# Programing with Multiple Processes in C

fork, wait, execlp, WIFEXITED, WEXITSTATUS, file operations, and make

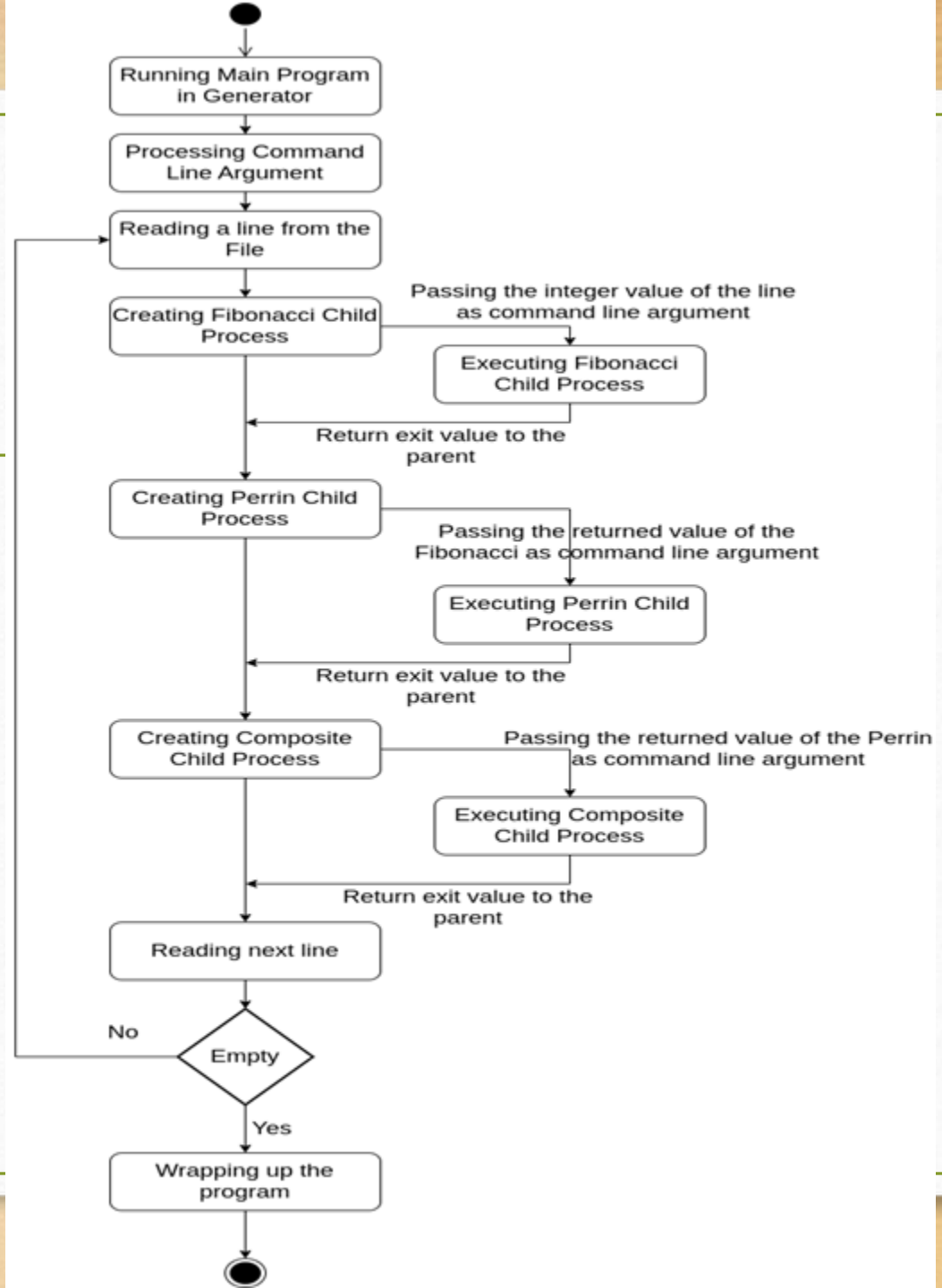
# Assignment Information

- Four executables will be needed
  - **Generator –** Main program, that opens, reads the characters and closes the file, forks child processes.
  - ***Generator.c, Fibonacci.c, Perrin.c and Composite.c.***

# Outline

- Learn how to use the following
  - Passing command line argument to Main Program
  - File Operation (fopen, perror, fgets, sizeof, strcspn, atoi)
  - Creating new child process (fork, perror)
  - Executing the program in the child process, passing argument as a command-line argument (execlp)
  - Waiting for the child process to terminate and  (wait)
  - Checking if the child process terminated normally (WIFEXITED)
  - Extracting the exit status of the child process (WEXITSTATUS)

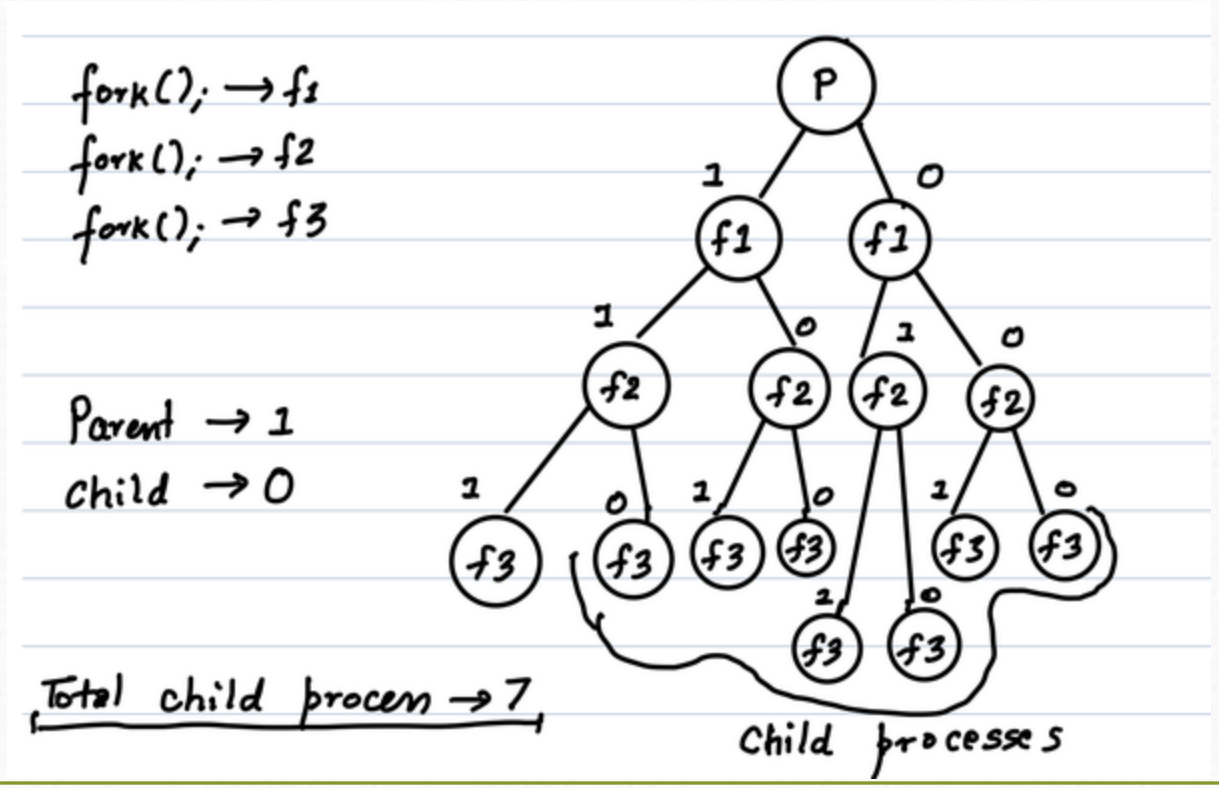
# Flowchart


Running Main Program in Generator
Processing Command Line Argument
Reading a line from the File
Creating Fibonacci Child Process
Passing the integer value of the line as command line argument
Executing Fibonacci Child Process
Return exit value to the parent
Creating Perrin Child Process
Passing the returned value of the Fibonacci as command line argument
Executing Perrin Child Process
Return exit value to the parent
Creating Composite Child Process
Passing the returned value of the Perrin as command line argument
Executing Composite Child Process
Return exit value to the parent
Reading next line
No
Empty
Yes
Wrapping up the program

# fork()

- Generates an exact copy of parent process except for the value it returns.
- Both Processes continue to work after the fork() execution.
- In a child process, fork() returns zero
- In the parent process it will return the child's process ID
- If return value is -1, then fork() failed.
- Any process can retrieve its process ID with getpid().
- Syntax:
  - pid_t pid=fork();

```
#include <stdio.h>
#include <sys/types.h>
#include <unistd.h>
int main() {
fork();
fork();
fork();
printf("hello\n");
return 0;
}
```



# wait()

- Makes parent process wait until the child has been entirely executed .
- Use WIFEXITED() to check whether child process has terminated normally, as opposed to dying with a signal .
- Use WEXITSTATUS() to retrieve return value of child process
- Syntax: pid_t wait(int *stat_loc);

# execlp()

- Executes a new program within a child process
- Arguments passed - the name of the executable and filename like "./Starter", ”Starter"
- Also pass any needed command line arguments as parameters
- Terminate list of arguments with NULL
- Syntax
  - *int execlp( const char * file, const char * arg0, const char * arg1, … const char * argn, NULL );*
  - *execlp(“./Fibonacci”, “Fibonacci”, arg_str, NULL);*

# File Operations

- We need several functions for this assignment.
- They are:
  - fopen()
  - fclose()
  - fgets() or fgetc()

# fopen()

- Used to open a file, whose name is given as the argument.
- It returns a pointer to the opened file.
- Syntax:
  - FILE * fp = fopen(const char *filename, const char *mode)

# fclose()

- Closes the stream to the file.
- Buffers are flushed.
- Syntax
  - int fclose(FILE *stream)

# fgets()

- Reads a line from a file
- Puts the line into the provided array/string
- Syntax:

```
int fgets(char *s, int size, FILE *stream)
```

- Use:

```
char buf[256];
while (fgets(buf, sizeof(buf), in)
        // deal with the string in buf
```

# Why use make?

- Enables developers to easily compile large and complex programs with many components.
- Situation: There are thousands of lines of code, distributed in multiple source files, written by many developers and arranged in several sub-directories. This project also contains several component divisions and these components may have complex inter-dependencies.

# Variable assignments in make

- By convention, predefined variable names used in a Makefile are in upper case, and user-defined variables are lower case.

  Example: CC = gcc

- We can use the value assigned later as $()

  Example: $(CC)

# Makefile Structure

- Makefile contains definitions and rules.
- A definition has the form:

  VAR = value

- A rule has the form:

  Output files: input files

  <tab>Commands to turn inputs to outputs

- All commands must be tab-indented.  Spaces don't work!
- The make <target> command executes the rule with the <target>. If target not is specified, it defaults to the first rule defined in the Makefile.

# Patterns and Special variables

- % : Wildcard pattern-matching, for generic targets.
- $@ : Full target name of the current target.
- $? : Returns the dependencies that are newer than the current target.
- $* : Returns the text that corresponds to % in the target.
- $< : Name of the first dependency.
- $^ : Name of the all dependencies with space as the delimiter.

# Demo Makefiles

```
CC = gcc
CFLAGS = -Wall -g

TARGETS = Driver Worker

all: $(TARGETS)

Driver: Driver.o
	$(CC) $(CFLAGS) -o Driver Driver.o

Worker: Worker.o
	$(CC) $(CFLAGS) -o Worker Worker.o

%.o: %.c
	$(CC) $(CFLAGS) -c $< -o $@

clean:
	rm -f *.o $(TARGETS)

run: Driver
	./Driver input.txt
```

***CC = gcc***

- This line defines a **variable** called `CC` that assigns `gcc` which represents C compiler

***CFLAGS = -Wall -g***

- This defines the compiler flags that will be passed to gcc during compilation.
  - `-Wall`: This enables all common compiler warnings
  - `-g`: This flag includes **debugging information** in the compiled binaries

***TARGETS = Driver Worker***

- This defines a variable `TARGETS`, which contains the **list of final executables** that the `Makefile` will produce: `Driver`, `Worker`.

***all: $(TARGETS)***

- This defines the **default target** (named `all`), which will be executed if no specific target is given when running `make`.

***Driver: Driver.o***

***$(CC) $(CFLAGS) -o Driver Driver.o***

- This rule defines how to build the `Driver` executable.
  - This is the command to **link** the `Driver.o` object file and produce the final `Driver` executable.
  - `$(CC)` is `gcc`, and `$(CFLAGS)` are the compiler flags (`-Wall -g`).
  - `-o Driver` specifies the output file, which will be named `Driver`.

# Demo Makefiles

```
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TARGETS = Driver Worker

all: $(TARGETS)

Driver: Driver.o
	$(CC) $(CFLAGS) -o Driver Driver.o

Worker: Worker.o
	$(CC) $(CFLAGS) -o Worker Worker.o

%.o: %.c
	$(CC) $(CFLAGS) -c $< -o $@

clean:
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run: Driver
	./Driver input.txt
```

***%.o: %.c***

- This is a **pattern rule** that defines how to compile any `.c` file into a `.o` (object) file.
- `%.o` and `%.c` are placeholders (wildcards), where `make` will substitute the `%` with the actual file name (e.g., `Driver.c` to `Driver.o`).
- This rule applies to all the `.c` files without having to explicitly list each file.

***$(CC) $(CFLAGS) -c $< -o $@***

- This is the command to compile a `.c` file into an object file.
- `$(CC)` is `gcc`, and `$(CFLAGS)` are the compiler flags.
- `-c` tells the compiler to **compile only** (i.e., generate an object file, not a full executable).
- `$<` represents the **first prerequisite** (in this case, the `.c` file being compiled).
- `$@` represents the **target** (in this case, the `.o` file being generated).

***clean:***

***rm -f *.o $(TARGETS)***

- This command removes all `.o` files and the target executables

***run: Driver***

- This rule defines a `run` target, which depends on the `Driver` executable.
- It will ensure that `Driver` is built before attempting to run it.

***./Driver input.txt***

- This is the command to **run the `Driver` program** with `input.txt` as the command-line argument.

# Demo Makefiles

```
CC = gcc
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TARGETS = Driver Worker

all: $(TARGETS)

Driver: Driver.o
	$(CC) $(CFLAGS) -o Driver Driver.o

Worker: Worker.o
	$(CC) $(CFLAGS) -o Worker Worker.o

%.o: %.c
	$(CC) $(CFLAGS) -c $< -o $@

clean:
	rm -f *.o $(TARGETS)

run: Driver
	./Driver input.txt
```

When you run `make`:

- `make` starts with the `all` target and builds the required executables (`Generator`, `Fibonacci`, `Perrin`, `Composite`).
- It checks the `.c` files for changes, compiles them into `.o` files, and then links them into executables.

To clean up the project:

- You can run `make clean`, which removes all the generated object files and executables.

To run the `Generator` program:

- You can use `make run`, which will build `Generator` if necessary, and then execute it with the argument `input.txt`.

# Thank You

# Acknowledgements


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