Introduction
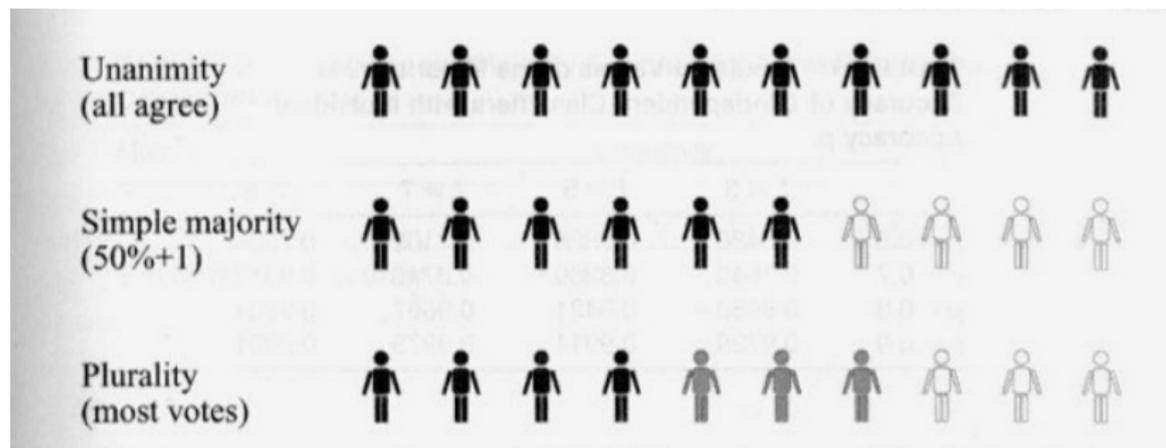
- Voting: decision-making strategy
- Majority vote
- Weighted majority voting
- Naive Bayes combination

- Three Main Types of Majority Voting

Unanimity (all agree)

Simple majority (50%+1)

Plurality (most votes)

[1]

Ensemble of Classifiers Increases Accuracy

- The accuracy of the ensemble is

$$P_{maj} = \sum_{m=\lfloor L/2 \rfloor+1}^{L} \binom{L}{m} p^m (1-p)^{L-m}$$ assuming that the

probability of success p is the same for all classifiers

TABLE 4.1 Tabulated Values of the Majority Vote Accuracy of L Independent Classifiers with Individual Accuracy p.

	$L=3$	$L=5$	$L=7$	$L=9$
$p=0.6$	0.6480	0.6826	0.7102	0.7334
$p=0.7$	0.7840	0.8369	0.8740	0.9012
$p=0.8$	0.8960	0.9421	0.9667	0.9804
$p=0.9$	0.9720	0.9914	0.9973	0.9991

[1]

Majority Voting Perormance

No.	111 a	101 b	011 c	001 d	110 e	100 f	010 g	000 h	P_{maj}	$P_{maj} - p$
Pattern of success										
1	0	3	3	0	3	0	0	1	0.9	0.3
2	2	2	2	0	2	0	0	2	0.8	0.2
3	1	2	2	1	3	0	0	1	0.8	0.2
4	0	2	3	1	3	1	0	0	0.8	0.2
5	0	2	2	2	4	0	0	0	0.8	0.2
6	4	1	1	0	1	0	0	3	0.7	0.1
7	3	1	1	1	2	0	0	2	0.7	0.1
8	2	1	2	1	2	1	0	1	0.7	0.1
9	2	1	1	2	3	0	0	1	0.7	0.1
10	1	2	2	1	2	1	1	0	0.7	0.1
11	1	1	2	2	3	1	0	0	0.7	0.1
12	1	1	1	3	4	0	0	0	0.7	0.1
Identical classifiers										
13	6	0	0	0	0	0	0	4	0.6	0.0
14	5	0	0	1	1	0	0	3	0.6	0.0
15	4	0	1	1	1	1	0	2	0.6	0.0
16	4	0	0	2	2	0	0	2	0.6	0.0
17	3	1	1	1	1	1	1	1	0.6	0.0
18	3	0	1	2	2	1	0	1	0.6	0.0
19	3	0	0	3	3	0	0	1	0.6	0.0
20	2	1	1	2	2	1	1	0	0.6	0.0
21	2	0	2	2	2	2	0	0	0.6	0.0
22	2	0	1	3	3	1	0	0	0.6	0.0
23	2	0	0	4	4	0	0	0	0.6	0.0
24	5	0	0	1	0	1	1	2	0.5	−0.1
25	4	0	0	2	1	1	1	1	0.5	−0.1
26	3	0	1	2	1	2	1	0	0.5	−0.1
27	3	0	0	3	2	1	1	0	0.5	−0.1
Pattern of failure										
28	4	0	0	2	0	2	2	0	0.4	−0.2

[1]

- Upper bounds and lower bounds can be established on the performance of the classifiers
- The upper bound is $p_{maj} = \binom{L}{l+1}\alpha$ assuming α the probability of each combination of classifiers
- The lower bound is $p_{maj} = \frac{pL-1}{l+1}$ where p is the overall accuracy of an individual classifier

Weighted Voting

- Classifiers are not all equal
- Weigh more accurate classifiers

Examples

- Where weighted voting works
- Where weighted voting does not work

$$b_i \propto \log \frac{p_i}{1 - p_i}$$

Note: Minimum error not guaranteed

Key Points

- Weights give more accurate classifiers more power
- Works well in some cases, poorly in others
- Minimum error not guaranteed

Conclusion

- Voting: decision-making strategy
- Majority vote
- Weighted majority voting
- Naive Bayes combination

Questions?

References

📄 Ludmila I. Kuncheva.
Combining Pattern Classifiers: Methods and Algorithms.
Wiley-Interscience, July 2004.