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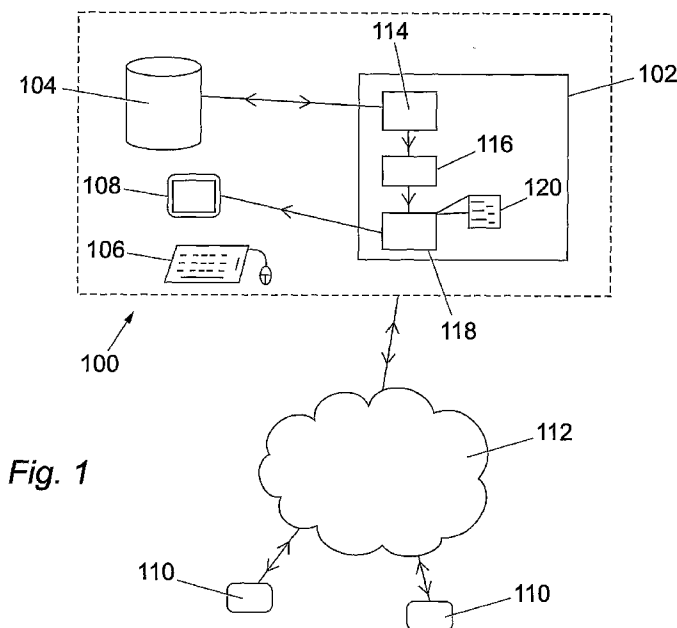


Fig. 1

(57) Abstract: An evidential support system for determining the strength of agreement between a plurality of sets of evidential data comprising an input port for receiving a plurality of sets of evidential data from at least one external source, a data storage device for storing interval data corresponding to a plurality of confidence intervals and correlation value data corresponding to possible values of combinations of pre-determined weighting values, a correlation unit for determining a correlation between entries in the at least two of the plurality of sets evidential data, a comparison unit for comparing the strength of correlations between said entries, the correlation unit being arranged to assign pre-determined weight data to each entry in a set of evidential data and being further

arranged to determine intersections between entries the at least two of the plurality of sets of evidential data, the correlation unit being arranged to determine correlation value data based upon the pre-determined weight data assigned to intersecting entries in the at least two sets of the plurality of sets of evidential data, the comparison unit being arranged to receive the correlation value data from the correlation means and to access the interval data stored upon the data storage device and to assign each correlation value datum to a respective credible interval range associated with an interval datum, and the comparison unit being further arranged to compare interval data associated with respective correlation value data in order to determine identifier data indicative of relative belief strengths of the plurality of sets of evidential data.

EVIDENTIAL SUPPORT SYSTEM AND METHOD

This invention relates to an evidential support system and method.

5

Evidential support systems based on the Dempster-Shafer theory of evidence carry out the numerical calculation of a likelihood of a hypothesis being true based upon a contingent belief.

10

For example, if A informs B that B's cat has been seen in a specific area and B knows that A is 90% reliable B places a 0.9 probability that the cat is indeed in that area. Additionally, when the cat has escaped previously it has been found in a different, overlapping area 70% of the time. So the probability of the cat being found in the overlapping sub-area is $0.9 \times 0.7 = 0.63$. Some belief can also be allocated to the non-overlapping areas.

15

Moreover, the probability of the cat being in some unknown area is $0.1 \times 0.3 = 0.03$.

20

So Dempster-Shafer theory allows for an amount of a belief to remain unallocated. For another example if there are three suspects for a crime Bayesian probability theory requires that the sum of the probabilities allocated to each of the suspects must equal unity. In Dempster-Shafer theory it is allowable to allocate each suspect an amount of belief, for example 0.3 to each suspect, leaving 10% of the belief unallocated.

25

Another current approach is to apply a non-numeric measure of reliability to a problem in a manner similar to fuzzy logic.

30

Currently, these systems require to calculate and assign specific values to each proposition and the evidence supporting the hypothesis and demand exact numerical comparisons to determine whether a particular, or set, of propositions are more strongly supported than another proposition. This is

extremely computationally intensive. The computationally intensive nature of the current systems and method of evidential reasoning limits their applicability in large scale operations, for example a tribunal with many hundreds of linked hypotheses and possibly may hundreds of thousands of pieces of evidence.

According to a first aspect of the present invention there is provided an evidential support system for determining the strength of agreement between a plurality of sets of evidential data comprising:

an input port for receiving a plurality of sets of evidential data from at least one external source;

a data storage device for storing interval data corresponding to a plurality of confidence intervals and correlation value data corresponding to possible values of combinations of pre-determined weighting values;

a correlation unit for determining a correlation between entries in the at least two of the plurality of sets evidential data;

a comparison unit for comparing the strength of correlations between said entries;

the correlation unit being arranged to assign pre-determined weight data to each entry in a set of evidential data and being further arranged to determine intersections between entries the at least two of the plurality of sets of evidential data;

the correlation unit being arranged to determine correlation value data based upon the pre-determined weight data assigned to intersecting entries in the at least two sets of the plurality of sets of evidential data;

the comparison unit being arranged to receive the correlation value data from the correlation means and to access the interval data stored upon the data storage device and to assign each correlation value datum to a respective credible interval range associated with an interval datum; and

the comparison unit being further arranged to compare interval data associated with respective correlation value data in order to determine identifier data indicative of relative belief strengths of the plurality of sets of evidential data.

5

Such a system allows the assignation of a credible interval to the likelihood of a hypothesis under test being true based upon the evidence available to support the hypothesis by the use of stored interval values.

10

The use of stored interval values allows the relative likelihoods of a hypothesis being true to be assessed less rigidly than absolute values, in a manner akin to so-called "fuzzy logic". The use of stored pre-determined correlation values and their subsequent calling by the comparison means reduces the computational load on the comparison means as these values need not be calculated each time a hypothesis is tested.

15

The identifier data may be null if the belief strength of one of the sets of evidential data is greater than that of another by a pre-determined threshold value.

20

Such a null value of the identifier data allows, for example, a weak piece of evidence to be ignored in the face of a much stronger piece of evidence. This reduces the number of calculations required to analyse evidence data sets as certain evidence data is excluded by having null identifier data.

25

The comparison unit may be arranged to compare the combined belief strengths of a plurality of entries in an evidential data set to the strength of an entry in another evidential data set.

Such a multiple comparison allows a number of apparently weak pieces of evidence to be pieced together to overcome an apparently strong piece of evidence.

- 5 The interval data may be stored on the storage device as a look up table.
The interval data may be in the form of a non-numeric identifier.

The correlation value data may be stored on the storage device as a look up table, or as discrete data entries.

10

The use of look-up tables allows for rapid and repeated access of repeatedly used values thereby speeding up the computational process.

15

According to a second aspect of the present invention there is provided a method of evidential reasoning comprising:

storing interval data corresponding to a plurality of confidence intervals and correlation value data corresponding to possible values of combinations of pre-determined weighting values;

20

determining a correlation between entries in at least two of a plurality of sets evidential data;

comparing the strength of correlations between said entries;
assigning pre-determined weight data to each entry in a set of evidential data;

25

determining intersections between entries the at least two of the plurality of sets of evidential data;

determining correlation value data based upon the pre-determined weight data assigned to intersecting entries in the at least two sets of the plurality of sets of evidential data;

accessing the interval data stored upon the storage means;

assigning each correlation value datum to a respective credible interval range associated with an interval datum; and
comparing interval data associated with respective correlation value data in order to determine the relative strengths of the plurality sets of evidential data to generate identifier data associated with said relative strengths.

The method may further comprise assigning a non-numeric identifier data indicative of relative strength of the plurality of sets of evidential data to each set of interval data.

The method may comprise assigning null identifier data null if the belief strength of one of the sets of evidential data is greater than that of another by a pre-determined threshold value.

The method may comprise comparing the combined belief strengths of a plurality of entries in an evidential data set to the strength of an entry in another evidential data set.

The method may comprise storing the interval data on the storage device as a look up table.

The method may comprise storing the correlation value data as a look up table.

According to a third aspect of the present invention there is provided software which when executed upon a processor of a comparison unit causes the comparison unit to:
receive correlation value data associated with respective evidential data sets from a correlation unit;

access interval data stored a data storage device and to assign each correlation value datum to a respective credible interval range associated with an interval datum; and

5 interval data associated with respective correlation value data in order to determine identifier data indicative of relative belief strengths of the plurality of sets of evidential data

10 According to a fourth aspect of the present invention there is provided an expert system comprising an evidential support system according to the first aspect of the present invention.

15 The expert system may comprise rules and data from which the evidential weights are determined. These weights may be determined using additional data structures, for example look-up tables. The additional data structures may comprise data entries relating to rule strengths versus data strengths which yields evidence strength weight data. The rules contained within said data entries may be sequenced, or chained.

20 The expert system may comprise a diagnostic system. The diagnostic system may be arranged to diagnose faults in a telecommunications network based upon an array of identifier data.

25 Alternatively, the expert system may be arranged to diagnose a medical condition from data input in relation to a patient's condition. The patient may be human or animal.

30 According to a fifth aspect of the present invention there is provided a video camera monitoring system comprising a video camera and an evidential support system according to the first aspect of the present invention.

The video camera monitoring system may be arranged to identify an object within the field of the view of the video camera based upon an array of identifier data.

5

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

10

Figure 1 is a schematic diagram of an evidential support system, for establishing the a likelihood of correlation between pieces of evidence, according to an aspect of the present invention;

15

Figure 2 is a table exhibiting properties of data elements of an evidential support system according to an aspect of the present invention;

20

Figure 3 is a table representing a data structure comprising an element of a comparator unit of the system of Figure 1;

25

Figure 4 is schematic diagram of a video surveillance system comprising an evidential support system according to an aspect of the present invention;

30

Figure 5 is telecommunications diagnostic system comprising an expert system according to an aspect of the present invention;

Figure 6 is a flow chart detailing steps in a method of evidential reasoning according to an aspect of the present invention; and

Figure 7 is a software carrier bearing software according to an aspect of the present invention.

Referring now to Figures 1 to 3, an evidential support system 100 comprises a processing unit 102, a data storage device 104, a data input device 106 and a display device 108. In one embodiment the system 100 is in communication with a plurality of terminals 110 via a network 112. Typically, the network 112 is a private network, virtual private network (VPN) or a public network such as the Internet.

The processing unit 102 comprises a control processor 114, a correlation unit 116 and a comparator unit 118.

Usually, the data storage device 104 comprises a digital versatile disc (DVD) or a magnetic disc. It will be appreciated that any suitable data storage device may be used.

Typically, the data input device 106 comprises a keyboard and mouse combination. However, it will be appreciated that the data input device 106 is not limited to the above mentioned and may comprise any suitable input device, for example a microphone and speech recognition unit combination.

In use, details of known evidence and a list of possible hypotheses to which the evidence is related are entered into the support system 100 via the data input device 106. The evidence and hypothesis data is stored upon the data storage device 104. The control processor 114 accesses evidence and hypothesis data from the storage device 104 and passes the data to the correlation unit 116.

The correlation unit 116 assigns a weight to each piece of the evidence data. The weight assigned to the piece of evidence may be user input via

the data input device 106 or it may be derived from an algorithm executed at the correlation unit 116. The correlation unit 116 generates an intersection look-up table 200 based upon the evidence data and the weightings assigned to each piece of evidence.

5

In the present simplified example, the hypotheses relate to which of four suspects, a-d, is likely to be guilty of a crime. The evidence relation to the crime is that the criminal was left handed and a woman. In the present look-up table the evidence that the criminal is left handed forms the
10 columns and the evidence that the criminal is female forms the rows. A weighting is assigned to each piece of evidence dependent upon how important it is felt to be. For example, if the evidence that the criminal is left handed is strong, such as video evidence a large weighting could be given to this. However, if the evidence is largely anecdotal such as a
15 witness saw the criminal open a door with their left hand a low weighting could be given to this. In the present example the evidence that suspects b,c and d are left handed is reasonably strong so that a weighting of 0.7 is made to this evidence. There is no evidence in this regard for suspect a. The remaining 30% of the weighting remains unassigned in accordance
20 with Dempster-Shafer theory.

Similarly, the evidence that suspects a and b are women is very strong and so is given a weighting of 0.9. The remaining 10% of the weighting remains unassigned.

25

In this simplified example the only intersection of the two sets of evidence is for suspect b which yields the likelihood that suspect b is the criminal of 0.63.

Whilst this is useful in itself it does not provide an indication of the relative strength of this evidential combination when compared to other evidential combinations. A datum corresponding to the numerical value of the evidential strength is passed from the correlation unit 116 to the
5 comparator unit 118.

The comparator unit 118 comprises a data structure 120 which delineates relative strengths of evidential combinations. Typically, the data structure 120 is a look-up table an example of which is shown in Figure 3. In the
10 look-up table of Figure 3 for example, numeric ranges of likelihoods of the accuracy of individual evidential combinations are assigned non-numeric belief strengths, for example "VERY WEAK", "WEAK", "AVERAGE", "STRONG" or "VERY STRONG". In the present example the range of belief strengths is divided on a linear scale, with 0.2 being assigned to
15 each of the available non-numeric strengths.

The data structure 120 details what relative strengths of evidential combinations are the most convincing. For example, an evidential combination having a "VERY WEAK" belief strength is clearly less
20 convincing than an evidential combination having a "VERY STRONG" belief strength. However, three evidential combinations having "AVERAGE" belief strengths may be as compelling, when considered together, as an evidential combination having a "STRONG" belief strength.

25 It is envisaged that a similar look-up table will be available for conversion of data values and rules strengths, each expressed in the range A-E of Figure 3, to evidence strengths, also in the range A-E.

30 Such analysis using standard computational methods is highly intensive when considering the large body of evidence associated with a murder

investigation. The use of the present system 100 reduces this computational load by the use of the comparator unit 118 to provide a ready mechanism for the comparison of evidential combinations.

- 5 It will be appreciated that there may be more or less than five belief strengths. It will be further appreciated that the division of the belief strengths need not be linear but can be based upon a sliding, arbitrary scale or other non-linear division scale.
- 10 It will be further appreciated that such an evidential support system has applications, *inter alia*, in forensic science and medicine. For example in medicine the system may diagnose a patient's condition from input parameters such as blood oxygen, temperature, pigmentation, iris responsiveness or any other measurable metric associated with the
- 15 patient.

Referring now to Figure 4, a video surveillance system 400 comprises a video camera 402, a network 404, a data storage device 406 and an evidential support system 408.

20

Typically, the video camera 402 comprises an optical video camera, although it may comprise a video camera arranged to sense any suitable part of the electromagnetic spectrum, for example infra-red radiation.

- 25 In a preferred embodiment the network 404 is a closed circuit or a virtual private network (VPN). In an alternative embodiment the network 104 may be the Internet.

- Usually, the video storage device 406 comprises a DVD, video tape or any
- 30 other suitable video recording medium.

The evidence support system 408 comprises an input-output (IO) port 410, a data storage unit 412, a recognition unit 413, a correlation unit 414 and a comparator unit 416.

5

The network 404 connects the video camera 402, the video storage device 406 and the support system 408.

10 In use, the video camera 402 captures images of a location and passes data corresponding to the captured images across the network 404 to the video storage device 406 and the support system 408. The video storage device 406 records the data as video images on a video storage medium.

15 The support system 408 receives the image data at the IO port 410. The image data is directed to both the data storage unit 412 and the recognition unit 413. The data storage unit 412 stores the video data for later playback. The recognition unit 413 processes the image data in order to determine if any objects within the field of view of the video camera 402 can be identified.

20

For example, if the video camera is covering a car park the recognition unit 413 would typically be able to identify a person as such with 90% accuracy. However, if a cat enters the field of view of the video camera 402 the recognition unit 413 may be unsure as to what it is viewing. In this case the recognition unit 413 passes the data to the correlation unit 414.

25

In the present example, the hypothesis under test is that the object entering the field of view of the video camera 402 is a cat. An alternative hypothesis is that the object is a small person. A further alternative hypothesis is that the object is neither a cat nor a small person.

30

The evidence that can be obtained from the video data is that the object is capable of perambulation, is smaller than a car, has a tail and four legs. It will be appreciated that other evidence can be obtained from videos.

5

The correlation unit 414 and the comparator unit 416 operate as described hereinbefore with reference to Figure 1 in order to assess the evidence and give an evidential strength as to whether that the cat is a person or not. The recognition unit 413 can then use this evidential strength, for example, to determine whether to flag an intrusion to an operator of the system 400.

10

The use of rules and the propagation of chains of rules is envisaged for use in such a video surveillance system in a manner that will be described in detail hereinafter with reference to Figure 5.

15

Referring now to Figure 5, a telecommunications system 500 comprises a plurality of linked telecommunication devices 502a-g and an expert fault diagnostic system 504 comprising an evidential support system 506 as described hereinbefore with reference to Figure 1.

20

A fault in one of the telecommunication devices 502c may not be directly diagnosed in relation to that device and may only be discernable further within the telecommunications system 500. This gives rise to a situation where direct evidence of a fault may lead to an incorrect conclusion as to where the fault occurred. The evidential support system 506 allows for the propagation using chains of rules, derived from data structures comprising data entries relating to rule strengths versus data strengths, of evidencerelated to likely fault locations by means of updating a parent belief node, and subsequent propagation of beliefs through the parent

25

30

belief node to one or more child nodes. Thus, the accurate tracing of a fault in the complex telecommunication system 500.

- Referring now to Figure 6, an evidential reasoning method comprises
- 5 storing interval data corresponding to a plurality of credible interval ranges and correlation value data corresponding to possible values of combinations of pre-determined weighting values (Step 600). Pre-determined weight data is assigned to each entry in at least two sets of evidential data (Step 602). Intersections between entries the at least two
- 10 of the plurality of sets of evidential data are determined (Step 604). Correlation value data based upon the pre-determined weight data assigned to intersecting entries in the at least two sets of the plurality of sets of evidential data is determined (Step 606). The interval data stored upon the storage means is accessed (Step 608). Each correlation value
- 15 datum is assigned to a respective credible interval range associated with an interval datum (Step 610). Interval data associated is compared with respective correlation value data in order to determine the relative strengths of the plurality sets of evidential data (Step 612).
- 20 In a preferred embodiment the method comprises assigning a non-numeric identifier data indicative of relative strength of the plurality of sets of evidential data to each set of interval data (Step 614).

- Referring now to Figure 7, a software carrier 700 bears software which
- 25 when executed causes a processor to operate as the comparison unit of Figure 1.

It will be appreciated that although described with reference to hardware units the present invention may be implemented in software by the use of

suitable software modules to emulate the functions of the aforementioned hardware units.

5 While various embodiments of the invention have been described, it will be apparent to those skilled in the art once given this disclosure that various modifications, changes, improvements and variations may be made without departing from the scope of the invention.

CLAIMS

1. An evidential support system for determining the strength of agreement between a plurality sets of evidential data comprising:

5 an input port for receiving a plurality of sets of evidential data from at least one external source;

a data storage device for storing interval data corresponding to a plurality of credible interval ranges and correlation value data corresponding to possible values of combinations of pre-determined weighting values;

10 a correlation unit for determining a correlation between entries in the at least two of the plurality of sets evidential data;

a comparison unit for comparing the strength of correlations between said entries;

the correlation unit being arranged to assign pre-determined weight data

15 to each entry in a set of evidential data and being further arranged to determine intersections between entries the at least two of the plurality of sets of evidential data;

the correlation unit being arranged to determine correlation value data based upon the pre-determined weight data assigned to intersecting

20 entries in the at least two sets of the plurality of sets of evidential data;

the comparison unit being arranged to receive the correlation value data from the correlation means and to access the interval data stored upon the data storage device and to assign each correlation value datum to a respective credible interval range associated with an interval datum; and

25 the comparison unit being further arranged to compare interval data associated with respective correlation value data in order to determine identifier data indicative of relative belief strengths of the plurality of sets of evidential data.

2. The system of claim 1 wherein the identifier data is null if the belief strength of one of the sets of evidential data is greater than that of another by a pre-determined threshold value.

5 3. The system of either claim 1 or claim 2 wherein the comparison unit is arranged to compare the combined belief strengths of a plurality of entries in an evidential data set to the strength of an entry in another evidential data set.

10 4. The system of any preceding claim wherein the interval data is stored on the storage device as a look up table.

5. The system of any preceding claim wherein the interval data is in the form of a non-numeric identifier.

15 6. The system of any preceding claim wherein the correlation value data is stored on the storage device as a look up table, or as discrete data entries.

20 7. A method of evidential reasoning comprising the steps of:
storing interval data corresponding to a plurality of credible interval ranges
and correlation value data corresponding to possible values of
combinations of pre-determined weighting values;
determining a correlation between entries in at least two of a plurality of
25 sets evidential data;
comparing the strength of correlations between said entries;
assigning pre-determined weight data to each entry in a set of evidential
data;
determining intersections between entries the at least two of the plurality
30 of sets of evidential data;

determining correlation value data based upon the pre-determined weight data assigned to intersecting entries in the at least two sets of the plurality of sets of evidential data;

accessing the interval data stored upon the storage means;

- 5 assigning each correlation value datum to a respective credible interval range associated with an interval datum; and
- comparing interval data associated with respective correlation value data in order to determine the relative strengths of the plurality sets of evidential data to generate identifier data associated with said relative strengths.

10

8. The method of claim 7 comprising assigning a non-numeric identifier data indicative of relative strength of the plurality of sets of evidential data to each set of interval data.

15

9. The method of either claim 7 or claim 8 comprising assigning null identifier data if the belief strength of one of the sets of evidential data is greater than that of another by a pre-determined threshold value.

20

10. The method of any one of claims 7 to 9 comprising comparing the combined belief strengths of a plurality of entries in an evidential data set to the strength of an entry in another evidential data set.

25

11. The method of any one of claims 7 to 10 comprising storing the interval data on the storage device as a look up table.

12. The method of any one of claims 7 to 11 comprising storing the correlation value data as a look up table.

13. An expert system comprising an evidential support system;
according to any one of claims 1 to 6.

14. The expert system of claim 13 comprising rules and data from
5 which the evidential strength weight data is determined.

15. The expert system of either claim 13 or claim 14 wherein evidential
strength weight data is determined using additional data structures
comprising data entries relating to rule strengths versus data strengths
10 which yield the evidential strength weight data.

16. The expert system of claim 15 wherein the rules contained within
said data entries can be sequenced, or chained.

15 17. The expert system of claim 16 wherein the rules contained within
the data entries are interrelated in causal sequences.

18. The expert system of claim any one of claims 13 to 17 comprising a
diagnostic system.
20

19. The expert system of claim 18 wherein the diagnostic system is
arranged to diagnose faults in a telecommunications network based upon
an array of identifier data.

25 20. The expert system of claim 18 wherein the diagnostic system is
arranged to diagnose a medical condition from data input in relation to a
patient's condition based upon an array of identifier data.

21. A video camera monitoring system comprising a video camera and
30 an evidential support system according to any one of claims 1 to 6.

22. The system of claim 21 wherein the evidential support system is arranged to identify an object within the field of the view of the video camera based upon an array of identifier data.

5

23. An evidential support system substantially as described hereinbefore with reference to Figures 1 to 3 of the accompanying drawings.

10

24. A method of evidential reasoning substantially as described hereinbefore with reference to Figure 6 of the accompanying drawings.

25. A video surveillance system substantially as described hereinbefore with reference to Figure 4 of the accompanying drawings.

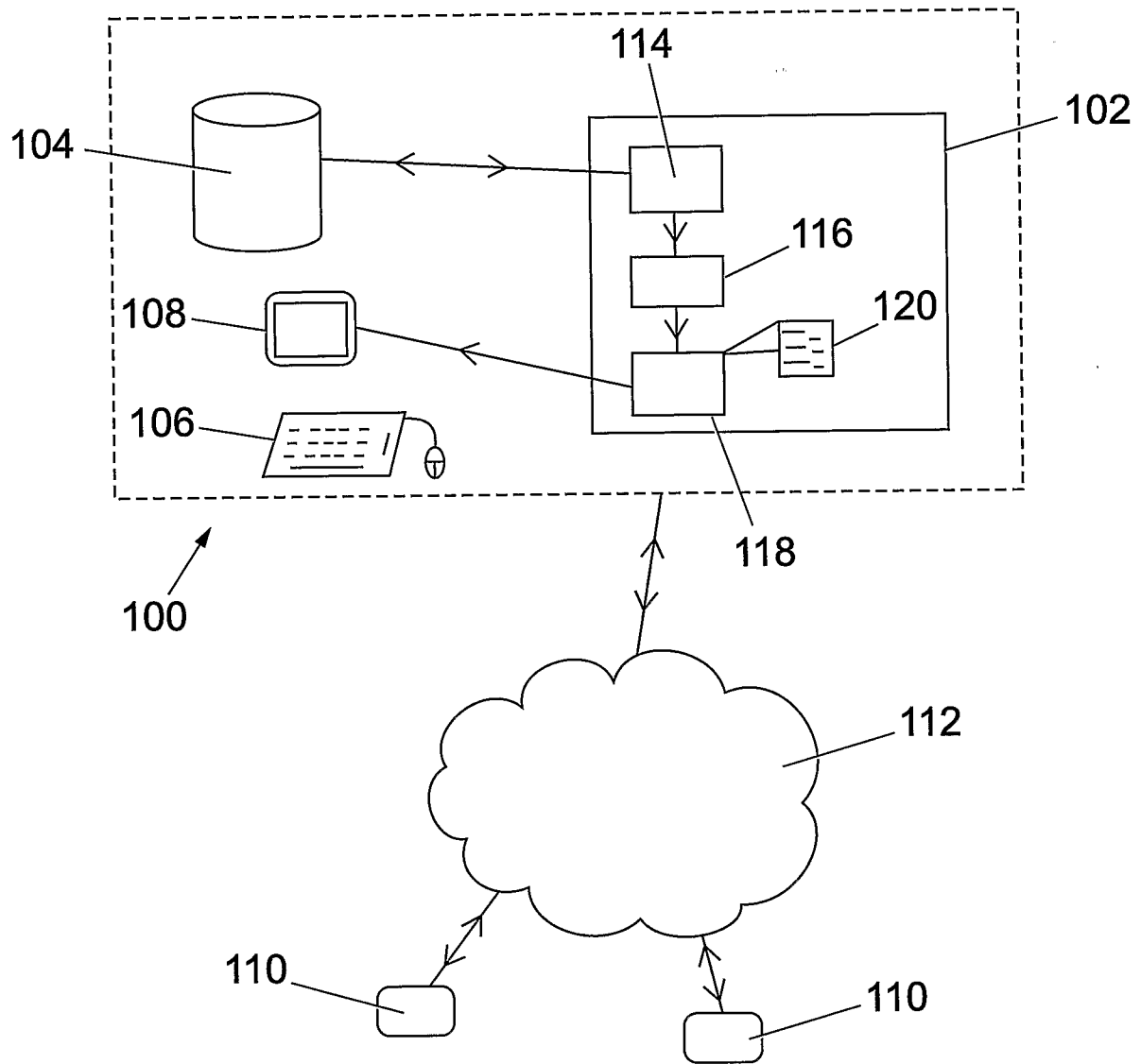
15

26. An telecommunications diagnostic system substantially as described hereinbefore with reference to Figure 4 of the accompanying drawings.

20

27. An expert system substantially as described hereinbefore with reference to the accompanying drawings.

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*Fig. 1*

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		left handed	
		[b, c, d] 0.7 (strong)	♂ 0.3 (weak)
Female [a,b]			
0.9 (very strong)		[b] 0.63	[a,b] 0.27
	♂		
0.1 (very weak)		[b, c, d] 0.7	♂ 0.03

Fig. 2

		E	D	C	B	A
Data	E	E/E	E/D	E/C	E/B	E/A
	D		D/D	D/C	D/B	D/A
	C			C/C	C/B	C/A
	B				B/B	B/A
	A					A/A

Where

E = Very Weak

D = Weak

C = Average

B = Strong

A = very Strong

Fig. 3

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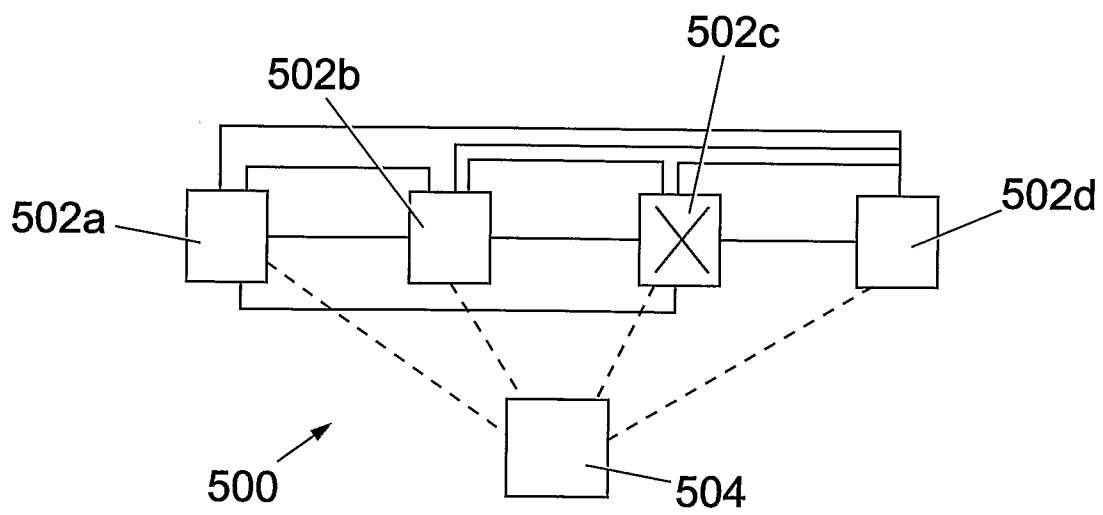
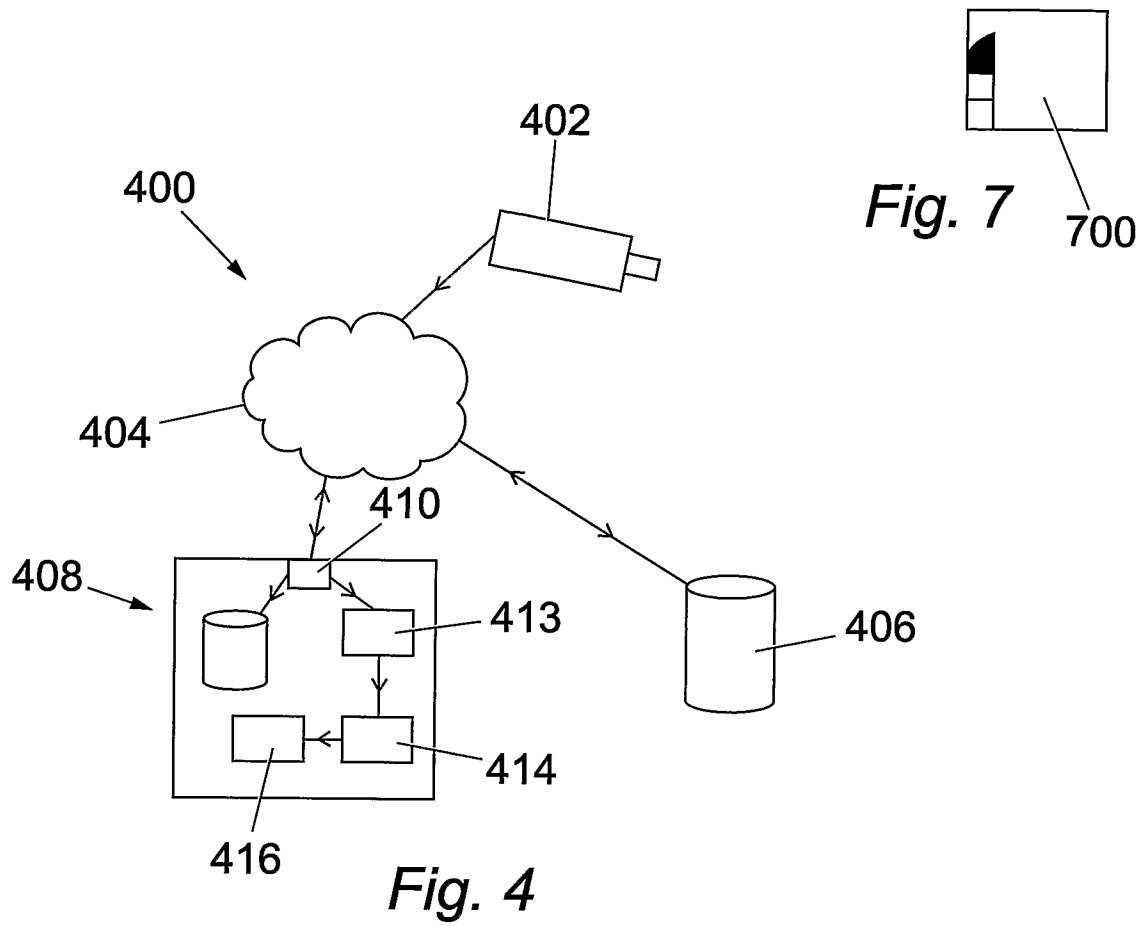


Fig. 5

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Fig. 6

