

Detekcija ljudi u elektromagnetskom polju Wi-Fi signala

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Elektromagnetski valovi

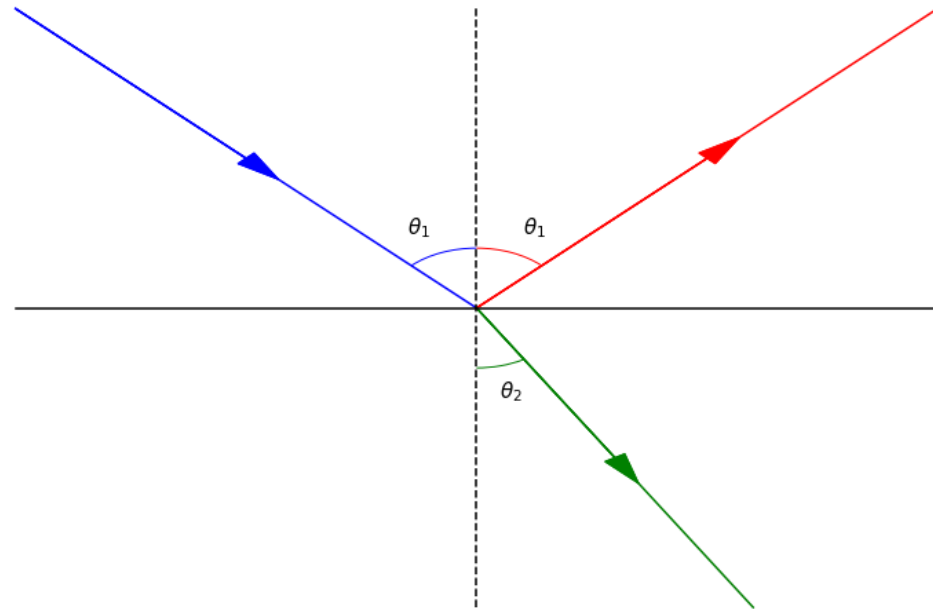
Valna jednadžba za elektromagnetske valove

$$\nabla^2 \mathbf{E} = \mu \varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

$$\nabla^2 \mathbf{B} = \mu \varepsilon \frac{\partial^2 \mathbf{B}}{\partial t^2}$$

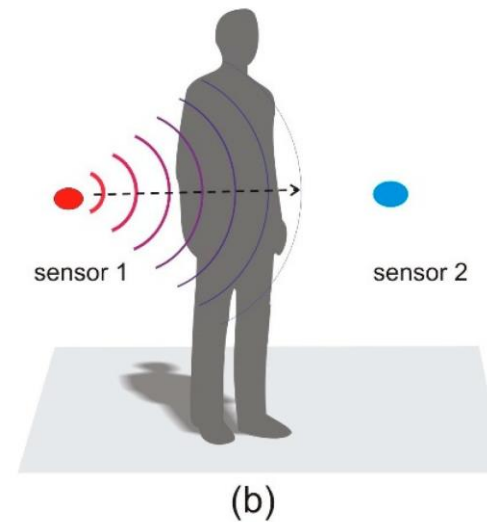
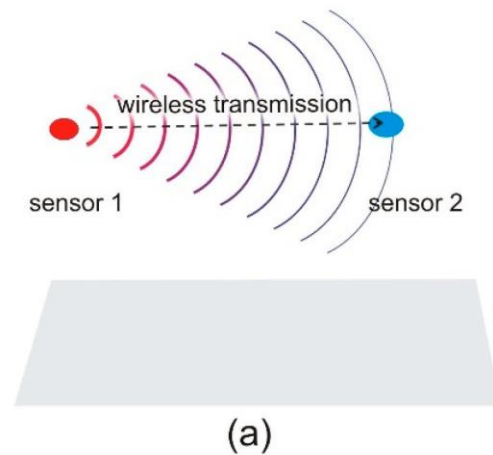
Snellov zakon

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$



Wi-Fi zračenje

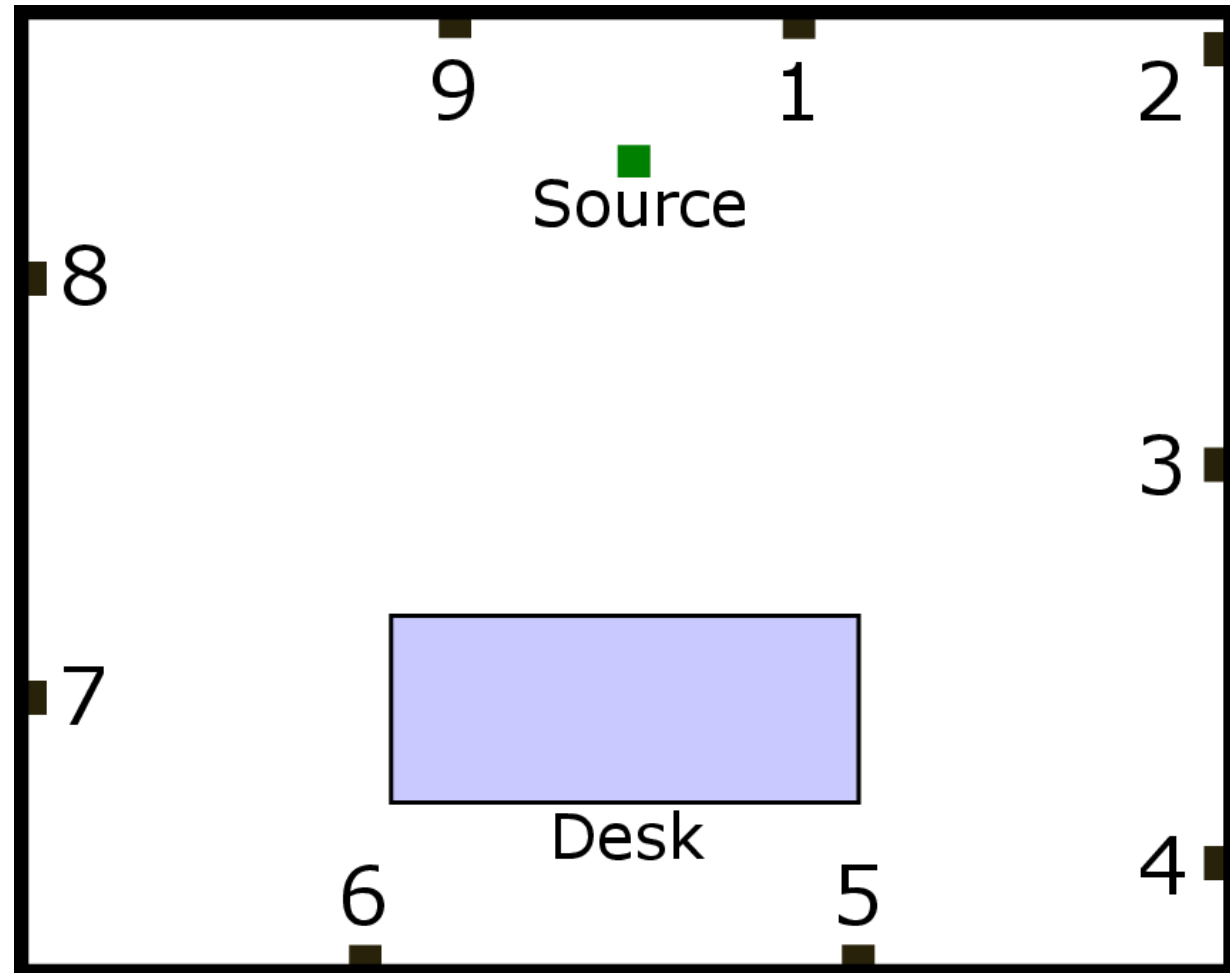
- EM zračenje na Wi-Fi frekventnom području ($\approx 2.4MHz$)
- Informacije o signal:
 - Received Signal Strength Indicator (RSSI)
 - Channel State Information (CSI)



Mjerenja

Ciljevi:

1. Detektirati prisutnost ljudi
2. Odrediti broj prisutnih ljudi



Mjerenja

Time	RSSI	RSSI_2	RSSI_3	RSSI_4	RSSI_5	RSSI_6	RSSI_7	RSSI_8	RSSI_9
0.000000	-62	-64	-64	-65	-63	-65	-67	-73	-65
0.103295	-66	-63	-63	-67	-63	-62	-67	-73	-67
0.202423	-61	-62	-64	-68	-65	-65	-67	-73	-66
0.307754	-63	-63	-62	-68	-64	-63	-66	-73	-67
0.411594	-61	-63	-63	-67	-64	-64	-67	-73	-66
...
1194.120668	-60	-62	-67	-67	-61	-64	-66	-79	-71
1194.225522	-62	-61	-66	-66	-63	-64	-65	-72	-71
1194.331375	-61	-60	-66	-66	-61	-64	-67	-74	-72
1194.432060	-61	-61	-64	-66	-61	-64	-65	-76	-72
1194.533965	-62	-61	-65	-66	-62	-64	-65	-76	-70

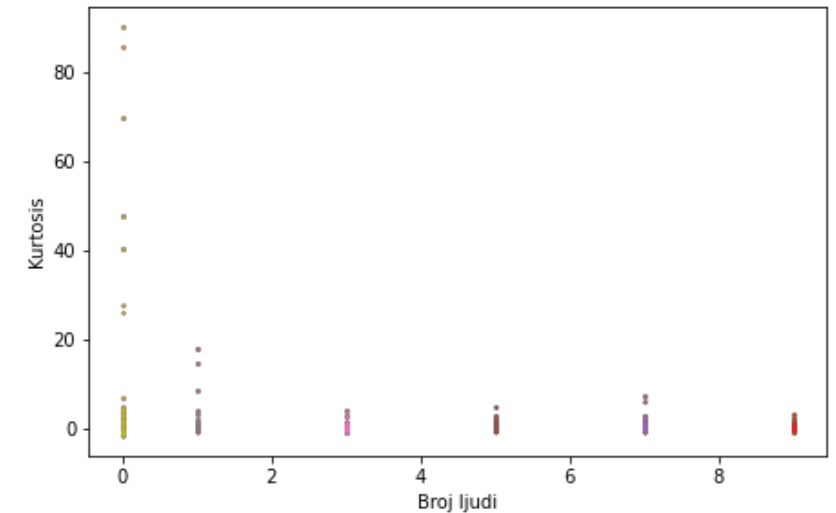
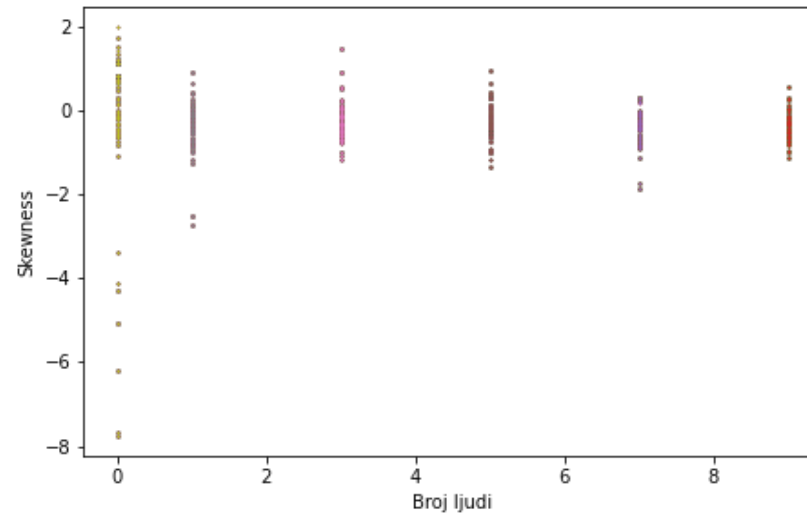
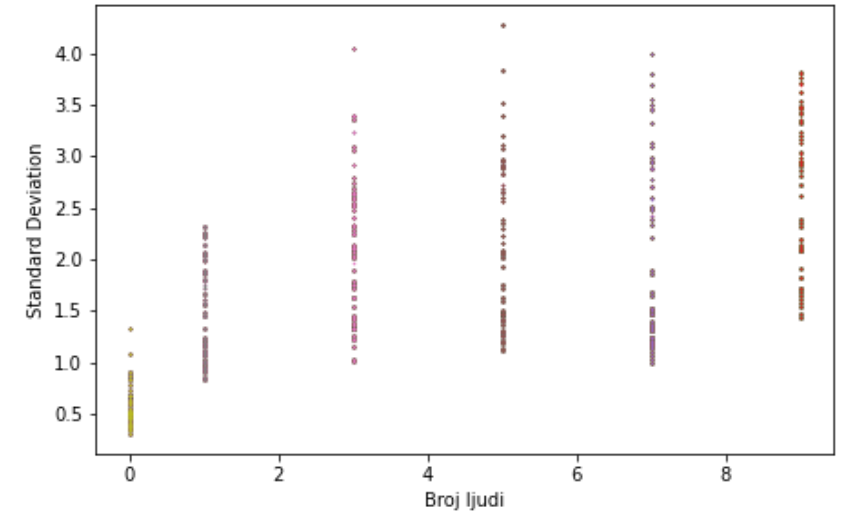
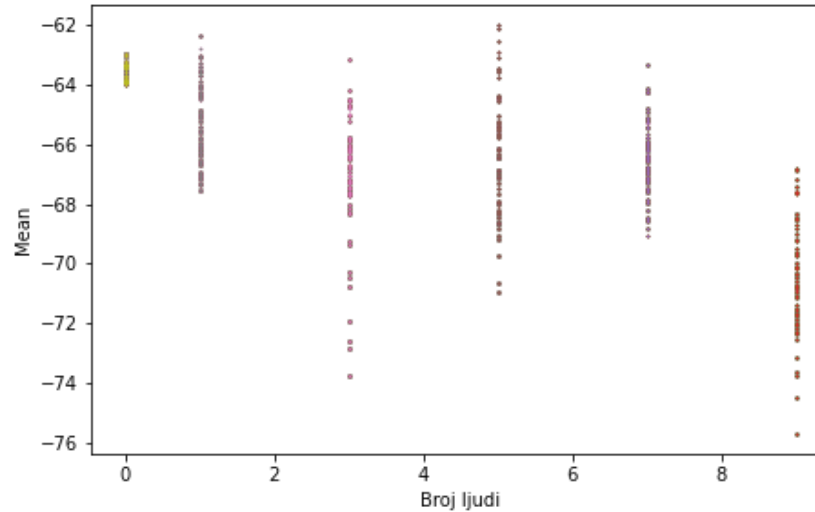
Statistička analiza

$$\mu \equiv \frac{1}{n} \left(\sum_{i=1}^n x_i \right)$$

$$\sigma \equiv \sqrt{E(X - \mu)^2}$$

$$\mu_3 \equiv E \left[\left(\frac{X - \mu}{\sigma} \right)^3 \right]$$

$$Kurt \equiv E \left[\left(\frac{X - \mu}{\sigma} \right)^4 \right]$$



Statistička analiza - rezultati

Broj ljudi	Broj točnih predviđanja	Udio točnih predviđanja (%)
Without people	379 / 400	94.8
1 person	44 / 59	74.6
3 people	58 / 59	98.3
5 people	59 / 59	100.0
7 people	59 / 59	100.0
9 people	59 / 59	100.0

Metode strojnog učenja (K najbližih susjeda)

Za određivanje prisutnosti ljudi algoritam ima sto postotnu točnost, dok za određivanje broja ljudi ima točnost od 94.21%

K najbližih susjeda	Srednja točnost unakrsne provjere (%)	Točnost na testnom setu (%)
Detektor 1	93.54	91.74
Detektor 2	66.87	62.81
Detektor 3	94.58	95.04
Detektor 4	93.13	95.04
Detektor 5	100.00	100.00
Detektor 6	90.83	95.87
Detektor 7	88.54	93.39
Detektor 8	97.50	98.35
Detektor 9	100.00	100.00

K najbližih susjeda	Srednja točnost unakrsne provjere (%)	Točnost na testnom setu (%)
Detektor 1	62.50	57.85
Detektor 2	59.17	53.72
Detektor 3	61.67	57.85
Detektor 4	82.71	82.64
Detektor 5	72.29	66.12
Detektor 6	66.46	68.60
Detektor 7	63.75	59.50
Detektor 8	67.29	66.12
Detektor 9	65.63	58.68

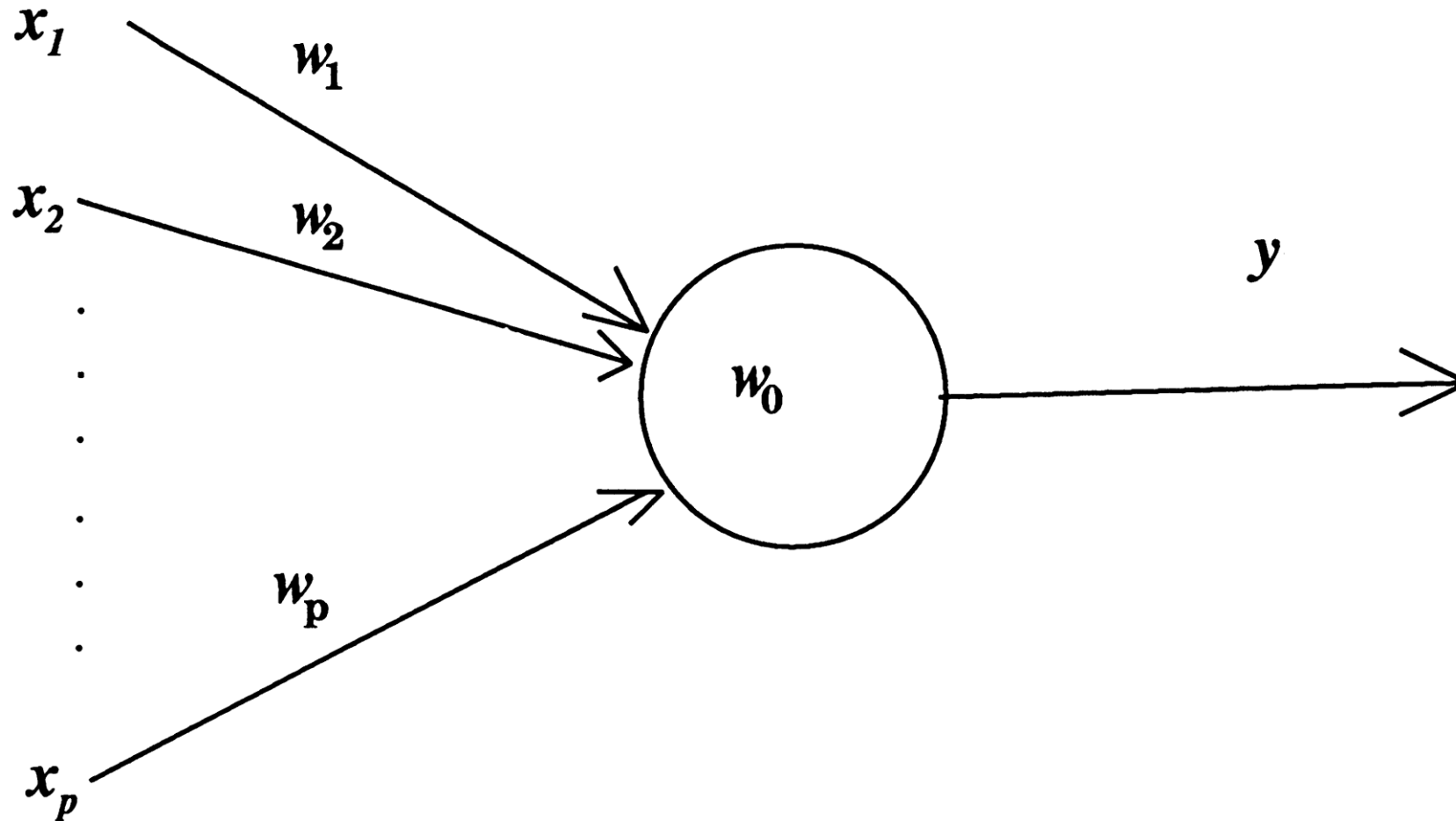
Metode strojnog učenja (Slučajna šuma)

Za određivanje prisutnosti ljudi algoritam ima sto postotnu točnost, dok za određivanje broja ljudi ima točnost od 98.35%

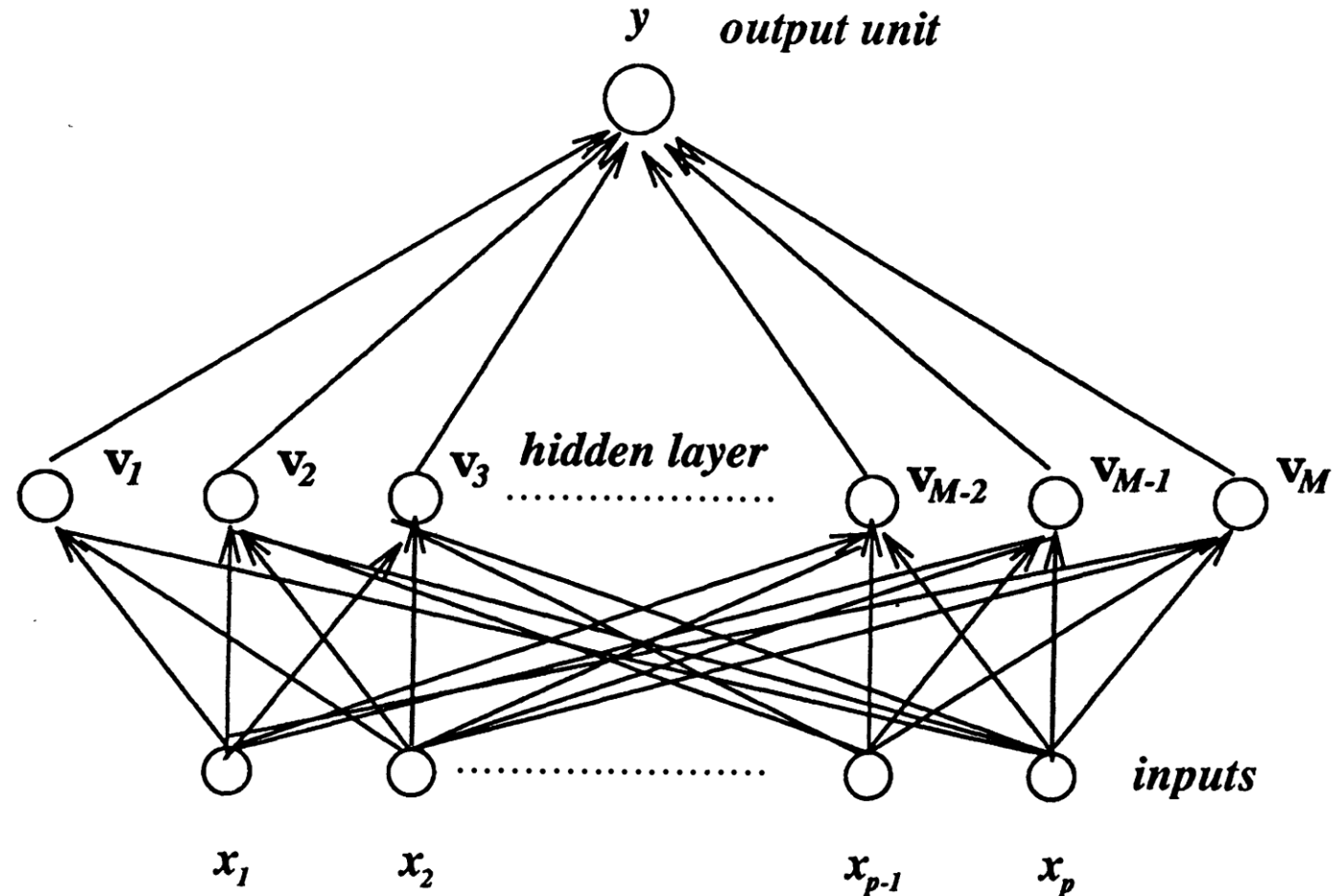
Slučajna šuma	Srednja točnost unakrsne provjere (%)	Točnost na testnom setu (%)
Detektor 1	94.17	95.04
Detektor 2	97.08	95.87
Detektor 3	98.33	100.00
Detektor 4	95.83	98.35
Detektor 5	100.00	100.00
Detektor 6	97.50	97.52
Detektor 7	97.71	98.35
Detektor 8	98.33	98.35
Detektor 9	100.00	100.00

Slučajna šuma	Srednja točnost unakrsne provjere (%)	Točnost na testnom setu (%)
Detektor 1	66.04	61.98
Detektor 2	65.83	69.42
Detektor 3	68.33	69.42
Detektor 4	89.17	86.78
Detektor 5	74.58	72.73
Detektor 6	68.13	69.42
Detektor 7	69.38	66.94
Detektor 8	68.75	66.12
Detektor 9	70.42	63.64

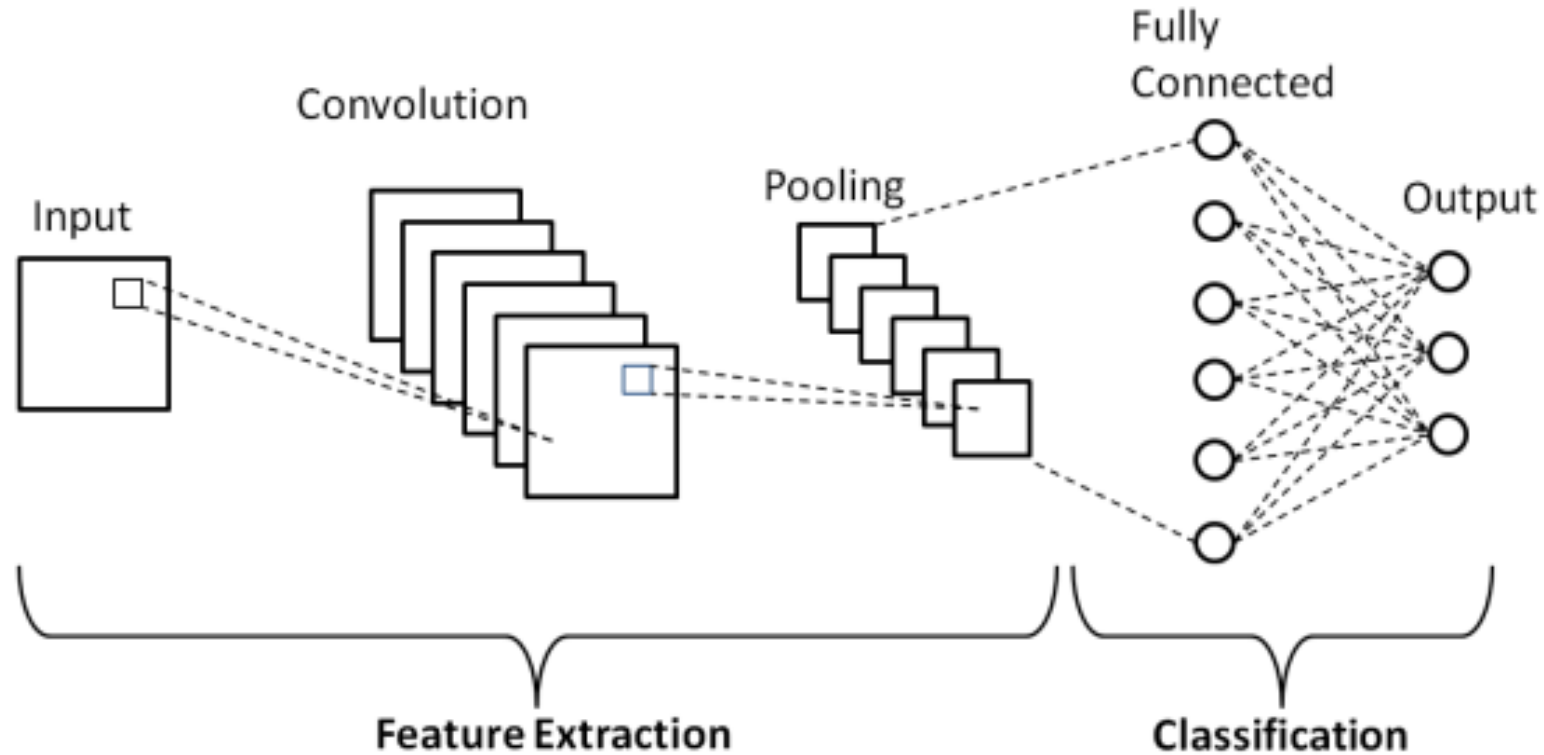
Metode dubokog učenja (Standardna neuralna mreža)



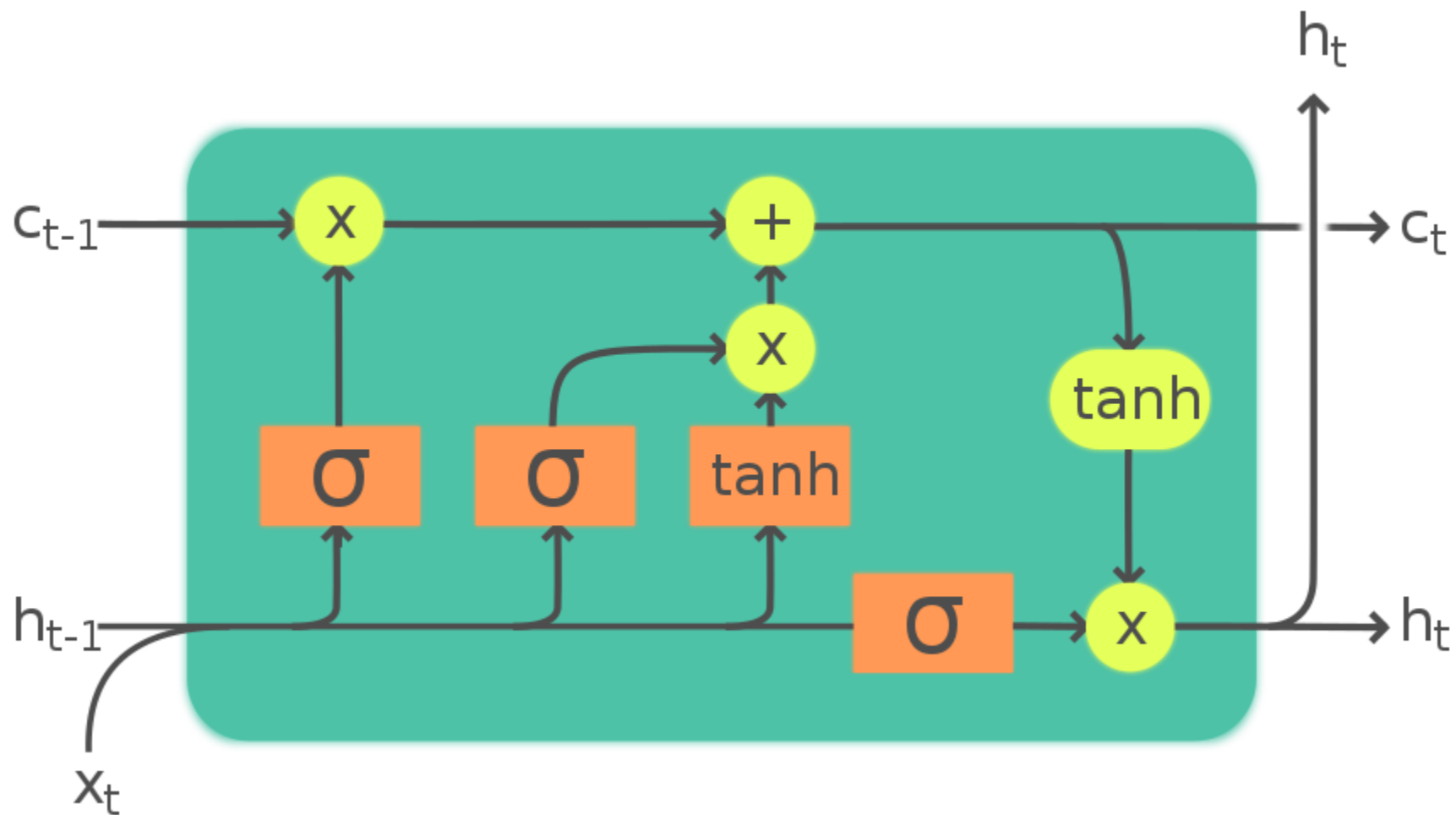
Metode dubokog učenja (Standardna neuralna mreža)



Metode dubokog učenja (Konvolucijska neuralna mreža)



Metode dubokog učenja (LSTM mreža)



Metode dubokog učenja - rezultati

Za određivanje prisutnosti ljudi svi algoritmi ima sto postotnu točnost, kao i za određivanje broja ljudi

Detektor	CNN (%)	LSTM (%)	LSTM-CNN (%)	Detektor	CNN (%)	LSTM (%)	LSTM-CNN (%)
1	90.91	91.74	91.74	1	64.46	57.85	62.81
2	96.69	97.52	97.52	2	66.12	59.50	71.90
3	99.17	98.35	97.52	3	70.25	62.81	70.25
4	97.52	90.91	97.52	4	85.95	77.69	76.86
5	100.0	100.0	100.0	5	64.46	60.33	66.94
6	98.35	97.52	96.69	6	65.29	60.33	60.33
7	96.69	97.52	97.52	7	70.25	63.64	73.55
8	100.0	100.0	100.0	8	66.12	62.81	64.86
9	100.0	100.0	100.0	9	61.16	57.02	58.68

Zaključak

- Pokušali smo detektirati prisutnost i odrediti broj ljudi u Wi-Fi polju
- Koristili smo različite metode s različitim razinom uspjeha
- Broj senzora i njihov prostorni raspored bitno utječu na točnost rezultata

Literatura

- [1] J. Liu, H. Liu, Y. Chen, Y. Wang, and C. Wang, Wireless sensing for human activity: A survey, IEEE Communications Surveys Tutorials PP, 1 (2019).
- [2] Januszkiewicz, Analysis of human body shadowing effect on wireless sensor networks operating in the 2.4 ghz band, Sensors 18, 10.3390/s18103412 (2018).
- [3] B. Cheng and D. M. Titterington, Neural Networks: A Review from a Statistical Perspective, Statistical Science 9, 2 (1994).
- [4] D. Jukić, S. Domazet, A. Ivanko, D. Raca, S. Nikolić, M. Knežević, F. Jović, N. Raca, and H. Buljan, Determining the presence and the number of people by using a wi-fi signal (2023), arXiv:2308.06773 [eess.SP].