



RULES: You have 2 hours to complete the test

You can use no texts, written notes, computers, calculators, mobile phones

Please write your name and student ID number on all sheets

The solutions of exercises 1-2 and of exercise 3 should be written on different sheets

1. State space search (10+1 points)

- 1.1 Explain the difference between **uninformed** and **informed search** at a conceptual level. Then compare the Uniform Cost and A* strategies, highlighting the **differences** in the corresponding procedures (you do not need to describe the whole procedures, only the differences). Finally clarify whether the **solutions** to state space problems built by informed search are better than the solutions built by uninformed search.
- 1.2 Considering the A* informed strategy, specify and compare the optimality conditions in the case of **tree search** and **graph search**.

2. Planning (10+1 points)

- 2.1 Concisely describe the three main difficulties of planning: the **qualification** problem, the **frame** problem, and the **ramification** problem.
- 2.2 Suggest a STRIPS representation for the problem stated below:

Consider a **room** whose map is represented as a 10×10 grid (cells are numbered from 1 to 100). In the room there are an **agent** (at a cell), a **shelf** (at some other cell) and a **table** (still at some other cell). On the shelf there are a number of **books**. The goal for the agent is to **have a specific book on the table**. To take a book from the shelf the agent has to be at the same position of the shelf, and to place the book on the table the agent has to be at the same position of the table.

Represent the relevant **actions** so that they are **parametric** with respect to: (i) the positions of the agent, of the shelf, and of the table; (ii) the number of books that are initially on the shelf; (iii) the specific book that the agent wants to have on the table.

Then represent a specific **initial state** (specifying the positions of agent, shelf, and table, and listing which books are on the shelf) and a specific **goal** (specifying which book has to be brought to the table).

Finally describe a **plan** solving the specified problem (you are not required to describe the planning process).

3. Logic (10+1 points)

- 3.1 Represent statements $a \sim e$ in predicate calculus, convert formulae $a \sim d$ and the negation of e to clause form, and prove that e is a logical consequence of $a \sim d$. (Note: you may need to make some hidden assumptions explicit.)
 - a) Aristocats are cats and they are very smart.
 - b) There is no cat that does not like catnip.
 - c) Animals that like food rich in phosphorus have strong teeth.
 - d) Catnip that smart cats like is naturally rich in phosphorus.
 - e) Aristocats have strong teeth.

Logic solution:

- a) Aristocats are cats and they are very smart.
 $\text{ALL}.x (A(x) \rightarrow C(x)) \text{ AND } \text{ALL}.x(A(x) \rightarrow VS(x))$
 $\text{NOT } A(x) \text{ OR } C(x)$ [1]
 $\text{NOT } A(x) \text{ OR } VS(x)$ [2]
- b) There is no cat that does not like catnip.
 $\text{NOT EXISTS}.x(C(x) \text{ AND } \text{NOT EXISTS}.y(N(y) \text{ AND } L(x,y)))$
 $\text{NOT } C(x) \text{ OR } N(f(x))$ [3]
 $\text{NOT } C(x) \text{ OR } L(x,f(x))$ [4]
- c) Animals that like food rich in phosphorus have strong teeth.
 $\text{ALL}.x \text{ ALL}.y(I(x) \text{ AND } F(y) \text{ AND } L(x,y) \text{ AND } P(y) \rightarrow T(x))$
 $\text{NOT } I(x) \text{ OR } \text{NOT } L(x,y) \text{ OR } \text{NOT } F(y) \text{ OR } \text{NOT } P(y) \text{ OR } T(x)$ [5]
- d) Catnip that smart cats like is naturally rich in phosphorus.
 $\text{ALL}.x \text{ ALL}.y(N(x) \text{ AND } C(y) \text{ AND } S(y) \text{ AND } L(y,x) \rightarrow P(x))$
 $\text{NOT } N(x) \text{ OR } \text{NOT } C(y) \text{ OR } \text{NOT } S(y) \text{ OR } \text{NOT } L(y,x) \text{ OR } P(x)$ [6]
- e) (Negation) There is an Aristocat without strong teeth.
 $\text{EXISTS}.x(A(x) \text{ AND } \text{NOT } T(x))$
 $A(a)$ [7]
 $\text{NOT } T(a)$ [8]

Hidden assumptions:

If you are very smart you are also smart

$VS(x) \rightarrow S(x)$

$\text{NOT } VS(x) \text{ OR } S(x)$ [9]

Catnip is food

$N(x) \rightarrow F(x)$

$\text{NOT } N(x) \text{ OR } F(x)$ [10]

Cats are animals

$C(x) \rightarrow I(x)$

$\text{NOT } C(x) \text{ OR } I(x)$ [11]

e can be proven to be a logical consequence as usual by applying the resolution technique to clauses [1] to [11].