ISE480 Sequencing and Scheduling
What is Scheduling About?

Planning (deciding what to do) and scheduling (setting an order and time for planned events) are decision making processes that are used on a regular basis in many manufacturing and service industries.

- **Applied Operations Research (OR)**
  - Models
  - Algorithms

- **Solution using computers**
  - Implement algorithms
  - Draw on common databases
  - Integration with other systems
Operational Research

Mathematical Programming

Combinatorial Optimisation

Scheduling Theory

Problems of optimal arrangement, sequencing and timetabling
Operational Research

Mathematical Programming

Combinatorial Optimisation

Scheduling Theory

efficient allocation of one or more resources to activities over time
Scheduling concerns optimal allocation or assignment of resources, over time, to a set of tasks or activities.

It should be done in such a way that the company optimizes its objectives and achieves its goals.
Resources

✓ Machines in a work shop
✓ Runways at an airport
✓ Crew at a construction site
✓ Processing units in a computing environment
Activities (tasks)

✔ Operations in a work shop
✔ Take-offs and landings at an airport
✔ Stages in a construction project
✔ Computer programs to be executed

Each activity may have a priority level, an earliest possible starting time and a due date.
Objectives

✓ Minimize the time to complete all activities (makespan),
✓ Minimize the number of activities that are completed after the committed due dates (late jobs),
✓ Minimize the maximum time duration the activity is completed after the committed due date,
✓ Etc..
Resources (machines):
- machines at a workshop,
- runways at an airport,
- crews at a construction site,
- processing units in a computing environment.

Tasks (jobs):
- operations in a workshop,
- takeoffs and landings,
- stages at a construction project,
- computer programs.

Scheduling Theory
efficient allocation of one or more resources to activities over time

"machines process jobs"
Application Areas

✓ Procurement and production

✓ Transportation and distribution

✓ Information processing and communications
Manufacturing, e.g.:
- job shop / flow shop scheduling
- workforce scheduling
- tool scheduling

Services, e.g.:
- Hotel / airline reservation systems
- Hospitals (operating rooms; nurses, doctors)

Transportation and distribution, e.g.:
- vehicle scheduling and routing
- Railways, airways, sea ways
Information processing and communications:
- CPU’s, series and parallel computing
- call centers

Time-tabling, e.g.:
- lecture planning at a University
- soccer competition
- flight scheduling

Warehousing, e.g.:
- AGV scheduling and routing

Maintenance, e.g.:
- maintenance of a fleet of ships, airplanes, roads
Scheduling in manufacturing

Due to increasing market competition, companies strive to:

✓ shorten delivery times
✓ increase variety in end-products
✓ shorten production lead times
✓ increase resource utilization
✓ improve quality, reduce WIP
✓ prevent production disturbances (machine breakdowns)

--> more products in less time!
Different types of manufacturing control

- Make and assemble to stock
- Make to stock, assemble to order
- Make to order
- Engineer to order
Manufacturing Scheduling

- Short product life-cycles
- Quick-response manufacturing
- Manufacture-to-order

More complex operations must be scheduled in shorter amount of time with less room for errors!
Scheduling in services

- Workforce Scheduling in
  - Call Centers
  - Hospitals
  - Employment agencies
  - Schools, universities

- Reservation Systems in
  - Airlines
  - Hotels
  - Car Rentals
  - Travel Agencies

- Postal services
Scope of Course

- Levels of planning and scheduling
  - Long-range planning (several years),
  - middle-range planning (1-2 years),
  - short-range planning (few months),
  - scheduling (few weeks), and
  - reactive scheduling (now)

- These functions are now often integrated
Scheduling in a manufacturing planning and control framework

- Long range forecasting and sales planning
- Facility and resources planning
- Demand management, aggregate and workforce planning
- Order acceptance and resource group loading
- Shop floor scheduling, workforce scheduling
Scheduling in Manufacturing

1. Production planning, master scheduling
   - Orders, demand forecasts
   - Quantities, due dates

2. Material requirements planning, capacity planning
   - Material requirements
   - Shop orders, release dates

3. Scheduling and rescheduling
   - Detailed scheduling
   - Schedule

4. Dispatching

5. Shop floor management
   - Shop status
   - Shop floor

6. Shop floor management
   - Job loading
   - Data collection
Scheduling in Services

- Database
  - Status
  - Data
  - Accept/reject
  - Orders, reservations
  - Customer

- Scheduling
  - Pricing

- Database
  - Forecasts
  - Yield management
Scheduling Systems

- Enterprise Resource Planning (ERP)
  - Common for larger businesses

- Materials Requirement Planning (MRP)
  - Very common for manufacturing companies

- Advanced Planning and Scheduling (APS)
  - Most recent trend
  - Considered advanced feature of ERP
Relations with other management areas

✓ Product and process design
✓ Process planning
✓ Inventory management and materials planning
✓ Purchasing and procurement management
✓ Warehousing and physical distribution
Scheduling Problem

- Allocate scarce resources to tasks
- Combinatorial optimization problem

Max (Min) profit (cost)
Subject to constraints

- Mathematical techniques and heuristics
Our Approach

- Scheduling Problem
  - Problem Formulation
  - Model
    - Solve with Computer Algorithms
  - Conclusions
Scheduling Models

- Project scheduling
- Job shop scheduling
- Flexible assembly systems
- Lot sizing and scheduling
- Interval scheduling, reservation, timetabling
- Workforce scheduling
General Solution Techniques

- Mathematical programming
  - linear, non-linear, (mixed) integer programming
- Exact methods (enumeration)
  - branch-and-bound
  - dynamic programming
  - cutting plane / column generation methods
- Local search methods, metaheuristics
  - simulated annealing
  - tabu search
  - adaptive search
  - k-opt methods
  - genetic algorithms
  - neural networks
Cont..

- Constraint Programming
- Heuristics
  - dispatching rules
  - composite dispatching rules
  - beam-search
- Decomposition Techniques
  - Temporal decomposition (rolling horizon approach)
  - Machine decomposition (Shifting Bottleneck)
- Hybrid Methods
  - combined usage of scheduling methods
Important characteristics of optimization techniques

- Quality of Solutions Obtained (How Close to Optimal?)
- Amount of CPU-Time Needed (Real-Time on a PC?)
- Ease of Development and Implementation (How much time needed to code, test, adjust and modify)
- Implementation costs (Are expensive LP-solvers required?)
Scheduling System Design

- Databases
- Schedule generation
- User interfaces

Diagram:

- Order master file
- Shop floor data collection
- Database Management
- Automatic Schedule Generator
- Schedule Editor
- Performance Evaluation
- Graphical Interface
- User
Gantt charts

Henry Laurence Gantt (1861-1919)

Gantt chart is the horizontal bar chart, with the x-axis representing the time and the y-axis representing machines. A colour and/or pattern code may be used to indicate operations of the same job.
Examples

- Paper bag factory
- Gate assignments at an airport
- Scheduling tasks in a CPU

What are the resources (machines), tasks (jobs), and objectives?
Example 1 Paper Bag Factory

Different types of paper bags

- 3 production stages
  - printing of the logo
  - gluing of the side
  - sewing of one or both ends
- several machines for each stage
  - differences in speed and function
  - processing speed and processing quantity
  - setup time for a change of the bag type
- due time and late penalty
- minimization of late penalties, setup times
Example 2
Gate Assignments at Airport

Different types of planes (size)
- different types of gates (size, location)
- flight schedule
- randomness (weather, take off policy)
- service time at gate
- deplaning of passengers
- service of airplane
- boarding of passengers
- minimization of work for airline personnel
- minimization of airplane delay
Example 3 Tasks in a CPU

- different applications
- unknown processing time
- known distributions (average, variance)
- priority level
- multitasking environment
- preemption
- minimization of the sum of expected weighted completion times
5 job single machine exercise

Minimize $\sum w_j C_j$

where $C_j$ is the completion time of job $j$,
$p_j$ is the processing time of job $j$,
$w_j$ is the weight (priority) of job $j$
(First try Min $\sum C_j$)

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Reading Assignment

Chapters 1, 2 and 3 from
Pinedo, M., Planning and Scheduling in Manufacturing and Services, Springer, 2005

Chapters 1 and 2 from

Chapter 1 from
Baker, K. And D. Tietsch, Principles of Sequencing And Scheduling, J. Wiley, 2009