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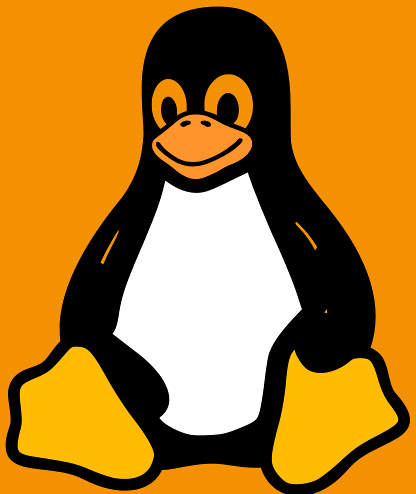

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OS 7 – Synchronisation 2

The lecture is based on the work and the documents of Prof. Dr. Ludwig Frank

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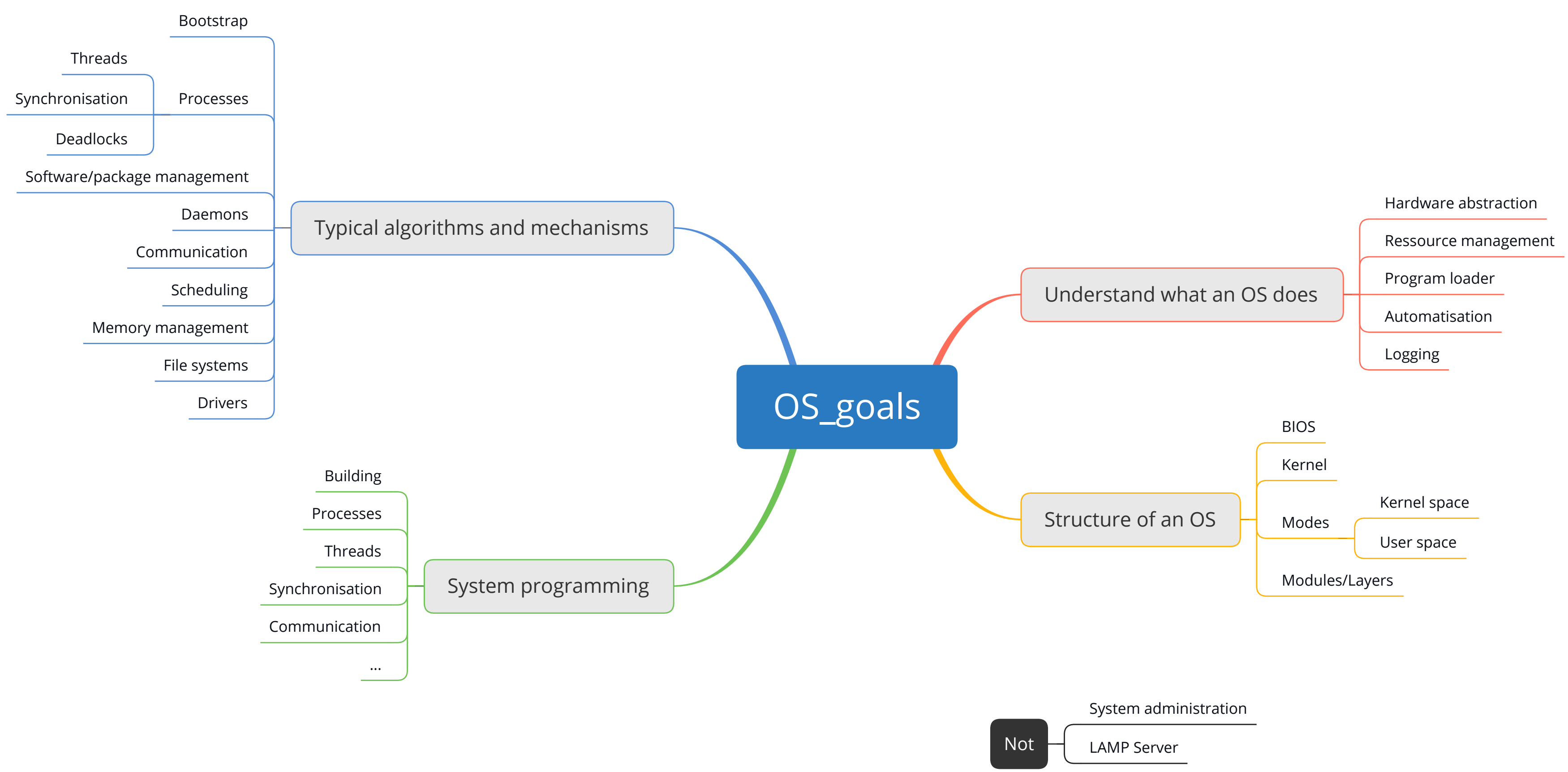
Goal



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Goal

OS::Synchronisation

- Producer-consumer problem
- Reader-writer problem
- Monitor concept

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Intro

Standard problems...

- Mutual exclusion (last week – check!)
- Producer-consumer problem
- Reader-writer problem

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Producer-consumer

Producer-consumer problem

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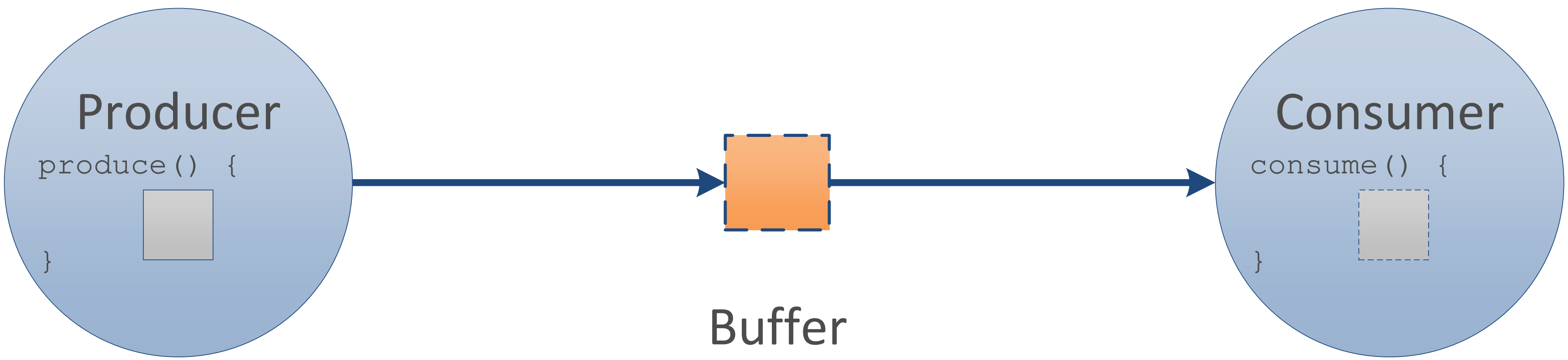
Producer-consumer (1): illustration



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Producer-consumer (1): facts

- **One or more** processes "**produce**" something
- **One or more** processes "**consume**" something
- There is a **buffer** with **one place** to **store** the produced "**artefact**"
- **Producer**
  - If it delivers an "artefact" it **can immediately produce** the **next**
  - If the buffer is full, the **producer waits until the buffer is free**
- **Consumer**
  - If it has consumed an "artefact" it **can immediately fetch** the **next**
  - If the buffer is empty, the **consumer waits until the buffer is full**

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Producer-consumer (1): pseudo C code

```
int buffer = 0;
seminit(buffer_free, 1);
seminit(buffer_full, 0);

void producer() {
    while(1) {
        int artefact = produce();

        P(buffer_free);
          buffer = artefact;
        V(buffer_full);


    }
}

void consumer() {
    while(1) {


        P(buffer_full);
          int artefact = buffer;
        V(buffer_free);

        consume(artefact);
    }
}

int main() {
    //start threads...
}
```

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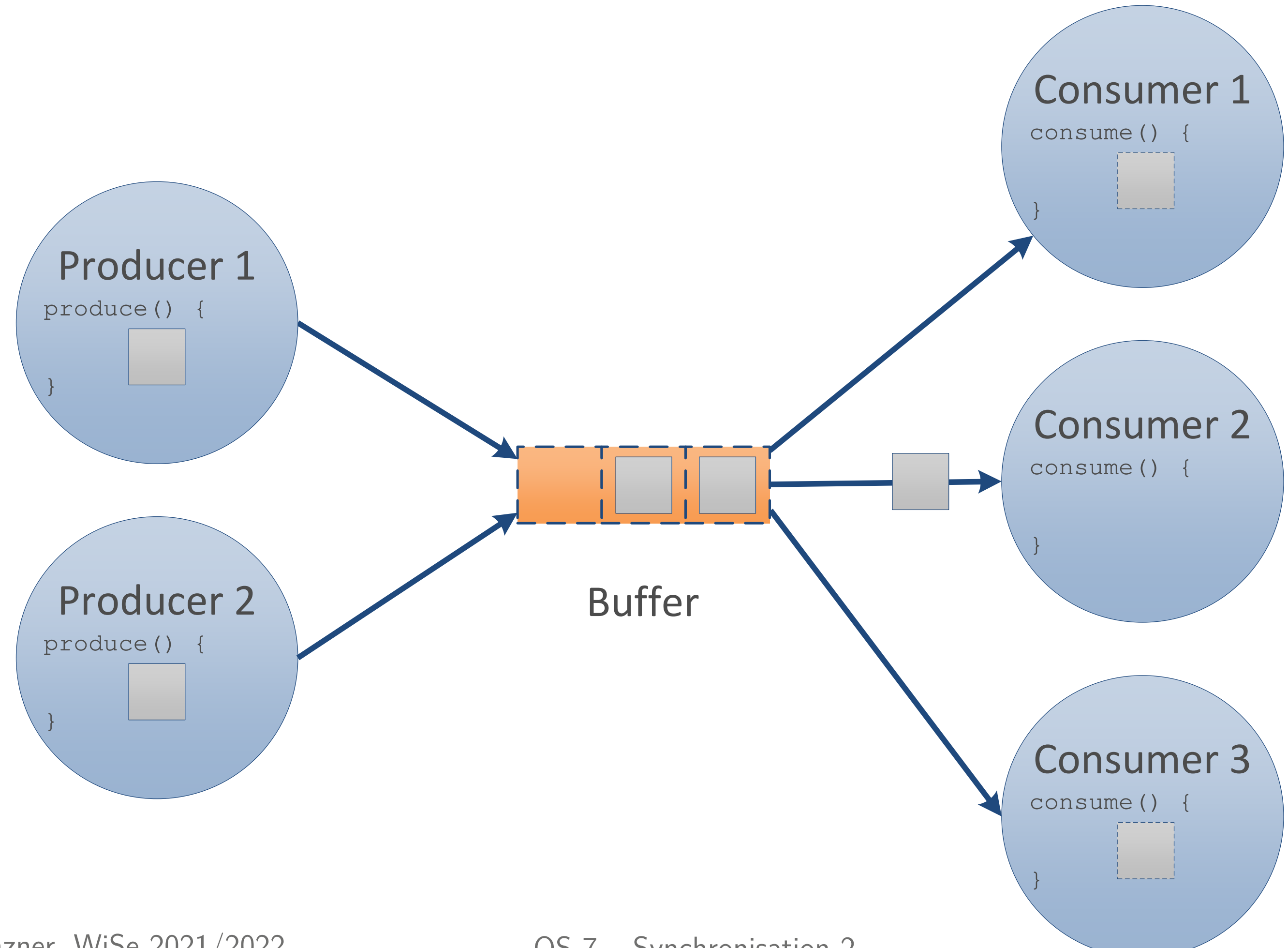
Producer-consumer (2): illustration



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Producer-consumer (2): facts

- **One or more** processes "**produce**" something
- **One or more** processes "**consume**" something
- There is a **buffer** with **N places** to **store** the produced "**artefacts**"
- **Producer**
  - If it delivers an "artefact" it **can immediately produce** the **next**
  - If the buffer is full, the **producer waits until the buffer has a free place**
- **Consumer**
  - If it has consumed an "artefact" it **can immediately fetch** the **next**
  - If the buffer is empty, the **consumer waits until the buffer contains at least one artefact**

Producer-consumer (2): pseudo C code

```c
const unsigned int N = 3;
int buffer[N];
seminit(buffer_free, N);
seminit(buffer_full, 0);
seminit(buffer_critical, 1); //binary semaphore
```

```c
void producer() {
    while(1) {
        int artefact = produce();

        P(buffer_free);

        P(buffer_critical);
          store_in_buffer(artefact);
        V(buffer_critical);

        V(buffer_full);


    }
}
```

```c
void consumer() {
    while(1) {


        P(buffer_full);

        P(buffer_critical);
          int artefact = fetch_from_buffer();
        V(buffer_critical);

        V(buffer_free);

        consume(artefact);
    }
}
```

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Reader-writer

Reader-writer problem

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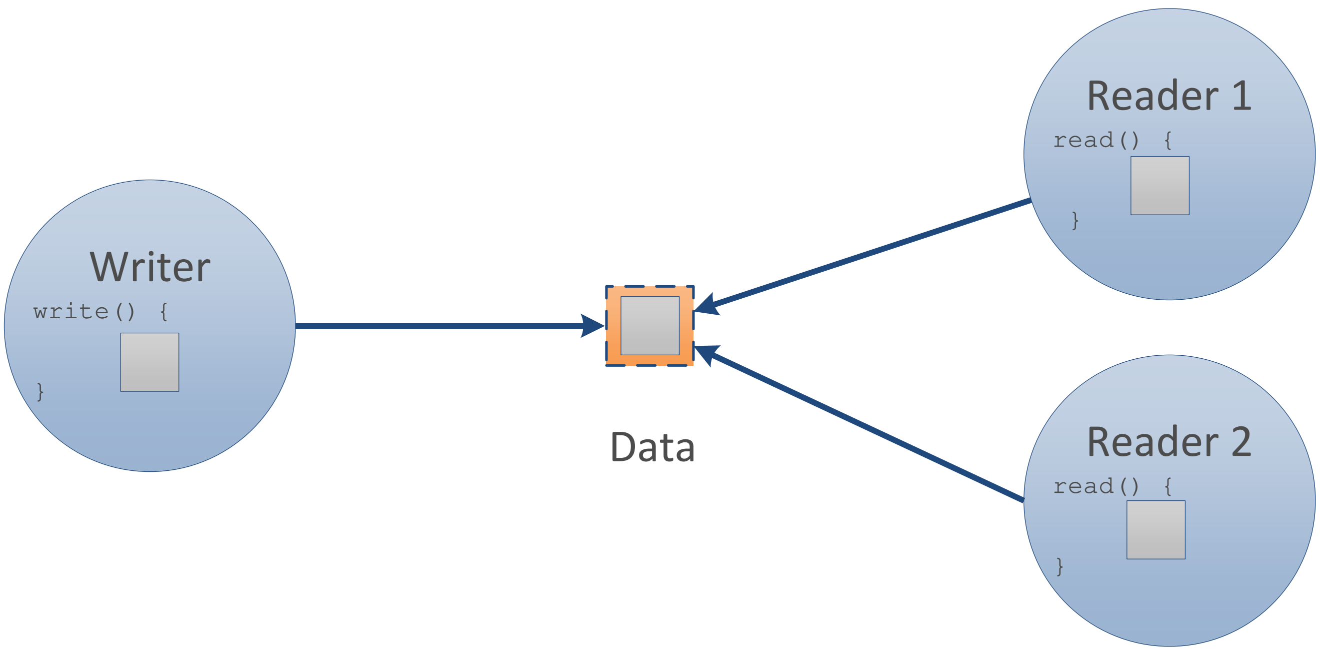
Reader-writer: illustration



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Reader-writer: facts

- **One or more** writers "**write**" something
- **One or more** readers "**read**" something
- There is a **shared area** for the data.
- **Writer**
  - After the data is written, a writer **can immediately collect** the **next** set of data
  - If **no readers** currently **read**, it **can write** the new set of data
  - If **readers** currently **read**, it **waits until all readers have finished**
- **Reader**
  - After the data is fully read, it can **work independently** with the data
  - If a writer is currently writing the readers have to **wait until the writer has fully provided the data**
  - It is not a consuming read, the **data stay in the shared data area**

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Reader-writer: pseudo C code

```c
int shared_data = 0;
int num_active_readers = 0;
seminit(data_access, 1);
seminit(readers, 1);
```

```c
void writer() {
  while(1) {
    int data = produce();
    P(data_access);
      write_data(data);
    V(data_access);
  }
}
```

```c
void reader() {
  while(1) {
    P(readers);
      ++num_active_readers;
      if(num_active_readers == 1) {
        P(data_access);
      }
    V(readers);
    data = read_data();
    P(readers);
      --num_active_readers;
      if(num_active_readers == 0) {
        V(data_access);
      }
    V(readers);
    work_with(data);
  }
}
```

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Monitor concept

Monitor concept, a short introduction.

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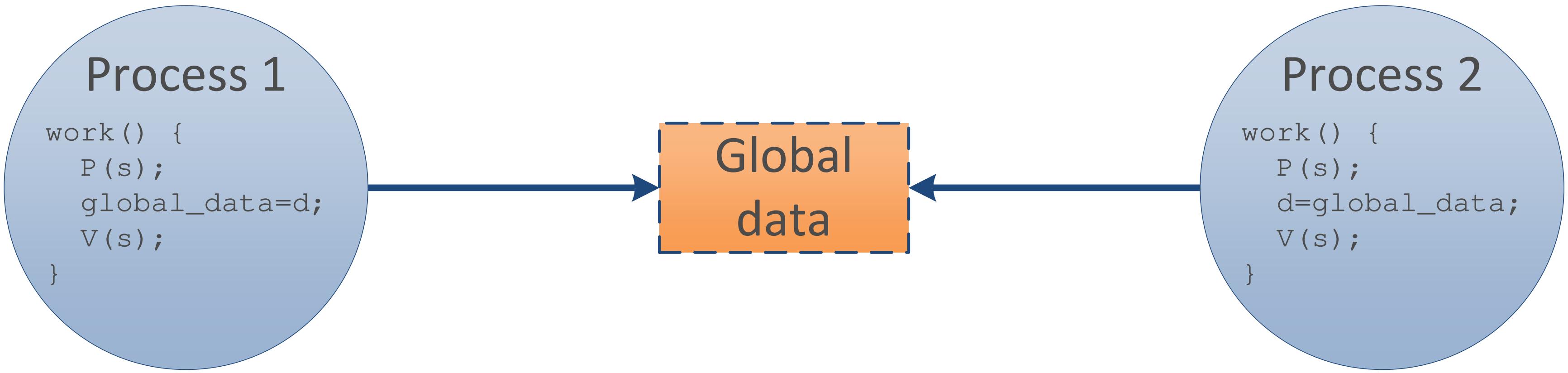
Problems with “raw” semaphores



- Implementation is difficult
- Depends on the correctness of all processes/threads
- Verification of correctness is difficult
- Difficult to determine which access functions read or change shared data
- Data is independent of access functions

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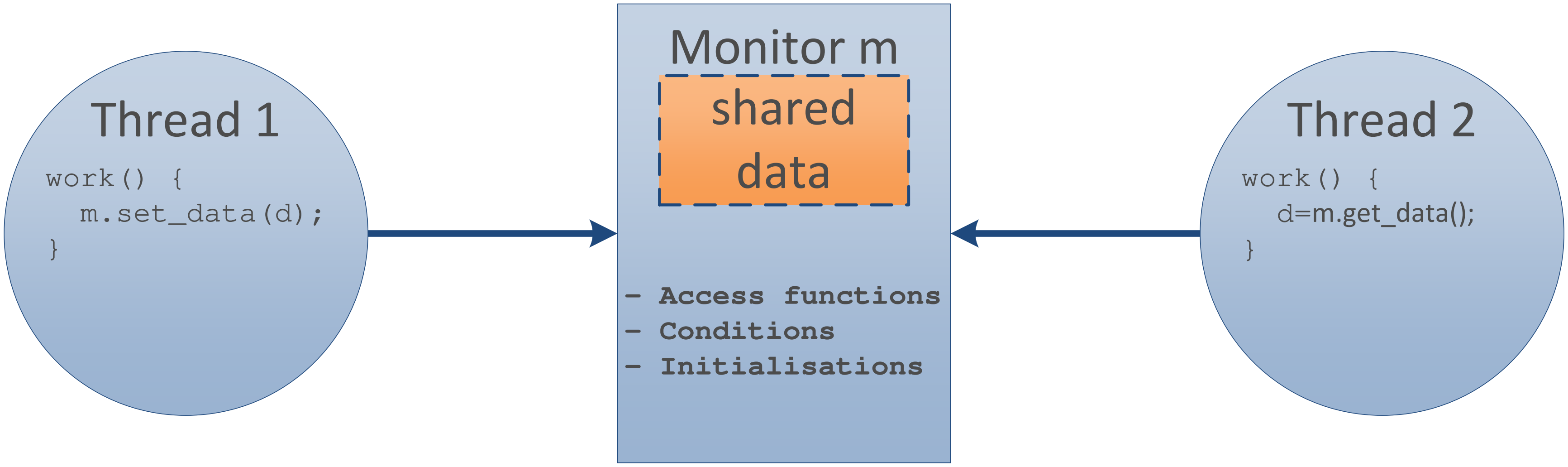
Monitor concept: illustration



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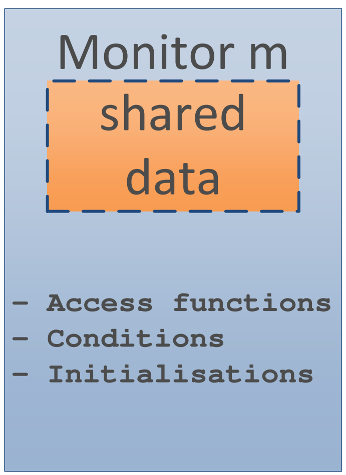
Monitor concept: facts



- Contains data and access functions
- Does all the initialisation of data
- Checks the conditions internally
- Access to the shared data is only possible via the access functions
- **Only** one **“active“** process/thread **can be inside an access function**

Pro

- Less error prone: less todo for the users (processes/threads)
- Concentration of the difficult know-how inside the monitor

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Monitor concept (light): pseudo C code

Monitor module

```
void* buffer = NULL;
seminit(buffer_free, 1);
seminit(buffer_full, 0);

void set_data(void* data) {
  P(buffer_free);
    buffer = data;
  V(buffer_full);
}

void* get_data() {
  P(buffer_full);
    void* data = buffer;
    buffer = NULL;
  V(buffer_free);
  return data;
}
```

Main module

```
void producer() {
    while(1) {
        void* data = produce();
        set_data(data);
    }
}
void consumer() {
    while(1) {
        void* data = get_data();
        consume(data);
    }
}
```

- This is a lightweight monitor example
- Usually, condition variables and mutexes are used

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Monitor concept: mutex and condition

Idea A mutex controls the access functions of a monitor. The conditions helps to implement the waiting logic.

Operation	Description
`Mutex mutex`	Creates an instance of a mutex. A mutex is like a binary semaphore. The only difference is, that only the calling process/thread can unlock it.
`Condition cond`	Creates a condition variable. A condition variable is a synchronisation primitive that enables a process/thread to wait until a particular condition occurs.
`lock(mutex)`	Locks a mutex. The others wait.
`unlock(mutex)`	Unlocks a mutex.
`wait(cond, mutex)`	Waits until the condition is fulfilled. The mutex is free while waiting.
`signal(cond)`	Signals that the condition is fulfilled. Notifies one.

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Monitor concept: pseudo C code

Monitor module

```
void* buffer = NULL;
Mutex mutex;
Condition buffer_free, buffer_full;
void set_data(void* data) {
  lock(mutex);
    if(buffer != NULL) { wait(buffer_free, mutex); }
    buffer = data;
    signal(buffer_full);
  unlock(mutex);
}
void* get_data() {
  lock(mutex);
    if(buffer == NULL) { wait(buffer_full, mutex); }
    void* data = buffer;
    buffer = NULL;
    signal(buffer_free);
  unlock(mutex);
  return data;
}
```

Main module

```
void producer() {
  while(1) {
    void* data = produce();
    set_data(data);
  }
}
void consumer() {
  while(1) {
    void* data = get_data();
    consume(data);
  }
}
```

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Summary and outlook

Summary

- Producer-consumer problem
- Reader-writer problem
- Monitor concept

Outlook

- Process communication
- Signals
- Sockets
- Pipes