

# Machines and Resources

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## Constraint Based Production Scheduling

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# Key Points



- Introduce Different Types of Resources
- Disjunctive Resources - One Task at a Time
- Cumulative Resources - Demands and Capacity
- Machine Choice - Use one of multiple machines
- Calendars - Not working all the time

# Outline



Disjunctive Resources

Preemption

Cumulative Resources

Machine Choice

Work in Progress and Planned Downtimes

Calendars

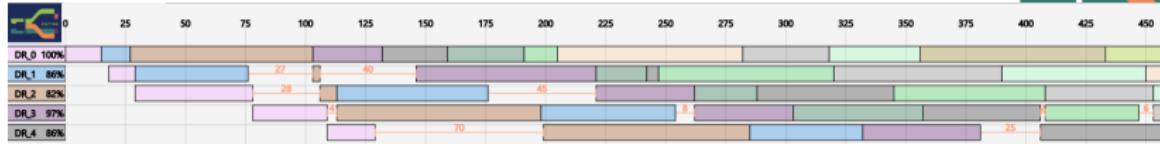
Summary

# Disjunctive Resource

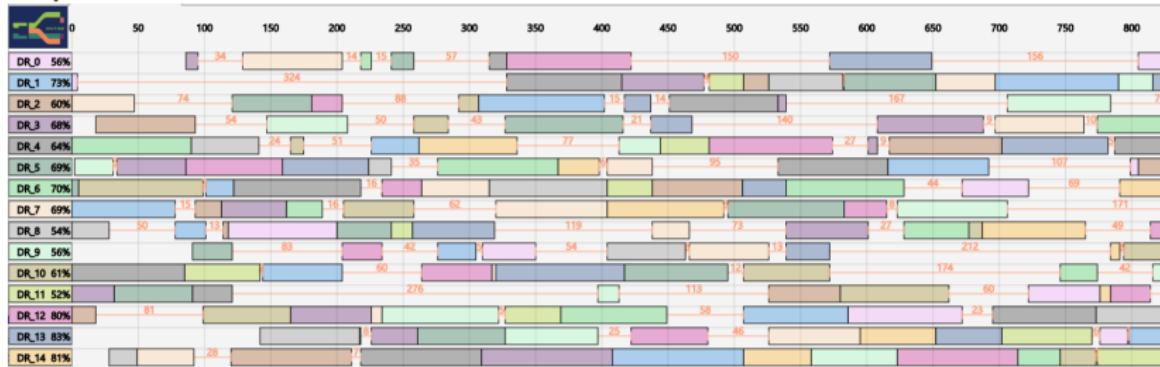


- A *disjunctive resource* works on one task at a time
- Each task runs uninterrupted from start to end
- The machine may be *idle* between tasks
- The machine may be unused at start and end of schedule
  - Some of this may be unreachable, there is not work that can be done in these periods
  - Problem of cold start, especially for flow-shop type problems
- Active time is time between first and last use
- Resource utilization compares productive time to active or available time

# Disjunctive Machines Examples



Flow-Shop example, some unreachable time on later resources in process, some idle time



Job-Shop example, a lot of idle time

# Preemption



- Normal constraint for disjunctive constraints is one task at a time
- Once a task is started, it runs until it is finished
- *Preemption* allows to stop a task, run a different task, then resume the previous task to the end
- Example: This is how Operating Systems run tasks inside a computer
  - This works since cost of suspending a task is relatively low
  - Also needed as tasks continuously produce output which is expected
- In manufacturing, preemption often is an exception in an emergency

# How to Deal with Preemption in Scheduling



1. Handle this as manual intervention for critical situations
2. Dedicated preemptive scheduling constraints
3. Allow limited number of interruptions
  - Split each task into multiple pieces of unknown length
  - Normally, schedule all parts together for total duration
  - For preemption, schedule other task after first/second part
  - All parts of task must add up to total duration

# Outline



Disjunctive Resources

Cumulative Resources

Demand and Capacity

Variants

Manpower

Nested Skill Levels

Assigned Operators

Fractional Manpower Needs

Machine Choice

Work in Progress and Planned Downtimes

Calendars

# Cumulative Resources



- A cumulative resource provides capacity over time, the sum of the demands at each timepoint cannot exceed the available capacity at that time
- Resource demand by one task is considered constant from start to end
  - Need to break task into smaller segments to model time variable demand
- In itself a hard problem, so full propagation not possible
  - Active research area since 1993, when the constraint was introduced in CHIP

# Time Variable Resource Cost



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# Soft/Hard Limit, Overtime Cost



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# Lower Utilization Limit



-

# Outline



Disjunctive Resources

Cumulative Resources

Machine Choice

Identical Machines

Machine Dependent Speed

Machine Preferences

Work in Progress and Planned Downtimes

Calendars

Summary

# Choosing which machine to use



- Problem with Job-shop/Flow-shop: There is only one machine
  - What happens if any of those machines stops working?
  - Do we stop production completely
- Most plants have multiple machine for the same task
- Three fundamental alternatives
  - Multiple, identical machines
  - Multiple machines with different speeds
  - Preferences for specific machines, but viable alternatives exist
- On the other hand, sometimes identical machines are treated as different
  - Dedicated lines for major products, avoiding setup/cleaning times

# Outline



Disjunctive Resources

Cumulative Resources

Machine Choice

Work in Progress and Planned Downtimes

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Disjunctive Resources

Cumulative Resources

Machine Choice

Work in Progress and Planned Downtimes

## Calendars

Factory Wide Calendars

Machine Specific Calendars

Changing Work Pattern

Varying Machine Speed

Task/Break Interaction

# Outline



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Summary

# Summary



- Introduced different resource types
- Identifying resources is a key element of defining scheduling problem
- As simple as possible - as complex as required