Operating System
Hanging/Freezing Problem

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CS 646. Fall-2021

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Outline

INTRODUCTION

PROBLEM DEFINITION AND EXAMPLES

MAJOR REASONS

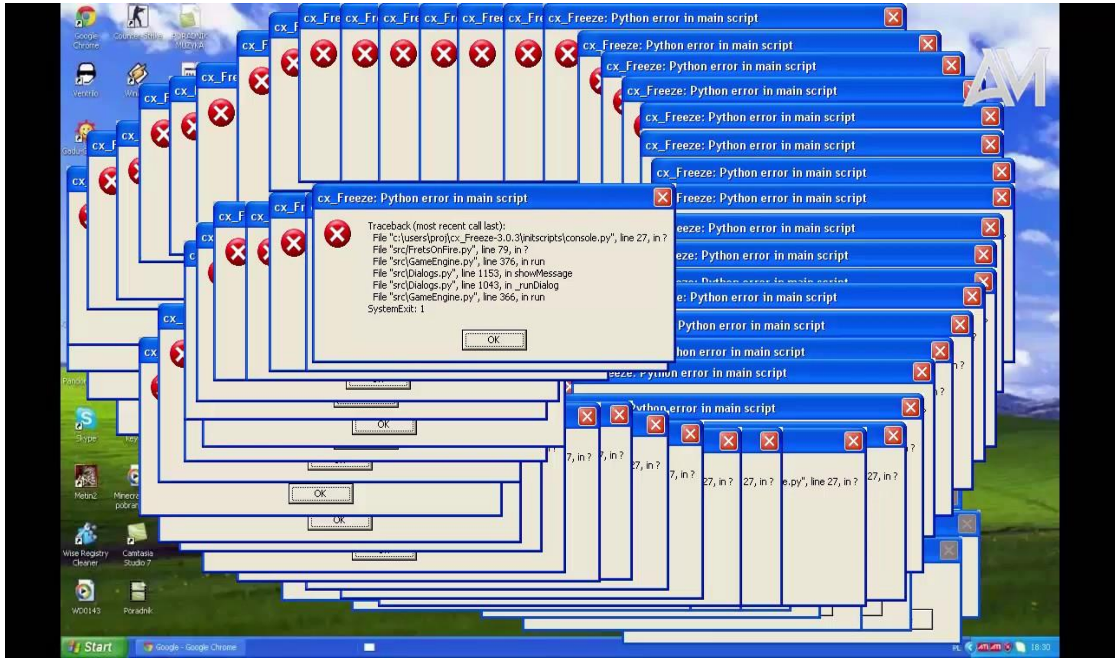
SOLUTIONS

CONCLUSION

Introduction

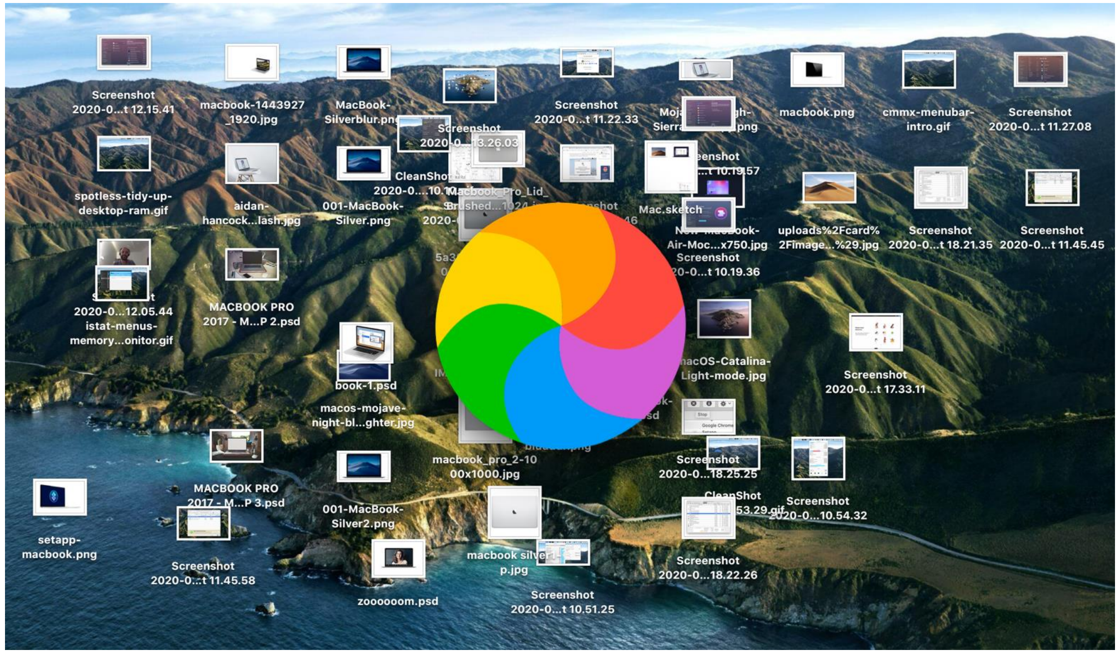
- The operating System (OS), and its applications may hang/freeze during
  - boot time
  - startup time
  - run time of a program

  regardless of the manufacturer
- Application hang
  - single program unresponsiveness

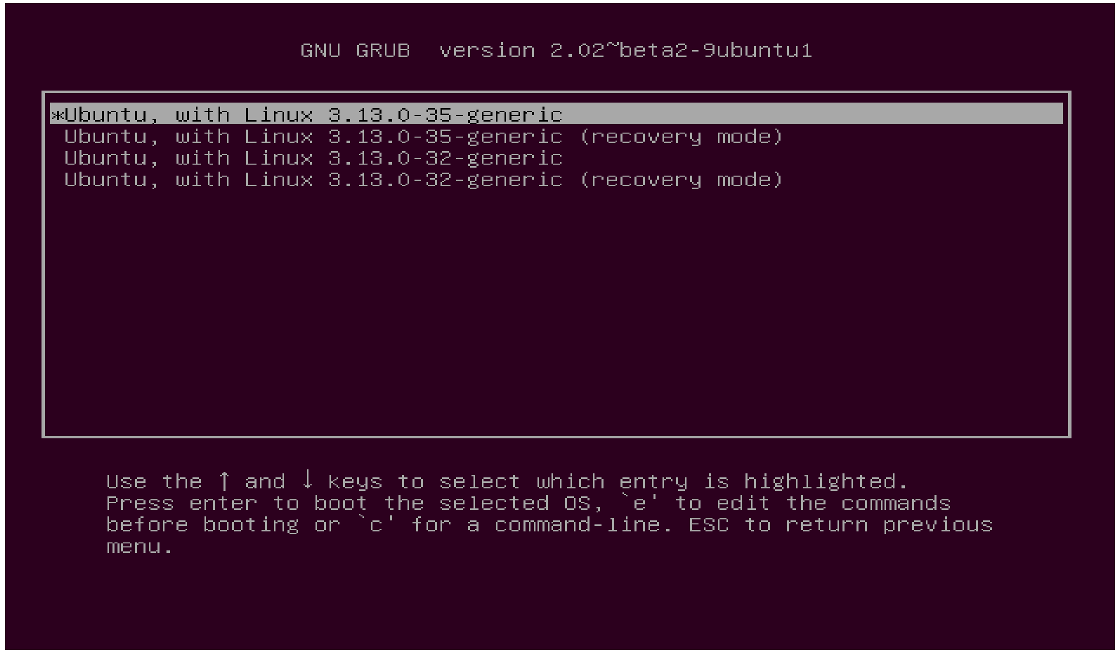


cx_Freeze: Python error in main script

```
Traceback (most recent call last):
  File "c:\users\proj\cx_Freeze-3.0.3\initscripts\console.py", line 27, in ?
  File "src/FretsOnFire.py", line 79, in ?
  File "src\GameEngine.py", line 376, in run
  File "src\Dialogs.py", line 1153, in showMessage
  File "src\Dialogs.py", line 1043, in _runDialog
  File "src\GameEngine.py", line 366, in run
SystemExit: 1
```



Screenshot 2020-0...t 12.15.41
macbook-1443927 1920.jpg
MacBook-Silverblur.png
Screenshot 2020-0...t 11.22.33
macbook.png
cmmx-menubar-intro.gif
Screenshot 2020-0...t 11.27.08
spotless-tidy-up-desktop-ram.gif
aidan-hancock...lash.jpg
001-MacBook-Silver.png
CleanShot
Mac.sketch
uploads%2Fcard%2Fimage...%29.jpg
Screenshot 2020-0...t 18.21.35
Screenshot 2020-0...t 11.45.45
2020-0...12.05.44
istat-menus-memory...onitor.gif
MACBOOK PRO 2017 - M...P 2.psd
book-1.psd
macos-mojave-night-bl...ghter.jpg
macOS-Catalina-Light-mode.jpg
Screenshot 2020-0...t 17.33.11
macbook_pro_2-10 00x1000.jpg
Screenshot 2020-0...18.25.25
MACBOOK PRO 2017 - M...P 3.psd
001-MacBook-Silver2.png
setapp-macbook.png
Screenshot 2020-0...t 11.45.58
zoooooom.psd
macbook silver p.jpg
Screenshot 2020-0...t 10.51.25
Screenshot 2020-0...18.22.26
Screenshot 2020-0...10.54.32



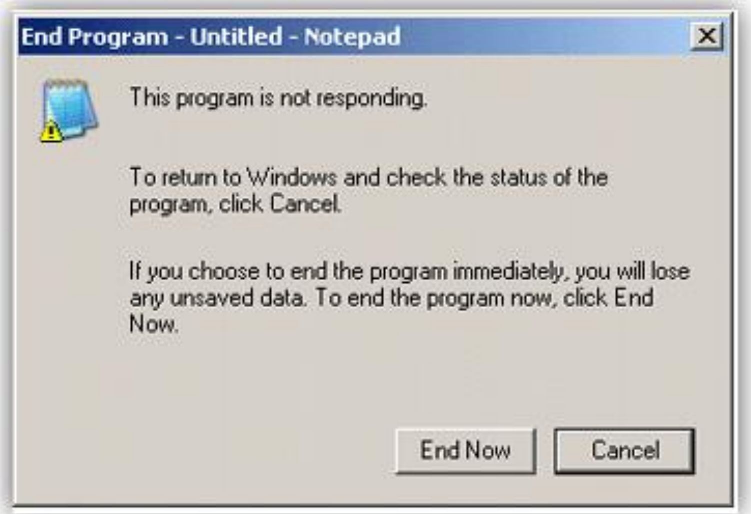
```
GNU GRUB  version 2.02~beta2-9ubuntu1

*Ubuntu, with Linux 3.13.0-35-generic
 Ubuntu, with Linux 3.13.0-35-generic (recovery mode)
 Ubuntu, with Linux 3.13.0-32-generic
 Ubuntu, with Linux 3.13.0-32-generic (recovery mode)

   Use the ↑ and ↓ keys to select which entry is highlighted.
   Press enter to boot the selected OS, `e' to edit the commands
   before booting or `c' for a command-line. ESC to return previous
   menu.
```

What is Unresponsiveness/ hanging/freezing?

- A hang or freeze is an incident when either a process or system ceases to respond to inputs
- Example: The GUI of the MS Windows no longer responds to the user typing on the keyboard or moving the mouse
- It may be temporary (if caused by a condition that resolve itself, e.g., slow HW)
- It may also be permanent and need manual intervention (e.g., HW or SW logic error)

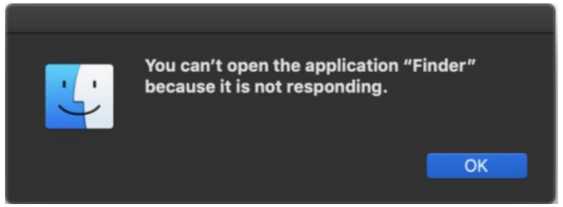


End Program - Untitled - Notepad

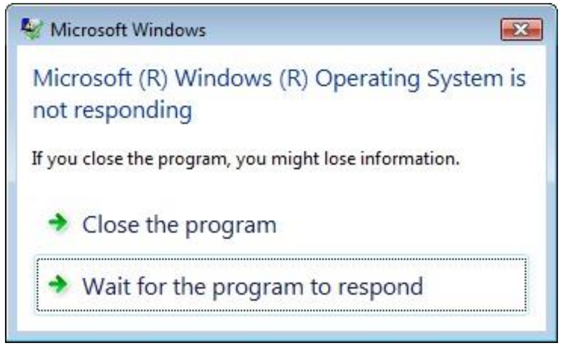
This program is not responding.

To return to Windows and check the status of the program, click Cancel.

If you choose to end the program immediately, you will lose any unsaved data. To end the program now, click End Now.



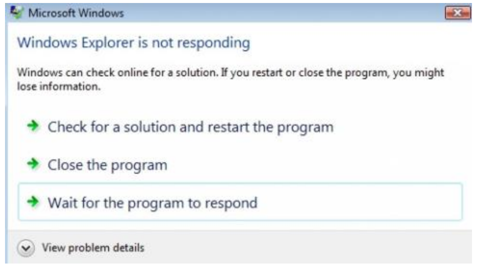
You can't open the application "Finder" because it is not responding.



Microsoft Windows

Microsoft (R) Windows (R) Operating System is not responding

If you close the program, you might lose information.

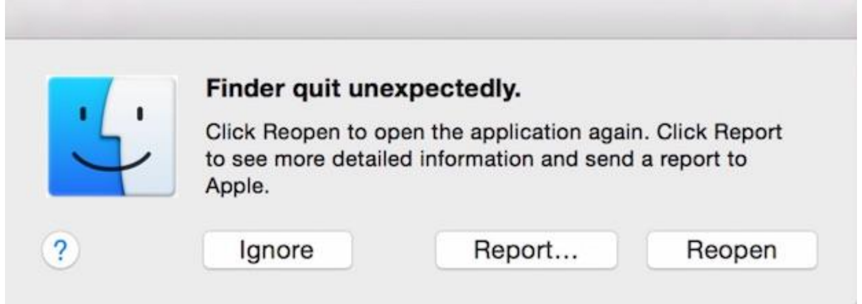


Microsoft Windows

Windows Explorer is not responding

Windows can check online for a solution. If you restart or close the program, you might lose information.

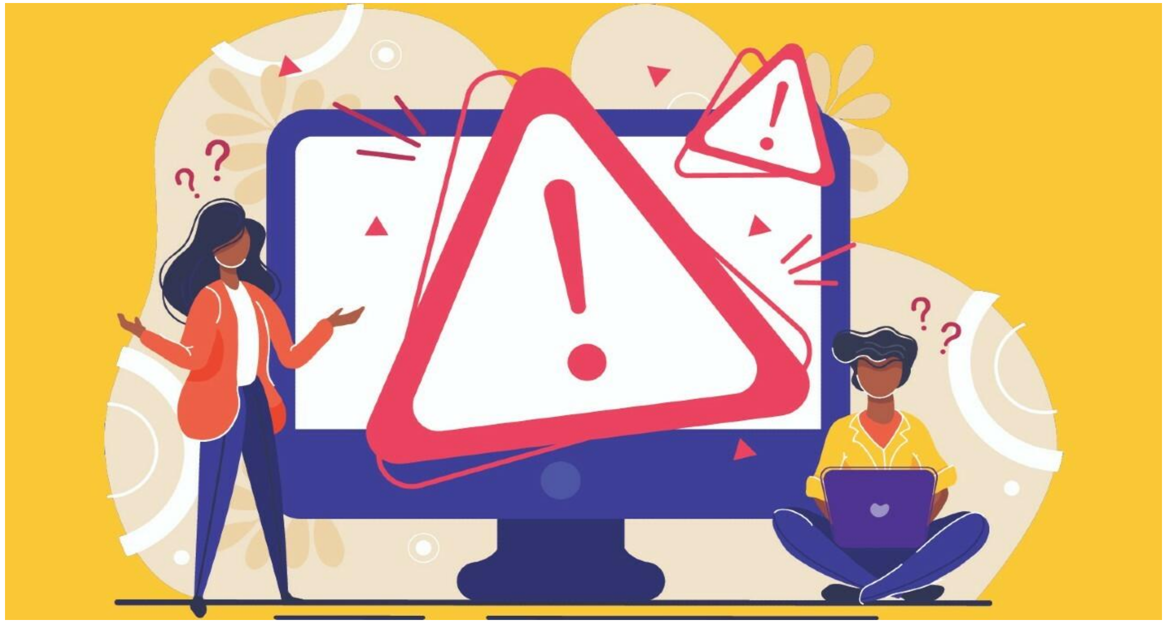
Check for a solution and restart the program
Close the program
Wait for the program to respond
View problem details



Finder quit unexpectedly.

Click Reopen to open the application again. Click Report to see more detailed information and send a report to Apple.

Major Causes



Software defects

- Infinite loop
- Long-running uninterruptible computation
- Race condition between processes (deadlock event)
- Misconfiguration
- Driver issues

Hardware defects

- Resource exhaustion (thrashing)
- Under-performing hardware (throttling)
- External events (slow network)
- Compatibility problems

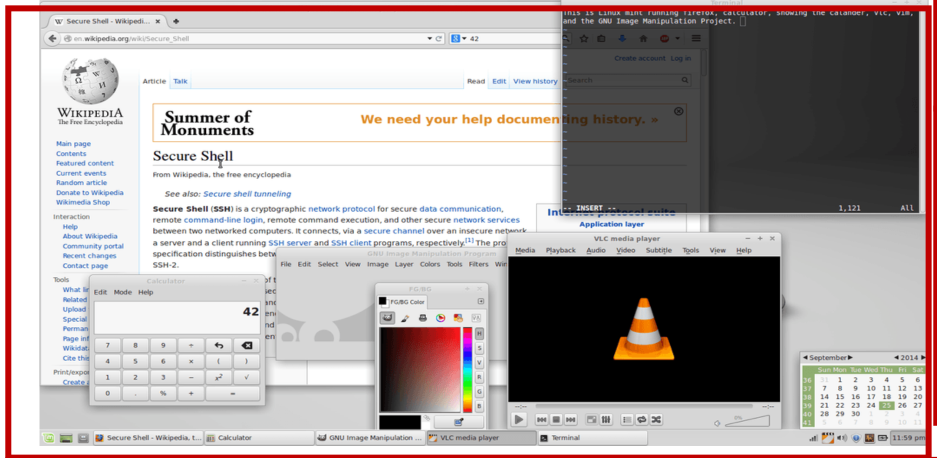
Memory fragmentation

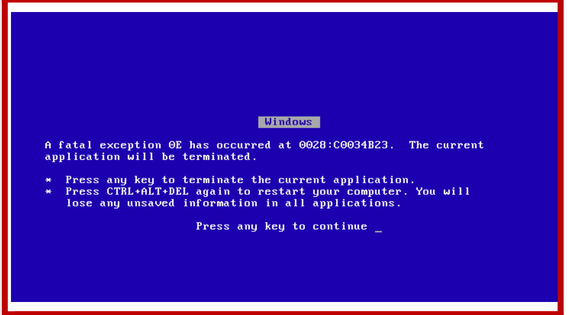
Slow system APIs

Spyware

Major Causes (cont'd)

- HW misconfiguration
- External devices
- Hard drive malfunction
- Too many apps running
- Driver issues
- Insufficient RAM
- BIOS Setting
- OS issues



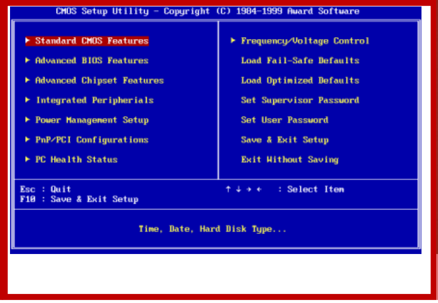


```
                         Windows

A fatal exception 0E has occurred at 0028:C0034B23.  The current
application will be terminated.

*  Press any key to terminate the current application.
*  Press CTRL+ALT+DEL again to restart your computer. You will
   lose any unsaved information in all applications.

                  Press any key to continue _
```

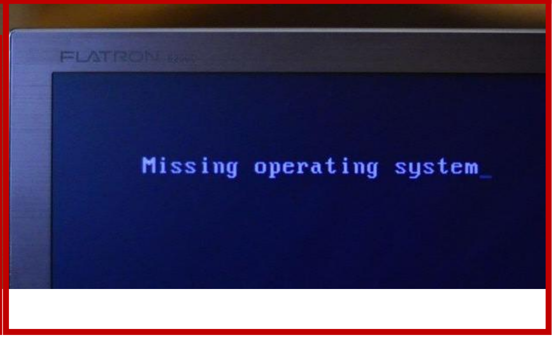


```
       CMOS Setup Utility - Copyright (C) 1984-1999 Award Software

 ▶ Standard CMOS Features        ▶ Frequency/Voltage Control
 ▶ Advanced BIOS Features           Load Fail-Safe Defaults
 ▶ Advanced Chipset Features        Load Optimized Defaults
 ▶ Integrated Peripherals           Set Supervisor Password
 ▶ Power Management Setup           Set User Password
 ▶ PnP/PCI Configurations           Save & Exit Setup
 ▶ PC Health Status                 Exit Without Saving

Esc : Quit                      ↑ ↓ → ←   : Select Item
F10 : Save & Exit Setup

                    Time, Date, Hard Disk Type...
```

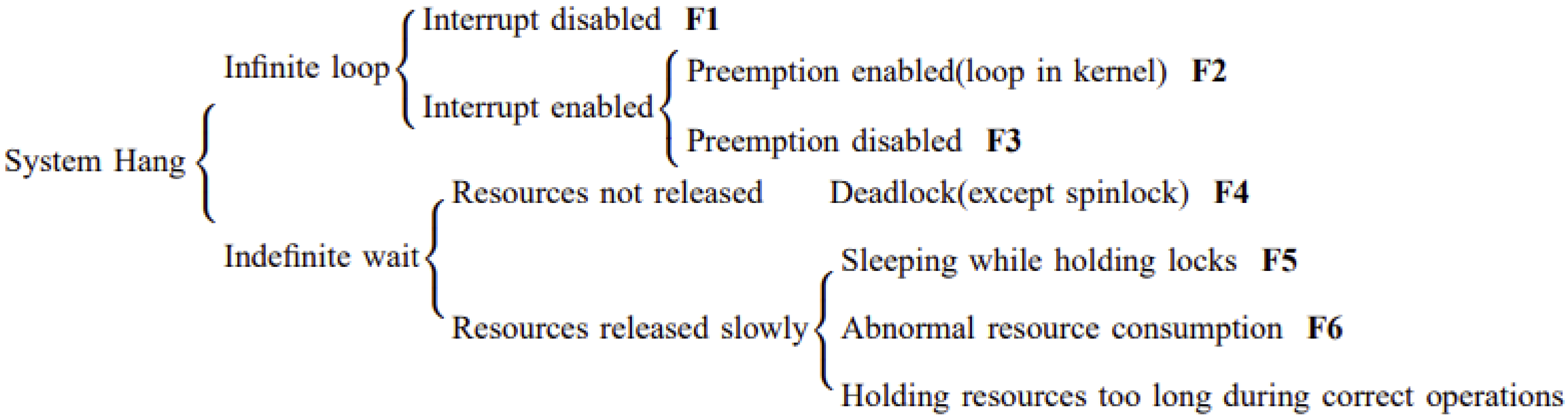


```
Missing operating system_
```

Related Work

What is System Hang and How to Handle it

Zhu, Yian, et al. "**What is system hang and how to handle it.**" *2012 IEEE 23rd International Symposium on Software Reliability Engineering*. IEEE, 2012.



- System Hang
  - Infinite loop
    - Interrupt disabled **F1**
    - Interrupt enabled
      - Preemption enabled(loop in kernel) **F2**
      - Preemption disabled **F3**
  - Indefinite wait
    - Resources not released
      - Deadlock(except spinlock) **F4**
    - Resources released slowly
      - Sleeping while holding locks **F5**
      - Abnormal resource consumption **F6**
      - Holding resources too long during correct operations

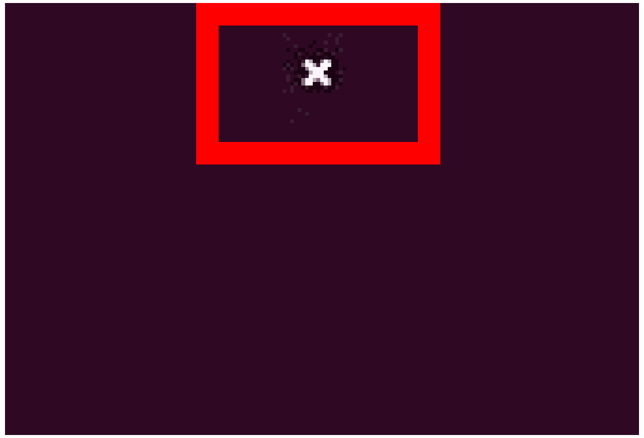
Figure 1. Categories of system hang causes (**F:Fault** in abbreviation)

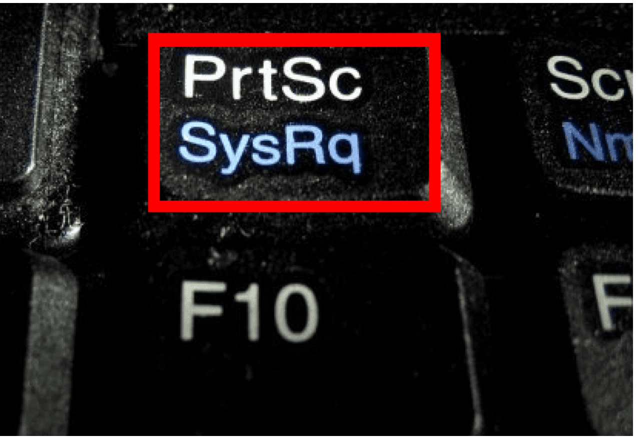
Image source: [1]

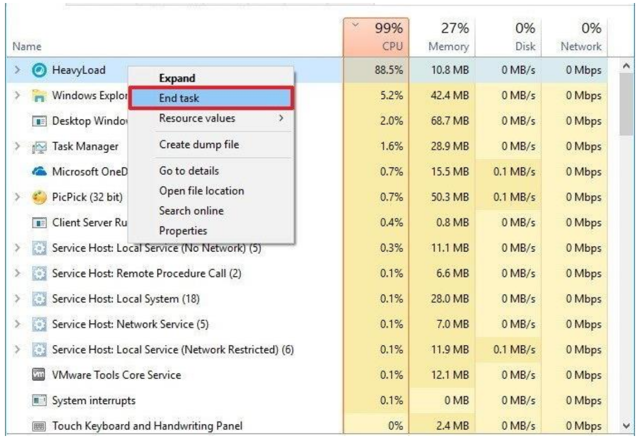
Solution

Temporary Solutions

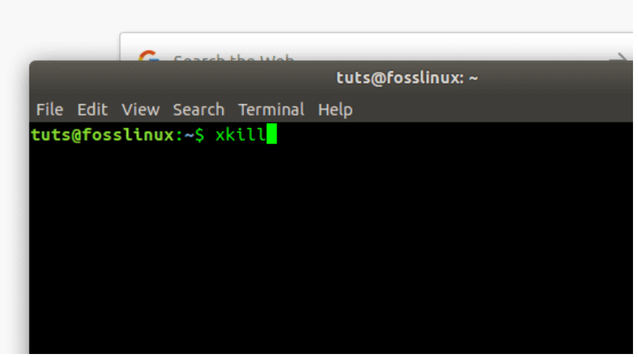
- Wait
- Try closing applications
  - Task Manager (Windows)
  - Force Quit (Mac)
  - xkill command (Linux)
- Reboot
- Call IT



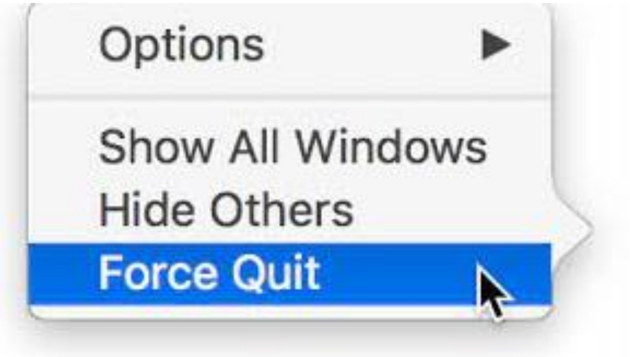




Name	99% CPU	27% Memory	0% Disk	0% Network
HeavyLoad	88.5%	10.8 MB	0 MB/s	0 Mbps
Windows Explor	5.2%	42.4 MB	0 MB/s	0 Mbps
Desktop Windo	2.0%	68.7 MB	0 MB/s	0 Mbps
Task Manager	1.6%	28.9 MB	0 MB/s	0 Mbps
Microsoft OneD	0.7%	15.5 MB	0.1 MB/s	0 Mbps
PicPick (32 bit)	0.7%	50.3 MB	0.1 MB/s	0 Mbps
Client Server Ru	0.4%	0.8 MB	0 MB/s	0 Mbps
Service Host: Local Service (No Network) (5)	0.3%	11.1 MB	0 MB/s	0 Mbps
Service Host: Remote Procedure Call (2)	0.1%	6.6 MB	0 MB/s	0 Mbps
Service Host: Local System (18)	0.1%	28.0 MB	0 MB/s	0 Mbps
Service Host: Network Service (5)	0.1%	7.0 MB	0 MB/s	0 Mbps
Service Host: Local Service (Network Restricted) (6)	0.1%	11.9 MB	0.1 MB/s	0 Mbps
VMware Tools Core Service	0.1%	12.1 MB	0 MB/s	0 Mbps
System interrupts	0.1%	0 MB	0 MB/s	0 Mbps
Touch Keyboard and Handwriting Panel	0%	2.4 MB	0 MB/s	0 Mbps



```
tuts@fosslinux:~$ xkill
```



In-depth Analysis & Robust Solutions

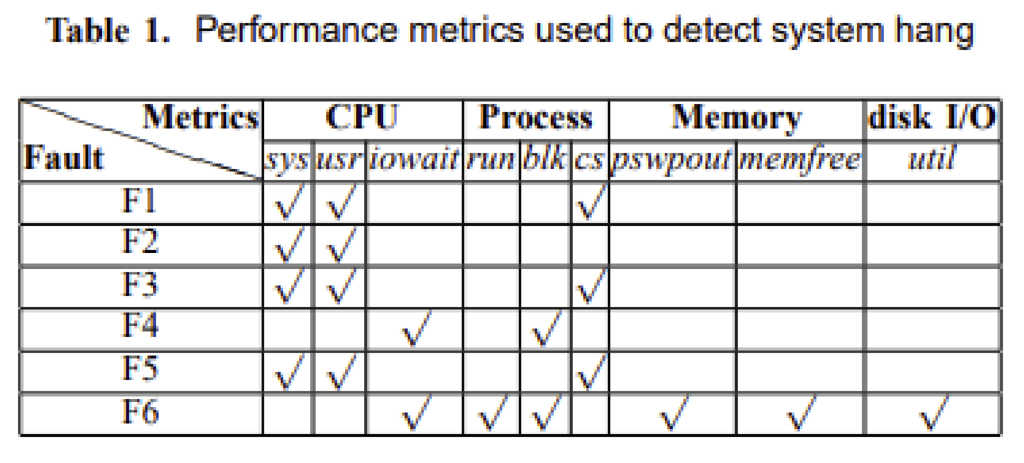


Table 1. Performance metrics used to detect system hang

Metrics / Fault	CPU			Process			Memory		disk I/O
	sys	*usr*	*iowait*	*run*	*blk*	*cs*	*pswpout*	*memfree*	*util*
F1	√	√				√			
F2	√	√							
F3	√	√				√			
F4			√		√				
F5	√	√				√			
F6			√	√	√		√	√	√

Image source: [1]

Detection

- Monitoring performance metric
- Improved Watchdog Timer [2]
- System Hang Detector (SHD) [3]
- Monitoring I/O throughput [4]

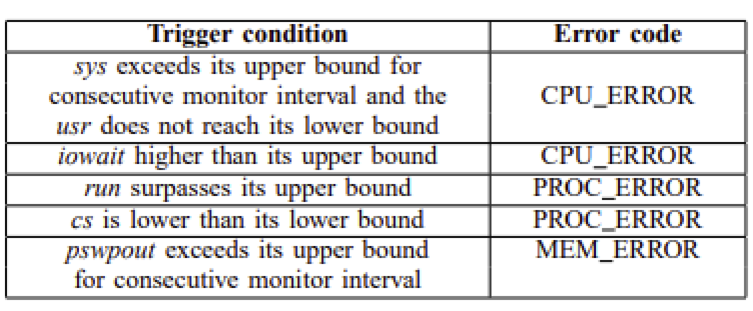
Recovery

- Analyze and remove any newly installed HW
- Keep OS running through killing the current running process [2]
- Killing the sleeping processes that hold a large piece of memory (which wait for a signal that would never happen) [1]

Self-Healing Framework Concept [1]

Light Detector:

- System performance metrics are obtained dynamically
- Triggers alerts with error code when finds some anomalous metrics



Trigger condition	Error code
sys exceeds its upper bound for consecutive monitor interval and the *usr* does not reach its lower bound	CPU_ERROR
iowait higher than its upper bound	CPU_ERROR
run surpasses its upper bound	PROC_ERROR
cs is lower than its lower bound	PROC_ERROR
pswpout exceeds its upper bound for consecutive monitor interval	MEM_ERROR

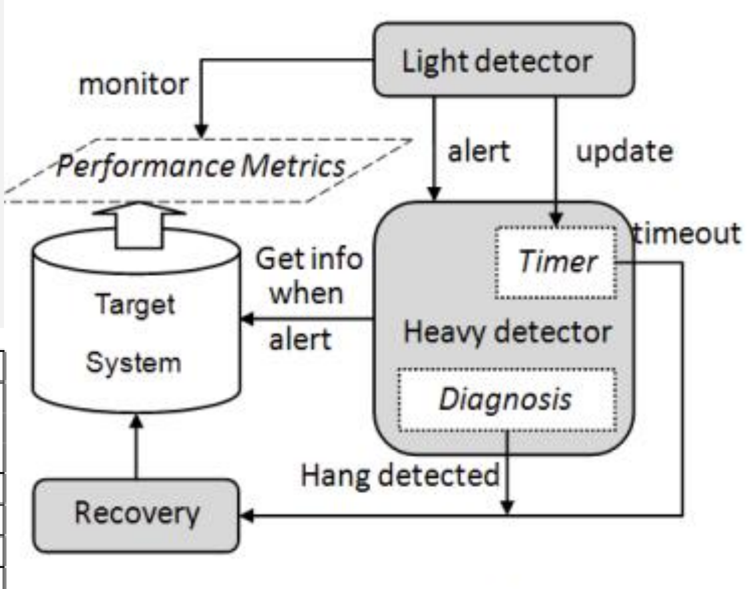


Figure 3. An overview of SHFH

Image source: [1]

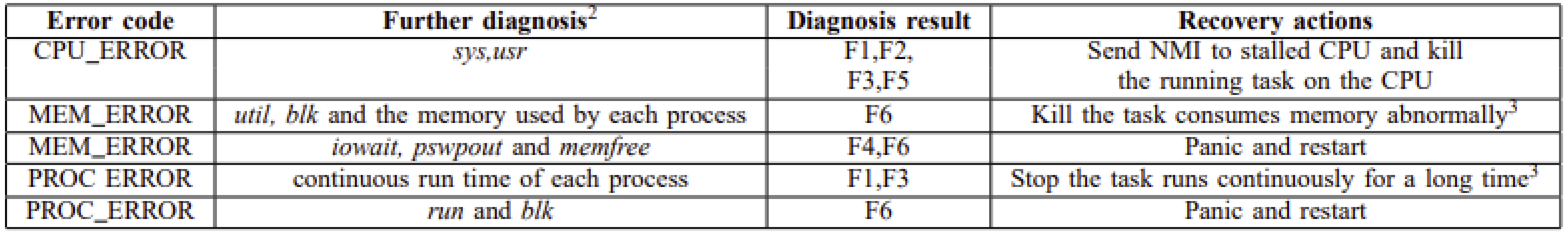
Heavy Detector:

Trigger conditions:

- Receiving an alert message from the light detector
- Timeout signal from the timer that is periodically updated by the light detector

Recovery:

- Kill or stop the suspicious process/thread
- Send an NMI (Non-Maskable Interrupt) to a particular CPU to wake up the stalled CPU
- Panic the system and then restart



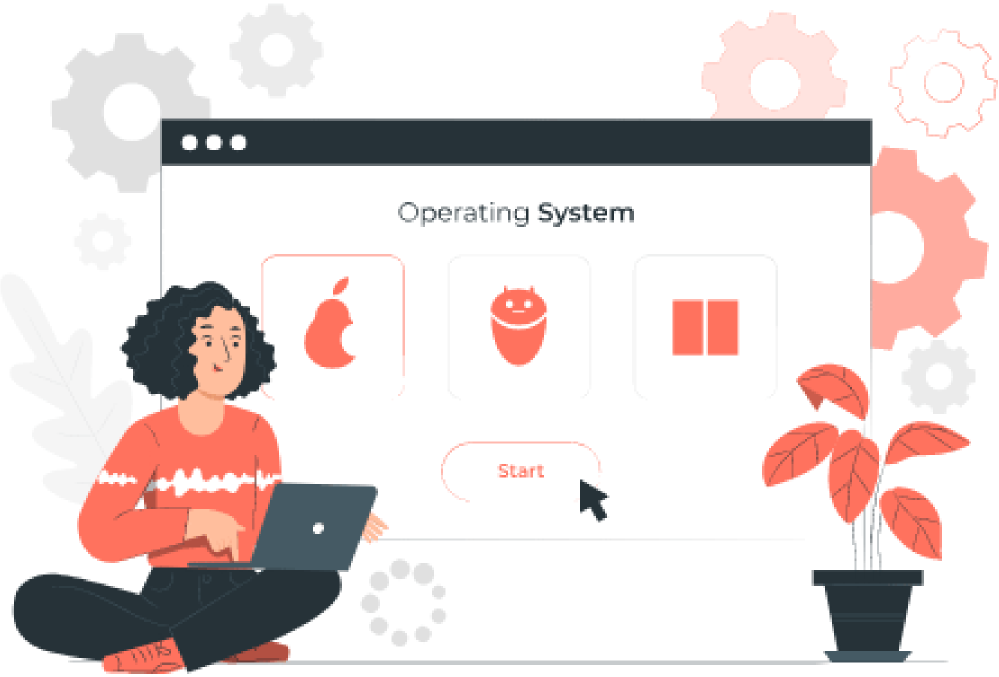
Error code	Further diagnosis[2]	Diagnosis result	Recovery actions
CPU_ERROR	*sys,usr*	F1,F2, F3,F5	Send NMI to stalled CPU and kill the running task on the CPU
MEM_ERROR	*util*, *blk* and the memory used by each process	F6	Kill the task consumes memory abnormally[3]
MEM_ERROR	*iowait*, *pswpout* and *memfree*	F4,F6	Panic and restart
PROC ERROR	continuous run time of each process	F1,F3	Stop the task runs continuously for a long time[3]
PROC_ERROR	*run* and *blk*	F6	Panic and restart

Conclusion

OS, whether it is for computer/laptop/mobile or any embedded system, **may hang or freeze** anytime between booting and shutdown

There can be **many reasons** for this unresponsiveness, e.g., SW fault, HW fault/limitations, Malicious activities, etc.

Some of these problems **can be solved automatically** (e.g., slow HW) **while** the **others may need manual intervention** (e.g., Spyware or infinite loop)



Q&A