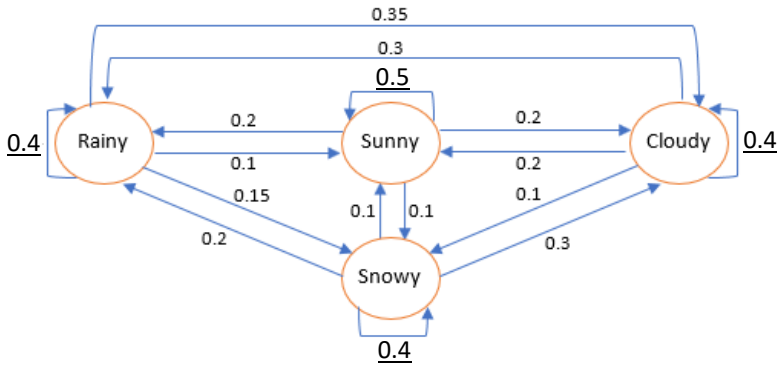
**Exercise N°1 (9.5 pts):** The following Markov model is organized around 4 states that describe the weather conditions of a given day (Sunny, Rainy, Cloudy, Snowy):




Initial state probabilities are: (Sunny: 0.3, Rainy: 0.2, Cloudy: 0.3, Snowy: 0.1) **(are not used at all)**
Emission probabilities for each state are as follows:

| | **Warm** | **Cold** | **Wet** | **Breezy** |
|---|---|---|---|---|
| **Sunny** | **0.6** | **0.1** | **0.2** | **0.1** |
| **Rainy** | **0.1** | **0.3** | **0.5** | **0.1** |
| **Cloudy** | **0.2** | **0.2** | **0.3** | **0.3** |
| **Snowy** | **0.05** | **0.5** | **0.1** | **0.35** |

**Complete missing probabilities (Reflexive arcs) (01 pt)**

Assuming today's weather is **rainy**, answer the following questions:

1) What will the weather be like tomorrow? **(01 pt)**
   **40% of chance will be a rainy weather**
2) What is the probability that the weather will be **snowy** the day after tomorrow? **(2.5 pts)**

| | Tomorrow | After tomorrow | Probability |
|---|---|---|---|
| Case 1 (Path 1) | Rainy | Snowy | 0.4 × 0.15 = 0.06 |
| Case 2 (Path 2) | Cloudy | Snowy | 0.35 × 0.1 = 0.035 |
| Case 3 (Path 3) | Snowy | Snowy | 0.15 × 0.4 = 0.06 |
| Case 4 (Path 4) | Sunny | Snowy | 0.1 × 0.1 = 0.01 |

   P(Snowy/After-Tomorrow) = P(Path1) + P(Path2) + P(Path3) + P(Path4)
   = 0.06+0.035+0.06+0.01 = 0.165
   **16.5% of chance that the weather will be Snowy after tomorrow**
3) What is the probability that the weather for the upcoming week will be:
   (rainy-snowy-snowy-rainy-cloudy-cloudy-sunny)? **(01 pt)**
   **P(Week)= 0.4 × 0.15 × 0.4 × 0.2 × 0.35 × 0.4 × 0.2 = 0.0001344 = 1.344 ×10$^{-4}$**
4) What is the most probable weather for three days (today and the two following days) to have the following conditions' sequence: (Cold-Wet-Warm)? **(04 pts)**
   **We should evaluate 16 possible paths.**
   **Noting that P(rainy) = 1 since we know that today is rainy**

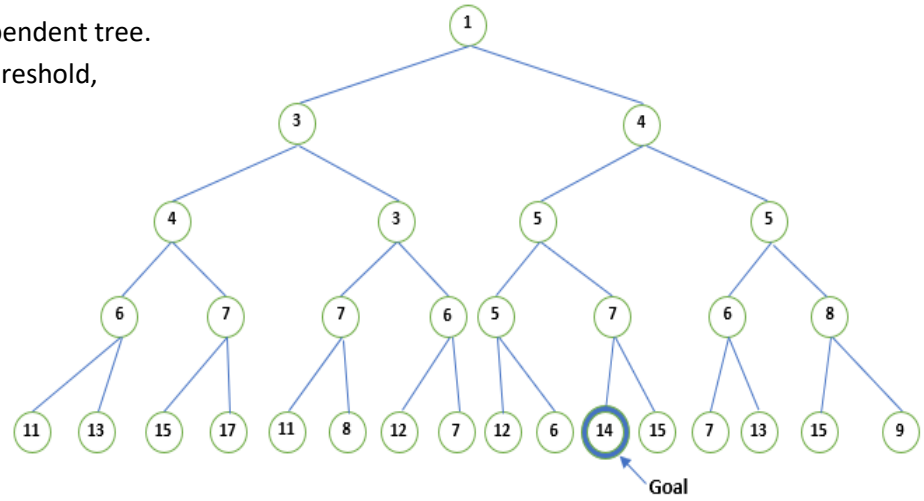
| | Paths | |
|---|---|---|
| **1** | **rainy ⇒ rainy ⇒ rainy** | P(rainy)xP(cold\|rainy)xP(rainy⇒rainy)xP(wet\|rainy)xP(rainy⇒rainy)xP(warm\|rainy)<br>= 1x0.3 x 0.4x0.5 x 0.4x0.1 = 0.0024 |
| **2** | **rainy⇒ rainy ⇒ cloudy** | **P(rainy)xP(cold\|rainy)xP(rainy⇒rainy)xP(wet\|rainy)xP(rainy⇒cloudy)xP(warm\|cloudy)**<br>**= 1x0.3 x 0.4x0.5 x 0.35x0.2 = 0.0042** |
| **3** | **rainy⇒ rainy ⇒ snowy** | P(rainy)xP(cold\|rainy)xP(rainy⇒rainy)xP(wet\|rainy)xP(rainy⇒snowy)xP(warm\|snowy)<br>= 1x0.3 x 0.4x0.5 x 0.15x0.05 = 0.00045 |
| **4** | **rainy ⇒ rainy ⇒ sunny** | P(rainy)xP(cold\|rainy)xP(rainy⇒rainy)xP(wet\|rainy)xP(rainy⇒sunny)xP(warm\|sunny)<br>= 1x0.3 x 0.4x0.5 x 0.1x0.6 = 0.0036 |
| **5** | **rainy⇒ cloudy ⇒ rainy** | P(rainy)xP(cold\|rainy)xP(rainy⇒cloudy)xP(wet\|cloudy)xP(cloudy⇒rainy)xP(warm\|rainy)<br>= 1x0.3 x 0.35x0.3 x 0.3x0.1 = 0.00315 |
| **6** | **rainy⇒ cloudy⇒ cloudy** | P(rainy)xP(cold\|rainy)xP(rainy⇒cloudy)xP(wet\|cloudy)xP(cloudy⇒cloudy)xP(warm\|cloudy)<br>= 1x0.3 x 0.35x0.3 x 0.4x0.2 = 0.00252 |
| **7** | **rainy ⇒ cloudy ⇒ snowy** | P(rainy)xP(cold\|rainy)xP(rainy⇒cloudy)xP(wet\|cloudy)xP(cloudy⇒snowy)xP(warm\|snowy)<br>= 1x0.3 x 0.35x0.3 x 0.1x0.05 = 0.0001575 |
| **8** | **rainy ⇒ cloudy ⇒ sunny** | P(rainy)xP(cold\|rainy)xP(rainy⇒cloudy)xP(wet\|cloudy)xP(cloudy⇒sunny)xP(warm\|sunny)<br>= 1x0.3 x 0.35x0.3 x 0.2x0.6 = 0.00378 |
| **9** | **rainy ⇒ snowy ⇒ rainy** | P(rainy)xP(cold\|rainy)xP(rainy⇒snowy)xP(wet\|snowy)xP(snowy⇒rainy)xP(warm\|rainy)<br>= 1x0.3 x 0.15x0.1 x 0.2x0.1 = 0.00009 |
| **10** | **rainy ⇒ snowy ⇒ cloudy** | P(rainy)xP(cold\|rainy)xP(rainy⇒snowy)xP(wet\|snowy)xP(snowy⇒cloudy)xP(warm\|cloudy)<br>= 1x0.3 x 0.15x0.1 x 0.3x0.2 = 0.00027 |
| **11** | **rainy ⇒ snowy ⇒ snowy** | P(rainy)xP(cold\|rainy)xP(rainy⇒snowy)xP(wet\|snowy)xP(snowy⇒snowy)xP(warm\|snowy)<br>= 1x0.3 x 0.15x0.1 x 0.4x0.05 = 0.00009 |
| **12** | **rainy ⇒ snowy ⇒ sunny** | P(rainy)xP(cold\|rainy)xP(rainy⇒snowy)xP(wet\|snowy)xP(snowy⇒sunny)xP(warm\|sunny)<br>= 1x0.3 x 0.15x0.1 x 0.1x0.6 = 0.00027 |
| **13** | **rainy ⇒ sunny ⇒ rainy** | P(rainy)xP(cold\|rainy)xP(rainy⇒sunny)xP(wet\|sunny)xP(sunny⇒rainy)xP(warm\|rainy)<br>= 1x0.3 x 0.1x0.2 x 0.2x0.1 = 0.00012 |
| **14** | **rainy ⇒ sunny ⇒ cloudy** | P(rainy)xP(cold\|rainy)xP(rainy⇒sunny)xP(wet\|sunny)xP(sunny⇒cloudy)xP(warm\|cloudy)<br>= 1x0.3 x 0.1x0.2 x 0.2x0.2 = 0.00024 |
| **15** | **rainy ⇒ sunny ⇒ snowy** | P(rainy)xP(cold\|rainy)xP(rainy⇒sunny)xP(wet\|sunny)xP(sunny⇒snowy)xP(warm\|snowy)<br>= 1x0.3 x 0.1x0.2 x 0.1x0.05 = 0.00003 |
| **16** | **rainy ⇒ sunny ⇒ sunny** | P(rainy)xP(cold\|rainy)xP(rainy⇒sunny)xP(wet\|sunny)xP(sunny⇒sunny)xP(warm\|sunny)<br>= 1x0.3 x 0.1x0.2 x 0.5x0.6 = 0.0018 |

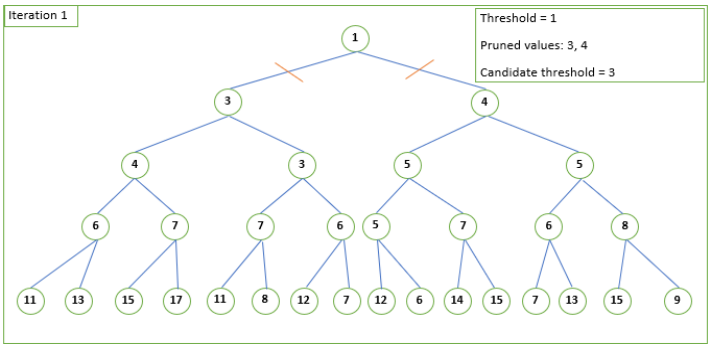
The most probable weather for the three days (today and the two following days) to have (cold-wet-warm) is:
**rainy⇒ rainy ⇒ cloudy**

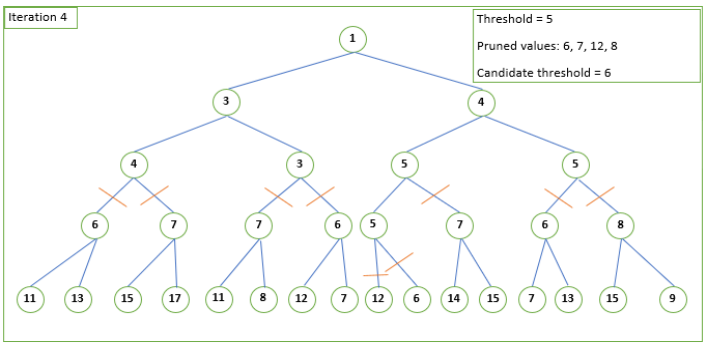
**Exercise N°2 (06 pts):** We want to perform an Iterative Deepening A* (IDA*) algorithm on the following tree. Each node is labelled with a utility value.

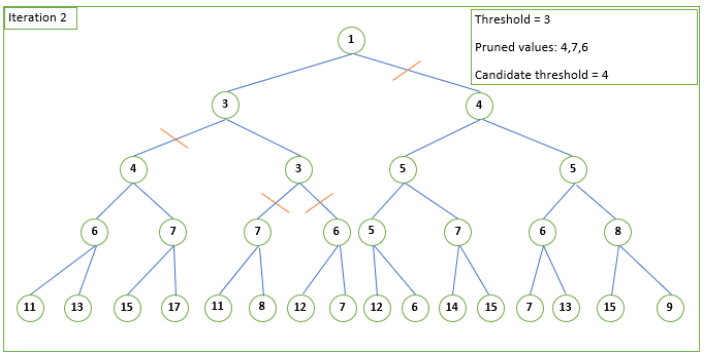
**Work to do:**

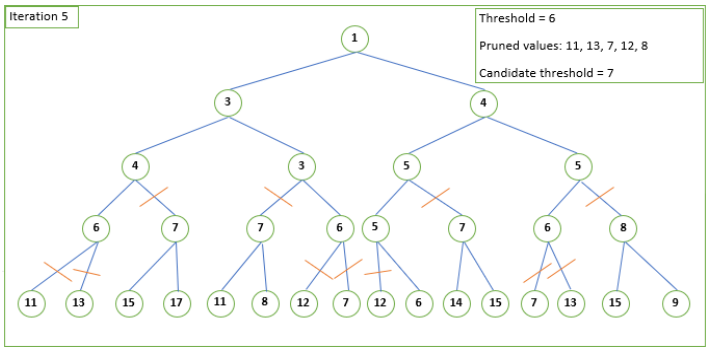
- Illustrate each iteration with an independent tree.
- Indicate for each iteration: Current threshold, Pruned values, Candidate threshold.

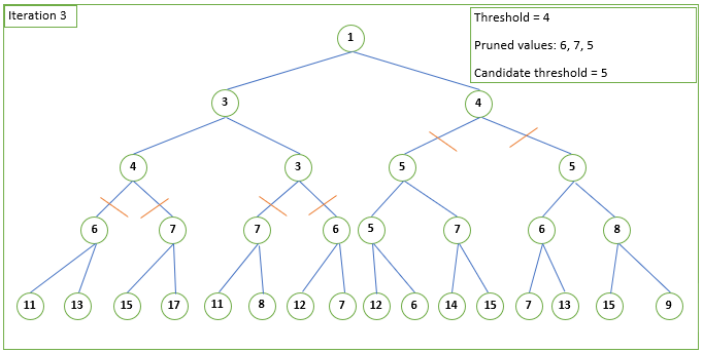


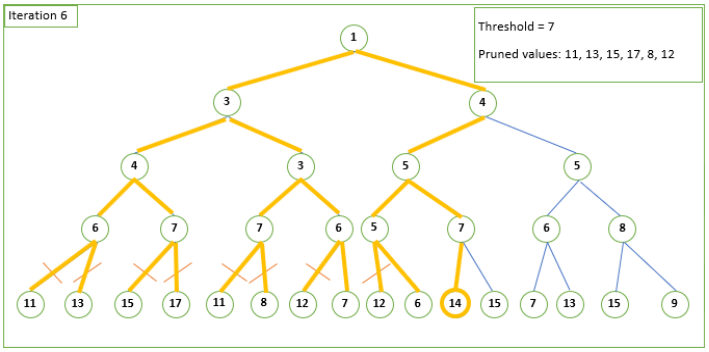



**Exercise N°3 (4.5 pts):** Consider a text corpus composed of the following sentences:

(1) A field of machine intelligence

(2) The study of intelligent agents

(3) The machine becomes increasingly intelligent

Generate the appropriate TF-IDF vectorization for the text corpus (Provide a detailed description of your approach).

**Solution:**

$$TF(Term\ Frequency) = \frac{Number\ of\ occurences\ of\ the\ word\ in\ sentence}{Number\ of\ words\ in\ sentence}$$ (0.25 pt)

$$IDF(Inverse\ Document\ Frequency) = \log\left(\frac{Number\ of\ sentences\ in\ the\ corpus}{Number\ of\ sentences\ that\ include\ the\ word}\right)$$ (0.25 pt)

**Term Frequency (TF) (1.5 pt)**

| | A | field | of | machine | intelligence | The | study | intelligent | agents | becomes | increasingly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 1/5 | 1/5 | 1/5 | 1/5 | 1/5 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) | 0 | 0 | 1/5 | 0 | 0 | 1/5 | 1/5 | 1/5 | 1/5 | 0 | 0 |
| (3) | 0 | 0 | 0 | 1/5 | 0 | 1/5 | 0 | 1/5 | 0 | 1/5 | 1/5 |

×

**Inverse Document Frequency (IDF) (01 pt)**

| A | field | of | machine | intelligence | The | study | intelligent | agents | becomes | increasingly |
|---|---|---|---|---|---|---|---|---|---|---|
| log(3/1)<br>0.47 | log(3/1)<br>0.47 | log(3/2)<br>0.17 | log(3/2)<br>0.17 | log(3/1)<br>0.47 | log(3/2)<br>0.17 | log(3/1)<br>0.47 | log(3/2)<br>0.17 | log(3/1)<br>0.47 | log(3/1)<br>0.47 | log(3/1)<br>0.47 |

=

**TF×IDF Vectorization (1.5 pt)**

| | A | field | of | machine | intelligence | The | study | intelligent | agents | becomes | increasingly |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | 0.094 | 0.094 | 0.034 | 0.034 | 0.094 | 0 | 0 | 0 | 0 | 0 | 0 |
| (2) | 0 | 0 | 0.034 | 0 | 0 | 0.034 | 0.094 | 0.034 | 0.094 | 0 | 0 |
| (3) | 0 | 0 | 0 | 0.034 | 0 | 0.034 | 0 | 0.034 | 0 | 0.094 | 0.094 |