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«Київський політехнічний інститут імені Ігоря Сікорського»
Інститут прикладного системного аналізу
Кафедра математичних методів системного аналізу

**Лабораторна робота № 1**

з дисципліни «Байєсівський аналіз даних в наукових дослідженнях»

Виконав аспірант 2 курсу
групи КН-31ф
Кузнєцов О.А.
Перевірив
д.т.н., доц. Терентьєв О. М.

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**

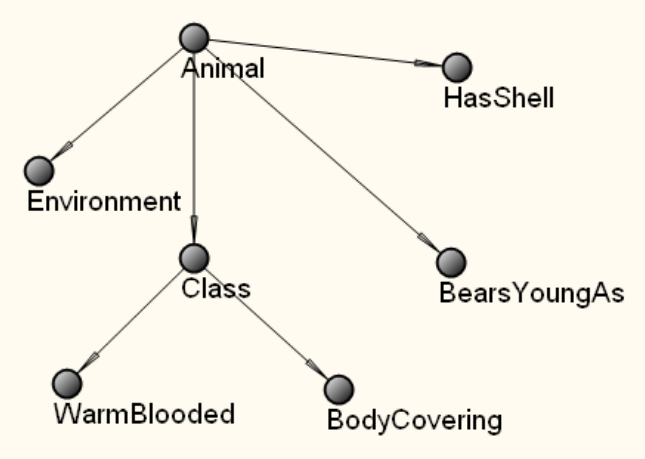


Рис. 1 – Структура мережі Animals

**Таблиці умовних ймовірностей мережі Animals**

Табл. 1 – таблиця значень вершини Animal

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

Табл. 2 – таблиця значень вершини 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 |

Табл. 3 – таблиця значень вершини HasShell

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

Табл. 4 – таблиця значень вершини BearsYoungAs

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

Табл. 5 – таблиця значень вершини 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 |

Табл. 6 – таблиця значень вершини WarmBlooded

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

Табл. 7 – таблиця значень вершини BodyCovering

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

## Мережа Asia

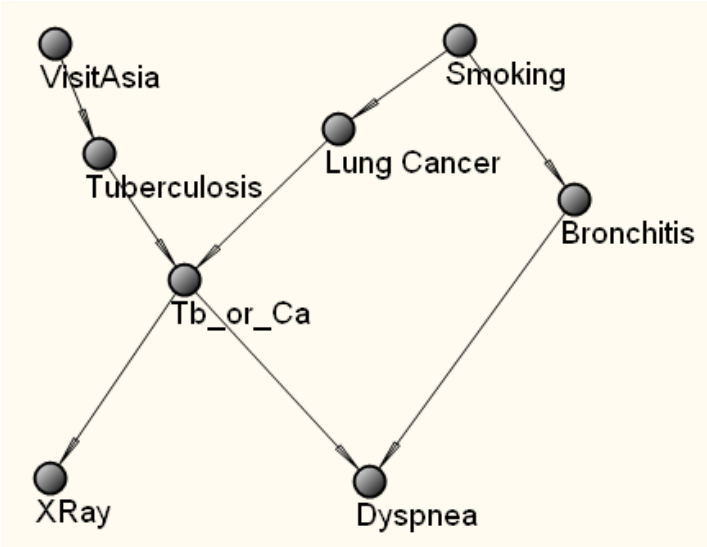


Рис. 2 – Структура мережі Asia

**Таблиці умовних ймовірностей мережі Asia**

Табл. 8 - таблиця значень вершини VisitAsia

| ***Visit*** | ***NoVisit*** |
|---|---|

| | |
|---|---|
| 0,01 | 0,99 |

Табл. 9 - таблиця значень вершини Smoking

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

Табл. 10 - таблиця значень вершини Tuberculosis

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

Табл. 11 - таблиця значень вершини Lung Cancer

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

Табл. 12 - таблиця значень вершини Tb_or_Ca

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

Табл. 13 - таблиця значень вершини XRay

| **Tb_or_Ca** | ***abnormal*** | ***normal*** |
|---|---|---|
| ***True*** | 0,98 | 0,02 |
| ***False*** | 0,05 | 0,95 |

Табл. 14 - таблиця значень вершини Bronchitis

| **Smoking** | ***Present*** | ***Absent*** |
|---|---|---|

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

Табл. 15 - таблиця значень вершини 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

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State: VisitAsia: Visit, Tuberculosis: Absent, Smoking: NoSmoking, Lung Cancer: Present, Bronchitis: Present, Tb_or_Ca: True, XRay: Abnormal, Dyspnea: False, Probability: 0.0000013965

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

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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

## 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).

**Додаток до лабораторної**

**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
```

**Розрахунок і обробка 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 детальніше можна переглянути за посиланням на github:

https://github.com/Kinelan/Bayes/tree/main/Lab%201