IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 2016

BEng Honours Degree in Computing Part III
MEng Honours Degrees in Computing Part III
MSc in Advanced Computing
MSc in Computing Science
MSc in Computing Science (Specialist)
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the Associateship of the City and Guilds of London Institute

PAPER C304

LOGIC-BASED LEARNING

Friday 18 March 2016, 14:00
Duration: 120 minutes

Answer THREE questions

Paper contains 4 questions
Calculators not required

1 **This question is about learning methods based on inverse entailment.**

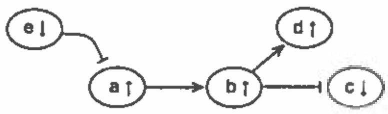
a Consider the following learning task $T = \langle B, E^+, E^-, M \rangle$:

$$B = \left\{ \begin{array}{l} path(X,Y) \leftarrow link(X,Y). \\ path(X,Y) \leftarrow link(X,Z), path(Z,Y). \\ node(1). \quad link(1,1). \\ node(2). \quad link(1,2). \end{array} \right\} \qquad M = \left\{ \begin{array}{l} modeh(*, loop\_on(+node)) \\ modeb(*, path(+node, -node)) \\ modeb(*, link(+node, +node)) \end{array} \right\}$$

$$E^+ = \{loop\_on(1)\} \quad E^- = \{loop\_on(2)\}$$

Give two clauses $H1$ and $H2$ such that $H1$ subsumes $Bot(B, loop\_on(1))$ but is not a solution for the task T, and $H2$ is a solution for the task T derivable by bottom generalisation. Explain your answer.

b Consider the problem domain of gene regulatory networks. The status of a gene may be up or down. An example network of five genes, (a, b, c, d, e), is given below. An arrow between two genes indicates an activation, whereas a line between two genes ending with a vertical bar indicates an inhibition.



Let $T = \langle B, E^+, E^-, M \rangle$ be a learning task whose background knowledge B, examples E^+ and E^-, and mode declarations M are defined as follows.

$$B = \left\{ \begin{array}{llllll} gene(a). & gene(d). & link(b,d). & diffStatus(b,c). & diffStatus(d,c). & sameStatus(a,b). \\ gene(b). & gene(e). & link(a,b). & diffStatus(e,a). & sameStatus(b,d). & \\ gene(c). & link(b,c). & link(e,a) & diffStatus(c,d). & sameStatus(d,b). & \\ \multicolumn{6}{l}{regulates(G1,G2) \leftarrow gene(G3), activates(G1,G3), regulates(G3,G2).} \\ \multicolumn{6}{l}{regulates(G1,G2) \leftarrow inhibits(G1,G2).} \end{array} \right\}$$

$$M = \left\{ \begin{array}{l} modeh(inhibits(+gene,+gene)). \\ modeh(activates(+gene,+gene)). \\ modeb(link(+gene,+gene)). \\ modeb(diffStatus(+gene,+gene)). \\ modeb(sameStatus(+gene,+gene)). \end{array} \right\} \qquad E^+ = \{\ regulates(a,c). \quad regulates(b,c).\ \} \qquad E^- = \left\{ \begin{array}{l} regulates(a,d). \\ regulates(d,c). \\ regulates(e,c). \end{array} \right\}$$

i) Use the hybrid abductive inductive learning algorithm (HAIL) to show that the following hypothesis H is an inductive solution for the task T.

$$H = \left\{ \begin{array}{l} activates(G1,G2) \leftarrow sameStatus(G1,G2), link(G1,G2). \\ inhibits(G1,G2) \leftarrow link(G1,G2), diffStatus(G1,G2). \end{array} \right\}$$

ii) State whether H can be computed by Progol5, and explain why or why not. (No proof is required.)

The two parts carry, respectively, 25% and 75% of the marks.

2 **This question is about meta-level learning.**

a Consider the following learning task $T = \langle B, E^+, E^-, M \rangle$ defined as follows:

$$B = \left\{ \begin{array}{l} p(X) \leftarrow q(X) \\ r(X,Y) \leftarrow t(Y), s(X,Y) \\ t(a) \end{array} \right\} \qquad M = \left\{ \begin{array}{l} modeh(*, q(+any)) \\ modeh(*, s(+any, +any)) \\ modeb(*, r(+any, -any)) \end{array} \right\}$$

$$E^+ = \{p(a)\} \qquad E^- = \{p(b)\}$$

Give the definition of kernel set $K(B,e)$, for $e \in E^+$. Explain whether the given task T has a hypothesis H derivable by kernel set subsumption.

b Consider the learning task $T = \langle B, E^+, E^-, M \rangle$ given below:

$$B = \left\{ \begin{array}{l} animal(rabbits). \\ animal(foxes). \\ animal(eagles). \\ animal(snakes). \\ prey(foxes, rabbits). \\ prey(eagles, snakes). \\ starve(X) \leftarrow prey(X,Y), fewer(Y). \\ getEaten(rabbits). \end{array} \right\} \quad M = \left\{ \begin{array}{l} modeh(\star, extinct(+animal)) \\ modeh(\star, fewer(+animal)) \\ modeb(\star, starve(+animal)) \\ modeb(\star, getEaten(+animal)) \end{array} \right\}$$

$$E^+ = \{extinct(foxes)\} \qquad E^- = \{extinct(eagles)\}$$

i) Give the top-theory constructed by the top-directed abductive learning (TAL) algorithm for the learning task T.

ii) Show that the following hypothesis H is an inductive solution generated by the TAL algorithm.

$$H = \left\{ \begin{array}{l} extinct(X) \leftarrow starve(X) \\ fewer(X) \leftarrow getEaten(X) \end{array} \right\}$$

iii) State whether H is derivable by kernel set subsumption, and explain why or why not.

The two parts carry, respectively, 25% and 75% of the marks.

3 Consider the following two ASP programs:

$$B = \left[\begin{array}{l} refuse(P,F) \leftarrow \text{not } eat(P,F), person(P), food(F). \\ person(p1). \\ person(p2). \\ food(nuts). \\ food(bread). \\ allergic(p1,nuts). \\ allergic(p2,bread). \end{array}\right]$$

$$H = \left[\ eat(P,F) \leftarrow \text{not } refuse(P,F), \text{not } allergic(P,F), person(P), food(F).\ \right]$$

a i) Write down the answer sets of $B \cup H$ (no proof required).

ii) Consider the learning task T_1 with background knowledge B, and examples $E^+ = \{eat(p1,bread), eat(p2,nuts)\}$ and $E^- = \{eat(p1,nuts)\}$. Using your answer to part (i), explain why H is a brave inductive solution of T_1.

iii) Consider the learning task T_2 with background knowledge B, and examples $E^+ = \{refuse(p1,nuts)\}$ and $E^- = \{eat(p2,bread)\}$. Is H a cautious inductive solution of T_2? Explain why, using your answer to part (i).

b Consider the following mode declarations:

$$M = \left[\begin{array}{l} modeh(1, eat(+person, +food)) \\ modeb(1, \text{not } refuse(+person, +food)) \\ modeb(1, \text{not } allergic(+person, +food)) \end{array}\right] \quad (V_{max} = 2, L_{max} = 2)$$

i) Write down a maximal set of skeleton rules for the mode declarations M.

ii) Write down the ASPAL encoding of the brave induction task T_1 given the mode declarations M.

iii) Give an Answer Set of the program constructed in part (ii) which demonstrates that H is an inductive solution of the task.

c i) H is not the optimal solution of T_1 that is compatible with M. Write down a smaller hypothesis which is also an inductive solution of T_1 that is compatible with M.

ii) Write down sets of examples E^+ and E^- such that $\langle B, E^+, E^- \rangle$ forms a learning from answer sets task T_3 and H is the only set of normal rules that is compatible with M and an inductive solution of T_3.

The three parts carry, respectively, 30%, 45%, and 25% of the marks.

4a Let

B_1 be $supports(floor, chair) \leftarrow$

B_2 be $supports(chair, jill) \leftarrow$

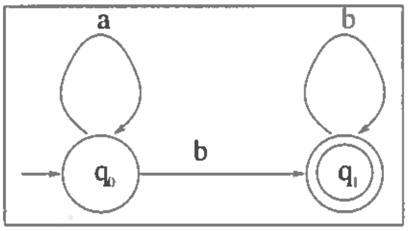
$B = B_1 \wedge B_2$ be the background knowledge

$E = supports(floor, jill) \leftarrow$ be an example and
$M = P(x,y) \leftarrow Q(x,z), R(z,y)$ be a metarule.

i) Letting H stand for the hypothesis, state the condition for Meta-Interpretive Learning which H, B, E and M must satisfy.

ii) For B and E above, within the context of Inverse Entailment what is $\perp$ (the most specific hypothesis)? Explain.

b Consider the finite state acceptor below for the language a^*b^+.



In each case below explain your answer.

i) Give a Prolog program in the form of a Definite Clause Grammar which accepts a^*b^+.

ii) Provide a set of 5 positive examples of sequences for a^*b^+.

iii) Give a 3 clause Prolog meta-interpreter for regular languages.

iv) Provide the set of abduced ground facts which when added to your meta-interpreter makes it accept a^*b^+.

c Consider once more the a^*b^+ finite state acceptor from part b in the context of Bayesian Meta-Interpretive Learning. In each case below explain your answer.

i) Show diagrammatically the stochastic derivation of the Parity acceptor from the sequence *abb*.

ii) Using your diagram calculate the probability of the Parity acceptor given the example sequence *aabb*.

iii) Describe the difference between sampling with and without replacement.

iv) What is the computational advantage of sampling hypotheses without replacement?

The three parts carry, respectively, 20%, 45%, and 35% of the marks.