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### Measures, Metrics, and Indicators Derived from the Ubiquitous Two-by-Two Contingency Table, Part B: Examples

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### Authors' contributions

This work was carried out in collaboration between the two authors. Author AMAR designed the study, compiled the necessary formulas, provided the test cases and commented on them, managed the literature search, and wrote the manuscript. Author SMA wrote the computer program, and obtained the numerical results. Both authors approved the final manuscript.

### Article Information

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### ABSTRACT

This paper (the second of two sibling papers) continues the tutorial exposition presented in the first part of indicators derived from the ubiquitous two-by-two contingency table (confusion matrix). The indicators considered herein are those given in the context of clinical testing or binary classification. We present a pedagogical program that computes all important indicators based on knowledge of either (a) the set of four entries of the contingency table  $\{TP_{ij}, FP_{ij}, FN_{ij}, TN_{ij}\}$ , or (b) the set of true (pre-test) prevalence, sensitivity, and specificity  $\{Prev, Sens_{ij}, Spec_{ij}\}$ . The paper presents a potpourri of test cases to reveal and unravel many of the properties and inter-relationships among the indicators studied. All our test cases confirm the theoretical results and arguments in the sister paper. In particular, these test cases collectively assert that the Matthews correlation coefficient (MCC) is the most reliable single metric derivable from the contingency matrix. A concise classification of types of prediction is given in terms of the set of four basic indicators {*Sens<sub>ij</sub>, Spec<sub>ij</sub>, PPV<sub>ij</sub>, NPV<sub>ij</sub>*} or in terms of MCC alone. Keywords: Diagnostic testing; binary classification; sensitivity; specificity; positive predictive value; negative predictive value; Matthews correlation coefficient.

### **1. INTRODUCTION**

A contingency table (Also called a confusion matrix) is a powerful tool in data analysis employing matrix format for comparing two categorical variables [1-12]. This table (albeit very simple) can be used, and is still being used [12], to derive an amazingly huge number of metrics or indicators in terms of its four entries, called True Positives, False Positives, False Negatives, and True Negatives and denoted  $TP_{ij}, FP_{ij}, FN_{ij}$ , and  $TN_{ii}$ , where the subscripts ijare used to assert the notion that a test i is assessed, judged or measured relative to a reference or standard test *j*. One of the derived indicators, the Index of Association (Matthews Correlation Coefficient (MCC)) is noted to be the most reliable single metric derivable from the contingency matrix [13-16]. The aim of this paper is to extend our earlier work in the sister paper [12] and supplement the existing tutorials on quantities derivable from the contingency table [17-27]. The exposition used herein is a novel one as it presents a good number of carefully-selected test cases, and then provides pedagogical comments on the results obtained for each test case. These comments are ultimately summarized in a single table.

The organization of the rest of this paper is as follows. Section 2 is a brief primer about the metrics and indicators considered. Section 3 presents a pedagogical program that computes all important indicators based on knowledge of either (a) the set of the four entries of the contingency table  $\{TP_{ij}, FP_{ij}, FN_{ij}, TN_{ij}\}$ , or (b) the set of true (pre-test) prevalence, sensitivity, and specificity  $\{Prev, Sens_{ii}, Spec_{ii}\}$ . Section 3 also offers a potpourri of test cases to reveal and unravel many of the properties and interrelationships among the aforementioned metrics and indicators. These test cases collectively assert the claim that the Matthews correlation coefficient (MCC) is the most reliable single metric derivable from the contingency matrix. The results obtained are summarized in a concise classification of the types of prediction in terms of the set of four basic indicators {*Sens*<sub>ij</sub>, *Spec*<sub>ij</sub>, *PPV*<sub>ij</sub>, *NPV*<sub>ij</sub>} or in terms of MCC alone. Section 4 concludes the paper.

### 2. METRICS AND INDICATORS CONSIDERED HEREIN

Table 1 (borrowed from the sibling paper [12] and originally adapted from [4]) lists some of the

measures or indicators commonly used in diagnostic testing or binary classification. The table expresses each of these quantities in terms of the four elements of the contingency matrix, states its range of values, and identify the value for perfect testing or classification. Many quantities have ranges [0.0, 1.0], but a few belong to  $[0.0, \infty)$  or [-1.0, +1.0]. Direct measures and indicators are highlighted in a greenish color, while inverse ones are shown with a reddish color. Pre-test quantities are designated neither way since they are test-independent.

## 3. DISPLAY AND COMMENT ON TEST CASES

We implemented all the equations of Table 1 in a program to compute all the metrics and indicators therein based on knowledge of either (a) the set of four entries of the contingency table  $\{TP_{ij}, FP_{ij}, FN_{ij}, TN_{ij}\}$ , or (b) the set of true (pretest) prevalence, sensitivity, and specificity {Prev, Sens<sub>ij</sub>, Spec<sub>ij</sub>}. Techniques of solving ternary problems of conditional probability [1-12] incorporated to attain the were needed computations. Table 1 shows fifteen sets of input values used to test our program, which were carefully selected to reveal certain theoretical aspects stressed in [12]. Figs 1-15 display snapshots of computer outputs obtained for the various test cases. Each of these figures was included for a reason, and every figure (except one) has two versions supplied by the two sets of inputs to yield the same output. Many useful comments are included within the captions of these figures. The results obtained for the four basic indicators are checked for consistency in Table 3 according to the novel tests introduced in [8-10].

All our test cases confirm the theoretical results and arguments in the sister paper [12]. In particular, they assert that the MCC is the most reliable single metric that can be derived from the contingency table, and that all the four basic indicators Sensii, Specii, PPVii and NPVii must be high for the MCC to be high. This is in line with the fact that the MCC has attracted the attention of the diagnostic testing and the machine learning communities as a method that summarizes the contingency matrix into a single value. Table 4 summarizes the results of this paper in a concise classification of the types of prediction in terms of the set of four basic indicators

 $\{Sens_{ij}, Spec_{ij}, PPV_{ij}, NPV_{ij}\}$  or in terms of MCC alone. This summary attests once more to the powerfulness of MCC. The sister paper [12] ponders whether novel composite indicators might

share this powerfulness, and proposes three novel indicators for this purpose, namely, the arithmetic mean, the harmonic mean, and the signed geometric mean of informedness and markedness.

# Table 1. Commonly used quantities pertaining to diagnostic testing (borrowed from the sister paper [12] and originally adapted from [4]). Direct measures and indicators are highlighted in a greenish color, while inverse ones are shown with a reddish color. Pre-test quantities are designated neither way

Measure or indicator	Formula in terms of entries of the contingency matrix	Range	Perfect value
Sensitivity (True Positive Rate (TPR), Recall, Probability of Detection)	$Sens_{ij} = TP_{ij}/(TP_{ij} + FN_{ij})$	[0.0, 1.0]	1.0
Specificity, Inverse recall (True Negative Rate (TNR))	$Spec_{ij} = TN_{ij}/(TN_{ij} + FP_{ij})$	[0.0, 1.0]	1.0
Precision (Positive Predictive Value (PPV))	$PPV_{ij} = TP_{ij} / (TP_{ij} + FP_{ij})$	[0.0, 1.0]	1.0
Inverse precision (Negative Predictive Value (NPV))	$NPV_{ij} = TN_{ij}/(TN_{ij} + FN_{ij})$	[0.0, 1.0]	1.0
False Negative Rate (FNR)	$FNR_{ij} = 1 - Sens_{ij} = FN_{ij}/(TP_{ij} + FN_{ij})$	[0.0, 1.0]	0.0
False Positive Rate (FPR) (Fall- Out, False Alarm)	$FPR_{ij} = 1 - Spec_{ij} = FP_{ij}/(TN_{ij} + FP_{ij})$	[0.0, 1.0]	0.0
False Discovery Rate (FDR)	$FDR_{ij} = 1 - PPV_{ij} = FP_{ij}/(TP_{ij} + FP_{ij})$	[0.0, 1.0]	0.0
False Omission Rate (FOR)	$FOR_{ij} = 1 - NPV_{ij} = FN_{ii}/(TN_{ii} + FN_{ii})$	[0.0, 1.0]	0.0
Likelihood Ratio for Positive Test	$(LR+)_{ij} = Sens_{ij}/(1 - Spec_{ij})$	[0.0, ∞)	ø
Likelihood Ratio for Negative Test	$(LR-)_{ij} = (1 - Sens_{ij})/Spec_{ij}$	[0.0, ∞)	0.0
Diagnostic Odds Ratio	$DOR_{ij} = (TP_{ij} * TN_{ij})/(FP_{ij} * FN_{ij})$	<b>[0.0, ∞)</b>	∞
Inverse of the DOR	$DOR_{ii}^{-1} = (FP_{ii} * FN_{ii})/(TP_{ii} * TN_{ii})$	[0.0, ∞)	0.0
Youden's Index (Informedness) Markedness	$YI_{ij} = Sens_{ij} + Spec_{ij} - 1$ $M_{ii} = PPV_{ii} + NPV_{ii} - 1$	[-1.0,1.0] [-1.0,1.0]	1.0 1.0
Error of the First Kind	$E1_{ii} = FP_{ii}/N$	[0.0, 1.0]	0.0
Error of the Second Kind	$E2_{ii} = FN_{ii}/N$	[0.0, 1.0]	0.0
Total Diagnostic Error	$E_{ii} = (FP_{ii} + FN_{ii})/N$	[0.0, 1.0]	0.0
Diagnostic Accuracy	$A_{ii} = (TP_{ii} + TN_{ii})/N$	[0.0, 1.0]	1.0
Pre-Test Prevalence	$PTP_{ii} = (TP_{ii} + FN_{ii})/N$	[0.0, 1.0]	_
Pre-Test Odds	$PTO_{ii} = (TP_{ii} + FN_{ii})/(FP_{ii} + TN_{ii})$	[0.0, ∞)	_
Post-Positive-Test Odds	$PPTO_{ii} = PTO_{ii}(LR+)_{ii} = TP_{ii}/FP_{ii}$	[0.0, ∞)	~
Post-Negative-Test Odds	$PNTO_{ii} = PTO_{ii}(LR-)_{ii} = FN_{ii}/TN_{ii}$	[0.0, ∞)	0.0
F <sub>1</sub> score	$F_1 = 2 T P_{ii} / (2 T P_{ii} + F P_{ii} + F N_{ii}).$	[0.0, 1.0]	1.0
Index of Association or	$\phi_{ij} = \phi_{ji} = (TP_{ij} * TN_{ij} - FP_{ij} *$	[-1.0, 1.0]	1.0
Matthews Correlation	$FN_{ij})/SQRT((TP_{ij} + FN_{ij})(TP_{ij} +$		
Coefficient (INCC) $\varphi_{ij} = \varphi_{ji}$	$FP_{ij}$ ) $(TN_{ij} + FP_{ij})(TN_{ij} + FN_{ij})$ )		

TP	TN	FP	FN	Comments	Displayed in Figure
10	990	0	0	Perfect prediction	1
500	500	0	0	Perfect prediction	2
9	900	90	1	Low MCC	3
90	800	100	10	Medium MCC	4
250	250	250	250	Equal entries, zero MCC	5
90	9009	891	10	Gigerenzer et al. [16], Rushdi & Rushdi [3, 6]	6
9	900	1	90	Low MCC	7
90	800	10	100	Medium MCC	8
400	400	100	100	Medium MCC	9
0	1000	0	0	Many NaN results	10
35	35	15	15	Mirror image of case 15	11
4	76	19	1	Chicco et al. [16]	12
95	0	5	0	Chicco [13]	13
90	1	5	4	Chicco [13]	14
15	15	35	35	Negative MCC	15
63	72	28	37	https://en.wikipedia.org/wiki/Receiver_operating_characteris	16
77	23	77	23	tic	17
24	12	88	76		18
76	88	12	24		19

Table 2. Various sets of contingency-matrix entries to test the program

Table 3. Checking consistency among our sets of the four prominent diagnostic indicators. According to the scheme in [8-10], when the sets are consistent they are depicted as uncolored entries, and when they are somewhat problematic they are highlighted in yellow. If the sets are obviously inconsistent they are labelled as orange, and finally if they are dramatically inconsistent, they are highlighted in red. The results of all our cases are wonderfully uncolored (i.e., consistent). There is only some lack of information when original values are missing or an undefined 0/0 is encountered. The diagnostic checking difference (DCD) is admirably equal to 0.0000 in all cases, while the diagnostic checking ratio (DCR) deviates from 1.0000 by no more than 0.0004

#		Origin	al Value	S	Checki	ng Values		Com	puted Va	lues
	Sens <sub>ij</sub>	Spec <sub>ij</sub>	<b>PPV</b> <sub>ij</sub>	NPV <sub>ij</sub>	<b>DCD</b> <sub>ij</sub>	DCR <sub>ij</sub>	Sens <sub>ij</sub>	Spec <sub>ij</sub>	PPV <sub>ij</sub>	NPV <sub>ij</sub>
1a	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
3a	0.9000	0.9091	0.0909	0.9989	0.0000	1.0001	0.9008	0.9098	0.0902	0.9989
4a	0.9000	0.8889	0.4737	0.9877	0.0000	1.0001	0.9003	0.8893	0.4728	0.9877
5a	0.5000	0.5000	0.5000	0.5000	0.0000	#DIV/0!	0.5000	0.5000	0.5000	0.5000
6a	0.9000	0.9100	0.0917	0.9989	0.0000	1.0001	0.9007	0.9106	0.0911	0.9989
7a	0.0909	0.9989	0.9000	0.9091	0.0000	0.9999	0.0902	0.9989	0.9008	0.9098
7b	0.0909	0.9989	0.9008	0.9091	0.0000	1.0000	0.0909	0.9989	0.9008	0.9091
8a	0.4737	0.9877	0.9000	0.8889	0.0000	0.9999	0.4728	0.9877	0.9003	0.8893
8b	0.4737	0.9877	0.9003	0.8889	0.0000	1.0000	0.4736	0.9877	0.9003	0.8889
9a	0.8000	0.8000	0.8000	0.8000	0.0000	1.0000	0.8000	0.8000	0.8000	0.8000
10		1.0000		1.0000	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
11a	0.7000	0.7000	0.7000	0.7000	0.0000	1.0000	0.7000	0.7000	0.7000	0.7000
12a	0.8000	0.8000	0.1739	0.9870	0.0000	0.9999	0.7998	0.7998	0.1741	0.9870
12b	0.8000	0.8000	0.1739	0.9870	0.0000	0.9999	0.7998	0.7998	0.1741	0.9870
13a	1.0000	0.0000	0.9500		0.0000	#DIV/0!	#DIV/0!	0.0000	#DIV/0!	#DIV/0!
14a	0.9574	0.1667	0.9474	0.2000	0.0000	1.0004	0.9575	0.1669	0.9473	0.1998

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#		Origin	al Value	S	Checki	ng Values		Com	puted Va	lues
	Sens <sub>ij</sub>	Spec <sub>ij</sub>	PPV <sub>ij</sub>	NPV <sub>ij</sub>	<b>DCD</b> <sub>ij</sub>	DCR <sub>ij</sub>	Sens <sub>ij</sub>	Spec <sub>ij</sub>	PPV <sub>ij</sub>	NPV <sub>ij</sub>
15a	0.3000	0.3000	0.3000	0.3000	0.0000	1.0000	0.3000	0.3000	0.3000	0.3000
16a	0.6300	0.7200	0.6923	0.6606	0.0000	1.0001	0.6300	0.7200	0.6923	0.6606
17a	0.7700	0.2300	0.5000	0.5000	0.0000	#DIV/0!	0.7700	0.2300	0.5000	0.5000
18a	0.2400	0.1200	0.2143	0.1364	0.0000	0.9996	0.2401	0.1200	0.2142	0.1364
19a	0.7600	0.8800	0.8636	0.7857	0.0000	1.0000	0.7599	0.8800	0.8636	0.7858



Fig. 1a. First test case with input of contingency matrix entries. This is a case of perfect prediction with negatives more than positives (low prevalence). Except for pre-test prevalence and pre-test odds (which are test-independent), all outcomes are as anticipated in Table 1 for perfect prediction

Enter TP,	FN, TN Cor	, FP Iditions			Enter	PREVALEN	NCE, SENSITIVIT	Y, and SPECI	FICITY
<b>Test Positive</b>	TP		FP		SPEC	FICITY		1.000	
Test Negative	TN		FN		SENSI	TIVITY		1.000	
N =					PREVA	LENCE		0.0100	
		Rest	Ca	lculate			Rest	Cal	ulate
ensitivity True Positiv	e Rate (TP	R 1.0000	Specifici	ity True Negativ	e Rate (TNR)	1.0000	Positive P	redictive Value	1.0000
Negative Predictive	Value (NP	v) 1.0000	) (	Complement fo	r Sensitivity	0.0000	Complemen	t for Specificity	0.0000
Complen	ent for PF	v 0.0000		Complem	ent for NPV	0.0000	Likelihood Ratio f	or Positive Test	x
Likelihood Ratio for N	legative Te	est 0.0000		Diagnostic	Odds Ratio	x	Inve	rse of the DOR	0.0000
	idon's Ind	ex 1.0000		Error of th	e First Kind	0.0000	Error of th	e Second Kind	0.0000
Yo	auch s Illu	10000							

Fig. 1b. First test case with input of pre-test prevalence, sensitivity, and specificity. This is a case of perfect prediction with negatives more than positives (low prevalence). Except for pre-test prevalence and pre-test odds (which are test independent), all outcomes are as anticipated in Table 1 for perfect prediction

- a x **Exploring Ternary Problems of Conditional Probability** Enter TP, FN, TN, FP Enter PREVALENCE, SENSITIVITY, and SPECIFICITY Conditions **Test Positive** TP FP SPECIFICITY 500 0 **Test Negative** TN FN SENSITIVITY 500 0 N = PREVALENCE 1000 Calculate Rest Calculate Rest Positive Predictive Value 1.0000 Sensitivity True Positive Rate (TPR) 1.0000 Specificity True Negative Rate (TNR) 1.0000 Negative Predictive Value (NPV) 1.0000 Complement for Sensitivity 0.0000 Complement for Specificity 0.0000 Likelihood Ratio for Positive Test  $\infty$ Complement for PPV 0.0000 Complement for NPV 0.0000 Likelihood Ratio for Negative Test 0.0000 Inverse of the DOR 0.0000 Diagnostic Odds Ratio 🗴 Youden's Index 1.0000 Error of the First Kind 0.0000 Error of the Second Kind 0.0000 Total Diagnostic Error 0.0000 Diagnostic Accuracy 1.0000 Pre-Test Prevalence 0.5000 Pre-Test Odds 1.0000 Post-Positive-Test Odds 🗴 Post-Negative-Test Odds 0.0000 Index of Association or Matthews Correlation Coefficient (MCC) 1.0000

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Fig. 2a. Second test case with input of contingency matrix entries. This is a case of perfect prediction with negatives equal to positives (prevalence equal to one half). Again, all outcomes are as anticipated in Table 1 for perfect prediction (except for pre-test prevalence and pre-test odds, which are test-independent)

MainWindow								- 0			
	E	xploring '	Terna	ry Problem	is of Cor	nditional	Probability				
Enter TP,	FN, TN, Con	FP ditions			Enter	PREVALEN	NCE, SENSITIVITY, and SPECI	FICITY			
<b>Test Positive</b>	TP		FP		SPEC	FICITY	1.000				
Test Negative	TN		FN		SENS	TIVITY	1.000				
N =					PREVA	ALENCE	0.5000				
	]	Rest	C	alculate			Rest Calcula				
Sensitivity True Positive	e Rate (TP)	R 1.0000	Specifi	city True Negative	e Rate (TNR)	1.0000	Positive Predictive Value	1.0000			
Negative Predictive	Value (NPV	0 1.0000		Complement fo	r Sensitivity	0.0000	Complement for Specificity	0.0000			
Complen	ent for PP	v 0.0000		Compleme	ent for NPV	0.0000	Likelihood Ratio for Positive Test	(m			
Likelihood Ratio for N	legative Te	st 0.0000		Diagnostic	Odds Ratio	x	Inverse of the DOR	0.0000			
You	ıden's Inde	x 1.0000		Error of the	e First Kind	0.0000	Error of the Second Kind	0.0000			
Total Diag	nostic Erro	er 0.0000		Diagnost	ic Accuracy	1.0000	Pre-Test Prevalence	0.5000			
Pi	re-Test Odd	s 1.0000		Post-Positiv	e-Test Odds	x	Post-Negative-Test Odds	0.0000			
Ind	ex of Assoc	iation or Matt	hews Co	rrelation Coeffic	ient (MCC)	1.0000					

Fig. 2b. Second test case with input of pre-test prevalence, sensitivity, and specificity. This is a case of perfect prediction with negatives equal to positives (prevalence equal to one half). Again, all outcomes are as anticipated in Table 1 for perfect prediction (except for pre-test prevalence and pre-test odds, which are test independent)

MainWindow									- 0 X
	Ex	ploring	Ferna	ry Problem	s of Cor	ditional	Probability		
Enter TP, 1	FN, TN, I Conc	FP litions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECI	FICITY
<b>Test Positive</b>	TP	9	FP	90	SPECI	FICITY			
Test Negative	TN	900	FN	1	SENSI	TIVITY			
N =	1000				PREVA	LENCE			
	R	est	C	alculate			Rest	Cal	culate
Sensitivity True Positive	Rate (TPR	0.9000	Specifi	city True Negative	Rate (TNR)	0.9091	Positive Pred	ictive Value	0.0909
Negative Predictive	Value (NPV)	0.9989		Complement for	Sensitivity	0.1000	Complement for	Specificity	0.0909
Complem	ent for PPV	0.9091		Compleme	nt for NPV	0.0011	Likelihood Ratio for P	ositive Test	9.9010
Likelihood Ratio for N	egative Test	0.1100		Diagnostic	Odds Ratio	90.0000	Inverse	of the DOR	0.0111
You	ıden's Index	0.8091		Error of the	First Kind	0.0900	Error of the S	econd Kind	0.0010
Total Diag	nostic Erroi	0.0910		Diagnosti	ic Accuracy	0.9090	Pre-Test	Prevalence	0.0100
Pr	e-Test Odds	0.0101		Post-Positive	e-Test Odds	0.1000	Post-Negative	e-Test Odds	0.0011
Inde	ex of Associa	tion or Matt	hews Co	rrelation Coeffic	ient (MCC)	0.2695			

Fig. 3a. Third test case with input of contingency matrix entries. This is a case of a very low PPV, a very high NPV, moderately high sensitivity and specificity and a relatively low MCC

	E	xploring	Terna	ry Problem	s of Cor	nditional	Probability			
Enter TP,	FN, TN Coi	, FP nditions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECII	FICITY	
<b>Test Positive</b>	TP		FP		SPEC	FICITY	0.90	)91		
Test Negative	TN		FN		SENS	TIVITY	0.90	)00		
N =					PREVALENCE 0.0				D100	
		Rest	C	alculate			Rest	Calc	ulate	
ensitivity True Positive	Rate (TP	r) <mark>0.9000</mark>	Specifi	city True Negativ	e Rate (TNR)	0.9091	Positive Predi	ctive Value	0.0909	
Negative Predictive	Value (NP	v) 0.9989	]	Complement fo	r Sensitivity	0.1000	Complement for	Specificity	0.0909	
Complem	ent for Pl	ev 0.9091	)	Complem	ent for NPV	0.0011	Likelihood Ratio for P	ositive Test	9.9010	
Likelihood Ratio for N	legative T	est 0.1100		Diagnostic	Odds Ratio	90.0099	Inverse	of the DOR	0.0111	
You	ıden's Ind	ex 0.8091		Error of th	e First Kind	0.0900	Error of the Se	cond Kind	0.0010	
Total Diag	nostic Err	or 0.0910		Diagnost	ic Accuracy	0.9090	Pre-Test	Prevalence	0.0100	
		1 0 0101			T. (01)	0 1000	Dest Ventine	T. (011	0.0011	

Fig. 3b. Third test case with input of pre-test prevalence, sensitivity, and specificity. This is a case of a very low PPV, a very high NPV, moderately high sensitivity and specificity, and a relatively low MCC. Each numerical value in this figure is the same as the corresponding one in Fig. 3a (to within permissible round-off errors)

MainWindow									- 0		
	F	Exploring	Terna	ry Problem	is of Cor	nditional	Probability				
Enter TP,	FN, TN Co	, FP nditions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECI	FICITY		
Test Positive	TP	90	FP	100	SPEC	FICITY					
Test Negative	TN	800	FN	10	SENS	TIVITY					
N =	1000				PREVA	ALENCE					
		Rest	C	Calculate Rest					culate		
Sensitivity True Positive	e Rate (TI	PR) 0.9000	Specifi	city True Negativ	e Rate (TNR)	0.8889	Positive Pred	ictive Value	0.4737		
Negative Predictive	Value (NP	<b>PV) 0.9877</b>		Complement fo	r Sensitivity	0.1000	Complement for Specificity 0.111				
Complem	nent for P	PV 0.5263	]	Complem	ent for NPV	0.0123	Likelihood Ratio for P	ositive Test	8.1008		
Likelihood Ratio for N	legative T	est 0.1125	)	Diagnostic	Odds Ratio	72.0000	Inverse	of the DOR	0.0139		
You	ıden's Inc	lex 0.7889	)	Error of th	e First Kind	0.1000	Error of the S	econd Kind	0.0100		
Total Diag	nostic Eri	ror 0.1100	)	Diagnos	tic Accuracy	0.8900	Pre-Test	Prevalence	0.1000		
Pı	re-Test Od	lds 0.1111		Post-Positiv	e-Test Odds	0.9000	Post-Negative	e-Test Odds	0.0125		
Ind	ex of Asso	ciation or Matt	hews Co	rrelation Coeffic	cient (MCC)	0.6033					

Fig. 4a. Fourth test case with input of contingency matrix entries. This is a case of a low (but not very low) PPV, a very high NPV, moderately high sensitivity and specificity, and a relatively medium MCC

Entor TP	EN TN	FD								
Luci II,	Cor	ditions			Enter	PREVALEN	NCE, SENSITIVITY, and	I SPECI	FICITY	
Test Positive	TP		FP		SPECI	FICITY	0.888	89		
Test Negative	TN		FN		SENSI	TIVITY	0.900	)0		
N =					PREVA	LENCE	E 0.1000			
		Rest	C	alculate			Rest	Calo	ulate	
nsitivity True Positiv	e Rate (TP	r) 0.9000	Specifi	icity True Negative	e Rate (TNR)	0.8889	Positive Predict	ive Value	0.473	
Negative Predictive	Value (NP	0.9877	]	Complement fo	r Sensitivity	0.1000	Complement for S	pecificity	0.111	
Complen	ient for PP	v 0.5263	]	Complem	ent for NPV	0.0123	Likelihood Ratio for Pos	itive Test	<mark>8.1</mark> 00	
ikelihood Ratio for !	Negative Te	st 0.1125	]	Diagnostic	Odds Ratio	72.0081	Inverse of	the DOR	0.013	
Yo	uden's Inde	ex 0.7889	]	Error of th	e First Kind	0.1000	Error of the Seco	ond Kind	0.010	
Total Dias	nostic Erre	or 0.1100		Diagnost	tic Accuracy	0.8900	Pre-Test P	revalence	0.100	
Total Diag	Dial Diagnostic Erro									

Fig. 4b. Fourth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case of a low (albeit not very low) PPV, a very high NPV, moderately high sensitivity and specificity, and a relatively medium MCC. Each numerical value in this figure is the same as the corresponding one in Fig. 4a (to within permissible round-off errors)

|--|

MainWindow									- 0		
	Ex	xploring '	Terna	ry Problem	s of Cor	nditional	Probability				
Enter TP,	FN, TN, Con	FP ditions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECI	FICITY		
<b>Test Positive</b>	TP	250	FP	250	SPEC	FICITY					
<b>Test Negative</b>	TN	250	FN	250	SENSI	TIVITY					
N =	1000				PREVALENCE						
	F	Rest	C	alculate			Rest	Calo	culate		
Sensitivity True Positiv	e Rate (TPF	8 <mark>0.5000</mark>	Specifi	city True Negative	e Rate (TNR)	0.5000	Positive Predi	ctive Value	0.5000		
Negative Predictive	Value (NPV	0.5000	]	Complement for	r Sensitivity	0.5000	Complement for Specificity 0.5000				
Complen	nent for PP	0.5000	]	Compleme	ent for NPV	0.5000	Likelihood Ratio for P	ositive Test	<b>1.0000</b>		
Likelihood Ratio for !	Negative Tes	t 1.0000	]	Diagnostic	Odds Ratio	1.0000	Inverse	of the DOR	1.0000		
Yo	uden's Inde	x 0.0000	]	Error of the	e First Kind	0.2500	Error of the Se	econd Kind	0.2500		
Total Diag	Total Diagnostic Error 0.5000			Diagnost	ic Accuracy	0.5000	Pre-Test	Prevalence	0.5000		
P	re-Test Odd	s 1.0000	]	Post-Positiv	e-Test Odds	1.0000	Post-Negative	-Test Odds	1.0000		
Ind	ex of Associ	ation or Matt	hews Co	rrelation Coeffic	ient (MCC)	0.0000					

Fig. 5a. Fifth test case with input of contingency matrix entries. This is the equal-entry case with a zero MCC

Enter IP,	FN, TN,	FP			Enter PREVALENCE, SENSITIVITY, and SPECIFICIT					
Test Positive	TP	ditions	FP		SPEC	FICITY	0.5000			
Test Negative	TN		FN SEN			SENSITIVITY 0.500				
N =					PREVALENCE		0.5000			
	F	Rest	C	alculate			Rest	culate		
nsitivity True Positive Rate (TPR) 0,5000 Specificity True Neg				icity True Negative	Rate (TNR)	0.5000	Positive Predictive Value	0.5000		
Negative Predictive	Value (NPV	0.5000	Complement for S		Sensitivity	0.5000	Complement for Specificity	0.5000		
Complem	ent for PP	0.5000		Compleme	ent for NPV	0.5000	Likelihood Ratio for Positive Test	1.0000		
Likelihood Ratio for N	legative Tes	t 1.0000		Diagnostic	Odds Ratio	1.0000	Inverse of the DOR	1.0000		
You	ıden's Inde	x 0.0000		Error of the	First Kind	0.2500	Error of the Second Kind	0.2500		
Total Diag	nostic Erro	r 0.5000		Diagnosti	ic Accuracy	0.5000	Pre-Test Prevalence	0.5000		
								(		

Fig. 5b. Fifth test case with input of pre-test prevalence, sensitivity, and specificity. This is the equal-entry case with a zero MCC. Each numerical value in this figure is the same as the corresponding one in Fig. 5a (to within permissible round-off errors)

MainWindow									- 6 )	
	E	xploring [	Ferna	ry Problem	s of Cor	nditional	Probability			
Enter TP,	, FN, TN Coi	, FP nditions			Enter PREVALENCE, SENSITIVITY, and SPECIFICITY					
Test Positive	TP	90	FP	891	SPECIFICITY					
Test Negative	TN	9009	FN	10	SENS	TIVITY				
N =	10000				PREVA	LENCE				
	R	est	Ca	lculate			Rest	Cal	culate	
Sensitivity True Positiv	ensitivity True Positive Rate (TPR) 0,9000 Specificity True Negati						Positive Pred	ictive Value	0.0917	
Negative Predictive	Value (NP	0.9989		Complement for Sensitivity 0.1000		0.1000	Complement for	Specificity	0.0900	
Complet	nent for PP	v 0.9083		Complement for NPV 0.0011			Likelihood Ratio for P	ositive Test	10.0000	
Likelihood Ratio for	Negative Te	st 0.1099		Diagnostic	Odds Ratio	91.0000	Inverse	of the DOR	0.0110	
Yo	Youden's Index 0.8100 Error of t				e First Kind	0.0891	Error of the S	econd Kind	0.0010	
Total Dia	Total Diagnostic Error 0.0901 Diagnos			Diagnost	ic Accuracy	0.9099	Pre-Test	Prevalence	0.0100	
P	Pre-Test Odds 0.0101 Post-Pos					0.1010	Post-Negative	-Test Odds	0.0011	
Inc	lex of Assoc	iation or Matt	hews Co	rrelation Coeffic	ient (MCC)	0.2709				

Fig. 6a. Sixth test case with input of contingency matrix entries. This is the celebrated example of Gigerenzer et al. [17] and Rushdi & Rushdi [3, 6], with a poor PPV (apparently despite, but actually because of, high sensitivity and specificity, as well as very high NPV) and a low MCC

Enter TP, FN, Test Positive T Test Negative T N =	TN, FP Conditions P N Rest	FP FN Calculate	Enter SPECI SENSI PREV	PREVALE IFICITY ITIVITY ALENCE	NCE, SENSITIVITY, and 0.910 0.900 0.010 Rest	SPECIFICITY 0 0 0
Test Positive T Test Negative T N =	P N Rest	FP FN Calculate	SPECI SENSI PREVA	IFICITY ITIVITY ALENCE	0.910 0.900 0.010 Rest	0 0 0
Test Negative T N =	N Rest	FN Calculate	SENSI PREVA	TIVITY ALENCE	0.900 0.010 Rest	0
N =	Rest	Calculate	PREVA	ALENCE	0.010	0
	Rest	Calculate			Rest	0114
			JL		Inst	Calculate
Sensitivity True Positive Rate	(TPR) 0.9000	Specificity True Negative	e Rate (TNR)	0.9100	Positive Predicti	ive Value 0.0917
Negative Predictive Value	(NPV) 0.9989	Complement fo	r Sensitivity	0.1000	Complement for Sp	pecificity 0.0900
Complement fo	r PPV 0.9083	Complem	ent for NPV	0.0011	Likelihood Ratio for Posi	itive Test 10.000
Likelihood Ratio for Negati	re Test <mark>0.1099</mark>	Diagnostic	Odds Ratio	91.0000	Inverse of t	the DOR 0.0110
Youden's	Index 0.8100	Error of the	e First Kind	0.0891	Error of the Seco	nd Kind 0.0010
Total Diagnostic	Error 0.0901	Diagnost	ic Accuracy	0.9099	Pre-Test Pr	evalence 0.0100
Pre-Tes	Odds 0.0101	Post-Positiv	e-Test Odds	0.1010	Post-Negative-Te	est Odds 0.0011

Fig. 6b. Sixth test case with input of pre-test prevalence, sensitivity, and specificity. This is the celebrated example of Gigerenzer et al. [17] and Rushdi & Rushdi [3, 6], with a poor PPV and a low MCC. Each numerical value in this figure is the same as the corresponding one in Fig. 6a (to within permissible round-off errors)

ManWindow	E	xploring '	Terna	ry Problem	s of Cor	ditional	Probability		- 0
Enter TP,	FN, TN, Con	FP ditions			Enter PREVALENCE, SENSITIVITY, and SPECIFICI				
<b>Test Positive</b>	TP	9	FP	1	SPEC	FICITY			
<b>Test Negative</b>	TN	900	FN	90	SENSI	TIVITY			
N =	1000				PREVA	LENCE			
	I	Rest	C	alculate			Rest	Cal	culate
Sensitivity True Positive	nsitivity True Positive Rate (TPR) 0,0909 Specificity True Nega					0.9989	Positive Predi	ictive Value	0.9000
Negative Predictive	Value (NPV	0.9091	Complement for Sensitiv			0.9091	Complement for	Specificity	0.0011
Complem	ent for PP	0.1000	Complement for N		ent for NPV	0.0909	Likelihood Ratio for P	ositive Test	82.6364
Likelihood Ratio for N	legative Tes	t 0.9101		Diagnostic	Odds Ratio	90.0000	Inverse	of the DOR	0.0111
You	ıden's Inde	x 0.0898		Error of the	e First Kind	0.0010	Error of the So	econd Kind	0.0900
Total Diag	nostic Erro	r 0.0910		Diagnost	ic Accuracy	0.9090	Pre-Test	Prevalence	0.0990
Pr	Pre-Test Odds 0.1099			Post-Positive-Test Odds 9		9.0000	Post-Negative	e-Test Odds	0.1000
Inde	ex of Associ	ation or Matt	hews Co	rrelation Coeffic	ient (MCC)	0.2695			

Fig. 7a. Seventh test case with input of contingency matrix entries. This is a case with a poor sensitivity and a low MCC. The poor sensitivity does not contradict (but actually results from) a combination of high predictive values with a very high specificity

MairWindow	E	xploring [	Terna	rv Problem	s of Cor	iditional	Probability		- 0
Enter TP, 1	FN, TN, Con	FP ditions			Enter	PREVALEN	NCE, SENSITIVITY, an	nd SPECI	FICITY
<b>Test Positive</b>	TP		FP		SPECI	SPECIFICITY 0.9989			
Test Negative	TN		FN		SENSI	TIVITY	0.09	)09	
N =					PREVA	LENCE	0.0990		
	I	Rest	C	alculate			Rest	Cal	culate
Sensitivity True Positive	nsitivity True Positive Rate (TPR) 0.0909 Specificity True Ne				Rate (TNR)	0.9989	Positive Predi	ctive Value	0.9008
Negative Predictive V	Value (NPV	0.9091	Complement for Sen		Sensitivity	0.9091	Complement for Specificity 0		0.0011
Complem	ent for PP	0.0992	)	Complement for N		0.0909	Likelihood Ratio for Po	ositive Test	82.6364
Likelihood Ratio for N	egative Te	st 0.9101	]	Diagnostic Odds R		90.7991	Inverse of the DOR ()		<mark>0.01</mark> 10
You	Youden's Index 0.0898			Error of the	First Kind	0.0010	Error of the Second Kind		0.0900
Total Diag	nostic Erro	r 0.0910		Diagnosti	ic Accuracy	0.9090	Pre-Test	Prevalence	0.0990
Pr	Pre-Test Odds 0.1099		Post-Positive-Test Odds		9.0799	Post-Negative	-Test Odds	0.1000	
Inde	x of Associ	ation or Matt	hews Co	orrelation Coeffic	ient (MCC)	0.2697			

Fig. 7b. Seventh test case with input of pre-test prevalence, sensitivity, and specificity. This is a case with a poor sensitivity and a low MCC. Each numerical value in this figure is the same as the corresponding one in Fig. 7a (to within permissible round-off errors)

MainWindow								- 1)	
	E	xploring '	Terna	ry Problem	s of Cor	nditional	Probability		
Enter TP,	FN, TN, Cor	, FP Iditions			Enter PREVALENCE, SENSITIVITY, and SPECIFICITY				
<b>Test Positive</b>	TP	90	FP	10	SPEC	FICITY			
Test Negative	TN	800	FN	100	SENS	TIVITY			
N =	1000				PREVA	LENCE			
		Rest	C	alculate			Rest	Calculate	
Sensitivity True Positive	ensitivity True Positive Rate (TPR) 0,4737 Specificity True Negat					0.9877	Positive Predictive V	alue 0.9000	
Negative Predictive	Value (NP	0.8889	]	Complement for	r Sensitivity	0.5263	Complement for Specifi	city 0.0123	
Complen	nent for PP	v 0.1000	]	Complement for NPV 0.1111			Likelihood Ratio for Positive	Test 38.5122	
Likelihood Ratio for N	Negative Te	st 0.5329		Diagnostic	Odds Ratio	72.0000	Inverse of the D	or 0.0139	
You	Youden's Index 0.4614			Error of the	e First Kind	0.0100	Error of the Second H	ind 0.1000	
Total Diag	nostic Err	or 0.1100		Diagnost	ic Accuracy	0.8900	Pre-Test Preval	ence 0.1900	
Pi	Pre-Test Odds 0.2346			Post-Positiv	e-Test Odds	9.0000	Post-Negative-Test C	dds 0.1250	
Ind	Index of Association or Matthews Correlation Coef								

Fig. 8a. Eighth test case with input of contingency matrix entries. This is a case with intermediate sensitivity and MCC

	E	xploring '	Terna	ry Problem	is of Cor	nditional	Probability		
Enter TP, 1	FN, TN Coi	, FP Iditions			Enter PREVALENCE, SENSITIVITY, and SPECIFIC				
<b>Test Positive</b>	TP		FP		SPECI	FICITY	0.98	377	
Test Negative	TN		FN		SENSI	TIVITY	0.47	137	
N =					PREVA	LENCE	0.1900		
		Rest	C	alculate			Rest	Calc	ulate
nsitivity True Positive Rate (TPR) 0.4737 Specificity True				city True Negative	e Rate (TNR)	0.9877	Positive Predi	ctive Value	0.9003
Negative Predictive	Value (NP	0.8889	]	Complement fo	r Sensitivity	0.5263	Complement for	Specificity	0.0123
Complem	ent for PF	v 0.0997	]	Complem	ent for NPV	0.1111	Likelihood Ratio for P	ositive Test	38.512
Likelihood Ratio for N	legative Te	st 0.5329	]	Diagnostic	Odds Ratio	72.2753	Inverse of	of the DOR	0.0138
You	ıden's Ind	ex 0.4614	]	Error of the	e First Kind	0.0100	Error of the Se	cond Kind	0.1000
Total Diag	nostic Err	or 0.1100		Diagnost	ic Accuracy	0.8900	Pre-Test	Prevalence	0.1900
Dr	e-Test Od	ds 0 2346		Post-Positiv	e-Test Odds	9.0337	Post-Negative	-Test Odds	0.1250

Fig. 8b. Eighth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case with intermediate sensitivity and MCC

REDITION	F	Exploring	Terna	ry Problem	ns of Cor	nditional	Probability		5	
Enter TP,	FN, TN Co	, FP nditions			Enter PREVALENCE, SENSITIVITY, and SPECIFICIT					
<b>Test Positive</b>	TP	400	FP	100	SPECIFICITY					
<b>Test Negative</b>	TN	400	FN	100	SENSI	TIVITY				
N =	N = 1000									
		Rest	C	alculate			Rest	Cal	culate	
Sensitivity True Positive	nsitivity True Positive Rate (TPR) <b>0.8000</b> Specificity True N						Positive Predi	ictive Value	0.8000	
Negative Predictive	Value (NP	v) <mark>0.8000</mark>	Complement for Sensitivity <b>0</b> .			0.2000	Complement for	Specificity	0.2000	
Complen	nent for P	PV 0.2000		Complem	ent for NPV	0.2000	Likelihood Ratio for P	ositive Test	4.0000	
Likelihood Ratio for N	legative T	est 0.2500		Diagnostic	Odds Ratio	16.0000	Inverse	of the DOR	0.0625	
You	ıden's Inc	lex 0.6000		Error of th	e First Kind	0.1000	Error of the Se	econd Kind	<mark>0.1000</mark>	
Total Diag	nostic Eri	ror 0.2000		Diagnos	tic Accuracy	0.8000	Pre-Test	Prevalence	0.5000	
Pı	re-Test Oc	lds 1.0000		Post-Positiv	e-Test Odds	4.0000	Post-Negative	-Test Odds	0.2500	
Ind	ex of Asso	ciation or Matt	hews Co	rrelation Coeffic	cient (MCC)	0.6000				

Fig. 9a. Ninth test case with input of contingency matrix entries. This is a case with 'reasonable' direct metrics and an intermediate MCC

	E	xploring	Terna	ry Problem	is of Cor	nditional	Probability			
Enter TP,	FN, TN Coi	, FP Iditions			Enter PREVALENCE, SENSITIVITY, and SPECIFI					
<b>Test Positive</b>	TP		FP		SPECI	FICITY	0.80	)00		
Test Negative	TN		FN		SENSI	TIVITY	0.80	)00		
N =					PREVA	LENCE	0.50	)00		
		Rest	C	alculate			Rest	Cal	culate	
Sensitivity True Positive	e Rate (TP	R) 0.8000	Specifi	city True Negative	e Rate (TNR)	0.8000	Positive Predi	ctive Value	0.8000	
Negative Predictive	Value (NP	v) 0.8000		Complement fo	r Sensitivity	0.2000	Complement for	Specificity	0.2000	
Complem	ent for PI	v 0.2000		Complem	ent for NPV	0.2000	Likelihood Ratio for P	ositive Test	4.0000	
Likelihood Ratio for N	legative To	est 0.2500		Diagnostic	Odds Ratio	16.0000	Inverse	of the DOR	0.0625	
You	ıden's Ind	ex 0.6000		Error of the	e First Kind	0.1000	Error of the Se	cond Kind	0.1000	
Total Diag	nostic Err	or 0.2000		Diagnost	ic Accuracy	0.8000	Pre-Test	Prevalence	0.5000	
Pr	re-Test Od	ds 1.0000		Post-Positiv	e-Test Odds	4.0000	Post-Negative	-Test Odds	0.2500	
Inde	ex of Asso	riation or Matt	hews Co	rrelation Coeffic	cient (MCC)	0.6000				

Fig. 9b. Ninth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case with 'reasonable' direct metrics and an intermediate MCC

MainWindow									- 0
	E	xploring T	[ <mark>erna</mark> r	y Problem	is of Cor	nditional	Probability		
Enter TP	, FN, TN Coi	, FP nditions			Enter	PREVALE	NCE, SENSITIVITY, a	and SPECI	FICITY
Test Positive	TP	0	FP	0	SPEC	FICITY			
Test Negative	TN	1000	FN	0	SENS	TIVITY			
N =	1000				PREVA	ALENCE			
	R	est	Ca	lculate			Rest	Calo	culate
Sensitivity True Positiv	ensitivity True Positive Rate (TPR) ليس رقمًا Specificity True Negat					1.0000	Positive Pred	ictive Value	ليس رقمًا
Negative Predictive	Value (NPV	0 1.0000		Complement fo	r Sensitivity	ليس رقمًا	Complement for	r Specificity	0.0000
Complex	nent for PP	ليس رقمًا V		Complem	ent for NPV	0.0000	Likelihood Ratio for H	Positive Test	ليس رقمًا
Likelihood Ratio for	Negative Te	ليس رقمًا		Diagnostic	Odds Ratio	ليس رقمًا	Inverse	of the DOR	ليس رقمًا
Ye	uden's Inde	ليس رقمًا x		Error of the	e First Kind	0.0000	Error of the S	econd Kind	0.0000
Total Dia	gnostic Erro	or 0.0000		Diagnost	tic Accuracy	1.0000	Pre-Test	Prevalence	0.0000
I	re-Test Odd	ls 0.0000		Post-Positiv	e-Test Odds	ليس رقمًا	Post-Negative	e-Test Odds	0.0000
Ind	lex of Assoc	iation or Mattl	hews Cor	relation Coeffic	cient (MCC)	ليس رقمًا			

Fig. 10. Tenth test case with input of contingency matrix entries. This is an extreme case in which most computed values are undefined, and designated as NaN or Not a Number (ليس رفَسَا). We deliberately used the Arabic script for NaN to alert the reader that computations are incomplete. Since sensitivity is undefined, this figure is not duplicated

MainWindow									- 0
	E	ploring [	Ternar	y Problen	ns of Cor	ditional	Probability		
Enter TP,	, FN, TN, Cor	FP ditions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECI	FICITY
<b>Test Positive</b>	TP	35	FP	15	SPEC	FICITY			
Test Negative	TN	35	FN	15	SENSI	TIVITY			
N =	100				PREVA	LENCE			
	R	est	Cal	culate			Rest	Calo	culate
Gensitivity True Positiv	nsitivity True Positive Rate (TPR) 0.7000 Specificity True Negat					0.7000	Positive Predi	ictive Value	0.7000
Negative Predictive	Value (NPV	0.7000	(	Complement fo	or Sensitivity	0.3000	Complement for	Specificity	0.3000
Complex	ment for PP'	0.3000	<u> </u>	Complem	ent for NPV	0.3000	Likelihood Ratio for P	ositive Test	2.3333
Likelihood Ratio for	Negative Te	at 0.4286		Diagnostic	: Odds Ratio	5.4444	Inverse	of the DOR	0.183
Yo	ouden's Inde	x 0.4000		Error of th	e First Kind	0.1500	Error of the Se	econd Kind	0.1500
Total Dia	gnostic Erro	r 0.3000		Diagnos	tic Accuracy	0.7000	Pre-Test	Prevalence	0.5000
Р	Pre-Test Odd	s 1.0000		Post-Positiv	ve-Test Odds	2.3333	Post-Negative	-Test Odds	0.4286
Ind	lex of Associ	ation or Matt	hews Corr	relation Coeffi	cient (MCC)	0.4000			

Fig. 11a. Eleventh test case with input of contingency matrix entries. This is a case with somewhat 'reasonable' direct metrics and a low MCC

	Ex	xploring T	Fernary Problem	s of Cor	nditional	Probability			
Enter TP,	FN, TN, Con	FP ditions		Enter PREVALENCE, SENSITIVITY, and SPECIFICIT					
Test Positive	TP		FP	SPEC	FICITY	0.70	100		
Test Negative	TN		FN	SENSITIVITY		0.7000			
N =				PREVA	ALENCE	0.50	100		
	R	est	Calculate			Rest	Calculate		
Sensitivity True Positiv	ensitivity True Positive Rate (TPR) 0,7000 Specificity True Nega					Positive Predi	ctive Value 0.7000		
Negative Predictive	Value (NPV	0.7000	Complement for	Sensitivity	0.3000	Complement for	Specificity 0.3000		
Compler	nent for PP	0.3000	Compleme	ent for NPV	0.3000	Likelihood Ratio for Po	ositive Test 2.3333		
Likelihood Ratio for 1	Negative Tes	at 0.4286	Diagnostic	Odds Ratio	5.4444	Inverse o	f the DOR 0.1837		
Yo	uden's Inde	x 0.4000	Error of the	First Kind	0.1500	Error of the Se	cond Kind 0.1500		
Total Diaș	gnostic Erro	r 0.3000	Diagnost	ic Accuracy	0.7000	Pre-Test	Prevalence 0.5000		
Р	re-Test Odd	s 1.0000	Post-Positive	e-Test Odds	2.3333	Post-Negative	Test Odds 0.4286		
Ind	lex of Associ	ation or Matt	hews Correlation Coeffic	ient (MCC)	0.4000				

Fig. 11b. Eleventh test case with input of pre-test prevalence, sensitivity, and specificity. This is a case with somewhat 'reasonable' direct metrics and a low MCC

Luci II	, FN, TN Coi	, FP nditions			Enter	PREVALEN	NCE, SENSITIVITY, and SPECIF	ICITY
Test Positive	TP	4	FP	19	SPEC	FICITY		
Test Negative	TN	76	FN	1	SENS	TIVITY		
N =	100				PREVA	ALENCE		
	R	lest	Cal	culate			Rest Calcu	ılate
ensitivity True Positi	ve Rate (TP	R) 0.8000	Specificit	y True Negativ	e Rate (TNR)	0.8000	Positive Predictive Value	0.1739
Negative Predictive	Value (NPV	0.9870	C	omplement fo	r Sensitivity	0.2000	Complement for Specificity	0.2000
Comple	ment for PP	v 0.8261	)	Complem	ent for NPV	0.0130	Likelihood Ratio for Positive Test	4.0000
Comple			Ĩ	Diagnostic	Odds Ratio	16.0000	Inverse of the DOR	0.0625
Comple Likelihood Ratio for	Negative Te	st 0.2500	)	Diagnostic				
Compre Likelihood Ratio for Yo	Negative Te uden's Inde	st 0.2500 ex 0.6000	)	Error of th	e First Kind	0.1900	Error of the Second Kind	0.0100
Compe Likelihood Ratio for Yo Total Dia	Negative Te ouden's Indo gnostic Erro	st 0.2500 ex 0.6000 or 0.2000	) ] ]	Error of th Diagnos	e First Kind tic Accuracy	0.1900 0.8000	Error of the Second Kind Pre-Test Prevalence	D.0100 D.0500

Fig. 12a. Twelfth test case with input of contingency matrix entries. This is a case with a poor PPV and a low MCC. The poor PPV does not contradict (but actually results from) a combination of high sensitivity and specificity with a very high NPV

MainWindow								- 0 X
	E	xploring 7	Fernary Problem	s of Coi	nditional	Probability		
Enter TP.	, FN, TN Co	, FP nditions		Enter	PREVALEN	NCE, SENSITIVITY, an	d SPECII	FICITY
Test Positive	TP		FP	SPEC	FICITY	0.80	00	
Test Negative	TN		FN	SENS	TIVITY	0.80	00	
N =				PREVA	ALENCE	0.05	00	
	I	Rest	Calculate			Rest	Calc	ulate
Sensitivity True Positiv	ve Rate (TH	r) <mark>0.8000</mark>	Specificity True Negative	Rate (TNR)	0.8000	Positive Predic	tive Value	0.1739
Negative Predictive	Value (NP	v) <mark>0.987</mark> 0	Complement for	Sensitivity	0.2000	Complement for S	Specificity	0.2000
Complet	nent for Pl	v 0.8261	Compleme	ent for NPV	0.0130	Likelihood Ratio for Po	sitive Test	4.0000
Likelihood Ratio for	Negative T	est 0.2500	Diagnostic	Odds Ratio	16.0000	Inverse of	f the DOR	0.0625
Yo	uden's Ind	ex 0.6000	Error of the	First Kind	0.1900	Error of the Sec	cond Kind	0.0100
Total Dia	gnostic Eri	or 0.2000	Diagnost	ic Accuracy	0.8000	Pre-Test P	revalence	0.0500
P	re-Test Od	ds 0.0526	Post-Positive	e-Test Odds	0.2105	Post-Negative-	Test Odds	0.0132
Inc	lex of Asso	ciation or Mattl	hews Correlation Coeffic	ient (MCC)	0.3107			

Fig. 12b. Twelfth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case with a poor PPV and a low MCC. The poor PPV does not contradict (but actually results from) a combination of high sensitivity and specificity with a very high NPV

n mer i r	FN TN	FP							
Linui II	Col	nditions			Enter	PREVALEN	NCE, SENSITIVITY, an	d SPECII	FICITY
Test Positive	TP	95	FP	5	SPECIFICITY				
Test Negative	TN	0	FN	0	SENSITIVITY				
N =	100				PREVA	LENCE			
	R	lest	Cal	culate			Rest	Calc	ulate
ensitivity True Positiv	ve Rate (TP)	r) 1.0000	Specificit	y True Negativ	e Rate (TNR)	0.0000	Positive Predic	tive Value	0.9500
Negative Predictive	Value (NPV	ليس رقمًا (/	c	omplement fo	or Sensitivity	0.0000	Complement for	Specificity	1.0000
Complex	nent for PP	v <mark>0.0500</mark>		Complem	ent for NPV	ليس رقمًا	Likelihood Ratio for Po	sitive Test	1.0000
	Negative Te	ليس رقمًا st		Diagnostic	: Odds Ratio	ليس رقمًا	Inverse o	f the DOR	س رقمًا
Likelihood Ratio for	inguint It					0.0500	Fron of the Sec	ond Vind	0 000
Likelihood Ratio for Yo	ouden's Inde	ex 0.0000		Error of th	e First Kind	0.0000	LITUI UI UIC SCI	lona Kina	010000
Likelihood Ratio for Ye Total Dia	ouden's Inde gnostic Erre	ex 0.0000 or 0.0500		Error of th Diagnos	e First Kind tic Accuracy	0.0500 0.9500	Pre-Test I	Prevalence	0.950

Fig. 13a. Thirteenth test case with input of contingency matrix entries. This is an extreme case in which many computed values are undefined, and designated as NaN or Not a Number (ليس رقسا). Unlike Fig. 10, this figure can be duplicated since none of sensitivity, specificity and pre-test prevalence is undefined

- 0 ) **Exploring Ternary Problems of Conditional Probability** Enter TP, FN, TN, FP Enter PREVALENCE, SENSITIVITY, and SPECIFICITY Conditions 0.000 Test Positive TP FP SPECIFICITY Test Negative TN FN SENSITIVITY 1.000 PREVALENCE .9500 N = Rest Calculate Rest Calculate Specificity True Negative Rate (TNR) 0.0000 Positive Predictive Value 0.9500 Sensitivity True Positive Rate (TPR) 1.0000 Negative Predictive Value (NPV) NaN Complement for Sensitivity 0.0000 Complement for Specificity 1.0000 Complement for PPV 0.0500 Likelihood Ratio for Positive Test 1.0000 Complement for NPV NaN Likelihood Ratio for Negative Test NaN Diagnostic Odds Ratio NaN Inverse of the DOR NaN Error of the First Kind 0.0500 Error of the Second Kind 0.0000 Youden's Index 0.0000 Diagnostic Accuracy 0.9500 Pre-Test Prevalence 0.9500 Total Diagnostic Error 0.0500 Pre-Test Odds 19.0000 Post-Positive-Test Odds 19.0000 Post-Negative-Test Odds NaN Index of Association or Matthews Correlation Coefficient (MCC) NaN

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Fig. 13b. Thirteenth test case with input of pre-test prevalence, sensitivity, and specificity. This is an extreme case in which many computed values are undefined, and designated as NaN or Not a Number. Unlike Figs. 10 and 13a, this figure has a true English screen in which the standard notation (NaN) replaces its Arabic equivalent (ليس رقما).

MairWindow									- 0
	E	xploring T	Fernar	y Problen	ns of Cor	nditional	Probability		
Enter TP	, FN, TN Coi	, FP nditions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECI	FICITY
<b>Test Positive</b>	TP	90	FP	5	SPEC	FICITY			
Test Negative	TN	1	FN	4	SENSI	TIVITY			
N =	100				PREVA	LENCE			
	R	lest	Ca	lculate			Rest	Cal	culate
Sensitivity True Positiv	ve Rate (TP)	R) 0.9574	Specific	ity True Negativ	ve Rate (TNR)	0.1667	Positive Predi	ictive Value	0.9474
Negative Predictive	Value (NPV	v) 0.2000		Complement fo	or Sensitivity	0.0426	Complement for	Specificity	0.8333
Complet	ment for PP	v 0.0526		Complen	nent for NPV	0.8000	Likelihood Ratio for P	ositive Test	1.1489
Likelihood Ratio for	Negative Te	st 0.2555		Diagnosti	c Odds Ratio	4.5000	Inverse	of the DOR	0.2222
Ye	ouden's Inde	ex 0.1241		Error of th	he First Kind	0.0500	Error of the Se	econd Kind	0.0400
Total Dia	gnostic Erro	or 0.0900		Diagnos	stic Accuracy	0.9100	Pre-Test	Prevalence	0.9400
I	Pre-Test Odd	ds 15.6667		Post-Positi	ve-Test Odds	18.0000	Post-Negative	-Test Odds	4.0000
Inc	lex of Assoc	iation or Matt	hews Cor	relation Coeffi	icient (MCC)	0.1352			



		Explo	ring Tei	rnary Problem	s of Cond	itional Pro	bability	
Enter TP	FN, TN, F Co	P nditions				Enter PREVA	LENCE, SENSITIVITY, and SPECIFICITY	
Test Positive	TP		FP		SPEC	IFICITY	0.1667	
Test Negative	TN		FN		SENSITIVITY		0.9574	
N =					PREVALENCE		0.9400	
		Rest		Calculate			Rest Calculate	
Sensitivity True Pos	itive Rate (TP	<sub>R)</sub> 0.9574		Specificity True Nega	tive Rate (TNR)	0.1667	Positive Predictive Value 0.9474	
Negative Predic	tive Value (NP	v) 0.1999		Complement	for Sensitivity	0.0426	Complement for Specificity 0.8333	
Com	plement for Pl	v 0.0526	Comple		ement for NPV	0.8001	Likelihood Ratio for Positive Test 1.1489	
Likelihood Ratio	for Negative T	est 0.2555		Diagnos	tic Odds Ratio	4.4959	Inverse of the DOR 0.2224	
	Youden's Ind	<sub>ex</sub> 0.1241		Error of	the First Kind	0.0050	Error of the Second Kind 0.0040	
Total	Diagnostic Err	or 0.0090		Diagn	ostic Accuracy	0.0910	Pre-Test Prevalence 0.0940	
	Pre-Test Od	<sub>ds</sub> 15.6667		Post-Posi	itive-Test Odds	17.9998	Post-Negative-Test Odds 4.0036	
	I	dar of Accoriation	n or Mottl	our Correlation Cos	finiant (MCC)	0.1352		

Fig. 14b. Fourteenth test case with input of pre-test prevalence, sensitivity and specificity. This is a case with a poor specificity, a poor NPV and a low MCC

	F	Exploring	Ternai	ry Problem	is of Cor	nditional	Probability		
Enter TP,	FN, TN Co	l, FP nditions			Enter	PREVALE	NCE, SENSITIVITY, a	nd SPECI	FICITY
<b>Test Positive</b>	TP	15	FP	35	SPEC	FICITY			
Test Negative	TN	15	FN	35	SENSI	TIVITY			
N =	100		PRE		PREVA	ALENCE			
		Rest	C	alculate			Rest	Calo	culate
nsitivity True Positiv	e Rate (TI	PR) 0.3000	Specific	city True Negativ	e Rate (TNR)	0.3000	Positive Predi	ctive Value	0.300(
Negative Predictive	Value (NP	ev) 0.3000		Complement fo	r Sensitivity	0.7000	Complement for	Specificity	0.7000
Complex	nent for P	PV 0.7000	]	Complem	ent for NPV	<b>0.7000</b>	Likelihood Ratio for P	ositive Test	0.4280
ikelihood Ratio for l	Negative T	lest 2.3333	)	Diagnostic	Odds Ratio	0.1837	Inverse	of the DOR	5.4444
Yo	uden's Inc	lex -0.4000		Error of th	e First Kind	0.3500	Error of the Se	econd Kind	0.3500
	nostic Er	ror 0.7000		Diagnos	tic Accuracy	0.3000	Pre-Test	Prevalence	0.5000
Total Diag									

Fig. 15a. Fifteenth test case with input of contingency matrix entries. This is a case with a negative MCC and a negative informedness (Youden's index)

	Ex	ploring	Fernary Problem	s of Cor	nditional	Probability		
Enter TP,	FN, TN, Con	FP ditions		Enter	PREVALE	NCE, SENSITIVITY, at	nd SPECIFICITY	
<b>Test Positive</b>	TP		FP	SPEC	FICITY	0.3000		
Test Negative	TN		FN	SENSITIVITY		0.30	)00	
N =			PREV		ALENCE	0.50	00	
	Re	est	Calculate			Rest	Calculate	
Sensitivity True Positiv	e Rate (TPR	0.3000	Specificity True Negative	Rate (TNR)	0.3000	Positive Predi	ctive Value 0.3000	
Negative Predictive	Value (NPV)	0.3000	Complement for	r Sensitivity	0.7000	Complement for	Specificity 0.7000	
Compler	nent for PPV	0.7000	Compleme	ent for NPV	0.7000	Likelihood Ratio for Po	ositive Test 0.4286	
Likelihood Ratio for 1	Negative Test	2.3333	Diagnostic	Odds Ratio	0.1837	Inverse o	f the DOR <b>5.4444</b>	
Yo	uden's Index	-0.4000	Error of the	e First Kind	0.3500	Error of the Se	cond Kind 0.3500	
Total Diaș	gnostic Erroi	0.7000	Diagnost	ic Accuracy	0.3000	Pre-Test	Prevalence 0.5000	
Р	re-Test Odds	1.0000	Post-Positiv	e-Test Odds	0.4286	Post-Negative	Test Odds 2.3333	
Ind	ex of Associa	tion or Matt	hews Correlation Coeffic	ient (MCC)	-0.4000			

Fig. 15b. Fifteenth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case with a negative MCC and a negative informedness (Youden's index)

	E	xploring	Ternary	y Problem	is of Cor	nditional	Probability		
Enter TP	, FN, TN Co	, FP nditions			Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECII	FICITY
<b>Test Positive</b>	TP	63	FP	28	SPECI	FICITY			
Test Negative	TN	72	FN	37	SENSI	TIVITY			
N =	200				PREVA	LENCE			
	F	Rest	Cal	culate			Rest	Calc	ulate
ensitivity True Positiv	ve Rate (TP	r) 0.6300	Specificit	ty True Negative	e Rate (TNR)	0.7200	Positive Predi	ctive Value	0.6923
Negative Predictive	Value (NP	v) 0.6606	0	Complement fo	r Sensitivity	0.3700	Complement for	Specificity	0.2800
Comple	ment for PI	ev 0.3077	]	Complem	ent for NPV	0.3394	Likelihood Ratio for P	ositive Test	2.2500
Likelihood Ratio for	Negative To	est 0.5139	]	Diagnostic	Odds Ratio	4.3784	Inverse	of the DOR	0.2284
Yo	ouden's Ind	ex 0.3500		Error of th	e First Kind	0.1400	Error of the Se	cond Kind	0.1850
Total Dia	gnostic Err	or 0.3250	]	Diagnost	ic Accuracy	0.6750	Pre-Test	Prevalence	0.5000
P	re-Test Od	ds 1.0000		Post-Positiv	e-Test Odds	2.2500	Post-Negative	-Test Odds	0.5139

Fig. 16a. Sixteenth test case with input of contingency matrix entries. This is a case of somewhat good prediction, with sensitivity (considerably) greater than the False Positive Rate (1.0 - specificity) and diagnostic accuracy greater than 0.5, but the MCC is below 0.5

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MainWindow							- 0 X
	E	xploring 1	Fernary Problem	s of Cor	nditional	Probability	
Enter TP,	, FN, TN Coi	, FP nditions		Enter	PREVALEN	NCE, SENSITIVITY, a	nd SPECIFICITY
Test Positive	TP		FP	SPEC	FICITY	0.	72
Test Negative	TN		FN	SENSI	TIVITY	0.	63
N =				PREVA	ALENCE	0.	50
	R	lest	Calculate			Rest	Calculate
Sensitivity True Positiv	e Rate (TP	R) 0.6300	Specificity True Negative	Rate (TNR)	0.7200	Positive Pred	ictive Value 0.6923
Negative Predictive	Value (NP	0.6606	Complement for	r Sensitivity	0.3700	Complement for	Specificity 0.2800
Compler	nent for PP	v 0.3077	Compleme	ent for NPV	0.3394	Likelihood Ratio for P	ositive Test 2.2500
Likelihood Ratio for 1	Negative Te	st 0.5139	Diagnostic	Odds Ratio	4.3784	Inverse	of the DOR 0.2284
Yo	uden's Ind	ex 0.3500	Error of the	First Kind	0.1400	Error of the S	econd Kind 0.1850
Total Dia	gnostic Err	or 0.3250	Diagnost	ic Accuracy	0.6750	Pre-Test	Prevalence 0.5000
P	re-Test Od	ds 1.0000	Post-Positive	e-Test Odds	2.2500	Post-Negative	-Test Odds 0.5139
Ind	lex of Assoc	iation or Matt	hews Correlation Coeffic	ient (MCC)	0.3514		

Fig. 16b. Sixteenth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case of somewhat good prediction, with sensitivity (considerably) greater than the False Positive Rate (1.0 – specificity) and diagnostic accuracy greater than 0.5, but the MCC is below 0.5.

MainWindow	E	mloring	Fernar	v Problem	s of Cor	ditional	Probability		- 0
Enter TP	, FN, TN, Cor	FP ditions		,	Enter	PREVALEN	NCE, SENSITIVITY, a	and SPECI	FICITY
Test Positive	TP	77	FP	77	SPEC	FICITY			
Test Negative	TN	23	FN	23	SENSI	TIVITY			
N =	200				PREVA	LENCE			
	R	est	Cal	culate			Rest	Cal	culate
Sensitivity True Positiv	ve Rate (TPI	R 0.7700	Specifici	ty True Negative	Rate (TNR)	0.2300	Positive Pred	lictive Value	0.5000
Negative Predictive	Value (NPV	0.5000	(	Complement fo	r Sensitivity	0.2300	Complement for	r Specificity	0.7700
Complet	ment for PP	v 0.5000	]	Complem	ent for NPV	0.5000	Likelihood Ratio for I	Positive Test	1.0000
Likelihood Ratio for	Negative Te	st 1.0000	]	Diagnostic	Odds Ratio	1.0000	Inverse	of the DOR	1.0000
Yo	ouden's Inde	x 0.0000		Error of the	e First Kind	0.3850	Error of the S	econd Kind	0.1150
Total Dia	gnostic Erro	r 0.5000		Diagnost	ic Accuracy	0.5000	Pre-Test	Prevalence	0.5000
I	Pre-Test Odd	s 1.0000		Post-Positiv	e-Test Odds	1.0000	Post-Negativ	e-Test Odds	1.0000
Inc	lex of Assoc	ation or Matt	hews Corr	relation Coeffic	ient (MCC)	0.0000			

Fig. 17a. Seventeenth test case with input of contingency matrix entries. This is a case on the random guess line, with sensitivity equal to the False Positive Rate (1.0 – specificity) and diagnostic accuracy equal to 0.5, but with a zero MCC and a zero informedness (Youden's index)

	I	Exploring	<b>Fernary Problem</b>	is of Cor	ditional	Probability	
Enter TP,	FN, TN Co	N, FP onditions		Enter	PREVALE	NCE, SENSITIVITY, a	nd SPECIFICITY
<b>Test Positive</b>	TP		FP	SPEC	FICITY	0.2	.3
Test Negative	TN		FN	SENSI	TIVITY	0.7	17
N =				PREVA	LENCE	0.5	50
	]	Rest	Calculate			Rest	Calculate
ensitivity True Positiv	e Rate (T	PR 0.7700	Specificity True Negative	e Rate (TNR)	0.2300	Positive Predi	ctive Value 0.500
Negative Predictive	Value (NI	ev) 0.5000	Complement fo	r Sensitivity	0.2300	Complement for	Specificity 0.770
Compler	nent for P	PV 0.5000	Compleme	ent for NPV	0.5000	Likelihood Ratio for P	ositive Test 1.000
Likelihood Ratio for	Negative T	Test 1.0000	Diagnostic	Odds Ratio	1.0000	Inverse of	of the DOR 1.000
Yo	uden's In	dex 0.0000	Error of the	e First Kind	0.3850	Error of the Se	cond Kind 0.115
Total Diag	gnostic Er	ror 0.5000	Diagnost	ic Accuracy	0.5000	Pre-Test	Prevalence 0.500
						100 C	

Fig. 17b. Seventeenth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case on the random guess line, with sensitivity equal to the False Positive Rate (1.0 – specificity) and diagnostic accuracy equal to 0.5, but with a zero MCC and a zero informedness (Youden's index)

MairWindow										- 0
	<b>Exploring Ternary Problems of Conditional Probability</b>									
Enter TP	Enter TP, FN, TN, FP Conditions					Enter PREVALENCE, SENSITIVITY, and SPECIFICITY				FICITY
Test Positive	TP	24	FP	88	5	SPECI	FICITY			
Test Negative	TN	12	FN	76	5	SENSI	TIVITY			
N =	200				]    P	PREVA	LENCE			
	R	est	Ca	lculate				Rest	Cal	culate
Sensitivity True Positiv	ve Rate (TPI	R 0.2400	Specific	ity True Negat	tive Rat	te (TNR)	0.1200	Positive Pred	ictive Value	0.2143
Negative Predictive	Negative Predictive Value (NPV)		)	Complement	for Se	nsitivity	0.7600	Complement for	Specificity	0.8800
Comple	Complement for PPV		Complement fo		for NPV	0.8636	Likelihood Ratio for P	ositive Test	0.2727	
Likelihood Ratio for	Likelihood Ratio for Negative Test 6.3		Diagnostic Oc		tic Odd	ds Ratio	0.0431	Inverse	of the DOR	23.2222
Ye	ouden's Inde	x -0.6400		Error of	the Fir	rst Kind	0.4400	Error of the S	econd Kind	0.3800
Total Dia	Total Diagnostic Error 0.82		Diagnostic Accura		ccuracy	0.1800	Pre-Test	Prevalence	0.5000	
H	Pre-Test Odds 1.0000		Post-Positive-Test Odds		est Odds	0.2727	Post-Negative	e-Test Odds	6.3333	
Inc	Index of Association or Matthews Correlation Coefficient (MCC					t (MCC)	-0.6447			

Fig. 18a. Eighteenth test case with input of contingency matrix entries . This is a case below the random guess line, with sensitivity less than the False Positive Rate (1.0 – specificity) and diagnostic accuracy less than 0.5, and with a negative MCC and a negative informedness (Youden's index)

MainWindow								- 5 )	
Exploring Ternary Problems of Conditional Probability									
Enter TP.	Enter TP, FN, TN, FP Conditions					Enter PREVALENCE, SENSITIVITY, and SPECIFICITY			
Test Positive	TP FP			SPECIFICITY		0.1	0.12		
Test Negative	TN FN			SENSI	SENSITIVITY 0.24				
N =	N =				LENCE	0.50			
	R	est	Calculate			Rest	Cal	culate	
Sensitivity True Positiv	ve Rate (TPF	0.2400	Specificity True Negative	Rate (TNR)	0.1200	Positive Predi	ctive Value	0.2143	
Negative Predictive	Value (NPV	0.1364	Complement for	Sensitivity	0.7600	Complement for	Specificity	0.8800	
Complet	ment for PP	0.7857	Compleme	nt for NPV	0.8636	Likelihood Ratio for P	ositive Test	0.2727	
Likelihood Ratio for	Negative Tes	t 6.3333	Diagnostic	Odds Ratio	0.0431	Inverse	of the DOR	23.2222	
Yo	ouden's Inde	x -0.6400	Error of the	First Kind	0.4400	Error of the Se	econd Kind	0.3800	
Total Dia	gnostic Erro	r <mark>0.8200</mark>	Diagnosti	ic Accuracy	0.1800	Pre-Test	Prevalence	0.5000	
P	Pre-Test Odd	s 1.0000	Post-Positive	-Test Odds	0.2727	Post-Negative	-Test Odds	6.3333	
Inc	lex of Associ	ation or Mattl	hews Correlation Coeffic	ient (MCC)	-0.6447				

Fig. 18b. Eighteenth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case below the random guess line, with sensitivity less than the False Positive Rate (1.0 - specificity) and diagnostic accuracy less than 0.5, and with a negative MCC and a negative informedness (Youden's index)

E ( TD	TAL TAL	ED							
Enter TP, FN, TN, FP Conditions					Enter PREVALENCE, SENSITIVITY, and SPECIFICITY				
Test Positive	TP	76	FP	12	SPEC	FICITY			
Test Negative	TN	88	FN	24	SENS	TIVITY			
N =	200				PREVA	ALENCE			
	R	est	Cal	culate			Rest	Calc	ulate
nsitivity True Positiv	ve Rate (TPI	0.7600	Specifici	ty True Negativ	e Rate (TNR)	0.8800	Positive Pred	ictive Value	0. <mark>863</mark> 6
Negative Predictive	Value (NPV	0.7857	] (	Complement fo	or Sensitivity	0.2400	Complement for	r Specificity	0.1200
Comple	ment for PP'	0.1364	]	Complem	ent for NPV	0.2143	Likelihood Ratio for F	Positive Test	6.3333
ikelihood Ratio for	Negative Te	at 0.2727	]	Diagnostic	Odds Ratio	23.2222	Inverse	of the DOR	0.0431
Yo	ouden's Inde	x 0.6400	]	Error of th	e First Kind	0.0600	Error of the S	econd Kind	0.1200
Total Dia	gnostic Erro	r 0.1800	]	Diagnos	tic Accuracy	0.8200	Pre-Test	Prevalence	0.5000
		1	1						

Fig. 19a. Nineteenth test case with input of contingency matrix entries. This is a case in which prediction decisions in Fig. 18 are reversed. It is a mirror image of the case in Fig. 18 with the values of sensitivity, specificity and accuracy replaced by their complements to 1.0, while MCC switched sign. This proves that the output of a consistently bad predictor could simply be inverted to obtain a good predictor

	E	xploring'	Ternary Problem	is of Coi	ıditional	Probability			
Enter TP, FN, TN, FP Conditions				Enter PREVALENCE, SENSITIVITY, and SPECIFICITY					
<b>Test Positive</b>	TP		FP	SPECIFICITY		0.88			
Test Negative	TN		FN	SENSITIVITY		0.76			
N =				PREVALENCE			0.50		
	R	est	Calculate			Rest	Cal	ulate	
ensitivity True Positiv	e <mark>Rate (TP</mark>	r) 0.7600	Specificity True Negative	e Rate (TNR)	0.8800	Positive Predic	ctive Value	0.8636	
Negative Predictive	Value (NP	0.7857	Complement for	r Sensitivity	0.2400	Complement for	Specificity	0.1200	
Compler	nent for PP	v 0.1364	Compleme	ent for NPV	0.2143	Likelihood Ratio for Po	ositive Test	6.3333	
Likelihood Ratio for	Negative Te	st 0.2727	Diagnostic	Odds Ratio	23.2222	Inverse o	f the DOR	0.0431	
Yo	uden's Ind	ex 0.6400	Error of the	e First Kind	0.0600	Error of the Se	cond Kind	0.1200	
Total Dia	gnostic Err	or 0.1800	Diagnost	ic Accuracy	0.8200	Pre-Test 1	Prevalence	0.5000	
	T (0)	1 0000	D. 4 D. 14.	a Test Odda	( 2222	Doct Nagativa	Test Odda	0 2725	

Fig. 19b. Nineteenth test case with input of pre-test prevalence, sensitivity, and specificity. This is a case in which prediction decisions in Fig. 18 are reversed. It is a mirror image of the case in Fig. 18 with the values of sensitivity, specificity and accuracy replaced by their complements to 1.0, while MCC switched sign. This proves that the output of a consistently bad predictor could simply be inverted to obtain a good predictor

 Table 4. Types of prediction in terms of the four basic indicators and in terms of Mathew

 Correlation Coefficient, borrowed from the sister paper [12]

	Direct Basic Indicators	Mathew Correlation
	{Sens <sub>ij</sub> , Spec <sub>ij</sub> , PPV <sub>ij</sub> , NPV <sub>ij</sub> }	Coefficient M
Perfect Prediction	$Sens_{ij} + Spec_{ij} = 2.0,$	M = +1.0
	$PPV_{ij} + NPV_{ij} = 2.0,$	
	$Sens_{ij} = Spec_{ij} = PPV_{ij} = NPV_{ij} = 1.0$	
Good Prediction	$1.0 < Sens_{ij} + Spec_{ij} \le 2.0,$	$0.0 < M \le 1.0$
	$1.0 < PPV_{ij} + NPV_{ij} \le 2.0,$	
Random-Guessing-Like	$Sens_{ij} + Spec_{ij} = 1.0,$	M = 0.0
Prediction	$PPV_{ij} + NPV_{ij} = 1.0,$	
Bad Prediction	$0.0 \le Sens_{ij} + Spec_{ij} < 1.0,$	$-1.0 \le M < 0.0$
	$0.0 \le PPV_{ij} + NPV_{ij} < 1.0,$	
Completely-contradictory	$Sens_{ij} + Spec_{ij} = 0.0,$	M = -1.0
Prediction	$PPV_{ij} + NPV_{ij} = 0.0,$	
	$Sens_{ij} = Spec_{ij} = PPV_{ij} = NPV_{ij} = 0.0$	

#### 4. CONCLUSIONS

This paper dealt with indicators derived of the ubiquitous two-by-two contingency table (confusion matrix) that has widespread applications in many fields, including, in particular, the fields of binary classification and clinical or epidemiological testing. The paper presented a variety of these indicators, and stressed the fact that among these the Index of Association (Matthews Correlation Coefficient) has particular advantages. The paper presented a potpourri of test cases to reveal and unravel many of the properties and inter-relationships among these indicators. The tests serve as further verification of the utility of the Matthews Correlation Coefficient as the most informative single metric that can be derived from the contingency table.

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### **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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