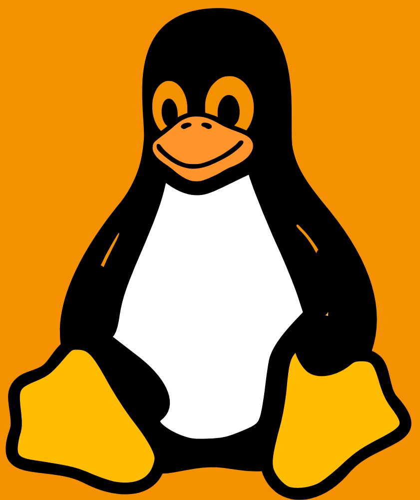
Prof. Dr. Florian Künzner

Technical University of Applied Sciences Rosenheim, Computer Science

OS 10 – Deadlocks



source: iconspng.com

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

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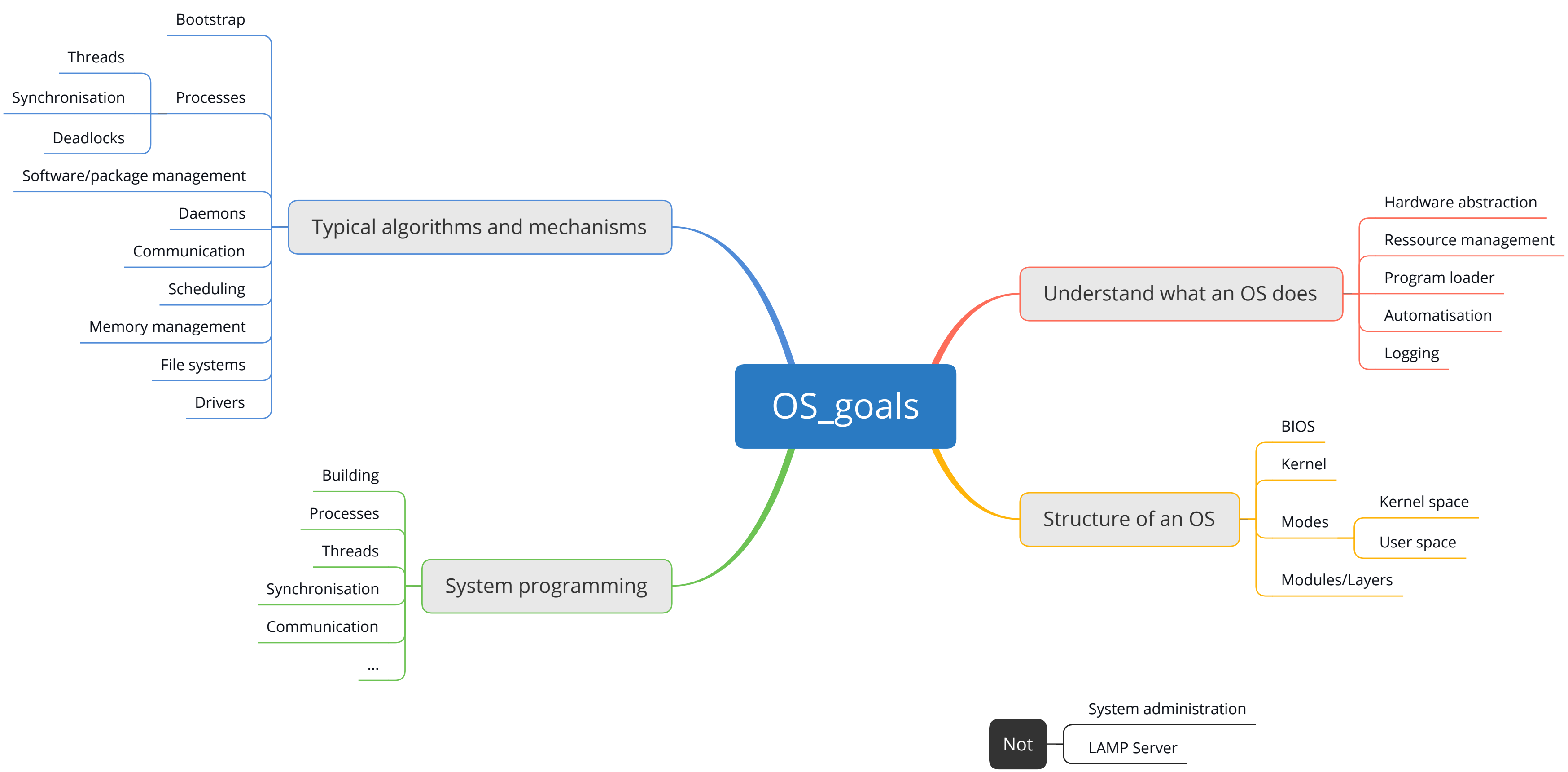
Goal



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Goal

OS::Deadlocks

- Intro
- Analysis
- Safe state
- Deadlock prevention
- Deadlock recovery

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Intro

Parallelisation with processes and threads and their synchronisation is nice, but...

Intro

Example 1

```
seminit(s, 0);
```

```
process1() {
    P(s);
    //critical area..,
    V(s);
}
```

```
process2() {
    P(s);
    //critical area..,
    V(s);
}
```

Problem

- **Deadlock**
- Reason: Critical area can't be accessed, because the **semaphore is initialised with 0**.

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Intro

Example 2

time

```
process1() {
  request(resource_a);
  //process change
  request(resource_b);
  //...
}
```

```
process2() {
  request(resource_b);
  //process change
  request(resource_a);
  //...
}
```

Problem

- **Deadlock**
- Reason: Resource is **already assigned** to other process (**both wait**)

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Definition

A **deadlock** is a situation where one ore more **processes wait for resource(s)** and **no one is able to get its required resource(s)**, because they are **waiting**.

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Analysis

How can a deadlock occur? We try a systematic analysis.

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Deadlock characterisation

A deadlock can occur under these conditions

Condition	Description
Mutual exclusion	Tasks **claim exclusive control** of the resources they require ("**mutual exclusion**" condition).
Hold and wait	Tasks **hold resources already allocated** to them while waiting for additional resources ("**wait for**" condition).
No preemption	Resources **cannot be forcibly removed** from the tasks holding them until the resources are used to completion ("**no preemption**" condition).
Circular wait	A circular chain of tasks exist, such that **each task holds one or more resources that are being requested by the next task** in the chain ("**circular wait**" condition).

Original paper: (E. G. COFFMAN et al., 1971) coffman_deadlocks.pdf

More details: `https://en.wikipedia.org/wiki/Deadlock`

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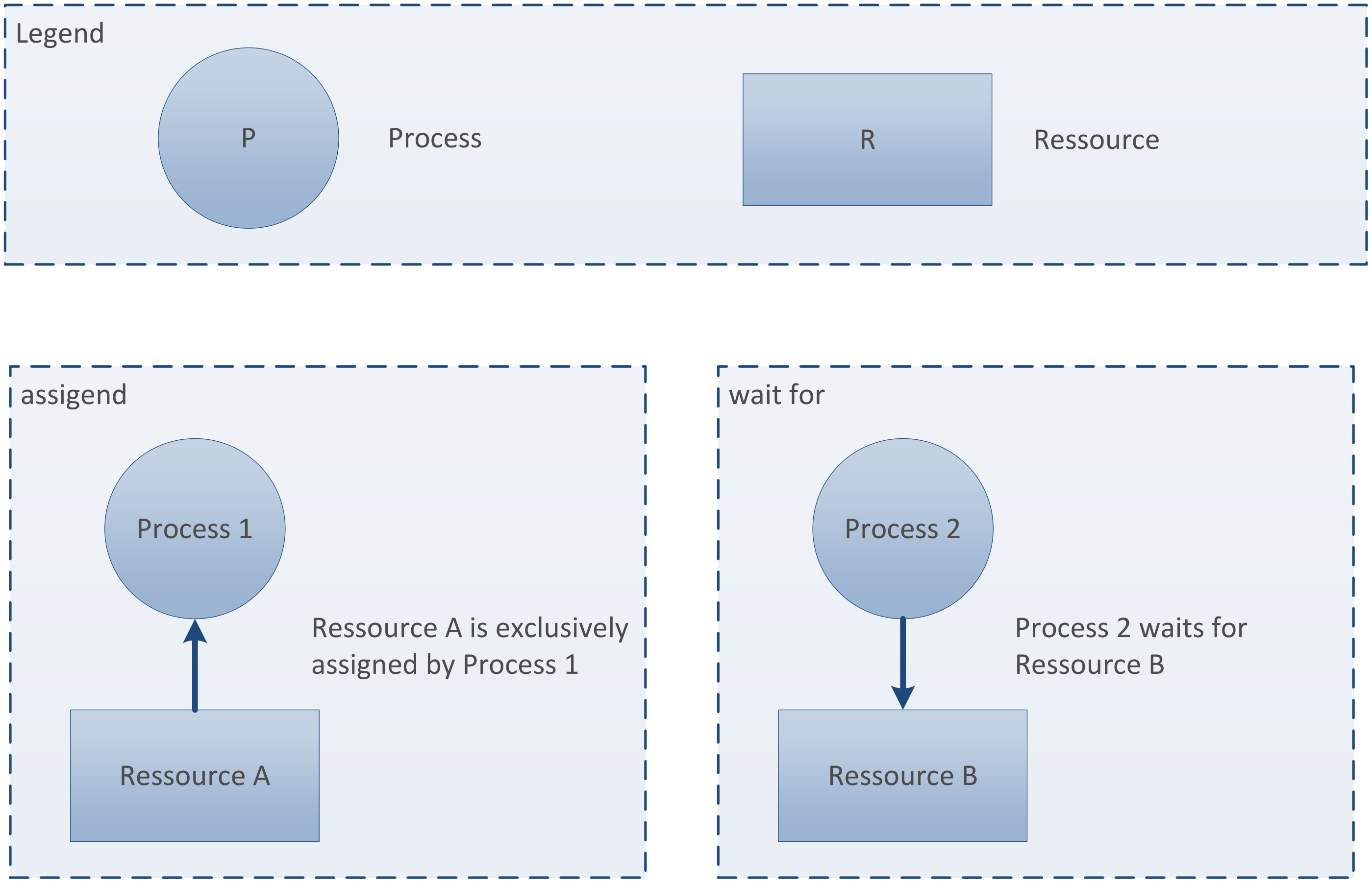
Analysis: notation



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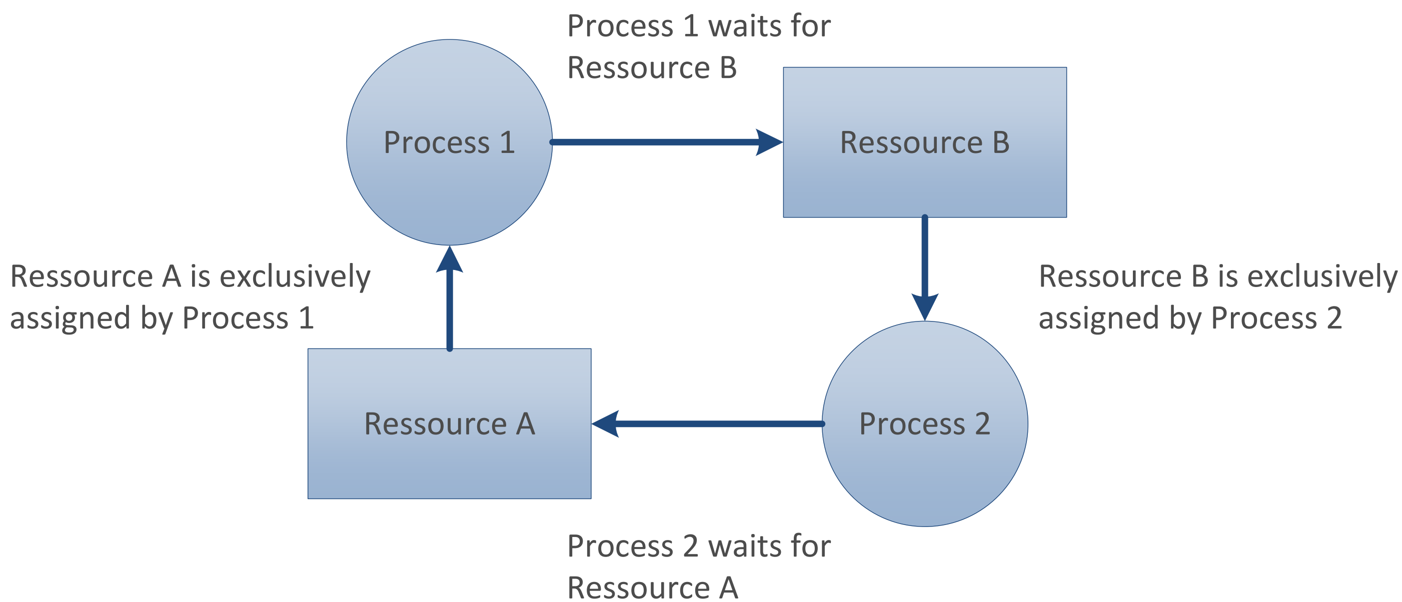
Analysis: example 1 (graphically)



- P1 <- A, P1 -> B, P2 <- B, P2 -> A
- **Circular wait: deadlock**.

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Questions?

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Safe state

Is the system in a safe state?

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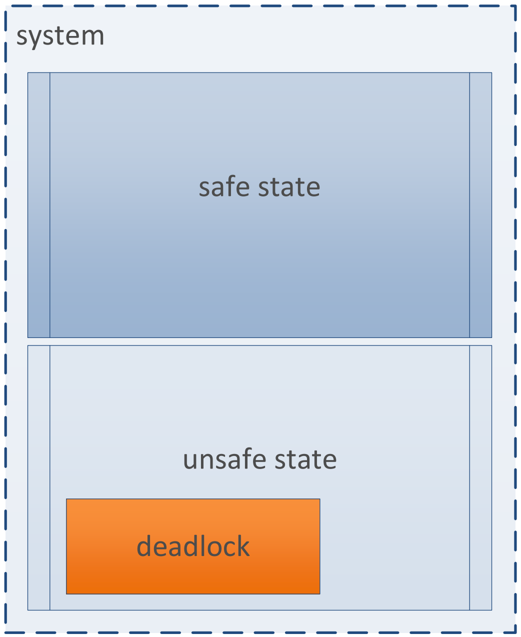
Safe state



Safe state

- A state is **safe**, if there is **no deadlock**, and there **exists at least one sequence** of processes that **ends not** in a **deadlock**.
- It is **guaranteed** that all processes can finish.

Unsafe state

- A state is **unsafe** if there is **a deadlock**, or there **exists only sequences** that **ends** in a **deadlock**.
- It is **not guaranteed** that all processes can finish.
- A deadlock is an unsafe state.

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Safe state: terms

Safe sequence of processes

A *sequence of processes* $(P_1, ..., P_n)$ is **safe** for a certain state of acquired resources, if *for every process* P_i $(1 \leq i \leq n)$ it is **guaranteed** that *all required resources* $(R_1, ..., R_m)$ can be **granted** including the resources that are acquired by P_j $(j < i)$.

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Safe state: example 1

There are 12 resources in total available.

Process	**Max. need**	**Acquisition** T_0	T_1	T_2	T_3	T_4	T_5	T_6
P_1	10	5	5	5	10	-	-	-
P_2	4	2	4	-	-	-	-	-
P_3	9	2	2	2	2	2	9	-
free		3	1	5	0	10	3	12

A safe sequence of processes exists ⇒ **the system is in a safe state** ☺

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Safe state: example 2

There are 12 resources in total available.

Process	**Max. need**	**Acquisition** T_0'	T_1	T_2
P_1	10	5	5	5
P_2	4	2	4	-
P_3	9	3	3	3
free		2	0	4

No safe sequence of processes exists ⇒ **the system is in an unsafe state** ☹

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Deadlock prevention

We try to **further investigate the conditions** under these a deadlock can occur, in order to **avoid it as much as possible**.

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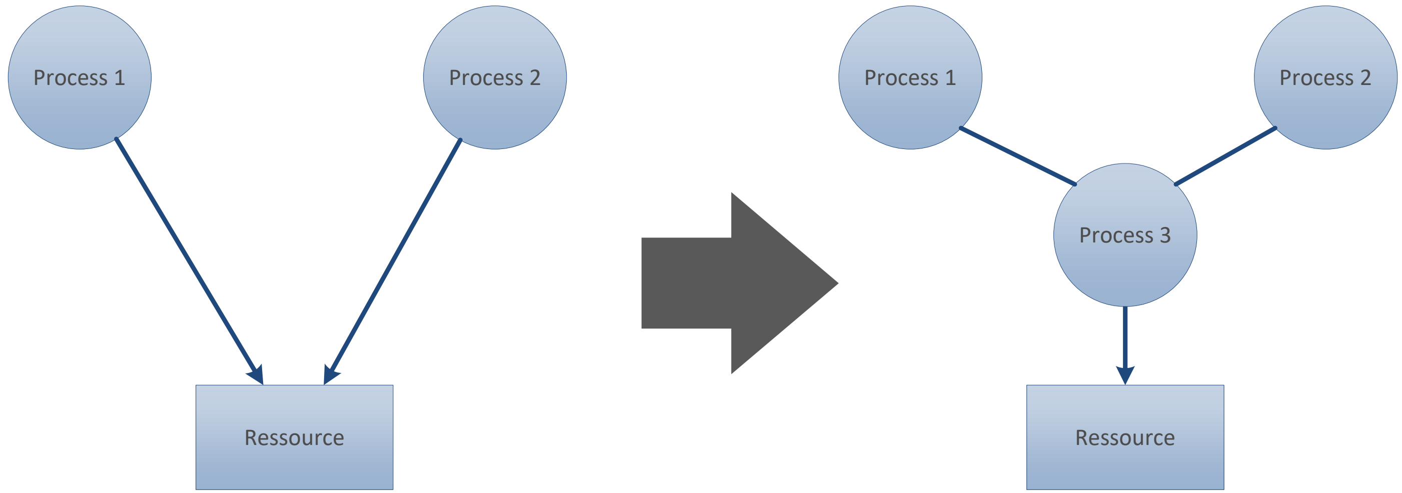
Prevent mutual exclusion

Idea: try to avoid the mutual exclusion.



Problems

- Not always possible
- Requires redesign of the application

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Prevent hold-on-wait

Idea: try to avoid the hold-on-wait.

A process tries to requests all resources at startup. If even one resource is not available, all resources are released, and the process waits.

Problems

- Often a process doesn't know at startup which resources it needs.
- This wastes resources, because they are acquired, but by no means used.
- It can happen that a process has to try it very often until it can acquire all resources.

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Prevent non-preemption

Idea: try to avoid the non-preemption.

Release all resources if a required resource isn't immediately available.

Problems

- With the release of a resource, often the whole work is lost and has to be repeated.
- It can happen that a process has to release the resources very often until it can complete its work.

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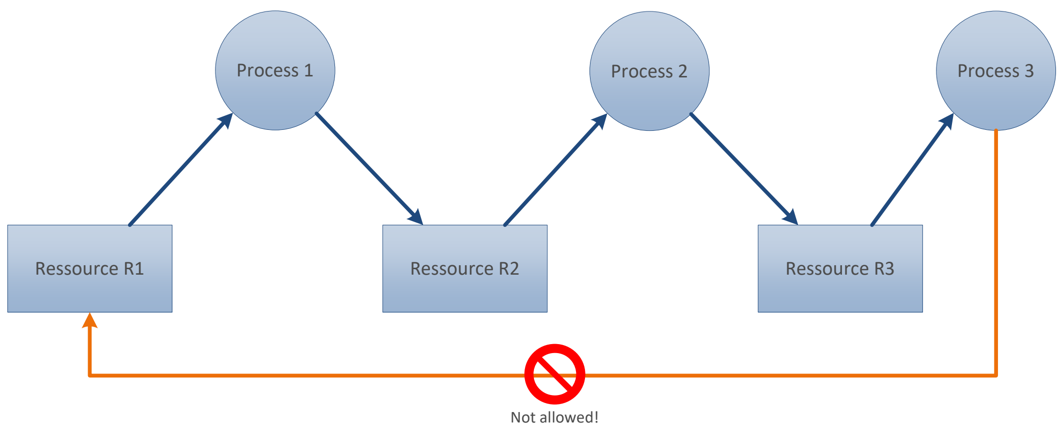
Prevent circular wait

Idea: try to avoid circles.

All resources are numbered. If a process has already acquired resource i, it can only acquire resource k (if $k > i$).



Problems

- Finding an order in which everyone is satisfied is not easy and not always possible.
- Some resources are created and removed at runtime. Numbering not possible.
- But: With this it is possible to proof the **deadlock free** acquisition: **All processes have to acquire the resources in the same order.**

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Deadlock prevention

The banker's algorithm

- For every resource that is acquired by a process it checks if the system stays in a safe state.
  - **True**: The **resource is given** to the process.
  - **False**: The **resource is not given** to the process.

Cost: $C = \texttt{num\_resources} * \texttt{num\_processes}^2$

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Deadlock recovery

What can we do if we are in an unsafe state with a deadlock?

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Deadlock recovery

Deadlock recovery strategies

- Terminate one or more processes involved in the deadlock
- Inform the system operator and give him instructions how to proceed (e.g. manual restart)
- Watchdog: automatically restart processes/device

source (compare): https://www.cs.uic.edu/~jbell/CourseNotes/OperatingSystems/7_Deadlocks.html

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Summary and outlook

Summary

- Deadlock intro
- Deadlock analysis
- Deadlock Safe state
- Deadlock prevention
- Deadlock recovery

Outlook

- Scheduling theory
- Scheduling algorithms