Name:

Birth Date:

Matriculation Number:

Exam
Artificial Intelligence 2

Feb. 18., 2021

	To be used for grading, do not write here												
prob.	1.1	1.2	1.3	2.1	2.2	3.1	3.2	4.1	4.2	4.3	4.4	Sum	grade
total	10	8	6	6	15	12	10	12	8	3	5	95	
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 95 points if you fully solve all problems. You will only need 90 points for a perfect score, i.e. 5 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 (16 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, Feb. 18., 2021 .....

(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 95 Punkte erreichen, wenn Sie alle Aufgaben vollständig lösen. Allerdings zählen 90 Punkte bereits als volle Punktzahl, d.h. 5 Punkte sind Bonuspunkte.
8. Überprüfen Sie Ihr Exemplar der Klausur auf Vollständigkeit (16 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.

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(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!

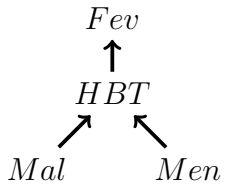
1 Bayesian Reasoning

Problem 1.1 (Medical Bayesian Network) 10 pt

Both Malaria and Meningitis can cause a fever, which can be measured by checking for a high body temperature. Of course you may also have a high body temperature for other reasons. We consider the following random variables for a given patient:

- Mal: The patient has malaria.
- Men: The patient has meningitis.
- HBT: The patient has a high body temperature.
- Fev: The patient has a fever.

Consider the following Bayesian network for this situation:



1. Explain the purpose of the edges in the network regarding the conditional probability table.
2. What would have happened if we had constructed the network using the variable order Mal, Men, Fev, HBT? Would that have led to a better network?
3. How do we compute the probability the patient has malaria, given that he has a fever? State the query variables, hidden variables and evidence and write down the equation for the probability we are interested in.

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Problem 1.2 (Bayesian Rules) 8 pt

For each of the following principles, state the key formula and explain the variables occurring in it:

1. Bayes rule
2. Marginalization

Problem 1.3 (Stochastic and Conditional independence) 6 pt

Consider the following random variables:

- three flips C_1, C_2, and C_3 of the same fair coin, which can be heads or tails
- the variable E which is 1 if both C_1 and C_2 are heads and 0 otherwise
- the variable F which is 1 if both C_2 and C_3 are heads and 0 otherwise

Out of the above 5 random variables,

1. give three random variables X, Y, Z such that X and Y are stochastically independent but not conditionally independent given Z,

2. give three random variables X, Y, Z such that X and Y are not stochastically independent but conditionally independent given Z.

2 Decision Theory

Problem 2.1 (Expected Utility) 6 pt

What is the formal(!) definition of *expected utility*? Explain every variable in the defining equation.

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Problem 2.2 (Textbook Decisions) 15 pt

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.

Abby's 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.

2. Explain precisely how to compute the utility of buying the book.

3 Markov Models

Problem 3.1 (Markov Decision Procedures) 12 pt

1. What are the mathematical components of an unambiguous Markov decision procedure?
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* MDPs and normal MDPs?

Problem 3.2 (Stock Market Predictions) 10 pt

You bought SpaceY stock recently and try to predict whether to buy more or sell. The stock market is in one of two possible states; bull state or bear state. In a bull state, it will (in the long term) be advantageous to buy stock; in a bear state it will be more advantageous to sell.

If the market is in a bull state, the probability it will still be in a bull state tomorrow is 60%. If it is in a bear state, the probability it will remain so tomorrow is 80%.

1. If we consider this as a hidden Markov model, what are the random variable, its domain, and its transition matrix T?

2. In terms of the stock market example, explain what probabilities are computed by *prediction*, *filtering* and *smoothing*. You do not need to give the formulas.

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4 Learning

Problem 4.1 (Sunbathing) 12 pt

Eight people go sunbathing. They are categorized by the attributes Hair and Lotion and the result of whether they got sunburned.

Name	Hair	Lotion	Result: Sunburned
Sarah	Light	No	Yes
Dana	Light	Yes	No
Alex	Dark	Yes	No
Annie	Light	No	Yes
Julie	Light	No	No
Pete	Dark	No	No
John	Dark	No	No
Ruth	Light	No	No

1. Which quantity does the information theoretic decision tree learning algorithm use to pick the attribute to split on?

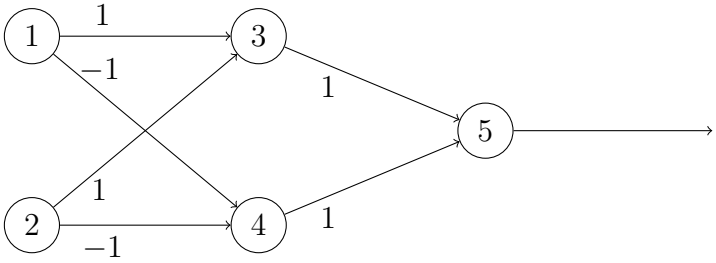
2. Compute that quantity for the attributes Hair and Lotion. (Simplify as much as you can without computing logarithms.)

3. Assuming the logarithms are computed, how does the algorithm pick the attribute?

Problem 4.2 (XOR Neural Network) 8 pt

Consider the following neural network with

- inputs a_1 and a_2
- units $3, 4, 5$ with activation functions such that $a_i \leftarrow \begin{cases} 1 & \text{if } \Sigma_j w_{ji} a_j > b_i \\ 0 & \text{otherwise} \end{cases}$
- weights w_{ij} as given by the labels on the edges



5 pt

1. Assume $b_1 = b_2 = b_3 = 0$ and inputs $a_1 = a_2 = 1$. What are the resulting activations a_3, a_4, and a_5?

3 pt

2. Choose appropriate values for b_1, b_2, and b_3 such that the network implements the XOR function.

Problem 4.3 (Overfitting) 3 pt

Explain what *overfitting* means and why we want to avoid it.

Problem 4.4 (Information Theory) 5 pt

Consider the learning curve, which gives the percentage of correct answers on the test set in terms of the size of the training set.

1. Informally describe the typical shape of this curve.
2. In practice, does the correctness commonly reach 100%? Briefly justify your answer.

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