<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01: Introduction</td>
<td>History, background</td>
</tr>
<tr>
<td>02: Foundations</td>
<td>Basic terminology and properties of graphs</td>
</tr>
<tr>
<td>03: Extensions</td>
<td>Directed &amp; weighted graphs, colorings</td>
</tr>
<tr>
<td>04: Network traversal</td>
<td>Walking through graphs (cf. traveling)</td>
</tr>
<tr>
<td>05: Trees</td>
<td>Graphs without cycles; routing algorithms</td>
</tr>
<tr>
<td>06: Network analysis</td>
<td>Basic metrics for analyzing large graphs</td>
</tr>
<tr>
<td>07: Random networks</td>
<td>Introduction modeling real-world networks</td>
</tr>
<tr>
<td>08: Computer networks</td>
<td>The Internet &amp; WWW seen as a huge graph</td>
</tr>
<tr>
<td>09: Social networks</td>
<td>Communities seen as graphs</td>
</tr>
</tbody>
</table>
Course overview

Goals

1. Introduce the basic mathematical tools to understand the fundamentals of complex networks
2. Provide the skills that are needed to perform basic analyses of such networks

Means

1. Study fundamental concepts from graph theory and random networks
2. Lots of exercises in proving properties of various well-known networks
3. Practice the use of network analysis tools: Mathematica with Combinatorica
## Course overview

### Goals

1. Introduce the basic mathematical tools to understand the fundamentals of complex networks
2. Provide the skills that are needed to perform basic analyses of such networks

### Means

1. Study fundamental concepts from graph theory and random networks
2. Lots of exercises in proving properties of various well-known networks
3. Practice the use of network analysis tools: Mathematica with Combinatorica
Some practical matters

- In principle: per week two lectures along with two tutorials
  - Maarten van Steen: lectures (in Dutch)
  - Maarten van Steen: exercise classes IMM students (Dutch)
  - Spyros Voulgaris: exercise classes CS students (English)
  - Albana Gaba, Mansoorek Zahedi, Parisa Zahedi: assistance practical work

- Homework assignments:
  - Using Mathematica/Combinatorica
  - Analyzing graphs

- There will be a midterm exam

- Exam will cover theory and homework

Note

This course is taught for the third time and still contains experimental elements (essentially: math in computer science context). Stay alert.
Some practical matters

- In principle: per week two lectures along with two tutorials
  - Maarten van Steen: lectures (in Dutch)
  - Maarten van Steen: exercise classes IMM students (Dutch)
  - Spyros Voulgaris: exercise classes CS students (English)
  - Albana Gaba, Mansoorek Zahedi, Parisa Zahedi: assistance practical work

- Homework assignments:
  - Using Mathematica/Combinatorica
  - Analyzing graphs

- There will be a midterm exam
- Exam will cover theory and homework

Note
This course is taught for the third time and still contains experimental elements (essentially: math in computer science context). Stay alert.
Some practical matters

- In principle: per week two lectures along with two tutorials
  - Maarten van Steen: lectures (in Dutch)
  - Maarten van Steen: exercise classes IMM students (Dutch)
  - Spyros Voulgaris: exercise classes CS students (English)
  - Albana Gaba, Mansoorek Zahedi, Parisa Zahedi: assistance practical work

- Homework assignments:
  - Using Mathematica/Combinatorica
  - Analyzing graphs

- **There will be a midterm exam**

- Exam will cover theory and homework

Note

This course is taught for the third time and still contains experimental elements (essentially: math in computer science context). Stay alert.
Some practical matters

- In principle: per week two lectures along with two tutorials
  - Maarten van Steen: lectures (in Dutch)
  - Maarten van Steen: exercise classes IMM students (Dutch)
  - Spyros Voulgaris: exercise classes CS students (English)
  - Albana Gaba, Mansoorek Zahedi, Parisa Zahedi: assistance practical work

- Homework assignments:
  - Using Mathematica/Combinatorica
  - Analyzing graphs

- There will be a midterm exam

- Exam will cover theory and homework

Note

This course is taught for the third time and still contains experimental elements (essentially: math in computer science context). Stay alert.
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>01: Introduction</strong></td>
<td>History, background</td>
</tr>
<tr>
<td>02: Foundations</td>
<td>Basic terminology and properties of graphs</td>
</tr>
<tr>
<td>03: Extensions</td>
<td>Directed &amp; weighted graphs, colorings</td>
</tr>
<tr>
<td>04: Network traversal</td>
<td>Walking through graphs (cf. traveling)</td>
</tr>
<tr>
<td>05: Trees</td>
<td>Graphs without cycles; routing algorithms</td>
</tr>
<tr>
<td>06: Network analysis</td>
<td>Basic metrics for analyzing large graphs</td>
</tr>
<tr>
<td>07: Random networks</td>
<td>Introduction modeling real-world networks</td>
</tr>
<tr>
<td>08: Computer networks</td>
<td>The Internet &amp; WWW seen as a huge graph</td>
</tr>
<tr>
<td>09: Social networks</td>
<td>Communities seen as graphs</td>
</tr>
</tbody>
</table>
What are these networks?

Observation

Many real-world systems can be viewed as a collection of nodes that are linked to each other.

1. Traffic infrastructure: roads, railways, shipping, airlines
2. Social communities: family ties, online communities
3. Communication networks: Internet, telecommunication

Question

What are the nodes and what are the links?
What are these networks?

**Observation**

Many real-world systems can be viewed as a collection of nodes that are linked to each other.

1. Traffic infrastructure: roads, railways, shipping, airlines
2. Social communities: family ties, online communities
3. Communication networks: Internet, telecommunication

**Question**

What are the nodes and what are the links?
The connected world

Observation
When it comes to connecting people, there is a long history of networks.

- In the very old days: carriers of messages (pigeons, ponies, etc.)
- Also in the old days: fire beacons, mirrors, drums, flags. **Note:** we need encoding schemes to use this type of communication.
- Since the late 1900s: communication networks
Historical communication networks

**Basic idea:** Set up pairs of shutter stations, with pairs in line of sight. Then, code the letters to be transmitted:
By the 1850s, communication was carried over more than 30,000 kms of electrical telegraph. Shutter stations became obsolete.

The world of telephony was a fact.
Observation

In traditional telecommunications networks, to hold a conversation, it was necessary to make a physical connection between the two parties ⇒ circuit-switched network.
In modern telephony networks, everything is **packetized**:

- Data (including **samples** from continuous media) is put into a **packet**.
- Packets are extended with address of destination and are independently **routed**.

![Diagram of packetized network](image-url)
From telephony to Internet

Next step

Connect many computers through switches that automatically discover and maintain **routes**. The Internet was born.
The modern Internet: Some “facts”

- 1.4 billion users = 1,400,000,000
- 1 trillion (static) Web pages = 1,000,000,000,000
- 180 million Web servers
- Probably over 20 million DNS servers (for resolving names)
- Over 2.5 billion Internet (IPv4) addresses (3.7 billion are usable)
The modern Internet on display

5 M edges
50 M routes
Red  Asia
Green Europe++
Blue  N-America
Yellow S-America
Cyan  CIDR addr.
White Unknown
Network examples: Dutch railways
Network examples: Airline flights

Continental Airlines

United Airlines

Question

What main differences can be seen?
Network examples: Airline flights

Continental Airlines

United Airlines

Question

What main differences can be seen?
Network examples: social networks

Yellow: obese  |  Green: nonobese  |  Purple: friend/marriage  |  Red: family