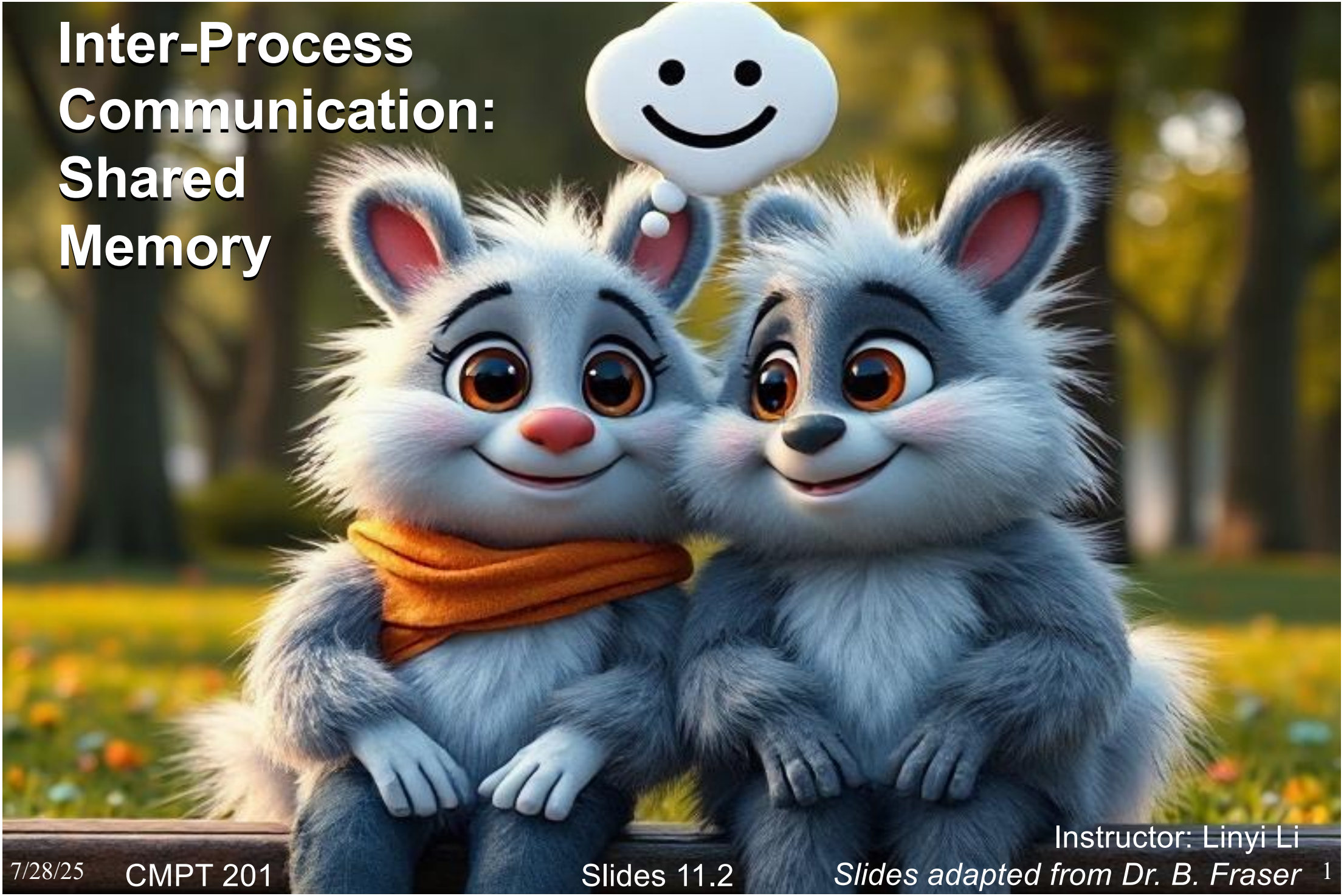
Inter-Process Communication: Shared Memory



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Topics

- Since memory is so useful and easy to access, can we load a whole file into memory?
- If processes have separate memory spaces, how can two processes share memory?

Memory Mapping

Intro to Memory Mapping

- Memory mapping
  - It's not *just* for IPC, but we'll need it!
- Uses for Memory Mapping:
  - .. Loading a file into memory
    vs using read()/write()
  - Allocating memory
  - .. Accessing memory-mapped devices using /dev/mem
    (useful for embedded systems; shared between processors!)

mmap()

void *mmap(void *addr, size_t length, int prot, int flags, int fd, off_t offset)

.. mmap() creates a memory mapping:

- addr: starting address of the new mapping.
  Usually NULL so OS pick the address.
- length: # bytes in mapping.
- prot: Memory protection for executable, readable, writable, or not accessible.
- flags: MAP_SHARED or MAP_PRIVATE, and optionally MAP_ANONYMOUS. (explained below)
- fd: .. the open file to be mapped. (explained below)
- offset: the offset into the file to be mapped.

- Returns a pointer to the beginning of the new mapping.

Types of Memory Mapping

- Two types of memory mappings
  - File mapping
    - File is loaded into a memory region
    - File I/O becomes memory access:
      - Replace read()/write() calls with pointer access to read or write file.
    - This is called a.. memory-mapped file.
    - flag argument: MAP_ANONYMOUS flag **is not** set.
  - Anonymous mapping
    - This is another way to allocate memory to our process (in addition to sbrk()).
    - malloc() uses both sbrk() and mmap().
    - flag argument: MAP_ANONYMOUS flag **is** set. fd argument is ignored.

Shared vs Private

- Memory Mapping can be shared or private.
- Shared Mapping:
  - .. Multiple processes can share a mapping.
  - E.g., .. create a mapping (file or anonymous) and fork() a child.
    - Since memory is cloned, the parent and the child will share the same mapping.
  - Or, multiple processes can map the same file.
- Private Mapping:
  - Changes in one process's memory mapping .. do not appear for other processes, and not written to file.

4 Possiblities

- **Private file** mapping:
  - A file is mapped to a process as a private mapping.
  - .. Changes not written to file or shared with other processes.

- **Shared file** mapping:
  - A file is mapped to a process as a shared mapping.
  - Changes propagate to:
    - ..the real file
    - and other processes mapping same file.

- **Private anonymous** mapping:
  - More memory is allocated to the calling process.
  - .. fork() copies memory but each process has private copy (changes not shared).

- **Shared anonymous** mapping:
  - More memory is allocated to the calling process.
  - Memory is shared; changes propagate to other process!

mmap() arguments: offset = 0
fd = -1 or shm_open()
flag |= MAP_ANONYMOUS

Unmap

- int munmap(void *addr, size_t length);
  - Unmaps the mapped memory.
  - Region is also automatically unmapped when process is terminated
- On the other hand, closing the file descriptor does not unmap the region.
  - All pages containing a part of the indicated range are unmapped

ABCD: Memory Mapping

- Which of the options below is best described by:
  - Used to allow fast access to a temporary copy of a file.
  - Used to have two processes access the same memory so they can both access a shared data structure.
  - Used to allow any number of processes to edit a file and see each others edits, plus reflect changes to file on disk.

(a) Shared anonymous mapping

(b) Private anonymous mapping

(c) Shared file mapping

(d) Private file mapping

Memory Mapping Activity

- Activity: memory-mapped file I/O.
  - Modify the example from man mmap as follows:
  - Receive only one command-line argument, which is a file name.
  - Create a file memory mapping for the entire file.
  - Print out the content of the entire memory mapping.

Shared Memory

Sharing memory

Two different ways to share memory between processes.

- For Related processes:

.. Create memory map then share with fork().

– mmap() with MAP_SHARED | MAP_ANONYMOUS (i.e., shared anonymous)

- For Unrelated Processes:

.. use a shared memory object (shm_open()) and then mmap()

– man 7 shm_overview

  - shm_open(): Open a shared memory object
  - ftruncate(): Set size
  - mmap(): Create memory mapping

shm_open()

int shm_open(const char *name, int oflag, mode_t mode)

- Similar to opening a file, but it's shared memory.
  - Just like creating a file; listed in /dev/shm/
  - E.g., ls /dev/shm/somename
- Returns: file descriptor for.. a shared memory object.
- name: Known by all participating processes.
  General form: /somename.
- flag: O_CREAT flag set when creating a new object.
- mode: For permissions on creation.

Size and Map

int ftruncate(int fd, off_t length)

- Memory object is created with size 0.
- ftruncate() sets its size.

void *mmap(void *addr, size_t length,
int prot, int flags, int fd, off_t offset)

- Create memory map for memory object
(after created by shm_open() and size set with ftruncate()).
- ..Pass shared memory object file descriptor as fd
(from shm_open()).

Cleanup

int munmap(void *addr, size_t length)

- Unmap shared memory when no longer needed.

int shm_unlink(const char *name)

- .. Remove shared memory object when done with shared memory.
  - Removes file from /dev/shm/.
- However, processes still using the shared memory object keep using it.

ABCD: shm_open()

- When do we need to call shm_open()?

(a)When two processes want to share memory.

(b)When a parent and child processes want to share memory without calling fork().

(c)When two unrelated processes want to share memory.

(d)When two processes share access to a file and each process knows the file's name.

Activity: Shared Memory

- Activity
  - Write two programs that communicates with each other via shared memory.
  - They should each receive a shared memory object file name as the only command-line argument.
  - One program should write an integer to the shared memory
  - The other program should read the integer written by the first program from the shared memory.

  Hint:

  - writer: shm_open, ftruncate, mmap, getchar (wait), munmap, shm_unlink
  - reader: shm_open, mmap, getchar (wait), munmap, close

Activity: Answer

- See 11-ipc/shm_reader.c, shm_writer.c in reference code of course website.

Summary

- Two processes can communicate by sharing memory.
- mmap()
  - Creates a memory mapping of a file or some memory.
  - Usually copied by fork()
  - Useful for parent-child shared memory.
  - mmap(), munmap()
- shm_open()
  - Creates a named shared memory object.
  - Useful for unrelated processes to share memory.
  - shm_open(), ftruncate(), mmap(), munmap(), shm_unlink()