Performance Analysis for Parallel Programs

How to estimate the benefit of parallelization?

- What is the ideal speedup on N machines/cores?

- Why cannot we achieve the ideal speedup?

How to estimate the benefit of parallelization?

- What is the ideal speedup on N machines/cores?
  - Nx

- Why cannot we achieve the ideal speedup?
  - Practical reason
    - Thread-related overhead
    - Non-CPU resource limitation
  - Algorithm reason
    - non-parallelizable code component

What affect real parallelization efficiency?

- Amdahl's law
  - https://www.techopedia.com/definition/17035/amdahls-law
- Critical path
  - You can represent a parallel program in a DAG, with an edge representing a task cannot start until another one finish
  - The longest path in your DAG is called critical path
  - The length of the critical path determines the execution time of your program with unlimited number of processors

How to estimate the benefit of parallelization?

- Amdahl's law
- Critical path

- Load imbalance
- Resource competition
- Data sharing cost (false sharing leads to huge performance lost)
- Synchronization overhead (lock, etc.)
- Other parallelization overhead (i.e., data duplication, work duplication, and aggregation)

Software bugs

Memory bugs

Concurrency bugs

Memory bug

Memory Layout

Buffer overflow

Uninitialized read

Memory leak

Memory layout

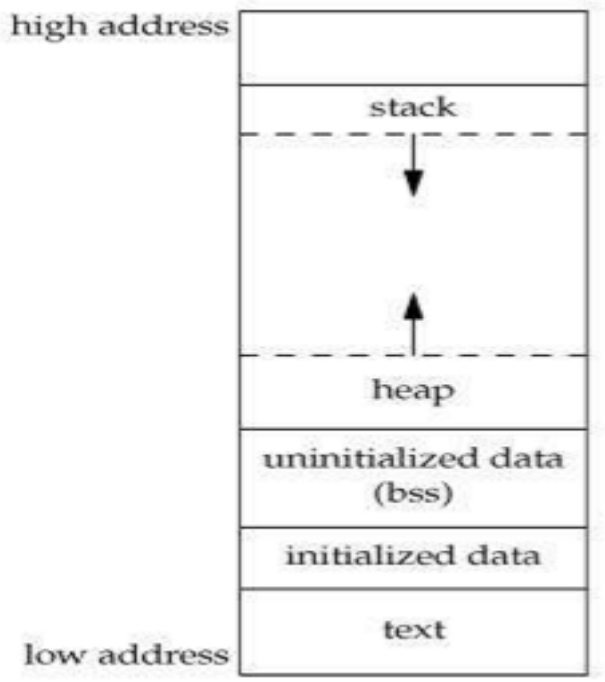
Text segment: store instruction (code)

Data: global/static initialized variable

BSS: global/static uninitialized variable

Heap: malloc

Stack: local variable



Memory layout (con't)

```
int x = 100;              //data segment
int main() {
  int a = 2;//stack
  static int y;           //BSS segment
  int *ptr  = (int *) malloc(2*sizeof(int));
  ptr[0] = 5;             //heap
  ptr[1] = 6;             //heap
  free(ptr);
  return 0;
}
```

Stack buffer overflow

1. Code example:

```
#include "stdio.h"
#include "string.h"

int main(int argc, void ** argv)
{

  if(argc<2) return 0;
  printf("%s is the argument\n",(char*) argv[1]);

  char p[10];
  strcpy(p, argv[1]);

  printf("%s is the string p\n", p);
  return 0;
}
```

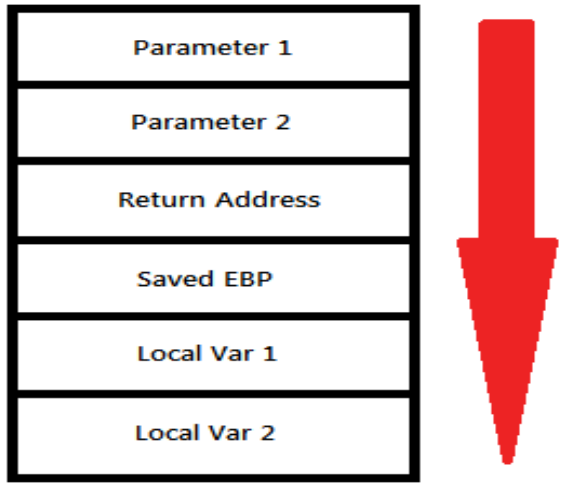
Stack buffer overflow

2. What is a stack buffer overflow bug:

read/write a buffer in stack beyond the buffer range.

3. Stack buffer overflow:

- Return address: next instruction after the function return.
- In the example code, strcpy over writes the return address
- This overwrite beyonding the array size is a buffer ove
- Consequence:
  - Invalid instruction: program crash
  - Jump to malicious program: hacker attack.



Heap buffer overflow

1. Code example:

```
#include "stdio.h"
#include "string.h”
#include “stdlib.h”

int main(int argc, void ** argv)
{

  if(argc<3) return 0;
  printf("%s and %s are the arguments\n",(char*) argv[1],
(char*) argv[2]);

  char* p1 = malloc(10);
  char* p2 = malloc(10);
  strcpy(p1, argv[1]);
  strcpy(p2, argv[2]);

  printf("%s is the string 1\n", p1);
  printf(“%s is the string 2\n”, p2);
  return 0;
```

Heap buffer overflow

2. What is a heap buffer overflow bug:

read/write a buffer in heap beyond the buffer range.

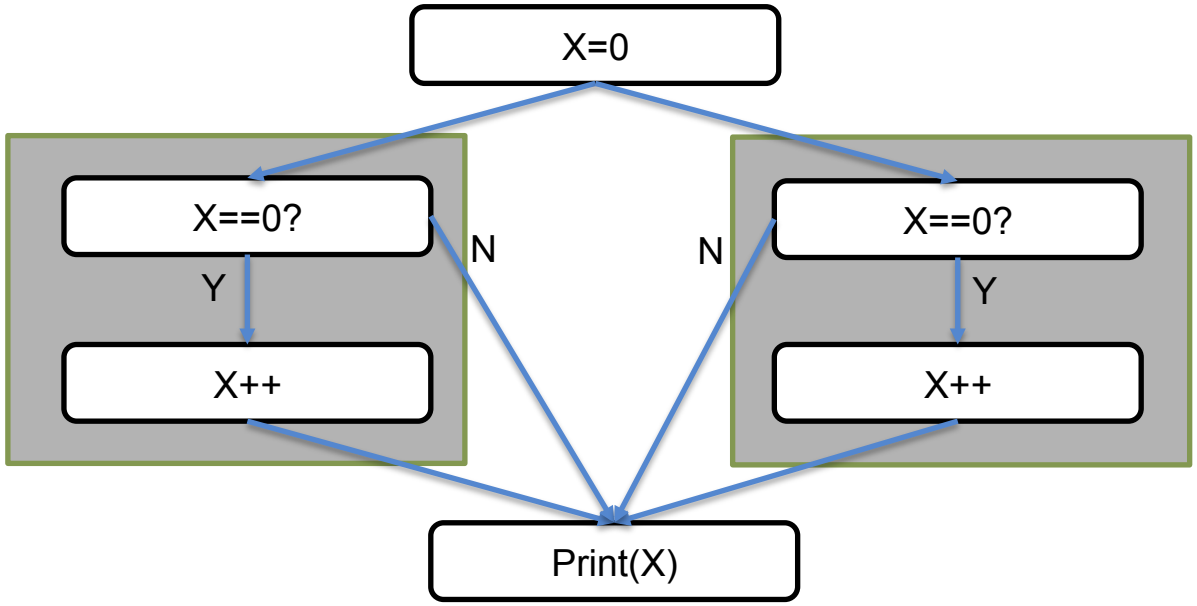
3. Impact of heap buffer overflow:

- Corrupt nearby data
- Crash the program if overflow into invalid program regions

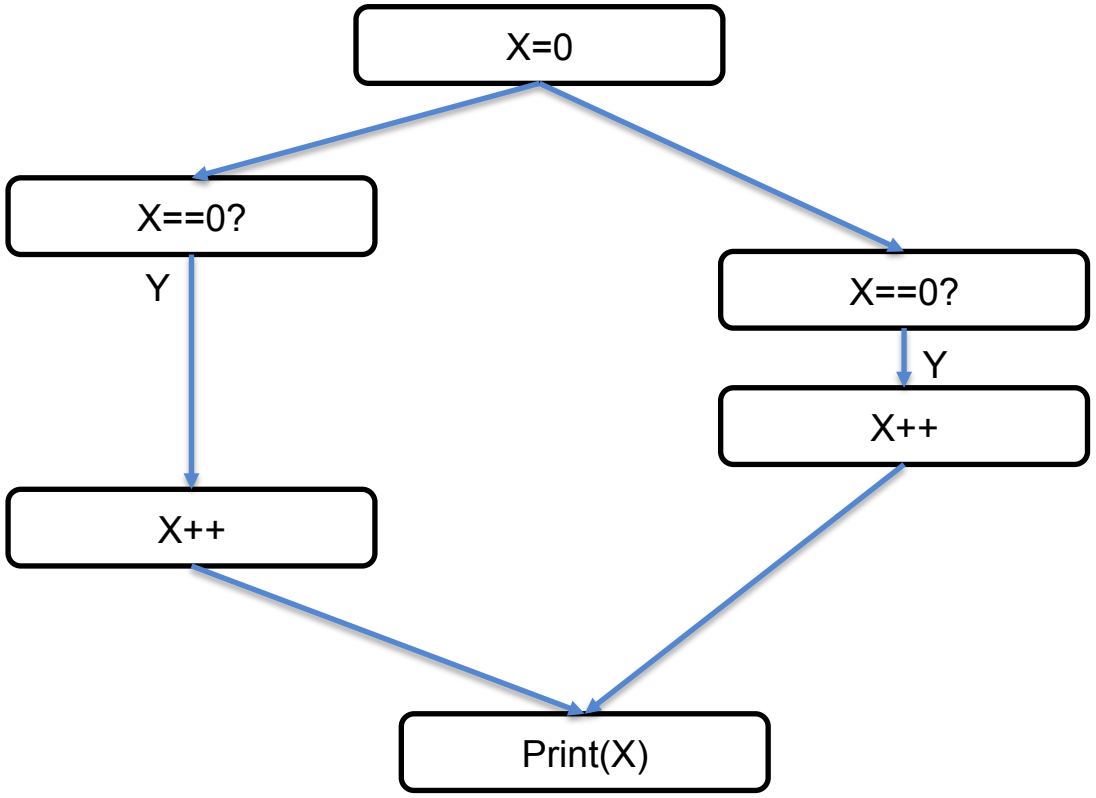
Concurrency bugs (data races)

Test 1: exact buy milk

```
public class test2{
    static int x = 0;
    public static void main(String argv[]){
        testThread t1 = new testThread();
        testThread t2 = new testThread();
        t1.start();
        t2.start();
        try{
            t1.join();
            t2.join();
        }catch(Exception e){}
        System.out.print(x+ " ");
    }
}
class testThread extends Thread{
    public void run(){
        if (test2.x == 0)
            test2.x ++;
    }
}
```



Test 1: exact buy milk



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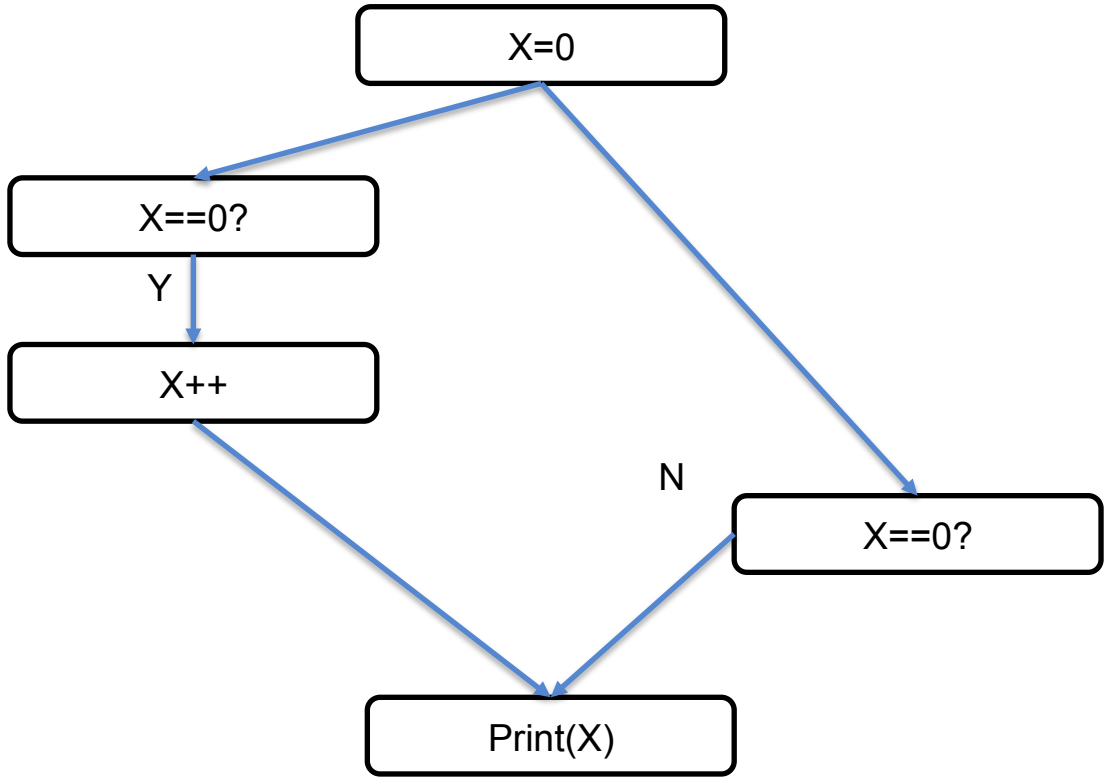

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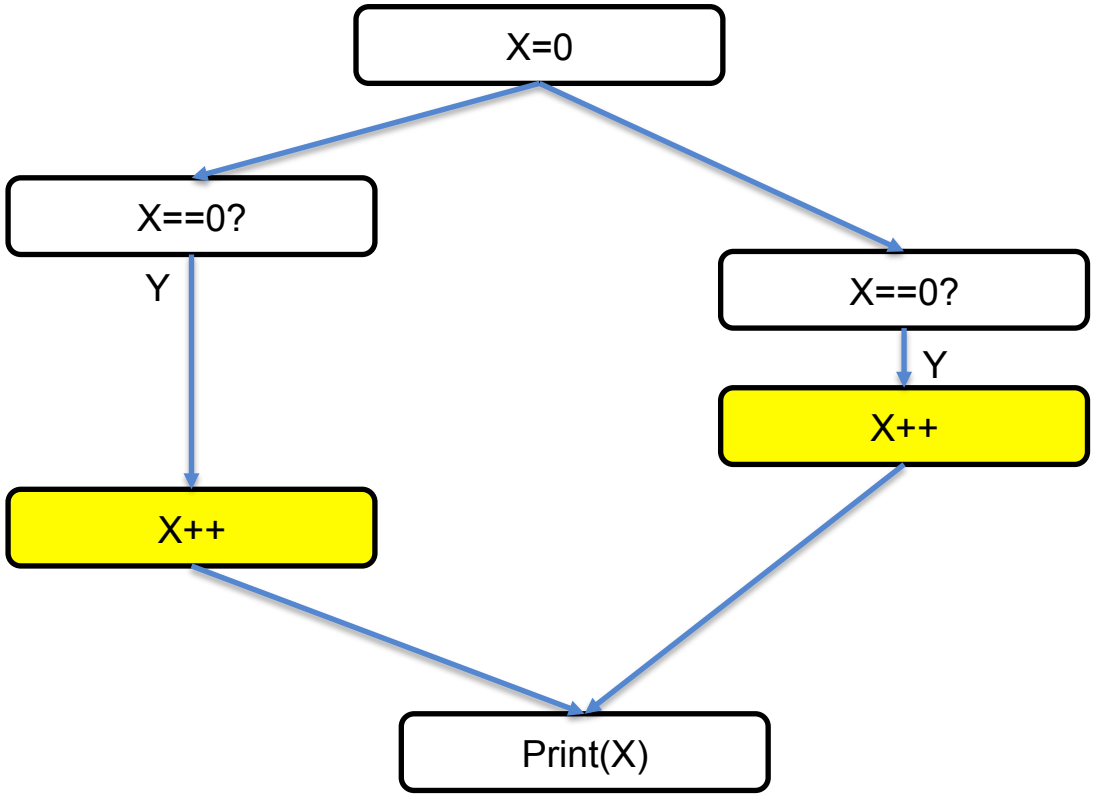
Test 1: exact buy milk



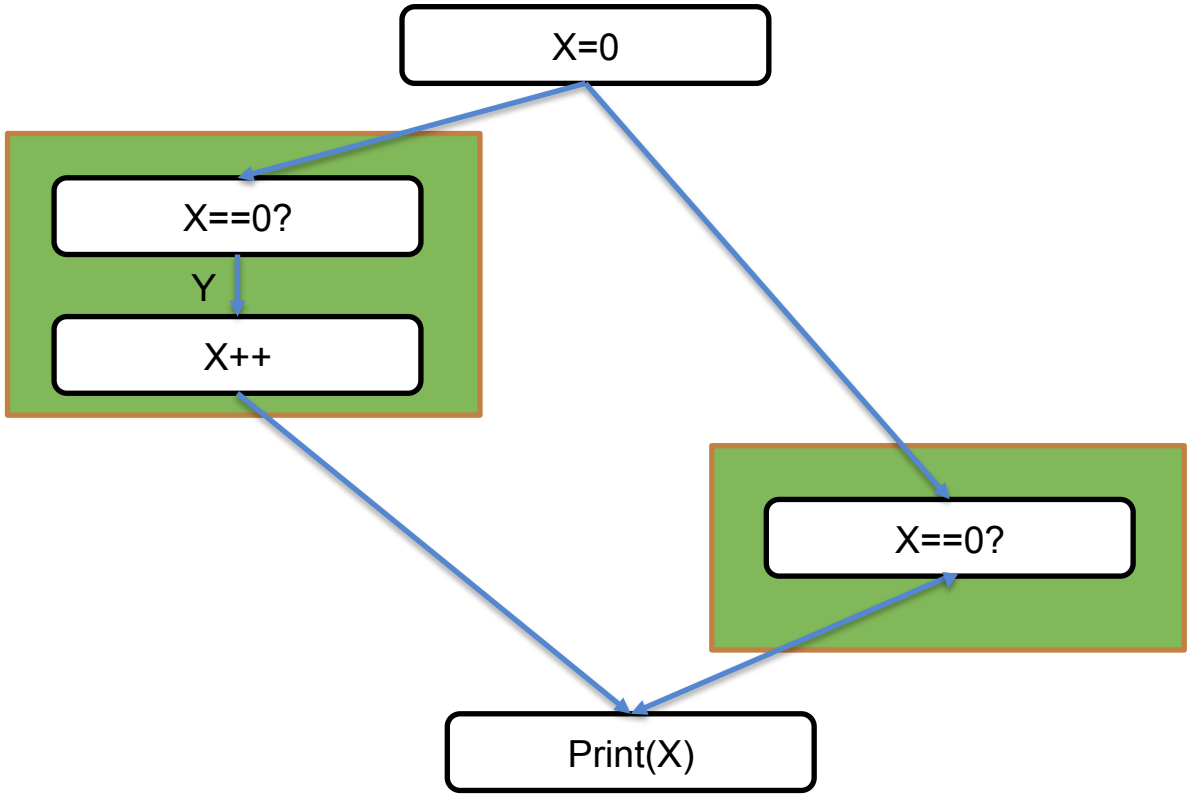
Data race:

two operations accessing same memory

relative order is undetermined

at least one is write

Test 1: Fixing



Two regions protected by the same lock cannot interleaving with each other.