KLASIFIKACIJA – NAIVNI BAJES

NIKOLA MILIKIĆ

EMAIL: nikola.milikic@fon.bg.ac.rs

URL: http://nikola.milikic.info

ŠTA JE KLASIFIKACIJA?

Zadatak određivanja klase kojoj neka instanca pripada

- instanca je opisana vrednošću atributa;
- skup mogućih klasa je poznat i dat

Primer – Predviđanje da li će se predstava odigrati

ToPlayOtNotToPlay.arff dataset

Outlook	Temp.	Humidity	Windy	Play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Kako sunčano vreme (outlook=sunny) utiće na ishod?

Pretpostavimo da znamo da je sunčano napolju

Outlook	Temp.	Humidity	Windy	Play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high		
overcast	hot	normal		
rainy	mild	high		

Onda je 60% šanse da bude Play = no

Kako vrednost atributa Outlook utiče na ishod?

Outlook	Temp.	Humidity	Windy	Play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	f	
rainy	cool	normal	t	
overcast	cool	normal		
sunny	mild	high		
sunny	cool	normal		
rainy	mild	normal		
sunny	mild	normal		
overcast	mild	high		
overcast	hot	normal		
rainy	mild	high		

	Play	
Outlook	yes	no
sunny	2	3
overcast	4	0
rainy	3	2
TOTAL	9	5

Kako vrednosti svih atributa utiču na ishod?

	Play	
Outlook	**yes**	**no**
sunny	2	3
overcast	4	0
rainy	3	2
TOTAL	9	5

Outlook	Temp.	Humidity	Windy	Play
sunny	hot	high	false	no
sunny	hot	high	true	no
overcast	hot	high	false	yes
rainy	mild	high	false	yes
rainy	cool	normal	false	yes
rainy	cool	normal	true	no
overcast	cool	normal	true	yes
sunny	mild	high	false	no
sunny	cool	normal	false	yes
rainy	mild	normal	false	yes
sunny	mild	normal	true	yes
overcast	mild	high	true	yes
overcast	hot	normal	false	yes
rainy	mild	high	true	no

Ponoviti za svaki atribut…

	Play			Play			Play			Play			Play
Outlook	**yes**	**no**	**Temp.**	**yes**	**no**	**Humid.**	**yes**	**no**	**Windy**	**yes**	**no**		
sunny	2	3	hot	2	2	high	3	4	false	6	2	yes	9
overcast	4	0	mild	4	2	normal	6	1	true	3	3	no	5
rainy	3	2	cool	3	1								
TOTAL	9	5	TOTAL	9	5	TOTAL	9	5	TOTAL	9	5	TOTAL	14

Pretvaramo brojeve pojavljivanja u procene verovatnoća

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	2	3	hot	2	2	high	3	4	false	6	2	yes	9
overcast	4	0	mild	4	2	normal	6	1	true	3	3	no	5
rainy	3	2	cool	3	1								
TOTAL	9	5	TOTAL	9	5	TOTAL	9	5	TOTAL	9	5	TOTAL	14

Pretvoriti brojeve u procene verovatnoća

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.22	0.60	hot	0.22	0.40	high	0.33	0.80	false	0.67	0.40	yes	0.64
overcast	0.44	0.00	mild	0.44	0.40	normal	0.67	0.20	true	0.33	0.60	no	0.36
rainy	0.33	0.40	cool	0.33	0.20								

2 pojavljivanja **Play = no**, gde je **Outlook = rainy**
5 pojavljivanja **Play = no**

Verovatnoća da će se igrati pod uslovima U1

Pod uslovima U1:

Outlook = sunny (0.22)
Temperature = cool (0.33)
Humidity = high (0.33)
Windy = true (0.33)

Izračunati verovatnoću da:

Play = yes (0.64)

Verovatnoća da će se igrati pod datim vremenskim uslovima

0.22 x 0.33 x 0.33 x 0.33 x 0.64 = **0.0053**

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.22	0.60	hot	0.22	0.40	high	0.33	0.80	false	0.67	0.40	yes	0.64
overcast	0.44	0.00	mild	0.44	0.40	normal	0.67	0.20	true	0.33	0.60	no	0.36
rainy	0.33	0.40	cool	0.33	0.20								

Verovatnoća da se NEĆE igrati pod uslovima U1

Pod uslovima U1:

Outlook = sunny (0.60)
Temperature = cool (0.20)
Humidity = high (0.80)
Windy = true (0.60)

Izračunati verovatnoću da:

Play = no (0.36)

Verovatnoća da se **NEĆE** igrati pod datim vremenskim uslovima

0.60 x 0.20 x 0.80 x 0.60 x 0.36 = **0.0206**

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.22	0.60	hot	0.22	0.40	high	0.33	0.80	false	0.67	0.40	yes	0.64
overcast	0.44	0.00	mild	0.44	0.40	normal	0.67	0.20	true	0.33	0.60	no	0.36
rainy	0.33	0.40	cool	0.33	0.20								

Računamo verovatnoće da li će se odigrati pod U1

Pod uslovima U1:

Outlook = sunny
Temperature = cool
Humidity = high
Windy = true

Verovatnoća da **Play = yes**: $\frac{0.0053}{0.0053 + 0.0206} = \mathbf{20.5\%}$

Verovatnoća da **Play = no**: $\frac{0.0206}{0.0053 + 0.0206} = \mathbf{79.5\%}$

Verovatnoća da se NEĆE igrati pod uslovima U2

Pod uslovima U2:

Outlook = ovecast (0.00)
Temperature = cool (0.20)
Humidity = high (0.80)
Windy = true (0.60)

Izračunati verovatnoću da:

Play = no (0.36)

Neće se igrati **0%**, odnosno Igraće se **100%**?

0.00 x 0.20 x 0.80 x 0.60 x 0.36 = **0.0000**

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.22	0.60	hot	0.22	0.40	high	0.33	0.80	false	0.67	0.40	yes	0.64
overcast	0.44	0.00	mild	0.44	0.40	normal	0.67	0.20	true	0.33	0.60	no	0.36
rainy	0.33	0.40	cool	0.33	0.20								

Primena Laplace estimator-a

Pojavljivanja iz originalnog dataset-a

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	2	3	hot	2	2	high	3	4	false	6	2	yes	9
overcast	4	0	mild	4	2	normal	6	1	true	3	3	no	5
rainy	3	2	cool	3	1								
TOTAL	9	5	TOTAL	9	5	TOTAL	9	5	TOTAL	9	5	TOTAL	14

Laplace estimator:
Dodati 1 svakom broju

Nakon dodavanja 1 svakom broju (Laplace estimator)

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	3	4	hot	3	3	high	4	5	false	7	3	yes	12
overcast	5	1	mild	5	3	normal	7	2	true	4	4	no	8
rainy	4	3	cool	4	2								
TOTAL	12	8	TOTAL	12	8	TOTAL	11	7	TOTAL	11	7	TOTAL	20

Računanje procena verovatnoća nakon primene Laplace estimator-a

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	3	4	hot	3	3	high	4	5	false	7	3	yes	9
overcast	5	1	mild	5	3	normal	7	2	true	4	4	no	5
rainy	4	3	cool	4	2								
TOTAL	12	8	TOTAL	12	8	TOTAL	11	7	TOTAL	11	7	TOTAL	14

Pretvoriti inkrementirane vrednosti u procene verovatnoća nakon primene Laplace estimator

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.25	0.50	hot	0.25	0.38	high	0.36	0.71	false	0.64	0.43	yes	0.64
overcast	0.42	0.13	mild	0.42	0.38	normal	0.64	0.29	true	0.36	0.57	no	0.36
rainy	0.33	0.38	cool	0.33	0.25								

Verovatnoće da li će se odigrati predstava pod U2

	Play			Play			Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.25	0.50	hot	0.25	0.38	high	0.36	0.71	false	0.64	0.43	yes	0.64
overcast	0.42	0.13	mild	0.42	0.38	normal	0.64	0.29	true	0.36	0.57	no	0.36
rainy	0.33	0.38	cool	0.33	0.25								

Pod uslovima U2:

Outlook = ovecast, Temperature = cool, Humidity = high, Windy = true

Play = no: 0.13 x 0.25 x 0.71 x 0.57 x 0.36 = 0.046

Play = yes: 0.42 x 0.33 x 0.36 x 0.36 x 0.64 = 0.0118

Verovatnoća da **Play = no**: $\frac{0.0046}{0.0046 + 0.0118} = \mathbf{28\%}$

Verovatnoća da **Play = yes**: $\frac{0.0118}{0.0046 + 0.0118} = \mathbf{72\%}$

Verovatnoće pod uslovima U1 pre i nakon primene Laplace estimator-a

Pod uslovima U1:

Outlook = sunny
Temperature = cool
Humidity = high
Windy = true

Bez korišćenja Laplace estimator-a:

Play = no: 79.5%
Play = yes: 20.5%

Korišćenjem Laplace estimator-a:

Play = no: 72.0%
Play = yes: 28.0%

Efekat **Laplace estimator**-a opada povećanjem broja uzoraka.

Predikciona pravila

Outlook	Temp.	Humid.	Windy	Play
overcast	cool	high	false	no
overcast	cool	high	false	yes
overcast	cool	high	true	no
overcast	cool	high	true	yes
overcast	cool	normal	false	no
overcast	cool	normal	false	yes
overcast	cool	normal	true	no
overcast	cool	normal	true	yes
overcast	hot	high	false	no
overcast	hot	high	false	yes
overcast	hot	high	true	no
overcast	hot	high	true	yes
overcast	hot	normal	false	no
overcast	hot	normal	false	yes
overcast	hot	normal	true	no
overcast	hot	normal	true	yes

Ponoviti prethodne kalkulacije za sve moguće kombinacije vremenskih prilika. Odbaciti kombinacije kod kojih je verovatnoća < 0.5

Predikciona pravila – verovatnoće svih kombinacija

	Play			Play		Play			Play			Play
Outlook	yes	no	Temp.	yes	no	Humid.	yes	no	Windy	yes	no		
sunny	0.25	0.50	hot	0.25	0.38	high	0.36	0.71	false	0.64	0.43	yes	0.64
overcast	0.42	0.13	mild	0.42	0.38	normal	0.64	0.29	true	0.36	0.57	no	0.36
rainy	0.33	0.38	cool	0.33	0.25								

Inst	Outlook	Temp.	Humid.	Windy	Play	Outlook	Temp.	Humid.	Windy	Play	Like.	Prob.
	overcast	cool	high	false	no	0.13	0.25	0.71	0.43	0.36	0.0034	14.2%
	overcast	cool	high	false	yes	0.42	0.33	0.36	0.64	0.64	0.0207	85.8%
	overcast	cool	high	true	no	0.13	0.25	0.71	0.57	0.36	0.0046	27.8%
	overcast	cool	high					0.36	0.36	0.64	0.0118	72.2%
	overcast	cool	normal					0.29	0.43	0.36	0.0014	3.6%
	overcast	cool	normal	false	yes	0.42	0.33	0.64	0.64	0.64	0.0362	96.4%
	overcast	cool	normal	true	no	0.13	0.25	0.29	0.57	0.36	0.0018	8.1%
7	overcast	cool	normal	true	yes	0.42	0.33	0.64	0.36	0.64	0.0207	91.9%
	overcast	hot	high	false	no	0.13	0.38	0.71	0.43	0.36	0.0051	24.9%
3	overcast	hot	high	false	yes	0.42	0.25	0.36	0.64	0.64	0.0155	75.1%

Izračunati verovatnoće za svih 36 kombinacija

Predikciona pravila – verovatnoće svih kombinacija

Inst	Outlook	Temp.	Humid.	Windy	Play	Prob.
	overcast	cool	normal	false	yes	96.4%
	overcast	mild	normal	false	yes	95.7%
13	overcast	hot	normal	false	yes	93.0%
7	overcast	cool	normal	true	yes	91.9%
	overcast	mild	normal	true	yes	90.4%
5	rainy	cool	normal	false	yes	87.6%
	overcast	cool	high	false	yes	85.8%
10	rainy	mild	normal	false	yes	85.5%
	overcast	hot	normal	true	yes	85.0%
2	sunny	hot	high	true	no	83.7%
	overcast	mild	high	false	yes	83.4%
9	sunny	cool	normal	false	yes	79.9%
	rainy	hot	normal	false	yes	77.9%
	sunny	mild	normal	false	yes	76.8%
	sunny	mild	high	true	no	75.5%
3	overcast	hot	high	false	yes	75.1%
	rainy	cool	normal	true	yes	75.1%
	rainy	hot	high	true	no	74.3%

Pravila koja predviđaju klasu svih kombinacija atributa

Inst	Outlook	Temp.	Humid.	Windy	Play	Prob.
	overcast	cool	high	true	yes	72.2%
	sunny	cool	high	true	no	72.0%
	rainy	mild	normal	true	yes	71.6%
1	sunny	hot	high	false	no	68.8%
12	overcast	mild	high	true	yes	68.4%
	sunny	hot	normal	false	yes	66.5%
14	rainy	mild	high	true	no	63.5%
	sunny	cool	normal	true	yes	63.0%
	rainy	cool	high	false	yes	61.7%
	rainy	hot	normal	true	yes	60.2%
	rainy	cool	high	true	no	59.1%
11	sunny	mild	normal	true	yes	58.6%
4	rainy	mild	high	false	yes	57.3%
8	sunny	mild	high	false	no	57.0%
	overcast	hot	high	true	yes	56.4%
	rainy	hot	high	false	no	55.4%
	sunny	hot	normal	true	no	54.0%
	sunny	cool	high	false	no	52.4%

Nedostaje instanca 6

Poređenje originalnih i predviđenih odluka

Inst	Outlook	Temp.	Humid.	Windy	Play	Prob.	Actual
1	sunny	hot	high	false	no	72.6%	no
2	sunny	hot	high	true	no	86.1%	no
3	overcast	hot	high	false	yes	71.6%	yes
4	rainy	mild	high	false	yes	52.8%	yes
5	rainy	cool	normal	false	yes	85.5%	yes
6	rainy	cool	normal	true	yes	75.1%	no
7	overcast	cool	normal	true	yes	90.4%	yes
8	sunny	mild	high	false	no	61.4%	no
9	sunny	cool	normal	false	yes	76.8%	yes
10	rainy	mild	normal	false	yes	83.0%	yes
11	sunny	mild	normal	true	yes	54.2%	yes
12	overcast	mild	high	true	yes	64.3%	yes
13	overcast	hot	normal	false	yes	91.7%	yes
14	rainy	mild	high	true	no	67.6%	no

Weka

- Softver za data mining u Javi
- Skup algoritama za mašinsko učenje i data mining
- Razvijen pri Univerzitetu Waikato, Novi Zeland
- Open-source
- Vebsajt: http://www.cs.waikato.ac.nz/ml/weka

Skupovi podataka korišćeni na vežbama

- Korišćeni skupovi podataka sa sajta Technology Forge:

http://www.technologyforge.net/Datasets

ARFF fajl

- Attribute-Relation File Format – ARFF
- Tekstualni fajl

Atributi mogu biti:
- Numerički
- Nominalni

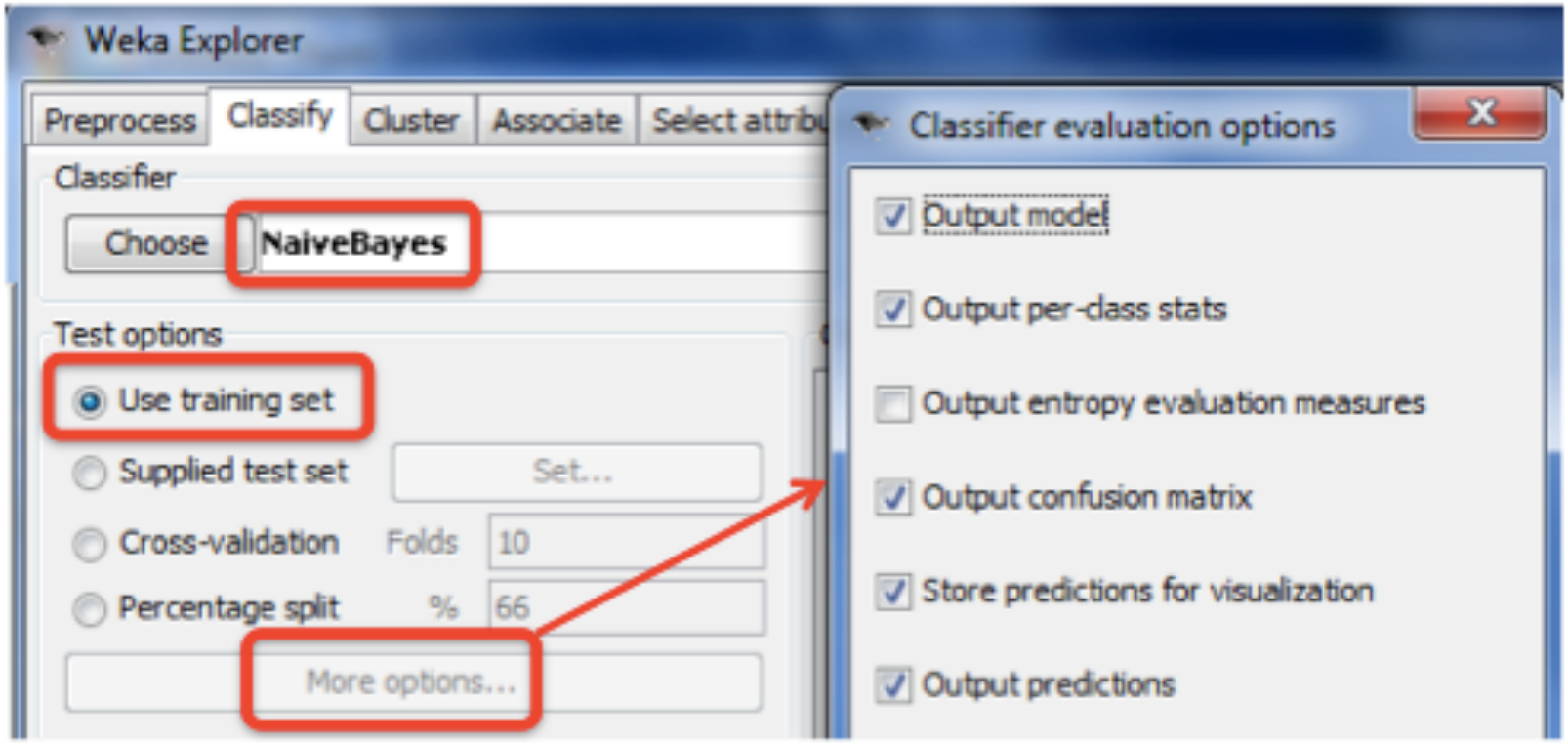
```
@relation TPONTPNom

@attribute Outlook {sunny, overcast, rainy}
@attribute Temp. {hot, mild, cool}
@attribute Humidity {high, normal}
@attribute Windy {'false', 'true'}
@attribute Play {no, yes}

@data
sunny, hot, high, 'false', no
sunny, hot, high, 'true', no
overcast, hot, high, 'false', yes
...
```

Pokretanje klasifikacije u Weka-i

ToPlayOtNotToPlay.arff dataset



Prikaz rezultata klasifikacije

	Play	
Outlook	yes	no
sunny	3	4
overcast	5	1
rainy	4	3
TOTAL	12	8

	Play	
Temp.	yes	no
hot	3	3
mild	5	3
cool	4	2
TOTAL	12	8

	Play	
Humid.	yes	no
high	4	5
normal	7	2
TOTAL	11	7

	Play	
Windy	yes	no
false	7	3

Play	
yes	12

Classifier output

```
Attribute                no      yes
                      (0.38)  (0.63)
================================
Outlook
  sunny                 4.0     3.0
  overcast              1.0     5.0
  rainy                 3.0     4.0
  [total]               8.0    12.0

Temp.
  hot                   3.0     3.0
  mild                  3.0     5.0
  cool                  2.0     4.0
  [total]               8.0    12.0

Humidity
  high                  5.0     4.0
  normal                2.0     7.0
  [total]               7.0    11.0
```

Klasifikator automatski primenjuje Laplace estimator

Prikaz rezultata klasifikacije

Classifier output

```
=== Predictions on training set ===

 inst#     actual  predicted error prediction
     1       1:no       1:no       0.704
     2       1:no       1:no       0.847
     3      2:yes      2:yes       0.737
     4      2:yes      2:yes       0.554
     5      2:yes      2:yes       0.867
     6       1:no      2:yes   +   0.737
     7      2:yes      2:yes       0.913
     8       1:no       1:no       0.588
     9      2:yes      2:yes       0.786
    10      2:yes      2:yes       0.845
    11      2:yes      2:yes       0.568
    12      2:yes      2:yes       0.667
    13      2:yes      2:yes       0.925
    14       1:no       1:no       0.652
```

Instanca 6 je obeležena kao pogrešno klasifikovana

Verovatnoća svake instance u datasetu

Precision, Recall i F measure

```
=== Detailed Accuracy By Class ===

                 TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
                   0.8       0          1         0.8       0.889      0.911    no
                   1         0.2        0.9       1         0.947      0.922    yes
Weighted Avg.      0.929     0.129      0.936     0.929     0.926      0.918
```

True Positives Rate

False Positives Rate

$$\text{Precision} = \frac{TP}{(TP + FP)}$$

$$\text{Recall} = \frac{TP}{(TP + FN)}$$

$$\text{F measure} = \frac{2 * \text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$

Matrica zabune (Confusion Matrix)

		Predicted Class: Yes	Predicted Class: No
Actual Class	Yes	TP	FN
	No	FP	TN

TP = True Positive

FP = False Positive

TN = True Negative

FN = False Negative

```
=== Confusion Matrix ===

 a b   <-- classified as
 4 1 | a = no
 0 9 | b = yes
```

Primer 2 – Skup podataka “Jestive pečurke”

- Skup podataka “Jestive pečurke” je nastao na osnovu knjige “National Audubon Society Field Guide to North American Mushrooms”
- Skup podataka obuhvata opise hipotetičkih uzoraka pečuraka koje spadaju jednoj od 23 vrste pečuraka
- Postoji ukupno 8124 instanci sa 22 atributa nominalnih vrednosti koje opisuju karakteristike pečuraka i imaju podatak da li su pečurke jestive ili ne
- Naš cilj je da predvidimo da li je nepoznata pečurka jestiva ili ne

Preporuke i zahvalnice

Weka Tutorials and Assignments @ The Technology Forge

- Link: http://www.technologyforge.net/WekaTutorials/

(Anonimni) upitnik za vaše kritike, komentare, predloge:

http://goo.gl/cqdp3I

PITANJA?

NIKOLA MILIKIĆ

EMAIL: nikola.milikic@fon.bg.ac.rs

URL: http://nikola.milikic.info