Introduction

What PGMs are, what this course is about and how it is organised.

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This class is a conceptual introduction to probabilistic graphical models (PGMs), it also covers course organisation.

ILOs After this class the student

- understands what PGMs are about at a conceptual level;
- recognises what PGMs are meant for;
- knows what this course will cover;
- knows how this course is organised.

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Textbook for this course: Koller and Friedman [2].

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Probabilistic Graphical Models

Probabilistic Graphical Models (PGMs)

Probabilistic graphical models combine

- statistics and probability theory
- and computer science

to solve hard problems involving variables we are **uncertain** about.

Medical diagnosis: uncertainty about predisposing factors, symptoms, test results, diseases, treatment outcomes, etc.

Image segmentation: uncertainty about the class of pixel (or super-pixels) e.g., 'sky', 'water', 'grass', 'cow', 'flight', etc.

Translation: uncertainty about bilingual dictionary entries and transfer rules.

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Medical diagnosis: uncertainty about predisposing factors, symptoms, test results, diseases, treatment outcomes, etc.

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What do these problems have in common?

- large number of variables,
- significant uncertainty about the right answer.

The **model** is a declarative representation of our understanding of the world.

It is expressed in terms of the variables we are reasoning about and how we believe or assume they interact with one another.

Probabilistic Graphical Models

PGMs are designed to help us deal with uncertainty.

The model itself is a *representation* of our uncertainty about the world. And it can be used to *support decision making*.

Uncertainty comes in many forms and for many reasons:

- Partial knowledge of the state of the world
- Noisy observations
- Modelling limitations
- Inherent ambiguity and/or stochasticity

Probability theory is the most widely used framework for uncertainty representation.

For other mathematical frameworks for uncertainty representation see Halpern [1].

Graphs allow us to represent complex systems involving many interacting variables.

We will use graphs to code domain knowledge and represent probability distributions.

Graphs are not only efficient data structures that support efficient algorithms, they are amenable to systematic analysis: we can ascertain properties of distributions by studying the graph structure.

What is a probabilistic graphical model?

A representation of the world that takes into account the things we care and are uncertain about and our assumptions about their relationships.

What can we do with it?

Answer queries about the world and make decisions under uncertainty.

How do we construct them?

A combination of domain knowledge and learning from historical data.

Widespread Applications

- Medical diagnosis
- Fault diagnosis
- Natural language processing
- Traffic analysis
- Social network models
- Message decoding
- Computer vision
- Speech recognition
- Robot localisation and mapping
- Forecasting (weather, finances, supply chains, etc.)

and the list goes on...

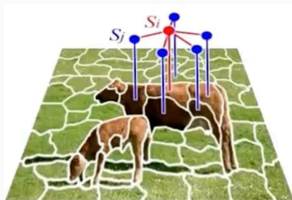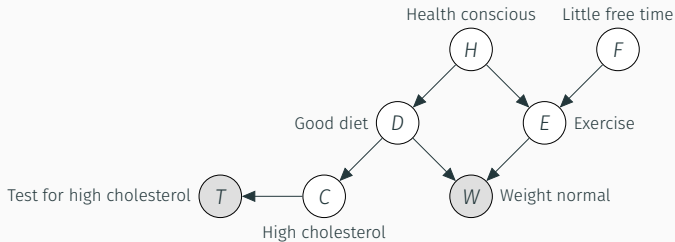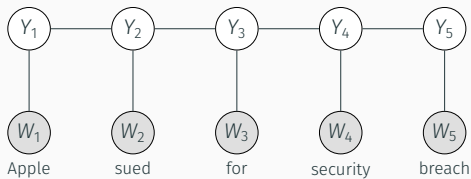Health conscious · H · Little free time · F

Good diet · D · E · Exercise

Test for high cholesterol · T · C · W · Weight normal

High cholesterol

Image by Daphne Koller

Y_1 — Y_2 — Y_3 — Y_4 — Y_5

W_1 (Apple) · W_2 (sued) · W_3 (for) · W_4 (security) · W_5 (breach)

Representation

- Directed and undirected graphical models
- Parameterisation

Reasoning

- Exact and approximate inference
- Decision making

Learning

- Parameters
- Observed and unobserved data

Course Organisation

Learning Activities

HCs: we develop the main theory planned for the week and solve some exercises; sometimes there's reading that's necessary before or after the class.

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LCs: we translate the main ideas in PGMs to Python code; because PGMs deal with graph structure, probabilistic inference and statistical learning, programming exercises will often help you consolidate your knowledge of the theory.

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WCs: we work on exam-like exercises, discuss feedback, and sometimes cover some side topics that help you get a good hold of the material.

Exams: midterm (40%) and endterm (40%).

Programming: weekly assignments (due on Friday), the best 5 (out of 6) contribute to 20% of your final grade.

In-class bonus: weekly exercises offered in-class (HC) only, each week we offer 0.5 points for a total of 3 points throughout the entire course; these points go directly to your final grade.

Exam-like questions: these are available for self-study and self-assessment; a subset of these are available as 0-points assignments on ANS, if you submit you get individual feedback.

Grade

Your final grade is obtained as follows:

$$\text{grade} = \mathsf{SIS}(0.8 \times \text{exam} + 0.2 \times \text{programming} + \text{bonus})$$

This grade is rounded and clipped for SIS as follows

- lowerbounded by 1 (e.g., 0.2 is mapped to 1);
- rounded to the closest half point if between 1 and 5 or between 6 and 10 (e.g., 4.2 is mapped to 4.0, 6.8 is mapped to 7);
- rounded to the closest point if it falls between 5 and 6 (e.g., 5.4 is mapped to a 5, while 5.5 is mapped to a 6).

No minimum requirement on any one of the partial grades, but the final grade must be a 6.0 for you to pass this course.

Disclaimer: check *https://canvas.uva.nl/courses/53146/ pages/assessment-and-grade* for the official rules, this is only a summary.

Platforms

The course is managed entirely on Canvas, this is the official source of information, announcements, deadlines, and material: *https://canvas.uva.nl/courses/53146*

We use a few additional tools, for specific purposes:

- ANS: exam-like exercises, grading and feedback
- Ed: asynchronous Q&A (see Ed House Rules on Canvas) *https://canvas.uva.nl/courses/53146/pages/ ed-house-rules?module_item_id=2640464*

Class recordings are available from Canvas, see Webcolleges: *https: //canvas.uva.nl/courses/53146/external_tools/21068*

Rest of HC1a: BNs (semantics)

LC1: BNs in code

HC1b: BNs (reasoning and influence)

WC1: BN exercises (semantics, reasoning and influence)

References

[1] Joseph Y Halpern. *Reasoning about uncertainty*. MIT press, 2017.

[2] Daphne Koller and Nir Friedman. *Probabilistic graphical models: principles and techniques*. MIT press, 2009.