NTNU

Department of Computer and Information Science

# Examination paper for (course code) (course title)

## TDT4136 - Introduction to Artificial Intelligence

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**Examination date:** 19/12/2016

**Examination time (from-to):** 09:00 – 13:00

**Permitted examination support material:** D No
printed or handwritten material is permitted.
Calculator is permitted.

**Other information:**
Results: 19 January 2017
If you believe that some information is missing in the formulation of a problem, briefly describe the necessary assumptions you made.

**Language:** English

**Number of pages (front page excluded):** 6

**Number of pages enclosed:** 7

**Checked by:**

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Date Signature

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# (NOTE: All the answers need to be written down into answer sheets, not into the question list.)

# TASK 1: Task Environment (10p)

Specify the task environment of the following four agents.

*Note 2020: Several students have pointed out that there sometimes exists reasonable alternative answers to questions about agent environments. On future exams these kinds of questions will be discussion questions where you will explain your answers and what assumptions you make.*

Possible answers:
Observable: Fully (F) or partially (P).
Agents: Single (S) or Multi (M)
Deterministic: Deterministic (D) or stochastic (S).
Episodic: Episodic (E) or sequential (S)
Static: Static (S), semi (I) or dynamic (D)
Discrete: Discrete (D) or continuous (C)

Agent 1: Deep Blue
Deep Blue is a chess playing agent that played and won against Garry Kasparov in 1997. Consider one game against Garry using a clock.

Agent 2: Roomba
Roomba is a vacuum-cleaning robot that drives around and vacuums the floors in all the rooms of a home.

Agent 3: A Tesla factory paint-robot.
A paint robot on the Tesla factory paints one and one car. The cars are transported by a transport robot to and from the paint robot. The paint robot uses a spray-painting robot arm to paint the cars.

Agent 4: Stats Monkey the robot journalist
Stats Monkey collects box scores and play-by-play data to spit out credible accounts of college baseball games while the games are being played.

*Answer to be written down into answer sheet following the given table:*

| Task Environment | Observable P/F | Agents S/M | Deterministic D/S | Episodic E/S | Static S/D/I | Discrete D/C |
|---|---|---|---|---|---|---|
| Deep Blue | | | | | | |
| Roomba | | | | | | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Paint robot | | | | | | |
| Stats Monkey | | | | | | |

# TASK 2: Propositional and first-order logic (20p)

a) (4p) What are the advantages and disadvantages of the propositional logic ? What is the difference between implication and entailment in propositional logic ? (*The answer should be shorter than one page)*.

b) (4p) Convert the following formula to CNF (conjunctive normal form)

$$(A \wedge B) \Rightarrow (\neg A \Leftrightarrow B)$$

c) (2p) Multiple choice

The formula $\forall x \exists y\ P(x,y) \rightarrow \exists q\ P(q,q)$ would be treated as a validity

1. Under all possible circumstances
2. By an inference engine that implements occurs check as Skolem functions
3. By an inference engine that implements occurs check as Skolem constants
4. Under no possible circumstances

d) (3p) True or False (*correct answer= 1p; wrong answer= -½p; total score will be 0-3p*)

1. Universal Instantiation is built on Skolemization.
2. The Backward Chaining Algorithm can be described as follows:
   i. Pose the original query as a goal.
   ii. Find every clause in the knowledge base whose right-hand side unifies with the goal under some substitution.
   iii. Prove in turn every conjunct on the left-hand sides of each of these clauses, keeping track of the accumulated substitutions.
3. There exists a sentence S in First Order Logic such that S cannot be converted into an inferentially equivalent sentence in Conjunctive Normal Form.

e) The statement "Every Russian school boy knows a game"[1] has two interpretations:

A. There exists a game such that every Russian school boy knows this game.

B. For each Russian school boy, there exists a game so that the boy knows this game.

Questions:

1. (2p) Formulate each of these two interpretations in first order logic.

2. (2p) Convert the formulas into clausal form.

3. (3p) Use either a resolution proof or the Tableaux method to show that the logical formulation of interpretation A implies the logical formulation of interpretation B.

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1 *The saying "Every Russian schoolboy knows …" (that you must recapture with the pawn!) is attributed to the Soviet chess Grandmaster David Bronstein who used it to imply how little Western chess players (in the 1950s) understood of the game compared to any Russian. However, Bronstein never met Magnus Carlsen* 🏝

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# TASK 3: Search (20p)

You are going to evaluate search algorithms that can find the shortest indoor walking paths. Figure 2 illustrates seven rooms and the actual walking distances between them. Table 1 specifies the straight-line distances between room 127D and all the other rooms. The evaluation function f(n) evaluates node n. When we evaluate the algorithms, we start our path search in room 181 and we want to find the shortest path to room 127D, which is our end node.

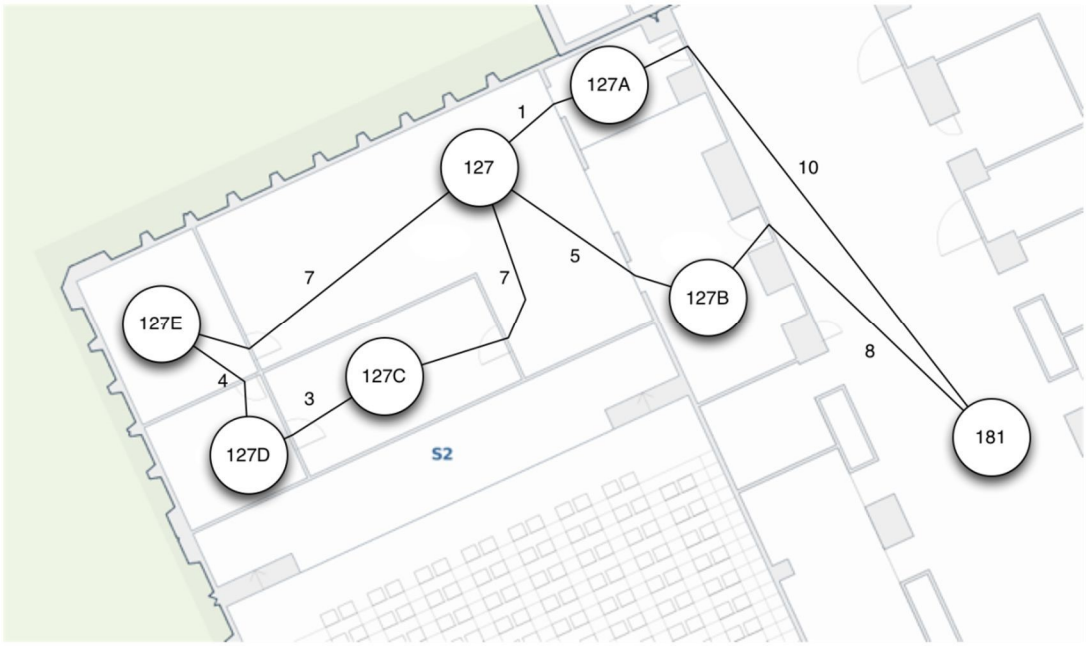


*Figure 1: The graph represents the possible walking paths between the seven rooms 127D, 127E, 127C, 127, 127A, 127B and 181. The numbers close to the paths indicate the actual walking distances between the connected rooms.*

*Table 1: Straight line distance between the rooms and 127D*

| Room | SLD from 127D |
|---|---|
| 127 | 7 |
| 127A | 10 |
| 127B | 9 |
| 127C | 3 |
| 127E | 2 |
| 181 | 14 |

a) Greedy best-first search (3p): What is the evaluation function f(n) for greedy best-first search? Write the function and describe the term(s) on the right hand side.

b) A* (3p): What is the evaluation function for A*? Write the function and describe the term(s) on the right hand side.

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c) Greedy best first search (3p): For each step in the search, write the evaluation function for the node that is selected for expansion.

d) A* (3p): For each step in the search, write the evaluation function including all the terms and their values for the node that is selected for expansion.

e) Admissible heuristics (4p): Explain what an admissible heuristics is in one sentence only. Give two examples of admissible heuristics for the 8-puzzle where the objective is to slide tiles horizontally or vertically into the open space until the goal state is reached.

f) Optimality of A* for graph search (1p): Must the heuristics be both admissible and consistent in order for the Russel and Norvig version of A* to be optimal when applied to graph search? Alternatives: Yes or No.

g) Search algorithms (3p): Which of the search algorithms 1) A*, 2) genetic algorithms, 3) minimax, 4) constraint propagation should be chosen for the following search problems:
    1. Search for a schedule of flights that has some restrictions.
    2. Search for best action in backgammon.
    3. Find the best design of a car.
    4. Find the shortest route for a self-diving car.

# TASK 4: Constraint satisfaction (20p)

Figure 2 shows the water regions in Norway, which there are eleven of, and these are Finnmark (F), Troms (T), Norland (N), Sør-Trøndelag (ST), Møre og Romsdal (MR), Østfold (Ø), Sogn of Fjordane (SF), Hordaland (H), Buskerud (B), Rogaland (R) and Vest-Agder (VA).

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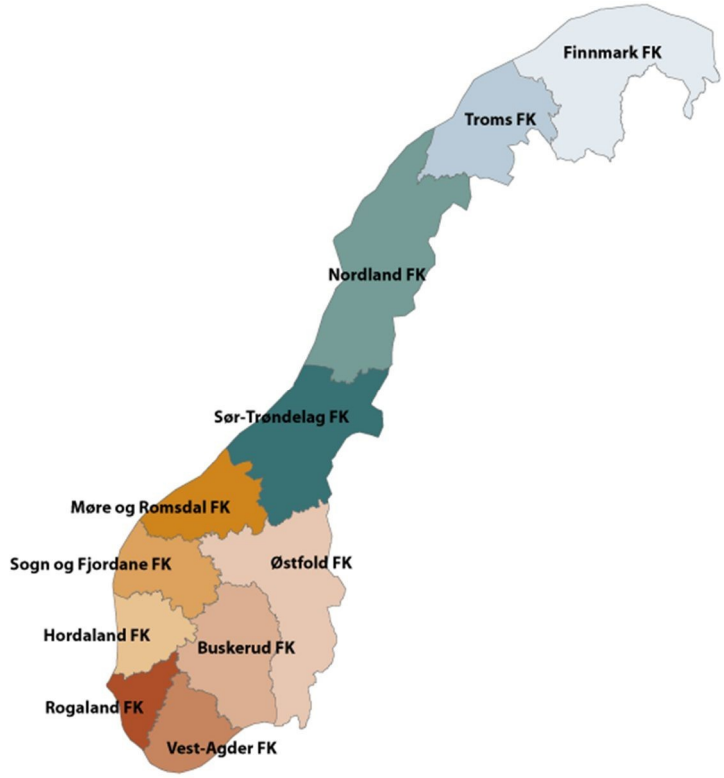


*Figure 2: Water regions of Norway.*

You are going to color the map. Unlike the artist that has colored the map of figure 2, you can use three colors only (red, green and blue), but no neighboring regions can have the same color. To solve this problem, you have to use your knowledge of constraint satisfaction. You will use the full constraint graph for b, and the reduced constraint graph for d and e. The reduced constraint graph only includes the regions south of Møre og Romsdal (that is we are not including Møre and Romsdal in the reduced constraint graph).

a) Constraint satisfaction problems (3p): Specify 1) the variables, 2) the domain and 3) give at least three examples of constraints.

b) Graph (3p): Draw the full constraint graph illustrating the water regions of Norway. Use the abbreviations in your graph: F, T, N and so on.

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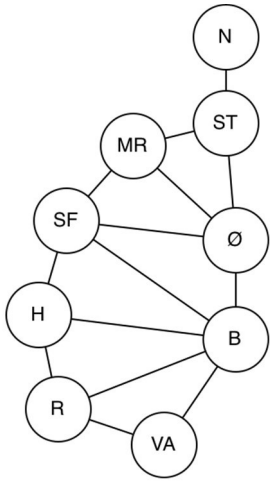


c) Description (3p): Which of the following terms describe the domain and the constraints of the specified problem?
   1. Discrete domain,
   2. Continuous domain,
   3. Finite domain,
   4. Infinite domain,
   5. Linear constraints
   6. Nonlinear constraints,
   7. Unary constraints,
   8. Binary constraints,
   9. N-ary constraints.

d) Backtracking search (4p): Illustrate the first three levels of the search tree of backtracking search using the constraint graph. Each node in the tree should list all the assignments made by that point in the search. Use the reduced constraint graph. You should assign values to nodes in the following order: *SF, H, R, VA, Ø*.

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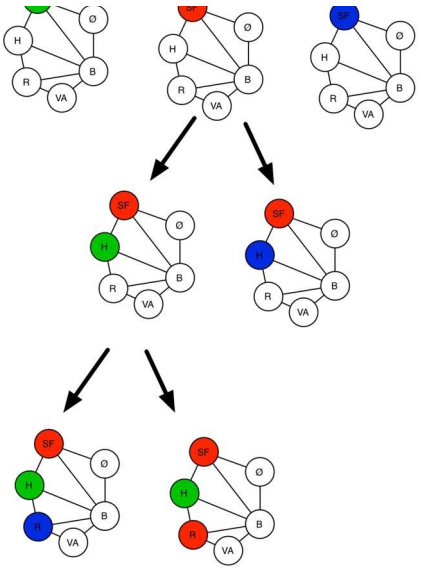


e) Forward checking (4p): Illustrate forward checking with a table. Each variable should have a column in the table, showing the remaining domain for that variable at each point in the search (represented by rows). Show three steps. Use the reduced constraint graph.

f) Heuristics (3p): Of the three heuristics minimum-remaining-values (MRV), degree (D) and least-constraining-value (LCV):
   a. Which heuristic should be used to choose which region to color next?
   b. Which heuristic should be used to decide the order to examine values?

# TASK 5: Planning (10p)

a) Characterizing planning (5p): How can a planning (problem) be characterized? Name two situations when planning is useful. (*The answer should be shorter than one page)*.

b) Plan representation (5p): Explain how a plan can be represented? Give an example of withdrawing cash from an ATM in either STRIPS or PDDL. (*The answer should be shorter than one page*.)

# TASK 6: Natural Language Processing (20p)

a) (6p) True or False (*correct answer= 1p; wrong answer= -½p; total score will be 0-6p)*
   - Sentiment analysis is a text classification application.

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- The purpose of smoothing is to avoid dramatic effects of low-frequency counts.
- The bag of words model can be seen as a simple language model.
- 'Freeze', 'halt', 'cease' and 'finish' are examples of stop words.
- The task of Information Retrieval is to return the answer to a user query.
- Information Extraction systems are often based on templates

b) (2p) What are the main features of human languages that make parsing of these different from the parsing of programming languages?

c) (2p) Sentiment analysis of Twitter messages (tweets) faces several challenges. Give examples of at least four problems that need to be addressed.

d) (4p) The documents in a collection that were returned respectively not returned by an Information Retrieval system in response to a given query were analysed for relevance and shown to be distributed as follows:

| | Returned | Not returned |
|---|---|---|
| Relevant | 60 | 40 |
| Not relevant | 20 | 180 |

1. What was the system's precision?
2. What was the system's recall?
3. What is $F_1$ score?
4. Calculate the $F_1$ score of the system.

e) (6p) Suppose you have access to the following knowledge sources:
- Dictionaries of basic word forms (lemmas) for English and Norwegian,
- Morphological inflection rules for the same two languages,
- A large set of English e-mails already classified as spam,
- A large set of Norwegian e-mails already classified as spam,
- A large set of English e-mails already classified as not being spam,
- A large set of Norwegian e-mails already classified as not being spam,
- A huge set of unclassified e-mails written in a wide range of human languages, and
- A stream of incoming messages, each of the length of no more than one sentence.

Describe how you would go about building a system which would analyze each incoming message and produce one of the following outputs:

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1. The message is not written in a human language.
2. The message is written in a human language which is neither English nor Norwegian.
3. The message is written in English and is spam.
4. The message is written in Norwegian and is spam.
5. The message is written in English and is not spam.
6. The message is written in Norwegian and is not spam.

You do not need to produce a complete solution, but rather sketch the steps that would have to be taken.

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