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The Application of Propositional Logic to Logical Judgment Items in the Administrative Aptitude Test

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Abstract: In the logical judgment questions of the Administrative Aptitude Test (AAT) in China's civil service examinations, current problem-solving methods rely more on empirical summarization and question-sense training, aiming for speed and accuracy, but lacking rigorous logical proof. This article applies the theory of propositional logic in discrete mathematics, combined with the characteristics of recent AAT logical judgment questions, to analyze the correspondence between the stem expressions of the questions and the propositional logic structure. It provides a rigorous proof process for some logical judgment questions, offering a clear and verifiable theoretical basis for such problems.

Keywords: Propositional logic; Administrative Aptitude Test (AAT); Discrete mathematics

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1. Introduction

The Administrative Aptitude Test is a core examination subject in civil servant recruitment, in which the logical reasoning module primarily assesses examinees' ability to grasp conditional relationships, truth-value relations, and inferential structures [1]. Examination preparation materials such as Huatu Education [2] have compiled common question types and solution strategies for the logical reasoning section of the Administrative Aptitude Test from a test-preparation perspective. In routine preparation, this module has consistently been an area prone to score loss. One reason is that most questions are expressed in natural language, which appears straightforward on the surface but often involves nested conditions, negation transformations, and confusion between sufficient and necessary conditions. Another reason is that many solution methods rely more on heuristic summaries and empirical generalizations, lacking a unified and stable formal representation. Consequently, when confronted with lengthy passages or questions involving multiple relationships, examinees frequently grasp the literal meaning of the sentences without clarifying the underlying inferential structure.

As an important component of discrete mathematics, propositional logic provides a relatively clear approach to handling such reasoning tasks. Its advantage lies in well-defined rules and easily verifiable derivation processes, enabling the symbolization of logical relationships in natural language and the analysis of reasoning via proof systems in natural deduction. In the context of the logical reasoning questions in the Administrative Aptitude Test, this method is not intended to replace existing test-taking techniques but rather to offer a more stable theoretical foundation for such question types and to demonstrate that the theoretical knowledge of discrete mathematics can indeed be applied to practical examination problems.

2. Theoretical foundations related to propositional logic

2.1. Natural deduction system

Propositional logic is a fundamental part of mathematical logic in discrete mathematics. In Discrete Mathematics by Qu *et al.* [3], propositions are defined as declarative sentences with definite truth values, and discussions revolve around propositional variables, connectives, well-formed formulas, and truth assignments. This theoretical framework exactly corresponds to common expressions in logical reasoning questions of the AAT, such as "if... then...," "only if...," "and," "or," "not," etc.

"Discrete Mathematics" [3] systematically lists the 16 basic equivalences of propositional formulas in the chapter on propositional logic. These equivalences serve as the foundation for equivalence reasoning and formula simplification. A formal system I typically consists of four parts: an alphabet $A(I)$, a set of well-formed formulas $E(I)$, a set of axioms $A_X(I)$, and a set of inference rules $R(I)$. The natural deduction system P is given by an alphabet, a set of well-formed formulas, and a set of inference rules. In this system, the alphabet specifies basic symbols such as propositional variables, connectives, and parentheses; the well-formed formulas define the valid combinations of these symbols; and proofs are constructed by applying the inference rules.

This paper formalizes the corresponding problems from the Administrative Aptitude Test into symbolic form, and then, using the natural deduction system, writes out the derivation process from premises to conclusion in a standardized manner. By employing the twelve commonly used rules in the natural deduction system P, the complete inference and proof process is presented.

2.2. Three methods of proof

Using the above inference rules, when constructing proofs in a natural deduction system, three methods are commonly employed: direct proof, proof by contradiction, and proof by additional premise.

(1) Direct proof

Starting from the set of premises, without introducing any extra assumptions, inference rules are applied directly to derive the validity of the conclusion step by step.

Write the formal structure of the proof: premises and conclusion.

Premises: $A_1, A_2, \ldots, A_k$

Conclusion: B

In a natural deduction system, a direct proof is sufficient: apply inference rules step by step from each formula of the premises to derive the final conclusion B.

Applicable scenarios: deductive reasoning with a clear logical chain and simple structure. It is the preferred method for the vast majority of ‘thus it can be inferred’ type problems.

(2) Proof by additional premise

When the conclusion is a conditional proposition ($A \rightarrow B$), introduce the antecedent A as an additional premise, derive B, and thereby prove the original proposition.

To prove:

Premises: $A_1, A_2, \ldots, A_k$

Conclusion: $C \rightarrow B$

Equivalent proof

Premises: $A_1, A_2, \ldots, A_k, C$

Conclusion: B

Applicable scenarios: When the conclusion itself is an implication (conditional statement), or in complex logical problems that require additional assumptions to proceed with the derivation.

(3) Proof by contradiction

Introduce the negation of the conclusion as an additional premise into a new proof system. If a logical contradiction is derived, then the original conclusion holds.

To prove:

Premises: $A_1, A_2, \ldots, A_k$

Conclusion: B

Method: Add the negation of the conclusion ($\neg B$) as an additional premise, then derive a contradiction, thereby showing that the assumption is false.

Applicable scenarios: Problems where a direct proof path is unclear, or those involving “necessarily/impossible” or strong constraints.

3. Proof methods of some real AAT exam questions

3.1. Proof by additional premise

2026 Heilongjiang Provincial Civil Service Examination Questions: A school organizes preliminary rounds for chess, Go, and Gobang (five-in-a-row) competitions. The preliminary round is a single-elimination tournament, with each participant playing only one match; the winner advances to the quarterfinals. Four students from Class A—Zhang, Li, Wang, and Zhao—have registered for the competitions.

It is known that:

(1) If Zhang advances to the quarterfinals of chess, then Zhao advances to the quarterfinals of Gobang.

(2) Only if Li advances to the quarterfinals of Go will Wang not advance to the quarterfinals of chess.

(3) Unless Zhao does not advance to the quarterfinals of Gobang, Li will not advance to the quarterfinals of Go. Which of the following can be deduced?

A. Zhang advances to the quarterfinals of chess, or Wang advances to the quarterfinals of chess.

B. Zhang advances to the quarterfinals of chess, or Wang does not advance to the quarterfinals of chess.

C. Zhang does not advance to the quarterfinals of chess, or Wang advances to the quarterfinals of chess.

D. Zhang does not advance to the quarterfinals of chess, or Wang does not advance to the quarterfinals of chess.

Analysis: The following is the process of constructing a proof of reasoning using the method of propositional logic.

Step 1: Propositional Symbolization

Let □ denote that Zhang advances to the chess quarterfinals, □ denote that Zhao advances to the Gomoku quarterfinals, □ denote that Li advances to the Go quarterfinals, and □ denote that Wang advances to the chess quarterfinals.

The conditions (1), (2), and (3) in the problem statement can be symbolized as□ $p \to q$, $\neg s \to r$, $q \to \neg r$. Options A, B, C, and D are all disjunctive formulas and can be symbolized as: $p \vee s$, $p \vee \neg s$, $\neg p \vee s$, $\neg p \vee \neg s$. Options can be equivalently transformed into by the substitution rule: $\neg p \to s$ or $\neg s \to p$, $\neg p \to \neg s$ or $s \to p$, $p \to s$ or $\neg s \to \neg p$, $p \to \neg s$ or $s \to \neg p$.

The answer to this question is option C; the next step is simply to construct a proof in a natural deduction system, which will provide a rigorous proof of the answer.

Step 2: Constructing a proof in a natural deduction system.

Premises: $p \to q$, $\neg s \to r$, $q \to \neg r$

Conclusion: $p \to s$

Since the conclusion is an implication, the conditional proof method can be applied, and the formal structure of the inference is changed to:

Premises: $p \to q$, $\neg s \to r$, $q \to \neg r$, p

Conclusion: s

Proof:

(1) $p \to q$ Premise Introduction

(2) $q \to \neg r$ Premise Introduction

(3) $p \to \neg r$ (1) (2) Hypothetical Syllogism

(4) p Additional Premise Introduction

(5) $\neg r$ (3) (4) Modus Ponens

(6) $\neg s \to r$ Premise Introduction

(7) s (5)(6) Modus Tollens

Step 3: Conclusion

Add option C as a premise. Then, take the antecedent in the conclusion as an additional premise and incorporate it into the premise set of the inference form structure. Through the proof, the consequent of the original conclusion is derived, thereby verifying the correctness of option C by means of the additional premise proof method.

3.2. Proof by contradiction

2026 Tianjin Municipal Civil Service Examination Questions: In order to enrich the cultural and recreational life of the community, the Xingfu Community plans to set up five activity rooms: Chess, Calligraphy, Tai Chi, Paper Cutting, and Traditional Chinese Painting. The opinions of the residents were collected, and the following conclusions were drawn:

(1) Only if the Calligraphy activity room is set up will the Chess activity room not be set up.

(2) The Tai Chi activity room and the Traditional Chinese Painting activity room will not be set up at the same time.

(3) If the Calligraphy activity room is set up, then the Paper Cutting activity room will not be set up.

(4) As long as the Chess activity room is set up, the Traditional Chinese Painting activity room will be set up.

It is known that the community will definitely not set up the Calligraphy activity room. Which of the following must be true?

A. The Paper Cutting activity room is set up.

B. The Tai Chi activity room is not set up.

C. The Traditional Chinese Painting activity room is not set up.

D. The Chess activity room is not set up.

Analysis: The following is the process of constructing a proof of reasoning using the method of propositional logic.

The answer to this question is option B. Next, we will construct a proof of the reasoning in a natural deduction system.

Step 1: Propositional Symbolization

Let ***x*** denote setting up a Chinese chess activity room, ***s*** denote setting up a calligraphy activity room, ***t*** denote setting up a Tai Chi activity room, ***j*** denote setting up a paper-cutting activity room, and ***g*** denote setting up a traditional Chinese painting activity room. The problem statement can be symbolized as: $\neg x \to s$, $\neg(t \wedge g)$, $s \to \neg j$, $x \to g$, $\neg s$

The correct answer is option B, which can be symbolized as: $\neg t$.

Step 2: Constructing a proof in a natural deduction system.

Premises: $\neg x \to s$, $\neg(t \wedge g)$, $s \to \neg j$, $x \to g$, $\neg s$

Conclusion: $\neg t$

Proof:

(1) $\neg x \to s$ Premise Introduction

(2) $\neg s$ Premise Introduction

(3) x (1)(2) Modus Tollens

(4) $x \to g$ Premise Introduction

(5) g (3)(4) Modus Ponens

(6) $\neg(t \wedge g)$ Premise Introduction

(7) t Negation of Conclusion Introduction

(8) $t \wedge g$ (5)(7) Conjunction

(9) λ (6)(8) Conjunction

Step 3: Conclusion

Taking option B as the conclusion, the proof by contradiction in the natural deduction system ultimately yields a result that indicates the assumption (setting up a Tai Chi activity room) is untenable; therefore, a Tai Chi activity room should not be set up, and the original option is correct.

3.3. Direct proof

2026 Guangdong Provincial Civil Service Examination Questions: A certain unit plans to organize its staff to visit the Science and Technology Museum, the Cultural Center, the Museum, and the Art Museum. However, due to time constraints, not all four venues can be visited. Some staff members put forward the following suggestions, which were adopted:

(1) It is not recommended to visit both the Cultural Center and the Museum.

(2) At least one of the Art Museum and the Cultural Center should be visited.

(3) The Art Museum was visited last year, so it will not be visited this year.

Which of the following options, when added, would lead to the conclusion that “the unit will definitely visit the Science and Technology Museum?”

A. If we do not visit the Science and Technology Museum, then we will visit the Museum.

B. Only if we do not visit the Science and Technology Museum will we visit the Museum.

C. Only if we do not visit the Museum will we not visit the Science and Technology Museum.

D. If we visit the Museum, then we will not visit the Science and Technology Museum.

Analysis: The following is the process of constructing a proof of reasoning using the method of propositional logic.

Step 1: Propositional Symbolization

Let □ denote visiting the science and technology museum, □ denote visiting the cultural center, □ denote visiting the museum, and □ represent visiting the art gallery. For the given problem statement, it can be symbolized as: $\neg(w \wedge b)$, $m \vee w$, $\neg m$ 。

For option A, it can be symbolized as: $\neg k \to b$ 。

In conclusion, this unit will definitely go to the science museum, symbolized as: k 。

Step 2: Constructing a proof in a natural deduction system.

Premises: $\neg(w \wedge b)$, $m \vee w$, $\neg m$, $\neg k \to b$

Conclusion: k

Proof:

(1) $\neg m$ Premise Introduction

(2) $m \vee w$ Premise Introduction

(3) w (1)(2) Disjunctive Syllogism

(4) $\neg(w \wedge b)$ Premise Introduction

(5) $\neg w \vee \neg b$ (4) Substitution

(6) $\neg b$ (3)(5) Disjunctive Syllogism

(7) $\neg k \to b$ Premise Introduction

(8) k (6)(7) Modus Tollens

Step 3: Conclusion

After symbolizing option A as part of the premises, a proof of reasoning was then constructed in the natural deduction system, that is, option A can derive the target conclusion, thus providing a complete proof.

4. Retrospect

The three examples above make it clearer that the propositional logic and truth-reasoning problems in the Administrative Aptitude Test (Xingce) can indeed be transformed into propositional logic problems in discrete mathematics, and further rigorously proved within a natural deduction system. Discrete mathematical thinking and exam-taking skills are not contradictory; they simply focus on different aspects. Exam-taking skills emphasize quick judgment, often using mnemonics like “only if → then push backward” or “deny the consequent to deny the antecedent." Discrete mathematics, on the other hand, focuses on why these mnemonics hold, requiring every step of transformation to be written as a formal derivation and providing a rigorous proof. This article adopts the latter approach to illustrate that Xingce propositional logic problems do not have to rely solely on experience—they can also be placed into a verifiable formal system for cross-checking the results of the proof.

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Author contributions

Qianfang Liu conceived the idea of the study and wrote the paper. Yuhao Yang performed the experiments. Peng Ma checked the paper.

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