CSCE 313-200
Introduction to Computer Systems
Spring 2024

Preliminaries II

Dmitri Loguinov
Texas A&M University

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Agenda

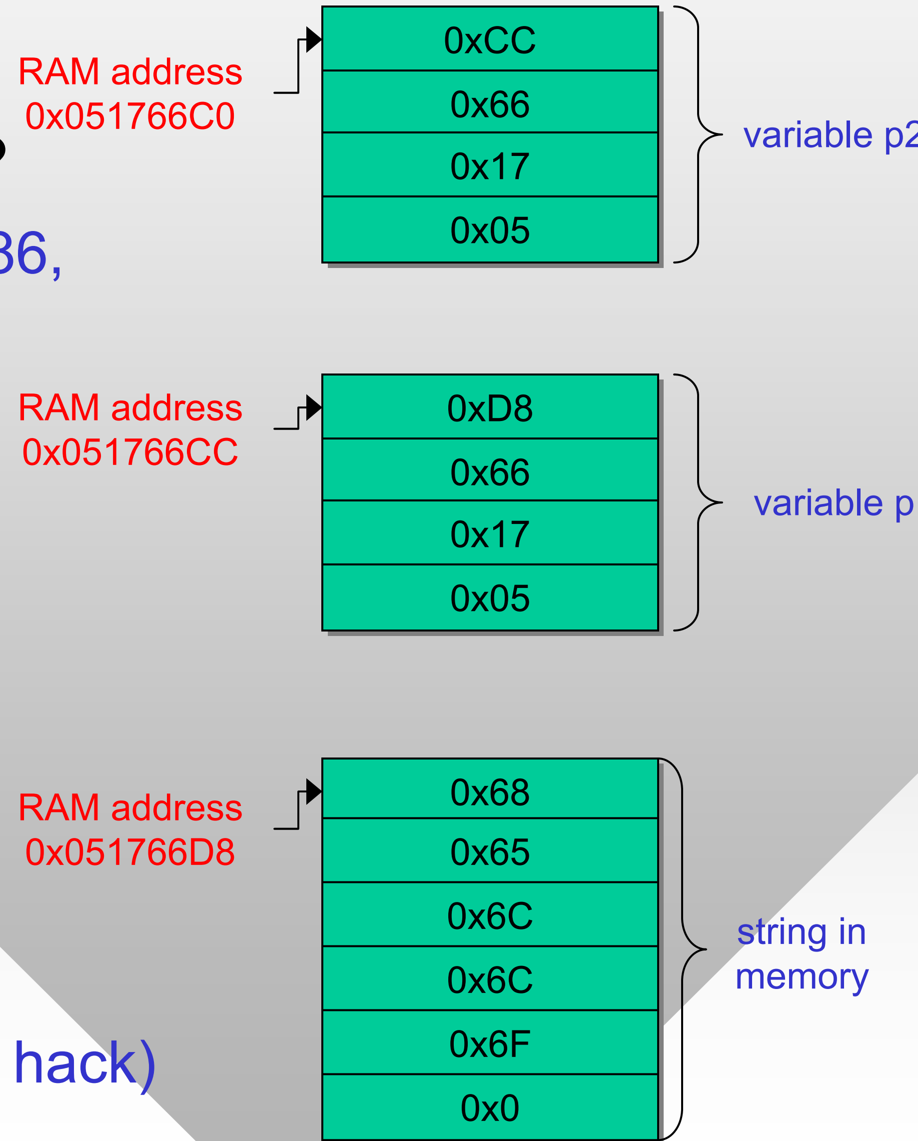
- Pointers
- Homework setup
- Cave lights
- Cave search
- Pipes

Pointers

- What is a C/C++ pointer?
  - 4-byte number in Win32/x86, 8-byte in x64

```
// example assumes Win32
char str [] = "hello";
short *p = (short*) str;
printf (“%X %X %X\n”, p, &p, *p);
printf (“%X %X %X\n”, str, &str, *str);
char **p2 = (char**) &p;
printf (“%X %X %X %X\n”, p2, &p2,
          *p2, **p2);
```

- What is a static array?
  - Immutable pointer hidden in compiler space
  - &str same as str (compiler hack)



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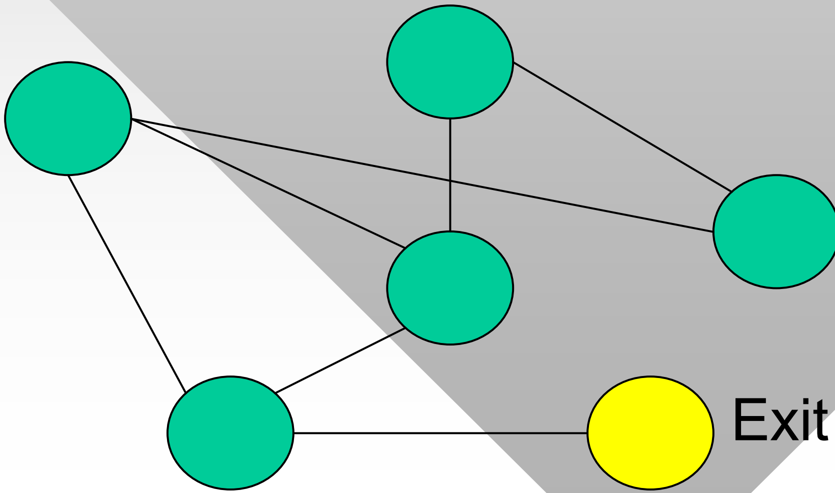
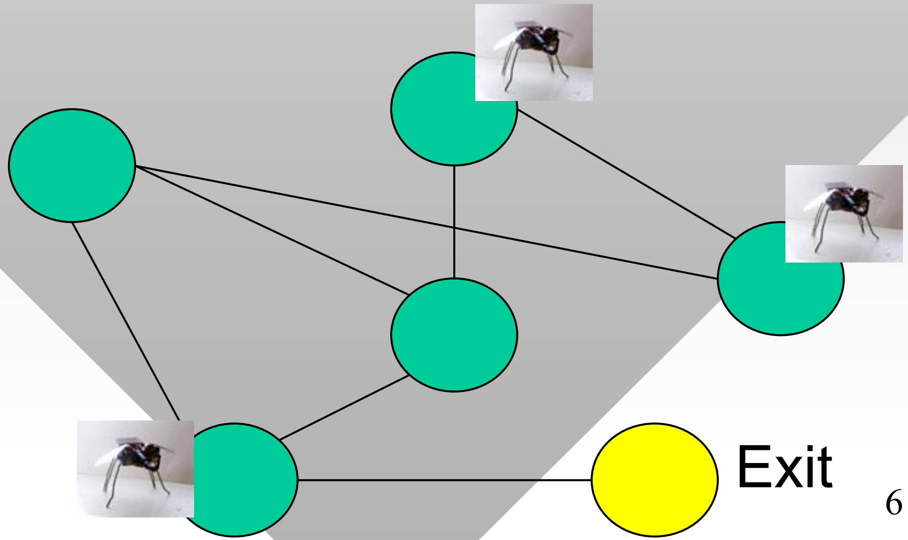
Homework Setup

- Implement four parallel search algorithms on a weighted graph under random edge-traversal delay
- Now the details
  - Assume you have a space rover stuck in some cave on a remote planet with many interconnected rooms
  - The cave is dark and its topology is unknown
  - As the rover is slow, it cannot directly search for the exit



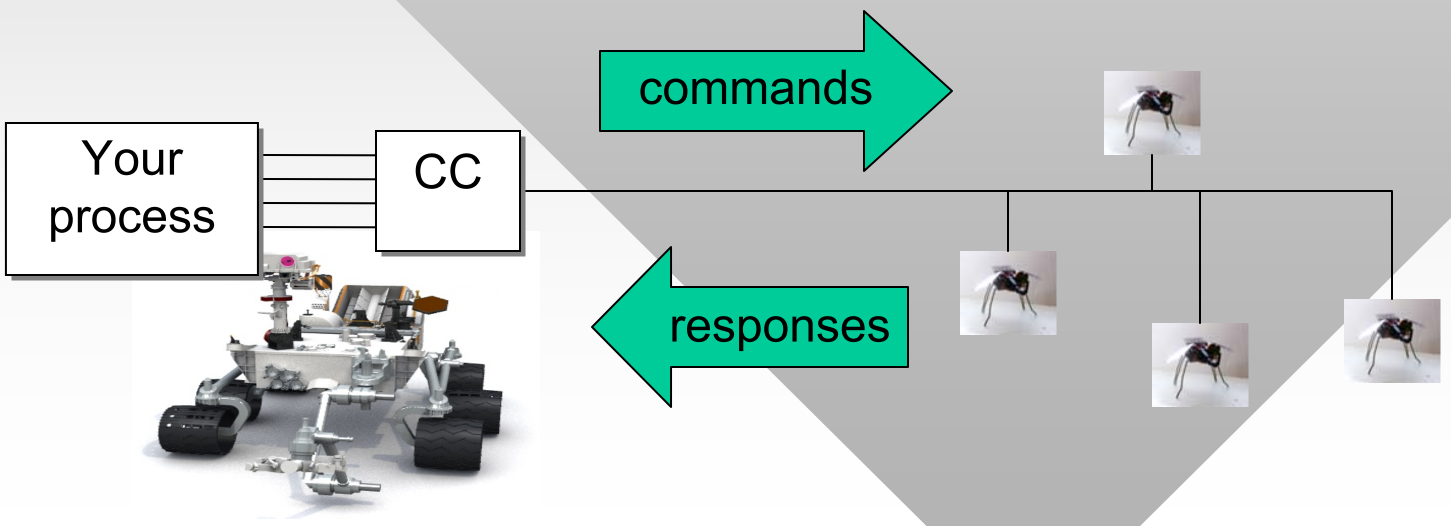
Homework Setup

- However, it has a number of flybots
  - These can travel all over the cave much quicker and search for the exit
- Main problem is flybots are somewhat dumb
  - Cannot remember which rooms they have been to
  - Cannot decide which next room to explore
  - Cannot talk to each other
- But they can figure out a path to a given room from its ID
  - No need to construct the graph yourself

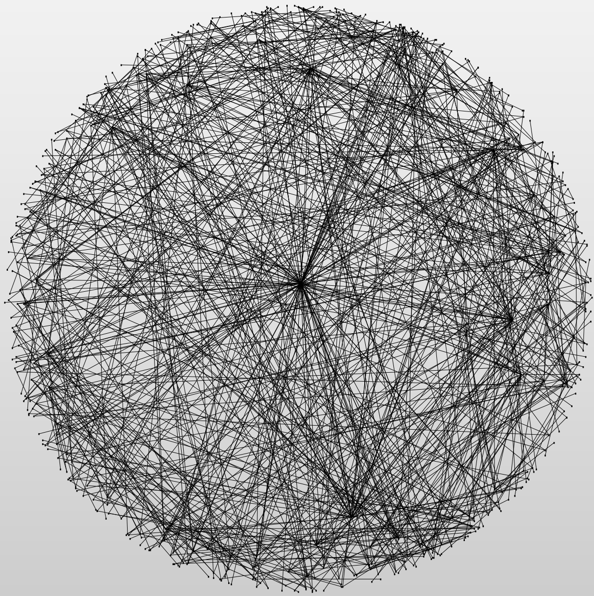


Preliminaries: Homework Setup

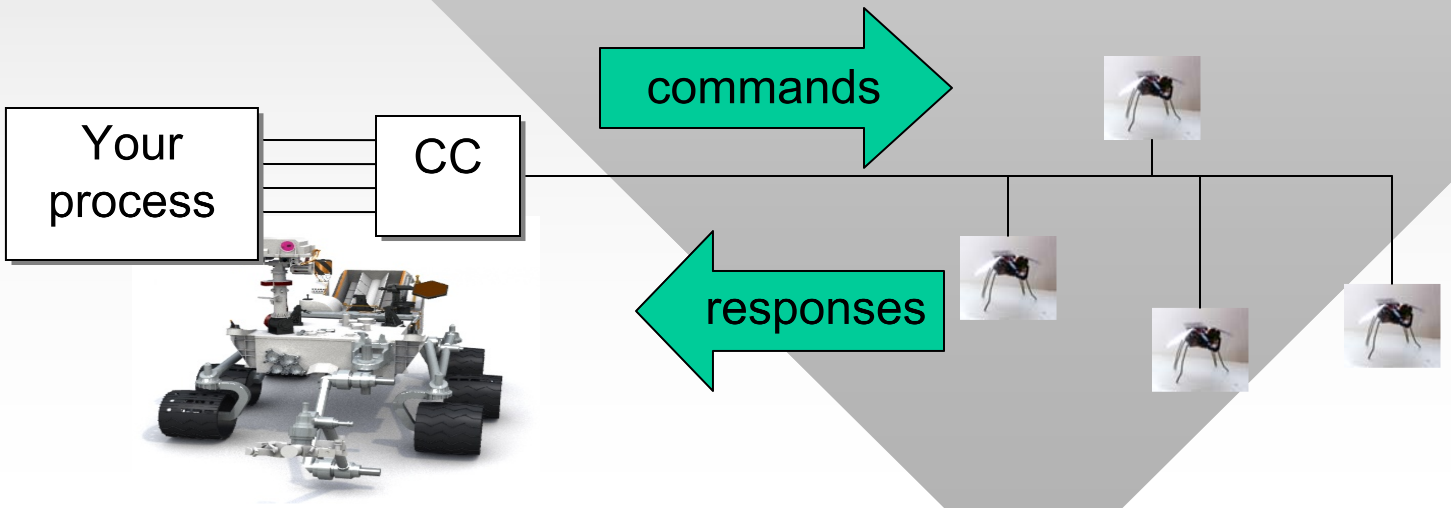
- Your job is to write software that can control the flybots from the rover to find the exit in the shortest time
- Communication from your process goes through the Command Center (CC) block on the rover
  - Commands: MOVE to a given room R
  - Responses: list of R's neighboring rooms



Homework Setup



- Response delays are random
  - Based on distance traveled and power state of flybot antenna
  - Report will determine the average delay
- Target cave size 10M rooms
  - Single robot requires over 2 months
  - Obviously there is a need to massively parallelize the search



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Cave Lights

- So far, the problem is solvable by the most basic parallel BFS
  - Final element is to make the graph weighted
- Assume the cave is pitch black, except certain rooms where light penetrates from the outside
  - Presence of light could indicate there is an exit
  - Or there might be a ceiling hole through which the rover cannot escape
- Light propagation
  - Given a light source of intensity $L \geq 1$, all neighboring rooms get their light boosted by $L/2$, which repeats recursively
  - Exponential decay of light until it drops below 1 unit

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Cave Search

- What would be a good search technique for this problem?
  - Key observation: the exit and surrounding rooms are likely to have non-zero light intensity
- Assume we maintain two structures:
  - Set of unexplored nodes U
  - Set of discovered nodes D
- Note: each room in D has been inserted into U, but not necessarily visited by a robot yet
- The main difference between the four studied algorithms is how to select the next node from U

Cave Search

- BFS and DFS are classic, already covered in 221
- Best First Search (bFS)
  - Largest intensity of light among U
  - May find sub-optimal paths when distracted by a bright, but lengthy path
- A* tries to overcome this
  - Heuristically weighs both distance and amount of light
  - For each candidate node i, compute its quality

    $$Q_i = L_i + w / (d_i + 1)$$

    where L_i is amount of light in the room, d_i is its distance from the rover, and w is some weight
  - Next explore room with the largest Q_i
- What do we get with $w = 0$ and $w = \infty$?
- How to implement bFS and A* efficiently?

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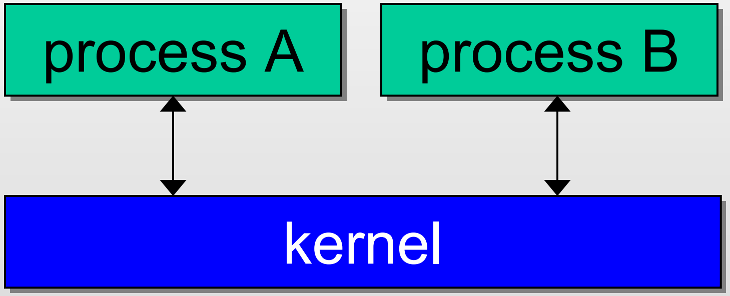
Pipes



- Pipes are communication channels between processes
  - Lossless
  - Implemented as FIFO queues through the kernel
- Anonymous pipes
  - Can communicate only with child processes
  - One-way, byte-based queue
  - Requires 2 pipes for duplex communication
  - Often used to redirect `stdin/stdout` of the child →

```
cat a.txt | grep hello | more
```

- Named pipes
  - Globally unique names
  - Duplex (bi-directional)
  - Can be both byte-based and message-based
- Homework uses the latter type

Pipes

```
class ResponseRobot {
public:
        DWORD   status;
        char    msg [64];
};
```

```
class NodeTuple64 {
public:
        uint64   node;
        float    intensity;
};
```

- Robot responses consist of a header, followed by an array of tuples (node, intensity)
  - Node is an 8-byte hash of a neighboring room
  - Intensity is a float value (amount of light)

buffer

CC.exe

ResponseRobot

NodeTuple64

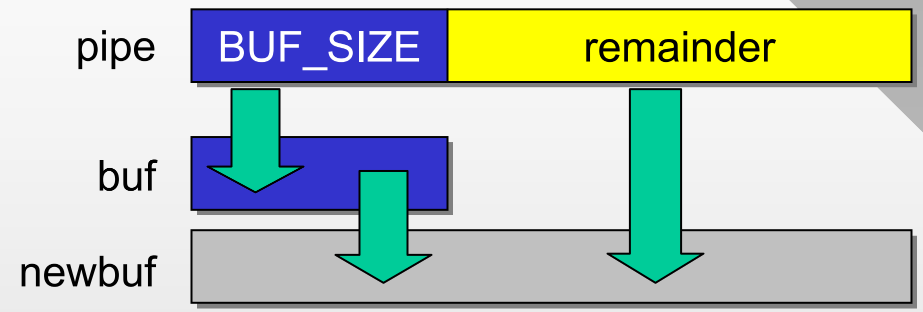
NodeTuple64

...

buffer

your program

Pipes



- By default, CC pipes are blocking and synchronous
  - Only one message at a time can be in the pipe
  - However, its size is unknown a-priori
- Idea: receive as much of the message as buffer allows, then peek at the pipe, receive the rest
  - Here is pseudo-code (needs more work to be functional)

```
#define BUF_SIZE 128   // small initial size to prevent over-allocation
char *buf = malloc (BUF_SIZE);
ReadFile (pipe, buf, ..., &read, ...);
if (read == BUF_SIZE) {            // buffer filled to the max?
        PeekNamedPipe (pipe, ..., &remainder, ...);
        if (remainder > 0) {
                // realloc buffer to full size
                ReadFile (pipe, ...);  // receive remainder
        }
}
```

Pipes

- Optimization
  - Per-message allocation/deletion of buf should be avoided
  - Retain newbuf until some future message overflows it
  - *For monster caves, keep the buffer only if smaller than 5 KB*
- Pipe names
  - Case insensitive:
  - Dot . represents the same host

fixed — user-created

\\server\pipe\pipename

- Pipe names must be globally unique
  - If users run multiple copies of CC.exe on the same host, the pipe name must specify which of them to use
  - This homework uses \\.\pipe\CC-X, where X is the process ID of the CC in hex

Wrap-up

- Reminder: hw1-part1 is due in a week
  - Error checking for all function calls, proper disconnect
  - Wait for CC.exe to quit, common mistake to exit before CC
  - Print initial room and all CC/robot text responses
- See the grade sheet at the end of the handout
- Task: allocate a buffer with 100 bytes and fill in three NodeTuple64 classes starting from byte 37
  - The i-th node has ID i and intensity 1 / (i+1)

```
char buf [100];
NodeTuple64 *nt = (NodeTuple64 *) (buf + 37);
for (int i = 0; i < 3; i++) {
        nt[i].node = i;
        nt[i].intensity = 1.0 / (i+1);
}
```