Name:

Birth Date:

Matriculation Number:

Exam
Artificial Intelligence 2

July 30., 2019

	To be used for grading, do not write here													
prob.	1.1	1.2	2.1	2.2	3.1	3.2	3.3	3.4	4.1	4.2	5.1	5.2	Sum	grade
total	7	5	4	10	10	4	8	3	10	8	5	6	80	
reached														

Exam Grade: Bonus Points: Final Grade:

Organizational Information

Please read the following directions carefully and acknowledge them with your signature.

1. Please place your student ID card and a photo ID on the table for checking
2. The grading information on the cover sheet holds with the proviso of further checking.
3. no resources or tools are allowed except for a pen.
4. You have 90 min(sharp) for the test
5. You can reach 80 points if you fully solve all problems. You will only need 70 points for a perfect score, i.e. 10 points are bonus points.
6. Write the solutions directly on the sheets.
7. If you have to abort the exam for health reasons, your inability to sit the exam must be certified by an examination at the University Hospital. Please notify the exam proctors and have them give you the respective form.
8. Please make sure that your copy of the exam is complete (18 pages including cover sheet and organizational information pages) and has a clear print. **Do not forget to add your personal information on the cover sheet and to sign this declaration (next page).**

Declaration: With my signature I certify having received the full exam document and having read the organizational information above.

Erlangen, July 30., 2019 ....

(signature)

Organisatorisches

Bitte lesen die folgenden Anweisungen genau und bestätigen Sie diese mit Ihrer Unterschrift.

1. Bitte legen Sie Ihren Studentenausweis und einen Lichtbildausweis zur Personenkontrolle bereit!
2. Die angegebene Punkteverteilung gilt unter Vorbehalt.
3. Es sind keine Hilfsmittel erlaubt außer eines Stifts.
4. Die Lösung einer Aufgabe muss auf den vorgesehenen freien Raum auf dem Aufgabenblatt geschrieben werden; die Rückseite des Blatts kann mitverwendet werden. Wenn der Platz nicht ausreicht, können bei der Aufsicht zusätzliche Blätter angefordert werden.
5. Wenn Sie die Prüfung aus gesundheitlichen Gründen abbrechen müssen, so muss Ihre Prüfungsunfähigkeit durch eine Untersuchung in der Universitätsklinik nachgewiesen werden. Melden Sie sich in jedem Fall bei der Aufsicht und lassen Sie sich das entsprechende Formular aushändigen.
6. Die Bearbeitungszeit beträgt 90 min.
7. Sie können 80 Punkte erreichen, wenn Sie alle Aufgaben vollständig lösen. Allerdings zählen 70 Punkte bereits als volle Punktzahl, d.h. 10 Punkte sind Bonuspunkte.
8. Überprüfen Sie Ihr Exemplar der Klausur auf Vollständigkeit (18 Seiten inklusive Deckblatt und Hinweise) und einwandfreies Druckbild! **Vergessen Sie nicht, auf dem Deckblatt die Angaben zur Person einzutragen und diese Erklärung zu unterschreiben!**

Erklärung: Durch meine Unterschrift bestätige ich den Empfang der vollständigen Klausurunterlagen und die Kenntnisnahme der obigen Informationen.

Erlangen, July 30., 2019 ....

(Unterschrift)

Please consider the following rules; otherwise you may lose points:

- If you continue an answer on another page, please indicate the problem number on the new page and give a page reference on the old page.
- Always justify your statements (we would like to give poins for incorrect answers). Unless you are explicitly allowed to, do not just answer "yes", "no", or "42".
- If you write program code, give comments!

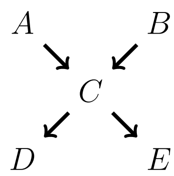
1 Bayesian Reasoning

Problem 1.1 (Medical Bayesian Network 2)
Both smoking and living in a city with high air pollution can cause lung cancer, which can be indicated by a patient coughing up blood. We consider the following random variables for a given patient: 7 pt

- *Smoke*: The patient is a smoker.
- *Smog*: The patient lives in a polluted city.
- *Blood*: The patient is coughing up blood.
- *LC*: The patient has lung cancer.

1. Draw the corresponding Bayesian network for the above data using the algorithm presented in the lecture, assuming the variable order $Smoke, Smog, Blood, LC$. Explain rigorously(!) the exact criterion for whether to insert an arrow between two nodes.
2. Which arrows are causal and which are diagnostic? Which order of variables would be better suited for constructing the network?
3. How do we compute the probability the patient is a smoker, given that they have lung cancer? State the query variables, hidden variables and evidence and write down the equation for the probability we are interested in.

Problem 1.2 (Stochastic and Conditional independence)
Consider the following Bayesian network: 5 pt



Find

1. two variables that are stochastically independent, but not conditionally independent for some condition, and

2. two variables that are **not** stochastically independent, but conditionally independent for some condition.

For both pairs, state the condition explicitly and justify why they are correct answers. Assume that the conditional probabilities modelled by this network are not degenerate or exceptional in any way (e.g. no 0 or 1 entries).

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2 Decision Theory

Problem 2.1 (Expected Utility)
What is the formal(!) definition of *expected utility*? Explain every variable in the defining equation. 4 pt

Problem 2.2 (Textbook Decisions)

Abby has to decide whether to buy Russell&Norveig for 100$. There are three boolean variables involved in this decision: B indicating whether Abby buys the book, M indicating whether Abby knows the material in the book perfectly anyway and P indicating that Abby passes the course. Additionally, we use a utility node U. 10 pt

Abbys utility function is additive, so $U(B) = -100$. Furthermore, she evaluates passing the course with a utility of $U(P) = 2000$. The course has an open book final exam, so B and P are not independent given M. Assume the conditional probabilities $P(P|B, M)$, $P(P|B, \neg M)$, $P(P|\neg B, M)$, $P(P|\neg B, \neg M)$, $P(M|B)$, $P(M|\neg B)$ are given.

1. Draw the decision network for this problem. 4 pt
2. Explain how to compute the utility of buying the book. State the equation underlying this algorithm explicitly. 6 pt

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3 Markov Models

Problem 3.1 (Markov Decision Procedures)

10 pt

1. What are the mathematical components of a Markov decision procedure? (In other words: If you had to give me an unambiguous MDP, which mathematical objects would you have to give me?)

2. What is the Bellman equation and what algorithm is it used for? How does that algorithm work?

3. What is the difference between *partially observable Markov decision procedures* and normal MDPs?

Problem 3.2 (Prediction, Filtering, Smoothing)
Explain the goals of *prediction, filtering* and *smoothing* in terms of conditional probabilities 4 pt

Problem 3.3 (Markov Mood Detection)

On any given day d, your roommate Moody is in one of two states – either he is happy (H_d) or he is in a bad mood (B_d). Usually when he's in a bad mood, it's because he had a fight with his boyfriend and those tend to go on for a couple of days, so $P(B_{d+1}|B_d) = 0.7$, but aside from that he's a cheery guy, so ($P(H_{d+1}|H_d) = 0.85$). 8 pt

Of course you try to avoid talking to people, but you can hear his music blasting all day which tends to shift depending on his mood. On a good day he usually listens to Jazz (i.e. $P(J_d|H_d) = 0.7$), on a bad day he slightly prefers Death Metal ($P(DM_d|B_d) = 0.6$). He has a limited taste in music, so it's always one of the two.

You know that he was in a good mood at day d_0. Assume he's been listening to death metal for n days straight since then. Explain how to compute the probability that he is in a bad mood on day d_{n+1}. State the equations underlying this algorithm explicitly.

Problem 3.4 (Stationary)
Define what it means for a Markov model to be *stationary*, and why we are interested in stationarity. 3 pt

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4 Learning

Problem 4.1 (Home Decisions)
Eight people go sunbathing. Some of them got a sunburn, others didn't: 10 pt

Name	Hair	Height	Weight	Lotion	Result
Sarah	Blonde	Average	Light	No	Sunburned
Dana	Blonde	Tall	Average	Yes	None
Alex	Brown	Short	Average	Yes	None
Annie	Blonde	Short	Average	No	Sunburned
Julie	Blonde	Average	Light	No	None
Pete	Brown	Tall	Heavy	No	None
John	Brown	Average	Heavy	No	None
Ruth	Blonde	Average	Light	No	None

Explain how the information-theoretic decision tree learning algorithm would proceed on this table (up to two iterations). Explicitly state how to compute the information gain (and what that means).

Note that you do not need to compute any actual values; if it is helpful for your explanation, you may guess any values you might want to use.

Note that *Name* is only an index, not a (meaningful) attribute!

Problem 4.2 (Backpropagation)

Explain what *Backpropagation* means in the context of Neural Networks, when and why we need it, and how to do it using an example. 8 pt

5 Communication with Natural Language

Problem 5.1 (Ambiguity)

5 pt

1. Explain the concept of ambiguity of natural languages.
2. Give two examples of different kinds of ambiguity and explain the readings.

Problem 5.2 (Language Identification)

You are given an English, a German, a Spanisch, and a French text corpus of considerable size, and you want to build a language identification algorithm A for the EU administration. Concretely A takes a string as input and classifies it into one of the four languages $\ell^* \in \{English, German, Spanish, French\}$. The prior probability distribution for the strings being English/German/Spanisch/French, is $\langle 0.4, 0.2, 0.15, 0.15 \rangle$. 6 pt

How would you proceed to build algorithm A? Specify the general steps and give/derive the formula for computing ℓ given a string $\mathbf{c}_{1:N}$.

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