JKAU: Comp. IT. Sci., **Vol**. **10** No. 1, pp: 49 – 72 (1442 A.H. / 2021 A.D.)

Doi: 10.4197/Comp.10-1.3

Inter-relationships among the Four Basic Indicators of Diagnostic Testing: A Signal-Flow-Graph Approach

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Abstract. Ternary problems of conditional probability formulated in conjunction with a normalized version of the two-by-two contingency table might be solved by arithmetic or algebraic techniques to produce useful inter-relationships among the various marginal, conjunctive, and conditional probabilities associated with that table. In particular only tedious and indirect algebraic methods can be used to inter-relate the four most prominent indicators of diagnostic testing (sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)). In general, it is theoretically possible to express any one of these four indicators in terms of the other three. Such a possibility is materialized herein, in a direct and appealing arithmetic fashion, through the use of a (Mason) signal flow graph, which carefully selects for its constituent relations, an appropriate combination of the total probability law, Bayes' rule and the complementation formula. Despite the relative simplicity of the four formulas expressing each of the four diagnostic indicators in terms of the other three, they seem not to be well known in the open literature. We call a set of four values satisfying these formulas (to within permissible round-off errors) a consistent set. We define two checking functions of these four values that we call the Diagnostic Checking Difference (DCD) and the Diagnostic Checking Ratio (DCR) that are exactly 0 and 1, respectively, for consistent values. The deviation of the DCD and the DCR from 0 and 1, respectively, is, therefore, a measure of inconsistency for any purported set of the four diagnostic indicators. An interesting observation is that the unbiased measures of informedness and markedness emerge naturally within these two functions, suggesting that the remaining terms within these checking functions might also serve as unbiased measures. We made an extensive testing of published sets of the four basic indicators, to check whether these sets are consistent or not. In a dominant majority of cases, the published sets are consistent, thereby independently attesting to the correctness of our formulas. However, in a small (albeit significant) number of cases, we came across sets that are dramatically inconsistent. Even some prominent celebrated medical journals were not inconsistency free. This is particularly curious, because there is no much room for error when computing the four indicators out from the raw data of true positives, true negatives, false positives, and false negatives. Since the four indicators constitute only three independent entities (rather than four), an expert is not free to guess the four separately. Any attempt to estimate the four indicators via expert opinion or some sort of model should be confined to estimating only three of them, with the fourth being deduced numerically from the rest.

Keywords: Ternary problem, Conditional probability, Signal flow graphs, Sensitivity, Specificity, Predictive values, Consistency indicators, Informedness, Markedness, Dual quantities.

1. Introduction

In a recent paper[1]; we introduced two complementary versions of a new Karnaugh-map-like length/area proportional diagram that represents the two-by-two contingency matrix. We utilized these two diagram versions collectively to obtain arithmetic or algebraic solutions of ternary problems of conditional probability. In particular, we constructed an algebraic solution of one such problem that enabled us to prove a virtually unknown interdependence among the two predictive values, sensitivity, and specificity. In fact, we employed a method of symbolic algebraic derivation to express any one of these four prominent indicators of diagnostic testing in terms of the other three. Our present work is a sequel and an extension of our earlier work in Rushdi & Serag[1], and more importantly, an exploration of the ramifications of the existence of the so-far unknown inter-relationships among the four basic diagnostic indicators[2, 3].

To set the stage for our major work, we offer a novel derivation of the aforementioned four relationships via a novel Mason signal flow graph, which employs elementary probability relations. We observe that these interrelations are just variants (through symmetry and/or double complementation (duality)) of a single relation. In fact, each of the four relations can be derived by equating a single function that we call the Diagnostic Checking Difference (DCD) to 0, or, equivalently equating another function that we call the Diagnostic Checking Ratio (DCR) to 1. We also note that the deviation of the DCD and the DCR from 0 and 1, respectively, is a measure of inconsistency for any purported set of the four diagnostic indicators. An interesting observation is that the unbiased measures of informedness and markedness emerge naturally within these two functions. We employ our findings to assess the consistency of results published in the open literature, and to set a useful constraint on methods of estimation of the four basic indicators through modeling or via expert opinion.

The organization of the rest of this paper is as follows. Section 2 is a brief primer about diagnostic testing and its basic indicators, while Section 3 is an introduction to signal flow graphs. Section 4 uses a signal flow graph to prove a virtually unknown inter-dependence among the two predictive values, sensitivity, and specificity. In fact, Section 4 utilizes obvious symmetries to express any one of these four indicators in terms of the other three, under the assumption that each of the four exists, and no division by zero is encountered. As a bonus, Section 5 applies the new formulas extensively to data available in the open literature. Most sets of values of sensitivity, specificity, and predictive values tested agree with our formulas. However, some reported sets of the four basic indicators experience some appreciable incoherence among their values according to our formulas. Section 6 concludes the paper.

2. On Diagnostic Testing and Its Basic Measures

This section is intended for a brief primer about diagnostic testing and its most basic indicators. Figure 1 demonstrates a two-by-two contingency matrix for test or classification i with respect to test or classification j. Each of the two variables i and j belongs to the set $\{+1, -1\}$ of indices. The test i reports positive cases (arbitrarily assigned the value $+1$), in which a certain disease, attribute, trait, or condition is present, or reports negative cases (arbitrarily assigned the value -1), in which this condition is absent. This test is assessed or evaluated by a reference or standard test j, which has its own labeling of cases, again as positive or negative.

The reference test j designates various cases of the assessed test i as "true" or "false," depending on whether it agrees or disagrees with test i. As a result, the matrix four entries are called True Positives, False Positives, False Negatives, and True Negatives. These entries are usually assigned the standard abbreviations TP, FP, FN, and TN. In the sequel, we will use the subscripted abbreviations TP_{ij}, FP_{ij}, FN_{ij}, and TN_{ij}, where we use the subscripts ij for all measures (and later for indicators derived from them) to assert the notion that i is assessed, judged or measured relative to j. The sum of these four entries is the size of the reported population or the total number of cases N. If the tests i and j interchange their roles (so that test j is now assessed relative to test i) then the four measures are relabeled as $TP_{ji}, FP_{ji}, FN_{ji}$, and TN_{ji} such that $TP_{ji} = TP_{ij}$, and $TN_{ji} = TN_{ij}$ but with $FP_{ji} = FN_{ij}$, and $FN_{ji} = FP_{ij}$.

We use the symbols $A = \{j = +1\}$ and $B = \{i = +1\}$ to denote the events of positive cases (presence of the considered condition) according to the tests j and i, respectively. Hence, the complementary events $\overline{A} = \{j = -1\}$ and $\overline{B} = \{i = -1\}$ denote the events of negative cases (absence of the considered condition) according to the tests j and i, respectively. There are eight conditional probabilities concerning these two events and their complements, as shown in Fig. 2. These can be identified as the eight most prominent indicators used in diagnostic testing. These are the Sensitivity ($Sens_{ij}$) or True Positive Rate (TPR_{ij}), the Specificity ($Spec_{ij}$) or True Negative Rate (TNR_{ij}), the Positive and Negative Predictive Values (PPV_{ij} and NPV_{ij}), together with their respective complements (to 1.0), namely the False Negative Rate (FNR_{ij}), False Positive Rate (FPR_{ij}), False Discovery rate (FDR_{ij}) and False Omission Rate (FOR_{ij})[4-10]. The former four indicators are considered more popular or more prominent[11], and they act as direct or agreement measures while the latter four serve as discrepancy or disagreement measures between the two tests i and j. Due to the four complementation relations within pairs of these eight measures, the number of independent quantities among them is at most four. It seems that there is a widespread (and at least implicit) belief that this number is exactly four (usually obtained by counting the four direct indicators $Sens_{ij}, Spec_{ij}, PPV_{ij}$ and NPV_{ij})[12-24]. We show in Section 4 that this number is, in fact, three, by simply being able to express any of the four direct indicators in terms of the other three. The pliabilities or flexibilities ascribed to these indicators by Trevethan[24] are not really unqualified.

3. Use of Signal Flow Graphs in Analyzing Indicators of Diagnostic Testing

Linear signal flow graphs have a variety of useful applications[25-31]. A linear signal flow graph (SFG), is a specialized directed graph in which nodes represent system variables, and a directed branch or edge represents a transmittance from the node at which the branch originates to the one at which it terminates. An edge emanating from a certain node and incident on a (not necessarily different) node brings to the latter node the value of the former node weighted (multiplied) by the transmittance carried by the edge. There are two main closely-related types of an SFG[32-34], namely

- Mason SFG (employed herein)[35]: This is an SFG in which the weighted sum of nodes having arrows incident on a specified node (sum of the values of these nodes, each multiplied by the transmittance on the corresponding edge towards the specified node) is equal to the value of the specified node.

- Coates SFG[36]: This is an SFG in which the aforementioned weighted sum of nodes with arrows incident on a specified node is equal to zero.

In general, a linear signal flow graph is associated with a set of linear scalar equations, or, equivalently, a matrix equation. The SFG can be used to solve n linearly-independent scalar equations in n unknowns (i.e., an equation involving a full-rank matrix). The solution depends on the application of superposition (thanks to linearity) as well as the construction of certain gain formulas, each of which relates a required sink node to a specific source node, subject to the condition that all other source nodes are killed, i.e., are set to zero. A gain formula is written through visual inspection of the graph that leads to the enumeration of all loops and all source-to-sink paths, as well as the determination whether touching exists among subsets of loops or between each path and these subsets of loops. Two loops (or one loop and a path) are said to be touching if they share at least one node.

Rushdi & Rushdi[4] attempted to use Mason SFGs for interpreting, representing, and comprehending the eight diagnostic measures of diagnostic testing. Later, Rushdi & Talmees[8, 9] followed suite in employing the methodology of digital communication and DNA replication[37] to represent the laws of total probability governing these measures via specific SFGs called the Channel Diagram and the Inverse Channel Diagram. It was noted that the Channel Diagram and the Inverse Channel Diagram should be used one at a time. None of them should be superimposed on the other, for otherwise the resulting SFG will be singular, i.e., its Δ will be zero leading to a zero in the denominator of any Mason gain formula deduced from the SFG.

In a notable departure from conventional Mason SFGs, a new type of graphs called trinomial graphs was introduced to handle ternary problems of conditional probability[38, 39], in general, with a particular stress on the context of diagnostic testing. These trinomial graphs have some resemblance with SFGs, and were later enhanced slightly by Rushdi & Talmees[8, 9] to stress their parallelism with signal flow graphs.

4. Formula Derivation via a Novel Signal Flow Graph

In this section, we utilize a novel signal flow graph (SFG) to compute the specificity in terms of the sensitivity and predictive values (in the absence of knowledge about the prevalence). Figure 3 demonstrates this novel SFG, which resembles the celebrated Channel Diagram (CD) or the Inverse Channel Diagram (ICD)[8] in the feature that all three graphs use the four marginal probabilities $P(A)$, $P(B)$, $P(\overline{A})$ and $P(\overline{B})$ as graph nodes. However, while either the CD or the ICD graphs uses four distinct conditional probabilities as its transmittances, the new SFG has transmittances that involve three conditional probabilities only, namely, $P(B|A) = Sens_{ij}, P(A|B) = PPV_{ij},$ and $P(\bar{A}|\bar{B}) = NPV_{ij}$. Our objective in this section is to compute a fourth conditional probability $(P(\bar{B}|\bar{A}) = Spec_{ij})$ in terms of these three solely.

Each of the CD and ICD graphs implements the total probability law twice to express two of its nodes as sink nodes in terms of the other two as source nodes. Our novel SFG in Fig. 3, however, treats all four nodes of marginal probabilities as sink nodes and expresses them ultimately in terms of two source nodes of a value of one each. This SFG uses the total probability law only once to express the marginal probability $P(A)$ *via*:

$$P(A) = P(A|B)P(B) + P(A|\bar{B})P(\bar{B}). \quad (1)$$

The SFG uses Bayes' rule to express the marginal probability $P(B)$ (under the assumption that $P(A|B)$ is not zero) *via*,

$$P(B) =. P(B|A)P(A)/P(A|B) \tag{2}$$

Finally, the SFG uses the complementation law twice to express each of $P(\overline{A})$ and $P(\overline{B})$, namely

$$P(\overline{A}) = 1.0 - P(A), \tag{3}$$

$$P(\overline{B}) = 1.0 - P(B). \tag{4}$$

In passing, we note that an earlier (albeit, aborted) attempt to create a similar SFG involved combining the CD and ICD together. The resulting SFG involved four sink nodes, each expressed via the law of total probability. This SFG lacks any source nodes and turns out to be singular of zero delta. In the sequel, we will assume that all our steps are legitimate, i.e., when we encounter any division, we assume that the divisor is non-zero. Now, we observe that the SFG of Fig. 3 has two touching loops, of loop gains

$$L_1 = \left(P(B|A) \,/\, P(A|B)\right) P(A|B) = P(B|A). \tag{5}$$

$$L_2 = -\left(P(B|A) \,/\, P(A|B)\right) P(A|\bar{B}). \tag{6}$$

The delta of the SFG (the denominator of any Mason Gain Formula (MGF) for the SFG[32, 35]) is given by

$$\Delta = 1 - L_1 - L_2$$
$$= 1 - P(B|A) + \left(\frac{P(B|A)}{P(A|B)} \times P(A|\bar{B})\right),$$
$$= [P(A|B) - P(B|A)P(A|B) + P(B|A)\, P(A|\bar{B})] \,/\, P(A|B). \tag{7}$$

Utilizing Mason gain formula (MGF)[32, 35] , we obtain

$$P(A) = \frac{(1)P(A|\bar{B})(1)}{\Delta} = \frac{P(A|\bar{B})}{\Delta}. \tag{8}$$

Now, we apply MGF again, or combine (2) and (8), to get

$$P(B) = \left(\frac{P(B|A)}{P(A|B)}\right) P(A) = \frac{P(B|A)}{P(A|B)} \frac{P(A|\bar{B})}{\Delta}. \tag{9}$$

The conditional probability $P(B|\bar{A})$ is given by

$$P(B|\bar{A}) = \frac{P(A \cap \bar{B})}{P(\bar{A})} = \frac{P(\bar{A}|B)\, P(B)}{P(\bar{A})}, \tag{10}$$

with its denominator $P(\bar{A})$ being obtained again by MGF as

$$P(\bar{A}) = 1 - P(A) = 1 - \left(\frac{P(A|\bar{B})}{\Delta}\right) = \frac{\Delta - P(A|\bar{B})}{\Delta}. \tag{11}$$

When we combine (9)-(11) with (7), we obtain

$$P(B|\bar{A}) = \frac{P(\bar{A}|B) \frac{P(B|A)}{P(A|B)} P(A|\bar{B})}{\Delta - P(A|\bar{B})} = \frac{P(\bar{A}|B)\, P(B|A)\, P(A|\bar{B})}{[P(A|B) - P(B|A)P(A|B) + P(B|A)\, P(A|\bar{B})] - P(A|\bar{B})\, P(A|B)}$$

$$= \frac{P(B|A)\,[1 - P(A|B) - P(\bar{A}|\bar{B}) + P(A|B)P(\bar{A}|\bar{B})]}{P(A|B)P(\bar{A}|\bar{B}) + P(B|A)[1 - P(A|B) - P(\bar{A}|\bar{B})]} \tag{12}$$

Therefore the required specificity $\left(P(\bar{B}|\bar{A}) = 1 - P(B|\bar{A})\right)$ is given by

$$P(\bar{B}|\bar{A}) = \frac{P(A|B)P(\bar{A}|\bar{B})[1 - P(B|A)]}{P(A|B)P(\bar{A}|\bar{B}) + P(B|A)[1 - P(A|B) - P(\bar{A}|\bar{B})]}.$$

Now if we apply symmetry (interchange of A and B) and/or duality or double complementation (interchange of A and $\bar{A}$, as well as interchange of B and $\bar{B}$), we obtain the following relations

$$P(\bar{A}|\bar{B}) = \frac{P(B|A)\, P(\bar{B}|\bar{A})\, [1 - P(A|B)]}{P(B|A)P(\bar{B}|\bar{A}) + P(A|B)[1 - P(B|A) - P(\bar{B}|\bar{A})]}$$

$$P(B|A) = \frac{P(A|B)P(\bar{A}|\bar{B})[1 - P(\bar{B}|\bar{A})]}{P(A|B)P(\bar{A}|\bar{B}) + P(\bar{B}|\bar{A})[1 - P(A|B) - P(\bar{A}|\bar{B})]} \tag{15}$$

$$P(A|B) = \frac{P(B|A)\,P(\bar{B}|\,\bar{A})\,[1-P(\bar{A}|\bar{B})]}{P(B|A)P(\bar{B}|\bar{A}) + P(\bar{A}|\bar{B})[1-P(B|A)-P(\bar{B}|\bar{A})]} \quad (16)$$

We use equations (13-16) to express each of the four most prominent indicators of diagnostic testing (Specificity, Negative Predictive Value, Sensitivity, and Positive Predictive Value) solely in terms of the other three, namely

$$Spec_{ij} = \frac{PPV_{ij} * NPV_{ij}\,[1- Sens_{ij}]}{PPV_{ij} * NPV_{ij} + Sens_{ij}\,[1- PPV_{ij} - NPV_{ij}]} \quad (13a)$$

$$NPV_{ij} = \frac{Sens_{ij} * Spec_{ij}\,[1-PPV_{ij}]}{Sens_{ij} * Spec_{ij} + PPV_{ij}[1- Sens_{ij} - Spec_{ij}]} \quad (14a)$$

$$Sens_{ij} = \frac{PPV_{ij} * NPV_{ij}\,[1-Spec_{ij}]}{PPV_{ij}\;NPV_{ij} + Spec_{ij}\,[1-PPV_{ij}-NPV_{ij}]} \quad (15a)$$

$$PPV_{ij} = \frac{Sens_{ij} * Spec_{ij}\,[1-NPV_{ij}]}{Sens_{ij} * Spec_{ij} + NPV_{ij}\,[1- Sens_{ij} - Spec_{ij}]} \quad (16a)$$

Despite the relative simplicity of the four formulas expressing each of the four diagnostic indicators in terms of the other three, they seem not to be well known in the open literature. We call a set of four values satisfying these formulas (to within permissible round-off errors) a consistent set. We define two checking functions of these four values that we call the Diagnostic Checking Difference (DCD) and the Diagnostic Checking Ratio (DCR) that are exactly 0 and 1, respectively, for consistent values. The mathematical definition of the DCD and DCR is

$$DCD_{ij} = P(B|A)\,P(\bar{B}|\,\bar{A})\,[P(A|B) + P(\bar{A}|\bar{B}) - 1 - P(A|B)P(\bar{A}|\bar{B})[P(B|A) + P(\bar{B}|\bar{A}) - 1]$$

$$= Sens_{ij} * Spec_{ij}\,\left[PPV_{ij} + NPV_{ij} - 1\right] - PPV_{ij} * NPV_{ij}\,[Sens_{ij} + Spec_{ij} - 1]. \quad (17)$$

$$DCR_{ij} = \frac{P(B|A)\,P(\bar{B}|\,\bar{A})\,[P(A|B) + P(\bar{A}|\bar{B}) - 1]}{P(A|B)P(\bar{A}|\bar{B})[P(B|A) + P(\bar{B}|\bar{A}) - 1]}$$

$$= \frac{Sens_{ij} * Spec_{ij}\,\left[PPV_{ij} + NPV_{ij} - 1\right]}{PPV_{ij} * NPV_{ij}\,[Sens_{ij} + Spec_{ij} - 1]}. \quad (18)$$

Each of the probability equations (13-16) or the indicator equations (13a-16a) might be deduced by equating (17) to 0 or equating (18) to 1. This means that each of the various inter-relationships among the four prominent indicators of diagnostic testing is simply a manifestation of the zero value of DCD_{ij} (or, equivalently, of the unity value of DCR_{ij}). It is interesting to note that the two checking functions DCD_{ij} and DCR_{ij} naturally involve the two dual unbiased indicators called Youden's Index (YI_{ij}) (Informedness (I_{ij})), and Markedness (M_{ij})[22] defined by

$$Informedness_{ij} = YI_{ij} = I_{ij} = Sens_{ij} + Spec_{ij} - 1, \quad (19)$$

$$Markedness_{ij} = M_{ij} = PPV_{ij} + NPV_{ij} - 1. \quad (20)$$

With this observation, we can rewrite (17) and (18) as

$$DCD_{ij} = Sens_{ij} * Spec_{ij} * Markedness_{ij} - PPV_{ij} * NPV_{ij} * Informedness_{ij}\,. \quad (17a)$$

$$DCR_{ij} = \frac{Sens_{ij} * Spec_{ij} * Markedness_{ij}}{PPV_{ij} * NPV_{ij} * Informedness_{ij}}\,. \quad (18a)$$

The inverse pairs $\{Sens_{ij},\ PPV_{ij}\}$, $\{Spec_{ij},\ NPV_{ij}\}$, and $\{Informedness_{ij},\ Markedness_{ij}\}$ constitute elements of DCD_{ij} and DCR_{ij}. In fact, the former quantity is the difference of two inverse products, while the latter one is the ratio of these two inverse products. The diagnostic checking ratio might be expressed as the quotient of two functions of the form

$$DCR_{ij} = P_{ij}/S_{ij}, \quad (19a)$$

$$S_{ij} = f(Sens_{ij}, Spec_{ij}), \quad (19a)$$

$$P_{ij} = f(PPV_{ij}, NPV_{ij}), \quad (19b)$$

Such that

$$f(a,b) = \frac{(a+b-1)}{a*b}. \quad (19d)$$

5. Assessment of Data Available in the Literature

Taking into consideration the results of Section 4, we observe that the deviation of the DCD and the DCR from 0 and 1, respectively, might be viewed as a measure of inconsistency for any purported set of the four diagnostic indicators (sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)). Table 1 provides some extensive tests of some published sets of these four basic indicators, which are used to check whether these sets are consistent or not. For each published set of $\{Sens_{ij}, Spec_{ij}, PPV_{ij}, NPV_{ij}\}$ the table computes the checking difference DCD_{ij} via (17), and the checking ratio DCR_{ij} via (18). It also uses equations (13a-16a) to compute a new value for each of the four prominent indicators in terms of the old values of the other three indicators. No attempt has been made to obtain the limit in certain cases, in which an equation among (13a-16a) yields an undefined value of $(0/0)$. In such cases, our EXCEL calculator inadvertently reported a division-by-zero problem though no such problem really exists, as the correct limit of the undefined value can always be obtained via appropriate manipulations. We arbitrarily assume that a published set is consistent (uncolored entries) if the absolute value of the relative error is less than or equal to 2%. We arbitrarily consider such a small error accountable for by normal or acceptable round-off errors. Otherwise, we consider a set to be somewhat problematic or slightly inconsistent (with error still within 4%, highlighted in yellow), or inconsistent (with error still within 6%, highlighted in orange). If the absolute relative error exceeds 6%, we arbitrarily label the corresponding set as dramatically inconsistent (highlighted in red).

In a dominant majority of cases, the published sets are observed to be practically consistent (to within permissible round-off errors). This observation independently attests to the correctness of our formulas, and eases some of the growing concern about the correctness of published scientific results[40, 41]. However, in a small (albeit significant) number of cases, we came across sets that are slightly inconsistent, inconsistent, or dramatically inconsistent. Some of the problematic data appear in highly-cited articles published in prestigious journals. This is particularly curious, because there is no much room for error when computing the four indicators out from the same raw data of true positives, true negatives, false positives, and false negatives. Table 1 has sections devoted to papers selected from the New England Journal of Medicine and Nature Medicine, usually viewed as the top two journals in basic and clinical sciences[42]. Results from these papers, are just like those from papers in the rest of the table, as they still contain some values that are obviously inconsistent. Even these top journals are not inconsistency free.

Since the four indicators constitute only three independent entities (rather than four), an expert is not free to guess the four separately. Any attempt to estimate the four indicators via expert opinion should be confined to estimating only three of them, with the fourth being deduced numerically. The same restriction applies to methods devised for modelling the four indicators. For example, Coughlin *et al*.[43] constructed a logistic model for the sensitivity, specificity, and the predictive values of a diagnostic test. They argued that their modeling approach may be useful for obtaining smoothed estimates of sensitivity, specificity, and predictive values, such as when it is impractical to calculate these measures directly for small strata because of sample size limitations. They reported values for the four indicators, first when computed from raw data and later when computed according to their proposed model. Table 2 tests both types of values for consistency, and asserts that all sets of values obtained by these authors are reasonably consistent, indeed. An interesting sequel to this observation is to try to prove that the model of Coughlin *et al.*[43] *per se* is theoretically consistent, i.e., consistency extends from the studied set of values to the model as a whole.

i \ j	$+1$	-1
$+1$	TP_{ij} (True Positives)	FP_{ij} (False Positives) (Type I Error)
-1	FN_{ij} (False Negatives) (Type II Error)	TN_{ij} (True Negatives)

Fig. 1. The two-by-two contingency matrix of test or classification i with respect to test or classification j. This matrix has integer entries that add to the total number of cases N. The symbols $A = \{j = +1\}$ and $B = \{i = +1\}$ denote the events of positive cases according to tests j and i, respectively.

			B conditioned	
	$P(\bar{A}\|\bar{B}) =$ $P(j = -1\|i = -1)$ $= NPV_{ij}$	$P(A\|\bar{B}) =$ $P(j = +1\|i = -1)$ $= FOR_{ij}$	$P(B\|\bar{A}) =$ $P(i = +1\|j = -1)$ $= FPR_{ij}$	$P(\bar{B}\|\bar{A}) =$ $P(i = -1\|j = -1)$ $= Spec_{ij} = TNR_{ij}$
Conditioning uncomplemented	$P(\bar{A}\|B) =$ $P(j = -1\|i = +1)$ $= FDR_{ij}$	$P(A\|B) =$ $P(j = +1\|i = +1)$ $= PPV_{ij}$	$P(B\|A) =$ $P(i = +1\|j = +1)$ $= Sens_{ij} = TPR_{ij}$	$P(\bar{B}\|A) =$ $P(i = -1\|j = +1)$ $= FNR_{ij}$
		Conditioned uncomplemented		

Fig. 2. Definition of the eight conditional probabilities concerning events $A = \{j = +1\}$ and $B = \{i = +1\}$, which constitute the eight most prominent indicators of diagnostic testing. The four shaded entries are direct measures, usually taken for the most basic ones.

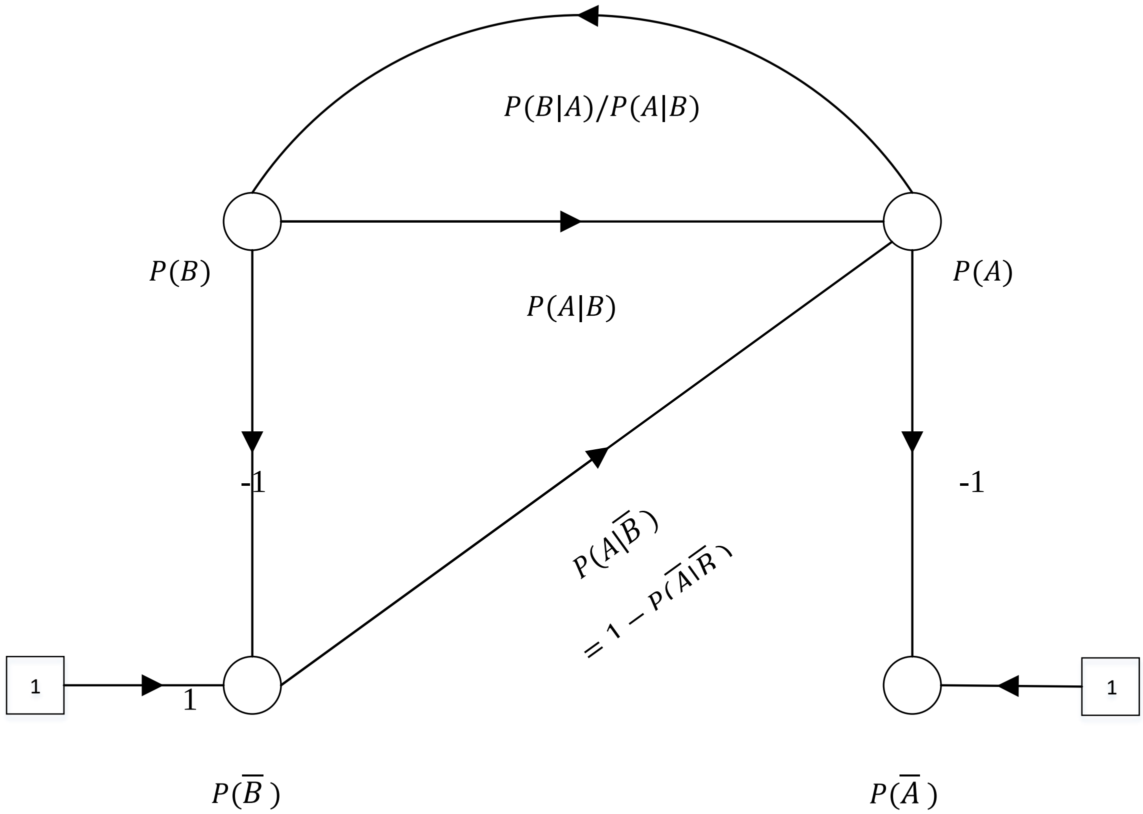

Fig. 3. A signal flow graph that uses the total probability law to express *P(A)*, Bayes' rule to express *P(B)*, and complementation to express $P(\overline{A})$ and $P(\overline{B})$, with transmittances that involve three conditional probabilities only.

Table 1. Checking consistency among sets of the four prominent diagnostic indicators published in various sources in the open literature. In a dominant majority of cases, the published sets are consistent (uncolored entries), and in a small number of cases, there are sets that are somewhat problematic (highlighted in yellow), or dramatically inconsistent (highlighted in red). Exact meanings of colors are given in the sub-table below.

#	Original Values				Checking Values		Computed Values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
1	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	[4]
	0.8000	0.8528	0.6222	0.9336	0.0000	1.0000	0.7999	0.8527	0.6224	0.9336	
	0.8400	0.8088	0.4667	0.9621	0.0000	1.0000	0.8400	0.8088	0.4666	0.9621	
	0.8571	0.7915	0.4000	0.9716	0.0000	1.0001	0.8573	0.7918	0.3996	0.9716	
	0.8571	0.8286	0.5333	0.9621	0.0000	1.0000	0.8572	0.8287	0.5332	0.9621	
	0.9207	0.8655	0.6444	0.9763	0.0000	1.0000	0.9206	0.8654	0.6446	0.9763	
2	0.6538	0.5024	0.1417	0.9204	0.0000	1.0013	0.6541	0.5027	0.1416	0.9203	[44]
	0.8846	0.4493	0.1679	0.9688	0.0000	1.0003	0.8848	0.4498	0.1676	0.9687	
	0.5000	0.8454	0.2889	0.9309	0.0000	1.0002	0.5002	0.8455	0.2887	0.9308	
	0.8462	0.8792	0.4681	0.9785	0.0000	1.0000	0.8462	0.8792	0.4680	0.9785	
	0.3462	0.9469	0.4500	0.9202	0.0000	0.9999	0.3460	0.9469	0.4502	0.9203	

	0.3846	0.9807	0.7143	0.9269	0.0000	0.9999	0.3842	0.9807	0.7146	0.9270	
	0.7250	0.6500	0.8610	0.4410	-0.0001	0.9995	0.7246	0.6496	0.8612	0.4415	
3	0.9500	0.5750	0.8700	0.7930	0.0000	0.9999	0.9499	0.5744	0.8703	0.7934	[45, Abstract]
	0.9330	0.6000	0.8750	0.7500	0.0001	1.0003	0.9333	0.6013	0.8744	0.7490	
	0.6700	0.8800	0.9300	0.5000	-0.0022	0.9913	0.6443	0.8674	0.9371	0.5285	
	0.2400	1.0000	1.0000	0.3000	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
4	0.2400	1.0000	1.0000	0.3000	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	[46]
	0.9500	0.8800	0.9500	0.8800	0.0000	1.0000	0.9500	0.8800	0.9500	0.8800	
	0.9000	0.8800	0.9500	0.7800	0.0002	1.0003	0.9018	0.8821	0.9490	0.7765	
	0.8300	0.9300	0.8900	0.9000	0.0010	1.0017	0.8457	0.9372	0.8782	0.8891	
5	0.8600	0.4100	0.4800	0.8300	0.0017	1.0162	0.8664	0.4232	0.4665	0.8222	[47]
	0.7200	0.9300	0.8800	0.8400	0.0016	1.0034	0.7434	0.9374	0.8668	0.8233	
	0.9570	0.9510	0.8650	0.9860	0.0001	1.0001	0.9588	0.9530	0.8598	0.9854	
	0.9570	0.9650	0.9000	0.9860	0.0000	1.0001	0.9583	0.9661	0.8970	0.9855	
6	0.9150	0.9720	0.9150	0.9720	0.0000	1.0000	0.9150	0.9720	0.9150	0.9720	[48]
	0.9150	0.9930	0.9770	0.9730	0.0000	1.0000	0.9152	0.9930	0.9769	0.9729	
	0.8940	0.9930	0.9770	0.9660	0.0000	1.0000	0.8948	0.9931	0.9768	0.9657	
	0.8940	1.0000	1.0000	0.9660	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.9179	0.6333	0.8491	0.6250	-0.0169	0.9422	0.8445	0.4562	0.9205	0.7743	
	0.8794	0.5194	0.7746	0.6400	-0.0083	0.9579	0.8497	0.4559	0.8159	0.6963	
	0.8520	0.4944	0.7714	0.6154	-0.0015	0.9908	0.8467	0.4840	0.7787	0.6252	
	0.8369	0.5730	0.7727	0.5667	-0.0167	0.9068	0.7682	0.4642	0.8404	0.6695	
7	0.8865	0.6204	0.8088	0.6786	-0.0102	0.9635	0.8453	0.5335	0.8581	0.7511	[49]
	0.8723	0.5000	0.7931	0.5789	-0.0087	0.9492	0.8405	0.4355	0.8325	0.6405	
	0.8723	0.4667	0.7895	0.5500	-0.0090	0.9389	0.8397	0.4016	0.8302	0.6145	
	0.8511	0.5333	0.8000	0.5455	-0.0109	0.9348	0.8077	0.4565	0.8448	0.6202	
	0.9179	0.6333	0.8491	0.6250	-0.0169	0.9422	0.8445	0.4562	0.9205	0.7743	
	0.1370	1.0000	1.0000	0.4880	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.1640	1.0000	1.0000	0.4960	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
8	0.1920	0.9830	0.9330	0.5000	0.0001	1.0010	0.1941	0.9832	0.9322	0.4967	[50]
	0.3010	0.9670	0.9120	0.5320	-0.0008	0.9939	0.2868	0.9647	0.9174	0.5491	
	0.4520	0.9170	0.8680	0.5780	-0.0003	0.9985	0.4491	0.9161	0.8693	0.5809	
	0.7120	0.6170	0.6930	0.6380	-0.0001	0.9996	0.7118	0.6167	0.6932	0.6382	
	0.7700	0.7000	0.2400	0.9600	-0.0005	0.9955	0.7646	0.6936	0.2456	0.9611	
	0.3200	0.9100	0.2900	0.9100	-0.0025	0.9595	0.2900	0.8977	0.3200	0.9209	
9	0.6800	0.7200	0.2300	0.9500	0.0007	1.0083	0.6882	0.7276	0.2234	0.9482	[51]
	0.7500	0.6200	0.2000	0.9500	-0.0006	0.9922	0.7443	0.6129	0.2048	0.9514	
	0.6500	0.7800	0.2600	0.9500	0.0003	1.0024	0.6531	0.7824	0.2574	0.9493	
	0.7800	0.6900	0.2300	0.9700	0.0028	1.0265	0.8127	0.7315	0.1962	0.9635	
10	0.6964	0.7788	0.2327	0.9638	0.0000	1.0000	0.6964	0.7788	0.2327	0.9638	[52]

	0.6633	0.8198	0.2618	0.9619	0.0000	0.9999	0.6631	0.8197	0.2620	0.9619	
	0.6360	0.8486	0.2881	0.9603	0.0000	0.9999	0.6359	0.8485	0.2882	0.9603	
	0.5928	0.8881	0.3380	0.9577	0.0000	1.0000	0.5929	0.8881	0.3379	0.9577	
	0.5430	0.9075	0.3613	0.9537	0.0000	1.0000	0.5429	0.9075	0.3614	0.9537	
	0.4230	0.9448	0.4530	0.9448	0.0016	1.0099	0.4530	0.9508	0.4230	0.9381	
	0.5680	0.6630	0.3092	0.8525	0.0000	1.0001	0.5680	0.6630	0.3092	0.8525	
	0.5178	0.7263	0.3345	0.8501	0.0000	1.0002	0.5179	0.7264	0.3344	0.8501	
	0.4485	0.7896	0.3616	0.8435	0.0000	1.0001	0.4486	0.7896	0.3615	0.8435	
	0.9510	0.7550	0.3360	0.9920	0.0002	1.0008	0.9532	0.7638	0.3254	0.9916	
11	0.8050	0.9490	0.6800	0.9770	0.0010	1.0020	0.8291	0.9563	0.6439	0.9731	[53]
	0.2680	0.9900	0.7860	0.9120	0.0003	1.0014	0.2777	0.9905	0.7776	0.9080	
	1.0000	0.2060	0.8650	0.9880	-0.0003	0.9981	0.9995	0.0000	1.0000	1.0000	
	1.0000	0.0720	0.8920	0.9590	-0.0003	0.9948	0.9996	0.0000	1.0000	1.0000	
	1.0000	0.0680	0.8920	0.9560	-0.0003	0.9944	0.9996	0.0000	1.0000	1.0000	
	0.9990	0.4680	0.7840	0.9970	0.0001	1.0003	0.9993	0.5470	0.7256	0.9959	
	0.9990	0.0540	0.6490	0.9600	-0.0002	0.9949	0.9987	0.0425	0.7038	0.9686	
	0.9990	0.0510	0.6490	0.9570	-0.0002	0.9942	0.9987	0.0396	0.7069	0.9667	
12	0.9970	0.0880	0.2700	0.9900	0.0001	1.0040	0.9974	0.0992	0.2447	0.9886	[54]
	0.9990	0.0610	0.4350	0.9850	-0.0001	0.9956	0.9987	0.0482	0.4971	0.9883	
	0.9990	0.0310	0.5220	0.9650	0.0000	0.9980	0.9989	0.0293	0.5369	0.9670	
	0.9990	0.0280	0.5220	0.9600	0.0000	0.9965	0.9989	0.0256	0.5453	0.9634	
	0.9980	0.3750	0.2610	0.9990	0.0000	1.0005	0.9983	0.4142	0.2306	0.9988	
	0.9990	0.0310	0.5220	0.9650	0.0000	0.9980	0.9989	0.0293	0.5369	0.9670	
	0.9990	0.0280	0.5220	0.9600	0.0000	0.9965	0.9989	0.0256	0.5453	0.9634	
	0.9990	0.0630	0.4350	0.9860	-0.0001	0.9964	0.9988	0.0515	0.4882	0.9887	
	0.6600	0.8100	0.7600	0.7200	-0.0006	0.9978	0.6564	0.8075	0.7629	0.7232	
	0.5700	0.8800	0.8100	0.7000	0.0007	1.0026	0.5756	0.8824	0.8064	0.6951	
	0.7100	0.7200	0.7000	0.7300	0.0001	1.0004	0.7104	0.7204	0.6996	0.7296	
	0.7900	0.6900	0.7000	0.7500	-0.0067	0.9734	0.7587	0.6504	0.7362	0.7821	
	0.8200	0.5500	0.6200	0.7700	-0.0007	0.9958	0.8172	0.5453	0.6245	0.7734	
	0.8400	0.3200	0.5300	0.7000	0.0025	1.0415	0.8483	0.3339	0.5143	0.6866	
13	0.8400	0.3200	0.5300	0.7000	0.0025	1.0415	0.8483	0.3339	0.5143	0.6866	[55]
	0.8400	0.3200	0.5300	0.7000	0.0025	1.0415	0.8483	0.3339	0.5143	0.6866	
	0.5300	0.7900	0.7000	0.6500	0.0009	1.0065	0.5353	0.7935	0.6955	0.6451	
	0.6900	0.7600	0.7300	0.7300	0.0014	1.0059	0.6977	0.7666	0.7228	0.7228	
	0.6600	0.7900	0.7400	0.7200	0.0001	1.0004	0.6605	0.7904	0.7396	0.7196	
	0.6100	0.8800	0.8200	0.7100	-0.0008	0.9973	0.6033	0.8770	0.8241	0.7157	
	0.4600	0.7600	0.6400	0.6100	0.0015	1.0176	0.4675	0.7655	0.6330	0.6028	
	0.3500	0.8600	0.7000	0.5900	0.0006	1.0065	0.3534	0.8618	0.6968	0.5864	
14	0.7600	0.7190	0.1010	0.9860	-0.0002	0.9966	0.7556	0.7142	0.1032	0.9863	[56]

	0.6670	0.7980	0.0620	0.9920	0.0001	1.0050	0.6748	0.8036	0.0600	0.9917	
	0.6670	0.8000	0.0670	0.9910	-0.0001	0.9981	0.6641	0.7979	0.0678	0.9911	
	0.8303	0.6540	0.0900	0.9900	0.0003	1.0067	0.8382	0.6668	0.0854	0.9894	
15	0.8571	0.6393	0.6207	0.8667	0.0000	1.0001	0.8572	0.6395	0.6205	0.8666	[57]
	0.6905	0.9344	0.8788	0.8143	0.0000	1.0000	0.6906	0.9344	0.8787	0.8142	
	0.5476	0.9836	0.9583	0.7595	0.0000	1.0000	0.5475	0.9836	0.9583	0.7596	
	0.7100	0.8852	0.8108	0.8182	0.0005	1.0012	0.7144	0.8874	0.8075	0.8150	
	0.9800	0.5902	0.6212	0.9730	-0.0010	0.9972	0.9762	0.5467	0.6620	0.9773	
	0.6400	0.9672	0.9310	0.7973	0.0001	1.0002	0.6428	0.9676	0.9302	0.7953	
	0.9048	0.2950	0.4690	0.8182	0.0000	0.9998	0.9048	0.2949	0.4691	0.8183	
16	0.0180	0.9880	0.0930	0.9380	0.0000	1.0533	0.0185	0.9883	0.0907	0.9364	[58]
	0.2450	0.8710	0.1110	0.9460	0.0000	0.9986	0.2447	0.8708	0.1112	0.9461	
	0.5950	0.6050	0.0910	0.9580	0.0002	1.0117	0.5985	0.6085	0.0898	0.9574	
	0.8650	0.3180	0.0770	0.9730	0.0000	1.0031	0.8657	0.3194	0.0766	0.9728	
	0.9740	0.1450	0.0770	0.9880	0.0001	1.0140	0.9759	0.1549	0.0716	0.9870	
	0.0580	0.9880	0.4730	0.8510	0.0001	1.0027	0.0586	0.9881	0.4702	0.8496	
	0.4040	0.8710	0.3650	0.8890	0.0001	1.0016	0.4054	0.8717	0.3636	0.8884	
	0.7510	0.6050	0.2590	0.9300	0.0001	1.0014	0.7520	0.6062	0.2580	0.9297	
	0.9260	0.3180	0.1990	0.9590	0.0000	0.9992	0.9257	0.3171	0.1996	0.9592	
	0.9860	0.1450	0.1750	0.9820	-0.0001	0.9971	0.9856	0.1411	0.1796	0.9826	
17	0.9300	0.2400	0.6600	0.6800	-0.0004	0.9947	0.9289	0.2369	0.6638	0.6837	[59]
	0.9400	0.2600	0.6700	0.7200	-0.0012	0.9879	0.9369	0.2499	0.6816	0.7305	
	0.9500	0.2300	0.6600	0.7300	-0.0015	0.9826	0.9462	0.2164	0.6773	0.7451	
18	0.9230	0.5000	0.9091	0.5455	0.0000	1.0001	0.9231	0.5003	0.9090	0.5452	[60]
	0.7537	0.7537	0.9225	0.3132	-0.0127	0.9133	0.6395	0.6395	0.9536	0.4403	
	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	0.8217	1.0000	1.0000	0.3429	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	1.0000	1.0000	1.0000	1.0000	0.0000	1.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
	0.9700	0.3500	0.5540	0.7560	-0.0288	0.7853	0.8773	0.1064	0.8489	0.9334	
	0.9090	0.4400	0.7060	0.4370	-0.0505	0.5312	0.7035	0.1573	0.9100	0.7657	
	0.8910	0.7100	0.4790	0.8550	-0.0348	0.8584	0.6889	0.3987	0.7724	0.9561	
	0.9530	0.7990	0.9270	0.7850	-0.0051	0.9907	0.9210	0.6957	0.9567	0.8639	
	0.4000	0.7390	0.8500	0.2860	0.0064	1.1897	0.4450	0.7730	0.8249	0.2499	
	0.9000	0.9370	0.8910	0.8040	-0.0135	0.9775	0.6927	0.7884	0.9703	0.9424	
19	0.2800	0.8900	0.7600	0.5000	0.0002	1.0030	0.2813	0.8906	0.7588	0.4984	[61]
	0.8600	0.4300	0.6500	0.7100	-0.0007	0.9947	0.8577	0.4253	0.6543	0.7139	
	0.2200	0.8900	0.7700	0.4100	0.0005	1.0149	0.2233	0.8919	0.7666	0.4053	
	0.7500	0.5900	0.7500	0.5900	0.0000	1.0000	0.7500	0.5900	0.7500	0.5900	
20	0.3333	0.7937	0.1333	0.9259	0.0000	0.9991	0.3331	0.7936	0.1334	0.9260	[62]
	0.3333	0.9481	0.2667	0.9617	0.0000	1.0000	0.3333	0.9481	0.2667	0.9617	

	0.0000	0.9847	0.0000	0.9485	0.0000	#DIV/0!	0.0000	#DIV/0!	0.0000	#DIV/0!	
	0.4167	0.9592	0.3846	0.9641	0.0000	1.0000	0.4165	0.9592	0.3848	0.9641	
	0.2708	0.9214	0.1962	0.9501	0.0007	1.0189	0.2839	0.9260	0.1861	0.9469	
	0.1848	0.0865	0.1662	0.0175	-0.0109	6.1567	0.0361	0.0154	0.5465	0.0972	
	0.3846	0.9237	0.3333	0.9380	0.0000	1.0000	0.3845	0.9237	0.3334	0.9380	
	0.2727	0.9528	0.2308	0.9619	0.0000	1.0001	0.2729	0.9528	0.2306	0.9619	
	0.0000	0.9466	0.0000	0.9466	0.0000	#DIV/0!	0.0000	#DIV/0!	0.0000	#DIV/0!	
	0.4167	0.9796	0.5556	0.9648	0.0000	1.0000	0.4164	0.9796	0.5559	0.9648	
	0.2685	0.9507	0.2799	0.9528	0.0009	1.0161	0.2892	0.9553	0.2596	0.9479	
	0.1893	0.0230	0.2307	0.0127	-0.0010	1.4274	0.1408	0.0163	0.2994	0.0180	
	0.9167	0.9048	0.9167	0.9048	0.0000	1.0000	0.9167	0.9048	0.9167	0.9048	
21	0.8571	1.0000	1.0000	0.8095	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	[63]
	0.8333	0.9524	0.9524	0.8333	0.0000	1.0000	0.8333	0.9524	0.9524	0.8333	
	0.7500	1.0000	1.0000	0.7083	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.5940	0.9030	0.1700	0.9850	-0.0001	0.9990	0.5910	0.9019	0.1718	0.9852	
	0.1880	0.9540	0.1200	0.9720	-0.0001	0.9962	0.1858	0.9534	0.1215	0.9724	
	0.0630	0.9340	0.0310	0.9670	0.0000	1.3086	0.0621	0.9331	0.0314	0.9675	
	0.0310	0.9660	0.0300	0.9680	0.0000	0.6875	0.0319	0.9669	0.0292	0.9671	
22	0.6560	0.8370	0.1190	0.9860	-0.0002	0.9967	0.6494	0.8330	0.1221	0.9864	[64]
	0.7580	0.7920	0.1160	0.9890	-0.0001	0.9990	0.7560	0.7902	0.1171	0.9891	
	0.5170	0.9120	0.1770	0.9810	0.0000	1.0001	0.5172	0.9121	0.1769	0.9810	
	0.2940	0.8660	0.0740	0.9710	0.0000	0.9966	0.2928	0.8653	0.0744	0.9712	
	0.2730	0.9320	0.1270	0.9730	0.0001	1.0044	0.2767	0.9332	0.1250	0.9725	
	0.7930	0.7160	0.0930	0.9900	0.0003	1.0056	0.8011	0.7260	0.0889	0.9895	
	0.9800	0.9800	0.9800	0.9800	0.0000	1.0000	0.9800	0.9800	0.9800	0.9800	
	0.2900	0.9400	0.8300	0.5500	-0.0014	0.9866	0.2758	0.9359	0.8396	0.5672	
	0.8700	0.9000	0.9000	0.8600	-0.0009	0.9985	0.8600	0.8920	0.9075	0.8700	
	0.8200	0.9900	0.9600	0.9200	-0.0010	0.9986	0.7360	0.9838	0.9751	0.9495	
23	0.6100	0.5700	0.4100	0.7500	0.0003	1.0051	0.6113	0.5713	0.4087	0.7490	[65]
	0.4200	0.9900	0.9300	0.7800	-0.0022	0.9926	0.3224	0.9849	0.9529	0.8437	
	0.9000	1.0000	1.0000	0.9400	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.2300	0.9700	0.8200	0.6600	-0.0012	0.9894	0.2148	0.9673	0.8326	0.6795	
	0.7200	0.9800	0.9700	0.8500	0.0014	1.0025	0.7890	0.9862	0.9570	0.7958	
	0.5140	1.0000	1.0000	0.2610	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
24	0.4620	1.0000	1.0000	0.1250	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	[66]
	0.1710	1.0000	1.0000	0.1710	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.9760	0.8570	0.9760	0.8570	0.0000	1.0000	0.9760	0.8570	0.9760	0.8570	
	0.0556	0.9600	0.1429	0.8944	0.0000	0.9985	0.0556	0.9600	0.1430	0.8945	
25	0.5556	0.9467	0.5556	0.9467	0.0000	1.0000	0.5556	0.9467	0.5556	0.9467	[67]
	0.2222	0.9467	0.3333	0.9103	0.0000	1.0000	0.2222	0.9467	0.3333	0.9103	

	0.5000	0.8467	0.2813	0.9340	0.0001	1.0006	0.5007	0.8471	0.2807	0.9338	
	0.0556	0.9930	0.5000	0.8976	0.0001	1.0064	0.0582	0.9933	0.4879	0.8931	
26	0.5200	0.8100	0.2000	0.9400	-0.0031	0.9505	0.4788	0.7833	0.2277	0.9486	[68]
	0.4300	0.8400	0.3400	0.9100	0.0068	1.0809	0.4980	0.8735	0.2815	0.8849	
	0.3700	0.8600	0.3800	0.9000	0.0104	1.1327	0.4731	0.9038	0.2862	0.8548	
27	0.8717	0.8960	0.9430	0.7811	0.0001	1.0001	0.8726	0.8968	0.9425	0.7796	[69]
	0.9220	0.9634	0.9427	0.9498	0.0000	1.0000	0.9220	0.9634	0.9427	0.9498	
28	0.3800	0.7900	0.4300	0.6400	-0.0258	0.4492	0.2628	0.6863	0.5646	0.7535	[70]
	0.1400	0.8000	0.4400	0.4100	-0.0060	1.5521	0.1201	0.7703	0.4837	0.4532	
	0.3200	0.9200	0.7000	0.7100	0.0014	1.0119	0.3319	0.9239	0.6885	0.6987	
	0.5000	0.7600	0.5300	0.9100	0.0418	1.3334	0.7826	0.9194	0.2385	0.7374	
	0.3600	0.9500	0.8000	0.7200	-0.0007	0.9960	0.3512	0.9481	0.8061	0.7277	
	0.0500	1.0000	1.0000	0.6500	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.2300	0.8200	0.4200	0.6500	-0.0004	0.9672	0.2279	0.8183	0.4229	0.6527	
	0.5000	0.7400	0.5800	0.7200	0.0108	1.1075	0.5551	0.7803	0.5254	0.6733	
	0.3600	0.7100	0.5500	0.6600	0.0283	2.1124	0.4921	0.8084	0.4150	0.5298	
	0.2700	0.7600	0.6000	0.6600	0.0415	4.4909	0.4790	0.8873	0.3763	0.4385	
	0.8400	0.4100	0.4400	0.8200	-0.0007	0.9927	0.8374	0.4054	0.4447	0.8228	
	0.3800	0.7400	0.5700	0.6700	0.0217	1.4726	0.4860	0.8145	0.4621	0.5682	
	0.4100	0.7100	0.6700	0.6800	0.0472	1.8636	0.6380	0.8613	0.4446	0.4559	
	0.5000	0.5300	0.4700	0.6700	0.0277	3.9272	0.6149	0.6429	0.3571	0.5598	
	0.9100	0.2200	0.4000	0.8000	-0.0016	0.9625	0.9043	0.2087	0.4162	0.8105	
	0.8200	0.3000	0.4100	0.7500	0.0025	1.0667	0.8295	0.3140	0.3942	0.7375	
	0.3600	0.8400	0.4000	0.7300	-0.0191	0.6732	0.2556	0.7622	0.5220	0.8158	
	0.5000	0.7800	0.6400	0.7300	0.0135	1.1031	0.5755	0.8278	0.5673	0.6660	
	0.4600	0.8100	0.5700	0.7100	-0.0049	0.9548	0.4322	0.7921	0.5973	0.7326	
	1.0000	0.2700	0.4300	1.0000	0.0000	1.0000	1.0000	0.0000	#DIV/0!	1.0000	
	0.8100	0.3700	0.4400	0.8000	0.0086	1.1352	0.8426	0.4244	0.3850	0.7611	
	0.5000	0.8400	0.6700	0.7600	0.0075	1.0432	0.5505	0.8654	0.6238	0.7211	
	0.4800	0.6800	0.5200	0.7200	0.0184	1.3077	0.5673	0.7511	0.4327	0.6442	
	0.6800	0.8200	0.6800	0.9700	0.0326	1.0990	0.9378	0.9700	0.2304	0.8200	
	0.5000	0.6300	0.4500	0.6900	0.0037	1.0925	0.5168	0.6455	0.4334	0.6754	
	0.7700	0.6300	0.5700	0.8300	0.0048	1.0254	0.7917	0.6591	0.5386	0.8113	
	0.8600	0.5000	0.3900	0.9100	0.0012	1.0097	0.8660	0.5128	0.3779	0.9057	
	0.9100	0.4700	0.4300	0.9000	-0.0059	0.9598	0.8845	0.4017	0.4991	0.9224	
29	0.9600	0.0700	0.1500	0.9000	-0.0007	0.8296	0.9548	0.0621	0.1672	0.9110	[24]
	0.0500	0.9800	0.1000	0.9600	0.0001	1.0208	0.0516	0.9806	0.0970	0.9587	
	0.4500	1.0000	1.0000	0.5300	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.4700	0.8600	0.5000	0.8500	0.0012	1.0087	0.4798	0.8647	0.4901	0.8449	
	0.7100	0.7900	0.7200	0.7700	-0.0024	0.9915	0.6959	0.7786	0.7334	0.7817	

	0.9500	0.5750	0.8700	0.7930	0.0000	0.9999	0.9499	0.5744	0.8703	0.7934	
	0.7250	0.8750	0.9460	0.5150	0.0001	1.0005	0.7266	0.8759	0.9456	0.5130	
	0.8750	0.6500	0.8820	0.6340	-0.0001	0.9997	0.8746	0.6491	0.8824	0.6349	
	0.9750	0.1250	0.7700	0.6250	0.0000	1.0003	0.9750	0.1252	0.7697	0.6247	
	0.7580	0.4750	0.8120	0.3960	0.0000	0.9996	0.7579	0.4748	0.8121	0.3962	
30	0.7250	0.5000	0.8130	0.3770	-0.0001	0.9987	0.7246	0.4995	0.8133	0.3775	[45, Tables]
	0.5500	0.6500	0.8350	0.3330	0.0044	1.0800	0.5763	0.6740	0.8197	0.3096	
	0.9670	0.1000	0.7630	0.5000	-0.0001	0.9950	0.9666	0.0990	0.7650	0.5028	
	0.7420	0.6250	0.8560	0.4460	-0.0001	0.9996	0.7417	0.6246	0.8562	0.4464	
	0.7250	0.6250	0.8530	0.4310	0.0000	1.0001	0.7251	0.6251	0.8530	0.4309	
	0.6750	0.6500	0.8530	0.4000	0.0001	1.0010	0.6756	0.6507	0.8526	0.3993	
	0.2860	0.9600	0.5260	0.8970	0.0001	1.0006	0.2871	0.9602	0.5247	0.8965	
31	0.1180	0.9610	0.2670	0.9000	0.0000	0.9976	0.1174	0.9608	0.2681	0.9005	[43]
	0.2340	0.9520	0.4310	0.8890	0.0000	1.0003	0.2342	0.9521	0.4307	0.8889	
	0.1710	0.9670	0.3870	0.9060	0.0001	1.0013	0.1719	0.9672	0.3854	0.9054	
	0.9400	0.6200	0.5500	0.9600	0.0015	1.0052	0.9473	0.6519	0.5158	0.9544	
	0.9000	0.7300	0.6200	0.9400	0.0008	1.0021	0.9043	0.7396	0.6083	0.9372	
	0.8600	0.8000	0.6700	0.9200	-0.0009	0.9978	0.8537	0.7917	0.6812	0.9237	
	0.8000	0.8800	0.7600	0.9000	-0.0005	0.9990	0.7953	0.8769	0.7652	0.9026	
	0.7300	0.9200	0.8100	0.8800	0.0001	1.0002	0.7311	0.9204	0.8092	0.8794	
	0.6400	0.8500	0.6700	0.8300	-0.0005	0.9982	0.6363	0.8479	0.6736	0.8323	
	0.8400	0.5400	0.4700	0.8800	0.0016	1.0101	0.8471	0.5533	0.4566	0.8742	
	0.9400	0.6200	0.5500	0.9600	0.0015	1.0052	0.9473	0.6519	0.5158	0.9544	
32	0.9100	0.5900	0.5200	0.9300	-0.0002	0.9992	0.9091	0.5874	0.5227	0.9307	[71]
	0.6900	0.8600	0.7600	0.8100	-0.0003	0.9990	0.6873	0.8585	0.7623	0.8119	
	0.4200	0.8300	0.3600	0.8600	-0.0007	0.9909	0.4144	0.8267	0.3653	0.8627	
	0.8800	0.5000	0.5300	0.8700	0.0008	1.0045	0.8830	0.5072	0.5229	0.8667	
	0.6700	0.5900	0.2700	0.8900	0.0008	1.0123	0.6753	0.5958	0.2653	0.8876	
	0.9600	0.5200	0.5600	0.9600	0.0015	1.0060	0.9657	0.5600	0.5200	0.9533	
	0.8300	0.8000	0.4800	0.9600	0.0019	1.0064	0.8471	0.8194	0.4486	0.9549	
	0.9300	0.5400	0.5600	0.9200	-0.0011	0.9955	0.9258	0.5242	0.5756	0.9246	
	0.8300	0.6800	0.3700	0.9500	0.0013	1.0075	0.8400	0.6956	0.3532	0.9464	
										Nature	
	0.2460	0.9330	0.3650	0.8880	0.0001	1.0009	0.2466	0.9332	0.3643	0.8877	
	0.3170	0.8840	0.2980	0.8920	-0.0002	0.9965	0.3151	0.8831	0.2998	0.8928	
33	0.1830	0.9330	0.2990	0.8800	0.0000	1.0013	0.1834	0.9332	0.2984	0.8797	[72]
	0.0850	0.9510	0.2110	0.8690	-0.0001	0.9797	0.0837	0.9502	0.2137	0.8708	
	0.2890	0.8990	0.3080	0.8900	-0.0001	0.9982	0.2880	0.8986	0.3090	0.8905	

	0.0560	0.9860	0.3810	0.8700	-0.0001	0.9955	0.0553	0.9858	0.3843	0.8716	
	0.3940	0.7210	0.1810	0.8840	0.0001	1.0035	0.3946	0.7215	0.1806	0.8838	
	0.3660	0.8470	0.2720	0.8960	0.0002	1.0033	0.3677	0.8479	0.2706	0.8953	
	0.5560	0.6050	0.1800	0.8970	-0.0001	0.9964	0.5552	0.6042	0.1805	0.8973	
	0.4150	0.7740	0.2230	0.8950	0.0002	1.0048	0.4167	0.7752	0.2218	0.8944	
	0.3730	0.8640	0.2990	0.8980	-0.0001	0.9977	0.3715	0.8632	0.3003	0.8986	
	0.3450	0.8650	0.2850	0.8940	-0.0001	0.9984	0.3441	0.8645	0.2858	0.8944	
34	0.6500	0.7800	0.6900	0.7500	0.0006	1.0025	0.6532	0.7824	0.6870	0.7474	[73]
	0.6600	0.8300	0.5800	0.8700	-0.0007	0.9970	0.6543	0.8264	0.5861	0.8728	
35	0.6700	0.9200	0.8000	0.9240	0.0101	1.0233	0.8088	0.9599	0.6576	0.8537	[74]
36	0.7800	0.8460	0.8420	0.7860	0.0001	1.0003	0.7808	0.8466	0.8413	0.7852	[75]
	0.8050	0.8970	0.8920	0.8140	0.0001	1.0002	0.8058	0.8975	0.8915	0.8132	
	0.7560	0.8460	0.7560	0.8380	-0.0015	0.9961	0.7447	0.8380	0.7669	0.8460	
	0.7560	0.8710	0.8380	0.7670	-0.0046	0.9885	0.7161	0.8461	0.8640	0.8018	
37	0.5200	0.9200	0.7700	0.7800	-0.0011	0.9957	0.5079	0.9164	0.7785	0.7882	[76]
	0.7000	0.8100	0.8300	0.6800	0.0013	1.0046	0.7088	0.8164	0.8240	0.6708	
	0.5200	0.9800	0.7800	0.9300	-0.0009	0.9976	0.4901	0.9775	0.7998	0.9374	
	0.5900	0.7900	0.7700	0.6200	0.0004	1.0020	0.5922	0.7915	0.7684	0.6179	
	0.9600	0.5700	0.9600	0.5700	0.0000	1.0000	0.9600	0.5700	0.9600	0.5700	
	0.7800	0.6200	0.8300	0.5400	-0.0003	0.9981	0.7784	0.6178	0.8313	0.5423	
	0.3000	0.8700	0.6800	0.5700	-0.0006	0.9903	0.2962	0.8679	0.6839	0.5744	
	0.7800	0.8300	0.8700	0.7200	-0.0001	0.9996	0.7790	0.8292	0.8707	0.7212	
38	0.4290	0.9220	0.4290	0.9220	0.0000	1.0000	0.4290	0.9220	0.4290	0.9220	[77]
	0.6250	0.7620	0.5000	0.8420	0.0000	0.9997	0.6247	0.7618	0.5003	0.8422	
	0.5000	0.9520	0.8000	0.8330	0.0001	1.0003	0.5015	0.9523	0.7990	0.8322	
	0.4710	0.8370	0.5330	0.8000	-0.0001	0.9996	0.4706	0.8368	0.5334	0.8002	
	0.8300	0.7600	0.5300	0.8600	-0.0229	0.9148	0.6863	0.5866	0.7157	0.9320	
	0.7500	0.8100	0.2400	0.9800	0.0019	1.0147	0.7840	0.8376	0.2070	0.9759	
39	0.0000	1.0000	0.0000	0.9300	0.0000	#DIV/0!	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	[78]
	0.5900	0.9900	0.8600	0.9700	0.0010	1.0020	0.6674	0.9928	0.8150	0.9587	
	0.6200	0.9900	0.8500	0.9700	0.0004	1.0007	0.6492	0.9912	0.8332	0.9661	
	0.0500	0.9900	0.5000	0.8900	0.0015	1.0846	0.0756	0.9935	0.3917	0.8390	
	0.5500	0.9800	0.7700	0.9500	0.0004	1.0010	0.5649	0.9811	0.7592	0.9471	
	0.6800	0.9800	0.8400	0.9600	0.0009	1.0017	0.7200	0.9834	0.8127	0.9520	
	0.0800	0.9900	0.5300	0.8600	-0.0010	0.9681	0.0654	0.9876	0.5836	0.8842	
	0.4900	0.9800	0.7900	0.9200	-0.0007	0.9981	0.4689	0.9783	0.8037	0.9260	
	0.5700	0.9800	0.8400	0.9300	0.0005	1.0011	0.5874	0.9813	0.8302	0.9252	
	0.1000	0.9800	0.5600	0.8500	0.0021	1.0551	0.1283	0.9848	0.4900	0.8105	
	0.5000	0.9800	0.8100	0.9100	-0.0010	0.9972	0.4680	0.9773	0.8289	0.9200	
	0.5500	0.9800	0.8300	0.9200	-0.0005	0.9989	0.5340	0.9787	0.8389	0.9246	

	0.7500	1.0000	1.0000	0.9430	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.7500	0.9550	0.8000	0.9400	-0.0001	0.9997	0.7470	0.9543	0.8025	0.9409	
40	0.7500	0.9390	0.7500	0.9390	0.0000	1.0000	0.7500	0.9390	0.7500	0.9390	[79]
	0.8750	0.8480	0.5830	0.9660	0.0002	1.0004	0.8768	0.8502	0.5789	0.9654	
	0.9380	0.5610	0.3410	0.9740	0.0000	1.0001	0.9382	0.5616	0.3404	0.9739	
41	0.9550	0.9670	0.8380	0.9910	-0.0001	0.9999	0.9511	0.9641	0.8496	0.9918	[80]
	0.7650	0.9590	0.6200	0.9790	0.0000	1.0000	0.7648	0.9590	0.6202	0.9790	
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	0.9710	0.9900	0.9790	0.9860	0.0000	1.0000	0.9707	0.9899	0.9792	0.9861	
	0.9750	0.9880	0.9700	0.9900	0.0000	1.0000	0.9749	0.9880	0.9701	0.9900	
	0.9460	0.9360	0.7510	0.9880	-0.0001	0.9999	0.9444	0.9341	0.7568	0.9884	
	0.9130	0.9680	0.8090	0.9870	0.0000	1.0000	0.9140	0.9684	0.8070	0.9868	
	0.8900	0.9960	0.9910	0.9500	0.0000	1.0000	0.8936	0.9961	0.9907	0.9482	
	0.9490	0.9810	0.9540	0.9790	0.0000	1.0000	0.9493	0.9811	0.9537	0.9789	
	0.6000	0.9700	0.8000	0.9250	0.0002	1.0004	0.6041	0.9705	0.7973	0.9238	
	0.9750	0.9960	0.9540	0.9980	0.0000	1.0000	0.9765	0.9962	0.9511	0.9979	
	1.0000	0.9920	0.8030	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.9860	0.9870	0.6050	1.0000	0.0001	1.0002	1.0000	1.0000	0.0000	0.9997	
	0.9480	0.9930	0.7840	0.9990	0.0001	1.0001	0.9624	0.9950	0.7214	0.9986	
	0.8910	0.9970	0.9670	0.9910	0.0000	1.0001	0.9066	0.9975	0.9610	0.9893	
	0.9120	0.9940	0.8380	0.9970	0.0000	1.0000	0.9121	0.9940	0.8378	0.9970	
	0.7810	0.9930	0.6630	0.9960	0.0000	0.9999	0.7754	0.9928	0.6702	0.9961	
	0.9300	1.0000	0.9500	0.9940	-0.0003	0.9997	0.0000	0.9958	1.0000	1.0000	
	0.9600	0.9200	0.9800	0.8020	-0.0010	0.9986	0.9452	0.8921	0.9855	0.8492	
42	0.9900	0.5000	1.0000	0.4000	0.0020	1.0102	1.0000	1.0000	0.9933	0.0000	[81]
	0.8600	1.0000	1.0000	0.7140	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.9600	1.0000	1.0000	0.9900	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.8200	0.9900	0.7100	0.9970	0.0006	1.0010	0.8915	0.9944	0.5757	0.9946	
	1.0000	0.9000	0.8600	1.0000	0.0000	1.0000	1.0000	#DIV/0!	#DIV/0!	1.0000	
	0.3300	1.0000	1.0000	0.9800	0.0000	1.0000	#DIV/0!	1.0000	1.0000	0.0000	
	0.9600	0.9600	0.9600	0.9550	-0.0002	0.9998	0.9550	0.9550	0.9645	0.9600	
	0.9800	0.8600	0.9900	0.7810	0.0003	1.0005	0.9829	0.8781	0.9883	0.7525	
	0.9800	0.7400	0.9700	0.8330	0.0006	1.0010	0.9827	0.7670	0.9655	0.8118	
	1.0000	0.2300	0.9900	0.6000	-0.0009	0.9933	0.9980	0.0000	1.0000	1.0000	
	0.1000	1.0000	0.2000	0.9980	-0.0002	0.9920	0.0000	0.9991	1.0000	1.0000	
	0.8100	0.9200	0.4000	0.9870	0.0002	1.0007	0.8149	0.9223	0.3924	0.9866	
	0.6700	0.9900	0.4000	0.9870	-0.0039	0.9851	0.3383	0.9614	0.7258	0.9967	
	0.9500	0.5400	0.6500	0.9230	0.0000	0.9999	0.9499	0.5395	0.6504	0.9231	
	0.8600	0.7400	0.6300	0.9090	-0.0006	0.9983	0.8566	0.7347	0.6364	0.9113	
	0.9900	0.2500	0.8100	0.8470	-0.0020	0.9876	0.9861	0.1925	0.8563	0.8856	

	0.7300	1.0000	0.8600	0.9940	-0.0006	0.9990	0.0000	0.9974	1.0000	1.0000	
	0.6200	0.9900	0.7200	0.9820	-0.0004	0.9991	0.5863	0.9885	0.7475	0.9843	
	0.8700	0.8800	0.7700	0.9370	0.0002	1.0003	0.8716	0.8815	0.7674	0.9361	
	0.9700	0.6700	0.8300	0.9350	0.0005	1.0010	0.9719	0.6848	0.8203	0.9308	
	0.8300	1.0000	1.0000	0.9330	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
43	0.8640	0.6950	0.6710	0.8770	0.0001	1.0003	0.8645	0.6960	0.6700	0.8765	[82]
	0.9830	0.5000	0.4330	0.8000	-0.0528	0.6845	0.7534	0.0502	0.9353	0.9870	
	0.9320	1.0000	1.0000	0.9530	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.9490	1.0000	1.0000	0.9640	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.8700	0.6950	0.4440	0.9500	-0.0001	0.9996	0.8694	0.6939	0.4453	0.9502	
	0.9570	0.5000	0.2240	0.8000	-0.0704	0.1402	0.5359	0.0493	0.8477	0.9872	
	0.8260	1.0000	1.0000	0.9530	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	
	0.8700	1.0000	1.0000	0.9640	0.0000	1.0000	#DIV/0!	1.0000	1.0000	#DIV/0!	

	RED	ORANGE		YELLOW		WHITE		YELLOW		ORANGE		RED
DCR=1	· · < 0.94	· · 0.94	0.9599	· · 0.96	0.9799	· · 0.98	1.0199	1.02 · ·	1.0399	1.04 · ·	1.0599	>= 1.06
DCD=0	< −0.0600	−0.06 · ·	−0.041 ·	· · −0.04	−0.021	−0.02 · ·	0.0199	0.02 · ·	0.0399	0.04 · ·	0.0599	>= 0.06
Others ,%	<= − 6%	− 5.999% to − 4%		− 3.999% to − 2.0%		− 2.0% to 2.0%		2% to 3.999%		4% to 5.999%		>= 6%

Table 2. Checking consistency among sets of the four prominent diagnostic indicators published in Coughlin, *et al*. [43]. These sets appeared in calculated and modeled versions of Table 2 of [43].

	Original Values				Checking Values		Computed Values				Source
	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	DCD_{ij}	DCR_{ij}	$Sens_{ij}$	$Spec_{ij}$	PPV_{ij}	NPV_{ij}	
Table 2-Calculated	0.2860	0.9600	0.5260	0.8970	0.0001	1.0006	0.2871	0.9602	0.5247	0.8965	[43]
	0.1180	0.9610	0.2670	0.9000	0.0000	0.9976	0.1174	0.9608	0.2681	0.9005	
Table 2-Modeled	0.2340	0.9520	0.4310	0.8890	0.0000	1.0003	0.2342	0.9521	0.4307	0.8889	
	0.1710	0.9670	0.3870	0.9060	0.0001	1.0013	0.1719	0.9672	0.3854	0.9054	

6. Conclusions

Using the technique of signal flow graphs, this paper shows that the four most prominent indicators of diagnostic testing (Sensitivity, Specificity, Positive Predictive Value, and Negative Predictive Value) constitute three rather than four independent quantities. This observation is virtually unheard of, though it is implicit in earlier solutions of the ternary problem of conditional probability[1-3]. We defined two functions that check consistency for any set of four numerical values claimed to be the four basic diagnostic indicators. Most of data we came across met our criterion for consistency, but in a few cases, there were obvious unexplained blunders. Any attempt to estimate or model the four indicators should take our results into consideration.

Calculations made herein were simply implemented in a primitive way via an EXCEL sheet. We are currently developing a more elaborate program to handle the same calculations without exception of any limiting cases, and with an automated criterion to label a result as reasonably consistent, slightly inconsistent, considerably inconsistent, or dramatically inconsistent.

Acknowledgement

The first-named author (AMAR) is gratefully indebted to Dr. Rufaidah Rushdi, of Kasr Al-Ainy Faculty of Medicine (Cairo University, Arab Republic of Egypt) for stimulating discussions concerning epidemiological testing and its various measures, and for pointing out that interdependence of the four basic measures is implicit in the algebraic variant of the ternary problem of conditional probability. Both authors are greatly indebted to an anonymous reviewer, who offered constructive criticism and proposed many improvements for an earlier version of this manuscript.

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العلاقات البينية التي تربط المؤشرات الأساسية الأربعة للاختبارات التشخيصية: مقاربة تستخدم رسوم سريان الإشارة

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المستخلص. يمكن حل المسائل الثلاثية للاحتمالات الشرطية المصاغة بالاقتران مع نسخة مطبعة من جدول التوافق مثنى–مثنى باستخدام أساليب حسابية أو جبرية لإنتاج علاقات متبادلة مفيدة بين مختلف الاحتمالات الهامشية والتقاطعية والشرطية المرتبطة بهذا الجدول. وعلى وجه الخصوص، يتسنى استخدام الطرائق الجبرية وحدها لربط أبرز أربعة مؤشرات للاختبارات التشخيصية (الحساسية والتحديدية والقيمة التنبؤية الموجبة (ق ن و) والقيمة التنبؤية السالبة (ق ن س)). وبشكل عام، من الممكن نظريًا التعبير عن أي من هذه المؤشرات الأربعة بدلالة المؤشرات الثلاثة الأخرى مجتمعة. وتتبلور هذه الإمكانية هنا، بطريقة حسابية مباشرة، من خلال استخدام رسم (ماسون) لسريان الإشارات. حيث يستخدم هذا الرسم في العلاقات المكونة له مزيجا من قانون الاحتمال الكلي، وقاعدة بايز وصيغة التكملة. وعلى الرغم من البساطة النسبية للصيغ الأربع التي تعبر عن أي من المؤشرات التشخيصية الأربعة بدلالة المؤشرات الثلاثة الأخرى، فإنه يبدو أنها لم يُسمَع بها في الأدبيات العلمية المفتوحة. نحن نطلق على مجموعة من أربع قيم عددية تحقق هذه الصيغ الأربع (ضمن أخطاء التقريب المسموح بها) مجموعة متسقة. نحدد دالتين للاستيثاق من مثل هذه القيم الأربع نسميهما دالة فرق الاستيثاق التشخيصي (ف وش) ودالة نسبة الاستيثاق التشخيصي (ن وش)، وهاتان الدالتان تأخذان قيمتي الصفر والواحد، على الترتيب، عند التعويض فيهما بأربع قيم متسقة. وبالتالي، فإن انحراف قيمتي هاتين الدالتين عن الصفر والواحد، على الترتيب، يمثل مقياسا لعدم الاتساق لأية مجموعة مزعوم أنها تمثل مؤشرات التشخيص الأربعة. وثمة ملاحظة مثيرة للاهتمام هنا، وهي أن مقياسين غير متحيزين هما مقياسا المُنبئية والموسومية يظهران بشكل طبيعي ضمن تعبيري هاتين الدالتين، مما يشير إلى أن الحدين المتبقيين ضمن دالتي الاستيثاق هاتين قد يكونان أيضًا بمثابة مقياسين غير متحيزين. لقد أجرينا اختبارًا مكثفًا لبعض المجموعات المنشورة من المؤشرات الأساسية الأربعة، للتحقق مما إذا كانت هذه المجموعات متسقة أم لا. في الغالبية العظمى من الحالات، كانت المجموعات المنشورة متسقة، وبالتالي فإنها تشهد بشكل مستقل على صحة الصيغ التي

أوجدناها. ومع ذلك، ففي عدد صغير (وإن كان مهمًا) من الحالات، صادفنا مجموعات غير متسقة بشكل كبير. وهذا مثير للفضول بشكل خاص، لأنه لا يوجد مجال كبير للخطأ عند حساب المؤشرات الأربعة من البيانات الأولية للموجبات الصادقة والسالبات الصادقة والموجبات الكاذبة والسالبات الكاذبة. ونظرًا لأن المؤشرات الأربعة تشكل ثلاثة كيانات مستقلة فقط (بدلاً من أربعة) ، فإن الباحث لا يتمتع بحرية تخمين هذه المؤشرات الأربعة كلا على حدة، بل يجب أن تقتصر أية محاولة لتقدير هذه المؤشرات الأربعة من خلال رأي الخبراء أو من خلال أي نوع من النماذج على تخمين ثلاثة منها فقط ، ثم يتم استنتاج المؤشر الرابع عدديًا من هذه الثلاثة.

الكلمات المفتاحية: المسألة الثلاثية، الاحتمال الشرطي، رسوم سريان الإشارات، الحساسية، التحديدية، القيمتان التنبؤيتان، معيارا الاتساق، المُنبئية، الموسومية، الكميات المزاوجة.