# MOSS:

# A Mini Operating System Simulator

SERG talk, 4th March 2004

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# Introduction

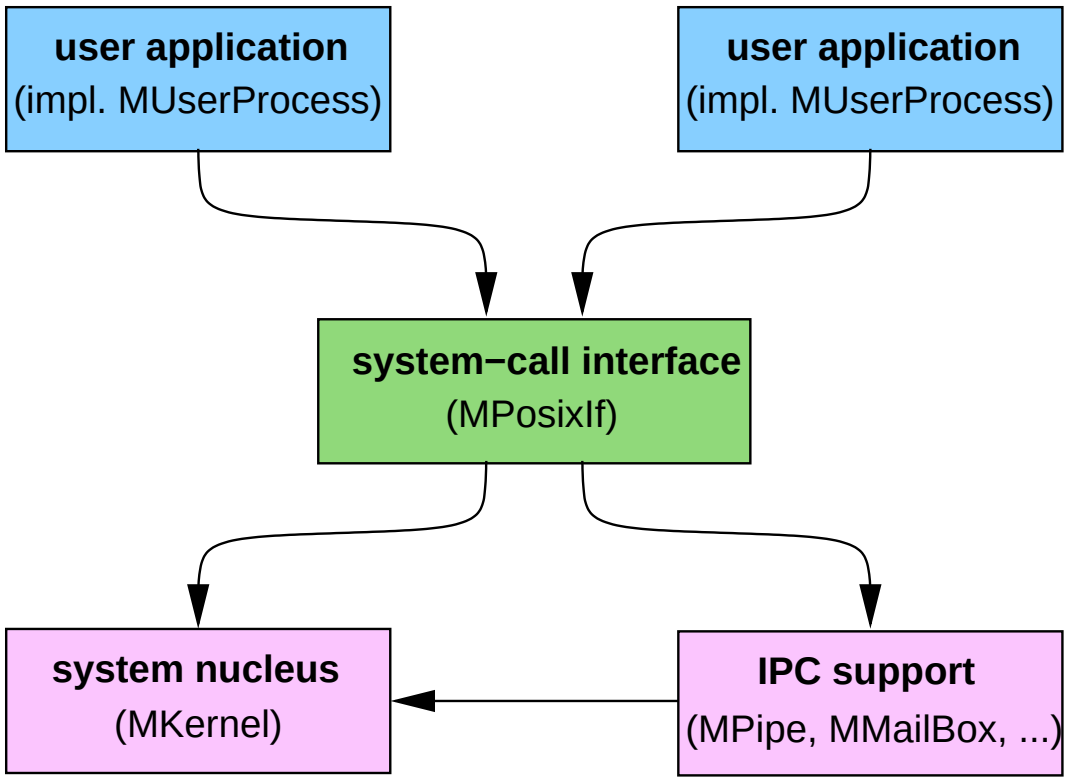
- An operating system simulator written in Java
- Emulates certain aspects of an operating system:
  - user and system processes
  - operating system ‘nucleus’
  - system-call interface
  - signals
  - process scheduling
- Some aspects are hard (or pointless) to emulate:
  - memory management
- Others are incomplete:
  - file-system

# Motivation

- Operating system programming often seen as difficult
  - code complexity
  - low-level nature of code/language
  - lengthy development cycle

- Want it to be easy!
  - ‘hands-on’ programming for students
  - potential prototyping platform

# Structure


user application
(impl. MUserProcess)
user application
(impl. MUserProcess)
system−call interface
(MPosixIf)
system nucleus
(MKernel)
IPC support
(MPipe, MMailBox, ...)

# OO and Operating Systems

- Operating systems are **not** generally object oriented

- Probably reasons for this:
  - suitable languages for implementation: low-level vs. high-level
  - overheads (e.g. garbage collection)
  - not exactly object oriented in the first place

- Most operating systems are written in C, with large amounts of assembler for low-level interaction with hardware.

# MOSS and Java

- Source files:
  - in Linux, for example, logical functionality is divided across different files:
    - scheduler, memory-management,
    - file-system interface (VFS),
    - process management, device drivers, ...

- MOSS does similar; different files contain logically different parts of the operating system

- Explicit use of object-orientation is avoided, but we still have to be “Java friendly”
  - classes provide wrappers for **static** methods – no ‘instance’s are required

- `MKernel.java` – largely concerned with process scheduling/management and signal delivery
- `MPosixIf.java` – provides the ‘system-call’ interface for (primarily) user processes
- `MInitTask.java` – the first process (initial task) of the system
- `MProcess.java` – ‘process control block’ (PCB)
- `MSystem.java` – system constants
- `MiniOSSim.java` – where ‘`main()`’ lives
- `MFile.java` – in-kernel “file-handle”
- `MJavaConsole.java` – provides access to the “Java console”

- Some use of interfaces (and *real* objects) is required
  - provides an equivalent to C's "structure of function pointers"

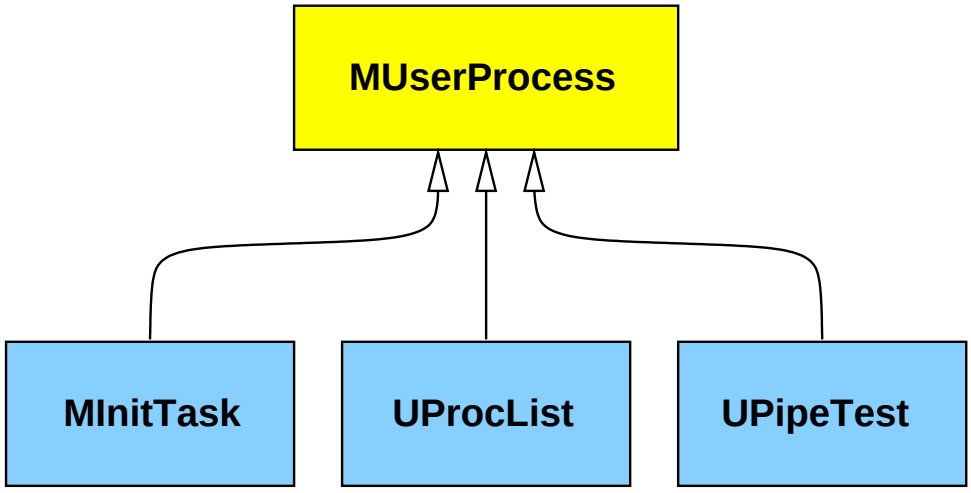
- `MUserProcess.java` – interface that *user-processes* implement

- `MKernelProcess.java` – interface that *kernel-processes* implement

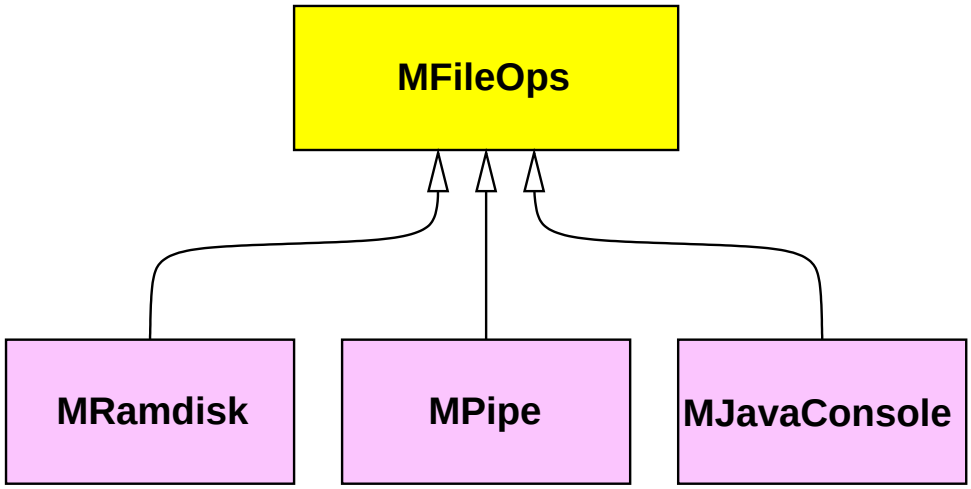
- `MFileOps.java` – interface for *file-operations*

- `MDirOps.java` – interface for *directory-operations*

- User-processes implement “MUserProcess”:




- Any device that provides ‘file-like’ interfacing implements “MFileOps”:



# Run-Time Environment

- MOSS is quite similar to a UNIX/POSIX system (e.g. Linux)
  - POSIX flavoured system-call interface
  - provision of **processes** with numeric IDs
  - process signalling mechanism
  - concept of process hierarchy (e.g. parent process)
  - pipes/streams – ‘stdin’, ‘stdout’ and ‘stderr’
  - multiple virtual processors

- Process scheduling is somewhat awkward, but emulated in a tidy way (virtual CPU)

# Java Threads and MOSS Processes

- In MOSS, the '`MProcess`' class provides the "base" for a process
  - it extends the Java '`Thread`' class, and thus exists as its own 'thread of control' within the JVM

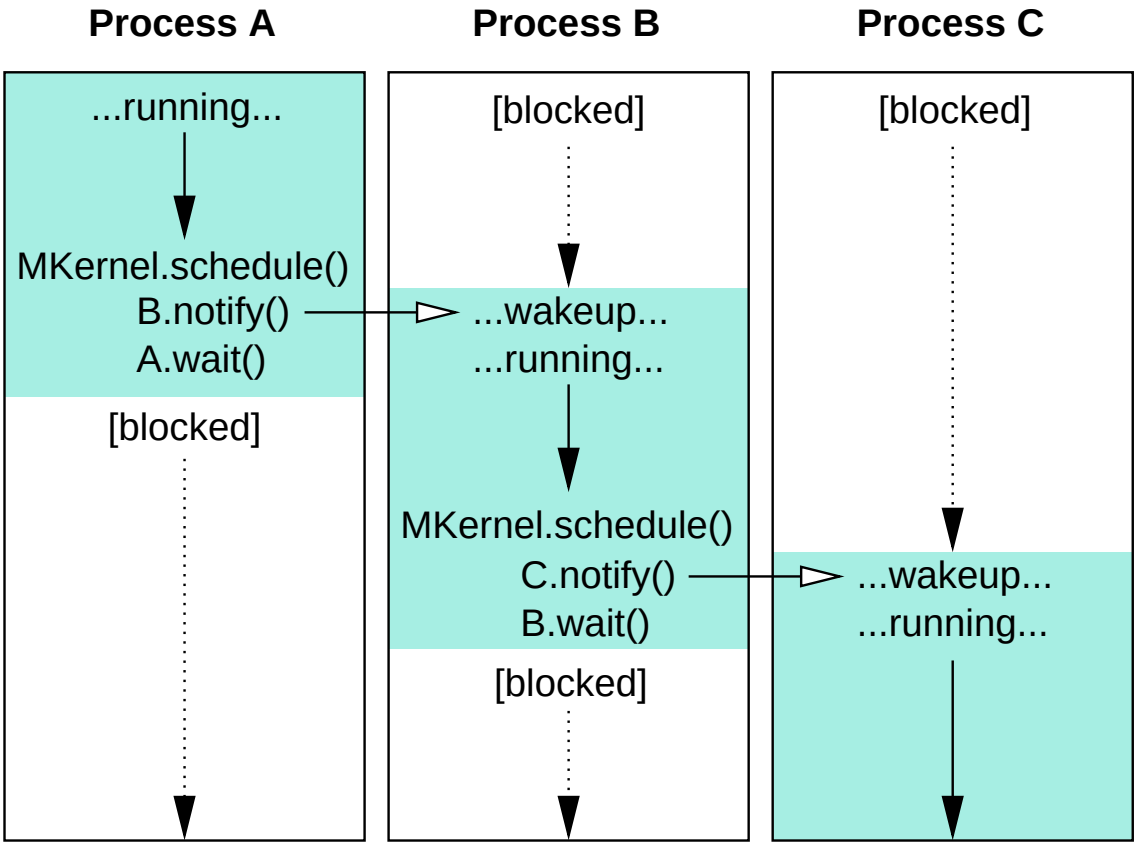
- A MOSS 'process' consists of two things:
  - an instance of a class that implements either '`MUserProcess`' or '`MKernelProcess`' (interfaces)
  - an '`MProcess`' instance that provides the 'thread' (emulated virtual machine)

# Scheduling

- Free-wheeling execution of Java threads is not an option
  - operating systems don't work like that

- Processes in MOSS 'run' on a **virtual CPU**
  - in actual fact, a rather null entity – the JVM takes care of running threads
  - virtual CPU retains a reference to the current process
  - kernel maintains an array of 'current' processes, indexed by CPU

- Context switching (changing from one process to another) is done using Java monitor methods (executed on the '`MProcess`' object)




- New processes are picked from the run-queue

- ‘core’ context-switch code is:

```
if (new_p != old_p) {
  synchronized (old_p) {
    if (new_p != null) {
      synchronized (new_p) {
        new_p.notify ();
      }
    }
    try {
      old_p.wait ();
    } catch (InterruptedException e) {
      panic ("MKernel::schedule().  interrupted:"
             + e.getMessage());
    }
  }
}
```

- ‘`old_p`’ is the **current** process, ‘`new_p`’ is the **next** process (i.e. the one we’re switching to)

- Processes are added to the run-queue by calling ‘`add_to_run_queue`’ in MKernel

- A **voluntary reschedule** is performed by calling ‘`reschedule`’ in MPosixIf. The implementation of this is:

```
MProcess current =
   MKernel.current[MProcessor.currentCPU()];

MProcess.sync_process_signals (current);
MKernel.add_to_run_queue (current);
MKernel.schedule ();
MProcess.sync_process_signals (current);
```

- The first line shows how the kernel can discover the current ‘process context’ – i.e. which process is executing

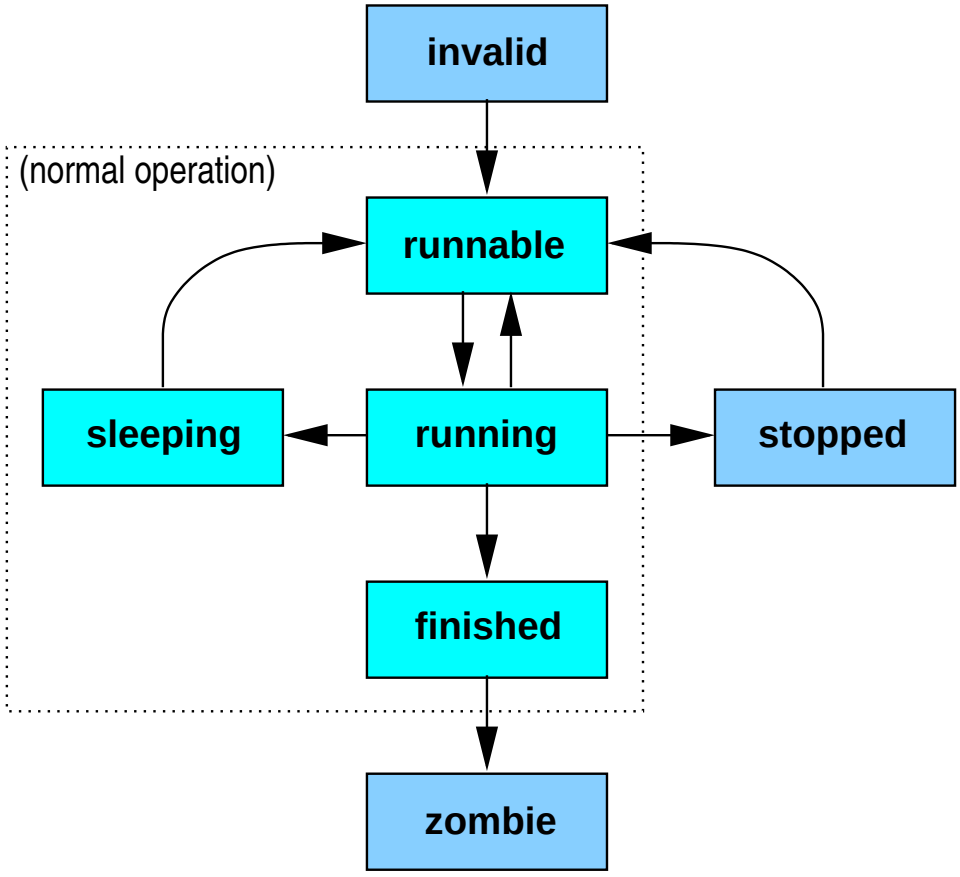
- The ‘`sync_process_signals`’ method is used to deliver signals to a process

- Signals are generated by calling ‘`queue_signal`’ in MKernel

- **Note:** MOSS is a non-preemptive system – if a user-process gets stuck in a loop, it stays there
  - there are ways around this (kernel-timer coupled with ‘dead’ handling if the thread ever interacts with the kernel again), but they’re messy..
  - better to write nice non-polling code `:-)`

- Processes have a **state**; one of:
  - ‘TASK_INVALID’ – invalid
  - ‘TASK_STOPPED’ – stopped process (job control)
  - ‘TASK_RUNNABLE’ – runnable process (on the run-queue waiting for execution)
  - ‘TASK_RUNNING’ – currently running process
  - ‘TASK_SLEEPING’ – waiting for I/O or timeout
  - ‘TASK_FINISHED’ – process terminated
  - ‘TASK_ZOMBIE’ – terminated and waiting for parent to collect status

- Process state transitions:



# Kernel Interfacing

- User processes interact with the kernel through **static** methods in '`MPosixIf`'
  - processes view each other as PIDs (simple integers)
  - file-descriptors (typically I/O streams) are also simple integers
  - return values from methods are mostly integer; conventionally, negative values indicate error (error codes defined in '`MSystem.java`')

- User processes **should not** directly interact with other parts of the system
  - although there is nothing to stop them...

# A Note on File Interfacing

- From a user-process perspective:
  - a simple integer (file-descriptor)
  - methods in MPosixIf such as '`open`, '`read`', '`write`', '`lseek`' and '`close`'
  - allows interfacing with I/O streams, pipes, files, ...

- From the MOSS kernel perspective:
  - an instance of a Java class implementing '`MFileOps`', linked by an '`MFile`'
  - provides a 'back-end' for the user-visible methods

# Blocking Processes

- When executing code inside the MOSS 'kernel', it is typically in the context of a MOSS process
  - the MOSS kernel code is executing in the Java **thread** provided by an `MProcess`
  - current process is accessed in a common way:

```
MProcess current =
    MKernel.current[MProcessor.currentCPU()];
```

- Sometimes, will want to suspend (de-schedule) the current process, e.g.:
  - blocking reads and writes (networking)
  - waiting for semaphores
  - other IPC

- When a process is descheduled, a reference to it must be stored somewhere so that it can be resumed

- Related code, in the context of a **different** process will generally be responsible for waking it up (re-schedule)

- There are two ways to sleep/wakeup a process in MOSS:
  - simple: not signal friendly
  - complex: very signal friendly

  ... race-hazards on multi-processor systems

- Simple blocking:
  - store reference to current process
  - set process state to ‘sleeping’
  - reschedule (`MKernel.schedule()`)

- Simple wakeup:
  - recover reference of blocked process
  - if state is not sleeping, return
  - otherwise add to run-queue

- Any ‘blocking’ code must be worked in around this general framework

- Need somewhere to store blocked processes:

```
MWaitQueue blocked = new MWaitQueue();
```

- Simple blocking:

```
MProcess current =
    MKernel.current[MProcessor.currentCPU()];

blocking.add_to_queue (current);
current.state = MProcess.TASK_SLEEPING;
MKernel.schedule ();
```

- Simple wakeup:

```
MProcess other =
    blocking.get_from_queue ();

if (other.state == MProcess.TASK_SLEEPING) {
  MKernel.add_to_run_queue (other);
}
```

- Complex blocking: usually done in two parts, boolean flags involved:

```
boolean do_sleep = false;

synchronized (local) {
  synchronized (current) {
    blocked.add_to_queue (current);
    current.state = MProcess.TASK_SLEEPING;
    do_sleep = true;
  }
  // maybe wake up other blocked process
}

if (do_sleep) {
  boolean xsleep;

  synchronized (current) {
    xsleep =
      ((current.state == MProcess.TASK_SLEEPING)
       && !current.signalled);
  }
  if (xsleep) {
    MKernel.schedule ();
  }
  if (current.signalled) {
    synchronized (local) {
      blocked.del_from_queue (current);
    }
    // return indicating interrupted
  }
}
```

- Corresponding ‘wakeup’ is much simpler, however:

```
synchronized (local) {
  MProcess other =
      blocked.get_from_queue ();
  if (other.state == MProcess.TASK_SLEEPING) {
    MKernel.add_to_run_queue (other);
  }
}
```

- The complexity in the ‘sleep’ occurs because a process may be awoken as the result of an asynchronous signal

# Example: the pipe

- User-processes call '`MPosixIf.pipe()`' to create
  - this creates a new '`MPipe`' object and stores the MFileOps reference inside the process's 'file-table' (indexed by descriptor)
  - two (integer) descriptors are returned

- Read, write, etc. operations result in calls to the underlying MPipe **object**
  - user-process $\leftrightarrow$ posix-if:

```
public static int read
    (int fd, byte buffer[], int count)
```

  - posix-if $\leftrightarrow$ pipe-implementation:

```
public int read
    (MFile handle, byte buffer[], int count)
```

- The given implementation of a pipe (in '`MPipe.java`') is not entirely trivial. It does, however, attempt to be correct.
  - this includes being safe against asynchronous signal delivery...

- The implementation supports multiple readers and multiple writers on the same pipe (although such usage is not recommended)

- Now handles *end-of-file* and *SIGPIPE*

# CO501 Assignment

- Choice of 5 different things:
  - A better ‘pipe’ IPC mechanism
  - A ‘mail-box’ IPC mechanism
  - A ‘semaphore’ IPC mechanism
  - A virtual device-driver
  - ‘mail-box’ demonstrator program(s)

- Most people chose to implement the ‘mail-box’ IPC mechanism

- Not marked yet, but there appears to be a wide range of solutions

# Early Conclusions

- Going well so far :-)
- Complex in the expected places/ways
  - particularly for multi-CPU handling
- User processes cannot be destructive
  - MPosixIf (and below) are ‘defensive’
  - JVM will handle “null-pointer” exceptions, etc.
- Quite similar to Linux in some of the code logic (and presumably other UNIX systems)

# The Future

- More code ...
  - currently around 6000 lines

- File-systems:
  - basic infrastructure for file-system handling is in place
  - “Object File-System” under construction (free-hanging OO)

- Networking:
  - not in place, but most likely a ‘`socket()`’ in ‘MPosixIf’
  - some operations (bind/accept/listen) might be a bit of a fudge

# The Future (2)

- Applications:
  - a “telnet server” or equivalent
  - NFS client (and perhaps a server)
  - graphical interface ?

- Loaded in BlueJ successfully, mostly for the students, who seem strangely unfamiliar with “vi”..
  - might be nice to put BlueJ to some practical use, however – e.g. visualising/fiddling the ‘Object FS’