

**操作系统课程设计**

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| **实验二、进程控制** | **Experiment 2, Process Control** |

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# Purpose

Design and implement the "ParentProcess" command for Windows and Linux.

The "ParentProcess" command

* accepts a program to run via command-line arguments,
* creates a separate process to run the program, and
* records the time the program runs.

Implemented under Windows:

* Use CreateProcess() to create a process
* Use WaitForSingleObject() to synchronize between the "ParentProcess" command and the newly created process
* Call GetSystemTime() to get the time

Implemented under Linux:

* Use fork()/execv() to create a process runner
* Use wait() to wait for the newly created process to end
* Call gettimeofday() to get the time

Requirements:

* parent process:
  + Name: ParentProcess(.exe)
  + Function: Start ChildProcess(.exe)
  + Print the child process start time, end time, time-consuming, accurate to ms
* subprocess:
  + Name: ChildProcess(.exe)
  + Function: print: Hi, my name is + your name
  + Delay 3s

Usage of ParentProcess:

$ ParentProcess.exe ChildProcess

# Problem Discussion

We need to design and implement the “ParentProcess” command for Windows and Linux.

**What is a “parentprocess” command?**

The sequence of instructions and data that can be executed a single time, multiple times or concurrently are called programs. A process is the execution of such programs. A parent process is a process that has created one ore more child processes. A child process is a process created by another process (the parent process).

For this experiment the parent process would be parentprocess.exe and the child process would be childprocess.exe. These executable files can be created by compiling a parentprocess.c and childprocess.c source file respectively.

According to the experiment requirements, the parent process command must accept a program to run via command line arguments. This can be done by adding commands after the name of the program (the executable .exe file) in the command-line shell of the operating system. For example:

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| --- | --- |
| **IN LINUX** |  |
| $ nano parantprocess.c | //creates the source file |
| $ gcc parentprocess.c -o parentprocess | //compiles the source and creates an executable file called parentprocess.exe |
| $ ./parentprocess.exe childprocess | //runs the parentprocess program and passes the childprocess command as an argument to it |

**Accepting Command Line Arguments in C Programming**

In C programming, it is possible to accept command line arguments through the declaration of main().

Main() can accept two arguments.

1. the number of command line arguments.
2. a full list of all the command line arguments.

The full declaration of main looks like this:

|  |
| --- |
| int main (int argc, char \*argv[]) |

The Windows specific version looks like this: (The \_T (or \_t) convention is one Microsoft uses to allow building of Unicode and building non-Unicode (usually multi-byte character set) without needing to change source code.)

|  |
| --- |
| int \_tmain (int argc, \_TCHAR \*argv[]) |

The integer argc is the **arg**ument **c**ount, the number of arguments passed into the program from the command line, including the name of the program.

The array of character pointers is the list of all the arguments. Argv[0] is the name of the program, or an empty string if the name is not available. After that, every element number less than argc is a command line argument.

In the example given above:

|  |  |
| --- | --- |
| $ ./parentprocess.exe childprocess | //runs the parentprocess program and passes the childprocess command as an argument to it |

argc would be equal to 2, argv[0] would be ./parentprocess, and argv[1] would be childprocess

**Creating A Separate Process To Run the Program**

Creating a child process is different in Windows and Linux. Let’s examine how to execute the requirements of this experiment in both Windows and Linux.

# Execution [Windows]

**Step 1: Create the parentprocess.c program**

In the Developer Command Prompt for Visual Studio 2022 create a C file using Notepad with the name parentprocess.c by running the following command:

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| --- |
| > notepad parentprocess.c |

In the file, write the following code:

|  |
| --- |
| // parentprocess.c  #include <windows.h>  #include <stdio.h>  #include <tchar.h>  void \_tmain(int argc, TCHAR \*argv[])  {  SYSTEMTIME st, et; // pointer to a SYSTEMTIME structure to receive the current system date and time.  STARTUPINFO si;  PROCESS\_INFORMATION pi;  ZeroMemory(&si, sizeof(si));  si.cb = sizeof(si);  ZeroMemory(&pi, sizeof(pi));  if (argc != 2) /\* argc should be 2 for correct execution \*/  {  printf("Usage: %s [cmdline]\n", argv[0]);  return;  }  // Start the child process.  if (!CreateProcess(NULL, // No module name (use command line)  argv[1], // Command line  NULL, // Process handle not inheritable  NULL, // Thread handle not inheritable  FALSE, // Set handle inheritance to FALSE  0, // No creation flags  NULL, // Use parent's environment block  NULL, // Use parent's starting directory  &si, // Pointer to STARTUPINFO structure  &pi) // Pointer to PROCESS\_INFORMATION structure  )  {  printf("CreateProcess failed (%d).\n", GetLastError());  return;  }  GetSystemTime(&st);  printf("The child process start time is: %02dh:%02dm:%02ds.%02dms\n", st.wHour, st.wMinute, st.wSecond, st.wMilliseconds);  // Wait until child process exits.  WaitForSingleObject(pi.hProcess, INFINITE);    GetSystemTime(&et);  printf("The child process end time is: %02dh:%02dm:%02ds.%02dms\n", et.wHour, et.wMinute, et.wSecond, et.wMilliseconds);  printf("The child process elapsed time is: %02ds.%02dms\n", et.wSecond-st.wSecond, et.wMilliseconds-st.wMilliseconds);  // Close process and thread handles.  CloseHandle(pi.hProcess);  CloseHandle(pi.hThread);  } |

The header file windows.h is the base header file for Win32 programming. It contains declaration of all the functions in the Windows API, all common macros used by Windows programmers for example HANDLE, CreateProcess and more. The Win32 API can be added to a C programming project by including the <windows.h> header file.

Read more about tchar.h here: [Generic-Text Mappings in tchar.h | Microsoft Learn](https://learn.microsoft.com/en-us/cpp/text/generic-text-mappings-in-tchar-h?view=msvc-170)

The CreateProcess() function creates a new process, which runs independently of the creating process. However, for simplicity, the relationship is referred to as a parent-child relationship.

If CreateProcess succeeds, it returns a PROCESS\_INFORMATION structure containing handles and identifiers for the new process and its primary thread.

The CreateProcess function takes a pointer to a STARTUPINFO structure as one of its parameters. STARTUPINFO structure specifies the window station, desktop, standard handles, and appearance of the main window for a process at creation time.

The members of this structure are used to specify characteristics of the child process’s main window. For console processes, the STARTUPINFO structure is used to specify window properties only when creating a new console (either using CreateProcess with CREATE\_NEW\_CONSOLE or with the AllocConsole function). The STARTUPINFO structure can be used to specify the following console window properties:

* The size of the new console window, in character cells.
* The location of the new console window, in screen coordinates.
* The size, in character cells, of the new console's screen buffer.
* The text and background color attributes of the new console's screen buffer.
* The title of the new console's window.

Members of STARTUPINFO: [STARTUPINFOA (processthreadsapi.h) - Win32 apps | Microsoft Learn](https://learn.microsoft.com/en-us/windows/win32/api/processthreadsapi/ns-processthreadsapi-startupinfoa)

PROCESS\_INFORMATION structure contains information about a newly created process and its primary thread. Its members include hProcess, hThread, dwProcessId, dwThreadId

Note: A handle is, in essence, an abstract pointer, in the sense that a pointer is usually defined as 'a special variable which points to the memory address of a resource

ZeroMemory() is a macro that fills a block of memory with zeros. It’s parameters include *destination[in]*, a pointer to the starting address of the block of memory to fill with zeros and *length[in]* the size of the block of memory to fill with zeros in bytes. This macro has no return value.

The sizeof operator returns the number of bytes occupied by a variable of a given type.

cb is a member of STARTUPINFO and it is the size of the structure in bytes.

**Use WaitForSingleObject() To Synchronize Tetween the "ParentProcess" Command and the Newly Created Process**

WaitForSingleObject function waits until the specified object is in the signalled state or the time-out interval elapses. It accepts a handle to the object and the time-out interval in milliseconds. If a nonzero value is specified, the function waits until the object is signaled or the interval elapses. If dwMilliseconds is zero, the function does not enter a wait state if the object is not signaled; it always returns immediately. If dwMilliseconds is INFINITE, the function will return only when the object is signaled.

**Call GetSystemTime() to get the time**

GetSystemTime function retrieves the current system date and time in UTC format. The function accepts a pointer to a SYSTEMTIME structure to receive the current system date and time.

**Step 2: Create the childprocess.c program**

In the Developer Command Prompt for Visual Studio 2022 create a C file using Notepad with the name childprocess.c by running the following command:

|  |
| --- |
| > notepad childprocess.c |

In the file, write the following code:

|  |
| --- |
| // childprocess.c  #include <stdio.h>  #include <windows.h>  int main()  {  printf("Hello my name is Xiaqila\n");  printf("Delay 3s\n");  Sleep(3000);  return 0;  } |

Sleep() function suspends the execution of the current thread until the time-out interval elapses. It accepts the time interval for which execution is to be suspended in milliseconds.

**Step 2: Compile the C program**

Use the following command to make executable version of the two programs.

|  |
| --- |
| > cl parentprocess.c  > cl childprocess.c |

This will output parentprocess.exe and childprocess.exe

**Step 3: Run the program**

Use the following command to run the newly created executable .exe programs.

|  |
| --- |
| > parentprocess childprocess |

These parameters are passed to void \_tmain(int argc, TCHAR \*argv[])

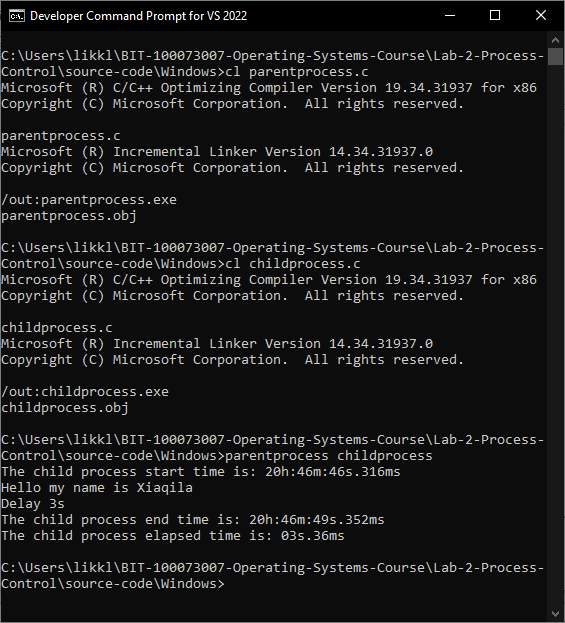
The following output is produced:

|  |
| --- |
| The child process start time is: 20h:46m:46s.316ms  Hello my name is Xiaqila  Delay 3s  The child process end time is: 20h:46m:49s.352ms  The child process elapsed time is: 03s.36ms |

## 

# Results Analysis [Windows]

Running parentprocess childprocess on the command line will start the parent process program. This program uses CreateProcess() to call the child process program which prints “Hello my name is Xiaqila” and sleeps for 3 seconds before returning. The parent process uses WaitForSingleObject() to wait for the child process to end. Once the child process is completed the parent process prints the child process end time and the child process elapsed time.



# Execution [Linux]

**fork()**

System call fork() is used to create processes. It takes no arguments and returns a process ID. The purpose of fork() is to create a new process, which becomes the child process of the caller. After a new child process is created, both processes will execute the next instruction following the fork() system call. Therefore, we have to distinguish the parent from the child. This can be done by testing the returned value of fork():

* If fork() returns a negative value, the creation of a child process was unsuccessful.
* fork() returns a zero to the newly created child process.
* fork() returns a positive value, the process ID of the child process, to the parent. The returned process ID is of type pid\_t defined in sys/types.h. Normally, the process ID is an integer. Moreover, a process can use function getpid() to retrieve the process ID assigned to this process.

Therefore, after the system call to fork(), a simple test can tell which process is the child. Unix will make an exact copy of the parent's address space and give it to the child. Therefore, the parent and child processes have separate address spaces.

**wait()**

The system call wait() is easy. This function blocks the calling process until one of its child processes exits or a signal is received. For our purpose, we shall ignore signals. wait() takes the address of an integer variable and returns the process ID of the completed process. Some flags that indicate the completion status of the child process are passed back with the integer pointer. One of the main purposes of wait() is to wait for completion of child processes.

The execution of wait() could have two possible situations.

If there are at least one child processes running when the call to wait() is made, the caller will be blocked until one of its child processes exits. At that moment, the caller resumes its execution.

If there is no child process running when the call to wait() is made, then this wait() has no effect at all. That is, it is as if no wait() is there.

**exec()**

The created child process does not have to run the same program as the parent process does. The exec type system calls allow a process to run any program files, which include a binary executable or a shell script. On this page, we only discuss one such system call: execvp(). The execvp() system call requires two arguments:

* The first argument is a character string that contains the name of a file to be executed.
* The second argument is a pointer to an array of character strings. More precisely, its type is char \*\*, which is exactly identical to the argv array used in the main program:

int main(int argc, char \*\*argv)

The first parameter, argc (argument count) is an integer that indicates how many arguments were entered on the command line when the program was started. The second parameter, argv (argument vector), is an array of pointers to arrays of character objects. The array objects are null-terminated strings, representing the arguments that were entered on the command line when the program was started.

The first element of the array, argv[0], is a pointer to the character array that contains the program name or invocation name of the program that is being run from the command line. argv[1] indicates the first argument passed to the program, argv[2] the second argument, and so on.

Note that this argument must be terminated by a zero.

When execvp() is executed, the program file given by the first argument will be loaded into the caller's address space and over-write the program there. Then, the second argument will be provided to the program and starts the execution. As a result, once the specified program file starts its execution, the original program in the caller's address space is gone and is replaced by the new program.

execvp() returns a negative value if the execution fails (e.g., the request file does not exist).

**gettimeofday()**

The gettimeofday() system function is defined in the sys/time.h header. It fills two structures with details about the current time of day:

int gettimeofday( struct timeval \*, struct tzp \*);

the *timeval* structure contains two members,

* tv\_sec: a *time\_t* value, the number of seconds elapsed since January 1, 1970.
* tv\_usec: a microsecond value, which the computer knows but isn’t included with the *time\_t* value

the *tzp* structure contains timezone information.

This will involve writing a C program and building an executable file to run in the terminal as the parent process

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| **实验内容 [Linux]** | Experiment Content [Linux] |
| 可以单次、多次或同时执行的指令和数据序列称为程序。进程是此类程序的执行。进程可以运行许多程序。在同一个进程中，操作系统可以加载不同的程序。像 fork()、exec()、wait() 这样的系统调用帮助我们运行进程。  **fork()**  系统调用 fork() 用于创建进程。它不接受任何参数并返回一个进程 ID。 fork() 的目的是创建一个新进程，该进程成为调用者的子进程。创建新的子进程后，两个进程都将执行 fork() 系统调用之后的下一条指令。因此，我们必须区分父母和孩子。这可以通过测试 fork() 的返回值来完成：   * 如果fork() 返回负值，则子进程的创建不成功。 * fork() 向新创建的子进程返回零。 * fork() 向父进程返回一个正值，即子进程的进程ID。返回的进程 ID 是 sys/types.h 中定义的 pid\_t 类型。通常，进程 ID 是一个整数。此外，进程可以使用函数 getpid() 来检索分配给该进程的进程 ID。   因此，在系统调用 fork() 之后，一个简单的测试就可以知道哪个进程是子进程。 Unix 将制作父地址空间的精确副本并将其提供给子。因此，父进程和子进程具有独立的地址空间。  **wait()**  系统调用 wait() 很简单。 此函数阻塞调用进程，直到其子进程之一退出或收到信号。 为了我们的目的，我们将忽略信号。 wait() 获取一个整数变量的地址并返回已完成进程的进程 ID。 一些指示子进程完成状态的标志用整数指针传回。 wait() 的主要目的之一是等待子进程完成。  wait() 的执行可能有两种可能的情况。  如果在调用 wait() 时至少有一个子进程在运行，则调用者将被阻塞，直到其子进程之一退出。 在那一刻，调用者恢复执行。  如果调用 wait() 时没有子进程在运行，那么这个 wait() 根本没有任何作用。 也就是说，好像没有 wait() 存在。  **exec()**  创建的子进程不必运行与父进程相同的程序。 exec 类型的系统调用允许进程运行任何程序文件，包括二进制可执行文件或 shell 脚本。在这个页面上，我们只讨论一个这样的系统调用：execvp()。 execvp() 系统调用需要两个参数：  • 第一个参数是一个字符串，其中包含要执行的文件的名称。  • 第二个参数是一个指向字符串数组的指针。更准确地说，它的类型是 char \*\*，与主程序中使用的 argv 数组完全相同：  int main(int argc, char \*\*argv)  第一个参数 argc（参数计数）是一个整数，表示程序启动时在命令行中输入了多少参数。第二个参数 argv（参数向量）是一个指向字符对象数组的指针数组。数组对象是以 null 结尾的字符串，表示程序启动时在命令行中输入的参数。  数组的第一个元素 argv[0] 是指向字符数组的指针，该数组包含从命令行运行的程序的程序名称或调用名称。 argv[1] 表示传递给程序的第一个参数，argv[2] 表示第二个参数，依此类推。  请注意，此参数必须以零结尾。  当执行 execvp() 时，第一个参数给出的程序文件将被加载到调用者的地址空间并覆盖那里的程序。然后，第二个参数将提供给程序并开始执行。结果，一旦指定的程序文件开始执行，调用者地址空间中的原始程序就消失了，并被新程序替换。  如果执行失败（例如，请求文件不存在），则 execvp() 返回负值。  **gettimeofday()**  gettimeofday() 系统函数在 sys/time.h 头文件中定义。 它用关于当前时间的详细信息填充两个结构：  int gettimeofday(struct timeval \*, struct tzp \*);  timeval 结构包含两个成员，  • tv\_sec：time\_t 值，自 1970 年 1 月 1 日以来经过的秒数。  • tv\_usec：一个微秒值，计算机知道但不包含在 time\_t 值中  tzp 结构包含时区信息。  这将涉及编写 C 程序并构建可执行文件以在终端中作为父进程运行 |  |

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| **实验环境 [Linux]** | Experiment **Environment [Linux]** |
| 确保已安装 GCC 以编译 C 程序 | Ensure GCC is installed to compile the C program |

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| **操作方法和实验步骤**  **(程序设计与实现) [Linux]** | **Operating Methods and Experimental Steps**  **(Program design and Implementation) [Linux]** |
| **第 1 步：创建 C 程序**  在终端中，通过运行以下命令，使用 nano 编辑器创建一个名为 parenprocess.c 的文件：  $ nano parentprocess.c  在该文件中，我们编写以下代码：  **关于代码：**  在这个节目中，我们  • 声明结构timeval start end 以捕获从gettimeofday() 返回的值。  • 将字符cmd 声明为“ls”作为运行int execvp(const char \*file, char \*const) 时要执行的文件。  • 声明在sys/types.h 中定义的pid\_t 类型的进程ID，以捕获我们运行fork() 时返回的进程ID。  • 运行fork() 创建一个子进程，它是父进程的精确副本。 我们进行一个简单的测试来判断哪个进程是子进程。  • 如果fork() 返回0，则执行子进程。我们通过调用 gettimeofday() 来捕获进程的开始时间。该过程打印我的名字并包含一个 execvp() 函数。 execvp() 函数将指向 cmd=”ls” 执行。 $ls 是 Linux 中最常用的命令之一。它用于列出当前目录中的文件和子目录。 $ls -l 用于显示所有详细信息以及文件名，例如大小、修改日期等...” execvp() 第二个参数接受从 int main(int argc, char \*argv[])。  • 如果fork() 返回的值大于0，则父进程继续，然后在调用wait(NULL) 时等待子进程完成。  • Wc 捕获父进程正在等待的子进程的进程ID。  • 当子进程完成时，我们使用gettimeofday() 来捕获子进程的结束时间。然后父进程打印子进程的开始时间、结束时间和经过时间。  通过点击退出纳米编辑器  CTRL + X  Y (YES)  Enter  CTRL + X  这将我们返回到终端  **第二步：用 gcc 编译器编译 C 程序**  我们使用以下命令来制作我们刚刚编写的程序的可执行 (.exe) 版本：  $ gcc parentprocess.c -o parentprocess  **第三步：运行程序**  我们使用下面的命令来运行程序并将“-l”参数传递给  int main (int argc, char \*argv[])  $ ./parentprocess -l | **Step 1: Create C program**  In the terminal, create a file using the nano editor with the name parenprocess.c by running the following command:  $ nano parentprocess.c  In the file we write the following code:    **About the code:**  In this program, we   * declare structs timeval start end to capture the value returned from gettimeofday(). * declare character cmd as “ls” as the file to be executed when int execvp(const char \*file, char \*const) is run. * Declare process ID of type pid\_t defined in sys/types.h to capture the process id returned when we run fork(). * Running fork() creates a child process which is the exact copy of the parent process. We conduct a simple test to tell which process is the child. * If fork() returns 0, the child process is executed. We capture the start time of the process by calling gettimeofday(). The process prints my name and includes an execvp() function. The execvp() function will point to cmd=”ls” for execution. $ls is one of the most frequently used commands in Linux. It is used to list down the files and sub-directories within the current directory. *$ls -l* is usedto display all the details along with the file names such as size, date modified, etc...” execvp() second argument accepts argv which was input from the command line at *int main(int argc, char \*argv[]).* * If fork() returns a value greater than 0, the parent process continues then waits for the child process to finish when wait(NULL) is called. * *Wc* captures the process ID of the child process the parent process is waiting for. * When the child process is complete we use gettimeofday() to capture the end time of the child process. The parent process then prints the start time, end time and elapsed time of the child process.   Exit the nano editor by hitting  CTRL + X  Y (YES)  Enter  CTRL + X  This returns us to the terminal  **Step 2: Compile the C program with gcc compiler**  We use the following command to make an executable (.exe) version of the program we just wrote:  $ gcc parentprocess.c -o parentprocess  **Step 3: Run the program**  We use the following command to run the program and pass the “-l” parameter to  int main (int argc, char \*argv[])  $ ./parentprocess -l |

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| **实验结果和分析 [Linux]** | **Experimental Results and Analysis [Linux]** |
| 运行 parentprocess(.exe) -l 将启动父进程程序。 该程序调用子进程，该子进程本质上是在命令行上执行“ls -l”。 这将返回当前目录中的文件和文件夹列表。 子进程完成后，父进程将打印子进程的开始时间、结束时间和经过时间。 | Running parentprocess(.exe) -l will start the parent process program. This program calls the child process which essentially executes “ls -l” on the command line. This will return a list of files and folders in the current directory. Once the child process is completed the parent process will print the start time, end time and elapsed time of the child process. |

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| **讨论、心得 [Linux]** | **Discussion and experience [Linux]** |
| 做这个实验真的很有见地。 它涉及组合不同的函数 fork、exec()、wait() gettimeofday() 以产生所需的输出。 我阅读了很多文章以了解我在下面引用的最佳方法。 | Doing this experiment was really insightful. It involved combining different functions fork, exec(), wait() gettimeofday() to produce the required output. I read quite a few articles to understand the best approach which I reference below. |

# Execution [Windows]

Set up Windows environment for compiling C program by following the steps listed here: [Walkthrough: Compile a C program on the command line | Microsoft Learn](https://learn.microsoft.com/en-us/cpp/build/walkthrough-compile-a-c-program-on-the-command-line?view=msvc-170).

# Environment [Windows]

Using the Developer Command Prompt for Visual Studio 2022 which includes a C compiler.

# Execution [Windows]

Reference:

* https://www.csl.mtu.edu/cs4411.ck/www/NOTES/process/fork/create.html
* <https://www.csl.mtu.edu/cs4411.ck/www/NOTES/process/fork/wait.html>
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