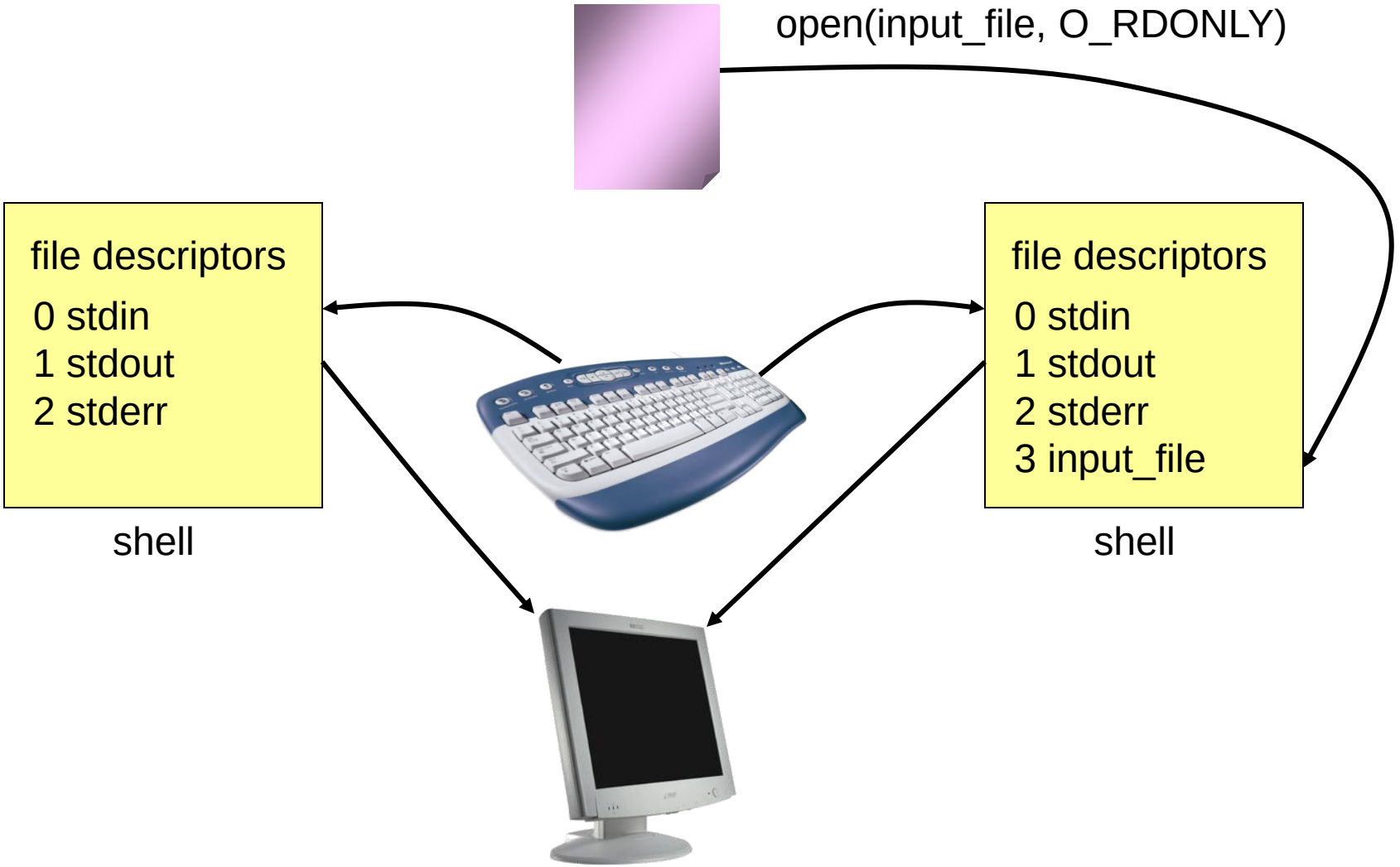

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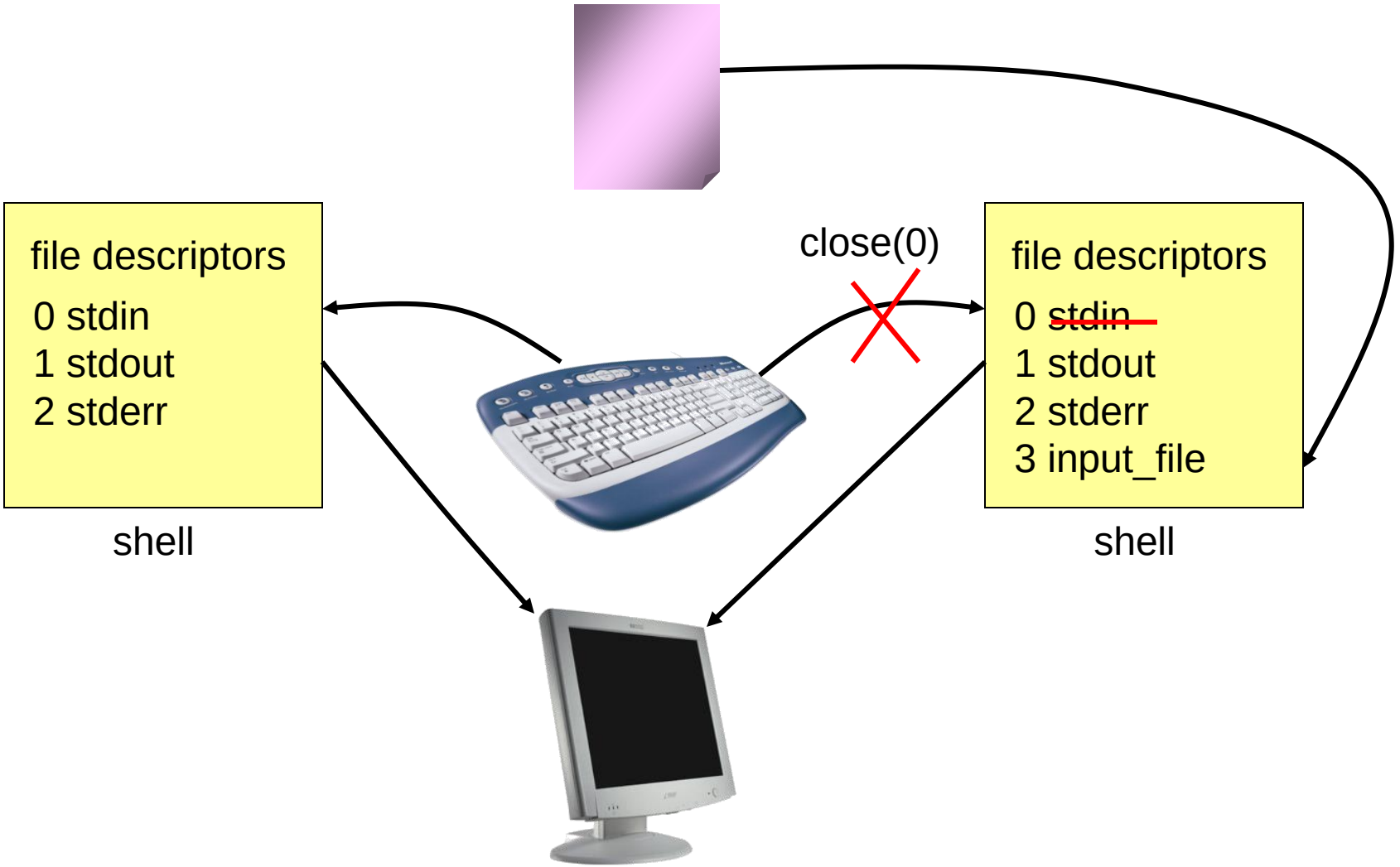

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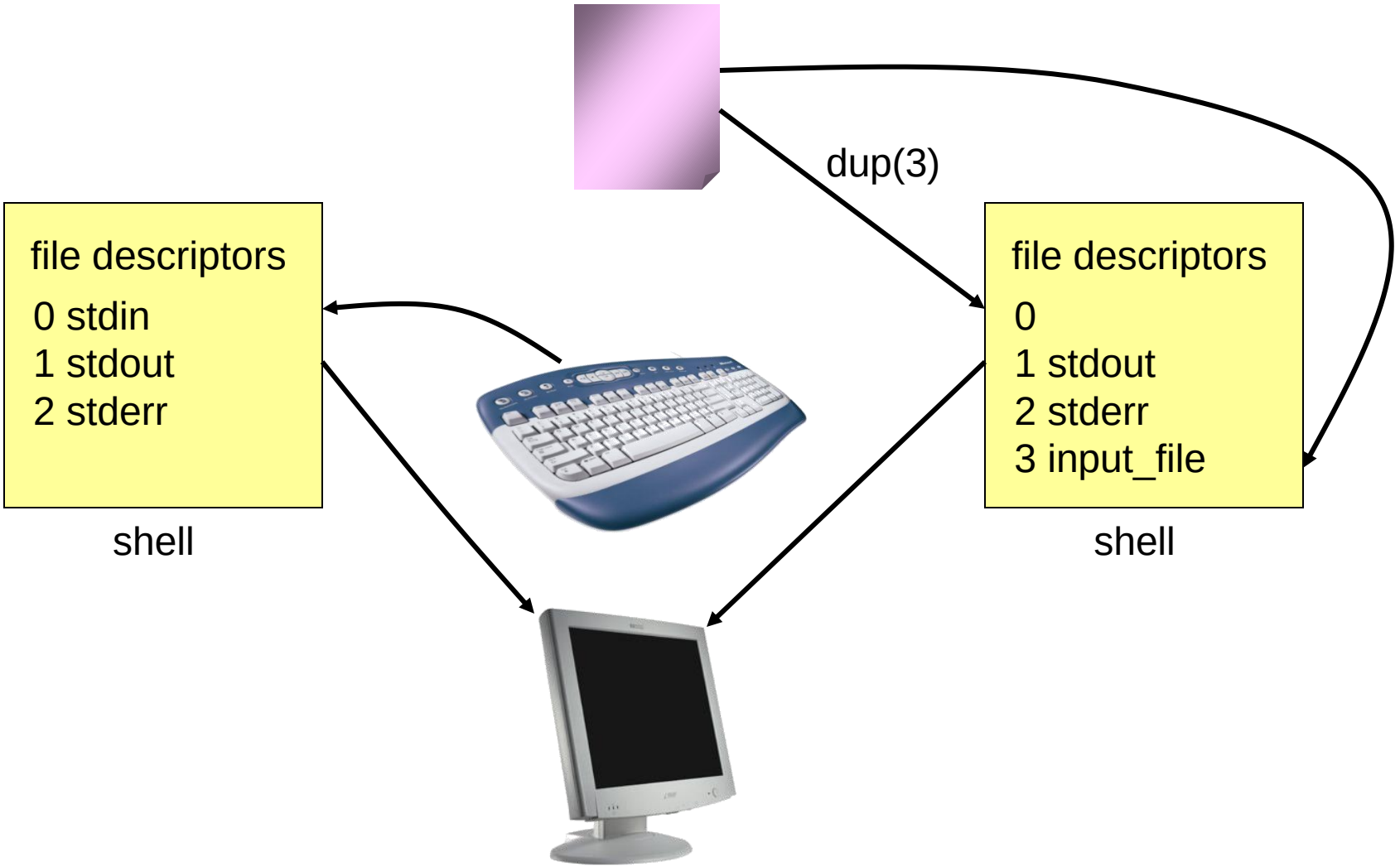

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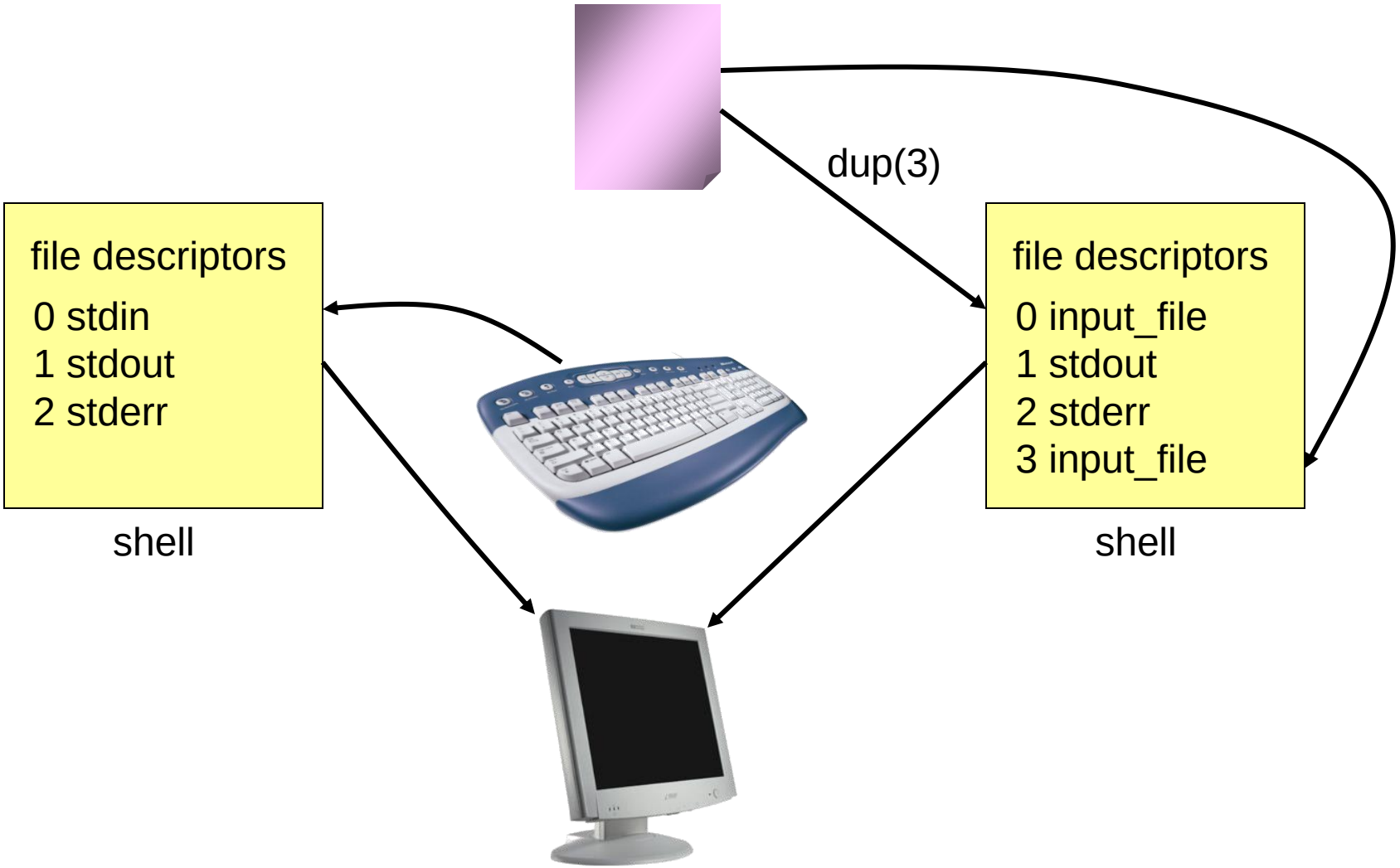

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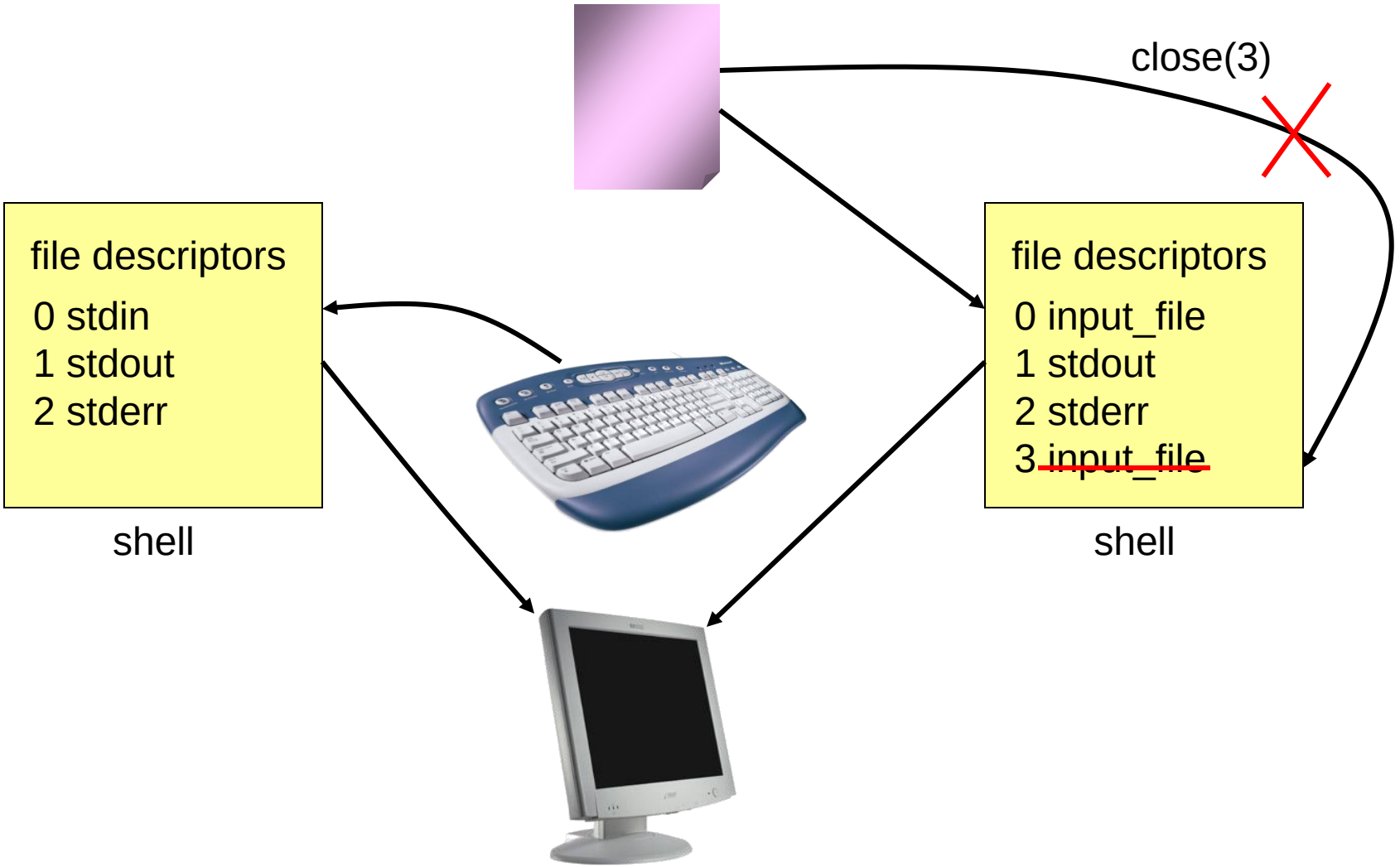

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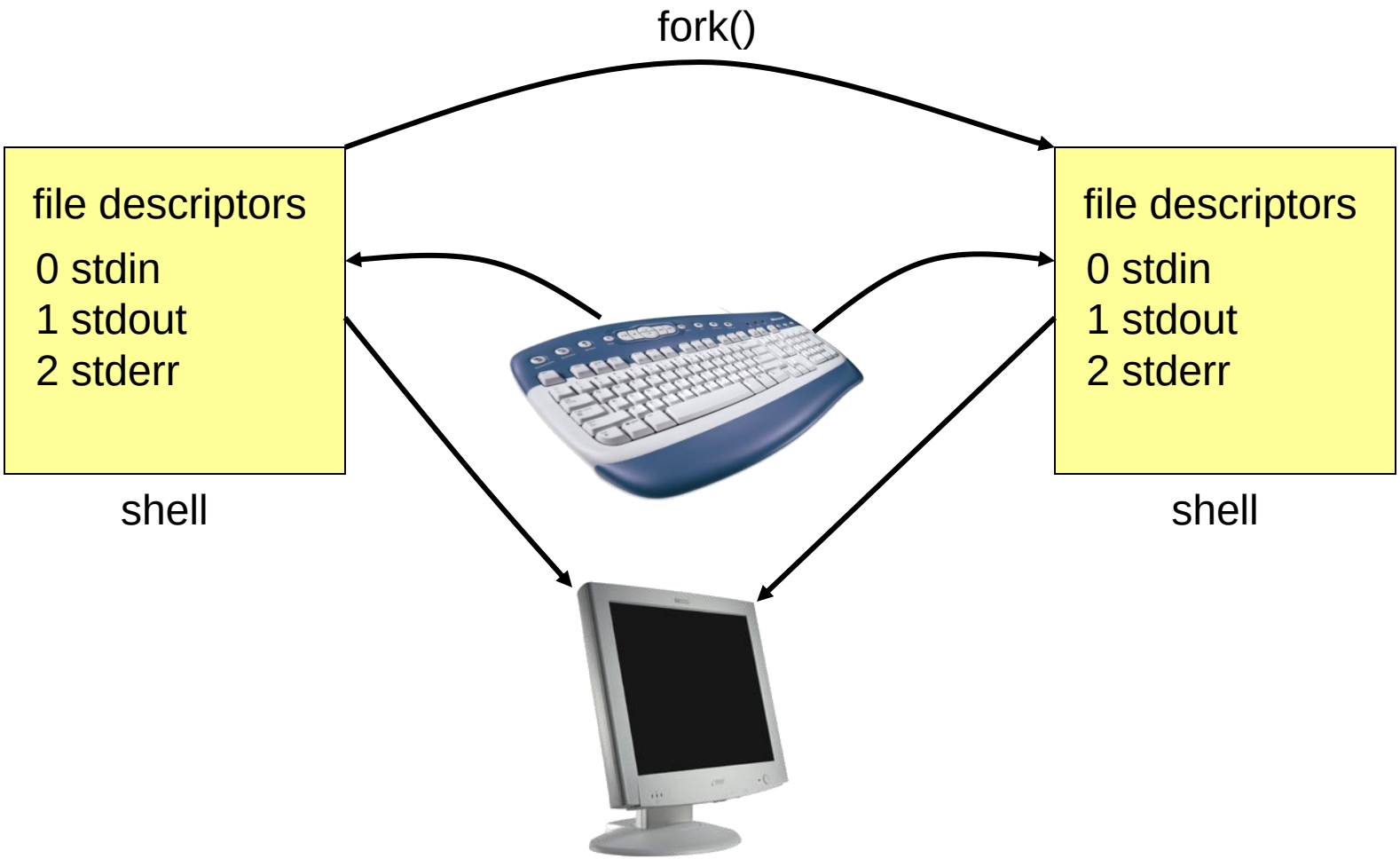

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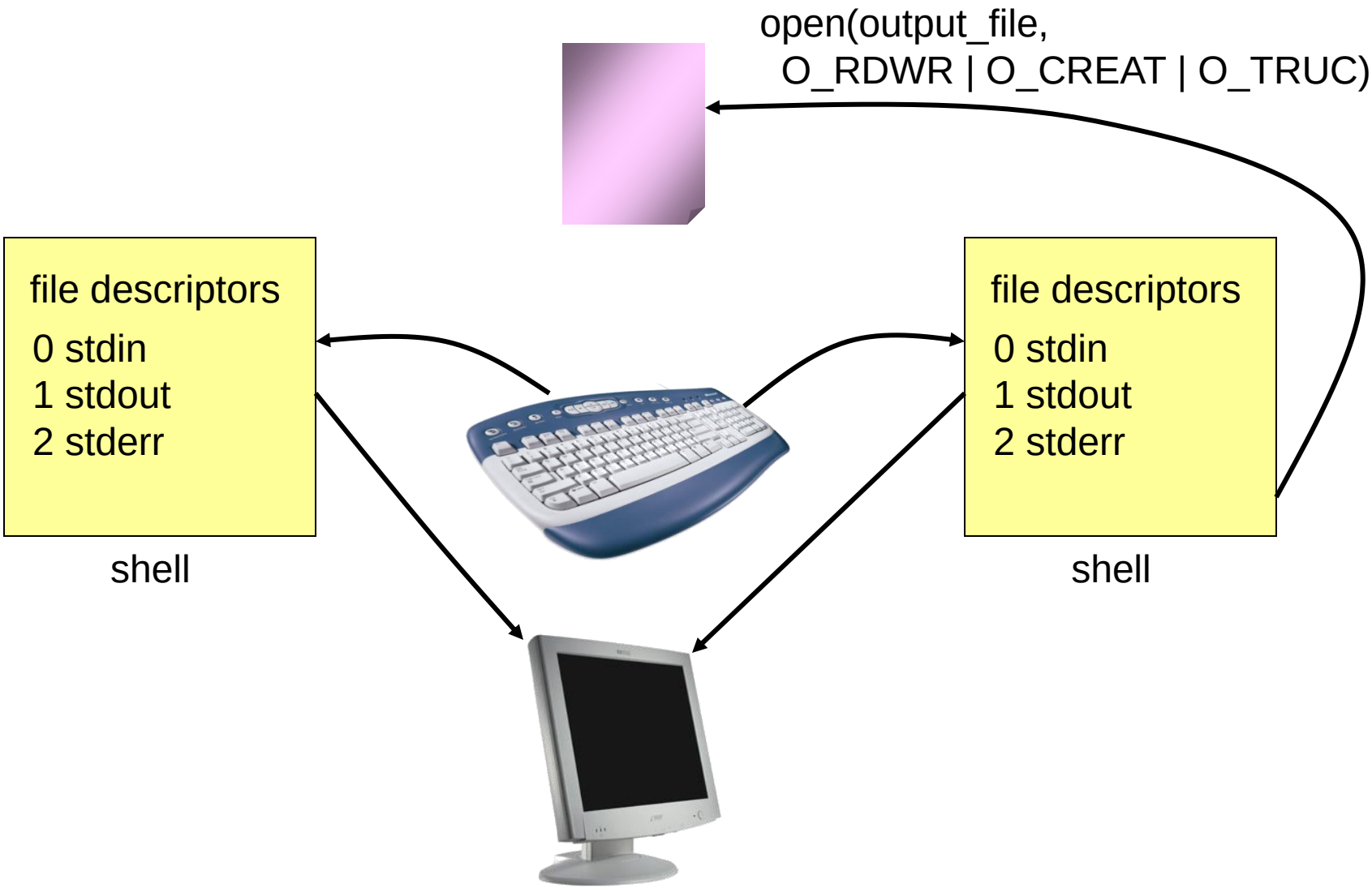

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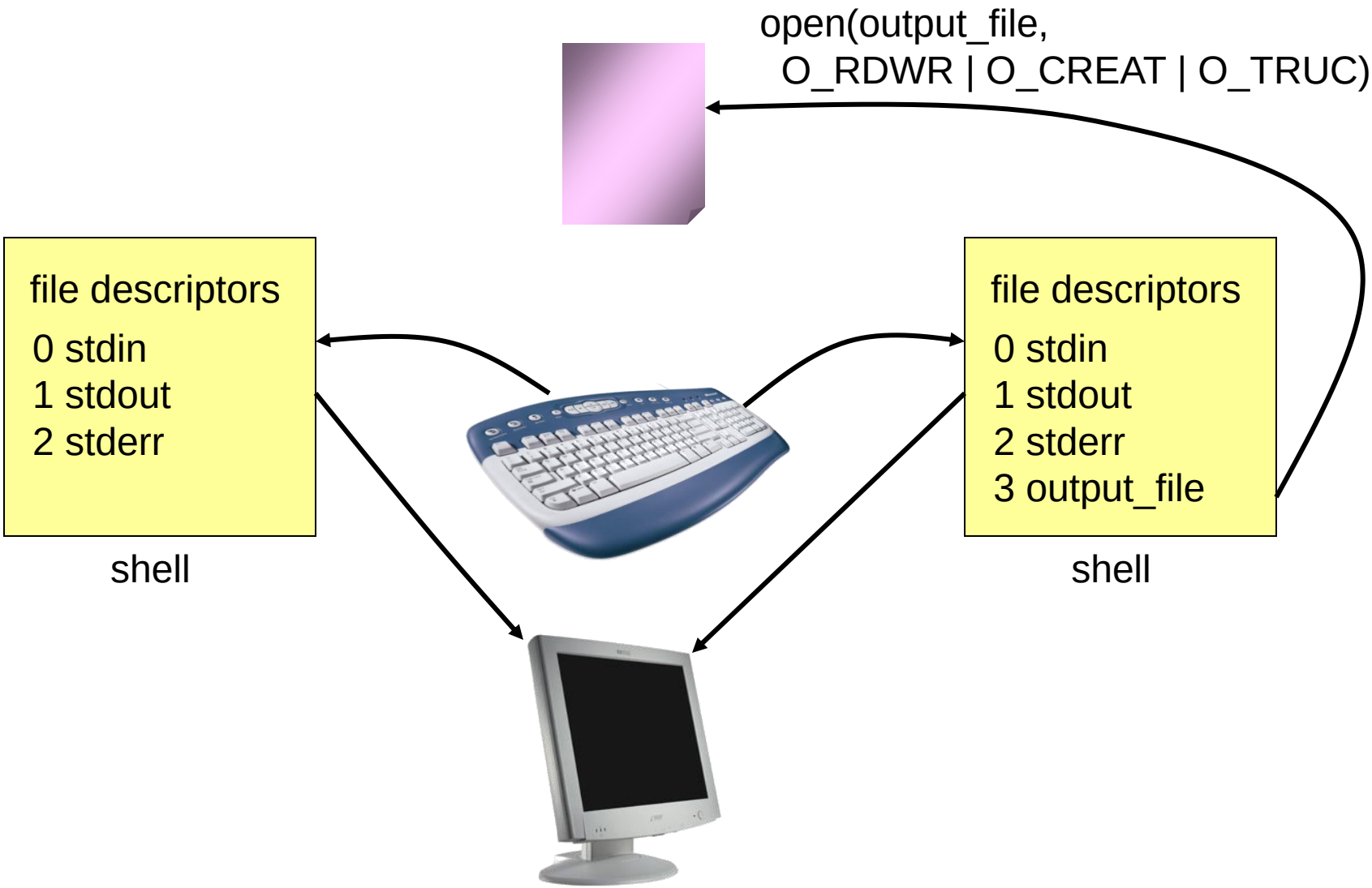

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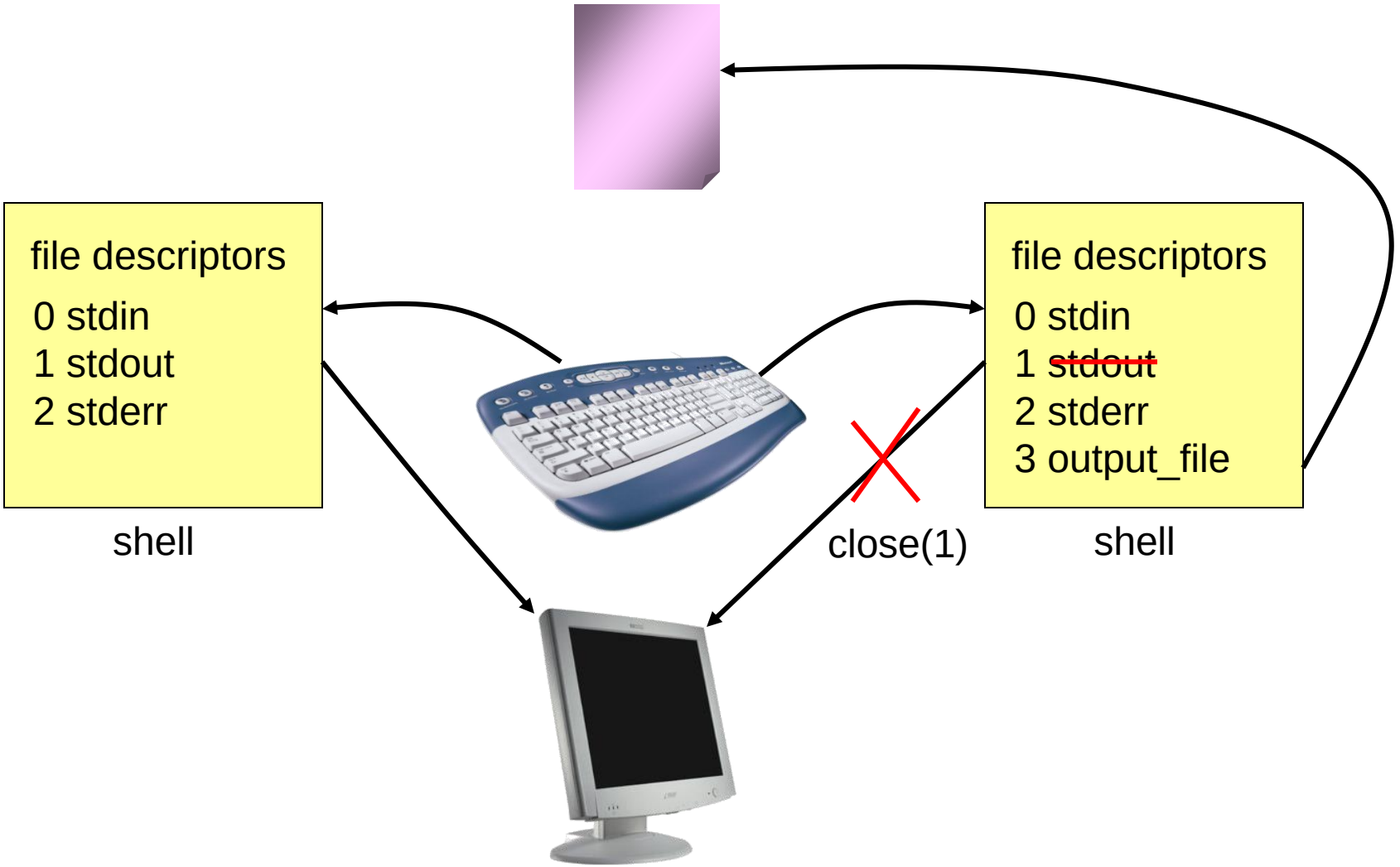

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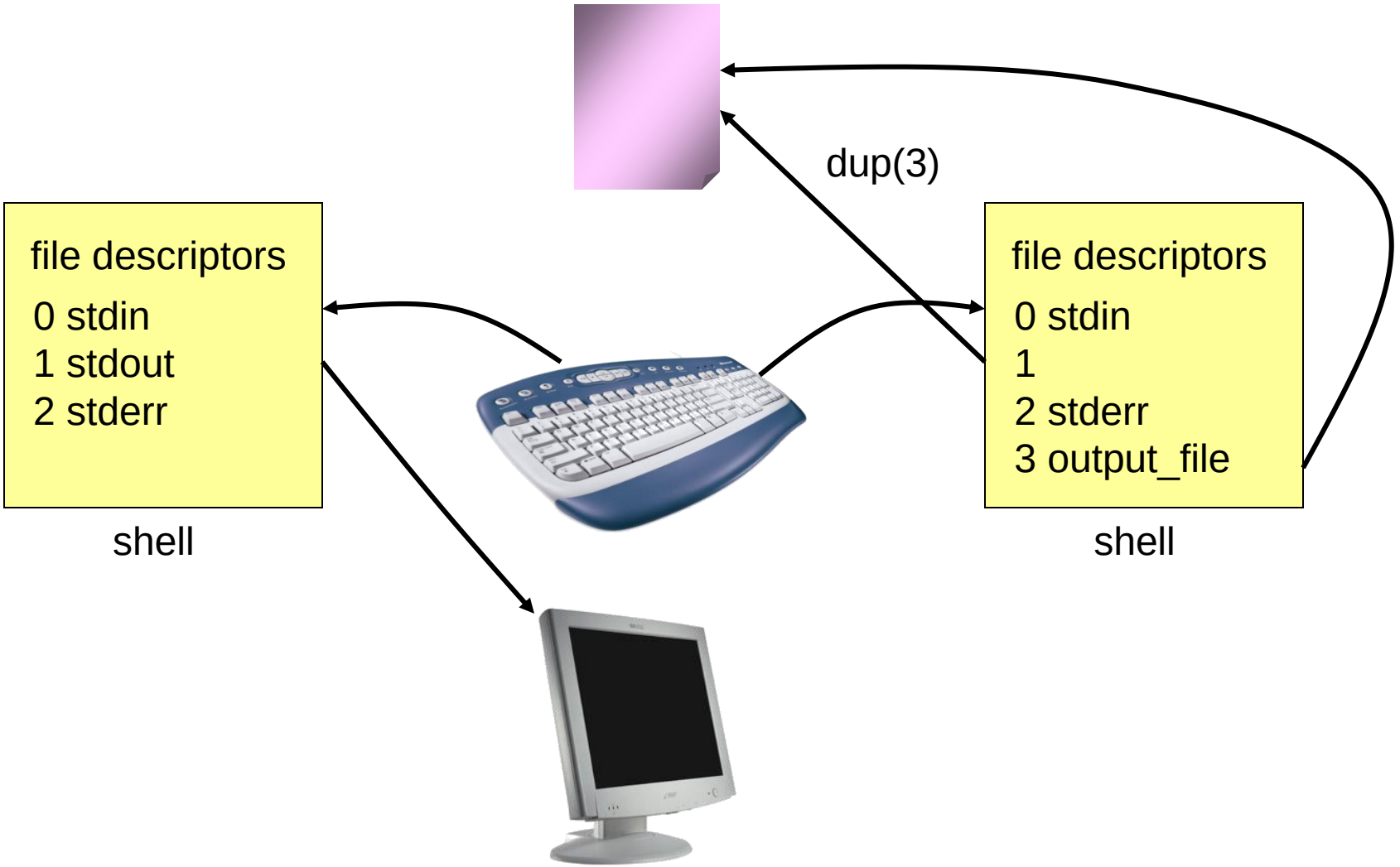

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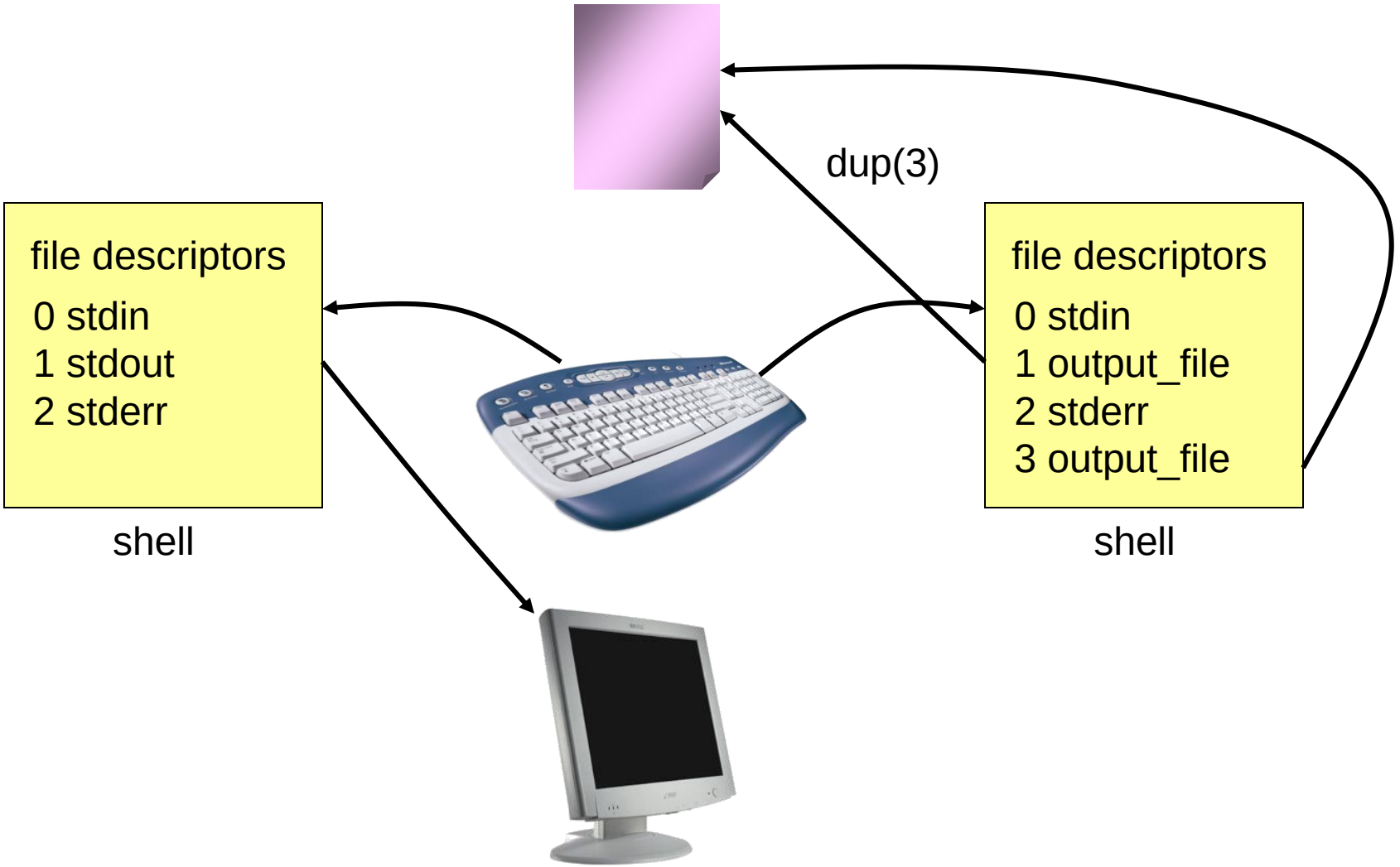

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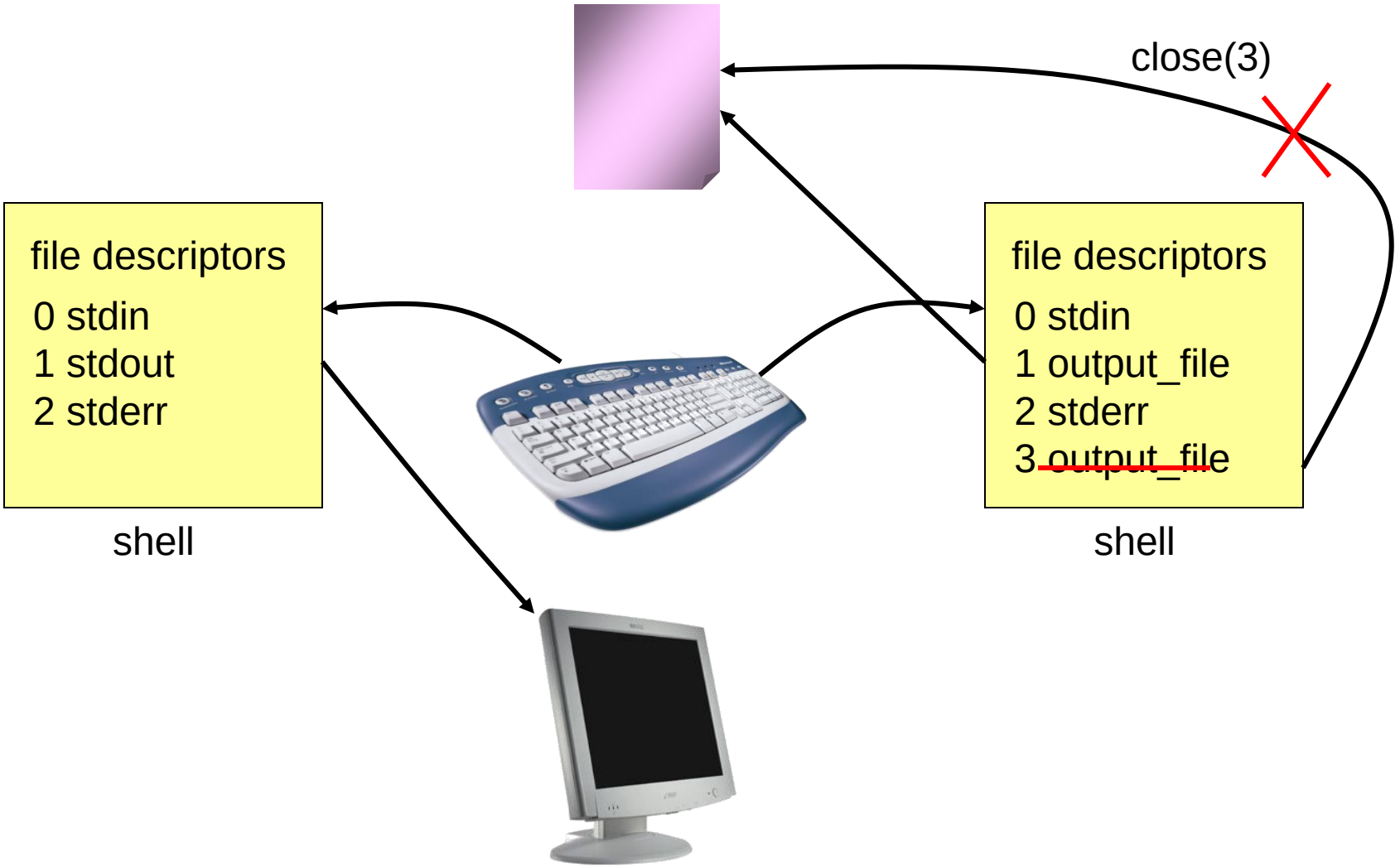

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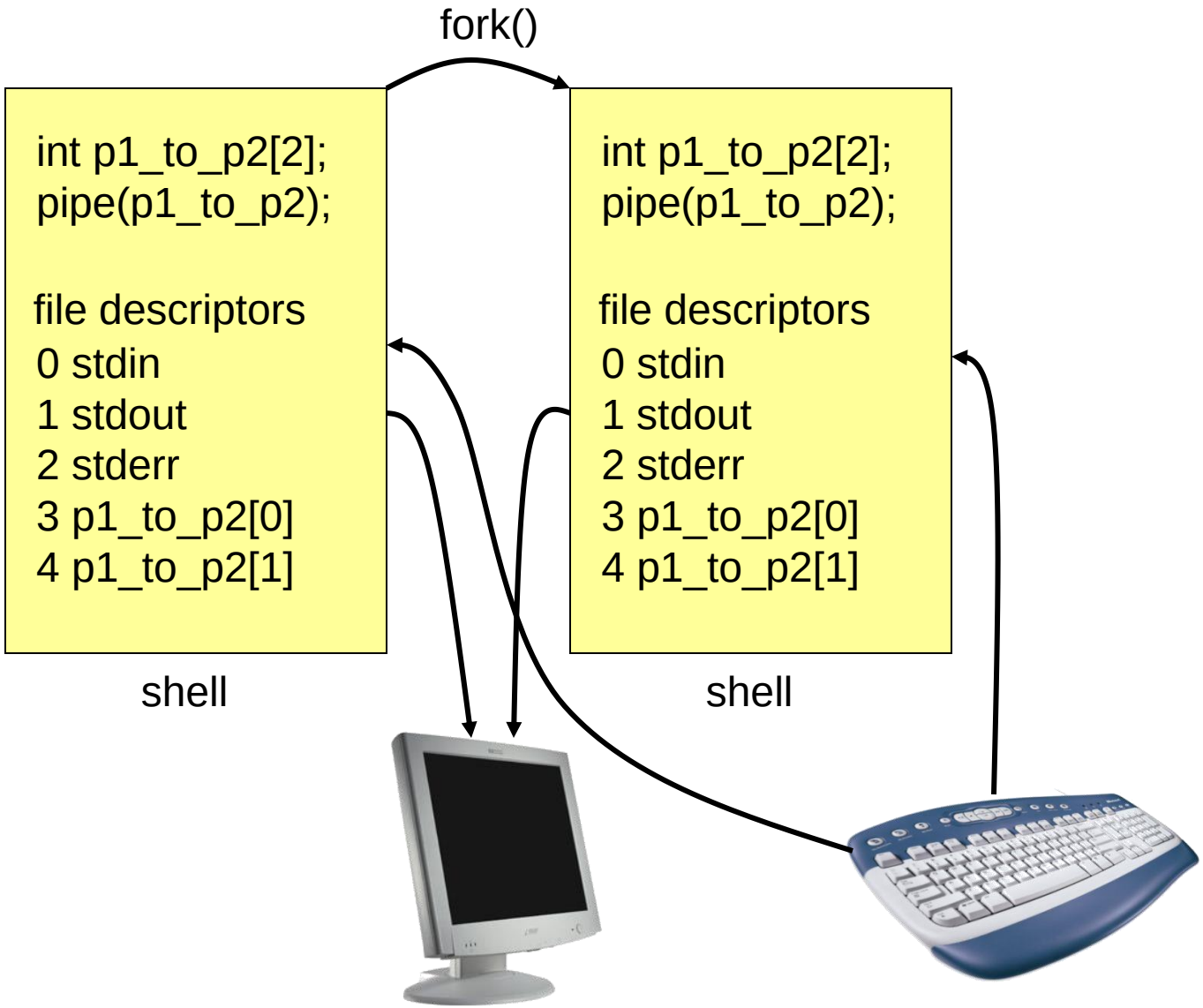
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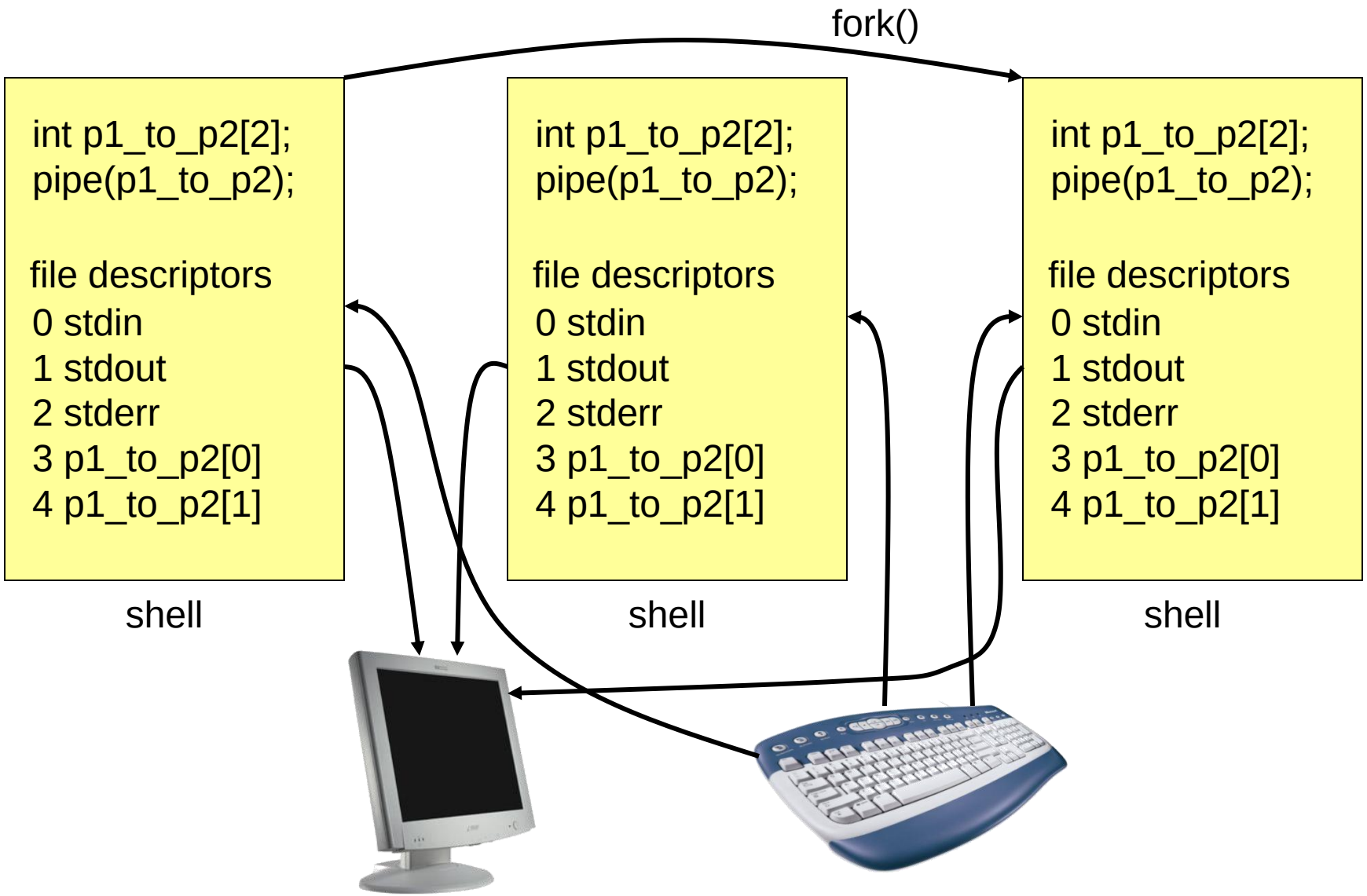
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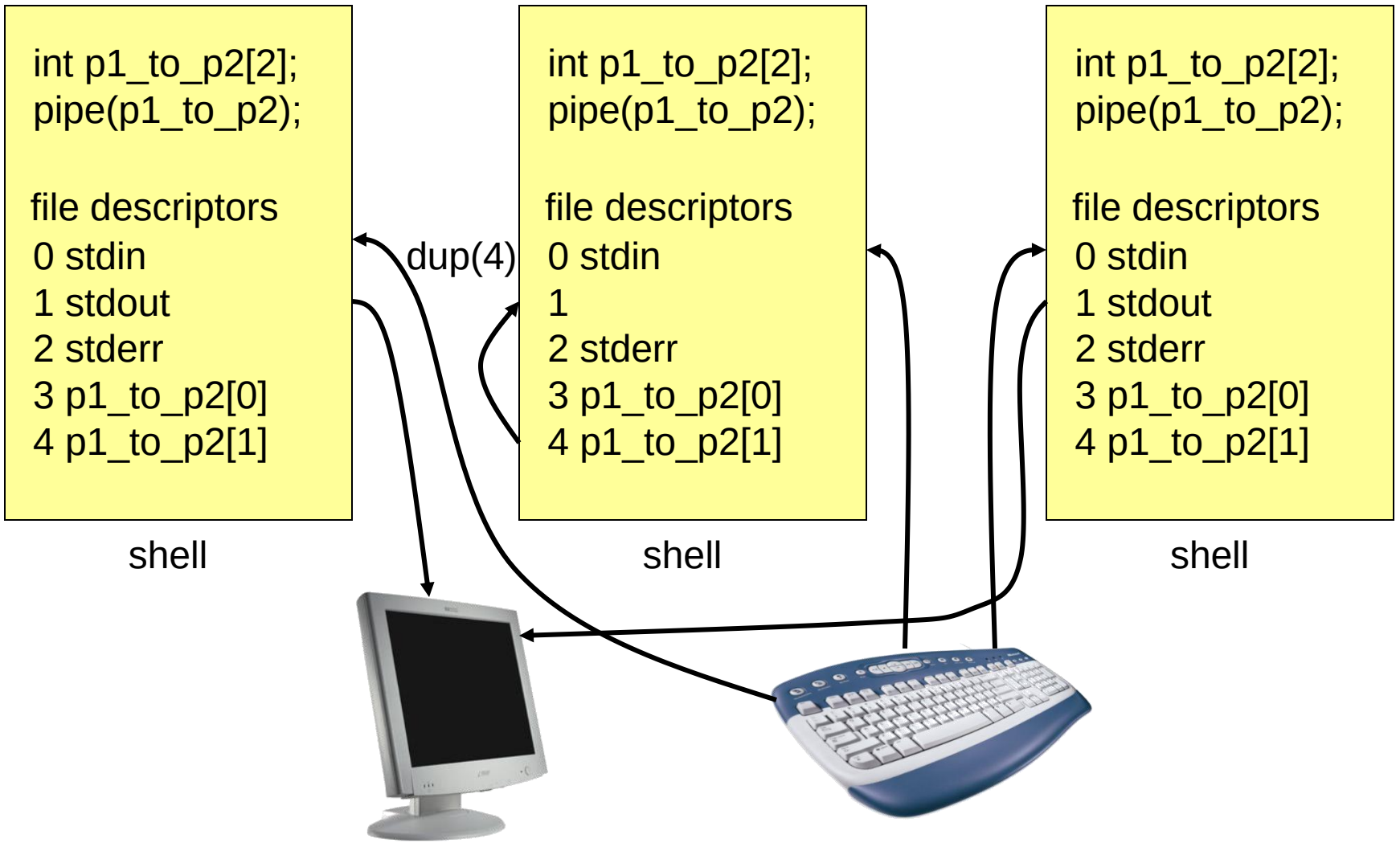
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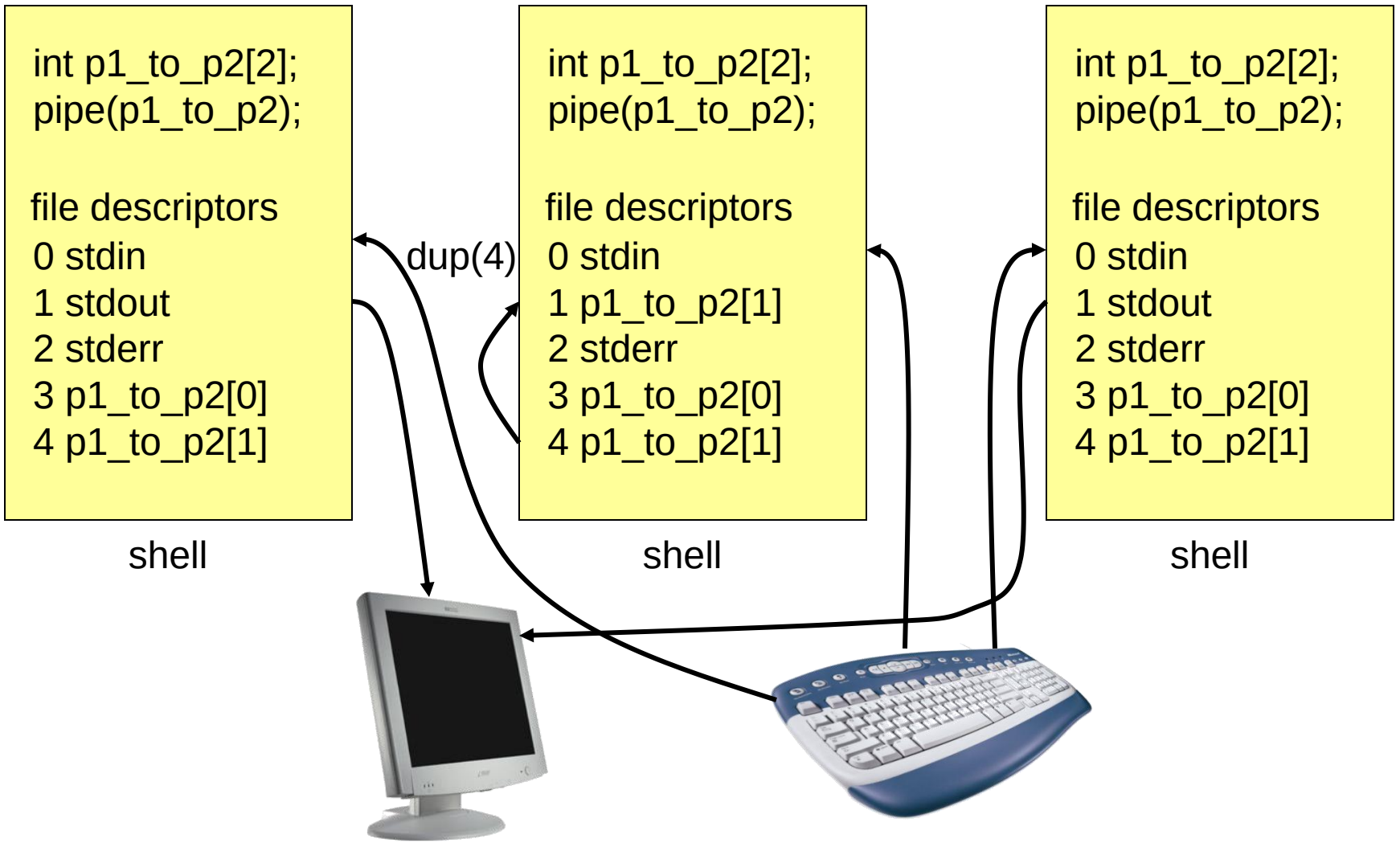
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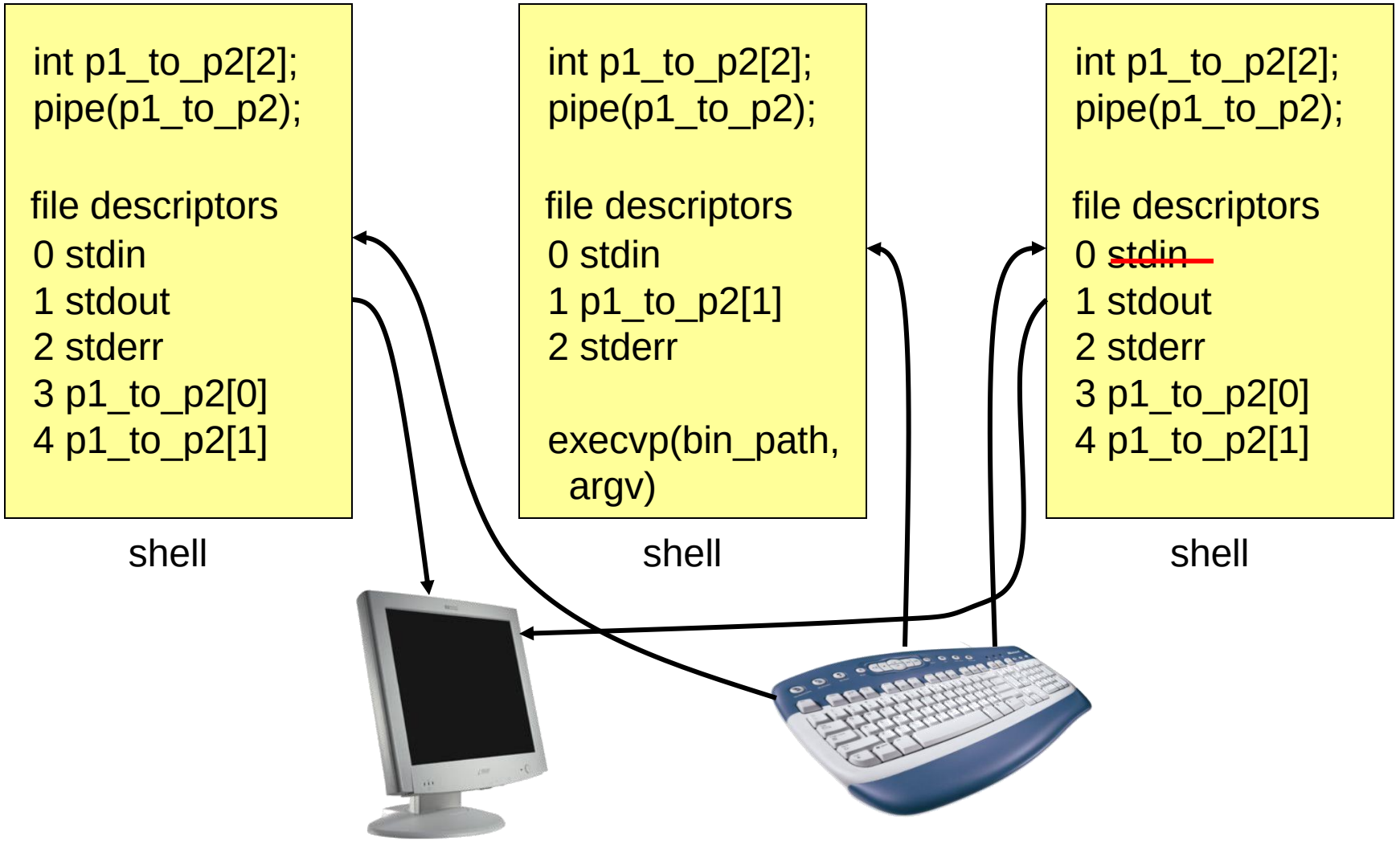
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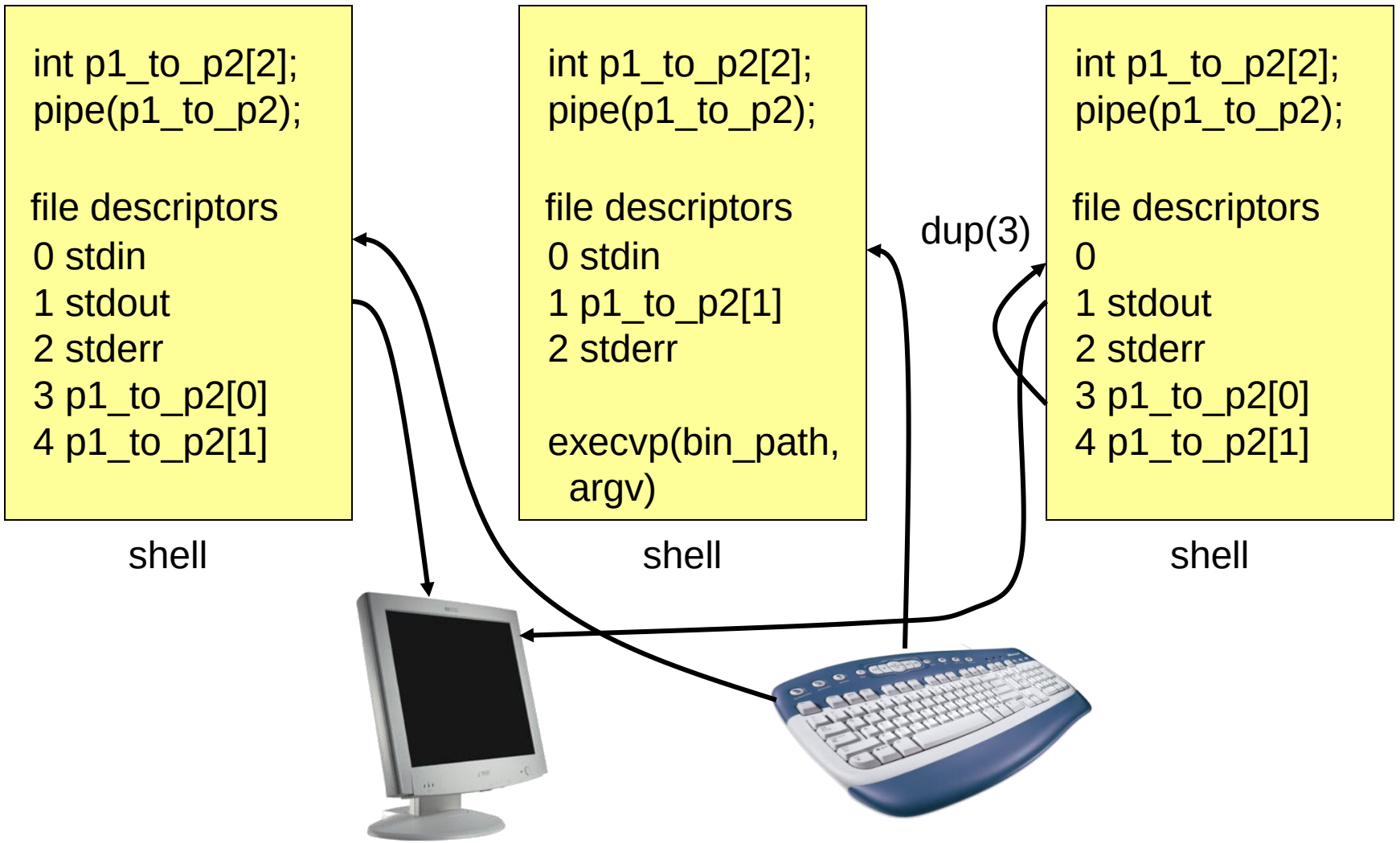
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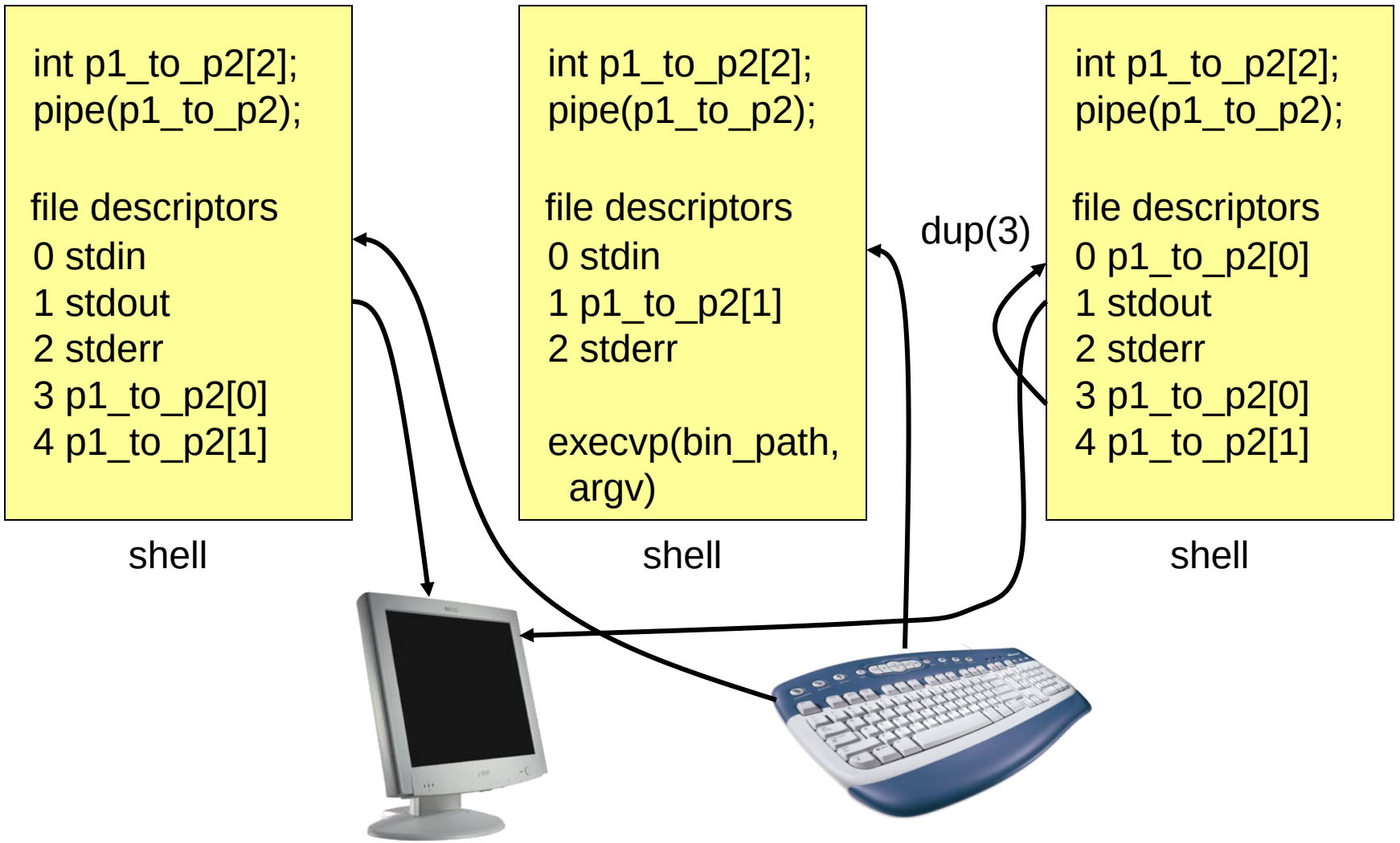
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Pipe

int p1_to_p2[2];
pipe(p1_to_p2);

file descriptors
0 stdin
1 stdout
2 stderr

waitpid(…)
waitpid(…)

shell

int p1_to_p2[2];
pipe(p1_to_p2);

file descriptors
0 stdin
1 p1_to_p2[1]
2 stderr

execvp(bin_path,
argv)

shell

int p1_to_p2[2];
pipe(p1_to_p2);

file descriptors
0 p1_to_p2[0]
1 stdout
2 stderr

execvp(bin_path,
argv)

shell

Takeaways

- Operating System Objects and APIs Used by a Fully Functional Shell
  - Session, Process Group, Controlling Terminal
  - File Descriptors: open, close, pipe, dup, read, write
  - State Machine Management: fork, execve, exit, wait, signal, kill, setpgid, getpgid, …
- As you dive deeper into the project, your sense of mystery around the operating system will gradually fade …