МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ УКРАЇНИ

„КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ”

НАВЧАЛЬНО-НАУКОВИЙ ІНСТИТУТ ПРИКЛАДНОГО СИСТЕМНОГО АНАЛІЗУ

Лабораторна робота №1

з курсу : «Байєсівський аналіз даних в наукових дослідженнях»

Виконав:

аспірант 2 курсу ННІПСА

Групи КН-31ф

Кузнєцов Олексій Андрійович

Київ – 2024

**Мета роботи**: Ознайомлення з основами теорії байєсівських мереж. Формула Байєса для обчислення значень ймовірностей.

**Завдання:** Напишіть комп’ютерну програму, що повинна:

– обчислювати значень ймовірностей станів вершин

– обчислювати значення спільної ймовірності мережі Байєса

Мова програмування будь-яка.

Програма може не будувати графічну структуру мережі Байєса.

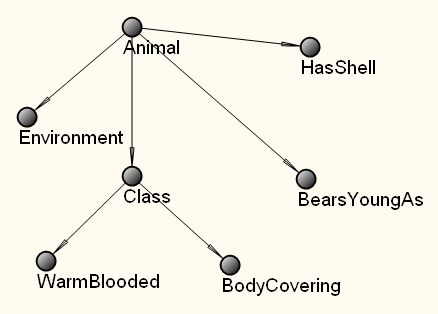
Головна мета – коректно запрограмовані формули для обчислення значень ймовірностей.

На вхід програмі подаються значення умовних ймовірностей вершин.

**Постановка завдання:**

**Мережа Animals**

Структура мережі.

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Таблиці умовних ймовірностей

**Animal**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Monkey*** | ***Penguin*** | ***Platypus*** | ***Robin*** | ***Turtle*** |
| 0,2 | 0,2 | 0,2 | 0,2 | 0,2 |

**Environment**

|  |  |  |  |
| --- | --- | --- | --- |
| **Animal** | ***Air*** | ***Land*** | ***Water*** |
| ***Monkey*** | 0 | 1 | 0 |
| ***Penguin*** | 0 | 0,5 | 0,5 |
| ***Platypus*** | 0 | 0 | 1 |
| ***Robin*** | 0,5 | 0,5 | 0 |
| ***Turtle*** | 0 | 0,5 | 0,5 |

**HasShell**

|  |  |  |
| --- | --- | --- |
| **Animal** | ***True*** | ***False*** |
| ***Monkey*** | 0 | 1 |
| ***Penguin*** | 0 | 1 |
| ***Platypus*** | 0 | 1 |
| ***Robin*** | 0 | 1 |
| ***Turtle*** | 1 | 0 |

**BearsYoungAs**

|  |  |  |
| --- | --- | --- |
| **Animal** | ***Live*** | ***Eggs*** |
| ***Monkey*** | 1 | 0 |
| ***Penguin*** | 0 | 1 |
| ***Platypus*** | 0 | 1 |
| ***Robin*** | 0 | 1 |
| ***Turtle*** | 0 | 1 |

**Class**

|  |  |  |  |
| --- | --- | --- | --- |
| **Animal** | ***Bird*** | ***Mammal*** | ***Reptile*** |
| ***Monkey*** | 0 | 1 | 0 |
| ***Penguin*** | 1 | 0 | 0 |
| ***Platypus*** | 0 | 1 | 0 |
| ***Robin*** | 1 | 0 | 0 |
| ***Turtle*** | 0 | 0 | 1 |

**WarmBlooded**

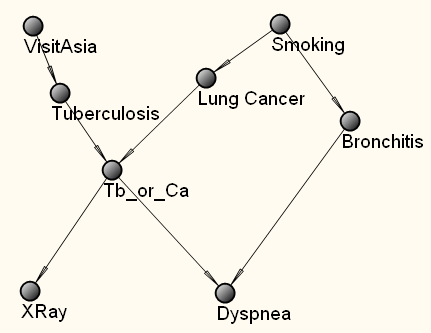
|  |  |  |
| --- | --- | --- |
| **Class** | ***True*** | ***False*** |
| ***Bird*** | 1 | 0 |
| ***Mammal*** | 1 | 0 |
| ***Reptile*** | 0 | 1 |

**BodyCovering**

|  |  |  |  |
| --- | --- | --- | --- |
| **Class** | ***Fur*** | ***Feathers*** | ***Scales*** |
| ***Bird*** | 0 | 1 | 0 |
| ***Mammal*** | 1 | 0 | 0 |
| ***Reptile*** | 0 | 0 | 1 |

**Мережа Asia**

Структура мережі.



Таблиці умовних ймовірностей

**VisitAsia**

|  |  |
| --- | --- |
| ***Visit*** | ***NoVisit*** |
| 0,01 | 0,99 |

**Smoking**

|  |  |
| --- | --- |
| ***Smoking*** | ***NoSmoking*** |
| 0,5 | 0,5 |

**Tuberculosis**

|  |  |  |
| --- | --- | --- |
| **VisitAsia** | ***Present*** | ***Absent*** |
| ***Visit*** | 0,05 | 0,95 |
| ***NoVisit*** | 0,01 | 0,99 |

**Lung Cancer**

|  |  |  |
| --- | --- | --- |
| **Smoking** | ***present*** | ***Absent*** |
| ***Smoking*** | 0,1 | 0,9 |
| ***NoSmoking*** | 0,01 | 0,99 |

**Tb\_or\_Ca**

|  |  |  |  |
| --- | --- | --- | --- |
| **Tuberculosis** | **Lung Cancer** | ***True*** | ***False*** |
| ***Present*** | ***present*** | 1 | 0 |
| ***Present*** | ***Absent*** | 1 | 0 |
| ***Absent*** | ***present*** | 1 | 0 |
| ***Absent*** | ***Absent*** | 0 | 1 |

**XRay**

|  |  |  |
| --- | --- | --- |
| **Tb\_or\_Ca** | ***abnormal*** | ***normal*** |
| ***True*** | 0,98 | 0,02 |
| ***False*** | 0,05 | 0,95 |

**Bronchitis**

|  |  |  |
| --- | --- | --- |
| **Smoking** | ***Present*** | ***Absent*** |
| ***Smoking*** | 0,6 | 0,4 |
| ***NoSmoking*** | 0,3 | 0,7 |

**Dyspnea**

|  |  |  |  |
| --- | --- | --- | --- |
| **Tb\_or\_Ca** | **Bronchitis** | ***True*** | ***False*** |
| ***True*** | ***Present*** | 0,9 | 0,1 |
| ***True*** | ***Absent*** | 0,7 | 0,3 |
| ***False*** | ***Present*** | 0,8 | 0,2 |
| ***False*** | ***Absent*** | 0,1 | 0,9 |

**Результати роботи програми:**

**Мережа Animals**

Significant Joint Probabilities with State Descriptions:

State: Animal: Monkey, Environment: Land, HasShell: False, BearsYoungAs: Live, Class: Mammal, WarmBlooded: True, BodyCovering: Fur, Probability: 0.2000000000

State: Animal: Penguin, Environment: Land, HasShell: False, BearsYoungAs: Eggs, Class: Bird, WarmBlooded: True, BodyCovering: Feathers, Probability: 0.1000000000

State: Animal: Penguin, Environment: Water, HasShell: False, BearsYoungAs: Eggs, Class: Bird, WarmBlooded: True, BodyCovering: Feathers, Probability: 0.1000000000

State: Animal: Platypus, Environment: Water, HasShell: False, BearsYoungAs: Eggs, Class: Mammal, WarmBlooded: True, BodyCovering: Fur, Probability: 0.2000000000

State: Animal: Robin, Environment: Air, HasShell: False, BearsYoungAs: Eggs, Class: Bird, WarmBlooded: True, BodyCovering: Feathers, Probability: 0.1000000000

State: Animal: Robin, Environment: Land, HasShell: False, BearsYoungAs: Eggs, Class: Bird, WarmBlooded: True, BodyCovering: Feathers, Probability: 0.1000000000

State: Animal: Turtle, Environment: Land, HasShell: True, BearsYoungAs: Eggs, Class: Reptile, WarmBlooded: False, BodyCovering: Scales, Probability: 0.1000000000

State: Animal: Turtle, Environment: Water, HasShell: True, BearsYoungAs: Eggs, Class: Reptile, WarmBlooded: False, BodyCovering: Scales, Probability: 0.1000000000

**Мережа Asia**

Significant Joint Probabilities with State Descriptions:

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000132300

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000014700

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000002700

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000000300

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000068600

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000029400

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000001400

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000000600

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0001190700

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000132300

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000024300

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000002700

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000617400

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000264600

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000012600

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000005400

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000006615

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000000735

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000000135

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000000015

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000012005

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000005145

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000000245

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000000105

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000654885

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000072765

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000013365

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000001485

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0001188495

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000509355

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000024255

State: VisitAsia: Visit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000010395

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0002513700

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000279300

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000051300

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000005700

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0001303400

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000558600

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000026600

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000011400

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0001026000

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0000256500

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.0019494000

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.0004873500

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0000085500

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0000769500

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.0001624500

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.0014620500

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State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000002565

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000000285

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000228095

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000097755

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000004655

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000001995

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0000564300

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0000141075

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.0010721700

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.0002680425

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0000164588

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0001481288

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.0003127163

State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.0028144463

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0002619540

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000291060

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000053460

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000005940

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0001358280

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000582120

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000027720

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000011880

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0023575860

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0002619540

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000481140

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000053460

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0012224520

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0005239080

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000249480

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000106920

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000130977

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000014553

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000002673

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000000297

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0000237699

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000101871

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000004851

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000002079

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0012966723

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0001440747

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000264627

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000029403

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0023532201

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0010085229

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000480249

State: VisitAsia: NoVisit, Tuberculosis: Present, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000205821

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0259334460

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0028814940

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0005292540

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000588060

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0134469720

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0057629880

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0002744280

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0001176120

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0105850800

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0026462700

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.2011165200

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.0502791300

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0008820900

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0079388100

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.0167597100

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: Smoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.1508373900

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0012966723

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0001440747

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000264627

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000029403

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: True, Probability: 0.0023532201

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0010085229

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: True, Probability: 0.0000480249

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Absent, Tb\_or\_Ca: True, XRay: Normal, Dyspnea: False, Probability: 0.0000205821

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0058217940

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0014554485

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.1106140860

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Present, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.0276535215

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: True, Probability: 0.0016980232

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Abnormal, Dyspnea: False, Probability: 0.0152822092

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: True, Probability: 0.0322624418

State: VisitAsia: NoVisit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Absent, Bronchitis: Absent, Tb\_or\_Ca: False, XRay: Normal, Dyspnea: False, Probability: 0.2903619758

**Код програми:**

**Опис мережі Animals**

from pgmpy.models import BayesianNetwork  
from pgmpy.factors.discrete import TabularCPD  
  
def create\_animals\_model():  
 #Define the structure of the Bayesian Network  
 model = BayesianNetwork([  
 ('Animal', 'Environment'),  
 ('Animal', 'HasShell'),  
 ('Animal', 'BearsYoungAs'),  
 ('Animal', 'Class'),  
 ('Class', 'WarmBlooded'),  
 ('Class', 'BodyCovering')  
 ])  
  
 #Define the CPDs (Conditional Probability Distributions)  
 cpd\_animal = TabularCPD(  
 variable = 'Animal',  
 variable\_card = 5,  
 values = [[0.2], [0.2], [0.2], [0.2], [0.2]],  
 state\_names = {'Animal': ['Monkey', 'Penguin', 'Platypus', 'Robin', 'Turtle']}  
 )  
  
 cpd\_environment = TabularCPD(  
 variable = 'Environment',  
 variable\_card = 3,  
 values = [[0, 0, 0, 0.5, 0],  
 [1, 0.5, 0, 0.5, 0.5],  
 [0, 0.5, 1, 0, 0.5]],  
 evidence = ['Animal'],  
 evidence\_card = [5],  
 state\_names = {'Environment': ['Air', 'Land', 'Water'], 'Animal': ['Monkey', 'Penguin', 'Platypus', 'Robin', 'Turtle']}  
 )  
  
 cpd\_has\_shell = TabularCPD(  
 variable = 'HasShell',  
 variable\_card = 2,  
 values = [[0, 0, 0, 0, 1],  
 [1, 1, 1, 1, 0]],  
 evidence = ['Animal'],  
 evidence\_card = [5],  
 state\_names = {'HasShell': ['True', 'False'], 'Animal': ['Monkey', 'Penguin', 'Platypus', 'Robin', 'Turtle']}  
 )  
  
 cpd\_bears\_young\_as = TabularCPD(  
 variable = 'BearsYoungAs',  
 variable\_card = 2,  
 values = [[1, 0, 0, 0, 0],  
 [0, 1, 1, 1, 1]],  
 evidence = ['Animal'],  
 evidence\_card = [5],  
 state\_names = {'BearsYoungAs': ['Live', 'Eggs'], 'Animal': ['Monkey', 'Penguin', 'Platypus', 'Robin', 'Turtle']}  
 )  
  
 cpd\_class = TabularCPD(  
 variable = 'Class',  
 variable\_card = 3,  
 values = [[0, 1, 0, 1, 0],  
 [1, 0, 1, 0, 0],  
 [0, 0, 0, 0, 1]],  
 evidence = ['Animal'],  
 evidence\_card = [5],  
 state\_names = {'Class': ['Bird', 'Mammal', 'Reptile'], 'Animal': ['Monkey', 'Penguin', 'Platypus', 'Robin', 'Turtle']}  
 )  
  
 cpd\_warm\_blooded = TabularCPD(  
 variable = 'WarmBlooded',  
 variable\_card = 2,  
 values = [[1, 1, 0],  
 [0, 0, 1]],  
 evidence = ['Class'],  
 evidence\_card = [3],  
 state\_names = {'WarmBlooded': ['True', 'False'], 'Class': ['Bird', 'Mammal', 'Reptile']}  
 )  
  
 cpd\_body\_covering = TabularCPD(  
 variable = 'BodyCovering',  
 variable\_card = 3,  
 values = [[0, 1, 0],  
 [1, 0, 0],  
 [0, 0, 1]],  
 evidence = ['Class'],  
 evidence\_card = [3],  
 state\_names = {'BodyCovering': ['Fur', 'Feathers', 'Scales'], 'Class': ['Bird', 'Mammal', 'Reptile']}  
 )  
  
 #Add CPDs to the model  
 model.add\_cpds(cpd\_animal, cpd\_environment, cpd\_has\_shell, cpd\_bears\_young\_as, cpd\_class, cpd\_warm\_blooded, cpd\_body\_covering)  
  
 #Validate the model  
 assert model.check\_model()  
  
 return model

**Опис мережі Asia**

from pgmpy.models import BayesianNetwork  
from pgmpy.factors.discrete import TabularCPD  
  
def create\_asia\_model():  
 # Define the structure of the Bayesian Network  
 model = BayesianNetwork([  
 ('VisitAsia', 'Tuberculosis'),  
 ('Smoking', 'Lung Cancer'),  
 ('Smoking', 'Bronchitis'),  
 ('Tuberculosis', 'Tb\_or\_Ca'),  
 ('Lung Cancer', 'Tb\_or\_Ca'),  
 ('Tb\_or\_Ca', 'XRay'),  
 ('Tb\_or\_Ca', 'Dyspnea'),  
 ('Bronchitis', 'Dyspnea')  
 ])  
  
 # Define the CPDs (Conditional Probability Distributions)  
 cpd\_visit\_asia = TabularCPD(  
 variable='VisitAsia',  
 variable\_card=2,  
 values=[[0.01], [0.99]],  
 state\_names={'VisitAsia': ['Visit', 'NoVisit']}  
 )  
  
 cpd\_smoking = TabularCPD(  
 variable='Smoking',  
 variable\_card=2,  
 values=[[0.5], [0.5]],  
 state\_names={'Smoking': ['Smoking', 'NoSmoking']}  
 )  
  
 cpd\_tuberculosis = TabularCPD(  
 variable='Tuberculosis',  
 variable\_card=2,  
 values=[[0.05, 0.01],  
 [0.95, 0.99]],  
 evidence=['VisitAsia'],  
 evidence\_card=[2],  
 state\_names={'Tuberculosis': ['Present', 'Absent'], 'VisitAsia': ['Visit', 'NoVisit']}  
 )  
  
 cpd\_lung\_cancer = TabularCPD(  
 variable='Lung Cancer',  
 variable\_card=2,  
 values=[[0.1, 0.01],  
 [0.9, 0.99]],  
 evidence=['Smoking'],  
 evidence\_card=[2],  
 state\_names={'Lung Cancer': ['Present', 'Absent'], 'Smoking': ['Smoking', 'NoSmoking']}  
 )  
  
 cpd\_tb\_or\_ca = TabularCPD(  
 variable='Tb\_or\_Ca',  
 variable\_card=2,  
 values=[[1, 1, 1, 0],  
 [0, 0, 0, 1]],  
 evidence=['Tuberculosis', 'Lung Cancer'],  
 evidence\_card=[2, 2],  
 state\_names={'Tb\_or\_Ca': ['True', 'False'], 'Tuberculosis': ['Present', 'Absent'], 'Lung Cancer': ['Present', 'Absent']}  
 )  
  
 cpd\_xray = TabularCPD(  
 variable='XRay',  
 variable\_card=2,  
 values=[[0.98, 0.05],  
 [0.02, 0.95]],  
 evidence=['Tb\_or\_Ca'],  
 evidence\_card=[2],  
 state\_names={'XRay': ['Abnormal', 'Normal'], 'Tb\_or\_Ca': ['True', 'False']}  
 )  
  
 cpd\_bronchitis = TabularCPD(  
 variable='Bronchitis',  
 variable\_card=2,  
 values=[[0.6, 0.3],  
 [0.4, 0.7]],  
 evidence=['Smoking'],  
 evidence\_card=[2],  
 state\_names={'Bronchitis': ['Present', 'Absent'], 'Smoking': ['Smoking', 'NoSmoking']}  
 )  
  
 cpd\_dyspnea = TabularCPD(  
 variable='Dyspnea',  
 variable\_card=2,  
 values=[[0.9, 0.7, 0.8, 0.1],  
 [0.1, 0.3, 0.2, 0.9]],  
 evidence=['Tb\_or\_Ca', 'Bronchitis'],  
 evidence\_card=[2, 2],  
 state\_names={'Dyspnea': ['True', 'False'], 'Tb\_or\_Ca': ['True', 'False'], 'Bronchitis': ['Present', 'Absent']}  
 )  
  
 # Add CPDs to the model  
 model.add\_cpds(cpd\_visit\_asia, cpd\_smoking, cpd\_tuberculosis, cpd\_lung\_cancer, cpd\_tb\_or\_ca, cpd\_xray, cpd\_bronchitis, cpd\_dyspnea)  
  
 # Validate the model  
 assert model.check\_model()  
  
 return model

**Код розрахунку і обробки ймовірностей**

from pgmpy.inference import VariableElimination  
import itertools  
#from Animals import create\_animals\_model  
from Asia import create\_asia\_model  
  
  
# Create the model  
#model = create\_animals\_model()  
model = create\_asia\_model()  
  
# Automatically get the list of all variables (nodes) in the model  
variables = model.nodes()  
  
# Perform inference  
inference = VariableElimination(model)  
  
# Querying the joint probability for the entire network using automatically fetched variables  
joint\_prob = inference.query(variables=variables)  
  
  
# Helper function to map index to state names with variable labels  
def get\_state\_description(factor, index):  
 # Get all possible combinations of states  
 states = list(itertools.product(\*[factor.state\_names[var] for var in factor.variables]))  
 selected\_state = states[index]  
  
 # Pair variable names with their states and return them as formatted strings  
 return ', '.join([f"{var}: {state}" for var, state in zip(factor.variables, selected\_state)])  
  
  
# Write only significant joint probabilities to file with detailed state descriptions  
#with open('animals\_results\_filtered\_detailed.txt', 'w') as file:  
with open('asia\_results\_filtered\_detailed.txt', 'w') as file:  
 file.write("Significant Joint Probabilities with State Descriptions:\n")  
 for idx, prob in enumerate(joint\_prob.values.flatten()):  
 if prob > 0: # Only write non-zero probabilities  
 state\_description = get\_state\_description(joint\_prob, idx)  
 file.write(f" State: {state\_description}, Probability: {prob:.10f}\n")

Все можна переглянути за посиланням на github: <https://github.com/Kinelan/Bayes/tree/main/Lab%201>

**Висновки**

Основна мета цієї лабораторної полягала в тому, щоб змоделювати й проаналізувати дві різні Байєсівські мережі, коректно обчисливши ймовірності станів для кожної з них.

Для цього було побудовано дві Байєсівські моделі мережі: мережа Animal та мережі Asia, кожна з яких має власну структура власні змінні і ймовірність значень для кожної змінної. Після цього були обраховані **спільні ймовірності** для кожної моделі за допомогою алгоритму **Variable Elimination**, що дозволило визначити ймовірності для різних комбінацій станів змінних. Після цього всі значення були оброблені і у файл були записані лише, які мали хоч якусь релевантність (тобто не були нульовими).